Establishing a Hazardous Material Control Program: A Case Study of Success

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Introduction

The control of hazardous materials in academic laboratories is a complicated proposition. Many factors influence how substances are dealt with. Sanders (1986) identifies some of the major difficulties of hazardous materials control in academic settings, including large varieties of chemicals in small amounts, poor funding and a lack of commitment towards solutions by administrators and individual researchers. Further complicating the situation is the wide variety of laboratory research, the uniqueness of each lab, poor communication between faculty members, the pressures of deadlines and the isolation inherent in the "Ivory tower" of academia. In order to be successful as a researcher, it is necessary to be immersed in one's work (Park, pers. comm., 1988). This places a premium on researchers' time, leaving little for developing and maintaining a program for controlling their hazardous materials.

In order to comply with new, stricter environmental protection regulations, hazardous materials control programs are necessary. Control programs are series of measures implemented to improve the safety and control of hazardous chemicals and other materials. Due to the uniqueness of laboratories, each will require its own specific methodology. Elements to consider in any control program are proper storage and handling techniques, waste reduction, information availability and dissemination and the ability to maintain the program easily.

Storing substances correctly involves separating incompatible types, regulating temperature, shielding from sunlight, providing adequate ventilation and means of retention in the event of an earthquake. One of the principal requirements for safe storage of hazardous materials is for all containers to be clearly labelled.

Proper handling techniques include wearing adequate personal protective equipment such as gloves, safety glasses or goggles and a respirator when needed. Using the fumehoods for reactions that might result in spills or gas evolution and taking precautions to prevent mishaps during decanting are also involved.

Waste reduction must be a priority. Wastes not produced pose no health hazards and require no treatment or disposal. Caldart and Ryan (1985) identify different strategies for reduction through production-process changes such as substitution of less hazardous materials, recycling or reuse. These techniques can also save money on materials cost if less of the material is used to produce the same results.

Education and communication of relevant information play a critical role in hazardous chemicals control. Lab personnel must be aware of what they are dealing with as well as any changes in experimental procedures that might affect how to handle dangerous substances. The dangers or special characteristics of the material must be known to all who may come in contact with it. Labelling is vital to identify the substance and to warn of its hazards. In the event of an exposure, the lab staff must be trained in the use of emergency equipment to minimize the damage or care for injured personnel.

Developing a control program is futile if it is not maintained effectively. Diligence is crucial towards the long term success of the programs, but they cannot place excessive time demands upon the faculty who must run them. For this reason, organization and orderliness must be designed into the programs to ensure their viability. Areas most in need of this attention are inventories of materials, logical and consistent placement of instruments and materials within a lab, ease of clean-up after use, and the availability of safety supplies and equipment. Inventories must be kept up to date, samples must be accurately labelled and the lab must be designed to be easy to maintain and clean. Each instrument and material should have a designated location. In the laboratory studied, these processes work because of the dedication of the researcher and his assistant, who maintain the program day to day and constantly consult journals and other sources for methods to improve accuracy, safety or lab design.

This study examines the techniques developed by Geology Department Chairman George Brimhall and his colleagues for chemical control in his own lab. Brimhall's laboratory is noteworthy because it illustrates the aforementioned control program elements and demonstrates how such a program facilitates efficient research. The program grew directly out of Brimhall's quest for "safety and the highest attainable accuracy" in his ore analysis experiments (Brimhall, 1987). Since his instruments are capable of measuring elemental concentration to parts per billion, he must maintain a research environment free of contaminants. Therefore the control of fumes, particles and any other contaminants is necessary for his work. This report describes the specific processes which have useful applications but which, more importantly, stand as an example of what can be achieved. Every lab is unique, and so these procedures may not be applicable to a given research or teaching situation. By describing them, I hope to illustrate the approach which resulted in success in this situation and to encourage similar actions in other labs.

Past Studies

The National Research Council (1981, 1983, 1985) has published three authoritative works on managing chemicals in labs, assessing the need for improved control of hazardous substances and developing guidelines for their use. Their approach is purposely general so that the information applies to most labs. Caldart and Ryan (1985) examine methods for waste reduction through changes in production processes. Oldenburg and Hirschhorn (1987) explore the regulatory requirements now in existence and suggest improvements.

Background

In Brimhall's ore geology research, samples are analyzed chemically and optically to determine their composition of trace metals and other elements. An ore sample is first crushed and ground into a fine powder, then immersed in acid for "digestion" to dissolve the silicate structure and to put the metals into solution for analysis with an atomic absorption spectrophotometer (A. A.). Typical acids used for this process include concentrated hydrofluoric (HF), sulfuric (H_2SO_4), nitric (HNO_3), hydrochloric (HCl) and hydrobromic (HBr), as well as combinations such as aquaregia, a 3:1 mixture of HCl to HNO_3. So many are used because different acids or combinations are better for solubilizing certain elements than others. The solutions are diluted and their concentrations measured on the A. A.

For optical analysis, a mineral separation is performed. The crushed sample is added to Acetylene Tetrabromide (ATB), a heavy liquid with a density of about 3 g/c. c., and the mixture is centrifuged. The lower portion of the tube, containing the heavier fraction, is frozen with liquid nitrogen enabling the liquid upper portion, containing the lighter fraction, to be poured off into a Buechner funnel lined with ashless filter paper. A vacuum is applied to speed the drainage of the ATB through the filter paper, separating the sample and the ATB. When the lower portion of the tube thaws, the process is repeated. The sample fractions are washed with a solvent, and can be analyzed chemically, but are usually set in epoxy, polished and analyzed optically. Optical identification using a high-powered line-counting microscope and computers are performed for very accurate measurements of the mass percent and volume percent of a particular mineral. Other computers are used for graphics, fluid-flow modeling and to store all the information found on the samples in data files.

Methodology

Data were collected in interviews with George Brimhall, his research assistant Chris Lewis, and in tours of the lab. An overall description of the lab is detailed here, as well as specific facets identified as important to the control program. This report concludes with recommendations to individual researchers and the administration as to how control programs may be established.

Data

Brimhall's clean lab has many features that may not be found in many research labs, due to his need to avoid contamination (Figure 1). Entrance into the lab is through an airlock, and all personnel are required to wear cloth booties over their shoes. On the floor is a VWR Scientific "Lo-Count Mat," a large sticky panel resembling fly paper which traps large dust particles clinging to the bottoms of your shoes or booties. The doors are sealed with weatherstripping, held in place with duct tape, preventing particles from entering underneath the doors and helping to maintain higher air pressure inside the lab than in the outside hallway.

Air enters the Computer Room from two fully-opened ceiling registers equipped with furnace-type filters to trap air-borne dust particles and other contaminants. The filters are now held in place with duct tape, but runners are being fashioned to hold them and permit easier replacement when they become full (approximately every two months.) The air return registers have been sealed, providing an oversupply of air but leaving few routes of exit. This creates higher air pressure inside the room and causes the air to flow towards areas of relatively lower pressure. From the Computer Room, air flows through baffled vents in the door into the airlock, then into the A. A. Room. It exits through the fumehood and a small vent to the outside hallway. The exhaust from the A. A. and the cabinets for storing opened bottles are vented through the same system as the fumehoods. The Chemistry Room has a separate air system of its own, at a slightly lower pressure. Air passes through another filter as it enters from the museum next door and exits through the fumehood.

These techniques are used primarily to keep air-borne particles from interfering with delicate analyses, but they also improve the efficiency of fumehoods, protect the computers from dust damage and increase the safety of the lab staff since an accidental release of fumes in the Chemistry Room can be escaped from through the Airlock. The lab remains clean because when the Airlock door is opened, air rushes out, preventing contaminants from entering. Cabinets used for storing acids are vented through the same system as the fume hoods, so that

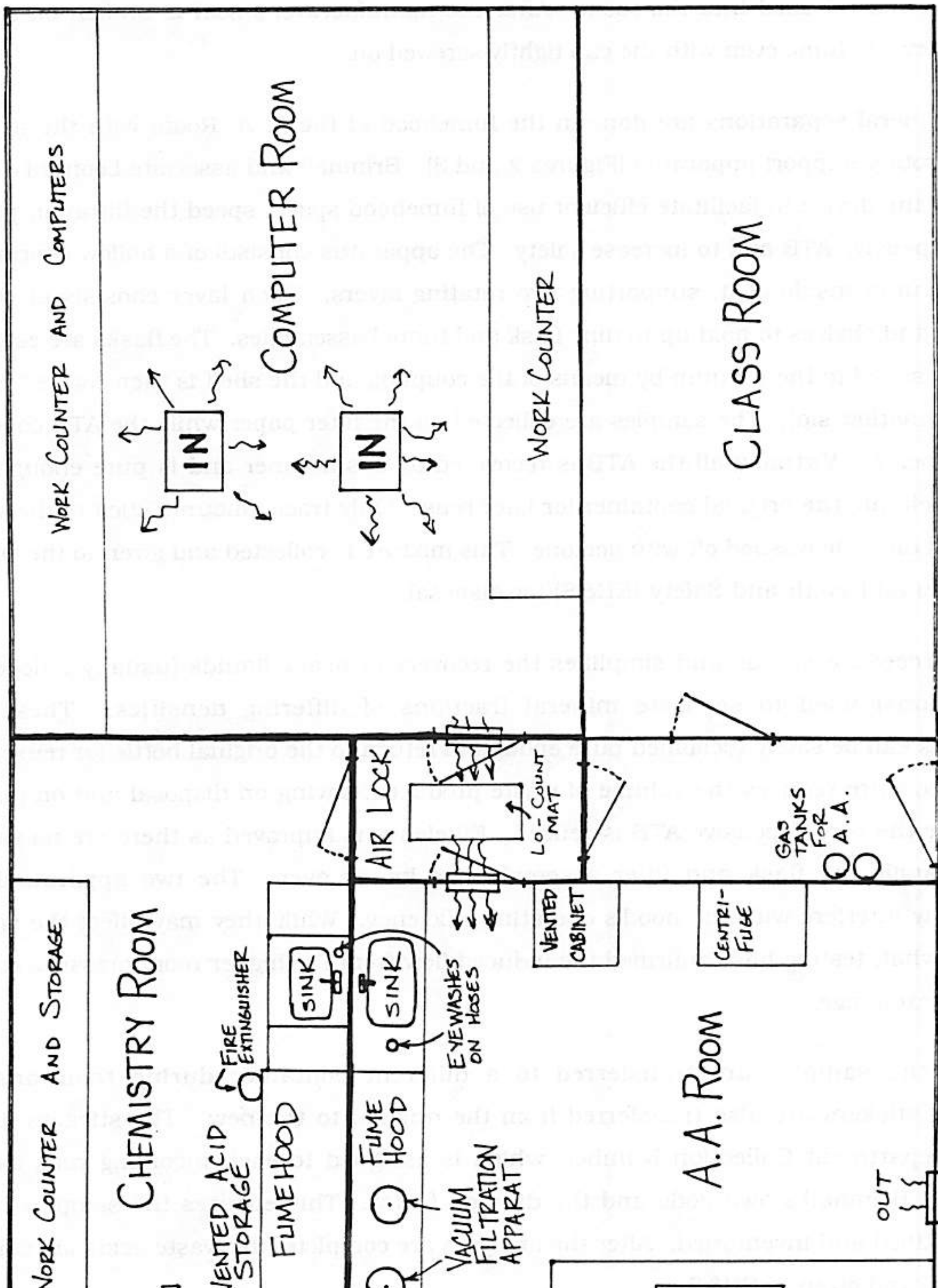

Figure 1
Floorplan of George Brimhall's Lab

vapors are not released into the room. After the manufacturer's seal is broken on the acid bottles, they will fume even with the cap tightly screwed on.

The mineral separations are done in the fumehood of the A. A. Room with the help of a patented rotary support apparatus (Figures 2 and 3). Brimhall and associate Leonard J. Vigus developed the device to facilitate efficient use of fumehood space, speed the filtration process, recover expensive ATB and to increase safety. The apparatus consists of a hollow central shaft with a vacuum inside of it, supporting two rotating layers. Each layer consists of vacuum couplings and shelves to hold up to nine flask and funnel assemblies. The flasks are easily and quickly attached to the vacuum by means of the coupling and the shelf is then rotated to allow access to another slot. The samples are collected on the filter paper while the ATB collects in the flask below. Virtually all the ATB is recovered in this manner and is pure enough to be poured back into the original container for later reuse. Only trace amounts stick to the sample grains and must be washed off with acetone. This mixture is collected and given to the Office of Environmental Health and Safety (EH&S) for disposal.

This procedure speeds and simplifies the recovery of heavy liquids (usually halogenated hydrocarbons) used to separate mineral fractions of differing densities. These toxic compounds can be safely reclaimed pure enough to return to the original bottle for reuse. This simple procedure reduces the volume of waste produced, saving on disposal and on material costs since the very expensive ATB is reused. Efficiency is improved as there are no vacuum lines to tangle, no flask and filter assemblies to knock over. The two apparati do not significantly interfere with the hood's operating efficiency. While they may affect the laminar flow somewhat, testing has confirmed the induced flow from the higher room pressure ensures proper air exchange.

When the samples are transferred to a different container during their analysis, identifying stickers are also transferred from the original to the new. The stickers list the Geology Department Collection Number, which is assigned to each incoming rock sample, followed by Brimhall's own code and the dilution factor. This ensures the samples can be easily identified and inventoried. After the analyses are complete, the waste acids are collected for disposal and given to EH&S.

A complete procedures and training manual for distributing information and ensuring consistent training was developed by the lab staff. New personnel must read the procedures manual before they may use the facilities. It describes the methodology of all experiments and equipment, lists any revisions or updates in procedures and contains the Material Safety Data

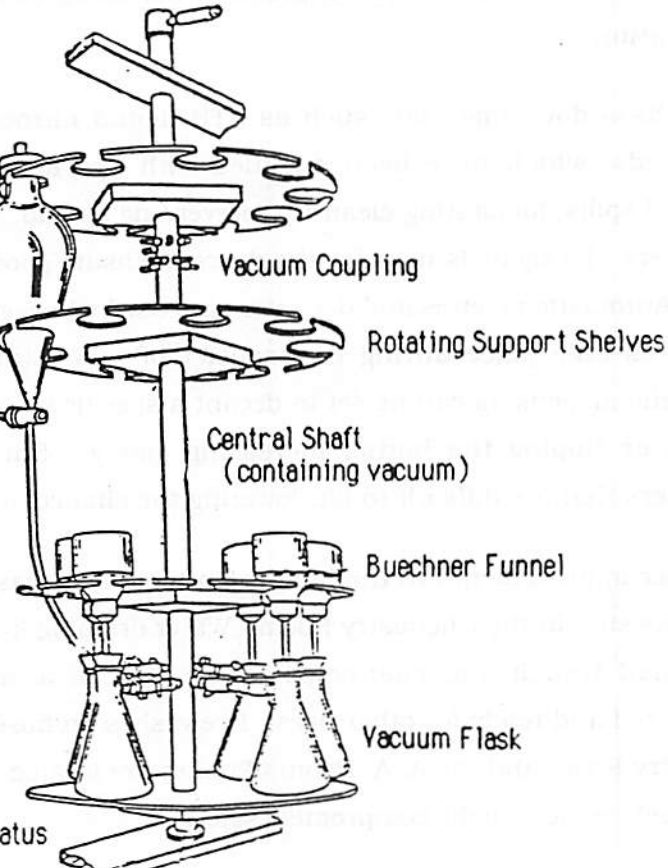

Figure 2
Schematic of Rotary Vacuum Fitration Apparatus
Adapted from U.S. Patent Papers
Used with permission

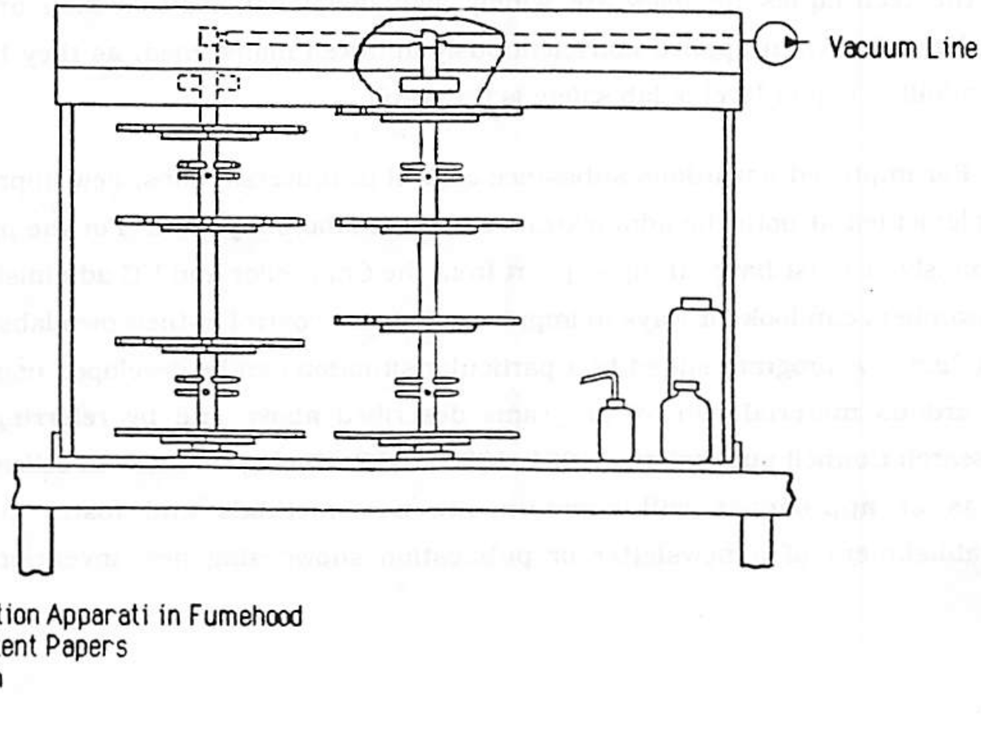

Figure 3
Rotary Vacuum Fitration Apparati in Fumehood
Adapted from U.S. Patent Papers
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Sheets (MSDS) for all chemicals being used. MSDSs are required by law and contain vital information about the chemical product, including hazards, proper storage and emergency information.

All hazardous materials such as ATB, liquid nitrogen or acids are handled only in the fumehoods, which have been modified with lips along the front edges to help minimize potential spills, facilitating clean-up, preventing spread, lessening opportunities for exposures to workers. Plexiglas is used for the doors to ensure good visibility as the acid fumes will etch glass. Automatic pipettes and decanters are used whenever possible, since many accidents and exposures take place during the transfer of a substance, from spills or dropped bottles. Automatic dispensers can be set to decant a specific volume of chemical and operated without moving or tipping the bottle, increasing safety. Slings with pivots are used for larger containers that are difficult to lift, lowering the chance of a mishap.

Other improvements to the lab design include a plastic drying rack mounted on the wall above the sink in the Chemistry Room. Water dripping from the washed containers is captured in a small trough and channeled to the sink in a small hose. The sink area remains uncluttered and ready for other uses. Eyewashes on hoses are located next to the sinks in the Chemistry Room and the A. A. Room. Phones are located in every room of the lab, preventing a "mad dash" which might compromise safety.

Conclusion

Brimhall's laboratory demonstrates that hazardous chemicals control is attainable. Most of the techniques he uses are widely available technologies which are not difficult to implement. When applied conscientiously and well maintained, as they have been by Prof. Brimhall, a higher level of lab safety is the result.

For improved hazardous substance control in university labs, new approaches need to be implemented at both the administrative and the laboratory level. For the process to be taken seriously, it must have strong support from the Chancellor and UC administration. Individual researchers can look for ways to improve substance control in their own labs, departments and buildings. A program suited to a particular situation can be developed using the elements of hazardous material control programs described above and by referring to the National Research Council publications (1981, 1983, 1985). Dialogues between colleagues to share new ideas or approaches will communicate new methods and foster cooperation. The establishment of a newsletter or publication showcasing new inventions, procedures or alternatives would be inexpensive and would improve communications between researchers in different disciplines.

The administration can do several things to stimulate better materials control. Making substance control easier and more convenient for labs will result in increased use of the services and better disposal. Current University policy is for each department to have a designated Safety Officer who handles hazardous material considerations, as well as general lab safety, and develops plans for fires and earthquakes. However, these appointees are usually researchers as well, and rarely have the time to oversee and maintain a program of this kind. For this reason it is necessary to have a full-time Safety Officer, not a researcher burdened with extra duties outside of his or her area of specialization. The Safety Officers could work with the individual researchers to develop control programs tailored to that particular situation, act as a liason between the researchers and the administration and deal with any new regulations. Additional funds will be needed to attract talented people to act as Safety Officers, but the costs will be offset by the additional safety and productivity that this system will generate.

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