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Fostering a Chemistry Safety Culture Despite Limited Resources: A Successful Example from Academic Research Laboratories in Argentina

Alejandro M. Fracaroli and Daniel A. Caminos*

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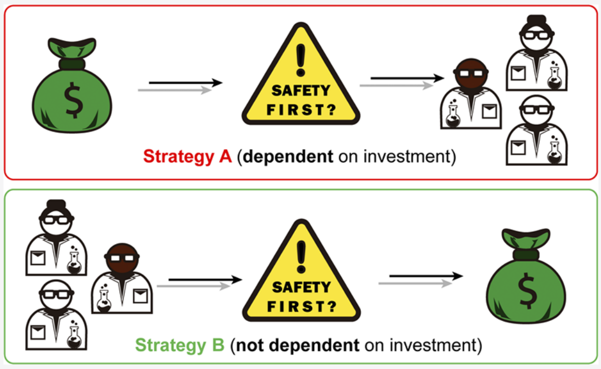

ABSTRACT: Scientists understand that no result is more important than the welfare of the investigators and the people around them. Safety culture is an integral part of industrial and academic jobs; however, safety training has only recently been added to chemistry classroom and laboratories. Chemistry laboratories expose workers to a variety of hazards, and implementing safety programs and regulations requires both changes and investment to improve the culture of safety. However, scientific research in developing countries frequently involves using creative alternatives to overcome obstacles related to limited financial resources. Therefore, we developed a 12 steps strategy termed *Safety Watch*, to foster chemistry safety culture in research laboratories without substantial financial resources. A significant milestone in this strategy was a Hygiene and Safety Internal Advising Committee (H&SIAC) composed of self-motivated researchers and students who allocated part of their time to detect, develop, and implement low-cost solutions to reduce or eliminate safety hazards. After almost 15 years, this safety watch has led to sustainable growth in the personnel safety culture, and concomitantly, promoted institutional support and attracted the necessary investment. We believe this bottom-up approach, where the safety culture is improved first by the laboratory workers, making the necessary investment easier to obtain later, is a model that can be applied to other research laboratories with similar work environments.

KEYWORDS: *Graduate Education/Research, Continuing Education, Organic Chemistry, Safety/Hazards, Problem Solving/Decision Making, Laboratory Management*

■ INTRODUCTION

We started with the premise that safety is a responsibility of every researcher in the laboratory beyond the particular position they hold at any given time, and the resources that may be available.

Unfortunately, it often is an accident that forces people to develop safety in a particular work environment. A clear example of this was the health and safety infrastructure reforms within the University of California system after the accident that took place on December 29, 2008, which cost the life of a 23-year-old student at UCLA.[1] In Argentina, the unfortunate accident that triggered the safety development happened on December 5, 2007, in an engineering pilot-scale plant located at the Universidad Nacional de Río Cuarto. This pilot plant caught fire, taking the lives of six researchers and leaving many others injured.[2]

After this event, the whole community of the national university system started to pay special attention to safety, especially from the perspective of the safety regulations already available in different colleges and research buildings. Policy-makers' immediate reaction to this tragic accident was to enforce existing safety regulations.[3] However, scientists soon realized that most of these regulations were intended for commercial and industrial facilities. Therefore, the implementation of these policies needed to be reviewed and adapted to academic research chemistry laboratories. For instance, one of the important differences between industrial and academic research laboratories relies on the assigned tasks for workers. In industry, employees have both assigned specific tasks and particular workstations. In contrast, researchers or "agents",[4] have dynamic tasks and workplaces. In academia, each agent constantly moves between laboratory experiments, literature reading, meetings, facilities usage in different buildings, and so on. Hence, for a research center it is difficult to implement

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Figure 1. Safety model here denoted as *safety watch* includes green-yellow steps that can be achieved with small or no associated economical cost. By the end of the process, steps marked in red will be resourceoriented and involve institutional support. The continuous iteration of this process led us to improve considerably the laboratory safety culture.

standard safety and evacuation plans with a specific role assigned to each agent.

Another important difference is the hierarchical order that is not as clear in academic laboratories as it is in companies. In this latter case, supervisors who manage other human resources have clear associated responsibilities in terms of performance and safety. Conversely, research advisors often are not directly responsible for the salary or jobs of the students, which in this particular case is provided by the national government. So, the formal or legal responsibility in the case of laboratory accidents is somehow shared by advisors, the College of Chemistry, and other formal employers. This situation results in senior professors or principal investigators being unclear about the full dimension of their legal responsibilities in the event of a laboratory member's injuries in a work accident.[5]

Over the last 20 years in Argentina, different universities have devoted some effort to establishing Hygiene and Safety (H&S) departments for H&S service and control. Nonetheless, the bottleneck of this initiative has been the necessary investment to update the scientific infrastructure to reach the current international standards on safety. So far, it has been more productive and time-efficient to work directly on fostering safety culture by both including H&S subjects in the undergraduate curricula and developing 1−2 day courses for university staff agents. Those courses usually cover general legislation, basic fire prevention, first aid, chemical risk, biological risk, and so on to reach the overall diverse activities and exposures in the university. But for researchers in the chemical sciences, this approach does not offer additional information or training. It is interesting to mention here that this situation and difficulties seem to be similar to universities in developing countries as Bangladesh[6a] and Trinidad and Tobago.[6b]

In our university, the College of Chemistry comprises seven research departments from which the Organic Chemistry and the Pharmaceutical Sciences departments share the same building. In particular, in our Organic Chemistry Department, we count an inventory of nearly 5000 different chemical compounds. This fact represents a special motivation to be the leading and proactive department on safety policies. The great diversity of chemical products, together with the high volume of flammable and carcinogenic solvents, represents a high risk that forced us to take additional preventive measures. These local safety actions were implemented as a complement to those provided by the university. In this article, we describe an approach for enhancing safety culture in chemistry research laboratories with little economic investment.

■ GENERAL APPROACH: THE SAFETY WATCH

To prevent an accident, we must work to reduce unsafe conditions and minimize unsafe actions.[7] As included in the general recommendations by the Occupational Safety and Health Administration (OSHA), USA,[8] the recommended controls to reduce potential hazards are

1. eliminate the risk
2. substitute the source of risk
3. implement engineering solutions to mitigate it
4. establish administrative regulations
5. use personal protective equipment (PPE)

A quick analysis of these recommendations allows us to find out that several of them require strong support from institutions, as well as investment and time. However, often the first two recommendations can be developed independent of economic investments and by fostering a safety culture in the laboratory.[9] As such, we decided to organize the agents in the workplaces to take on this task, because people in each different research areas will be more familiar with the specific hazards and related risks to their work.[9] The first observation was that this endeavor requires a time commitment and researchers' schedules were already too full with different responsibilities to assume this additional task individually. Thus, the Department of Organic Chemistry took the initiative to prioritize and organize the safety laboratory culture enhancement. To achieve this goal, the self-motivated department's agents work consecutively and iteratively in a 12-step program targeting cost-effective and time-efficient actions directed to enhance safety in all the workspaces of the department (the Safety Watch, Figure 1). In the next sections,

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J. Chem. Educ. XXXX, XXX, XXX−XXX

we describe the specifics of this strategy and the progress made in results for each step of the way.

Initiation and First Steps

As depicted in the Safety Watch, the first step we took was to create an H&S internal advising committee for the department (step 1, H&SIAC, in Figure 1), incorporating at least one member from each research laboratory or workspace. Thus, our department created H&SIAC with 15 members and 2 coordinators. A key factor for building the H&SIAC was to invite motivated agents from each and all the research groups, independent of the person's position (Ph.D. students, postdocs, administrative personnel, technicians, teaching assistants, and professors). The unique requirement to join the H&SIAC was to commit part of the time to improve safety in the different workspaces. We defined the duties and scope of work for these committee members so that everyone understood the real mission and legal responsibilities associated with the tasks. Specifically, H&SIAC's main objective was the early detection of hazards associated with the activities developed in our research department. Then H&SIAC advises the department on how to address these issues by implementing time- and cost-effective policies and solutions. Thus, the creation of this H&SIAC sent a clear message to all staff members about safety being a departmental priority. Top management's commitment such as the department's advisory board support in this issue was fundamental to prevent researchers from interpreting this committee as "the safety police".[10]

It is important to note here that the heterogeneity of the H&SIAC members was essential to establish fluid communication with all the workspaces in the department. Moreover, this broad composition—including students, scientists, technicians, and so on—was effective at providing different viewpoints on safety risks and potential actions to minimize them. The constant work performed by this committee gradually motivated more agents to become involved. Thus, this committee is annually renewed in one-third of its members to allow new members to participate in this common responsibility. In addition, the H&SIAC plays an important role in the communication between the department and the Hygiene and Safety Office at the College of Chemistry (H&SO). This communication is often difficult as H&SO is usually composed of experts in the field but not scientists, while the department authorities are typically senior professors and researchers (or group leaders). Thus, a better understanding of the safety risks provided by the H&SIAC usually helps in the communication between the corresponding H&SO and department authorities.

Brainstorming and Problem Solving at the Laboratory Group Level

In order for the H&SIAC to advise the department on safety matters, it was necessary to better understand the related safety hazards involved in the developed activities in each workspace. Therefore, H&SIAC members brainstorm about local safety risks and hazards[11] in each particular laboratory and other workspaces in the building (step 2). Again, the broad composition of H&SIAC resulted in identifying discrete risks because different workspaces have different specific risks associated with them, while other laboratories may have similar safety problems (see the Supporting Information, Table S1, page S4). At this point, it was important not only to discuss these risks but also to define a clear agenda and time-dependent objectives. In these sessions, it is important to avoid nonproductive catharsis-type discussions including colleagues' irresponsibility, insufficient funding, and so forth.[12] Instead, it was essential for these discussions to avoid demotivation by highlighting productive ways to tackle a particular safety issue. Usually, by the end of these meetings, a priority list of safety issues was listed on the whiteboard with potential solutions to them (Figure 2). As this process was interactive, it allowed the agents to bring back to the H&SIAC meetings their observations about how efficient a given solution was and improve it in case it was necessary. Consultation with laboratory mates sometimes revealed additional issues not previously observed.

Normally, after defining hazards and safety priorities, several important risks related to building and infrastructure were

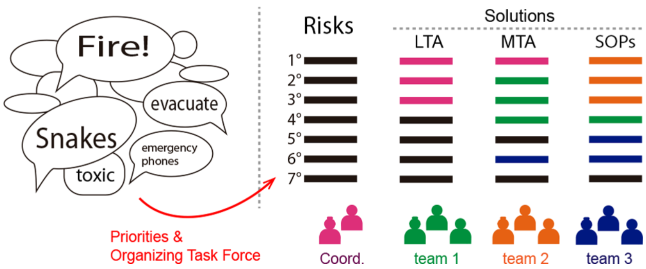

Figure 2. To improve the safety in the department, H&SIAC explore the actions during the brainstorming about the hazards and risks, by organizing a priority list. The safety issues to be addressed can be divided into long-term actions (LTAs), midterm actions (MTAs), and standard operations protocols (SOPs). We choose the first items to work in the first years and the rest to work in the next year's iteration. H&SIAC coordinators will then advise the department to solve LTA issues. Meanwhile, different teams will cover MTAs and SOPs.

identified and the department administration was informed; they in turn informed the corresponding H&SO. Nonetheless, a large percentage of the detected hazards were usually related to agents' working habits, and therefore these risks could be reduced with nonassociated cost actions. Elaborating a list of LTAs, MTAs, and SOPs allowed us to focus on the latter two and organize the course of action for the H&SIAC members (Figure 2). LTA solutions were mostly addressed by the institution as these solutions require a relatively large budget (i.e., a new room for gas cylinders). In the case of LTAs, the role of H&SIAC was to mediate communication and justify the investment requested to the H&SO. For midterm actions, in which we refer to some simple modifications or adaptations, the H&SIAC works with the department to get the issues solved with a small investment (i.e., hooks and chains to fix gas cylinders to the wall). In this case, H&SIAC advice helped the advisory board to elaborate a list of priorities to address in time and with the available budget. Finally, SOPs were defined as all the safety issues potentially solved by the adaptation or designing of new protocols, specific formation, or control by the Ph.D. advisor (i.e., gas cylinders change protocol).

Another finding throughout the Safety Watch implementation was that long group discussions and actions tend to be less efficient. In the first years, when the entire H&SIAC group tried to find solutions for a particular problem, periodic meetings become endless. Then, we organized task forces (step 3) within H&SIAC to work in particular assignments (three or four members, see Figure 2). Again, the diversity of the group allows us to strengthen the responses as people with different

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J. Chem. Educ. XXXX, XXX, XXX−XXX

skills contribute to different tasks (i.e., drawing, contacts, management, mediation, etc.). This strategy also provided the opportunity for task forces to keep updated on the progress of the developed solution and the related issues to that particular risk. These subgroups, in general, were responsible for elaborating, applying, and testing the suggested alternative low-cost solutions (step 4). If a particular task force presents two or more possible solutions to one problem that needs more analysis, those approaches were discussed with the committee. In this regard, one subgroup was working on the installation and maintenance of safety signs while another was focusing on the segregation and storage of chemicals in the hallway's special cabinets or in store rooms located outside the building. Periodic queries with the Fire Department were crucial to learn about potential actions to minimize risks. For instance, in one of their visits to our building, the firefighters suggested a content label for the storage cabinets in the hallways. In the case of fire, knowing the cabinet content enhances the firefighters' efficiency. Then, the task force in charge of safety signs implemented that advice at a very low cost by simply printing signs with the recommended format. Another useful recommendation was the installation of a simple doorbell with activation buttons located at accessible areas, as a provisional emergency alarm before the installation of the more expensive fire alarm system. Additional examples of these solutions can be found in the Supporting Information, pages S4 and S12. The general idea behind those examples is that being proactive instead of simply waiting for the high-cost solution to appear may also save lives.

Local Building Hygiene and Safety Information, Training

Periodic safety education is an integral part of fostering safety culture in the laboratory. Safety courses are an efficient way to communicate important recommendations such as safety updates in protocols, fire prevention and fighting, first aid, and so forth. As mentioned before, H&SO at the College of Chemistry organizes yearly a "mandatory general safety course". However, the course's content tends to be very broad, outdated, and with a general scope for permanent staff who have attended similar classes before. Also, considering the specific risks related to each department's activities, this theoretical content is often insufficient. A clear example of that is the result of an internal survey for staff members that the department carried out in 2011, which revealed that none of them knew how to pull the triggers for the fire alarm. Additionally, the Department of Organic Chemistry receives new members constantly (new teaching assistants, visiting professors, occasional users for instruments in the building, etc.). For all these people, the only available safety recommendations were communicated verbally by their laboratory colleagues or advisors. Considering this situation, H&SIAC undertook the task of complementing those general safety courses given by H&SO. The H&SIAC organizes an annual *Welcome Safety Meeting* (WSM), with special emphasis on new members of the institution and specifics for the activities developed in our department. In the WSM we combine theoretical concepts with practical demonstrations and local protocols. The original WSM consisted of a 4 h meeting covering specific topics related to H&S in the university and Department of Organic Chemistry. The presentations included different case studies of accidents in laboratories and the explanation of the important parts of our safety protocols.[13] The material used in the WSM also includes video tutorials, locally recorded or sourced on the Internet, to illustrate and learn from real accident scenarios. For instance, we present videos on topics such as an NIST video featuring fast acetone ignition in a laboratory,[14] fire extinguisher use,[15] personal and special protective equipment (PPE) location and use, fire alarm activation,[16] and emergency protocols,[17] among others. Those videos are quite effective and clear to the new agents,[18] and at the same time, the additional training allows us to complement the general safety knowledge with uniform and specific information related to our department. In Argentina, new agents usually join the different groups in the available research centers, in April according to government fellowship schedules. From 2014, WSM became mandatory and was scheduled for the second week of April to aim total coverage of the new agents, so that no one starts doing experiments without our basic and specific H&S info (step 5). This initiative laid the foundation of the current safety culture in our workspaces. Also, a short quiz at the end of it was helpful to determine whether the new members of the institution were taking this matter seriously. Despite this WSM, we realized that new staff joining after this meeting was held, and occasional workers, did not receive proper safety information. Therefore, in 2018 we moved to an *online safety training* (OST). This new OST allows new members of the department to take this training at any given time throughout the year, but requesting them to complete it before starting the assigned experiments and activities. Also, the *online* quiz results of OST are automatically registered, allowing us to keep a record for trained agents. Ultimately, the OST also represents an efficient way to communicate important modifications to the safety policies and protocols. Currently, permanent staff members in the department are also required to retake this OST every two years or when a critical update is made on the safety protocols. The online module is more versatile and fits in the complicated schedule of actual staff. By including professors in this training, legal responsibilities and emergency roles were better defined for all staff members. Thus, with a permanent staff of 104 agents in our department in 2018, 98 persons took the OST (94%), with mean scores of 96% in the online quiz (see Table S3, page S7 of the Supporting Information for additional details). These results demonstrate the efficacy of this new methodology.

Developing a Laboratory Safety Manual

Alongside OST, we realized that specific safety information for each research laboratory/workspace was important. For instance, OST did not cover handling specific reagents or instruments used in the different laboratories. Therefore, inspired by other universities, H&SIAC prompted the elaboration of a laboratory safety manual (LM, step 6), which compiles the specifics of the projects developed in each workspace. This LM helped us to incorporate the heterogeneity from the different research from each group to the department safety policy. Obtaining all the required information to build an LM with a unified and specific format required a great deal of time and work. To move forward with this objective, we used a step-by-step strategy (Figure 3). Until the H&S information was compiled for OST, it was easier for all groups to compile a laboratory manual with the same content and format for all the laboratories in the building. The content of this laboratory safety manual is discussed in the Supporting Information (page S8) and outlined below:

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J. Chem. Educ. XXXX, XXX, XXX−XXX

1. laboratory member information, including names, roles, and contact details
2. emergency phone numbers, roles, and plans
3. maps of workstations, exits, and campus
4. emergency protocols
5. hygiene and safety regulations
6. accident and incident records
7. SOPs, including MSDS for most hazardous chemicals, specific activities, instrument maintenance sheets, and so forth
8. laboratory cleaning records
9. additional information and records

An important feature of the LM is that it is always available and visible for permanent reference of all (new laboratory members, permanent staff, or visitors).

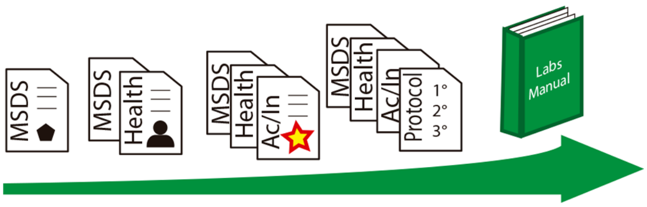

Figure 3. Laboratory manual construction over time. In our first step, the laboratory completes an MSDS folder for reactants and solvents. Second, we add a personnel health emergency information form for each laboratory member (see the Supporting Information, page S17). Then, we add an accident/incidents record for future analysis and prevention. Now, the laboratory manual also covers all maps, emergency protocols, phone numbers, instrumental care, maintenance, and laboratory cleaning schedule, etc. All the material in the LM has unified sections and is presented in a big green folder that is easy to find in each laboratory.

Emergency Procedures and Specially Assigned Tasks

Moving forward with Safety Watch, we sought to develop an emergency plan (step 7) based on the particularities of our building and activities. In organic chemistry research we are exposed to different risks, but laboratory fire is certainly a high probability accident and it requires a quick and trained response. As the fire in a laboratory can quickly get out of control,[14] the time span for the first response is very short. Therefore, every second is important in the consequence of this type of accident. Spills and gas leaks, depending on their nature, may require immediate or calmer action. Thus, an emergency can become chaotic and more dangerous if people do not know what to do. Agent training is key to achieving rapid and organized reactions in emergency containment. Usually, emergency plans are prepared by H&SO at the College, but again due to the inherent risks associated with our work, we decided to be proactive in this matter. As two different research departments (Pharmaceutical Sciences and Organic Chemistry) coexist in the same building, H&SIAC actively collaborated with the authorities of both to design and elaborate an emergency evacuation plan.

We approached the Fire Department of Córdoba to develop the first emergency protocol (Figure 1, step 7) with no associated cost. Later advice and feedback from the Civil Defense Office in the city government improved that emergency protocol's first version. All emergency instructions were included and explained in the OST. As mentioned above, a challenging part of designing an emergency plan is that most of the department's agents have diverse tasks and workstations throughout the day and year. Hence, it was not possible to assign a specific emergency role to a single person. It was then imperative to rethink and adapt the emergency response concepts. First, we consider two plausible scenarios: an emergency in an agent's laboratory or building evacuation.

1. *Emergency in the agent's laboratory:* In case of a small incident/accident in the laboratory such as a fume hood fire, toxic spill, or gas escape, all agents in the laboratory should be prepared to react immediately using local containment resources available. Therefore, we aim to facilitate the training of all agents in a particular research group or office for the use of available first-response elements, such as fire extinguishers, adsorbent materials for liquid spills, etc. Simultaneously, we recommend that another laboratory member pull the fire alarm. This supports the importance of always complying with the rule of "do not work alone in the laboratory"; this response procedure cannot be handled by an individual working alone.
2. *Building evacuation:* The second scenario concerns a sudden evacuation alarm sounding that unexpectedly interrupts routine work. This is the case, for instance, of large fires or highly toxic chemical spills in which it is dangerous to try to contain the incident. Also, this is the scenario that will indicate how to react if an accident/incident occurs in a neighboring laboratory. As mentioned above, building evacuation has to be performed according to the emergency evacuation plan that is triggered by the fire alarm activation. Upon hearing the fire alarm, we follow the three-step procedure abbreviated as *shut down, leave, and count.* "*Shut down*" refers to shut down of both the electric and natural gas service and shutting all the windows and

Table 1. Assigned Roles for Agents Holding Different Positions in the Research Departments

Academic Position	Role	Description
Undergraduate students and occasional visitors	Leave	Evacuate the building immediately; gather at the meeting point; wait for the rest of the group.
Ph.D. students, postdocs, and assistant researchers[a]	Shut down and leave	Shut down services in the laboratory; close the windows before evacuation.
Researchers and professors[a]	Group leader	Check that the laboratory is completely evacuated, and the services shut down; count laboratory members at the meeting point; report missing agents to the EC.
Department's director[a]	Emergency chief (EC)	Communicate with group leaders and agents from the laboratory where the accident took place; pass on that information to the emergency responders.

[a]If any of these agents are temporarily in a different workplace from their laboratory, they will act like a visitor and leave when the evacuation alarm is activated. In this protocol, every agent has an emergency role, depending on their hierarchical position. These strategies allow us to minimize risk, evacuate the building in 3 min, and easily determine whether anyone is missing. The Supporting Information (p S9) offers a complete description.

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J. Chem. Educ. XXXX, XXX, XXX−XXX

doors in the laboratory before leaving. This action was suggested by the fire department to avoid fire expansion. If possible, we recommended carefully stopping ongoing experiments that increase the risk to people when these experiments are unattended. *"Leave"* is self-explanatory, referring to the action of evacuating the building upon fire alarm activation, after shutting down operations, if applicable. Finally, *count* is related to finding your laboratory group at the meeting point and counting each member to be able to report a missing mate.

In this regard, instead of assigning an emergency role to a particular agent, we decided to train all of them and assign duties by the position they occupy. This way, there will always be at least one person for each role in the laboratory or office.[19] Therefore, the role is now assigned to a group of agents in each workspace as can be seen in Table 1.[20] This protocol allows us to immediately evacuate the most vulnerable agents from the safety training perspective —undergraduate students and visitors. The junior scientists perform all shut down operations before evacuating. Group leaders supervise all this operation and count their staff members at the meeting point. If someone is missing, group leaders report to the Emergency Chief (EC).[21] The EC role was assigned to the department's director.[20] When emergency service arrives (medical, fire-fighters, and police), these responders need to get specific information about the problem, dangers involved, and whether rescue will be necessary.[22] When an evacuation is initiated, the EC puts on a reflective vest, takes the complete staff manifest, and reports to the meeting point where he or she communicates with group leaders and then informs emergency service personnel (Figure S1B, Supporting Information). Thus, when an accident occurs or the fire alarm sounds, all laboratory members react immediately in their pre-established role.

As general valves for critical services such as electricity and natural gas are located outside of the laboratories, the emergency plan includes some *special tasks*. Any additional emergency tasks are assigned strategically according to the location of the agent's workplaces and displayed clearly in each laboratory door. As indicated in Figure 4, personnel from the laboratory located close to the floor electricity panel (black and yellow box) also have the assignment of shutting down electricity supply for that floor, while those agents close to the emergency exits have to open all emergency doors of the main exit. In this regard, during one of the previous drills, it was observed that people usually evacuate only using the already open door, while other emergency doors were also available. In this case, and many others, we benefit from the drills' feedback to improve the emergency evacuation plan. The building also has common spaces such as a cafeteria, instrumental laboratory, etc. In all these cases, H&SIAC has assigned agents with special tasks to cover these spaces. All these special tasks are indicated in the LM and signs posted on each laboratory or office door.

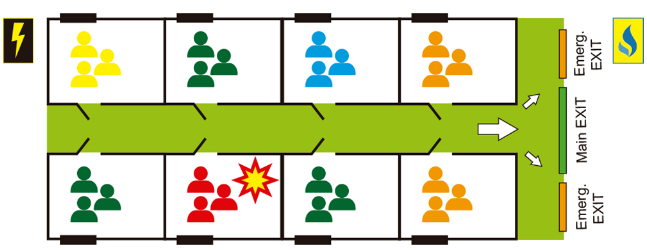

Figure 4. Simplified floor map. In an emergency (blast sign), laboratory members involved (red), activate evacuation alarm and content the situation. The agents in other laboratories proceed with evacuation protocol (green). Depending on the laboratory location, some agents have special tasks, such as shutting down building electricity (yellow), gas services (cyan), or opening all emergency exits (orange) to facilitate building evacuation.

With an emergency plan in place, we decided to overcome another important training challenge. Although most agents knew about the fire alarms triggers, none of them knew about the right activation procedure. Thus, we include a video tutorial about the alarm trigger in the OST. However, this information is not enough to prepare the agents for a real emergency.[23] Emergency drills are a useful tool to prepare agents to handle anxiety and panic in real situations. Emergency evacuation drills (step 8), are typically thought of as being an exercise that necessarily integrates Fire Department actions and emergency responders. Nonetheless, by the recommendation of the Fire Department, H&SIAC developed different drill levels with different exercise degrees (Table 2, and complete description in the Supporting Information). To perform these drills, we have an advantage in that our alarm system uses an mp3 track with a sound like an antiaircraft alert plus a male voice indicating the emergency.[24] For the simulations, we changed the mp3 track to another alarm sound from the *Star Trek* series, followed by a female voice indicating the drill level.[25] Both alarm sounds are shown in the OST. This track change allows us to perform surprise drills and avoid fear and chaos because people know when they are practice drills and when we are in a real emergency. In the drills every agent should act as responding to a real emergency in order to be familiarized with the emergency evacuation plan roles.

In this manner, the drills are often performed without shutting down the services but simulating such service shutdown by placing signs on the main switches and valves (see Figure S1A). With this action, drills have significantly less impact on the researchers' activities, and therefore enhance their participation and commitment. In these cases, the focus is put on the speed of the complete evacuation after the alarm is triggered, and the required content actions. The drills' results allow us to improve protocols and future training. In addition, the H&SIAC assemble a group of voluntary agents from both research departments who were assigned the role of drill organizers. It is important to mention here that there is no point in organizing separated actions when both research departments coexist in the same building.

As new and regular staff members need to be familiar with their emergency roles, we perform at least two drills per year of different levels. Usually, we add modifications to the emergency plan based on the agents' feedback and infrastructure improvements. To reach more people, we organize drills when most agents are present in both departments (for example, during exam periods).

■ OBSERVED RESULTS AND INSTITUTIONAL SUPPORT BUILDING

The gradual and periodic application of safety watch steps throughout the past 15 years led us to enhance the hygiene and safety in the department and the building in general. Evidence of that is that by the end of 2018, 94% of the department's agents were trained in specific hazards and SOPs to reduce the

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J. Chem. Educ. XXXX, XXX, XXX−XXX

Table 2. Drill Level and Description

Level	Main Objective	Description[a]
1	Evacuation time optimization	Fire alarm activation and building evacuation without service shut down; use of labels for simulated shutdown.
2	Emergency response and evacuation	Fire/spill simulation followed by alarm activation and evacuation without service shut down; use of labels for simulated shutdown.
3	Emergency response, evacuation, and emergency systems	Fire/spill simulation followed by alarm activation and evacuation with service shut down; use of emergency lights and uninterruptible power supply system (UPS).
4	Complete exercise	Coordinated exercise with the fire department and medical services, including roleplaying of injured people and their treatment, with service shut down and the use of emergency lights and UPS.

[a]The Supporting Information offers a complete description.

associated risks to their activities. Nevertheless, it is difficult to quantify the improvement in safety culture without specific statistical research. However, we have found signs of improvement. Today, a generation of students who started their activities in our research department are already graduated, and a good number are now working in the same department as Ph.D. students, assistant researchers, or young professors. These new members took the complete OST and incorporate safety practices in their daily activities. Thus, through these new generations we are certain that H&SIAC actions successfully fostered a stronger safety culture for these chemists. Additionally, the H&SIAC activities have reached all department agents regardless of their position and have achieved the top management commitment, which was found to be critical to incorporate safety practices in the laboratories. Also, in the last years of work, the H&SIAC became institutionalized as part of the permanent advising committees for the department (step 9). These actions became a positive influence and inspirational to other departments of the College and research institutes, in terms of safety policies. Therefore, after building this reputation, the H&SO in the College of Chemistry became motivated to support the department and the H&SIAC. Recently, H&SO helped us to obtain safety elements such as updated fire alarms, expensive Halon fire extinguishers, fire blankets, new safety showers, eyewash, spill containment kits, new PPEs, special masks, and signaling, among others.

The strategies developed and presented here led to interesting outcomes in terms of safety culture for the agents. Today, no agent can start working at the Department of Organic Chemistry without specific safety training about the associated hazards related to our work and the role that every person should play in an emergency. Also, thanks to the OST and the well-established H&SIAC and its heterogeneous composition, we have a fluent communication of safety-related issues. The emergency evacuation procedure has been tested yearly through different level drills. Today, most staff members are familiar with the alarm activation and procedures to minimize risks and consequences in an accident. H&SIAC constantly receives feedback from the agents. Thus, we permanently incorporate suggestions for improvements, making all agents part of the H&S developing process. Consequently and ultimately, fostering safety culture in our academic chemistry building, is a result of a collective effort. As mentioned before, two research departments share a research building, including ~200 people inside. The drills demonstrated that all these agents are able to fully evacuate the building within 3 min, which is according to Fire Department's recommendations. While there are still several things to improve, these exercises brought calm and organization to the staff in case of fire alarm activation. Today, emergency drills have become part of the regular schedule for agents and responders from the city. The firefighters or city civil defense office actively participates in some drills as observers and provides us with useful advice. As stated above, this positive example in the Department of Organic Chemistry has spread to other research buildings within the College and Research Institute to which we belong, which began to develop similar safety culture fostering programs (step 10).

As trained agents, the department employees are better prepared for similar emergency evacuation plans while working in different buildings. For example, in 2015 the H&SO from the College of Chemistry developed a level-4 drill in the teaching laboratories building. At the end of the drill, it was clear that only the teachers from the Organic Chemistry Department evacuated the building correctly, and then guided their students to the meeting point. Thus, not only is safety culture important for our staff, but also it is significant for people working along with them.

The department advisory board's support allowed us to achieve permanent training and communication with agents from all research groups and workspaces. Later in 2018, the advisory board established that the biannual OST and the laboratory cleanings (1 or 2 per year) are mandatory activities for all groups. Also, the department is now actively seeking funding from the college and university to apply higher-cost solutions in safety and hygiene (step 11). Last year, our department acquired masks with specific filters to handle toxic gas leaks such as ammonia, a compound routinely used in our building. Also, the H&SO provided new fire extinguishers and fire-retardant laboratory coats to the departments' agents, which were previously absent, (step 12). The availability and proper use of these new safety elements for firefighting and new PPEs, can be now incorporated in the OST, demonstrating that the development of this safety culture is really an iterative process in constant improvement.

■ CONCLUSIONS AND PERSPECTIVES

The strategy developed and presented here led us to foster a better safety culture in our workplaces. The presence of the H&SIAC has contributed to establish fluent communication throughout the department in regards to hygiene and safety. Important milestones such as the development of an emergency evacuation plan and a regular schedule for emergency drills among other positive outcomes were only possible due to the efforts of many different students, researchers, and professors who committed their time to the H&SIAC activities. Since the creation of the H&SIAC, the "safety and hygiene" concept in our department changed from being a simple recommendation to a departmental priority. Over these years of work, we achieved a sustainable improvement in safety culture by a process similar to that described as the Bradley Curve.[26] The implementation of an online course with specific protocols and information combined with drill exercises, allowed our department to be better prepared for emergencies. As a consequence, Ph.D. students and postdocs from our department incorporate H&S as a natural part of their activities (teaching, scientific research, industry, among others). From our experience, this safety culture can be grown independent of whether a large amount of economic resources can be invested, by simply establishing safety as a priority in our daily activities. We think that undergraduate students, Ph.D. students, postdocs, or researchers must acquire excellent skills in chemistry; but they must also be able to incorporate professional commitment to safety beyond available resources. While this article is not a statistical assessment on laboratory safety in our workplaces, we hope that the strategy, experience, and results presented here will serve as an alternative to other institutions similarly framed in terms of funding but with the strong motivation to adopt this safety watch to their research areas.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.9b01042.

Information to help to reproduce this strategy in other institutions (PDF, DOCX)

■ AUTHOR INFORMATION

Corresponding Author

Daniel A. Caminos – *Departamento de Química Orgánica, Facultad de Ciencias Químicas, Universidad Nacional de Córdoba, Córdoba X5000HUA, Argentina; Instituto de Investigaciones en Fisicoquímica de Córdoba INFIQC, Consejo Nacional de Investigaciones Científicas y Tecnicas, CONICET, Ciudad Universitaria, Córdoba X5000HUA, Argentina;* orcid.org/0000-0001-7974-7024; Email: dcaminos@unc.edu.ar

Author

Alejandro M. Fracaroli – *Departamento de Química Orgánica, Facultad de Ciencias Químicas, Universidad Nacional de Córdoba, Córdoba X5000HUA, Argentina; Instituto de Investigaciones en Fisicoquímica de Córdoba INFIQC, Consejo Nacional de Investigaciones Científicas y Tecnicas, CONICET, Ciudad Universitaria, Córdoba X5000HUA, Argentina;* orcid.org/0000-0003-3016-6813

Complete contact information is available at: https://pubs.acs.org/10.1021/acs.jchemed.9b01042

Notes

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(4) In this context, an "agent" is defined as any worker in the building, regardless of their position (professor, assistant, advisor, student, technician, administrative personnel, etc.). The word "agent" should not be confused with chemical agents, biological agents, or physical agents, which are usually present in many laboratories.

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(10) In our experience, and considering that one of the main roles for the H&SIAC is the communication of the safety and hygiene surveys and potential corrective actions, it is desirable that the H&SIAC be led by young scientists or professors as they will likely stay a long time in their position and they could provide a time-perspective to the solutions. Also, keep in mind that a professor will more readily accept a recommendation from a colleague professor than from a first-year Ph.D. student.

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J. Chem. Educ. XXXX, XXX, XXX–XXX

(11) According to the Canadian Centre for Occupational Health and Safety, Government of Canada, "hazard" is a potential source of harm to a worker; "risk" is the chance or probability that a person will be harmed. See: CCOHS. Hazard and Risk. https://www.ccohs.ca/oshanswers/hsprograms/hazard_risk.html (accessed 2020−06−09).

(12) Depending on the special situation of each department, the first meeting may be more or less productive. If the situation of H&S is serious, it is very likely that at the first meeting everyone will talk, shout, and even quarrel. People will have a lot of complaints about the irresponsible work of colleagues, students, professors, university, the government and more··· Leave about 30 min for people to do their catharsis and move on.

(13) Several of the resources used to develop this annual welcome safety meeting were produced locally (videos, photographs, etc.) or obtained from internet resources. In general, we prioritize the use of Spanish-language material for better understanding; when that is not available, we use alternatives in English.

(14) The video shows the ignition of 4 L of acetone in a laboratory. In just 45−60 s the flames overtake all the space. NIST—National Institute of Standards and Technologies, U.S. Department of Commerce. Lab Test No Sprinkler 4L Acetone Spill. https://www.youtube.com/watch?v=FJhRHng8gVM (accessed 2020−06−09).

(15) Startfirextintores. Fire Extinguishers: Como Usar su Extintor, 31 Mar 2012 31. https://www.youtube.com/watch?v=HGVZ_qAMprc (accessed 2020−06−09).

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(19) The emergency plan was adapted from an analogous one in a gas station. For emergencies, the roles in a gas station are assigned by personnel rather than by individuals so that in a given shift, a person in a particular role knows he or she will perform certain duties to respond to an emergency. Thus, for example, the person pumping gas will fight the fire with an extinguisher, the administrator on duty will shut down the electricity and gas services, and the shop employee will make emergency calls, etc.

(20) As seen in Table 1, in an emergency the department's Directors have been assigned with the role of Emergency Chief (EC). This particular role cannot be absent from the emergency response. In the case of director absence, our department established the order for the EC role followed by the vice-director, then the H&SIAC coordinator, and finally the department advisory board's senior member.

(21) For this, it is important that group leaders know the activities' schedule of their staff members (teaching schedules, courses assistant, extra-building assays, etc.).

(22) As was explained by the Fire Department, in an emergency, the fire chief looks to the building authority for information, while at the same time police often remove all unnecessary people from the area. The EC role is crucial to avoid the chaos and misinformation at the scene and to save lives.

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(24) The evacuation alarm can be heard online. https://soundcloud.com/danielcaminos/alarma-de-emergencia (accessed 2020−06−09).

(25) With this drill's (Spanish language) soundtrack, the alarm sounds by 3 min (evacuation time), then the sound decreases intensity and music could be heard, which allows the drill organizers to perform lab checking. Drill alarms by level can be heard online. Level 1: https://soundcloud.com/danielcaminos/alarma-nivel-1 (accessed 2020−06−09). Level 2: https://soundcloud.com/danielcaminos/alarma-simulacro-nivel-2-ed-cs (accessed 2020−06−09). Level 3: https://soundcloud.com/danielcaminos/alarma-nivel-3 (accessed 2020−06−09). Level 4: https://soundcloud.com/danielcaminos/alarma-nivel-4 (accessed 2020−06−09). All drill alarms were produced in 2013 by Gutiérrez-Nicolás, F. (voice); Rimondino, G. N.; Krapacher, C.; Agazzi, L.; Caminos, D.

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J. Chem. Educ. XXXX, XXX, XXX−XXX