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FEATURE

A research university's rapid response to a fatal chemistry accident: Safety changes and outcomes☆

The University of California at Los Angeles (UCLA) quickly and comprehensively transformed its laboratory safety program following a chemistry accident in December 2008 that caused the death of a researcher. UCLA's Chancellor immediately announced sweeping changes in the laboratory safety program and challenged UCLA to become "Best in Class" in academic laboratory safety. Given the size of UCLA's lab researcher population and the decentralized nature of the campus, it became a daunting task to reach out and improve compliance with newly implemented safety policies. The Office of Environment, Health and Safety (EH&S) improved their operations, enhanced overall inspection procedures, and instituted mandatory laboratory safety training of PIs and researchers. A Laboratory Hazard Assessment Tool (LHAT) was implemented to aid in the identification of hazards, track laboratory space and personnel, and guide lab groups in compliance with personal protective equipment (PPE) policies. Laboratory inspections were increased by more than 4-fold in 2012 as compared to 2007 and now followed a comprehensive checklist to improve reproducibility and thoroughness of the inspection process. To provide better customer service to the research community and expedite corrective actions, all laboratory inspection reports are required to be issued the next business day. Unannounced PPE inspections began in 2010, and inspection findings showed a robust decrease in non-compliance with the PPE policy within one year of its implementation. As of the first half of 2013, all PIs of active laboratory research programs had completed the initial, in-class PI-specific laboratory safety training. In 2012, more than 20,000 EH&S safety classes were completed either in-class or online by PIs, lab supervisors, research staff, students, and visitors to UCLA's research laboratories. Overall, analysis of outcomes from changes in UCLA's lab safety program indicates rapid improvements in compliance with lab safety regulations such as increased PPE use. Lab safety changes required commitment and cooperation at all levels – from executive leadership, to health and safety experts, to deans and department chairs, and to PIs and researchers.

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INTRODUCTION

The death of staff researcher Sheharbano Sangji resulting from injuries sustained in a 2008 chemistry laboratory fire required UCLA to respond quickly and effectively to this unexpected crisis while under intense regulatory scrutiny. Adding further complexity to the response efforts of the campus was unprecedented and widespread attention from both the mainstream and industry media, as well as from research institutions across the nation. The event had a profound impact campus-wide, especially on those involved in research and laboratory safety, including the Office of Environment, Health & Safety (EH&S), whose mission it is to protect the health and safety of the campus community. Since the 2008 accident at UCLA, the national landscape in laboratory safety has further intensified due to significant laboratory accidents at other universities including serious chemical accidents that prompted an investigation by the U.S. Chemical Safety Board.[1,2] As a result, UCLA has been asked to share laboratory safety findings and recommendations with numerous public and private research institutions. This exchange has been an educational and collaborative process.

To address immediate deficiencies, an interdisciplinary team of experts was formed consisting of lab safety specialists, injury prevention specialists, industrial hygienists and campus fire marshals. Within 30 days following the accident, the team conducted comprehensive inspections of more than 300 laboratories, chemical storage rooms, and shops within the Department of Chemistry and Biochemistry, where the devastating accident had occurred. The inspections identified numerous operational problems that extended campus-wide. Foremost, at the time of the accident it was not clear how many hazardous chemicals were stored in the thousands of laboratories on campus. Furthermore, there was only limited documentation on whether laboratory personnel were trained in the usage and storage of hazardous substances. It was also not known how many laboratories, PIs, or total researchers existed on campus – a conundrum caused by UCLA's decentralized research community. In addition, laboratory design flaws were identified that had the potential to increase the risk of accidental injuries. For example, the team discovered that storage cabinets for water reactive chemicals were located directly underneath emergency showers in eleven laboratories of the Department of Chemistry and Biochemistry, which had gone unnoticed and uncorrected for over a decade and had the potential to increase the risk of serious accidental injuries. Within weeks of their identification, improperly located safety showers were removed and signs posted in their place to direct researchers to a nearby location with a compliant emergency shower.

UCLA's Roadmap to Laboratory Safety

Following the fatal laboratory accident and concurrent with EH&S' emergency response actions, UCLA's Chancellor announced sweeping changes in the university's laboratory safety program and challenged UCLA to become "Best in Class" in laboratory safety among research institutions.[2,3] Top-down communication of laboratory safety became of paramount importance at UCLA. To assist in this effort and to help implement laboratory safety protocols, a Laboratory Safety Committee was established, which was led by faculty from several campus departments and included a research staff representative, EH&S senior safety officers, the EH&S director, the Senior Associate Dean of Research from the Medical School and UCLA's Vice Chancellor for Research. In July 2010, the Chancellor created a new position, the Associate Vice Chancellor for Research, charged with outreach to faculty members and researchers to support the campus laboratory safety initiatives and to act as a liaison between the research community, EH&S staff, and academic administration. The Laboratory Safety Committee conducted a thorough study of all aspects of laboratory safety at UCLA over the course of six months. In July 2009 the committee submitted the following recommendations to UCLA's Chancellor:

- *Develop a strong safety culture:* A top-down culture of safety consciousness should be developed that involves a management approach in which the Chancellor, Vice Chancellors, Deans, Department Heads and Principal Investigators (PIs) embrace the necessity of laboratory safety, support efforts to improve safety, and stress to staff that the health and safety of each individual depends on teamwork and personal responsibility.
- *Improve and expand outreach and training:* A critical element of safety education includes developing and encouraging basic attitudes and habits of prudent behavior in the laboratory so that safety is valued as an inextricable component of all laboratory activities. To achieve this, improvements in the quality, frequency, availability, tracking, and documentation of training are needed.
- *Increase accountability and oversight:* Oversight of safety in research activities should be expanded to ensure consistent maintenance of high professional standards and hold Principal Investigators and other laboratory staff accountable for implementation of safe laboratory practices and procedures. The Laboratory Safety Committee is charged specifically with oversight of research areas involving chemical and physical hazards to help strengthen laboratory safety and bring oversight closer to that in the more highly regulated areas of Radiation and Biological Safety.
- *Improve laboratory design:* It is essential that laboratories be designed by experts who are familiar with how laboratories operate. EH&S and faculty should routinely be included in the design of new or to be renovated laboratories to ensure presence of safe engineering controls and to comply with regulatory standards. Additionally, EH&S must be consulted whenever structural alterations take place to ensure health and safety of laboratory researchers as well as compliance with regulatory requirements. EH&S can also assist with optimization of chemical and hazardous

waste storage capacity and ergonomic design features.
- *Improve inventory and record keeping:* A systematic approach for the tracking of laboratory space, laboratory personnel, laboratory hazards, chemical and hazardous material inventories, etc. should be implemented and updated regularly.

Challenges and Goals

At the time when UCLA began to restructure its laboratory safety program several factors complicated this process. One was the impact of the national economic recession, which required university-wide work furloughs that also affected EH&S staff. The furloughs reduced the amount of time staff members were allowed to work and, as a consequence, decreased employee salaries making UCLA a less competitive work place. In addition, research groups often consider themselves as individual entities in which research practices are dominated by what works for their own safety, rather than by standardized safety operation procedures developed by a central authority. Because of this attitude, UCLA's research community initially responded to the extensive changes in lab safety procedures implemented at the beginning of 2009 with skepticism and resistance. While researchers often lacked knowledge about safety policies, EH&S staff, on the other hand, had little or no understanding of the experimental procedures conducted in laboratories. This disconnect created an atmosphere of mistrust and unwillingness to cooperate with one another. Because UCLA's EH&S was exempted from the general hiring freeze, safety inspectors that left as part of the normal personnel turnover were replaced by individuals with research background including several with Ph.D.s in Chemistry and other science disciplines. Furthermore, EH&S changed its interactions with the research community to provide better assistance and service and to emphasize collaboration with researchers.

The purpose of this paper is to provide those in the scientific research and laboratory safety communities with additional understanding regarding the improvements UCLA has implemented in the past four years. An additional goal is to convey an accessible template for lab safety program design available for replication within other research institutions. Furthermore, we present results on behavioral changes in UCLA researcher compliance indicative of a changing laboratory safety culture at UCLA.

METHODS

The UCLA Laboratory Hazard Assessment Tool (LHAT) was originally designed as a paper-based questionnaire using a template developed by the University of Iowa. In 2009, LHAT was developed into an online reporting system, and became a mandatory inspection item as of 2010. At least once each year or when there are changes in the laboratory, every PI, lab supervisor, or their authorized designee has to record or update lab personnel, lab rooms occupied, and types of hazards specific to their research activities. As of 2013, OSHA requires PPE training for each lab member – and this is now a mandatory component of LHAT. EH&S staff accesses the LHAT database to identify types of hazards used by each lab group, i.e., biohazards, chemical hazards, radiation hazards, laser hazards and nanomolecule related hazards. Furthermore, LHAT is used to determine each lab's hazard levels based on the types of hazards present. Hazard levels are classified into four major categories:

Level A: High hazard (e.g., pyrophoric chemicals)
Level B: Strong hazard (e.g., acutely toxic substances)
Level C: Moderate hazard (e.g., small volumes of flammables)
Level D: Low hazard (e.g., potential of minor spill)

Inspection data were recorded between 2007 and 2012. Inspections were performed annually as walk-through safety audits and were scheduled with the PI or lab manager. Laboratories evidencing level 'A' categorization are inspected twice per year. As of 2009, inspectors use a checklist that was greatly reorganized and expanded to now contain 91 lab inspection points arranged in 13 sections differentiated by types of risks (Appendix A). The sections collect information on laboratory personnel as well as types of hazards and verify information recorded in the LHAT database. The checklist identifies 23 serious findings, which prompts re-inspection after 48 h. Serious findings include health hazards that have the potential but do not pose an immediate danger to lab personnel (e.g., absence of secondary containment of hazardous chemicals contained in glass bottles, and improper storage of flammable compounds). In contrast, critical findings (e.g., not wearing appropriate PPE when working with a hazardous substance) that are 'immediately dangerous to life or health' (IDLH) require immediate correction at the time of inspection, or research must be discontinued until the IDLH is amended. Non-serious findings are defined as hazards or deficiencies that would not be directly injurious (e.g., lack of proper training, LHAT documentation, missing standard operation procedures, etc.), and require correction within 30 days.

Although PPE inspections are part of the regular scheduled laboratory inspections (Appendix A), each lab receives additional, unannounced PPE inspections. These inspections are performed by EH&S staff and identify a limited number of checklist items specific to the use of PPE as well as other related violations (e.g., food/drink in labs) that can be observed quickly. The purpose of these unannounced inspections is to determine compliance under 'real' working conditions in which researchers are unaware that they will be inspected.

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ANOVA and Student's *t*-test were used for all statistical analyses.

RESULTS

Although serious accidents such as the death of researcher Sheharbano Sangji in December of 2008 are extremely

rare in academic institutions, laboratory safety problems faced by UCLA may be common in colleges and universities and they potentially pose a risk to researchers' health and safety. In the following we describe the changes implemented to improve laboratory safety campus-wide, and the behavioral changes by the research community as monitored by compliance during unannounced PPE inspections.

EH&S LABORATORY SAFETY PROGRAM IMPROVEMENTS

Standardized Inspection Checklist

Although UCLA had a laboratory inspection process in place before 2008, a nearly complete lab inspection restructuring was implemented using a reorganized safety checklist to standardize the inspection process. A comparison of safety checklists from 16 public and private universities from across the US was used to develop UCLA's inspection list into an improved, digitized check list. The checklist was expanded to emphasize training documentation. Furthermore, documentation of standard operation procedures for hazardous chemicals was included. Design and infrastructure deficiencies are also part of the inspection check list and remain an inspection citation until corrected by the PI or the PI's department. Improvements also encompassed the identification of chemical hazards present in the labs, which is used by EH&S officers to validate the lab's risk level as identified through the LHAT database (see Methods). Using the same standardized checklist for all types of inspections (i.e., for the yearly laboratory safety inspections, radiation, biosafety, laser inspections and for inspections of animal facilities) provided two significant advantages. First, even though labs are inspected by different EH&S officers, the inspection outcome is reproducible and data collected are comparable (as determined by inspection spot checks). Second, data for many of the labs are collected through several different inspection processes (e.g., annual scheduled inspections, unannounced PPE inspections, Category A hazard inspections), in addition to the LHAT data entry. This allows for tracking of potential recurring safety problems and, on the other hand, for positive implementation of safety regulations for each laboratory group at UCLA.

Data Collection via the Laboratory Hazard Assessment Tool (LHAT)

To facilitate and maintain hazard-related record keeping, PIs or lab supervisors enter specified information (see Methods) into the Laboratory Hazard Assessment Tool (LHAT) data base and update it yearly. PIs' compliance with LHAT campus-wide was 83% and 88% in 2011 and 2012, respectively, while PIs within the Department of Chemistry and Biochemistry, where the fatal accident had occurred, have been 100% compliant since 2011.

Since LHAT data are recorded online, they can be accessed by EH&S officers who verify lab rooms and personnel during laboratory safety inspections. However, verification of students and personnel working in the lab is problematic since both LHAT recording and laboratory inspections present snapshots of the number of lab workers at a given time; due to the relatively high turnover of students, especially undergraduate researchers, lab helpers, visiting faculty and high school students, the determination of the accurate number of researchers present in academic institutions including UCLA remains a challenge. Thus, the number of researchers, 4326, recorded in the LHAT database as of 2012 is likely an underestimation when compared with the number of people who completed the mandatory in-class or online refresher course "Laboratory Safety Fundamental Concepts" that year (7356). To acquire a more accurate number of researchers, EH&S is currently implementing a new system tracking all trainees that will interface with Human Resource data to correct for employee status (i.e., current, no longer employed). The number of PIs active in wet lab research was recorded as 712 in 2012 and was verified independently through departmental sources. The number of laboratory rooms recorded in 2012, 3621, is expected to be slightly higher as lab safety inspectors still find rooms that are not listed in LHAT by PIs.

Newly Implemented Laboratory Safety Training

Prior to the 2008 accident, training was provided on an as needed basis, as mandated by state and federal guidelines. For example, radiation training is required for researchers working with radioactive materials.[4] However, the 2008 accident triggered an expansion of training activities to encompass all laboratory researchers at UCLA. Key to improving the laboratory safety culture was to educate each PI and laboratory supervisor in addition to the lab personnel and students to accept compliance with the expansion of the laboratory safety policies. The "Laboratory Safety for PIs/Laboratory Supervisors" class was developed by EH&S, which delineates the PI/supervisor's roles and responsibilities in addition to explaining current Cal/OSHA regulations. Furthermore the PIs and laboratory supervisors are taught an abbreviated version of the "Laboratory Safety Fundamental Concepts" class. This class has to be taken by every single student, researcher and guest to UCLA laboratories including visiting professors, visiting students, high school students, and volunteers. Topics cover the recognition and mitigation of laboratory hazards; the use of engineering controls, administrative controls and personal protective equipment; working safety with chemicals, the use of material safety data sheets (MSDSs), now renamed to safety data sheets (SDSs), procedures for disposing of hazardous chemical waste, and fire safety precautions for the laboratory. The class for PIs and lab supervisors and the general laboratory safety classes are both taught by senior Chemical Hygiene or Laboratory Safety Officers. Initially taken in-person, a refresher class can be completed online every subsequent year. As of the first half of 2013, every single PI and laboratory supervisor has completed the required in-person training.

Training Documentation

Additional EH&S-offered training classes are required when researchers

either work with or are exposed to specific hazards (Supplementary Table 1). While attendance for such classes was always required it was not regularly enforced before 2007. Completion of training is now part of the laboratory inspection checklist. From 2001 to 2006, the total number of safety trainees remained below 500 trainees per year (data not shown). A trainee is equal to one student per class; for example, a student taking six different classes is equivalent to six trainees. From 2007 to 2012, the number of trainees increased from 3327 in 2007 to 21789 trainees in 2012 (Figure 1). The marked increase in trainees in 2009 compared to 2008 reflects the substantial expansion in laboratory safety educational outreach and training by EH&S. The number of individuals trained in 2011 and 2012 was almost constant suggesting that training is approaching its saturation point and that researchers have adjusted their compliance behavior to maintain their training records up-to-date (Figure 1). This is substantiated by the number of individuals participating in the "Laboratory Safety Fundamental Concepts" class, who approximate one third of all trainees in 2011 and in 2012 (denoted by arrows in Figure 1) and represent an estimation of active researchers in laboratories on campus.

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While a substantial number of classes can be taken online, 50% or more of the training is performed in classrooms with EH&S instructors to answer questions or discuss potential problems arising in laboratory environments (Supplementary Table 1). Online classes present the material in the form of manageable units each ending in a small test that either confirms the correct answer with a short explanation or allows for self-correction. Classroom instructions are presented in lecture style ending with the test to verify comprehension of key safety concepts. Subsequent self-correction of the test serves as feedback reinforcement of the material.

In addition to online and classroom training, all incoming students and staff are trained in their respective laboratories on hazards and practices that specifically pertain to their research. Training includes the general execution and cleanup of experiments involving hazardous materials and the appropriate use of PPE. It also encompasses an overview of emergency procedures including the eyewash, safety shower and fire extinguisher locations. This training is performed and also documented by the laboratory supervisor or by senior personnel who is qualified to handle the hazard. Lab specific training is mandatory, and is one of the items on the annual lab safety inspection checklist. Lab specific training is not included in Figure 1.

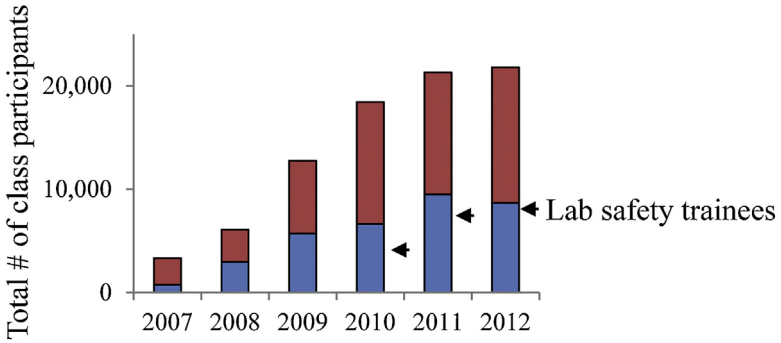

Figure 1. Total number of EH&S laboratory safety class participants. Data were not adjusted for participants who were enrolled in multiple EH&S classes (e.g., laboratory safety fundamental concepts, laser safety training, bloodborne pathogen training, hands-on fire extinguisher training, etc.) or completed the same class more than once per year (<5% of all trainees). Blue, completed the class online; red, completed the class with an instructor; arrows denote the total number of researchers and PIs having completed mandatory in-class laboratory safety training (Lab safety trainees); i.e., 4046 in 2010, 6553 in 2011 and 7356 in 2012 and provides an estimation of the number of researcher in laboratories at UCLA. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

IMPROVED ACCOUNTABILITY AND OVERSIGHT THROUGH INCREASED INSPECTION PROCEDURES

Scheduled Laboratory Safety Inspections

While laboratory self-inspections are recommended and are widely performed, UCLA relies on inspections by EH&S safety officers. EH&S' goal was to perform annual inspections of each laboratory, however, this was not accomplished until 2009. As of 2009, each laboratory was inspected at least once per year as indicated by the number of laboratory inspections exceeding the number of PIs active in research (Figure 2). Most of these multiple inspections were due to non-compliance findings during the initial inspections, which prominently increased in the years 2010–2012 (Figure 2). This increase is largely due to the newly implemented changes in UCLA's safety procedures. A breakdown of the laboratory safety inspection data from 2010 to 2012 illustrates that approximately 85–95% of all labs required re-inspection after 30 days (Figure 3A). While 38% of the labs were re-inspected because of serious finding after 48 h (see Methods) in 2010, this number decreased to 29% and 27% in 2011 and 2012, respectively, (Figure 3A) demonstrating a significant improvement of compliance behavior ($p < 0.01$) although not quite to the levels observed for radiation safety inspections (Figure 3B). The 48 h re-inspection process is highly effective as many of the violations are corrected during the inspection under the guidance of the inspecting EH&S safety officer. In the inspector's 48 h report these problems are listed as "corrected during inspection". Other problems are generally solved within 48 h or 72 h (>97% in 2012).

A common violation resulting in a 30 day re-inspection are non-compliance

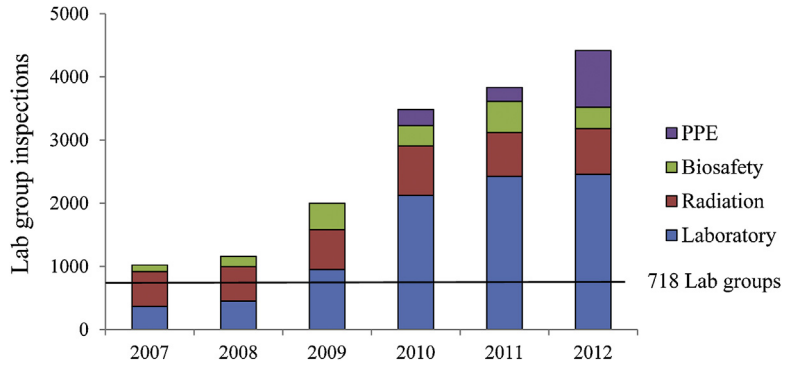

Figure 2. Number of campus-wide safety inspections. The number of campus-wide total inspections includes initial, critical 48 h, and 30-day follow-up inspections. The line denotes the approximate number of lab groups as of 2012.

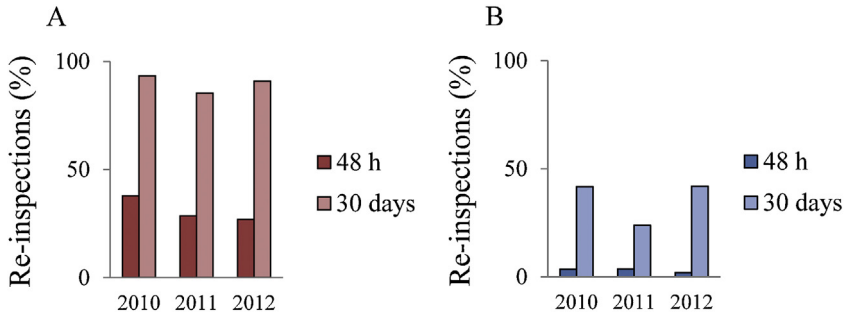

Figure 3. Re-inspections for laboratory safety (A) and radiation safety (B). Critical 48 h, and 30-day follow-up inspections mitigate deficiencies identified during the initial laboratory inspections.

with providing standard operation procedures (SOP) that meet EH&S' specifications for all hazardous chemicals used in the laboratory. In addition to the physical and chemical properties, SOPs include general information about the health hazard, recommended PPE and engineering controls to be used, first aid procedures and emergency phone numbers, storage and spill clean-up procedures, waste disposal and decontamination procedures. Furthermore, researchers have to provide a description of the experimental procedure(s) and document training with the hazardous chemical. UCLA's EH&S provides an SOP template and offers an expanding SOP library to facilitate compliance with SOP regulations. However, several researchers opted to dispose of the hazardous chemicals, which were no longer used in the lab, rather than to generate cumbersome SOPs. Thus, as an unintended consequence of the expanded inspections the amount of hazardous chemicals in some laboratories decreased. Problems triggering 30 day re-inspections may take longer to solve but were corrected 90% of the time within the year of 2012. In this case, labs continue to be inspected every 30 days until all violations have been mitigated.

UCLA holds its PIs accountable for correcting problems identified during inspections through an escalating reporting process that extends from the EH&S director to the PI's department chair and dean, Associate Vice Chancellor for Research with laboratory safety oversight, and Vice Chancellor for Research (Appendix B). Dependent on the severity of the violation, non-compliance within 48 h can trigger closure of the lab.

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Scheduled Radiation and Biosafety Inspections

The number of radiation safety inspections remained relatively constant over the past 6 years due to U.S. Nuclear Regulatory Commissions (NRC) requirements[5] (Figure 2) with 48 h re-inspections consistently below 5% and 30-day re-inspections always below 50% in the past three years (Figure 3B). The lower re-inspection rate suggests better compliance signifying an overall better adoption of the radiation safety culture, which has a long-standing history.[6]

Biosafety inspections more than doubled between 2009 and 2010, but then remained relatively constant thereafter (Figure 2). The increase in inspections is due to restructuring of the EH&S biosafety office with improved record collection in 2009. Re-inspection data are collected as of 2012. Biosafety regulations are not uniform but are based on the level of risk associated with the biohazard and generally follow NIH guidelines for research. Only the very highly regulated Select Agent Program receives annual inspections by EH&S inspectors and outside agencies, while other programs dealing with infected animal and human tissues, and risk group 2 infectious bacteria, viruses, prions and protozoa are regulated less stringently. At UCLA and other universities, biosafety inspections by EH&S inspectors are performed at the initial lab set up and every three years upon renewal of their Institutional Biosafety Committee (IBC) protocol. Thus, the number of biosafety inspections is not directly comparable with laboratory and radiation safety inspections (Figure 2). Nevertheless, the low 48 h re-inspection frequency together with fewer than 60% 30-day re-inspections (data not shown) hint toward a stable, accommodating biosafety culture.

Inspectors' Accountability

Two changes at EH&S turned out to be critical for UCLA's laboratory safety inspection processes. First, the inspection work done by each laboratory safety officer is reviewed every month by the senior laboratory safety officer who repeats one of the inspections the next day using the inspector's filled in checklist. The purpose of this quality control is to ensure reproducibility of the inspection process and safeguard compliance with regulations. As a

consequence, not only do the EH&S inspectors perfect their inspection routine but also the inspected lab group can rely on consistency of the process even if inspected by a different safety officer. Second, a prerequisite for effective 48 h and 30 day re-inspections is the timely delivering of the detailed inspection report to the inspected lab's PI by the next business day. The turnaround time for inspection reports has decreased significantly over the past years, and as of 2010, at least 98% of all inspection reports were issued on the same or next business day. Factors used to measure each inspectors' performance include the number of inspections conducted per month (30 inspections are required as a minimum), 90% timeliness of the inspection report, and the re-inspection of the lab within a required time frame.

The success of the improved inspection process is reflected in an annual survey that measures the lab's satisfaction with the inspection process. In this survey, lab members and PIs rated the quality and timeliness of the inspection report and the expertise, courtesy, and other aspects of interactions with their EH&S safety officer as 4–4.5 on a 5-point scale in 2011–2012.

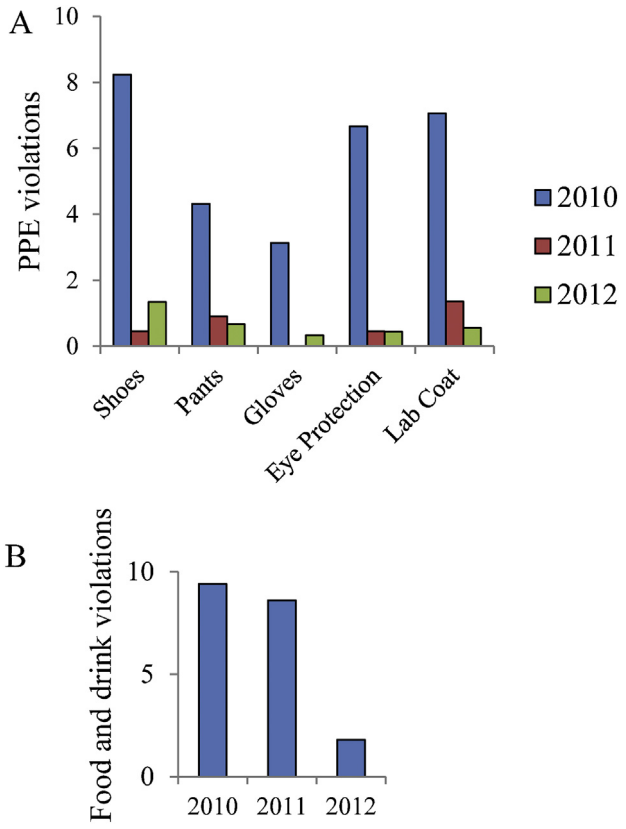

Figure 4. Number of PPE (A) and food and drink (B) violations per 100 lab groups per year. Violations were recorded during unannounced PPE inspections. Unannounced PPE inspections began in the fall of 2010; since the number of inspections per year varied, the findings were normalized to violations/100 lab groups/year. ANOVA and Student's *t*-test analysis was used to determine that the decrease in PPE violations from 2010 to 2011 and 2012 are highly significant in all categories ($p < 0.01$).

Unannounced PPE Inspections and Researcher's Compliance Behavior

Unannounced PPE inspections were instituted in the Fall of 2010 to increase oversight and further evaluate the use of required PPE by research staff and students (Figure 4). Specific PPE compliance checklist items for unannounced inspections include required clothing protocol (long pants and closed-toed shoes, with no exposure of bare skin) and required safety PPE protocol (lab coats, eye protection, gloves, etc.) as determined by risk assessments.

The first unannounced PPE inspections of a total of 255 lab groups were conducted in the third and fourth quarter of 2010 (Figure 2). In 2011, 221 labs were inspected and inspections were increased to 898 in 2012, visiting some of the lab groups more than once. The total deficiencies identified during these inspections ranged from 124 in 2010 to 52 and 67 in 2011 and 2012, respectively. To gain better insight into the types of PPE violations per year, the data were normalized to violations per 100 lab groups inspected per year (Figure 4A). The results show that PPE violations significantly decreased in 2011 and 2012 as compared to 2010 ($p < 0.01$). Overall, best compliance was observed with wearing protective gloves, with a 10-fold decrease of violations from 2010 to 2012. This level of compliance likely reflects the need of the researchers to either protect their hands from hazards they touch, and/or to protect their experiment from contamination by skin bacteria. Generally, worst non-compliances were identified with researchers not adhering to shoe and lab coat policy (Figure 4A). Not wearing a lab coat was identified as a primary contributing factor to the 2008 accident. However, lab coat violations decreased from 7% in 2010 of the normalized inspections, to 1% and below 1% in 2011 and 2012, respectively. Similar reductions in non-compliant conduct to 1% or below 1% of the normalized inspections were observed for all other categories suggesting that a combination of training and unannounced inspections had positively impacted the behavior of researchers over a relatively short period of time.

While not a dedicated PPE component, requisite food and drink protocol (none are allowed to be consumed or stored in any laboratory at UCLA) is also surveyed during unannounced inspections. In 2010 and 2011, 8–9 researchers per 100 lab groups still used food or drink in the lab, however, the number of these violations decreased 4-fold in 2012 (Figure 4B). Whether food violations remain low

will have to be established through further monitoring. Food and drink violations remain a problem due to building design flaws with nowhere for researchers to eat or drink close to their laboratory. This is especially challenging during sensitive experiments that can often require constant monitoring over a prolonged period of time.

DISCUSSION

This paper describes the changes in laboratory safety policies that were implemented at UCLA beginning in January of 2009. UCLA's safety policy changes occurred on three levels. UCLA's academic and administrative leadership spearheaded by UCLA's chancellor assumed active leadership in laboratory safety; UCLA's EH&S inspection program and data collection processes were effectively restructured and their training program was increased; finally, UCLA's research community displayed increased compliance with safety regulations in the years following the 2008 accident.

The immediate goal was to reorganize and centralize UCLA's laboratory safety program in order to prevent severe accidents from occurring again. Institutions like UCLA are challenged by their sheer size and complexity resulting in very different safety cultures across schools and departments of the university. Furthermore, laboratories within the same department displayed different safety practices. For this reason, the critical importance of safe laboratory operations had to be actively and personally communicated from the top. The Chancellor's and other senior university officials' proactive involvement proved essential to UCLA's expanding and improving laboratory safety culture. It is well accepted in the aviation, energy and manufacturing industries that effective and engaged senior leadership plays a significant role in institutional safety culture changes.[7–11] As a consequence of the newly implemented PI training at UCLA, laboratory safety policies were unified for all laboratories. Faculty operating research laboratories have gained a clearer understanding about their responsibility as well as liability for the safety of their research personnel and students. PIs as well as lab supervisors have to model workplace safety for their research staff and students; otherwise, formal training in classrooms and with online materials will be ineffective. Organizational and leadership support have been shown to be important contributors to an institution's positive safety climate.[12–14] However, many people will argue that a top-down approach – without input from PIs and researchers – creates an "us versus them" mentality. Involving researchers in policy formation is essential if it is to be embraced by the research community.[13,15]

Centralization of safety policies also extended to UCLA's EH&S department, in which all divisions, i.e., laboratory safety, radiation safety and biosafety now use the same inspection checklist, which was expanded to ease categorization of hazardous chemicals. Streamlining the inspection process together with a quick turnaround of inspection reports ensured reproducibility and provided consistent safety support to the research community. More importantly, together with collecting hazards information in the LHAT database, EH&S safety officers have gained an improved insight into the types and location of hazards presents in research laboratories. Expanded laboratory inspections and implementation of unannounced PPE inspections played a vital role in helping laboratories comply with safety regulations. The reorganization of UCLA's safety practices was a critical step toward establishing a shared perception of high-risk procedures between the organization and the researchers, a key attribute to establish a sustained safety climate.[16] Implemented training and inspection procedures ensure consistency and aid in closing the gap between espoused and enacted safety priorities.[17]

We measured basic attitudes and habits of researchers by examining compliance with LHAT data entry, participation in required training activities, and PPE compliance. LHAT data entry and training in laboratory safety are mandatory and citable offenses, if not followed – and therefore, participation is high (see results and Figure 1). In contrast, unannounced PPE inspections provide a snapshot of students' and researchers' compliance behavior (Figure 4). These types of random inspections most likely observe events that routinely occur in a lab, rather than the occasional non-compliant behavior. As compared with scheduled inspections, unannounced PPE inspections, therefore, allow for a more accurate benchmark of compliance with laboratory safety policies. The National Institute of Health's Institutional Animal Care and Use Committee Guidebook recommends unannounced inspections for that reason.[18] Unannounced inspections routinely occur for restaurants,[19,20] retail food facilities,[21] and are also used for some child care centers.[22] The overall significant improvement of PPE compliance suggests that positive outcomes of UCLA's enhanced safety policies have begun to take root.

Many studies indicate that supportive safety policies and programs positively affect how workers perceive their safety at work (improved safety climate) and ultimately lead to safer behaviors at the workplace (improved safety culture).[7,12,16,23,24] However, studies investigating the relationship between safety climate, safety behavior, and workplace injuries are often correlational, which limits the scope of interpretation. In the manufacturing sector, improvements in safety behavior positively correlated with safety climate scores, however, no significant correlation between safety scores and the number of accidents occurring was observed.[7] In developing a strong safety culture, UCLA's approach was linear yet multifaceted and closely associated with regulatory requirements.[2] Whether and how the changes in laboratory safety policies have impacted the safety perception and accident rate of UCLA's research community has yet to be established.

CONCLUSIONS

A fatal chemistry accident at UCLA in 2008 triggered a rapid expansion of UCLA's safety measures. Prior to 2008, safety regulations were not clearly

communicated, lacked documentation, and were not regularly enforced creating confusion and individualized safety practices in UCLA's laboratories. Restructuring of the inspection and training processes together with improved safety inspector accountability resulted in the establishment of clear safety expectations building the foundation for a successful laboratory safety program. The top-down management approach of safety policies not only unified UCLA's safety programs but also signified the importance of safety in the laboratory at every level from the university's chancellor to the undergraduate student volunteering in a research lab. Overall compliance with safety policies has greatly improved and UCLA's research community is beginning to accept the more stringent safety measures as a step forward in improving its safety culture.

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REFERENCES

1. Langerman, N. Deaths continue. *J Chem Health Saf,* **2011**, *18*(4), 38–39.
2. Mulcahy, M. B.; Young, A.; Gibson, J.; Hildreth, C.; Ashbrook, P.; Izzo, R.; Backus, B. J. College and university sector response to the U.S. Chemical Safety Board Texas Tech incident report and UCLA laboratory fatality. *Chem Health Saf,* **2013**, *10*(1), 6–13.
3. Gibson, J. H.; Wayne, N. L. Proceedings of the 2012 University of California Center for Laboratory Safety workshop. *J Chem Health Saf,* **2013**, *20*(1), 4–17.
4. CA, in Title 17, Division 1, Chapter 5, Subchapters 4.0, 4.5, & 4.6. California Office of Administrative Law. http://www.cdph.ca.gov/programs/Pages/RHB-Regulations.aspx [accessed 15.01.14].
5. U.S.NRC standards for protection against radiation. http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/full-text.html [accessed 15.01.14].
6. Jones, C. G. A review of the history of U.S. radiation protection regulations, recommendations, and standards. *Health Phys,* **2005**, *88*, 105–124.
7. Cooper, M. D.; Phillips, R. A. Exploratory analysis of the safety climate and safety behavior relationship. *J Saf Res,* **2004**, *35*(5), 497–512.
8. DeLaHunt, J. Safety culture. *J Chem Health Saf,* **2012**, *19*(6), 41–42.
9. Flin, R.; Yule, S. Leadership for safety: industrial experience. *Qual Saf Health Care,* **2004**, *13*(2), 45–51.
10. Langerman, N. The impact of the "UCLA Agreement". *J Chem Health Saf,* **2012**, *19*(6), 45–46.
11. Thompson, R. C.; Hilton, T. F.; Witt, L. A. Where the safety rubber meets the shop floor: a confirmatory model of management influence on workplace safety. *J Saf Res,* **1998**, *29*(1), 15–24.
12. DeJoy, D. M.; Schaffer, B. S.; Wilson, M. G.; Vandenberg, R. J.; Butts, M. M. Creating safer workplaces: assessing the determinants and role of safety climate. *J Saf Res,* **2004**, *35*(1), 81–90.
13. Kapp, E. A. The influence of supervisor leadership practices and perceived group safety climate on employee safety performance. *Saf Sci,* **2012**, *50*(4), 1119–1124.
14. Zohar, D.; Luria, G. Climate as a social-cognitive construction of supervisory safety practices: scripts as proxy of behavior patterns. *J Appl Psych,* **2004**, *89*(2), 322–333.
15. Hoffmeister, K.; Gibbons, A. M.; Johnson, S. K.; Cigularov, K. P.; Chen, P. Y.; Rosecrance, J. C. The differential effects of transformational leadership facets on employee safety. *Saf Sci,* **2014**, *62*, 68–78.
16. Zohar, D. A group-level model of safety climate: testing the effect of group climate on microaccidents in manufacturing jobs. *J Appl Psych,* **2000**, *85*(4), 587–596.
17. Zohar, D. Thirty years of safety climate research: reflections and future directions. *Accid Anal Prev,* **2010**, *42*(5), 1517–1522.
18. Pitts, M. A guide to the new ARENA/OLAW IACUC guidebook. *Lab Anim (NY),* **2002**, *31*(9), 40–42.
19. Reske, K. A.; Jenkins, T.; Fernandez, C.; VanAmber, D.; Hedberg, C. W. Beneficial effects of implementing an announced restaurant inspection program. *J Environ Health,* **2007**, *69*(9), 27–34.
20. Waters, A. B.; VanDerslice, J.; Porucznik, C. A.; Kim, J.; DeLegge, R.; Durrant, L. Examination of the association between announced inspections and inspection scores. *J Environ Health,* **2013**, *76*(2), 8–12.
21. County of Los Angeles Public Health. *Environmental health retail food inspection guide*. 2011. http://publichealth.lacounty.gov/eh/docs/Retail-FoodInspectionGuide.pdf [accessed 15.01.14].
22. Crowley, A. A.; Jeon, S.; Rosenthal, M. S. Health and safety of child care centers: an analysis of licensing specialists' reports of routine, unannounced inspections. *Am J Public Health,* **2013**, *103*(10), e52–e58.
23. Gillen, M.; Baltz, D.; Gassel, M.; Kirsch, L.; Vaccaro, D. Perceived safety climate, job demands, and coworker support among union and nonunion injured construction workers. *J Saf Res,* **2002**, *33*(1), 33–51.
24. DeJoy, D. M.; Della, L. J.; Vandenberg, R. J.; Wilson, M. G. Making work safer: testing a model of social exchange and safety management. *J Saf Res,* **2010**, *41*(2), 163–171.