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# Safety Management and Risk Assessment in Chemical Laboratories

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*Abstract:* The present paper highlights a new safety management program, MICE (*M*anagement, *I*nformation, *C*ontrol and *E*mergency), which has been specifically adapted for the academic environment. The process starts with an exhaustive hazard inventory supported by a platform assembling specific hazards encountered in laboratories and their subsequent classification. A proof of concept is given by a series of implementations in the domain of chemistry targeting workplace health protection. The methodology is expressed through three examples to illustrate how the MICE program can be used to address safety concerns regarding chemicals, strong magnetic fields and nanoparticles in research laboratories. A comprehensive chemical management program is also depicted.

**Keywords:** Chemical management · Magnetic field · Nanoparticles · Safety management

## 1. Introduction

In 2005, the Board of the Faculty of Basic Sciences, encompassing chemistry, physics and mathematics at EPFL, decided to allocate resources to create a Service of Occupational Health and Safety (SB-SST). It is quite unusual to find safety specialists at faculty level in academia and its spread of activities is certainly very uncommon because it embraces both operational safety management and research/development missions jointly with the research Group of Chemical and Physical Safety at the Institute of Chemical Sciences and Engineering (ISIC).

In accordance with the Swiss Directive MSST,[1] the SB-SST implemented a new concept of occupational health and safety dedicated to the academic environment, namely the MICE (*M*anagement, *I*nformation, *C*ontrol and *E*mergency) program (Fig. 1). A frequent mistake is to consider that safety management in academia is comparable to that in industry. One must recall that universities have large non-permanent workforce leading to high turnover, have a high average education level allowing a good understanding of safety challenges, are multicultural with many coworkers not fluent in the local language and have a light safety corporate culture, each research unit having its own processes and objectives. Taking into account these specificities, MICE focuses first on the management by offering tools directly adapted to the researcher, *i.e.* which can be integrated in the core activities. Information, including education, is also a key process for the diffusion and implementation of a safety culture throughout a cluster of independent units. Control using audits is a necessary assessment to monitor and guarantee that every unit implements a safe environment, respects the rules and properly educates coworkers. Emergency response is organized at EPFL level, SB-SST only supports the rescuers if necessary and take care of the remediation process.

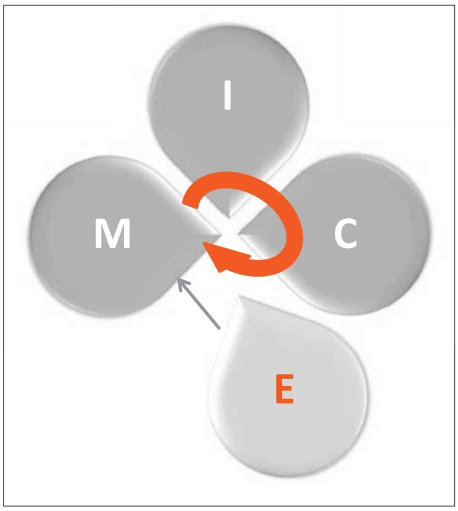


Fig. 1. The MICE program for safety management in academia.

## 2. Some Modern Safety Management Tools in Chemistry

### 2.1 *Assessment and Classification of Hazards in Laboratories (ACHiL)*

Fields of investigation and the analytical arsenal in chemistry are in permanent evolution as research progresses. In the mean time, other domains like biology, materials, environment, *etc.* are more and more attracted by understanding at the molecular level. This convergence leads to an increasing variety of techniques encountered in chemistry laboratories with, naturally, their related hazards. Besides the intrinsic dangers of substances (toxicity, explosively, inflammability, *etc.*), chemists have to face a broad spectrum of other hazards as low or high pressure, cryogenics, ionizing radiation, laser, magnetic fields, biohazards, nanoparticles, … Theoretically, safety management should study individually every process in the framework of risk analyses.[2] Such an objective is seriously threatened in academia due to constant research evolution leading to an absence of well-defined procedures. A key step of the MICE program is to address this issue by creating a platform allowing the researcher to check and classify the hazards present in the laboratory through Assessment and Classification of Hazards in Laboratories (ACHiL)[3] methodology. ACHiL focuses on hazards to

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avoid the common drawbacks of risk assessment which depends on the activity, the likelihood of occurrence, the impact, the protection level, the process, *etc*. The strategy is first to identify the hazard, then to classify it in a scale of danger in order to prioritize further risk analysis. ACHiL reviews 28 specific hazards encountered in laboratories using a four level scale: 0: hazard is not present, 1: moderate hazard, 2: medium hazard and 3: severe hazard. After completion of the survey, specialists address priority ACHiL level 3 hazards and 'hot spots', *i.e.* laboratories combining several ACHiL level 2 or 3 hazards for risk analysis. As expected (Fig. 2), chemicals are still the main safety concern at ISIC but lasers, magnetism and microorganisms are also widespread in these laboratories.

Within the framework of the MICE program, ACHiL is a keystone step initiating a variety of measures. Results of the inventory are used for completion of the laboratory door panel labeling indicating the top three hazards present in the room. This information recalls the basic commitments related with the hazard and gives an overview for emergency or technical contributors. Based on ACHiL, the MICE program has been developed for several specific hazards and some innovative contributions are further described.

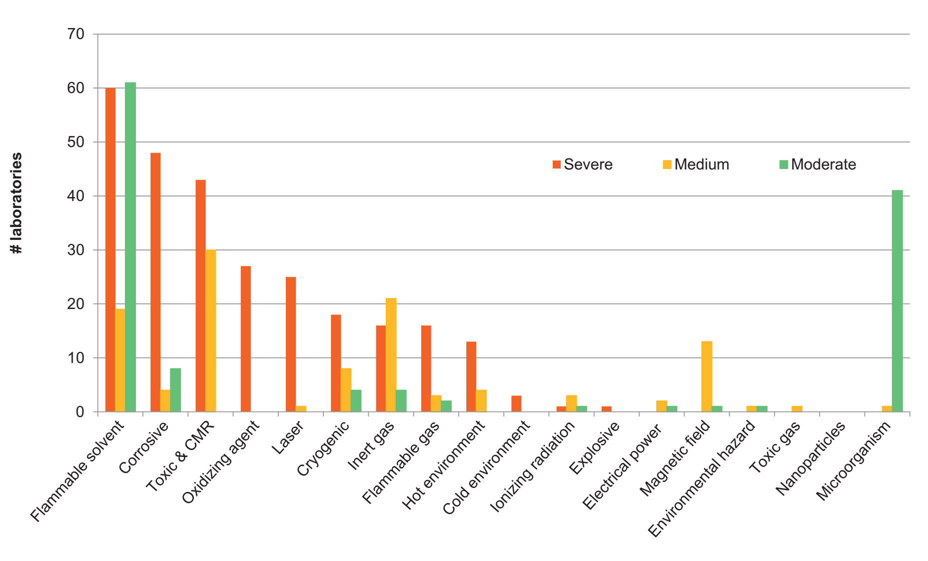


Fig. 2. Determination of specific hazard in ISIC laboratories through the ACHiL platform.

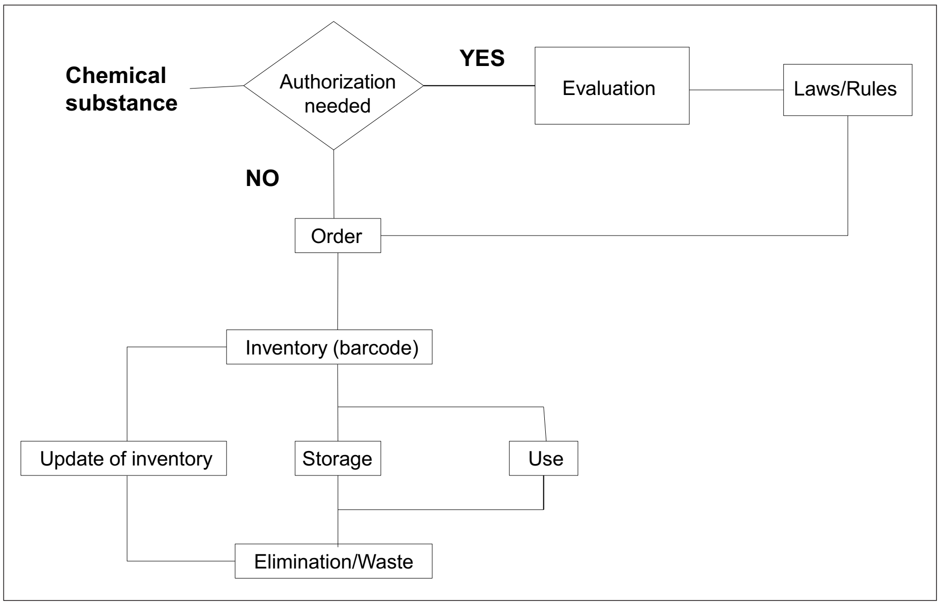


Fig. 3. MICE chemical management flowchart.

## 3. MICE Management of Chemicals

Chemical management is a crucial step in order to ensure a homogenous safety environment throughout an academic institution. Obviously, many chemicals should not be manipulated without confirmation that equipment is suitable for the purpose and that workers are correctly trained, especially for carcinogenic, mutagenic and reprotoxic substances (CMR), highly toxic compounds or with high energetic reactivities. In order to validate the safety measures at the workplace, health and safety professionals must have access to information regarding the existing substances throughout the laboratories. Each research group selects its own research area and objectives and chemicals can be allocated in two categories: a) widely used common solvents and inorganic salts and b) particular substances dedicated for specific research areas. Management of chemicals in academia must establish a process that ensures a safe work environment for students and staff without impairment of academic freedom.

To address this issue, SB-SST proposed a comprehensive chemical management system starting from the ordering of chemicals and culminating in special waste disposal (Fig. 3).

### 3.1 *Ordering Chemicals and Substances Subject to Authorization*

Chemical management in academia must start at the ordering stage to overcome the further independence of the research groups and the inherent lack of outside communication. At EPFL, all substances are ordered through chemical stores responsible for general negotiation with suppliers, for checking compliance between ordering and shipping and for introduction of every chemical in the inventory database (see below). Special treatment is applied for a couple of dozen substances leading to serious health concerns, in particular class 1 CMR or highly toxic products. Researchers must obtain an authorization for use of these compounds from SB-SST. The list of tagged substances is established upon Swiss legal requirements based on the *Particularly dangerous substances* legislation[4] and is available at the SB-SST web site.[5] This quality process allows research groups to access support from specialists regarding the possibility to replace very hazardous substances by less problematic ones, to verify if safety measures and operating procedures are sufficient, adequate and adapted for the planned project and eventually to determine monitoring measures.

### 3.2 *Inventory and Storage*

Currently, the ISIC inventory encompasses over 60'000 different chemical substances. All chemicals are inventoried independent of their physical state (solid, liquid or gas) in a dynamic central database (intranet interface), taking into account chemical information (quantity, purity, MSDS), and logistical information (storage place, owner). Furthermore, the inventory allows the users to know if a substance is already present at ISIC and could be borrowed for an initial test. In addition, the computational inventory is a powerful tool for health and safety specialists to search for all chemicals with the same specific hazard statement or by checking storage duration to prevent aging degradation.

Storage must be considered as a first line safety measure to prevent undesired events. According to CLP regulation (EC implementation of GHS),[6] substances have to be stored in an appropriate manner taking into account chemical compatibility and segregation depending on their intrinsic reactivity. This quality management is verified twice a year by workplace audit controls performed by SB-SST.

At the end of the process, wastes are treated in a similar manner as pure compounds. They are separated by chemical compatibilities and properties according to a decision tree[7] indicating the elimination transport number (according to the OMoD regulation[8]). Once correctly conditioned, they are brought to the chemical stores for transportation. No longer required substances and other chemical waste are collected, packed and identified by the chemical stores acting as the sole negotiator with suppliers and other external contacts.

| Field intensity [T] | Restrictions |
|---|---|
| 0.5 mT (5 G) | Yellow stripe, 0.5 mT ≤ B < 3 mT: Maximal field authorized for the public, people wearing pacemakers or ferromagnetic prosthesis or for the pregnant women. |
| 3mT (30 G) | Orange stripe, 3 mT ≤ B < 200 mT: Field starting from which ferromagnetic objects can be attracted by the field. |
| 0.2 T (2k G) | Red stripe, B > 200 mT: The value above which the zone is forbidden without preceding medical control and advice. |

Fig. 4. Safety classification depending on the static magnetic field.

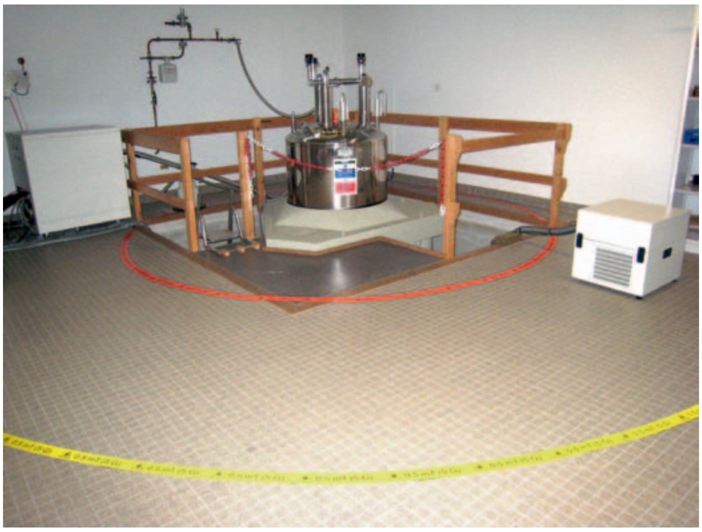

Fig. 5. Magnetic field warning stripes around a NMR instrument.

## 4. MICE Management of Strong Magnetic Fields

In the analytical arsenal, matter-magnetic field interactions are amongst the most powerful properties used by chemists to characterize substances and materials. These instruments include notably Nuclear Magnetic Resonance (NMR), Electron Paramagnetic Resonance (EPR) and Magnetic Resonance Imaging (MRI). Magnetic field intensity in these apparatuses ranges from 1 T to 20 T.

Magnetism is often feared or misunderstood because it cannot be directly detected or perceived by human senses. Highest risks due to intense magnetic fields are thermal effects, sense perturbation and attraction of ferromagnetic devices becoming potential projectiles.[9] Based on European safety guidance[10] and to ensure a safe and healthy environment for the personnel, we introduced the MICE management for strong magnetic field-emitting apparatus. Spatial magnetic field intensity distribution was measured in the area surrounding individual instrument and mapped. Depending on the field's intensity, three zones (Fig. 4) were defined, determining the threshold access for the public (including cleaning operators), for professionals and restricting the area without medical monitoring. Based on the cartography, the field intensity thresholds are marked on the laboratories' floor by colored warning stripes (Fig. 5). In the MICE program, training (*I*nformation) is given to researchers with a particular concern to potential pregnant women. During the *C*ontrol operations, we noticed a remarkable enhancement of shielding performances of recent commercial equipment compared to the less recent ones.

## 5. MICE Management of Nanoparticles

Nanoparticles are a very exciting domain of investigation opening a broad range of new application but little is known about their potential health effects.[11] A responsible safety management must address this new area without quenching creativity but also in protecting workers; a dramatic lesson was given by the lack of prudence practice regarding asbestos.

In order to propose a research-oriented solution, SB-SST assembled a 'nanosafe team' including specialists in health and safety, nanoparticle users and public health representatives. This group elaborated a decision tree system aimed at the determination of three levels of nano-hazard laboratories[12] and the subsequent protection measures. Depending on the formulation of nanomaterial (powder, suspension, solid matrix), the use or the production and the quantities, laboratories are sorted into three hazard levels (*Nano 3* = highest hazard to *Nano 1* = lowest hazard), which corresponds to similar approaches applied to other hazard types (biohazard, radioprotection). Depending on the classification, recommendations are given for technical, organizational and personal protective measures.

The target users of this safety and health methodology are primarily researchers. They can rapidly assess the hazard class of their activity and the corresponding protective measures. More detailed analyses of specific activities can be undertaken by safety and health experts when needed. According to our opinion and experience, the proposed management of nanomaterial safety is neither stifling nor harming innovation, as it is sometimes feared among researchers.[13]

## 6. Conclusions

The MICE management program has proven to be a powerful system to address safety hazards in research environments such as academia. This is especially true when particular hazards are present. The *M*anagement part of the program must follow the fast evolution of the research environment. It must not only provide wide and compulsory guidelines but allow researchers to be part of the process offering also direct benefit for their activities and thus creating value. The process and its benefit can only be understood and accepted through an *I*nformation concept including a personal training program. A quality management solution is always concluded by validation of measures. Because of academic freedom, this assessment can only be performed by an effective *C*ontrol *i.e.* by visiting individual research groups and checking the procedures.

The above measures taken in chemistry are first considered as support for research and teaching. Chemical management reduces notably the frequent inclination for conservation of old ideas leading to serious concerns in academia. In parallel, implementation of modern safety management for new safety issues (magnetism, nanoparticles) promotes safety as integrated part of the usual behavior in laboratories. The next target of the MICE program aims at the development of risk management tools that would allow professionals in health and safety together with researchers to adapt the safety environment at the rhythm of the research evolution rate.

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