Hazardous Substances: An Inventory of Four Science Laboratories

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Introduction

Regulations concerning hazardous substances in an educational setting may become more rigid in the future and require the inventory of all such substances on university premises. The inventory of the numerous laboratories at the University of California at Berkeley could prove to be long and tiresome if the University attempted it without some preparations. One must develop a proper methodology before any attempts at the actual task. As part of a team developing this essential methodology, I inventoried four laboratories in a science department. This inventory provided information on the quantities and types of hazardous substances present in small laboratories, and suggested the best ways researchers can inventory their own hazardous substances on campus.

Past Studies

Although there haven't been any inventory studies on the U.C. Berkeley campus, some information has been written about heavy liquids in laboratories (Hauff and Airey, 1980), which was useful information about the precautions to take when handling these heavy liquids. There is also information on the shelving and placement of hazardous substances (CSSS, 1984), which provided a sample worksheet, an inventory checklist, and a sample list of substances that might be encountered.

There is more information for high schools with regard to inventory. The Science Safety Handbook: for California High Schools (Gardner et al., 1987) was used for my inventory, although the lesser quantities and varieties of chemicals in high schools pose much less of a hazard.

Particularly useful as sources of information were two pamphlets by the Office of Environmental Health and Safety (1985, 1986). One contains definitions of hazard types and sources of information; the other includes chemical storage guides and other information gleaned from Material Safety Data Sheets (MSDS).

McLoone (1988), Sax (1984), and Weiss (1980) list chemicals by name and describe their physical and toxicological properties. These sources enabled me to classify each chemical by hazard class. (See Introduction to Inventory Section for further information on hazard class.) Marczewski and Karmin (1984) provide a practical overview of what should be included on chemical labels. Ottoboni (1984) gives toxicological definitions and an introduction to the subject of toxicity. Allegri (1986) gives a general introduction to the subject of hazardous materials and wastes.

Background

Some chemicals warrant special handling and storage precausions according to the different hazards which they pose. These chemicals can be classified into hazard classes which tell users how to handle and store them properly. Each chemical can be classified as radioactive, flammable and combustible, corrosive, toxic, carcinogenic, an oxidizer, peroxide-forming, cryogenic, pyrophoric, or water reactive. Quite a number of chemicals may fit into more than one hazard class. For example, perchloric acid could fit into three categories, toxic, corrosive, or oxidizer; carbon tetrachloride is both toxic and carcinogenic; aqua regia (or nitrohydrochloric acid) is both a flammable liquid and a corrosive material. The U.S. Department of Transportation's (DOT) Hazardous Materials Table lists which hazard classes take precedence over other hazard classes.

For my purposes, chemicals were classified in order according to the following nine categories, a variation of a list by McLoone (1987):

1)	Radioactive	7)	Toxic, poison, carcinogen
2)	Cryogen	8)	Combustible liquid
3)	Flammable liquid	9)	Water reactive
4)	Oxidizer	10)	Irritant
5)	Flammable solid or pyrophoric	11)	Other
6)	Corrosive liquid	12)	Unidentified.

Poisons and carcinogens were put under the toxic category although they are not the same by toxicological definitions (Ottoboni, 1984). Pyrophoric substances were included in the general category of flammable solid. Irritants are materials which pose a hazard, but are not hazardous enough to be classed into the nine prior categories. In the "other" category are materials that don't fit into the prior categories, but nonetheless are materials that present dangers if mixed with incompatible materials. The unidentified are substances which I could not classify under any of the eleven categories because of limited sources of information. (For a more detailed explanation of hazard class, see Introduction to Inventory Section.)

Methodology

I prepared for the four inventories by doing a practice inventory of a laboratory containing many chemicals with a form developed for this project (Appendix B, Introduction to Inventory Section). Three people, "the inventory representatives," did each inventory as a group. One person counted, the other listed, and the third asked questions of the person in charge of the lab. A checklist (Appendix A) was prepared for the inventory representatives which listed the peroxidizable compounds not to be touched, some questions for the lab supervisor to answer, and some cues for the inventory representatives, such as to remember to put on goggles and gloves prior to the job.

The practice inventory enabled the inventory team to iron out problems about what size of container and what amounts to put down for solids and for liquids. Also, with this practice, we were able to reduce the time involved at the inventory. For the practice lab, I wrote down everything, i.e., compound, manufacturer, type of container, etc. and found that it took an hour to list about twenty-five chemicals, which is too long. For the large lab containing over 200 reagents, I used a portable tape recorder for part of the inventory to try Gardner's (1987) method. For the other part, I used the checklist. It took four hours to do a large lab with the combination of the tape recorder method and the checking-and-listing method.

With the tape recorder at hand, I was able to reduce the time in the laboratory, which aided me to avoid irritating the researchers by staying too long. But I also made more work for myself because I had to transcribe the audio information onto paper or into computer. Ideally, if there were enough time, the written inventory lists would be better than the tape-recorded lists. Gardner's method will work better if the researcher had a secretary that takes dictation from a recorder. But even then, the researcher must state the spelling of each compound slowly on tape so that the secretary will not have to flip through indices of chemicals for the correct spellings while at the computer.

The Laboratories

The department inventoried doesn't have a central store room, and each laboratory orders its own stock. I inventoried four labs. One was a large lab containing more than 200 reagents; two were rather small labs containing fewer than 200 reagents, and the fourth one was a radiation lab which also contained fewer than 200 reagents. These four labs housed some heavy liquids, acids, some organic substances, and many other substances.

The inventory data table (Table 1) shows the total amounts of each hazard class in each room. Room A only contained hydrofluoric acid (HF) and acetic acid (corrosive), rust inhibitive enamel (flammable), and "unidentified" materials such as waterproof drawing ink

LABORATORY	HAZARD CLASS: RADIO-ACTIVE (g)	COMBUS-TIBLE LIQ	FLAMMABLE SOL	FLAMMABLE LIQ	OXIDIZER	CORROSIVE	TOXIC	WATER REACTIVE (kg)	CRYOGENIC (cubic feet)	IRRITANT (kg)	UNIDEN-TIFIED SOL (kg)	UNIDEN-TIFIED LIQ (L)	OTHER (kg)
A	0	0	0.2 L	0	0	3.0 L	0	0	0	0	0	1.7	0
B	0	0	0	0.6 L	0.5 kg + 5.6 L	18.5 kg + 44 L	0.8 L	0	0	0	0	0.5	0
C	262	3.5 L	3.8 kg	0.6 kg + 50 L	9.2 kg + 0.7 L	24 kg + 27 L	23.0 kg + 2.1 L	0.2	0	3.9	7.4	0.9	27.2
D	0	0.2 kg 0.5 L	0	55 L	0	8.2 kg + 5.1 L	4.8 kg + 0.5 L	0	248	0	0.5	11.2	0.3

Table 1: Data from the Inventory. All units are listed as given on the bottle.

and some liquids inside bottles labeled in short notation such as DSDP, for which I could not find better names. Researchers that work in this room do their experiments with HF in the fume hood, which has a very worn-out glass cover due to the HF vapors given off.

In Room B hazardous substances were inside a fume hood and in an undercounter cabinet. In the fume hood were substances such as perchloric acid (oxidizer) and acetone (flammable liquid). In the undercounter cabinets were oxidizers such as nitric acid, corrosives such as acetic (39 L), sulfuric and hydrochloric acid, and flammable liquids such as aqua regia.

Room C was the biggest lab I inventoried; it has two main sections, an office and a laboratory. In the office, one large wall cabinet contained all the chemicals. This cabinet stored several toxic reagents, including samples of expensive rare earth compounds. It also contained 262 g of radioactive substances (thorium nitrate, uranium acetate and uranium oxide) enclosed in a clear plastic bag within a cardboard box on the top-most shelf and labeled radioactive. The laboratory room space measures about 20' by 20'. It houses a fume hood, a metal cabinet, several undercounter cabinets, and a refrigerator. Under the fume hood was only one hazard class, 5.9 kg of corrosive HF acid. The metal cabinet contained toxics such as lead chromate and mercuric chloride, corrosives such as oxalic acid and potassium hydroxide, oxidizers such as ferric nitrate and silver nitrate, flammables such as zinc metal, iron powder and alcohol, water reactives such as magnesium, and poisons such as potassium cyanide and hydroquinone.

Inside a cabinet next to the wall, flammable and combustible organic materials were stored, such as acetone (flammable), benzene and chloroform (both flammable and carcinogenic). There were also a few corrosive materials, such as ethylene diamine and acetic anhydride. To the left of this cabinet in newly-arrived boxes below the sink were 5 liters of pyridine and tetraethylorthosilicate (both flammable). Next to the door by the office were a few cans of alcohol (flammable). The total amount of flammable liquids in Room C was more than 50 L.

Inside the middle island cabinet were two wooden shelves containing oxidizers and corrosives, with the top shelf containing mostly oxidizers such as perchloric acid, hydrogen peroxide, and nitric acid. On the lower shelf only corrosive acids acids were stored. In the refrigerator were poisons such as tributyl phosphate, and n,n-dimethylformamide, and the corrosive liquid, mercaptoacetic acid.

Room D is an x-ray laboratory. There is a small dark room for developing pictures, and a bigger room for some mechanical equipment, some of which use radiation. This lab surprisingly didn't contain any radioactive material, but it did contain some corrosive and poisonous developer, as expected from any place that develops its own pictures. A variety of hazard classes were found in this lab, such as flammable, combustible, and toxic substances, but compressed argon gas (248 ft^3) deserves special mention as the only cryogenic substance found in the labs (Table 1). This cryogen is a compressed gas inside a metal cylinder. I found it lying on its side on the floor underneath a table. Of the 55 L of flammable substances in this lab, 33.5 L of it was acetone.

Discussions and Recommendations

I found that the inventory form developed for this project was basically functional, but it needed some more information for the general public to be able to do the inventory. A brief description of hazard classes, a list of abbreviations for each hazard class and directions on how to use the inventory sheet should be added to the ideal form.

I saw several problems in each laboratory, but all of them could easily be remedied. Following is a list of the main problems in each laboratory and suggestions to ameliorate some of them.

Some problems were common to several laboratories. In most rooms, incompatible hazardous substances were stored together. The mixing of different hazard classes is dangerous because some substances, when mixed together, could produce fire or asphyxiating vapors-enough to cause injury and death. In some laboratories hazardous substances were stored on incompatible shelving material. For safe storage ideas see EH&S (1986). Two rooms had more than 20 L of flammable liquids stored outside of an approved flammable storage cabinet, a violation of the State Fire Marshall's requirements.

Room A: The main problem which may also apply to other labs, but was more evident in this one, was the use of shorthand notation in the labeling of substances. Use of shorthand notation will lead to the substance's becoming unidentifiable when the person who originally labeled and used the chemical leaves his work to others unfamiliar with his way of labeling chemicals. In the future, lab personnel should use the proper names when they label reagent bottles. This lab should also replace the corroded glass fume hood cover with a clear fiberglass or plastic one. HF will not corrode plastic.

Room B: Incompatible hazard classes should be separated and only necessary substances should be kept in the fume hood. For example, oxidizing acids (e.g. perchloric acid) should be separated from flammable and combustible substances (e.g. acetone). Flammable substances (e.g. aqua regia) should not be stored on the same shelf with corrosive substances (e.g. acetic acid). Flammable substances and corrosive substances must be placed on separate shelves. In addition, if the relatively large amount (39 L) of acetic acid is not necessary for any special experiments, then its reduction would be warranted just to reduce the dangers presented by extra hazardous corrosive substances.

Room C:

Office. The plastic enclosing the liquid radioactive substances is a good idea in case of accidental spillage. Radioactivity makes clean-ups difficult if the liquids spread, but if the liquid is encapsulated by a plastic bag, as it is in this case, spills can be solved by the simple disposal of the contaminated plastic bag. EH &S recommends that liquid radioactive substances be placed in the fume hood instead of on office shelves in case of vaporization (Van Valkenburgh, 1988, pers. comm.). People in the office shouldn't have to inhale radioactive vapors.

The physical separation of toxic substances from all other hazard classes is a good idea. Such was the case in the office, where mostly toxics such as the rare earths were stored. But in the laboratory, it was another story. I found several problems:

Metal Cabinet. First, corrosive substances (e.g. potassium hydroxide and oxalic acid) shouldn't be stored on metal shelves because corrosive substances could corrode metal. Second, incompatible hazard classes were stored together because they were organized alphabetically. Toxic materials (e.g. lead chromate and potassium cyanide) shouldn't be stored with corrosive materials (e.g. HCl and oxalic acid). Corrosive reagents (e.g. oxalic acid) shouldn't be stored with flammable liquids (e.g. alcohol). Although it is more convenient to alphabetize reagents so that they can be located easily, alphabetizing them could bring dangers associated with the mixing of incompatible hazard classes.

Cabinet Next to Wall. Flammable substances should always be separated from all other classes because this hazard class, like toxic substances, is usually not compatible with any other hazard class. Most substances in the cabinet next to the wall were flammable, but some corrosive substances were also kept in it. An all-flammable storage cabinet could be set up for this lab because there is practically one already in place-with the exception of the few corrosive substances in it. Of course, the department should get the type of cabinet approved for the safe storage of flammable liquids.

Middle Island Cabinet. Oxidizers such as perchloric acid should not be stored on wooden shelves because oxidizers will react with flammable material such as wood to produce a fire. Corrosive substances shouldn't be stored with oxidizing acids.

Refrigerator. Corrosive liquids (e.g. mercaptoacetic acid) shouldn't be stored inside refrigerators. They should be kept away from any metal.

Miscellaneous. Lab personnel should remove all hazardous substances from the floor. The cans of alcohol next to the doorway should not be there. Instead they should be stored inside a cabinet. Although it is true that things inside boxes don't pose much danger until they are opened, the substances inside the boxes should be unpacked and placed inside appropriate cabinets. Open bottles should not be returned to the box.

Room D: The metal cylinder of compressed argon gas, a cryogenic substance, should be safely secured to a convenient wall with a welded chain two-thirds of the way up the cylinder. If the whole 33.5 L of acetone are not necessary to do experiments in the immediate future, *then its* reduction could benefit the safety of the people in the lab just by having less flammable material around to pose a hazard.

Since neither rooms C nor D had approved flammable storage cabinets, their stock of 50 L and 55 L of flammable liquids respectively, violates the State Fire Marshall's 20-L maximum for storage of flammable liquids in any area outside of approved flammable storage cabinets. If the department wants to be in compliance with the State Fire Marshall's Office, then it could either move some of its excess flammable liquids to other rooms, or it could buy an approved flammable liquids storage cabinet. If the flammable liquids are not all necessary for lab experiments, the department could also reduce the amounts of them in both rooms by giving them to departments with capacity for them.

Conclusions

Although I saw several problems in the laboratories, they were small ones. None of them were irreparable, and just a little bit of education, time, and money devoted to proper storage and inventory could remedy the situation very easily.

However, if the department intends to do a department-wide inventory, a practice inventory using inventory sheets is a must for all lab personnel. With practice, the job will take less time because people will know how to use the inventory sheets and how to count materials correctly in the fastest way. Also, if the department wants its own laboratory personnel to inventory everything, the best way would be to give mandatory training sessions for all lab personnel before the task, preferably a week before, so that people can have time to think about the procedure and still remember it. The department does not necessarily have to give only one training session; several sessions in one day could be much better for people with busy schedules.

With better knowledge of stock on hand, the department can later look at the feasibility of a central stock room of its own similar to the one in the Chemistry Department.

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APPENDIX A

Procedure for Inventorying a Laboratory

1. Ask if there is an inventory system in place; this includes a standard label system. Do they know what a Material Safety Data Sheet is?

2. Ask for a quick tour of the laboratory:

   During tour, ask: Where do you store your chemicals?
   Are there any chemicals which we should be wary of?
   Is there anything which you would like us to be especially careful to avoid?

3. Do the inventory. It is advised that gloves be worn and goggles or glasses cover the eyes. BRING THESE BEFORE YOU GET TO THE LAB.

   One person will handle the chemicals, and one will write out the answers.

   It is advised that chemicals not be moved more than is necessary.

   Watch out for the following chemicals, especially if a precipitate of oily layer is seen around the neck or cap of the bottle (DO NOT TOUCH IF THIS IS THE CASE):

   absolute ethers (ethyl ether anhydrous)
   acetal
   acrolein (propenal: acrylic aldehyde)
   acrylic acid
   acrylonitrile (propene nitrile: vinyl cyanide)
   alkyl-substituted cycloaliphatics
   ALL OTHER ETHERS
   bis (2-methyloxyethyl) ether
   butadiene (erythrene)
   chloroprene
   chlortrifluorethylene
   cumene (isopropyl benzene)
   cyclohexane
   cyclohexene
   dealin
   diacetylene
   dicyclopentadiene
   diethyl ether (also called ethyl ether, ethyl oxide, or diethyl oxide)
   dioxane (diethylene oxide)
   divinyl acetylene
   ethylene glycol dimethyl ether (glyme or 1,2-di-methoxyethane)
   isopropyl ether
   liquid paraffins with branched chains
   methyl acetylene
   methylcyclopentane
   methyl 1-butylketone
   methyl methacrylate
   olefine (unsaturated hydrocarbons)
   potassium metal
   sodium amide (sodamide)

styrene
tetrafluoroethylene
tetrahydrofuran (cyclotetramethylene oxide)
tetrahydronaphthalene (tetralin)
vinyl acetate
vinyl acetylene
vinyl chloride
vinyl ethers
vinylidene chloride (1,1 dichloroethylene)
vinyl pyridine

If you still have time left, continue with questions.

4. Ask how chemicals are ordered and approximately how much each month.

5. Ask them how much they know about the safe and lawful storage of hazardous chemicals.

6. Ask for an approximation of the amounts of hazardous waste produced each month.

7. Ask how hazardous wastes are disposed of and how often each month.

8. Ask if they use some type of source recovery, recycling or recovery procedure.

9. Ask if they have developed any new methods to increase efficiency in the use and handling of hazardous substances.

10. Ask if they would like to recommend anything to increase the safety of their labs. (Emphasize that the chairman will look at the report to get some idea as to what is needed for the labs.)

11. Ask if they have ever read the EH&S pamphlet. Give them one if not or if they have lost theirs.