Chemical Waste Management for Laboratories

by

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Content
Introduction ................................................................................................................................................... 3
Definition of waste ........................................................................................................................................ 3
Legislative Framework ................................................................................................................................... 4
Starting a waste management system .......................................................................................................... 5
Chemicals recommended for use in a laboratory .......................................................................................... 6
Examples for substitution of hazardous chemicals ....................................................................................... 7
Classification and Labeling of Chemicals ....................................................................................................... 7
Preparation for the disposal of chemical residues in laboratories ............................................................... 8
Technical possibilities of chemical waste disposal ........................................................................................ 10
Technical possibilities of biological and microbiological waste disposal .................................................... 14
Transport of dangerous goods to their final disposal ................................................................................... 17
Conclusion ................................................................................................................................................... 20
Bibliography ................................................................................................................................................. 20
**Introduction**

Ever since humans have inhabited the earth, they have been confronted with the problem of their waste materials.

Waste materials are substances which are no longer of use. They may be in the form of solids, liquids or gases in a container. Waste materials may also include hazardous residues.

The adequate disposal of residual chemicals is an important factor in the preservation of nature, specifically the protection, of air and water, soil and forests and the preservation of quality of life.

Whilst the disposal of waste is generally regulated by relevant laws, the first priority should always be the prevention of waste. Where prevention is considered not possible, the order of treatment should be reuse, recycling and finally other recovery and disposal methods. The environmentally compatible avoidance and utilization of the waste is always of uppermost importance.

In developing countries however, there are often no specific rules for waste management or instructions about its treatment or elimination.

Suitable disposal facilities, such as high temperature waste incineration plants or controlled landfills for hazardous waste are often lacking with the result that chemical residues are often simply poured into the sink or treated as domestic waste, without considering the possible damage to nature, the environment and the health of the population.

This Manual is primarily intended to help find the best practical and application-oriented solutions for the disposal of their chemical waste.

On the basis of general and specific procedures and examples, it demonstrates the possibilities available to a chemist or person in charge of a chemical laboratory regarding the selection of chemicals and their pretreatment to ensure that no hazardous substances will be freed into the environment.

Definition of *waste* is defined by Wikipedia as unwanted or unusable material or substance which is discarded after primary use, or it is worthless, defective and of no use.

Waste from laboratories and research facilities is divided in special categories, some of which require particular attention and disposal. Waste legislation differentiates waste into non-hazardous and hazardous waste.

**Non-Hazardous Waste:**

*Communal Waste*

Is all solid waste with the exception of infectious, chemical, or radioactive waste. This waste stream can include items such as packaging materials and office supplies. Generally, it can be disposed of in a communal landfill or other such arrangements. Segregation of materials that can be reused or recycled will greatly reduce the impact burden of this waste stream.
**Hazardous Waste:**

*Infectious*
This constitutes discarded material from health-care activities on humans or animals which have the potential of transmitting infectious agents to humans as well as discarded objects or equipment from the diagnosis, treatment and prevention of disease (assessment of health status or identification purposes) that have been in contact with blood and its derivatives (tissues, tissue fluids or excreta) or wastes from infection isolation wards. Sharps items such as syringe needles, scalpels, infusion sets, knives, blades, broken glass etc., whether contaminated or not, should be considered as a subgroup of infectious health-care waste.

*Pharmaceutical*
Pharmaceuticals or materials containing pharmaceuticals, (including expired) and items containing or contaminated with pharmaceuticals (bottles, boxes containers and packaging).

*Biological and microbiological*
Consisting of or containing substances with infectious properties from laboratories, including contaminated bottles and equipment

*Chemical*
Consisting of or containing chemical substances, including laboratory chemicals; film developer; disinfectants (expired or no longer needed), solvents, cleaning agents and others.

*Radioactive*
This includes unused liquids from radiotherapy or laboratory research; contaminated glassware or packages

**Legislative Framework**
Every country should have a legislative framework for chemical waste management. Important are not only suitable laws and regulations, but also methods of their enforcement and control.

Issues to be considered surrounding chemical waste management include transport, procurement, occupational safety, use and disposal of hazardous materials and pollution prevention, all of which can incur significant costs. It is therefore recommended that governmental Ministries develop laws specifying that where possible waste be recycled and reused.

Such a legislation should include

- Responsibility for the use and disposal of a product
- Responsibilities of the producer (take-back obligations)
- Planning responsibility

The user of chemicals must also bear responsibility for his waste products. Therefore it is necessary for the user to develop a waste management system which is in line with the applicable laws in the country. Some countries for example prohibit the incineration of chemical waste.
Starting a waste management system

The most important principles of a waste management system are:

- Waste avoidance
- Waste reduction
- Waste reuse
- Waste disposal (with regard to the safety of the community and the environment)

Working with waste means taking on responsibility.

The producer of waste is responsible for its final disposal, even if he appointed other intermediaries, companies, transporters etc. He must ensure that there are no adverse health and environmental consequences of the waste handling, treatment and disposal activities. Therefore he is obliged to select reliable routes of disposal or implement a project capable of being certified, so that all the intermediate steps are documented. These documents must then be available at all times.

Universities, laboratories and research facilities striving to implement a waste management system are moving towards the achievement of a healthy and safe environment for their employees and communities.

For the implementation of a waste management system in laboratories the following steps are necessary:

1. Formation of a commission from the various departments of the institution
2. Nomination of a person responsible for the waste management system
3. Collection of data in order to assess the present situation by means of a questionnaire (see attachment 1 as an example). The questionnaire should give information about:
   - types of waste expected to be encountered
   - nature of the waste
   - quantity of waste
   - packaging
   - internal transport
   - temporary storage
   - final disposal
4. Analysis of the data from the questionnaire by the commission which, on the basis of this analysis, should formulate recommendations concerning
   - the replacement, where possible, of hazardous substances by products which are not harmful for environment and health are thus easier to dispose of
   - amount of each chemical used
   - packaging of waste chemicals
   - collection of waste chemicals
   - internal transport
   - storage
5. Distribution of responsibilities
6. Developing of special safety guidelines for the laboratory (see attachment 2- model of safety guidelines)
7. Stimulation and training of all employees who are working in this field
8. Regular environmental checks concerning identification and classification of all waste according to the relevant internal directives.
9. Permanent control and comparison of the amount of the remaining waste
10. Permanent documentation of all processes

**Finally a functioning waste management system could form the basis for environmental management system certification according to ISO 14001.**

**Chemicals recommended for use in a laboratory**

Before starting to work with new chemical substances, it is necessary to check, if they are not dangerous for the environment and health, and if they are safely to be eliminated under the existing conditions of the country

1. **Chemicals not hazardous to environment (= biodegradable chemicals)**

   An important element of information regarding the hazardous potential of a chemical to the environment is its water polluting classification. (For examples see attachment 3 water polluting classification)

   To protect water (rivers, seas, ground water, waste water, drinking water), it is necessary to assess and classify pollutants according to their water-hazardous properties. **There is an administrative regulations on Water Hazard Classes:**

   0: No hazard to waters (sometimes without classification)
   1: low hazard to waters
   2: hazardous to waters
   3: severely hazardous to waters

   That means, only substances of classification 0 and 1 are biodegradable and should be preferred. When substance with classification 1 are used, additionally they must be diluted with water 1:10 before being poured into the sink.

   The Globally Harmonized System GHS also gives information about hazards for health and environment

2. **Chemicals not hazardous to health**

   Comprehensive information relating to the properties of a chemical substance and its hazards are contained in its Safety Data Sheet (attachments 4 MSDS)

   Safety data sheets (SDS) or material safety data sheets (MSDS) are important components of product responsibility and are of great importance when considering. These data sheets are intended to provide workers and emergency personnel with procedures for handling or working with that substance in a safe manner, and include physical data (melting point, boiling point, flash point, etc.), toxicity, adverse health effects, first aid measures, reactivity, storage, disposal, protective equipment and spill-handling procedures. SDS formats can differ from country to country depending on the national requirements.
MSDSs are a widely used system for cataloging information on chemicals, chemical compounds and chemical mixtures. Information may include instructions for the safe use and potential hazards associated with a particular material or product. These data sheets should be both existent and accessible wherever chemicals are being used.

**Examples for substitution of hazardous chemicals**
The following chemicals are often used in diverse contexts although they are environmentally hazardous and/or dangerous to health. It is highly important that measures be taken to substitute these chemicals.

**Substances hazardous for health (carcinogenic substances)**
- Benzene may be substituted by toluene, xylene or d-limonene
- Ethidium bromide may be substituted by SYBR Green (Sigma-Aldrich)

**Substances hazardous for environment**
- Trichloroethylene may be substituted by dichloromethane (recyclable)
- Carbon tetrachloride may be substituted by dichloromethane

All substances potentially posing a chemical, health and/or environmental risk must be properly classified and labeled.

**Classification and Labeling of Chemicals**
The Globally Harmonized System of Classification and Labeling of Chemicals (GHS) is an internationally agreed-upon system, instigated in 1992 by the United Nations (but until 2016 not yet fully implemented in many countries). It replaces the numerous national classification and labeling standards, ensuring consistent uniform criteria on a global level. This system provides the infrastructure for all countries to implement a hazard classification and communication system.

**The two major elements of GHS are:**

1. **Classification of the hazards of chemicals according to the GHS rules:**
   - Physical Hazards
   - Health Hazards
   - Environmental Hazards
   - Hazard Communication

2. **Communication of the hazards and precautionary information using Safety Data Sheets and labels:**
   - GHS Label
   - GHS Safety Data Sheet (SDS)
Labels

According to GHS, the product label must contain certain prescribed information which describes the hazards associated with the product. The chemical identity, standardized hazard statements, signal words and symbols should appear on the label according to the classification of that chemical or mixture. In some cases, precautionary statements may also be required.

GHS (Labeling of Chemicals) Pictogram

Preparation for the disposal of chemical residues in laboratories

To eliminate waste from laboratories, it is necessary to gain knowledge about the type of substance in question.

Disposal methods will depend upon the properties of each individual residue. For example, acidic and highly toxic bases may in some cases be neutralized, diluted and discarded.
Never discard a laboratory waste without being certain that the intended disposal method is safe. If there are no government agencies responsible for the collection and disposal of waste from laboratories, it is recommended that waste chemicals be stored in separate standardized containers according to the class of compound.

The special groups for separation of chemicals are:

- Acids, organic and inorganic
- Bases, organic and inorganic
- Halogen-free organic solvents and solutions
- Halogenated organic solvents and organic solutions containing halogens
- Saline solutions with a pH between 6 and 8, organic and inorganic
- Solid organic and inorganic waste chemicals

These should be packaged securely in plastic bottles or boxes or in the original barrels. The containers must be properly labeled in order to eliminate doubt as to the identity of the waste in question. This identification must be clear, standardized with GHS-labels and legible (not handwritten and without chemical formulas).

It is important to coordinate the classification in advance with the authorized waste disposal company if there is one in the vicinity.

Before eliminating chemicals by authorized companies, one should aim at minimizing the generation of waste. Each user must be aware of the impacts that their actions may have on the environment and on health. It is the duty of all to take precautions so that the environmental impact is minimized.

In preparation for the disposal of laboratory waste in a proper manner, containers of suitable type and size must be obtained for collection of each class of waste prior to disposal. Collection containers must be of stable material capable of being well sealed and should be stored in a well ventilated area. Selection of the place of storage will depend upon the materials in question and their risk of explosion. In order to prevent health hazards, chemical waste should only be stored temporarily and disposed of with as little delay as possible.

Some examples:

- **Aqueous liquids**
  Aqueous solutions should be diluted and adjusted to a pH between 5 and 9 to reduce the reactivity of acids or bases before being stored in precisely labeled drums for subsequent disposal. When neutralizing caution should be taken as these chemical reactions can be dangerous (e.g. exothermic).(attachment 5 dangerous chemical reactions)

- **Liquids containing heavy metal salts**
  These generally require special chemical treatment before disposal both to reduce their reactivity and to reduce the volume of waste material. Heavy metals can be precipitated as their insoluble chlorides, sulfides and carbonates by treatment with hydrochloric acid, hydrogen or ammonium sulfide and ammonium carbonate respectively. These precipitates can then be
disposed of in appropriate containers. (see attachment 6 for examples of precipitation and encapsulation)

- Special metals
  Mercury should be avoided or substituted if there is no company available which offers recycling. It must be stored in a separate container. Mercury from broken thermometers can be detoxified as mercury amalgam
  Some valuable metals such as silver or copper can be processed electrolytically and then sold.

- Organic solvents, chlorinated and non-chlorinated
  Laboratories working with non-chlorinated organic solvents (esters, alcohols, aldehydes and light hydrocarbons) should store these liquids in suitable containers and send them for recycling to authorized companies. These companies must be licensed with certification in accordance with current environmental regulations.
  Chlorinated solvents should be avoided where possible or stored separately since in case of fire they can produce highly toxic products e.g. dioxins.

**Technical possibilities of chemical waste disposal**
Chemical waste products may be disposed of in the following ways:

- Chemical or physical treatment
- Disposal of solid waste on a monitored landfill
- Incineration

**Chemical or physical treatment of chemicals**
The purpose of treating hazardous waste is to either convert it into non-hazardous material or to stabilize or encapsulate the waste in such a way that it will not leak or represent a hazard when it is finally disposed of in the environment. Stabilization or encapsulating techniques are particularly necessary for inorganic wastes, in particular those containing toxic heavy metals.

Treatment methods can be generally classified as chemical and/or physical

**Chemical methods**

- **Neutralization**
  Waste acid is neutralized with an alkali e.g. sulfuric acid with sodium carbonate:
  \[ \text{H}_2\text{SO}_4 + \text{Na}_2\text{CO}_3 \rightarrow \text{Na}_2\text{SO}_4 + \text{H}_2\text{O} + \text{CO}_2 \uparrow \]

- **Oxidation / Hydrolysis**
  Using common oxidizing substances such as hydrogen peroxide:
  \[ \text{NaCN} + \text{H}_2\text{O}_2 \rightarrow \text{NaOCN} + \text{H}_2\text{O} \]
  \[ 2 \text{NaOCN} + 3 \text{H}_2\text{O} \rightarrow \text{Na}_2\text{CO}_3 + \text{CO}_2 \uparrow + 2 \text{NH}_3 \uparrow \]

  Or sodium hypochlorite:
  \[ 2 \text{NaCN} + 5 \text{NaOCl} + 2 \text{NaOH} \rightarrow 2 \text{Na}_2\text{CO}_3 + 5 \text{NaCl} + \text{H}_2\text{O} + \text{N}_2 \uparrow \]
• Reduction
   Particularly inorganic substances may be converted to a less mobile and toxic form by reduction, e.g. reducing Cr(VI) to Cr(III) by the use of ferrous(II)-sulfate:
   \[ K_2Cr_2O_7 + 7 H_2SO_4 + 6 FeSO_4 \rightarrow Cr_2(SO_4)_3 + K_2SO_4 + 3 Fe_2(SO_4)_3 \]

• Precipitation
   Hazardous soluble heavy metal salts may be precipitated as their insoluble salts and subsequently safely disposed of in a landfill e.g. precipitation of cadmium as its hydroxide by the use of sodium hydroxide:
   \[ CdSO_4(aq) + 2NaOH \rightarrow Cd(OH)_2(s) + Na_2SO_4 \]

*(See attachment 7 for more examples about chemical treatment)*

Physical methods

• Encapsulation
   This involves immobilization and stabilization of hazardous materials by their incorporation within a solid matrix.
   Thus, for example, 25% cement or lime plus sulfur (for better hardening) are added to the thickened solution to form a uniform paste. \( Ca_2SiO_4 \) is formed, which binds all heavy metals as \( CaMeSiO_4 \). After four weeks heavy metals can no longer be leached out by water. The presence of large amounts of organic substances can however impair this process.

Disposal of solid waste on a monitored landfill
Solid inorganic chemical waste can usually be deposited on a specially monitored landfill. This procedure is however prohibited for reactive and flammable residues due to the danger of soil contamination by the unchanged residues should there be leakage through the protective membrane. Such substances must therefore be disposed of in appropriate containers according to their chemical properties, impenetrable by air and water, in order to minimize the risk of chemical reaction.

Requirement for landfills
The disposal of chemical solid waste is carried out in properly designed and operated landfills. Controlled quantities of specific hazardous wastes may be broken down to nonhazardous substances, immobilized or adequately diluted by the physical, chemical and biochemical processes which naturally occur in landfills which accept predominantly normal municipal refuse. Such a practice is known as co-disposal and requires a degree of management and monitoring usually encountered only in modern regional landfills.

Types of landfills
Most refuse dumps or landfills can be classified into different categories according to the manner in which they have been designed, located and installed, particularly with regard to leachate management. Besides landfills for domestic waste, there are special types of landfill specifically for hazardous waste: These are authorized landfills with monitoring system.
The location of a landfill for hazardous waste depends on technical criteria and should be decided upon only after assessment of its possible environmental impact.

A further type of landfill is that dedicated solely to the containment of hazardous waste over a long period of time. The hazardous waste may or may not be encapsulated before deposition in the landfill. Extra precautions must be taken to prevent leaching from rainfall and to isolate and contain the wastes. This is done by the incorporation of at least a double membrane. At least one of these liners membranes should be a thick synthetic material, such as high density polyethylene (HDPE), which must be chemically resistant to the retained waste. Drains underneath and around the landfill are to be installed in order to monitor the integrity of containment over time.

Special experience is needed when dealing with materials of doubtful identity or with products from syntheses. Long term underground storage with the possibility of later retrieval should also be considered when such materials are deposited in a landfill.

Care must be taken to ensure that the amount and type of hazardous waste is compatible with the waste previously dumped in the landfill and the resultant processes occurring.

**Incineration**

**High Temperature Incineration**

Incineration is the controlled combustion process used to degrade organic substances. As an example, the exhaustive combustion of the simple hydrocarbon heptane is described by the chemical reaction:

\[ C_7H_{16} + 11 \text{O}_2 \rightarrow 7 \text{CO}_2 + 8 \text{H}_2\text{O} \]

In practice, complete combustion is difficult if not impossible to achieve, but for hazardous waste, destruction or removal in excess of 99.99% is necessary for the process to be generally acceptable.

- **Combustion Parameters**
  Incinerators for the treatment of hazardous waste must be carefully designed and operated if they are to achieve the efficiency of destruction required. Combustion of organics occurs in two stages. In the primary stage, volatile matter is driven off, leaving the remainder to burn to ash. The volatiles are combusted in the secondary stage. Incinerators are designed accordingly. High temperatures are required- for most wastes 800-900 °C is sufficient but for materials with high thermal stability, e.g. halogenated compounds, temperatures of 1100 °C or higher may be necessary. Moreover, this temperature must be maintained for a sufficient period of time to allow complete combustion and sufficient air must be provided to supply the oxygen required for combustion. The air should be introduced in such a way that the turbulence necessary to achieve effective mixing with the combustible materials is achieved.

- **Toxic Combustion Byproducts.**
  Public concern relating to the use of incineration for the disposal of hazardous waste relates particularly to emissions of potentially toxic combustion products from the process.

  Simple examples of such emissions are:
  - Carbon monoxide and hydrocarbons resulting from incomplete combustion of organic waste.
— Sulfur dioxide resulting from the combustion of wastes containing sulfur.
— Hydrogen chloride from the combustion of wastes containing chlorinated compounds
— Heavy metal fumes and particulates resulting from the incineration of organic wastes contaminated with heavy metals such as lead, cadmium or chromium.

1. Polychlorinated dibenzo dioxins and dibenzo furanes

Polychlorinated dibenzodioxins (PCDDs) and the corresponding dibenzofuranes (PCDFs) are often associated with emissions from waste incinerators. Emissions of hazardous pollutants resulting from incomplete combustion of wastes can be minimized by good incinerator design and efficient combustion practices. In the case of PCDDs and PCDFs, rapid reduction of flue gas temperature immediately following combustion is necessary to prevent the re-formation of these compounds. Gas scrubbers using alkaline liquors are used to control acid gases such as sulfur dioxide and hydrochloric acid.

Particulate emissions, including heavy metals in the form of particles, are controlled by the use of bag filters (both wet and dry), high energy scrubbers or, less frequently, electrostatic precipitators. High temperature incineration of organic hazardous wastes in properly designed and operating facilities can be performed in a manner that complies with standards regulating the emission of gaseous pollutants, such as those enacted in North America and the European Community.

Potential Environmental Impacts:

The ash resulting from incineration of hazardous waste may itself possess hazardous properties. This is likely to be the case when toxic heavy metals are present in the waste. The ash must therefore be constantly monitored and may require stabilization and encapsulation before disposal to landfills.

Aqueous waste materials are formed when water is used for temperature reduction of gases and/or when wet scrubbers are used for emission control. Some recycling may be possible after cooling and chemical treatment, but a quantity of liquid effluent will still need to be disposed of after appropriate treatment.

**Incineration in cement factories**

Furnaces used for the production of cement are designed and operated such that the parameters also required for the destruction of hazardous waste, as described above, are achieved. In many countries cement companies are officially licensed to perform the destruction of certain hazardous wastes.

Incineration in cement furnaces is particularly suitable for oily residues, solvents and residues with high calorific content and for all chemicals which are compatible with cement. It is inappropriate for organic halogens and phosphates as well as for reactive compounds.

Incineration in cement factories not only utilizes the calorific energy of the chemicals combusted but also the alkaline particulates present help to neutralize acidic combustion products.
Technical possibilities of biological and microbiological waste disposal

This type of waste is generated in all research, teaching, and environmental laboratories in which biological or microbiological agents are handled.

The different possibilities for treatment of biological and microbiological waste are:

1. Chemical disinfection / decontamination:
2. Autoclaving
3. Kill Tanks / Effluent Decontamination System (EDS)
4. Incineration

1. Chemical disinfection / decontamination:

This is defined as the reduction of many or all disease causing microorganisms in or on a surface or object, so that they are no longer considered to be capable of transmitting disease.

Disinfection requires the addition of suitable chemicals:

Advantages:

• its simplicity
• it is relatively cheap
• disinfectants are widely available

Disadvantages:

• the chemicals used are themselves hazardous substances
• for proper disinfection the correct concentrations and contact time must be followed
• the waste volume is not reduced
• the process generates hazardous effluents which need to be further treated

(Attachment 8: examples of chemical disinfection)

2. Autoclaving

This means the complete destruction or elimination of the pathogenic, reproductive or infective potential of a biological agent by use of saturated steam under pressure (e.g. 103 kPa, 121°C, 20 min)

Advantages:

• Autoclaved waste becomes safe household refuse
• Providing the correct program is applied, all biological agents are killed
• Ecologically sound technology
• Low operating costs

Disadvantages:

• Moderate up to high installation costs
• Unsuitable for materials also containing chemical or radioactive wastes
• The appearance of the waste does not change (anatomical waste, body parts!)
• The weight of the waste does not change
• Slow and time consuming

3. Kill Tanks / Effluent Decontamination System (EDS)

Kill Tanks are used to treat large amounts of (potentially) biologically contaminated waste water from large scale production plants, facilities for the keeping of animals, research laboratories etc.

Potentially biologically contaminated effluents can be treated in different ways: by chemical or thermal methods or a combination of both and/or pressure.

• **Chemical Treatment:** oxidizing agents such as sodium hypochlorite and peroxyacetic acid are generally used. The oxidizing agent is mixed directly with the effluent to achieve a specified concentration, held for a specified contact time and, if required, also heated.

**Advantages**

• Broad-spectrum antimicrobial activity
• Quite simple in terms of equipment and process requirements

**Disadvantages**

• Specific construction materials required (corrosion!)
• Needs adequate mixing
• Solids in the system are not penetrated
• Harmful biocides or their reaction products are involved. These must be detoxified before their discharge into the environment
• Possible release of harmful vapors or chemicals in the work area or the environment

• **Thermal-based treatment:** combination of heat and pressure

**Advantages:**

• Broad-spectrum antimicrobial activity
• Solids in the effluent can also be sterilized

**Disadvantages**

• Very expensive!
• Steam supply is needed
• High energy consumption (if not combined with heat recovery system)
• High temperatures increase corrosion
• Pressure vessels
• **Thermo-chemical treatment**: combination of heat and chemicals without pressure

**Advantages**

- Broad-spectrum antimicrobial activity
- No pressure vessel is needed
- Tank corrosion is reduced
- In comparison to thermal systems only 10% energy consumption
- More flexible (in case of unreliable steam supply)

**Disadvantages**

- Use of chemicals with all consequences (neutralization, vapor etc.)
- Adequate temperature and chemical combination has to be determined for each new step in the work

There are mainly two types of design for liquid waste decontamination: a batch operated process or a continuous process.

**Batch sterilization**

This is the most commonly used method. A system consisting of two or more tanks is installed, with one tank collecting waste from the facility. When this tank has reached a preset filling level, sterilization will begin and the second tank is switched to collecting further waste. Decontamination can be done either by chemical or thermal treatment. Upon completion of sterilization, the first tank is emptied and remains idle until tank 2 is full and sterilization begins. In this way, collection of effluent is not interrupted by the sterilization process.

**Continuous sterilization**

This is similar to batch and again often consists of two tanks. Contaminated waste is stored until a preset level is reached in the tank. This then triggers the start of the process. Once the process starts it will continue until the level of liquid in the tank is lowered to a shut down level or the flow of contaminated effluent from the facility stops. A continuous process is a heat-based flow-through system.

**4. Incineration** (see page 12)

Thermal inactivation at high temperatures (200°C to over 1000°C)

**Advantages**

- All microorganisms are completely destroyed
- All types of organic waste (liquid and solid) are destroyed
- Waste volume and weight are significantly reduced (> 95%)
- Large quantities of waste can be treated
- The waste is not recognizable
Disadvantages

- High construction costs
- Relatively high operating and maintenance costs
- Unsuitable for chemical and radioactive waste
- Incineration unsuitable for PVC or other wastes containing halogens

Transport of dangerous goods to their final disposal

Finally, after recycling, reuse and/or reduction in volume the residual material must be brought to an external disposal location. For this transport, there are international regulations with global validity.

UN Recommendations on the Transport of Dangerous Goods

The recommendations are contained in the UN Model Regulations prepared by the Committee of Experts on the Transport of Dangerous Goods of the United Nations Economic and Social Council (ECOSOC). They cover the transport of dangerous goods by all modes of transport except by bulk tanker. They are not obligatory or legally binding for individual countries, but have gained a wide degree of international acceptance: they form the basis of several international agreements and many national laws.

"Dangerous goods" (also known as "hazardous materials") may be pure chemical substances or mixtures. The transport hazards are grouped into nine classes, which may be subdivided into divisions and/or packing groups. The most common dangerous goods are assigned a UN number, a four digit code which identifies it internationally: less common substances are transported under generic codes such as "UN1993: flammable liquid, not otherwise specified".

ADR (formally, the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR)) is a United Nations treaty, originally drafted in 1957, that governs transnational transport of hazardous materials. "ADR" is derived from the French name for the treaty: Accord européen relatif au transport international des marchandises dangereuses par route. The latest version is from 1 January 2015. As of 2013, 48 states are party to ADR.

The agreement itself is brief and simple, and its most important article is article 2. This states that with the exception of certain exceptionally dangerous materials, hazardous materials may in general be transported internationally in wheeled vehicles, provided that two sets of conditions be met:

- Annex A regulates the merchandise involved, notably their packaging and labels.
- Annex B regulates the construction, equipment, and use of vehicles for the transport of hazardous materials.

The appendices consist of nine chapters, with the following contents

1. General provisions: terminology, general requirements
Classification: classification of dangerous goods

Dangerous Goods List sorted by UN number, with references to specific requirements set in chapters 3 to 9; special provisions and exemptions related to dangerous goods packed in limited quantities

Packaging and tank provisions

Consignment procedures, labeling, and marking of containers and vehicles.

Construction and testing of packages, intermediate bulk containers (IBCs), large package, and tanks

Conditions of carriage, loading, unloading, and handling

Vehicle crews, equipment, operation, and documentation

Construction and approval of vehicles

Hazard classes

The classes of dangerous goods according to ADR are the following:

Class 1 Explosive substances and articles
Class 2 Gases, including compressed gases, liquefied gases and dissolved gases and vapors under pressure
  - Flammable gases
  - Non-flammable and non-toxic gases
  - Toxic gases (e.g. chlorine, phosgene)

Class 3 Flammable liquids
Class 4.1 Flammable solids, self-reactive substances, and solid desensitized explosives
Class 4.2 Substances liable to spontaneous combustion
Class 4.3 Substances which, in contact with water, emit flammable gases
Class 5.1 Oxidizing substances
Class 5.2 Organic peroxides
Class 6.1 Toxic substances
Class 6.2 Infectious substances
Class 7 Radioactive material
Class 8 Corrosive substances
Class 9 Miscellaneous dangerous substances and articles

Each entry in the different classes has been assigned a 4 digit UN number. It is not usually possible to deduce the hazard class(es) of a substance from its UN number: they have to be looked up in a table. An exception to this are Class 1 substances whose UN number will always begin with a 0. See List of UN numbers

ADR pictograms

ADR pictograms for chemical hazards are based on GHS Transport pictograms and Non-GHS transport pictograms
1-Explosives  2.1-Flammable gases  2.2-Non-toxic/ non-flammable gases  2.3 Poison gases

3-Flammable liquids  4.1 Flammable solids  4.2 Spontaneously  4.3 Dangerous combustible when wet

5.1-Oxidizers  5.2-Organic peroxides  6.1-Poison  6.2-Infectious substances

7-Radioactive  8-Corrosive  9-Miscellaneous dangerous substances
Conclusion

The instructions of this Manual should indicate what the best practice is and will be of general validity.

In summary:

Before commencing work with hazardous substances in a laboratory located in a developing country where legislation regarding waste disposal is lacking, it is important to obtain information about the following:

- Biodegradability and hazard to health of the substances planned to be involved in the work
- Methods of their inactivation and treatment in the laboratory
- Technical facilities for the possible disposal options in the country in question

It was decided not to include laws and regulations in this manual, since these frequently change and each country has its own specific legislation.

The Author:

Dr. Roswitha Meyer, born 1940 in Verden/Aller, Germany, studied pharmacy at the Eberhard Karls University of Tübingen and received her PhD there in 1988 in organic chemistry. From 1969 to 2004 she worked as a research employee, first at the hospital pharmacy of the University Hospital and later at the Eberhard Karls University of Tübingen. Since 1976, she was responsible for the whole University and the University Hospital as "Commissioner for chemical hazardous wastes and hazardous materials transportation".

In 1993, she became a pharmacy specialist in ecology and toxicology. In 2004, she founded the environmental consulting company "MEYRO Consulting". Since 1989, she is involved in projects for clinical and chemical waste management, organized by GIZ, PTB and the SES (Senior Expert Service), mainly in Brazil, but also in India, Chile, Paraguay, Venezuela, Honduras, Thailand, Ghana, Kenya, Tanzania, and Ethiopia.

Since 2007, Dr. Meyer regularly organizes scientific seminars in Tübingen and Braunschweig for participants from Brazil, mainly from Rio/Niteroi

Bibliography


Sources

Dias da Silveira, Djalma, Meyer, Roswitha UFSM Santa Maria/RG  Project of Senior Expert Service  Bonn 2010-2015


THE MANAGEMENT OF HAZARDOUS WASTE  Written by Norman Thom, School of Environmental and Marine Sciences, University of Auckland, with summary box by John Packe (.access to source, jan. 2016)

Meyer, Roswitha. (Training documents about chemical waste management, transport of dangerous goods, safety management in laboratories, projects of PTB, Braunschweig, in East Africa and Ethiopia ( from 2009-2015)

Schibel, Jörg M. “Knowledge, Development and Transfer of Best Practice on Chemical and Biological Waste Management in South East Asia.” Nay Pyi Taw Mianmar. 12 June2014.


**Attachments 1-8**