Chemical waste risk reduction and environmental impact generated by laboratory activities in research and teaching institutions

Elizabeth de Souza Nascimento\textsuperscript{I}, Alfredo Tenuta Filho\textsuperscript{II}

\textsuperscript{I}Department of Clinical and Toxicological Analysis, Faculty of Pharmaceutical Sciences, University of São Paulo
\textsuperscript{II}Department of Food and Experimental Nutrition, Faculty of Pharmaceutical Sciences, University of São Paulo

ABSTRACT

The environmental impact caused by teaching and research with regard to chemical waste is of increasing concern, and attempts to solve the issue are being made. Education and research-related institutions, in most laboratory and non-laboratory activities, contribute to the generation of small quantities of waste, many of them highly toxic. Of this waste, some is listed by government agencies who are concerned about environmental pollution: disposal of acids, metals, solvents, chemicals and toxicity of selected products of synthesis, whose toxicity is often unknown. This article presents an assessment of the problem and identifies possible solutions, indicating pertinent laws, directives and guidelines; examples of institutions that have implemented protocols in order to minimize the generation of waste; harmonization of procedures for waste management and waste minimization procedures such as reduction, reuse and recycling of chemicals.


INTRODUCTION

The environmental impact of chemical waste produced by teaching and research is a topic that has been of great concern and discussion for at least two decades, as illustrated in the book by Ashbrook and Reinhardt (1985) on the generation of hazardous wastes in academic institutions. In the book, the authors stressed the need to implement a practice for the treatment of chemical waste in educational institutions, which in most laboratory and non-laboratory activities, contribute to the generation of small quantities of waste, many of them highly toxic. Some of this is listed by governmental agencies who are concerned about the quality of the environment. Examples include the disposal of toxic acids, metals, solvents, chemicals and also products of synthesis whose toxicity is often unknown. Furthermore, it is noteworthy that the composition of waste from research labs constantly changes according to each project being developed. This situation can no longer be ignored by academic institutions, and various research and educational institutions in Brazil are concerned about this problem and are integrating hazardous waste management into their...
activities. Some of these activities are available in frequent articles published in the Química Nova Journal, numbering among them articles by: Jardim, 1998; Cunha, 2001; Amaral et al., 2001; Afonso, et al., 2003; Alberguini et al., 2003; Bendassolli, 2003; Afonso, 2004; Gerbase, et al., 2005; Imbroisi, et al., 2006. There are also several books by Brazilian authors addressing the management of chemical waste in universities (Alberguini et al., 2005; Figueredo, 2006).

The work by Nolasco et al. (2006), analyses the implementation of programs for managing laboratory chemical waste in Brazilian universities, and states that several programs are responding to the requirements of the pillars of sustainability and ecological awareness, which were the main proposals of Agenda 21. The authors also mention that in the last decade, some of the oldest and most prominent Federal and State universities have been adapting and establishing proper measures for control waste.

These institutions include the Center for Nuclear Energy in Agriculture, University of São Paulo (Tavares, 2004), the University of Campinas - UNICAMP (Gerbase et al, 2005), the Institute of the Chemistry of the University of Rio de Janeiro - IQ / UERJ - (Barbosa et al., 2003), the Department of Chemistry, Federal University of Parana - DQ / UFPR (Cunha, 2001), the Institute of Chemistry of the Federal University of Rio Grande do Sul - IQ / UFRGS (Amaral et al., 2001), the Regional Integrated University of High Uruguayan and Missions - URI (Demaran et al., 2004), and the Federal University of Rio de Janeiro - UFRJ (Afonso et al., 2004). In addition to these sites, other initiatives are being carried out in other educational institutions, for example Borghesan et al. (2003), cited the University of São Paulo, São Carlos, while Mortari (2003) mentioned the Francisca University Center.

Otenio et al. (2008) also described a case study associated with the management of biowaste for milk at Embrapa Gado and pools the establishing of and maintaining programs for waste management in universities, teaching and research institutions, both governmental and private, largely outweigh the operational costs that these entail.

One of the most significant advantages is undoubtedly the fact that students are taught how to adequately deal with the waste produced in research and in classrooms, thereby minimizing damage to the environment. Moreover, another advantage, which should not be overlooked is that of working in a safe, healthy and clean environment, in line with the principles of ecology (Armour, 1996).

The United States of America’s legislation related to environmental care in educational institutions is the Resource Conservation and Recovery Act (RCRA), also known as “Solid Waste” Disposal Act, which came into force in 1976, and is an interesting example of the concern over the risks associated to ecological damage. Its objectives are to protect human health and the environment, reduce the generation of all types of waste, toxic or otherwise, and to promote the conservation of energy and natural resources. This law gives the U.S. Environmental Protection Agency (EPA) the power to regulate the disposal of toxic waste in the U.S.A. and authorization to bring civil and criminal charges against whoever violates this law. There have already been cases of not only industries, but also various American universities, being charged, condemned and subject to severe penalties. According to the amendment to this law, dated October 1990, (USA) individuals charged with this type of violation, can be personally prosecuted, convicted and sentenced to imprisonment in State or Federal prisons. Another penalty of significant importance to educational and research institutions committing this type of violation, is that they may no longer receive funds or subsidies from government organizations to support or sponsor their research.

In 2006, EPA proposed alternative and more flexible standards for the management of hazardous waste generated in academic institutions, as the environmental agency considered that the legislation, which had formerly been established for industries, needed to be adapted in various aspects. Academic institutions present different characteristics to those of industry, since the amounts of waste generated are smaller, diverse and distributed across various laboratories, manipulated by students in various situations that are not always supervised by trained individuals. Thus, the revised legislation came into force in 2008 (Monz, McDonough, 2006; Archer et al., 2000).

As stated above, although the amount of waste generated in academic institutions is small, less than 1% of the total generated nationally, waste in education institutions is considered heterogeneous, and may include highly toxic compounds. Therefore, any teaching and research institution committed to its employees’ and students’ health must consistently uphold the laws related to workers’ chemical safety, and laws on management of hazardous waste released by its laboratories.

The concept of waste minimization encompasses any action that reduces the amount and/or toxicity of anything to be discarded as hazardous waste. It is therefore essential that the waste is properly handled, stored and disposed of. When the waste generating source has been identified, whether highly hazardous or otherwise, protocols or operational procedures aimed at their appropriate disposal should be implemented.

Most of what is used in university laboratories, albeit related to research or teaching at some point, can become hazardous. Examples are solvents, glassware, reagents, packaging of dangerous products, biological material, out of order, broken or obsolete equipments, broken thermometers, and outdated or obsolete computers. A visitor to most unpretentious academic laboratories would see such material, which can cause safety problems and have an impact on environmental health if disposed of in an indiscriminate manner. Thus, it is important to urgently address this problem, where this can be done by cutting down on waste production, and properly treating and disposing of the waste which is produced.

HARMONIZATION OF WASTE MANAGEMENT PROCEDURES

The last few decades have seen great development in the creation of standards and quality systems in several professional activities many of them aimed at improving harmonization of procedures, the quality of manufactured products, and professional activities. Among these systems are the ISO - International Standards Organization, whose function is to ensure the desirable characteristics of products or services such as quality, environmental care, safety, reliability and efficiency. Most of the ISO guides are specified for products, processes or materials. ISO 9000 procedures focus on quality and ISO 14000 on the environment, and are considered generic systems of management standardization. The term generic used here has the connotation of allowing these systems to be applied to any organization, large or small, in order to carry out any activity in any sector of the economy, public administration, or government organizations. The ISO 9001 standard provides a series of requirements for implementing a quality management system, while the ISO 14000 pertains to an environmental management system (www.iso.org).

When organizations follow the spirit of ISO 14000, it means that they promote changes in attitude, operational procedures and in management, which then yields many benefits. This standardized protocol provides common sense information to help reduce the negative impact of several activities on the environment, therefore reducing costs by cutting down on waste and preventing pollution, in addition to contributing to the quality of the communities in which the organization operates (Rondinelli et al., 2000).

Thus, institutions both private and public can benefit from the implementation of such systems that significantly improve the environment in which they are located. A program of waste management is an integral part of the environmental care recommended...
by ISO 14000. Such programs can and should be implemented in educational institutions, and this necessarily includes constant evaluation of laboratory activities and processes, aimed at reducing the generation of disposable material and increasing recycling.

The waste generated by academic institutions such as universities, institutes and high schools can be classified into four main categories: household, biological and chemical waste, and radiation. The last three may or may not be considered dangerous. Those considered hazardous should be discarded as such and not as common garbage, seeking to minimize environmental impact and to adhere to specific waste management laws enforced by European, American, and Brazilian legislations (Council Directive 91/689/EEC, USEPA, 1996; Brazil, 2002).

Hazardous chemicals normally found in academia and requiring proper treatment are:

- chemical wastes generated in research laboratories, and during teaching activities;
- old chemical agents, considered an institutional liability, often difficult to identify and abandoned in the laboratory;
- chemical agents surpassing their expiration date and therefore in need of re-evaluation of their effectiveness, and need for disposal;
- bottles of chemicals without labels or with wrong or unreadable labels;
- material in a state of deterioration or in packages which are deteriorated, or damaged;
- unknown residues in chemicals containers;
- laboratory waste such as paper towels and rags;
- personal protective equipment: aprons, glasses, masks, gloves contaminated with harmful biological, chemical or radioactive material;
- non-recyclable batteries and gas cylinders;
- photographic film processing solutions;
- pesticides, equipment containing toxic compounds, different types of waste oils, used solvents, Thinner, oil remover, wood preservers;
- formaldehyde, formalin, acrylamide waste in liquid or gel form;
- mercury and other metals with high toxicity;
- defunct electronics, computers and thermometers;
- sharp devices such as: needles, syringes, chromatography needles, Pasteur pipettes, tips;
- bleach, ammonia, cleaning solvents, liquid wood polish;
- chemical bottles (glass and plastic) empty but contaminated;
- contaminated broken (or damaged) laboratory glass;
- mercury-contaminated, broken (or damaged) thermometers;
- carcinogenic and radioactive chemicals, pathogenic microorganisms.

RELEVANT LAWS RELATED TO WASTE DISPOSAL

Although very little legislation is directly related to the management of hazardous waste in teaching and research activities, there are many laws, rules and ordinances in a Federal, State and local realm related to the subject in question. An interesting portal to be consulted for information on health laws and regulations is the site: http://www.cvs.saude.sp.gov.br/publ_leis3.asp.

Examples of pertinent legislation:

- Resolution RDC 306/2004 (ANVISA) - technical regulations for the management of health services waste;
- Resolution CONAMA 357/2005 - sets the conditions and standards for effluents release;
- Resolution CONAMA 358/2005 - treatment and final disposal of health services waste;
- State Decree 8468/1976 - provides for environmental pollution prevention and control; Law No. 12300/2006 - establishing the Solid Waste State Policy (São Paulo State);
- Resolution SMA - 31, 22-7-2003 -management of chemical waste from health service establishments in São Paulo State;

In the case of chemical waste from laboratories, there is no specific legislation for their classification, treatment and disposal, thus one should use the NBR 10004:2004 - Standard for classification of solid waste, along with other resolutions and decrees, State or Federal, above mentioned organization (State Environmental Authority - SP: CETESB) is in charge of controlling this activity.

There are also other technical standards such as those released by the Brazilian Association of Technical Standards (ABNT) (www.abnt.org.br) listed below:
Resolutions Conama n. 358 and ANVISA n. 306

Resolutions CONAMA n.358 of 29 April 2005, and the Ministry of Environment and ANVISA in the DRC 306, 7 December 2004, seek to minimize occupational hazards and protect the health of workers and the general population. This resolution, in its Article 1, specifies that its application is related to all services that include assistance to human or animal health, laboratories of analysis for health products and, subject to this chapter, health educational and research institutions, among others. This resolution classifies the various types of waste into 5 categories, and indicates how each one should be handled:

I - GROUP A: Waste with the possible presence of biological agents that, by its characteristics of greater virulence or concentration, may pose a risk of infection.

a) A1:

1. Microorganisms cultures and stocks; residue waste of biological products manufacture except hem-derivatives; disposal of attenuated or live microorganisms, vaccines, culture medium of microorganisms and instruments used to transfer, inoculation or mixing of cultures, residue waste from laboratories of genetic manipulation;

2. Waste resulting from individuals or animal health care suspect or certain of contamination including class 4 risk biological agents, microorganisms of epidemiological relevance and risk of dissemination, or able to cause of emerging diseases that could become of epidemiologically important, or when its transmission mechanism is unknown;

3. Bags containing blood or blood transfusion rejected due to contamination or poor storage, or expired validated date;

4. Remains of laboratory samples containing blood or body fluids, containers and materials resulting from health care processes, containing blood or body fluids.

The generating unit should treat this type of waste before disposing of it.

b) A2:

Carcasses, body parts, other waste residues from animals used in experimental processes involving inoculation of microorganisms, and the corpses of animals suspected of being carriers of microorganisms of relevance and epidemiological risk of dissemination.

The generating unit should treat this type of waste before disposing of it.

c) A3:

Human body parts, products of fecundation weighing less than 500g and/or less than 25 cm, with gestation age less than 20 weeks:

The generating unit should organize for material to be cremated, incinerated, or buried.

d) A4:

1. Kits of arterial, intravenous and dialysis lines, when discarded;

2. Filters for air and gases aspirated from contaminated areas; filter membrane from hospital, clinical and research equipment, among others;

3. Remains of laboratory samples and their containers of feces, urine and secretions from patients that do not contain, nor are suspected to contain risk class 4 agents, and neither have relevance and epidemiological risk of dissemination, or microorganism causing emerging disease that has become important epidemiologically or their transmission mechanism is unknown, or suspected of prion contamination;

4. Fat residue waste from liposuction, liposculpture or other plastic surgery procedure that generates this type of waste;

5. Containers and materials resulting from health care processes, which contains no blood or body fluids;

6. Anatomical parts (organs and tissues) and other waste from surgical procedures or of anatomical and pathological studies or diagnostic confirmation;

7. Carcasses, anatomical parts, or other waste from animals not submitted to experimentation processes with inoculation of microorganisms;

8. Empty or semi used blood bag for transfusion.

The generating unit should discard this material without prior treatment at sites previously designated for Health Services waste.
e) A5:

Organs, tissues, body fluids, piercing or sharp material and other materials from human or animal health care, suspected or certain of contamination with prions.

The generating units must incinerate them.

II - GROUP B: Waste containing chemicals that may present risk to public health or the environment, depending on its characteristics of flammability, corrosivity, reactivity and toxicity.

a) Hormonal, antimicrobial, cytostatic, anticancer, immunosuppressant, digitalis, immunomodulatory, anti-retroviral products, when discarded by health services, pharmacies, drugstores and distributors; medicines and pharmaceutical raw materials residue waste;

b) Sanitizing, disinfectants waste; waste containing heavy metals, laboratory reagents, including containers contaminated with these materials;

c) Image processor effluent (developers and fixers);

d) Effluent of automated equipment used in clinical testing;

e) Other products considered dangerous, under classification of the ABNT NBR 10004 (toxic, corrosive, flammable and reactive).

The generating unit should treat them for final specific disposal, unless they are subjected to reuse, recycling or recovery processes.

III - GROUP C: Any material resulting from human activities containing radionuclides in quantities exceeding the limits specified in the rules for disposal of the National Commission of Nuclear Energy - CNEN and for which the reuse is inappropriate or not provided for. Any materials resulting from research and educational labs, health, clinical and laboratory testing services, nuclear and radiation medicine containing radionuclides exceeding limits of elimination fall into this group.

The generating unit should follow the rules of the Nuclear Energy National Commission - CNEN - for the treatment of radioactive waste.

IV - GROUP D: Biological, chemical or radiological waste not causing health or environmental risk, can be treated as household waste.

a) Sanitary paper, diapers, sanitary napkin, disposable pieces of clothing, food remains from patient, material used in anti-sepsia, and other similar material not classified as A1;

b) Food and food preparation scraps;

c) Cafeteria food scraps;

d) Waste from administrative areas;

e) Sweeping waste, flowers and gardens;

f) Residue waste gypsum from health care.

V - GROUP E: piercing or sharp material, such as shaving blades, needles, scalp, glass ampoules, drills, endodontic files, diamond burs, scalpel blade, lancets, capillary tubes, micropipettes, and spatulas; also all the broken glass utensils from laboratory (pipettes, blood collection tubes and Petri dishes) and others.

This legislation considers agents of class 4 exposure (high individual risk and high risk to the community) the pathogens that represent major threat to humans and animals, and which pose great risk to whom might handle it; or likely to be transferred from one individual to another; and those without preventive measures or treatment.

Hazardous chemical waste are those listed in Group B, as per CONAMA resolution 283 of 12 July 2001, and classified as hazardous, according to NBR 10004, by presenting characteristics of toxicity, reactivity, flammability and/or corrosivity. The non-hazardous chemical waste are the result of institutions' laboratory activities for provision of health services that do not exhibit the above characteristics, defined as follows:

- Flammability: any liquid whose flash point is less than 60 ºC, compressed gas with a high degree of ignition, oxidants, substances capable of catching fire, under normal pressure and temperature, by processes of friction, absorption of moisture or spontaneous changes;

- Corrosivity: aqueous solutions with pH below 2 or above 12.5, or compounds with high reactivity in water or forming potentially explosive mixture with water, or usually unstable, or those that generate fumes, smoke or toxic gases when mixed with water, or cyanide residues or sulfide gas generators, smoke or toxic fumes in pH between 2 and 12.5, or explosive compounds, and if capable of corroding steel at the rate of 6.55 mm per year, in temperature of 55 ºC;

- Reactivity (causes irritation): non-corrosive chemical agents which by contact with skin or mucosa, can cause inflammation. It is worth noting that corrosive substances at low concentrations may be irritating; hydrophilic agents such as ammonia, are irritating to the upper respiratory tract; organic solvents are irritants due to dissolution of the dermal lipid layer.

- Toxicity: toxic metals, pesticides, organic compounds, polychlorinated biphenyls, dioxins, among other residues. The toxicity is proven from toxicological in vivo and in vitro tests, adopting harmonized and internationally accepted protocols (USEPA, OECD). The University of Houston suggests a procedure for chemical safety and risk management, based on Title 40, Code of Federal Regulations, Protection of the Environment, (U.S. Environmental Protection Agency). According to EPA definition, pollution prevention is a reduction of waste at source and environmentally correct recycling, thus any plan to tackle this problem must consider the 3 Rs, of Reduce, Reuse and Recycle;

- Reduce the use of hazardous material and, where possible, use small quantities of chemical agents;
Another important way to minimize waste generation is to consider the use of less toxic chemicals, both in research laboratories and in the classroom. Avoid the use of unnecessary ingredients, such as emulsifiers in solvents to be used or discarded, and separate the different types of solvents for reuse or recycling. The university laboratories tend to generate a considerable amount of chemical waste as they often use outdated techniques and a large volume of solvents. Other suggestions designed to minimize the generation of waste are: replace the use of mercury thermometers for digital thermometers; replace sulfochromic solution or alcoholic solution of potassium hydroxide or potassium hydroxide for sonication, when possible for the cleaning laboratory glassware; replace tests with acids and strong bases, therefore more toxic, for vinegar and ammonia; replace carbon tetrachloride by cyclohexane, according to the process described below:

REDUCTION

In the process of waste reduction at source, the goal is to facilitate any activity that reduces or eliminates the generation of hazardous chemical waste. This activity can be implemented with good management when acquiring materials; when replacing toxic material with less harmful ones, and with good laboratory practice. Here are some suggestions that allow the reduction of waste at source according to the University of Florida:

- implement a policy of minimizing waste in the university research and students practice laboratory, and train all those involved in these activities. The reduction at the source can be achieved through improvement of methods or processes and replacement of ineffective equipment. In educational institutions, this is not always possible, but one should consider using more modern extraction techniques, such as solid phase extraction, or supercritical fluid, to minimize waste by using smaller volumes of organic solvents;
- do not mix dangerous classes of waste with non-hazardous ones;
- consider the possibility of using less toxic reagents, substituting for products with lower toxicity. In this context, it is possible to consider the replacement of products such as benzene, used as a solvent, with hexane or xylene; formalin or formaldehyde, used as a preservative for specimens in the laboratory, with ethanol; halogenated solvents in the extraction process with non-halogenated solvents; sodium dichromate with sodium hypochlorite, in some oxidation reactions; in studies using radioactive material, replace liquid scintillation-based toluene with a non-flammable solvent; in qualitative tests for heavy metals, replace sulfide ion with hydrogen peroxide. Replacement is not always possible because some substitutes do not always produce fully satisfactory results, or are toxic or too expensive. Thus, it is necessary to evaluate if the replacement material is suitable and delivers acceptable results. A common practice is to make an inventory of the compounds used in laboratories and to identify the likely replacement. The laboratory technician responsible for the use of these compounds needs to evaluate the possible replacements, using the information given by suppliers in the material safety data sheet (MSDS - Material Safety Data Sheet);
- centralize the acquisition of chemicals, and biological and radiation materials;
- make an inventory of purchased and used chemical agents in the laboratory: maintain a file containing their location, which should be updated annually. This facilitates the reduction of the quantity stored, and avoids the purchase of unnecessary material;
- provide employees with updated MSDS - Material Safety Data Sheet of the chemicals used in laboratories;
- acquire any chemical, biological and radiation materials in the least possible amount. The motto of the American Chemical Society (2008), is “Less is better”, it is safe and environmentally correct to buy less material, use less and, ultimately, dispose of less, allowing a reduction in risk of accidents, fires, or harm to human health, and at the same time reduces costs;
- purchase the equipment needed for immediate use and avoid purchasing materials in large quantities, even it seems to be economically advantageous, since stocking can be expensive, or dangerous, and may lead to products exceeding their expiration date. A significant part of disposal done by universities is related to the purchase of unnecessary equipment;
- label all reagents to allow their ready identification. Borrow material from other labs, or buy it in small quantities. There is a successful story about a chemicals redistribution program at the University of Wisconsin - Madison, which has existed since 1980. About 30% of excess chemical purchased for each quarter are redistributed by the university, which allows an economy of $ 10-20,000.00 on disposal of chemicals for the university. Thus, the institution donates chemicals to those who need them and at the same time, reduces the amount to be discarded, and all benefit from this type of procedure;
- consider the possibility of testing in micro-scale, using new glassware and techniques that reduce quantities used to milligrams, which yields many benefits such as lower costs, since small-scale experiments using fewer solvents and other chemical agents are generally processed more quickly, because it is faster to heat or cool small volumes, reduces exposure to harmful agents and reduces harmful emissions. However, please note that this technique can only be implemented to achieve the analytical proposed objective;
- consider the alternative of presentations/demonstrations on video, computer modeling and simulations, which eliminate environmental impacts, as substitutes for laboratory tests in the classroom. These multimedia simulations allow the student to observe more complex procedures than would be possible in traditional activities in the laboratory;
- consider prior separation of reagents and weighing in the laboratory, avoiding contamination of several rooms and environments;
- avoid using reagents containing toxic metals such as lead, chromium, arsenic, mercury, barium, silver, cadmium and selenium;
- do not use sulfochromic solutions: substitute them for less toxic solutions such as biodegradable detergents like
The recommended process of reducing production of harmful wastes is not always feasible, because the concept of research implies the handling of hazardous materials in the sink, allowing the evaporation of solvents, among other activities detrimental to the environment. The disposal of such waste, which is often not properly managed, poses a serious threat to the environment and public health.

As mentioned earlier, educational and research institutions generate pollution because they produce harmful waste, discard it inappropriately, and fail to apply waste management practices. This is due to the decentralized nature of research laboratories, which rely on graduate students and postdoctoral associates who are usually at the university for limited time, and the type of waste generation changes frequently, as the focus of the research changes.

According to IZZO, 2000, coordinating hazardous waste management at a university can be very complex, as most universities are decentralized, and the research activities are constantly changing. The management of such hazardous waste requires careful planning and implementation of waste reduction strategies.

Reuse and recycling

Reuse and recycle processes when possible in a new way, or treat and reuse it in the same way, or in another type of activity. Some examples of recycling are:

- Distillation of used solvents;
- In cleaning processes, the glassware can be initially washed with used solvents;
- Purchase only compressed gas cylinders from manufacturers that accept the return of empty or partially used ones;
- In pesticide studies, it is advisable to establish the practice of returning any unused material to the research sponsor;
- Avoid the contamination of fuel with solvents or heavy metals;
- Share chemical agents among the various university units;
- Control the use of metallic mercury.

If the above procedures are not suitable for specific situations to minimize waste, an alternative may be the final chemical treatment of the generated hazardous waste. The techniques routinely used in reducing chemical waste are: neutralization, precipitation, oxidation, reduction and distillation, practices to be conducted by trained laboratory technicians.

Neutralization

The most common treatment is to neutralize highly acidic or alkaline solutions, leading to a desirable pH of 6 to 9. Thus, if this solution does not contain other toxic compounds it can be treated as regular trash and discarded in the sewage. Strong acids or bases must be neutralized before being released into the sewage, including those with the following cations: Al^{3+}, Ca^{2+}, Fe^{2+}, Fe^{3+}, H^{+}, K^{+}, Li^{+}, Mg^{2+}, Na^{+}, (NH_{4})^{+}, Sn^{2+}, Sr^{2+}, Ti^{3+}, Ti^{4+}, Zr^{2+}; and anions: (BO_{3})^{3-}, (B_{4}O_{7})^{2-}, Br^{-}, (CO_{3})^{2-}, (HSO_{3})^{-}, (OCN)^{-}, (OH)^{-}, I^{-}, (NO_{3})^{-}, (PO_{4})^{3-}, (SO_{4})^{2-}, (SCN)^{-}, Zn^{2+}.

Precipitation, oxidation and reduction

These processes can remove hazardous components of chemical waste and the final product can be discarded as common trash. Precipitates derived from these reactions may require more effective waste treatment. The application of these procedures for chemical treatment in laboratories, apart from reducing hazardous waste, allows its incorporation as a common practice in teaching the students responsible management of chemical waste, fostering future generations of scientists with a better understanding of proper waste disposal.

The recycling of solvents, among other materials used in technical analysis, allows the reuse of material, which otherwise would be discarded as hazardous waste. These techniques require planning, when they are incorporated into the teaching laboratories activities. Solvent recycling, if well done, brings advantages to the academy in terms of risk reduction, harmful waste reduction, lower costs, and is also beneficial for the students because as previously mentioned, it allows them to learn about waste management in a responsible manner and understand the university commitment to hazardous waste reduction.

According to IZZO, 2000, coordinating hazardous waste management at a university can be very complex, as most universities are decentralized, and most research laboratories have an unstable workforce, relying heavily on graduate students and postdoctoral associates who are usually at the university for limited time, and the type of waste generation changes frequently, as the focus of the research changes.

As mentioned earlier, educational and research institutions generate pollution because they produce harmful waste, discard hazardous materials in the sink, allow the evaporation of solvents, among other activities detrimental to the environment. The recommended process of reducing production of harmful wastes is not always feasible, because the concept of research implies the handling of hazardous materials in the sink, allowing the evaporation of solvents, among other activities detrimental to the environment. The disposal of such waste, which is often not properly managed, poses a serious threat to the environment and public health.
study of new compounds and their disposal if the result is neither interesting nor relevant. This type of activity is quite different from industrial processes, where there are routine activities, constant use of raw materials and well known waste products. In research, the multitude of non-routine activities is inherently more difficult to control. Nevertheless, the suggestions described here may contribute to the prevention of environmental pollution, and minimize costs with health and the environment. The proper disposal of hazardous waste involves direct costs to the universities, as is the case at the University of Bristol which produced 1,209 tonnes of waste between August 07 and July 08, excluding construction waste. Of this 1,861 tonnes, the amount recycled or reused was 704 tonnes (39%). The total cost of waste management in 2008 was over £200,000. By increasing the amount of waste that can be reused and recycled it is possible to reduce the amount going to landfills and save money in the process (Bristol University, http://www.bristol.ac.uk/environment/wasted). Thus, while reducing the production of waste and encouraging recycling, they also reduce costs.

COMMITTEES/PROGRAMS FOR WASTE MANAGEMENT IN EDUCATIONAL INSTITUTIONS

Common sense dictates that the universities should maintain a committee, or program to minimize waste, which actively seeks ways to reduce it in their teaching and research units. This is being practiced in various academic institutions in America, Australia and Europe, among others, which can be checked out by visiting their electronic portals. Some examples are found at:

University of Delaware  www.udel.edu/OHS/chemical.html
Northwestern University  http://www.research.northwestern.edu/ora/safety/chemical/waste/
University of Western Australia  www.fm.uwa.edu.au/about/policies/chemical_waste
University of Louisville  http://louisville.edu/dehs/waste/waste/Guide/chap3.html
The University of Illinois  www.drs.uiuc.edu/wasteguide/
University of Minnesota  www.dehs.unm.edu/hazwaste_chemwaste_unm_cwmgbk.htm
University of Florida  http://www.ehs.ufl.edu/HMM/wmin.htm
Columbia University  http://www.ehs.columbia.edu/WasteMgt.html
University of Wisconsin  http://www2.fpm.wisc.edu/chemsafety/GUIDE2005/chapter%206.pdf
Duke University  www.safety.duke.edu/SafetyManuals/University/Q-Chemwastemgt.pdf
Arizona State University  http://www.asu.edu/uacq/EHS/chemical1.htm
University of Bath  http://www.bath.ac.uk/internal/waste/wastespecchem.htm
Toronto University  www.ehs.utoronto.ca/Resources/wmindex/wm5_2.htm
University of Minnesota  http://www.dehs.umn.edu/hazwaste.htm
Bowling Green State University  http://www.bgsu.edu/offices/envhs/page18356.html
University of Colorado  http://ecenter.colorado.edu/greening_cu/2000/page6.html
Universidade de Clenson  http://ehs.clemson.edu

Some universities also have Brazilian electronic portals that can be visited to evaluate their procedures for collection of chemical waste chemicals in their campi:

Universidade de São Paulo - Campus de São Carlos  http://www.sc.usp.br/residuos/rotulagem/downloads/normas_recolh.pdf
Universidade Federal de São Paulo  http://www.unifesp.br/reitoria/residuos/index.php
Universidade de Campinas  http://www.cgu.unicamp.br/residuos/sobre/gerquim.htm
Universidade Federal de Santa Catarina  http://www.cga.ufsc.br/programas/residuos.htm
Universidade de Brasilia  www.unb.br/resqui

Hazardous waste management programs encourage the minimization of waste in universities and provides incentives to these institutions to reduce the health environmental risks, and at the same time decrease the amount of hazardous waste to be handled, stored and transported, as well as reduce the cost of packaging, transportation, and disposal.

The University of Clenson (http://ehs.clemson.edu) offers an example of a safety and environmental health plan in the campus that applies to all faculty units, staff and students, as well as to all activities undertaken there. This plan includes the following: general safety on campus; accordance with the laws of occupational and environmental health, disaster management, emergency response to hazardous products, air quality in the external and internal environment of the university, management of lead used in the edifications throughout the university, ergonomic plan, plan for prevention, control and measures of chemicals spillage, policies against violence in the workplace; hygiene in the use of chemicals; biosafety manual; risk communications; nanotechnology manual; manual for management disposal of chemical agents; manual for respiratory protection, and control of exposure to blood borne pathogens, industrial hygiene and manual of radiation protection.

An example of pioneering initiatives in this area is the School of Pharmaceutical Sciences of the University of São Paulo that is taking on board the values outlined above on health and environmental quality, having decided to implement an environmental management system to establish a more suitable environmental performance, according to more modern canons.

CONCLUSION
Risk = Hazard (or toxicity) x Exposure

This risk approach allows the intrinsic toxicity of chemical compounds and also their conditions of exposure to be dealt with (Klaassen, 2007). Thus, while advocating the use of substances of lower toxicity, it is also creating a policy of damage prevention for humans and the environment. In the process of creating control over chemical exposure, alternatives to minimize chemical risk are also created. The laws related to minimizing chemical risk are based on maximum permissible or tolerable levels of exposure, the use of preventive measures to minimize exposure, the use of personal protection equipment, and also, measures to control technology and treatment of effluents. Since chemical safety is the opposite of chemical risk, any of the above presented alternatives such as the replacement of a less intrinsically toxic compound, or alteration of exposure conditions are welcome. If low risk products are used, no additional costs will be needed to secure conditions of exposure (Tundo, 2000).

In conclusion, the implementation of constant training of university teachers and students with regard to safety in the use, storage and disposal of dangerous products, is key for all above mentioned procedures of health and management quality to become a reality.

REFERENCES


Basic principles. 1. Environmental impact assessments (EIA) shall be included in project proposals which are submitted to Sida for assessment. Before


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*Correspondence: E. S. Nascimento. Departamento de Análises Clínicas e Toxicológicas, Faculdade de Ciências Farmacêuticas, Universidade de São Paulo. Av. Prof. Lineu Prestes, 580 - 05508-000 - São Paulo - SP, Brasil. E-mail: esnasci@usp.br
generating chemical waste, the researcher should determine how it will be collected and stored and obtain the necessary equipment (containers, labels) in advance. The choice of procedures depends on the type of waste and its final disposition. This section explains how to determine the final disposition of waste, select the appropriate waste container, and store waste in the lab or work area. It also suggests waste minimization strategies. Determining How to Dispose of a Chemical Waste. The final disposition of a chemical waste is determined by the answers to a series of questions: Step