Characteristics of chemical risks in academic research laboratory
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Research at the university level is expected to be original and pioneering. In tandem with broadening technology and more diversified research fields, the likelihood of dealing with new technologies and of developing unknown new substances has grown. Actually, in academic laboratories, researchers conduct a broad spectrum of experiments, and handle many chemical reagents in very complex ways at different places in the laboratory depending on the experiment purpose. However, even many of these researchers are unaware of the potential safety risks that are inherently inevitable. The Radio Frequency Identification system was employed to focus on the fluctuating characteristics of research activities and glean information from reagent checkout logs, chemical bottle traffic, and other similar data on chemical reagent behavior in an actual university laboratory. Such information was heretofore unobtainable by conventional chemical inventory system methods. Case studies were conducted to analyze experiment behavior in active university chemical laboratories, by monitoring experimenter behavior and chemical handling during experiments using fixed point observation technique. From this analysis, experimenter behaviors as well as the time duration in which experimenters handle chemicals for each operation are discussed from the perspective of deviation from the original protocol. The information obtained by observing experimenter behavior and chemical reagent usage in actual chemical laboratories is expected to raise the precision of discussion on the reasonable assessment and management of chemical risks in academic laboratories.

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I. Background of chemical risk management in Japanese university laboratories

Recently, research in university laboratories has been deepening, and research subjects are more diversified and segmentalized. Each experimenter in the laboratory is doing his or her experiment individually, using various kinds of chemicals in a very complex manner. Because of the individuality of the research, not only the safety education but also the on-the-job training of the experimenter in his or her laboratory has acquired more important meaning. In the meantime, each laboratory is obliged to obey confusing and sometimes contradicting rules and legal regulations for safety management. In experimental research, of course, safety should have first priority, but we are also anxious that too many regulations may hamper the progress of research. Therefore, the proper balancing of the importance of experiments and safety control is one key issue in the field of laboratory safety.

Another issue to consider is compliance with legal regulation for university research laboratories. In Japan, since 2004, the "Industrial Safety and Health Law" has been applied to all the Japanese universities because of recently becoming incorporated. This law was originally designed to protect employees in industry, and Japanese universities are now required to change their organizational framework for safety management to meet these legal requirements. However, because the aims, structure, and activities differ significantly between industry and academia, the optimum safety management system for a university is not necessarily the same as that for industry. In the same vein, the safety management system of industry cannot be simply applied to the university. In the United States, the Occupational Safety and Health Administration (OSHA) regulations adopted in 1970 also had the same problems. These early regulations did not recognize laboratories were different and applying general industry regulations did not work. Finally in 1991, OSHA adopted a separate standard to address laboratories.

In typical Japanese university chemical laboratories, many students and researchers work together on their own research subjects using various kinds of chemicals in a cramped space. To reduce chemical risks in the university laboratory, information on chemical use amounts and on diversity in operations conducted in the laboratory is indispensable.

For monitoring the chemical footprint to evaluate the risk of chemicals in a university laboratory, some systems concerning chemical safety and chemical management in laboratories are currently adopted in Japanese universities. For example, Pollutant Release and Transfer Register (PRTR) data show amounts of hazardous chemicals moved and amounts of pollutants released. The semi-annually required Working Environment Measurement reveals the concentration of the hazardous chemicals by sampling the air in the working environment for harmful gases. Another example is the Computer-based Registration System for Chemicals (CRSC), in which all chemicals in stock and
consumed daily in the laboratory are registered in a computer system. CRSC has been employed recently in many major Japanese universities, and has since become more sophisticated and popular.

These systems can provide such information as knowing how much chemicals were used in the laboratory and whether the experimenters in the laboratory are conducting their experiments under safe conditions. However, these data only show the overall laboratory conditions. The CRSC data communicate only the total amount of chemical usage, and the results of Working Environment Measurement tell only the condition of the experiment environment at a certain moment. In actual university laboratories, transdisciplinarity and diversification have complicated research activities, and how chemicals are used varies depending on research purpose. In addition, experimental operations and conditions may frequently vary in university laboratory research, which differs greatly from the situation in industry that mainly requires only routine operations. In this sense, the total amount of chemical usage, the chemical concentration in an experimental work place at a certain moment, and other similar data are insufficient in assessing and managing chemical risks in university research laboratories.

2. How chemicals behave in a university chemical laboratory

"Risk in chemical experiments" is defined as the "Extent of hazardous nature of chemical substance" multiplied by the "Probability of developing hazardousness during experiment". The probability assessment may be easy if the same operation is conducted as a routine task by equally skillful experimental researchers. However, in actual chemical laboratories, many chemical reagents are handled at different places for different purposes according to various factors. Chemicals are sometimes used in a fume hood and sometimes on a laboratory bench, depending on the purpose. And the manner of handling chemicals may differ greatly depending on the experimenter's background and chemical reagent usage. Therefore, considering the individuality and non-routine nature of laboratory experiments, the information on total amount of chemicals used in the laboratory and the information on the actual conditions of chemical usage—how experimenters and chemicals behave in a university chemical laboratory—are crucial for estimating the probability of a hazardous condition developing for each operation conducted in chemical laboratories.

As an example of the quantitative analysis concerning the handling behavior of chemical substances in experimental laboratories, our recent research is introduced in which a case study approach was conducted by monitoring a polymer chemistry laboratory.

In this research, checkout log data of chemical reagent bottles as well as the tracking the chemical bottle movement in the laboratory were analyzed. The RFID (radio frequency identification) system was used to collect the data. RFID system is a system that incorporates a device that reads a "tag" from a distance using radio waves to identify objects. Every chemical bottle in the laboratory was individually tagged, and when a bottle was moved out of storage and to a location, the bottle ID and time were automatically recorded in the RFID system computer. Analysis of the checkout log from the storage revealed that checkout duration could generally be classified into two groups: (1) short duration (10 minutes or shorter), and (2) long duration (30 minutes or longer). Examples of the short duration group included reagents in a desiccator and reagents with estimable pre-experiment amounts. The tendency for reagents in a desiccator to disfavor humidity may lead to their shorter checkout duration. In contrast, some 55% of the reagents in a refrigerator were out of storage for 30 minutes or more, and the average checkout duration was about 73 minutes. This may be because the reagents must be warmed up before use. Also, the reagents with process-dependent amounts tend to show longer duration because they must be kept near the operation area until the processes are completed. Another interesting finding in this study concerns the place of chemical usage. There were 73 times of reagent checkout from the storage during the monitored five days. Observations suggest that each reagent is used only at one location for each checkout from storage. Usage location refers to where reagents are used within the experiment location such as near a balance or in a fume hood; but experimenters, more often than not, put their checked-out reagent bottles on the laboratory bench before or after usage regardless of where the reagents are actually used. This result clearly suggests that the laboratory bench is a special place for the experimenters for the experimenters in this laboratory, and often functions as a hub before or after moving reagent bottles to another task location. Information on the behavior of experimenter handling of chemical reagents in an actual university laboratory has proven unobtainable heretofore by the limitation of conventional chemical inventory systems, and data from these new methods are expected to provide useful knowledge concerning the characteristics of reagent use in a laboratory.

3. Importance of identifying chemical risks in university research laboratories

In university laboratories, more and more experiments are conducted because of the recent progress in and diversification of research subjects. A wide variety of chemical reagents are handled in a very complex manner at various places in the laboratory depending on experiment purpose. In addition, the scenario of each experiment may be fluctuating, and easily affected and altered in response to how the experiment progresses while it is underway. For the risk assessment of laboratory experiments, we should consider such fluctuating characteristics of experimental works, and recognize the essential difficulties of risk assessment in laboratory experiments because of the variance in the operations.

We conducted another case study on experimental behavior analysis in an actual academic chemical laboratory.
by monitoring experimenter behavior and chemical handling during experiments using fixed point observation technique. From this analysis, the experimenter behaviors can be classified into 4 categories: (1) operation in the protocol, (2) operation not in the protocol, (3) moving around in the laboratory, (4) leaving the laboratory. In this case study, the experimenter spent about 8 hours for daily experiments, and spent only 10 – 20 % of the time for operations in protocol, whereas 25 – 50 % for the operation not in the protocol. Basically, the risk assessment is concluded for the operations in protocol, but this result strongly suggests that risks during operation not in the protocol are equally, if not, more crucial.

The time duration for operation and that for chemical usage were also compared in this study. The experimenter spent time at various locations in the laboratory, but the location of his chemical usage was very limited: only at fume hood, in front of scales, in front of waste tanks, and near the washing bottle decided place. The experimenter spent about 45% of the experimental time in the laboratory bench area, but the time of chemical usage on the laboratory bench was negligible. In contrast, the ratio of time duration for usage of chemicals to total operation time was relatively high at the fume hood, scale table, waste tanks, and washing bottle decided place. Such equipment and facilities are shared, making the atmosphere with volatile chemicals also shared. These data provide valuable information for designing intensive ventilation to reduce chemical exposure risks in such shared places. Particularly, the condition and the location of waste tanks are crucial because of the high risk of chemical exposure and because of the final destination of chemicals used in laboratory experiments.

4. Summary

What are important for clarifying the characteristics of chemical risks in academic research laboratories involve the collection and analysis of data on how chemicals are practically used, how researchers behave, and what is needed for risk assessment of chemicals in actual academic research laboratories. As an illustration of the importance, we introduced in this paper our previous research in which operations not in the protocol and risks in shared places are suggested as crucial in experimental laboratories by monitoring the behavior of an experimenter and the treatment of chemicals during the experiments using fixed point observation technique. Such practical data taken in an actual academic research laboratory are considered useful and valuable to substantially reduce chemical exposure risks.

"Laboratology" is a new concept area proposed for future research. Laboratory safety must be discussed more scientifically and quantitatively, and this concept will undoubtedly contribute to comprehending characteristics of the research activity more precisely and to the precision of discussion on risk assessment of laboratory experiments.

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References

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