



Chemical Waste Management for Laboratories

Dr. Roswitha Meyer



On behalf of the German federal government, the Physikalisch-Technische Bundesanstalt (PTB) promotes the improvement of framework conditions for economic activity, thereby supporting the establishment of metrology.

On behalf of



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Table of contents

Introduction	5
Legislative framework	6
Starting a waste management system	6
Chemicals recommended for use in a laboratory	7
Examples for substitutions of hazardous chemicals	8
Classification and Labelling of Chemicals	8
Preparation for the disposal of chemical residues in laboratories	10
Technical possibilities for chemical waste disposal	11
Chemical or physical treatment of chemicals	11
Disposal of solid waste in a monitored landfill	12
Incineration	12
Technical possibilities for biological and microbiological waste disposal	14
1. Chemical disinfection/decontamination:	14
2. Autoclaving	14
3. Kill tanks/Effluent Decontamination System (EDS)	14
4. Incineration (see page 12)	15
Transport of dangerous goods to their final disposal sites	16
Conclusion	18
References	18

Appendix 1: Survey on chemical waste management in laboratories	19
Appendix 2: A model of safety guidelines	20
Appendix 3: Water pollution classification	23
Appendix 4: Material Safety Data Sheet	24
Appendix 5: Dangerous chemical reactions	39
Appendix 6: Examples of precipitation	41
Appendix 7: Examples of chemical treatment	42
Appendix 8: Chemical disinfection – categories of decontaminants and their properties	44

Introduction

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

Waste materials are substances which are no longer of use. Waste is defined by Wikipedia as an “unwanted or unusable material” or “substance which is discarded after primary use, or it is worthless, defective and of no 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 nature preservation, 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 human health.

This manual is primarily intended to help responsible parties identify the most practical and application-oriented solutions for the disposal of chemical waste in developing countries. 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 pre-treatment to ensure that no hazardous substances will be freed into the environment.

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

Non-hazardous waste:

Communal Waste

All solid waste with the exception of infectious, chemical or radioactive waste is considered communal 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. Separating materials that can be reused or recycled greatly reduces the impact burden of this waste stream.

Hazardous waste:

Infectious

Infectious waste constitutes discarded material from medical or veterinary activities 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 (such as 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 quarantine wards. Sharp 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 healthcare waste.

Pharmaceutical

This type of waste is made up of pharmaceuticals or materials containing pharmaceuticals (including expired medications) and items containing or contaminated with pharmaceuticals (bottles, boxes, containers and packaging).

Biological and microbiological

These types of hazardous waste contain substances with infectious properties from laboratories, including contaminated bottles and equipment.

Chemical

Chemical waste consists of or contains chemical substances, including laboratory chemicals, film developer, disinfectants (expired or no longer in use), solvents, cleaning agents and others types.

Radioactive

This waste 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. Not only suitable laws and regulations are important, but also methods for their enforcement and control must be stated.

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 should be recycled and/or reused.

This 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/her waste products. Therefore it is necessary for the user to develop a waste management system which is in line with the applicable laws of 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/she appointed or hired other intermediaries, companies, transporters, etc. He/she must ensure that there are no adverse health and environmental consequences of waste handling, treatment and disposal activities. Therefore he/she 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.

The following steps are necessary for the **implementation** of a waste management system in laboratories:

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 Appendix 1 as an example). The **questionnaire** should provide information about:
 - the types of waste expected to be encountered
 - the nature of the waste
 - the quantity of waste
 - packaging
 - internal transport
 - temporary storage
 - final disposal
4. The commission should analyze the data from the questionnaire and use it to formulate recommendations concerning the following:
 - the replacement, where possible, of hazardous substances with products which are not harmful for the environment and health and are thus easier to dispose of

- the amount of each chemical used
 - the packaging of waste chemicals
 - the collection of waste chemicals
 - internal transport
 - storage
5. Responsibilities should be delegated
 6. Developing special safety guidelines for the laboratory (see a model of safety guidelines in Appendix 2)
 7. Sensitivity to waste and training of all employees who are working in this field
 8. Regular environmental checks concerning the identification and classification of all waste according to the relevant internal directives
 9. Constant control and comparison of the amounts of the remaining waste
 10. Constant documentation of all processes

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

Chemicals recommended for use in a laboratory

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

1. Chemicals which are not hazardous to the environment (biodegradable chemicals)

An important element of information regarding the hazardous potential of a chemical to the environment is its water pollution classification. (See Appendix 3 for examples of water pollution classifications.)

To protect water (rivers, seas, ground water, waste water or drinking water), it is necessary to assess and classify pollutants according to their water-hazardous properties. **There are administrative regulations for each of the German 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

Substances from classifications 0 and 1 are biodegradable and should be preferred. When substances with classification 1 are used, they must additionally be diluted with water (1:10) before being poured into the sink.

The Globally Harmonized System (GHS) also provides information about hazards for health and the environment.

2. Chemicals which are not hazardous to health

Comprehensive information relating to the properties of a chemical substance and its hazards are contained in its Safety Data Sheet (see Appendix 4 for an example of butane's material safety data sheet [MSDS]).

Safety data sheets (SDS) or material safety data sheets (MSDS) are important components of product responsibility and are of great importance. 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 for the chemicals. SDS formats can differ from country to country depending on the national requirements.

MSDSs are a widely used system for cataloguing 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 available and accessible wherever chemicals are being used.

Examples for substitutions 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 which are hazardous to health (carcinogenic substances)

- Benzene may be substituted with toluene, xylene or d-limonene
- Ethidium bromide may be substituted with SYBR Green (Sigma-Aldrich)

Substances which are hazardous to the environment

- Trichloroethylene may be substituted with dichloromethane (because it is recyclable)
- Carbon tetrachloride may be substituted with dichloromethane

All substances which potentially pose a chemical, health and/or environmental risk must be properly classified and labelled.

Classification and Labelling of Chemicals

The Globally Harmonized System of Classification and Labelling of Chemicals (GHS) is an internationally agreed-upon system, instigated in 1992 by the United Nations (but up to 2016 not yet fully implemented in many countries). It replaces the numerous national classification and labelling 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:

1. The classification of chemical hazards according to GHS rules:
 - Physical hazards
 - Health hazards
 - Environmental hazards
 - Hazard communication

2. The 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.

HCS Pictograms and Hazards










<p>Health Hazard</p>  <ul style="list-style-type: none"> • Carcinogen • Mutagenicity • Reproductive Toxicity • Respiratory Sensitizer • Target Organ Toxicity • Aspiration Toxicity 	<p>Flame</p>  <ul style="list-style-type: none"> • Flammables • Pyrophorics • Self-Heating • Emits Flammable Gas • Self-Reactives • Organic Peroxides 	<p>Exclamation Mark</p>  <ul style="list-style-type: none"> • Irritant (skin and eye) • Skin Sensitizer • Acute Toxicity (harmful) • Narcotic Effects • Respiratory Tract Irritant • Hazardous to Ozone Layer (Non-Mandatory)
<p>Gas Cylinder</p>  <ul style="list-style-type: none"> • Gases Under Pressure 	<p>Corrosion</p>  <ul style="list-style-type: none"> • Skin Corrosion/Burns • Eye Damage • Corrosive to Metals 	<p>Exploding Bomb</p>  <ul style="list-style-type: none"> • Explosives • Self-Reactives • Organic Peroxides
<p>Flame Over Circle</p>  <ul style="list-style-type: none"> • Oxidizers 	<p>Environment (Non-Mandatory)</p>  <ul style="list-style-type: none"> • Aquatic Toxicity 	<p>Skull and Crossbones</p>  <ul style="list-style-type: none"> • Acute Toxicity (fatal or toxic)

Figure 1: Labelling of Chemicals Pictogram

<h1 style="text-align: center;">ACETONITRILE</h1> <p>EN: Highly flammable liquid and vapour. Toxic in contact with skin. Keep away from heat/sparks/open flames/hot surfaces. – No smoking. Keep container tightly closed. Ground/bond container and receiving equipment. Use explosion-proof electrical/ventilating/lighting/... equipment. Use only non-sparking tools. Take precautionary measures against static discharge. Wear protective gloves/protective clothing/eye protection/face protection. IF ON SKIN: Wash with plenty of soap and water IF ON SKIN (or hair): Remove/Take off immediately all. Rinse skin with water/shower. Call a POISON CENTER or doctor if you feel unwell. Remove/Take off immediately all. Wash contaminated clothing before in case of fire. Use ... for extinction. Store in a well-ventilated place. Keep cool. Store locked up.</p> <p>FR: Liquide et vapeurs très inflammables. Toxique par contact cutané. Tenir à l'écart de la chaleur/des étincelles/des flammes nues/des surfaces chaudes. – Ne pas fumer. Maintenir le récipient fermé de manière étanche. Mise à la terre/liaison équipotentielle du récipient et du matériel de réception. Utiliser du matériel électrique/de ventilation/d'éclairage/... / antidéflagrant. Ne pas utiliser d'outils produisant des étincelles. Prendre des mesures de précaution contre les décharges électrostatiques. Porter des gants de protection/des vêtements de protection/un équipement de protection des yeux/du visage. EN CAS DE CONTACT AVEC LA PEAU: Laver abondamment à l'eau et au ... EN CAS DE CONTACT AVEC LA PEAU (/ Enlever immédiatement les vêtements Rincer la peau à l'eau / douche Appeler un CENTRE d'ANTIDROGUE ou le médecin. Laver les vêtements contaminés à l'eau et au ... pour l'extinction. Stocker dans un endroit bien ventilé. Tenir au frais. Garder sous clé.</p> <p>DE: Flüssigkeit und Dampf leicht entzündbar. Giftig bei Hautkontakt. Von Hitze/Funken/offener Flamme/heißen Oberflächen fern halten. Nicht rauchen. Behälter dicht verschlossen halten. Behälter und zu befüllende Anlage erden. Explosionsgeschützte elektrische Betriebsmittel/Lichtungsanlagen/ Beleuchtung/... verwenden. Nur funkenfreies Werkzeug verwenden. Maßnahmen gegen elektrostatische Aufladungen treffen. Schutzhandschuhe/Schutzkleidung/Augenschutz/Gesichtsschutz tragen. BEI BERÜHRUNG MIT DER HAUT: Mit viel Wasser und Seife waschen. BEI BERÜHRUNG MIT DER HAUT (oder dem Haar): Alle kontaminierten Kleidungsstücke sofort ausziehen. Kontaminierte Kleidung waschen. Im Brandfall: ... zum Löschen verwenden. An einem gut belüfteten Ort aufbewahren.</p> <p>BO: Силно запалима течност и пари. Токсичен при контакт с кожата. Да се пази от топлина/искри/открит огън/от горещи повърхности. – Тютюнопушенето забранено. Съхранява се в добре вентилирано помещение. Използват се само инструменти, които не произвеждат искри. Вземат се предпазни мерки срещу освобождаване на статично електричество. Използват се предпазни ръкавици/предпазна облекло/предпазни очила/предпазна маска за лице. ПРИ КОНТАКТ С КОЖАТА: Измийте обилно със сапун и вода. ПРИ КОНТАКТ С КОЖАТА (или косата): Незабавно сваляте цялото облекло. Обилно измийте кожата с водата/сапун. При неразположение се обадете в токсикологичен център. В случай на пожар: Използвайте ... за гаснене. Да се съхранява на добре вентилирано място. Да се държи на ключ. Да се съхранява под ключ.</p> <p>ACETONITRILE</p> <p>C2H3N</p> <p>ACE / acetic acid nitrile / cyanomethane / ethane nitrile / ethyl nitrile / methane carbonitrile / methyl cyanide</p> <p>6000</p> <p>4 03685 40012 5</p> <p>Adresse des Unternehmens</p>	<h1 style="text-align: center;">ACETONITRILE</h1> <p>C2H3N</p> <p>ACE / acetic acid nitrile / cyanomethane / ethane nitrile / ethyl nitrile / methane carbonitrile / methyl cyanide</p> <p>6000</p> <p>4 03685 40012 5</p> <p>Adresse des Unternehmens</p>
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Figure 2: Acetonitrile Label

Preparation for the disposal of chemical residues in laboratories

To eliminate waste from laboratories, it is necessary to gain information 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 (safely) discarded.

Never discard laboratory waste without being certain that the intended disposal method is safe. If no government agencies are 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.

These are the special groups for the separation of chemicals:

- 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, both organic and inorganic
- Solid organic and inorganic waste chemicals

These should be securely packaged in plastic bottles, boxes or in the original barrels. The containers must be properly labelled 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 (neither handwritten nor 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 disposing of chemicals by authorized companies, one should aim at minimizing the production of waste. Each user must be aware of the impacts that his/her actions may have on the environment and on human

health. It is the duty of all to take precautions so that the environmental impact is minimized.

In preparation for the proper disposal of laboratory waste, containers of suitable types and sizes must be obtained for collection of each class of waste prior to disposal.

Collection containers must be made 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.

Examples of chemical waste disposal requirements:

- 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 labelled drums for subsequent disposal. When neutralizing, caution should be taken as these chemical reactions can be dangerous (e.g. exothermic). (See Appendix 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 Appendix 6 for examples of precipitation.)
- 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 contain-

ers and send them to authorized companies for recycling. These companies must be licensed in accordance with current environmental regulations.

- Chlorinated solvents should be avoided where possible or stored separately since they can produce highly toxic products, e.g. dioxins, in case of fire.

Technical possibilities for chemical waste disposal

Chemical waste products may be disposed of in the following ways:

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

Chemical or physical treatment of chemicals

The purpose of treating hazardous waste is to 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.

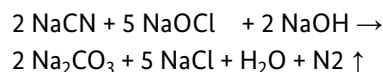
The treatment methods can be generally classified as chemical and/or physical:

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:
$$\text{NaCN} + \text{H}_2\text{O}_2 \rightarrow \text{NaOCN} + \text{H}_2\text{O} \uparrow$$

$$2 \text{NaOCN} + 3 \text{H}_2\text{O} \rightarrow \text{Na}_2\text{CO}_3 + \text{CO}_2 \uparrow + 2 \text{NH}_3 \uparrow$$

Or sodium hypochlorite:



■ 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:
$$\text{K}_2\text{Cr}_2\text{O}_7 + 7 \text{H}_2\text{SO}_4 + 6 \text{FeSO}_4 \rightarrow \text{Cr}_2(\text{SO}_4)_3 + \text{K}_2\text{SO}_4 + 3 \text{Fe}_2(\text{SO}_4)_3$$

■ Precipitation

Hazardous soluble heavy metal salts may be precipitated as their insoluble salts and subsequently safely disposed of in a landfill, e.g. the precipitation of cadmium as its hydroxide by the use of sodium hydroxide:
$$\text{CdSO}_4 (\text{aq}) + 2\text{NaOH} \rightarrow \text{Cd}(\text{OH})_2 (\text{s}) + \text{Na}_2\text{SO}_4$$

(See Appendix 6 for more examples of precipitation and Appendix 7 for more examples of chemical treatment.)

Physical methods

■ Encapsulation

This involves immobilization and stabilization of hazardous materials by their incorporation within a solid matrix. 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 in a monitored landfill

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

Requirements 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 into non-hazardous substances, immobilized or adequately diluted by the physical, chemical and biochemical processes which naturally occur in landfills accepting predominantly normal municipal refuse. Such a practice is known as co-disposal and requires a certain 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 landfills specifically designed for hazardous waste: These are authorized landfills with monitoring systems.

The location of a landfill for hazardous waste depends on technical criteria and should be decided upon only after assessment of its potential environmental impact.

A further type of landfill is that which is 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 waste. This is done by incorporating at least a double membrane. At least one of these liner membranes should be a thick synthetic material, such as high density polyethylene (HDPE), which must be chemically resistant to the retained waste. Drains under-

neath and around the landfill are to be installed in order to monitor the integrity of containment over time.

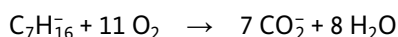
Special experience is needed when dealing with materials of doubtful identity or with products from syntheses. Long term underground storage with the possibility of later retrieval should also be considered when such materials are deposited in a landfill.

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 resulting 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:



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 organic materials occurs in two stages. In the primary stage, volatile matter is driven off, leaving the remainder to burn to ash. The volatile matter is 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, these temperatures must be maintained for a sufficient time period 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 by-products

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

■ 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 temperatures 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 the 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 in such a way that the parameters required for the destruction of hazardous waste, as described above, are also 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 furnaces not only utilizes the calorific energy of the chemicals combusted but also the alkaline particulates present help neutralize acidic combustion products.

Technical possibilities for 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 four 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:

Disinfection 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 treatment with suitable chemicals:

Advantages

- Its simplicity
- It is relatively cheap
- Disinfectants are widely available

Disadvantages

- The chemicals used are also hazardous substances
- For proper disinfection, the correct concentrations and contact time must be followed
- The volume of waste is not reduced
- The process generates hazardous effluents which need to be further treated. (See Appendix 8, “Chemical disinfection – categories of decontaminants and their properties”.)

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 programme is applied, all biological agents are killed
- Ecologically sound technology
- Low operating costs

Disadvantages

- Moderate to high installation costs
- Unsuitable for materials which also contain chemical or radioactive wastes
- The appearance of the waste does not change (anatomical waste, e.g. 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 animal holding, research laboratories etc.

Potentially biologically contaminated effluents can be treated in different ways: by chemical or thermal treatment 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
- Simple in terms of equipment and process requirements

Disadvantages

- Specific construction materials required (corrosion!)
- Requires 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 vapours or chemicals into 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 a 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, vapour etc.)
- Adequate temperature and chemical combination has to be determined for each new step in the process

There are mainly two types of designs for liquid waste decontamination strategies: 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 at a time. When this tank has reached a pre-set filling level, sterilization will begin and the second tank is switched on to begin collecting further waste. Decontamination can be performed 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. This way, effluent collection is not interrupted by the sterilization process.

Continuous sterilization

This is similar to batch sterilization and, again, often consists of two tanks. Contaminated waste is stored until a pre-set 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 shutdown 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 14)

Incineration is 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 volumes and weight are significantly reduced (> 95 %)
- Large quantities of waste can be treated
- The waste is not recognizable post incineration

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 sites

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 that are globally valid.

UN Recommendations on the Transport of Dangerous Goods

These 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, some of which are further separated 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) is a United Nations treaty, originally drafted in 1957, that governs the 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 parties 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 are met. These conditions are described in the ADR annexes:

- 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 and contain the following:

- 1 General provisions: terminology, general requirements
- 2 Classification: classification of dangerous goods
- 3 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
- 4 Packaging and tank provisions
- 5 Consignment procedures, labelling and marking of containers and vehicles.
- 6 Construction and testing of packages, intermediate bulk containers (IBCs), large packages, and tanks
- 7 Conditions of carriage, loading, unloading and handling
- 8 Vehicle crews, equipment, operation and documentation
- 9 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. They are divided into three categories:
 - 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 four-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 is Class 1 substances, whose UN numbers always begin with a 0.

ADR pictograms

The 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 have indicated what the best practices are for chemical waste management and are 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 used in the work
- Methods for substance 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.

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. Starting in 1976, she was responsible for the whole University and the University Hospital as the “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, mostly from Rio/Niteroi.

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(Appendices 1–8)

Appendix 1:

Survey on chemical waste management in laboratories

Institution:

I General information:

- 1) Which chemical waste management strategies are in use? If there is relevant legislation (a „waste act“), please enclose the text in English.
- 2) Name and address of the surveillance authority:
- 3) Do facilities for waste management exist? (Are there companies capable of treating or removing hazardous wastes? Landfills?)

II Special information on the laboratory

- 1) Name and address of laboratory:
- 2) Laboratory supervisor (name, e-mail address and telephone number):
- 3) Do operational instructions for the management of chemical substances/chemical waste (equivalent to the German “Ordinance on Hazardous Substances”) exist in the laboratory?
- 4) How and where is chemical waste stored?
- 5) Please list **all** chemical substances you use in your laboratory.
(Feel free to add more lines.)

Full name of chemical substance (no abbreviations or chemical formulas)	Total quantity present (e.g. number of vessels)	Is this substance still necessary (Yes or no)	If the substance is still necessary, which quantity is needed (on average) per month?	Are there any ways to pre-treat the substance before disposal? Which?

Appendix 2:

A model of safety guidelines

LABORATORY REGULATIONS FOR THE ROOMS OF THE _____

(institute)

1. Areas of Application

The laboratory regulations are applicable to all laboratory rooms of _____. The regulations must be familiar to all users of the laboratory rooms and signed (contact your supervisor and the laboratory technician). New workers will be instructed by their supervisor.

2. General Fundamentals

Fundamental to the laboratory regulations are the Operational Regulations for the Handling of Solid and Liquid Hazardous Substances, which are posted in Room _____.

3. Emergency Telephone Numbers

Fire Department _____
Emergency Doctor _____
Accident Doctor _____

4. Safety Equipment

First aid lockers: position _____
Eye wash: position _____
Fume cabinets: position _____
Fire blankets: position _____
Emergency showers: position _____
Fire extinguishers: position _____

All laboratory users must make themselves familiar with the locations of safety equipment before beginning work.

5. Accidents

In the case of an accident, first aid should be administered immediately and, if necessary, the Emergency Doctor called. The following person(s) must be notified:

_____ (Tel: _____)
(supervisor)

6. Hours of Room Usage

The laboratory rooms are only to be used during working hours. Outside working hours, usage is permitted only with the approval of the laboratory supervisor (special regulations are to be followed and a member of the institute must be within calling distance). No visitors are to be allowed into the laboratory rooms since no liability exists for persons not employed by the institute.

7. Eye Protection

Safety glasses must always be worn in the laboratory.

8. Respiratory Protection

For all work involving harmful steam, gas or dust, the appropriate respiratory protection apparatus must be worn (dust masks, breathing masks). Alternatively, the fume cabinets must be used.

9. Physical Protection

Laboratory clothing must be made of a material that will not melt when heat is applied (e.g. cotton).

Laboratory coats are to be worn.

Contaminated items of clothing with must be immediately taken off and aired.

Appropriate gloves (rubber gloves, fire resistant gloves) must be worn when handling corrosive or very hot (oven) materials.

10. Fire Protection

On the outbreak of fire, the supply of gas, electricity and air should be immediately cut off. Smaller fires may be suffocated by blanketing with a wet towel. Larger fires must be fought using fire extinguishers.

Burning clothes may be extinguished with the help of the emergency showers, or better, using a fire blanket

thrown over the person (and under certain conditions by rolling on the floor).

11. Supply Connections (Gas, Water, Electricity)

All laboratory users are required to familiarize themselves with the mechanisms to turn off the water, gas and electricity.

12. Dealing with Materials which are Health Hazards

The applicable operational regulations, which are posted in _____, provide information on dealing with materials which can be hazardous to health. Directions that are important for laboratory work must be understood before the work begins and be followed.

13. Storage and Labelling

Potent poisons must be securely locked away (position: _____). All containers in which chemicals are stored must be clearly and durably labelled.

14. Pipetting by Mouth must be Completely Avoided

Pipettes with pipette balls must be used when dispensing liquids. Care must be taken when diluting concentrated acids with water: Concentrated acids should be poured in a thin stream into stirred water. Alkali hydroxides are to be added in small amounts to stirred water.

Substances which produce volatile, poisonous or otherwise hazardous gases when mixed with water, acid, alkali or other materials should not be poured down drains.

15. Large Amounts of Flammable Materials

Large amounts of flammable materials are only to be stored in the chemical store specified for this purpose (position: _____), in unbreakable containers in the security cabinets provided. Storage of these materials in corridors, stairways or hallways is forbidden.

16. Working with Flammable Materials

The heating of flammable materials without constant supervision is totally forbidden. When working with flammable material in thin walled containers, these must be protected against breakage or placed during use in safety basins filled with non-burnable adsorption material, e.g. dry sand and large enough to trap the complete contents of the containers.

17. Heavy Loads

Safety shoes must be worn in the areas where heavy experimental apparatus is lifted and moved. The laboratory technician involved must familiarize himself/herself with the operational instructions for the use of the lifting equipment.

18. High Pressure

Safety glasses are to be worn in the vicinity of apparatus under high pressure. High pressure apparatus must be fitted with excess pressure release valves, the dimensions of which are adequate to guarantee protection from bursting.

19. Laboratory-specific Instructions

Additional laboratory-specific instructions are to be followed.

20. Behaviour in Work Areas

Laboratory rooms are work rooms and not common rooms. People are not permitted to stay in the laboratories if they are not working there. Each user is responsible for cleanliness, orderliness and his/her own safety. Individual access to a work area does not rule out the possibility that several others may be using the same work area at the same time. In such cases, mutual consideration, restriction to the necessary workspace and observation of cleanliness and orderliness are especially important.

Prior to the use of equipment, it is absolutely necessary that the appropriate operating instructions are understood, or introductory guidance obtained. Damaged or defective equipment should be immediately reported.

After the completion of work, the work area and apparatus should be clean and the chemicals used must be returned to the chemical cabinet.

Before leaving the laboratory room, the windows should be closed, gas and water taps should be shut off, electronic equipment excepting permanently active (e.g. drying cabinets, refrigerators and freezers) must be turned off, the lights switched off and the laboratory locked.

Disposal of chemical waste resulting from the work is to be performed by the user according to the regulations. (See the procedures for the collection of special waste in _____). Questions should be directed to the laboratory personnel.

21. Limitations

Should legal regulations or items in other individual regulations be above those laid down in these laboratory

rules, the affected parts of the laboratory rules become invalid; the remaining part of the laboratory rules remain unaffected.

City name, _____

Signature of the manager _____

Check List:

- **Emergency Telephone Number:**
- **Emergency Doctor:**
- **Fire Department:**
- **Ambulance service:**

- Safety cabinet:
- Fume cabinet:
- Emergency shower:
- Eye wash:
- Alarm system:
- Fire extinguisher:
- Fire blanket:
- Dust mask:
- First aid lockers:
- Dry sand (non-flammable material):
- Chemical adsorption material:
- Laboratory clothing
- Eye protection and rubber gloves
- If possible, thermometer without mercury:
- Laboratory regulations about hazardous materials (MSDS):

Appendix 3:

Water pollution classification

List of some chemical substances and their German classification of water pollution (WGK)

acetone	0	potassium alum	0
active charcoal	0	potassium dichromate	3
ammonia	2	potassium ferrocyanide	1
ammonia ferrisulphate	2	potassium permanganate	2
aniline	2	resorcin	1
chromosulfuric acid	3	sodium acetate	1
di-sodium phosphate	1	sodium bisulfite	1
ethanol	0	sodium citrate	0
ferric chloride	2	sodium hydroxide	1
formaldehyde	2	sodium phosphate	1
giemsa solution	2	sodium sulfate	0
glacial acetic acid	1	sodium thiosulfate	0
hexamine (hexamethylene-tetramine)	1	sulfuric acid	1
hydrochloric acid	1	xylene	2
iodine	2		
lithium carbonate	1		
mercuric oxide	3		
methanol	1		
osmium tetroxide	3		
oxalic acid	1		
paraffin (for histology)	0		
periodic acid	2		
phenol (carbolic acid)	2		

WGK

- 1 0 – generally non-polluting substance
- 0 1 – slightly polluting substance
- 2 2 – polluting substance
- 2 3 – highly polluting substance

Appendix 4: Material Safety Data Sheet



Safety Data Sheet according to Regulation (EC) No. 1907/2006 (REACH) as amended
Material Name: Methanol **SDS ID: Methanol-EU**

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1 Product identifier

Material Name

Methanol

Synonyms

Methyl alcohol, wood alcohol, methyl hydroxide

Chemical Family

Alcohols

Substance Registration Number(s)

01-2119433307-44-0031

EC Number

200-659-6

CAS Number

67-56-1

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses

Industrial use: Distribution of substance. Formulation & (re)packing of substances and mixtures. Use as a fuel. Use in cleaning agents. Use as laboratory reagent. Water treatment chemicals, wastewater. Professional use: Use as a fuel. Use in cleaning agents. Use as laboratory reagent. Use in oil and gas field drilling and production operations. Consumer use: Use in cleaning agents.

Uses advised against

None identified

1.3 Details of the supplier of the safety data sheet

Methanex Europe SA/NV I
 Waterloo Office Park - Building P
 Drève Richelle 161 - box 31
 B-1410 Waterloo
 Belgium
 Phone: +(32) 2 352 06 70
 E-mail: reach@methanex.com
 Fax: +(32) 2 352 06 99

1.4 Emergency telephone number

+44 (0) 1235 239 670 (24h/7d)

SECTION 2: Hazards identification

2.1 Classification of the substance or mixture

Classification according to Regulation (EC) No 1272/2008 [CLP]

Flammable Liquids - Category 2

Acute Toxicity - Oral - Category 3

Acute Toxicity - Dermal - Category 3

Acute Toxicity - Inhalation - Vapor - Category 3

Specific Target Organ Toxicity - Single Exposure - Category 1 (optic nerve, central nervous system)

2.2 Label elements

Labeling according to Regulation (EC) No. 1272/2008 [CLP]

Hazard symbols



Safety Data Sheet according to Regulation (EC) No. 1907/2006 (REACH) as amended

Material Name: Methanol

SDS ID: Methanol-EU



Signal word

Danger

Hazard statements

H225 Highly flammable liquid and vapor.

H301 Toxic if swallowed.

H311 Toxic in contact with skin.

H331 Toxic if inhaled.

H370 Causes damage to organs.

Precautionary statements

Prevention

P233 Keep container tightly closed.

P210 Keep away from heat, hot surfaces, sparks, open flames and other ignition sources. No smoking.

P240 Ground/Bond container and receiving equipment.

P241 Use explosion-proof electrical/ventilating/lighting equipment.

P243 Take action to prevent static discharges.

P242 Use non-sparking tools.

P271 Use only outdoors or in a well-ventilated area.

P280 Wear protective gloves/protective clothing/eye protection/face protection.

P260 Do not breathe dust/fume/gas/mist/vapors/spray.

P264 Wash thoroughly after handling.

P270 Do not eat, drink or smoke when using this product.

Response

P370+P378 In case of fire: Use appropriate media to extinguish.

P308+P311 If exposed or concerned: Call a POISON CENTER or doctor/physician.

P304+P340 IF INHALED: Remove person to fresh air and keep comfortable for breathing.

P303+P361+P353 IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower.

P361+P364 Take off immediately all contaminated clothing and wash it before reuse.

P301+P310 IF SWALLOWED: Immediately call a POISON CENTER/doctor.

P330 Rinse mouth.

P311 Call a POISON CENTER or doctor.

P321 Specific treatment (see label).

Storage

P403+P233 Store in a well-ventilated place. Keep container tightly closed.

P235 Keep cool.

P405 Store locked up.

Disposal

P501 Dispose of contents/container in accordance with local/regional/national/international regulations.

Statement of Unknown Toxicity

0% of the mixture consists of ingredient(s) of unknown acute toxicity.

2.3 Other hazards

If swallowed there is a risk of blindness.



Safety Data Sheet according to Regulation (EC) No. 1907/2006 (REACH) as amended
Material Name: Methanol **SDS ID: Methanol-EU**

SECTION 3: Composition / information on ingredients

CAS EC No Registration No	Component Name Synonyms	1272/2008 (CLP)	Percent
67-56-1 200-659-6 01-2119433307-44-0031	Methanol	Flam. Liq. 2 - H225 Acute Tox. (Oral) 3 - H301 Acute Tox. (Vapour) 3 - H331 Acute Tox. (Gas) 3 - H331 Acute Tox. (Dermal) 3 - H311 Acute Tox. (Dust/Mist) 3 - H331 STOT SE 1 - H370 STOT SE 2 - H371	100

Component Related Regulatory Information

Specific concentration limit (SCL): STOT SE 1; H370: $C \geq 10\%$, STOT SE 2; H371: $3\% \leq C < 10\%$

SECTION 4: First aid measures

4.1 Description of first aid measures

Inhalation

IF INHALED: Remove person to fresh air and keep comfortable for breathing. Administer oxygen if breathing is difficult. Immediately call a POISON CENTER or doctor.

Skin

IF ON SKIN (or hair): Remove/take off immediately all contaminated clothing. Wash with plenty of water. Immediately call a POISON CENTER or doctor. Wash contaminated clothing before reuse.

Eyes

IF IN EYES: Immediately flush eyes with water for at least 15 minutes, while holding eyelids open. Remove contact lenses, if present and easy to do. Continue rinsing. If irritation develops and persists, get medical attention.

Ingestion

IF SWALLOWED: Rinse mouth. Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Seek medical attention immediately.

4.2 Most Important Symptoms/Effects

Acute

Poison. May be fatal if swallowed. If swallowed there is a risk of blindness. Toxic if swallowed, in contact with skin or if inhaled. Ingestion causes nausea, weakness and central nervous system effects, headache, vomiting, dizziness, symptoms of drunkenness. Coma and death due to respiratory failure may follow severe exposures: Medical treatment necessary. A latent period of several hours may occur between exposure and the onset of symptoms.

Delayed

Causes damage to organs through prolonged or repeated exposure.

4.3 Indication of Immediate Medical Attention and Special Treatment

Treat symptomatically and supportively. The severity of symptoms depends upon the length and concentration of the exposure. If ingested, get immediate medical attention. Antidote: Fomepizole enhances elimination of metabolic formic acid. Antidote should be administered by qualified medical personnel.

Note to Physicians

Treat symptomatically. The severity of outcome following methanol ingestion may be more related to the time between ingestion and treatment, rather than the amount ingested. Therefore, there is a need for rapid treatment of any ingestion exposure. Call a POISON CENTER.



Safety Data Sheet according to Regulation (EC) No. 1907/2006 (REACH) as amended
Material Name: Methanol **SDS ID: Methanol-EU**

SECTION 5: Firefighting measures

5.1 Extinguishing media

Suitable extinguishing media

Carbon dioxide, regular dry powder, water spray, alcohol resistant foam, sand. Use water spray to cool fire fire-exposed containers. Water will not cool methanol below its flash point. Collect spillage.

Unsuitable Extinguishing Media

Do not use high-pressure water streams.

5.2 Special hazards arising from the substance or mixture

Highly flammable liquid and vapor. Mixtures >20% methanol with water: flammable. May form explosive mixture with air. Vapors are heavier than air and may travel along the ground to some distant source of ignition and flash back. Containers may rupture or explode if exposed to heat. Dangerous gases may accumulate in confined spaces.

Toxic.

Combustion

Releases toxic gases, vapors. Carbon monoxide, carbon dioxide, formaldehyde.

5.3 Advice for firefighters

Methanol: Burns with invisible flame. Flame may not be visible in daylight. Cool containers with water spray until well after the fire is out.

Fire Fighting Measures

Do not allow run-off from fire-fighting to enter drains or water courses. Keep unnecessary people away, isolate hazard area and deny entry.

Protective Equipment and Precautions for Firefighters

Wear full protective firefighting gear including self-contained breathing apparatus (SCBA) for protection against possible exposure.

SECTION 6: Accidental release measures

6.1 Personal precautions, protective equipment and emergency procedures

Wear appropriate personal protective equipment. Move container from fire area if it can be done without risk. Do not breathe gas/fume/vapor/spray. Avoid contact with eyes and skin.

6.2 Environmental precautions

Avoid release to the environment. Biodegradable at low concentrations. Soluble in water. When released, this product is expected to evaporate. Contact authorities in the event of pollution of soil and aquatic environment or discharge into drains. Dispose in accordance with all applicable federal, state/regional and local laws and regulations.

6.3 Methods and Materials for Containment and Cleaning Up

Wear suitable protective clothing and eye/face protection. Stop leak if this can be done without risk. Do not touch or walk through spilled material. Evacuate the area promptly and keep upwind of the spilled material. Ensure adequate ventilation. Avoid inhalation of mists or vapors. Avoid contact with eyes, skin and clothing. Remove all sources of ignition. Avoid friction, static electricity and sparks. Small spills: Absorb with sand or other non-combustible material. Use non-sparking tools and equipment. Collect spilled material in appropriate container for disposal. Clean contaminated surface thoroughly. Large spills: Contain the released material by diking the containment area with absorbent. A vapor suppressing foam may be used to reduce vapors. Collect spilled material in appropriate container for reuse or disposal.

6.4 Reference to other sections

Safe handling: see section 7. Personal protection equipment (PPE): see section 8. Disposal: see section 13.



Safety Data Sheet according to Regulation (EC) No. 1907/2006 (REACH) as amended
Material Name: Methanol **SDS ID: Methanol-EU**

SECTION 7: Handling and storage

7.1 Precautions for safe handling

Use in a well ventilated area. Wear personal protective clothing and equipment, see Section 8. Eliminate all sources of ignition. No smoking. Do not enter confined spaces unless adequately ventilated. Clean up contamination/spills as soon as they occur. Decontaminate personnel, spill area and all tools and equipment. Use explosion-proof equipment. Use good industrial hygiene practices in handling this material. Wash hands and other exposed areas with mild soap and water before eating, drinking or smoking and leaving work. Empty containers may contain residual amounts of this product; therefore, empty containers should be handled with care. Do not breathe vapor.

7.2 Conditions for safe storage, including any incompatibilities

Store in a well-ventilated place. Keep container tightly closed.

Keep cool.

Store locked up.

Keep/Store only in original container. Keep out of direct sunlight, and away from heat, water, and incompatible materials. Ground/Bond container and receiving equipment. Provide appropriate fire extinguishers and spill cleanup equipment in or near storage area. Store at room temperature. Store in a dry area. Store in fireproof room. Keep unauthorized personnel away.

Incompatible Materials

Lead, Aluminum, zinc, oxidizing agents, strong acids, strong bases, polyethylene, PVC (Polyvinyl chloride), nitrile

SECTION 8: Exposure controls/personal protection

8.1 Control parameters

Component Exposure Limits

Methanol	67-56-1
EU (IOELV):	200 ppm TWA ; 260 mg/m ³ TWA
	Possibility of significant uptake through the skin
ACGIH:	200 ppm TWA
	250 ppm STEL
Austria:	200 ppm TWA [TMW] ; 260 mg/m ³ TWA [TMW]
	800 ppm STEL [KZW] 4 X 15 min ; 1040 mg/m ³ STEL [KZW] 4 X 15 min
	skin notation
Belgium:	200 ppm TWA ; 266 mg/m ³ TWA
	250 ppm STEL ; 333 mg/m ³ STEL
	Skin
Bulgaria	200 ppm TWA ; 260 mg/m ³ TWA
	Skin notation
Croatia	200 ppm TWA [GVI]; 260 mg/m ³ TWA [GVI]



Safety Data Sheet according to Regulation (EC) No. 1907/2006 (REACH) as amended

Material Name: Methanol**SDS ID: Methanol-EU**

	Skin Notation
Cyprus	200 ppm TWA ; 260 mg/m3 TWA
	Skin-potential for cutaneous absorption
Czech Republic	250 mg/m3 TWA
	1000 mg/m3 Ceiling
	Potential for cutaneous absorption
Denmark.	200 ppm TWA ; 260 mg/m3 TWA
	Potential for cutaneous absorption
Estonia	200 ppm TWA ; 260 mg/m3 TWA
	250 ppm STEL ; 350 mg/m3 STEL
	Skin notation
Finland:	200 ppm TWA ; 270 mg/m3 TWA
	250 ppm STEL ; 330 mg/m3 STEL
	Potential for cutaneous absorption
France:	200 ppm TWA [VME] (restrictive limit); 260 mg/m3 TWA [VME] (restrictive limit)
	1000 ppm STEL [VLCT]; 1300 mg/m3 STEL [VLCT]
	Risk of cutaneous absorption
Germany (TRGS):	200 ppm TWA AGW (The risk of damage to the embryo or fetus can be excluded when AGW and BGW values are observed) exposure factor 4 ; 270 mg/m3 TWA AGW (The risk of damage to the embryo or fetus can be excluded when AGW and BGW values are observed) exposure factor 4
	skin notation
	skin notation
Germany (DFG):	200 ppm TWA MAK ; 270 mg/m3 TWA MAK
	800 ppm Peak ; 1080 mg/m3 Peak
	skin notation
Greece:	200 ppm TWA ; 260 mg/m3 TWA
	250 ppm STEL ; 325 mg/m3 STEL



Safety Data Sheet according to Regulation (EC) No. 1907/2006 (REACH) as amended
Material Name: Methanol **SDS ID: Methanol-EU**

	skin - potential for cutaneous absorption
Hungary	260 mg/m ³ TWA [AK]
	potential for cutaneous absorption
Ireland:	200 ppm TWA ; 260 mg/m ³ TWA
	600 ppm STEL (calculated) ; 780 mg/m ³ STEL (calculated)
	Potential for cutaneous absorption
Italy:	200 ppm TWA Media Ponderata nel Tempo ; 260 mg/m ³ TWA Media Ponderata nel Tempo
	skin - potential for cutaneous absorption
	200 ppm TWA ; 262 mg/m ³ TWA
	Skin - potential for cutaneous absorption
Latvia	200 ppm TWA ; 260 mg/m ³ TWA
	skin - potential for cutaneous exposure
Lithuania	200 ppm TWA [IPRD]; 260 mg/m ³ TWA [IPRD]
	Skin notation
Luxembourg	200 ppm TWA; 260 mg/m ³ TWA
Malta	200 ppm TWA ; 260 mg/m ³ TWA
	possibility of significant uptake through the skin
Netherlands:	133 mg/m ³ TWA ; 100 ppm TWA
	skin notation
Poland	100 mg/m ³ TWA [NDS]
Portugal:	200 ppm TWA [VLE-MP] (indicative limit value) ; 260 mg/m ³ TWA [VLE-MP] (indicative limit value)
	250 ppm STEL [VLE-CD
	skin - potential for cutaneous exposure (indicative limit value)
Romania	200 ppm TWA ; 260 mg/m ³ TWA
	200 ppm TWA ; 260 mg/m ³ TWA
Slovak Republic	200 ppm TWA ; 260 mg/m ³ TWA



Safety Data Sheet according to Regulation (EC) No. 1907/2006 (REACH) as amended

Material Name: Methanol

SDS ID: Methanol-EU

	Potential for cutaneous absorption
Slovenia	200 ppm TWA ; 260 mg/m ³ TWA
Spain:	200 ppm TWA [VLA-ED] (indicative limit value); 266 mg/m ³ TWA [VLA-ED] (indicative limit value)
	skin - potential for cutaneous exposure
Sweden:	200 ppm LLV ; 250 mg/m ³ LLV
	250 ppm Indicative STLV ; 350 mg/m ³ Indicative STLV
	Skin notation
United Kingdom:	200 ppm TWA ; 266 mg/m ³ TWA
	250 ppm STEL ; 333 mg/m ³ STEL
	Potential for cutaneous absorption

Component Biological Exposure Limits

Methanol	67-56-1
ACGIH:	15 mg/L Medium: urine Time: end of shift Parameter: Methanol (background, nonspecific)
Czech Republic	15 mg/L Medium: urine Time: end of shift Parameter: Methanol (background, nonspecific)

Derived No Effect Levels (DNELs)

Methanol	67-56-1
DNEL/DMEL (Workers)	
Acute - systemic effects, dermal	40 mg/kg bw/day
Acute - systemic effects, inhalation	260 mg/m ³
Acute - local effects, dermal	not quantifiable
Acute - local effects, inhalation	260 mg/m ³
Long-term - systemic effects, dermal	40 mg/kg bw/day
Long-term - systemic effects, inhalation	260 mg/m ³
Long-term - local effects, dermal	not quantifiable
Long-term - local effects, inhalation	260 mg/m ³
DNEL/DMEL (General population)	



Safety Data Sheet according to Regulation (EC) No. 1907/2006 (REACH) as amended
Material Name: Methanol **SDS ID: Methanol-EU**

Acute - systemic effects, dermal	8 mg/kg bw/day
Acute - systemic effects, inhalation	50 mg/m³
Acute - systemic effects, oral	8 mg/kg bw/day
Acute - local effects, dermal	not quantifiable
Acute - local effects, inhalation	50 mg/m³
Long-term - systemic effects, dermal	8 mg/kg bw/day
Long-term - systemic effects, inhalation	50 mg/m³
Long-term - systemic effects, oral	8 mg/kg bw/day
Long-term - local effects, dermal	not quantifiable
Long-term - local effects, inhalation	50 mg/m³

Predicted No Effect Concentrations (PNECs)

PNEC (Water)	
PNEC aqua (freshwater)	154 mg/l
PNEC aqua (marine water)	15.4 mg/l
PNEC aqua (intermittent releases)	1540 mg/L
PNEC (Sediment)	
PNEC sediment (freshwater)	570.4 mg/l
PNEC (Soil)	
PNEC soil	23.5 mg/kg.w.
PNEC sewage treatment plant	
PNEC stp	100 mg/L

8.2 Exposure Controls

Engineering controls

Provide adequate local exhaust ventilation to maintain worker exposure below exposure limits. Use explosion-proof electrical/ventilating/lighting equipment. Handle substance within a closed system. Ground/Bond container and receiving equipment. Maintain eye wash fountain and quick-drench shower in work area.

Eye/face protection

Use eye protection according to EN 166, designed to protect against liquid splashes.

Skin Protection

Wear appropriate chemical resistant clothing (EN ISO 6529).

Respiratory Protection



Safety Data Sheet according to Regulation (EC) No. 1907/2006 (REACH) as amended
Material Name: Methanol **SDS ID: Methanol-EU**

Any supplied-air respirator with a full face piece that is operated in a pressure-demand or other positive-pressure mode (EN 137). Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator.

Glove Recommendations

Wear suitable gloves tested to (EN 374), butyl rubber.

SECTION 9: Physical and chemical properties

9.1 Information on basic physical and chemical properties

Appearance	clear	Physical State	liquid
Odor	alcohol odor	Color	colorless
Odor Threshold	4.2 - 5960 ppm	pH	Not applicable
Melting Point	-97.8 °C	Boiling Point	64.7 °C
Boiling Point Range	Not available	Freezing point	-97.6 °C
Evaporation Rate	4.1 (butyl acetate = 1)	Flammability (solid, gas)	Not applicable
Autoignition Temperature	464 °C	Flash Point	11 °C
Lower Explosive Limit	5.5 %	Decomposition temperature	Not available
Upper Explosive Limit	36.5 %	Vapor Pressure	12.8 kPa (@ 20 °C)
Vapor Density (air=1)	1.1 (@ 20 °C)	Specific Gravity (water=1)	792 kg/m ³
Water Solubility	Not available	Partition coefficient: n-octanol/water	0.82
Viscosity	0.8 cP (25 °C, dynamic)	Solubility (Other)	Not available
Density	0.791 - 0.793 at 20 °C	VOC	100 %
Molecular Weight	32.04 (g/mol)	Critical Temperature	239.4 °C
Oxidising properties	Not oxidising	Explosive properties	Vapors may form explosive mixtures with air

Solvent Miscibility

Miscible

Miscible with water.



Safety Data Sheet according to Regulation (EC) No. 1907/2006 (REACH) as amended
Material Name: Methanol **SDS ID: Methanol-EU**

SECTION 10: Stability and reactivity

10.1 Reactivity

Containers may rupture or explode if exposed to heat.

10.2 Chemical stability

Stable under normal conditions of use. In use, may form flammable/explosive vapor-air mixture. Product is hygroscopic.

10.3 Possibility of hazardous reactions

Will not polymerize.

10.4 Conditions to avoid

Avoid heat, flames, sparks and other sources of ignition. Containers may rupture or explode if exposed to heat.

10.5 Incompatible materials

Lead, Aluminum, zinc, oxidizing agents, strong acids, strong bases, polyethylene, PVC (Polyvinyl chloride), nitrile

10.6 Hazardous decomposition products

Heat, carbon monoxide, carbon dioxide, flammable gases, formaldehyde

SECTION 11: Toxicological information

11.1 Information on toxicological effects

Acute and Chronic Toxicity

Poison. May be fatal if swallowed. If swallowed there is a risk of blindness. Toxic if swallowed, in contact with skin or if inhaled.

Component Analysis - LD50/LC50

The components of this material have been reviewed in various sources and the following selected endpoints are published:

Methanol (67-56-1)

Oral LD50 Rat 5600 mg/kg

Dermal LD50 Rabbit 15800 mg/kg

Inhalation LC50 Rat 64000 ppm 4 h

Product Toxicity Data

Acute Toxicity Estimate

Dermal	300 mg/kg
Inhalation - Vapor	3 mg/L
Oral	100 mg/kg

Irritation/Corrosivity Data

May cause irritation to eyes, skin and respiratory tract.

Respiratory Sensitization

No data available.

Dermal Sensitization

No data available.

Germ Cell Mutagenicity

No data available.

Component Carcinogenicity

None of this product's components are listed by IARC or DFG.

Reproductive toxicity

No data available.

Specific Target Organ Toxicity - Single Exposure

optic nerve, central nervous system



Safety Data Sheet according to Regulation (EC) No. 1907/2006 (REACH) as amended

Material Name: Methanol

SDS ID: Methanol-EU

Specific Target Organ Toxicity - Repeated Exposure

No target organs identified.

Aspiration hazard

No data available.

SECTION 12: Ecological information

12.1 Toxicity

Avoid release to the environment.

Component Analysis - Aquatic Toxicity

Methanol	67-56-1
Fish:	LC50 96 h Pimephales promelas 28200 mg/L [flow-through]; LC50 96 h Pimephales promelas >100 mg/L [static]; LC50 96 h Oncorhynchus mykiss 19500 - 20700 mg/L [flow-through]; LC50 96 h Oncorhynchus mykiss 18 - 20 mL/L [static]; LC50 96 h Lepomis macrochirus 13500 - 17600 mg/L [flow-through]
Algae:	EC50 72 hr Selenastrum capricornutum 22000 mg/l
Invertebrate:	EC50 48 hr Daphnia >10000 mg/l

12.2 Persistence and degradability

Rapidly degradable.

12.3 Bioaccumulative potential

No indication of bioaccumulation potential.

12.4 Mobility in soil

Mobile

Bioconcentration factor (BCF)

BCF: < 10

12.5 Results of PBT and vPvB assessment

Not fulfilling PBT and vPvB criteria.

SECTION 13: Disposal considerations

13.1 Waste treatment methods

Waste disposal according to directive 2008/98/EC, covering waste and dangerous waste. Incineration is the preferred disposal method.

Waste codes/waste designations according to LoW: EWC-code: 07 01 04*

Empty product containers may contain product residue. Recycle if possible.

Prevent entry into sewers, drains, ditches, underground or confined spaces and waterways.

Dispose in accordance with all applicable federal, state/regional and local laws and regulations.

SECTION 14: Transport information

		ADR	RID	ICAO	IATA	ADN	IMDG
14.1	UN Number	UN1230	UN1230	UN1230	UN1230	UN1230	UN1230



Safety Data Sheet according to Regulation (EC) No. 1907/2006 (REACH) as amended
Material Name: Methanol **SDS ID: Methanol-EU**

14.2	UN Proper Shipping Name	METHANOL	METHANOL	METHANOL	METHANOL	METHANOL	METHANOL
14.3	Transport Hazard Class(es)	3 Risks: 6.1	3 Risks: 6.1	3 Risks: 6.1	3 Risks: 6.1	3 Risks: 6.1	3 Risks: 6.1
14.4	Packing Group	II	II	II	II	II	II
14.5	Environmental Hazards	--	--	--	--	--	--
14.6	Special Precautions For User	--	--	--	--	--	--
14.7	Transport in Bulk According to Annex II of MARPOL and the IBC Code	--	--	--	--	--	--
14.8	Additional information	ADR Tunnel Code Restrictions: D/E	--	--	--	--	--

Component Marine Pollutants (IMDG)

Not regulated as dangerous goods.

International Bulk Chemical Code

This material contains one or more of the following chemicals required by the IBC Code to be identified as dangerous chemicals in bulk.

Methanol	67-56-1
IBC Code:	Category Y

SECTION 15: Regulatory information

15.1 Safety, health and environmental regulations/legislation specific for the substance or mixture**EU - REACH (1907/2006) - Annex XIV List of Substances Subject to Authorization**

No components of this material are listed.

EU - REACH (1907/2006) - Article 59(1) Candidate List of Substances Subject to Authorization

No components of this material are listed.

EU - REACH (1907/2006) - Annex XVII Restrictions of Certain Dangerous Substances, Mixtures and Articles

No components of this material are listed.

EU - Substances Depleting the Ozone layer (1005/2009)

No components of this material are listed



Safety Data Sheet according to Regulation (EC) No. 1907/2006 (REACH) as amended

Material Name: Methanol

SDS ID: Methanol-EU

EU - Persistent Organic Pollutants (850/2004)

No components of this material are listed

EU - Export and Import Restrictions (689/2008) - Chemicals and Articles Subject to Export Ban

No components of this material are listed

EU - Seveso III Directive (2012/18/EU) - Qualifying Quantities of Dangerous Substances

No components of this material are listed

EU - Plant Protection Products (1107/2009/EC)

No components of this material are listed

EU - Biocides (528/2012/EU)

No components of this material are listed

EU - Water Framework Directive (2000/60/EC) - amended by Directive 2008/105/EC

No components of this material are listed

EU - Limitation of Emissions of Volatile Organic Compounds Due to the Use of Organic Solvents in Certain Activities and Installations (1999/13/EC)

No components of this material are listed

EU Detergent Regulation 648/2004/EC

No components of this material are listed

Germany Regulations

Germany Water Classification - Product

hazard class 2 - hazard to waters

Germany Water Classification - Component

Methanol (67-56-1)

ID Number 145, hazard class 2 - hazard to waters

Denmark Regulations

Methanol	67-56-1
	Solvents
	Properties of concern with regard to the List of hazardous substances

Component Analysis - Inventory

Methanol (67-56-1)

US	CA	EU	AU	PH	JP - ENCS	JP - ISHL	KR - KEC/KECL	KR - TCCA	CN	NZ	MX	TW
Yes	DSL	EIN	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes

15.2 Chemical Safety Assessment

For this substance a chemical safety assessment has been carried out.

SECTION 16: Other information

16.1 Indication of changes

New SDS: 14 September 2016

16.2 Key / Legend

ACGIH - American Conference of Governmental Industrial Hygienists; ADR - European Road Transport; AU - Australia; BOD - Biochemical Oxygen Demand; C - Celsius; CA - Canada; CA/MA/MN/NJ/PA - California/Massachusetts/Minnesota/New Jersey/Pennsylvania*; CAS - Chemical Abstracts Service; CFR - Code of Federal Regulations (US); CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act; CLP - Classification, Labelling, and Packaging; CN - China; CPR - Controlled Products Regulations; DFG - Deutsche Forschungsgemeinschaft; DOT - Department of Transportation; DSD - Dangerous Substance Directive;



Safety Data Sheet according to Regulation (EC) No. 1907/2006 (REACH) as amended
Material Name: Methanol **SDS ID: Methanol-EU**

DSL - Domestic Substances List; EC - European Commission; EEC - European Economic Community; EIN - European Inventory of (Existing Commercial Chemical Substances); EINECS - European Inventory of Existing Commercial Chemical Substances; ENCS - Japan Existing and New Chemical Substance Inventory; EPA - Environmental Protection Agency; EU - European Union; F - Fahrenheit; IARC - International Agency for Research on Cancer; IATA - International Air Transport Association; ICAO - International Civil Aviation Organization; IDL - Ingredient Disclosure List; IDLH - Immediately Dangerous to Life and Health; IMDG - International Maritime Dangerous Goods; ISHL - Japan Industrial Safety and Health Law; IUCLID - International Uniform Chemical Information Database; JP - Japan; Kow - Octanol/water partition coefficient; KECI - Korea Existing Chemicals Inventory; KECL - Korea Existing Chemicals List; KR - Korea; LD50/LC50 - Lethal Dose/ Lethal Concentration; LEL - Lower Explosive Limit; LLV - Level Limit Value; LOLI - List Of Lists™ - ChemADVISOR's Regulatory Database; MAK - Maximum Concentration Value in the Workplace; MEL - Maximum Exposure Limits; MX - Mexico; NDSL - Non-Domestic Substance List (Canada); NFPA - National Fire Protection Agency; NIOSH - National Institute for Occupational Safety and Health; NJTSR - New Jersey Trade Secret Registry; NTP - National Toxicology Program; NZ - New Zealand; OSHA - Occupational Safety and Health Administration; PEL - Permissible Exposure Limit; PH - Philippines; RCRA - Resource Conservation and Recovery Act; REACH - Registration, Evaluation, Authorisation, and restriction of Chemicals; RID - European Rail Transport; SARA - Superfund Amendments and Reauthorization Act; STEL - Short-term Exposure Limit; TCCA - Korea Toxic Chemicals Control Act; TDG - Transportation of Dangerous Goods; TLV - Threshold Limit Value; TSCA - Toxic Substances Control Act; TW - Taiwan; TWA - Time Weighted Average; UEL - Upper Explosive Limit; UN/NA - United Nations /North American; US - United States; VLE - Exposure Limit Value (Mexico); WHMIS - Workplace Hazardous Materials Information System (Canada)

16.3 Key literature references and sources for data

Available upon request.

16.4 Methods Used for Classification of Mixture According to Regulation (EC) No 1272/2008

Available upon request.

16.5 Relevant H- and EUH-phrases (Number and full text) and Notes

H225 Highly flammable liquid and vapor

H301 Toxic if swallowed

H311 Toxic in contact with skin

H331 Toxic if inhaled

H370 Causes damage to organs.

16.6 Training advice

Read the Safety Data Sheet before handling product.

16.7 Further Information

Disclaimer:

The information above is believed to be accurate and represents the best information currently available to us. Users should make their own investigations to determine the suitability of the information for their particular purposes. This document is intended as a guide to the appropriate precautionary handling of the material by a properly trained person using this product. Methanex Corporation and its subsidiaries make no representations or warranties, either express or implied, including without limitation any warranties of merchantability, fitness for a particular purpose with respect to the information set forth herein or the product to which the information refers. Accordingly, Methanex Corp. will not be responsible for damages resulting from use of or reliance upon this information.

Appendix 5:

Dangerous chemical reactions

Chemicals	possible danger ex = explosion, ga = gasproduction, he = heat production, ig = ignition
acetaldehyde,+ acetic acid	he (polymerisation)
Acetone + chloroform	ex
Acetone + nitric acid	ig
Acetonitrile + heat	production of hydrocyanic acid
acetonitrile + nitric acid	production of hydrocyanic acid
Acrylamide + sulfuric acid	he (polymerisation)
Alcohol + perhydrol	ig/ex
Ammonia + chrome trioxide	ig/he
Ammonia + silver nitrate	ex
ammonium chloride + ammonium nitrate	ex
ammonium nitrate + sodium nitrate	ex
Aniline + oxidation	ex
Benzene + nitric acid	ex
bromine + ethyl alcohol	he
cyanogen bromide + alkali hydroxide or acids	ex
chrome sulphuric acid + acetic acid	he/ex
dichloromethane + nitric acid	he/ex(peroxide)
dimethyl sulphoxide + iron nitrate	ex
dioxan + oxidation	he
acetic acid + chrome trioxide	he/ex
acetic acid + perchloric acid	he/ex
acetic anhydride +acids	he/ex
ethyl alcohol + perhydrol	ex
ethyl alcohol + chrome trioxide	ig

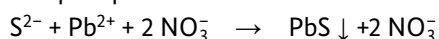
Chemicals	possible danger ex = explosion, ga = gasproduction, he = heat production, ig = ignition
formaldehyde + nitric acid	he/ga/ex
formaldehyde + perhydrol	ex
Iodine + ammonia	ex
potassium cyanide + potassium nitrate	ex
potassium dichromate +acetic anhydride	ex
potassium iodide + ammonia	ex
methyl alcohol + perchloric acid	ex
methyl alcohol + perhydrol	ex
methyl alcohol + nitric acid	ex
sodium acetate + potassium nitrate	ex
sodium hydroxide + chloroform/acetone	ex
sodium hydroxide + silver nitrate	ex
oxalic acid + silver	ex
perchloric acid	many reactions
peroxides	many reactions
phenol +formaldehyde	he/ex
picric acid + heavy metals	ex
Propanol + nitric acid	he/ex
Mercury + ammonia	ex
mercuric nitrate + ethyl alcohol	ex
nitric acid	many reactions
sulfuric acid	many reactions
silver nitrate +ammonia + methyl alcohol	ex
silver nitrate + sodium hydroxide	ex
silver nitrate + ethyl alcohol	ex
perydrol	many reactions
xylene + nitric acid	he/ex

Appendix 6:

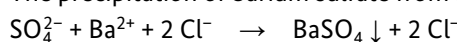
Examples of precipitation

Hydrochloric acid, hydrogen sulfide, ammonium sulfide and ammonium carbonate can produce insoluble chlorides, sulfides and carbonates of heavy metals.

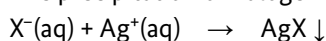
1. The precipitation of lead sulfide from lead salt solution:



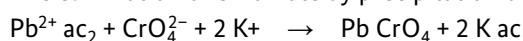
2. The precipitation of barium sulfate from barium salt solution:



3. The precipitation of halogenides such as chloride, bromide, iodide with silver:



4. The elimination of chromate by precipitation of lead chromate after adding a solution of lead acetate:



	Reagents	Precipitation
Bromide ions	Silver nitrate	Silver bromide $\text{Ag}^+ + \text{Br}^- \rightarrow \text{AgBr} \downarrow$
Iodide ions	Silver nitrate	Silver iodide $\text{Ag}^+ + \text{I}^- \rightarrow \text{AgI} \downarrow$
Chloride ions	Silver nitrate	Silver chloride $\text{Ag}^+ + \text{Cl}^- \rightarrow \text{AgCl} \downarrow$
Sulfide ions	Lead nitrate	Lead sulfide $\text{Pb}^{2+} + \text{S}^{2-} \rightarrow \text{PbS} \downarrow$
Carbon dioxide	Calcium hydroxide Barium hydroxide	Calcium carbonate $\text{Ca}^{2+} + \text{CO}_3^{2-} \rightarrow \text{CaCO}_3 \downarrow$ Barium carbonate $\text{Ba}^{2+} + \text{CO}_3^{2-} \rightarrow \text{BaCO}_3 \downarrow$
Phosphate ions	Silver nitrate	Trisilver phosphate $3 \text{Ag}^+ + \text{PO}_4^{3-} \rightarrow \text{Ag}_3\text{PO}_4 \downarrow$
Sulfate ions	Barium chloride	Barium sulfate $\text{Ba}^{2+} + \text{SO}_4^{2-} \rightarrow \text{BaSO}_4 \downarrow$
Sulfide ions	Lead nitrate	Lead sulfide $\text{Pb}^{2+} + \text{S}^{2-} \rightarrow \text{PbS} \downarrow$

Appendix 7:

Examples of chemical treatment

Many chemicals can be safely disposed of simply by discharging them into the sewerage system after neutralization or after other chemical treatment, in some cases even without any further treatment.

■ Treatment of water contaminated with hexavalent chromium Cr (VI)

Hexavalent chromium compounds (Cr [VI]) are highly toxic and for this reason water containing these substances must be adequately and appropriately treated before being discharged into the environment.

The most effective method of decontamination is the reduction of chromium (VI) to the less toxic trivalent chromium, Cr (III), and its subsequent precipitation. Both the precipitate and the remaining liquid phase are significantly less toxic than the original solution. The solid residue can be filtered off and, after stabilization in cement, deposited in a controlled landfill. Using this method, chromium concentrations of below 0.1 mg/l of water may be achieved.

It is recommended that laboratory tests be conducted to determine the efficiency of the process and to detect possible inhibition of the process by the presence of other contaminants in the water which would affect the exact amount of the reagents required.

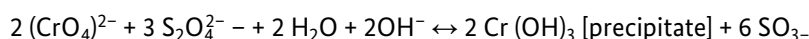
Method 1:

After the addition of sulfuric acid, sodium bisulfite (NaHSO₃) or iron sulfate (FeSO₄) is added. In a second stage, a base such as caustic soda (NaOH) is added, leading to the precipitation of chromium hydroxide.

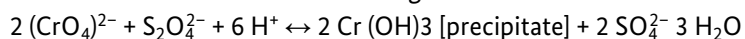
Method 2 (without adding acid):

Here, sodium dithionite (Na₂S₂O₄) is employed to both reduce chromate and precipitate the chromium as its hydroxide.

In a basic environment:

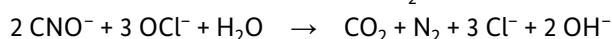
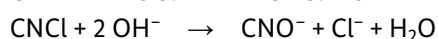
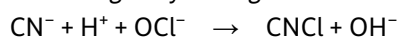


In an acidic environment and with high concentrations of chromium (I dichromate):

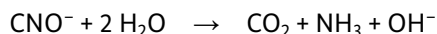
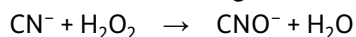


■ Decontaminating cyanide-containing solutions

Cyanide can be oxidized with sodium hypochlorite to cyanate at a pH of 10–11, and subsequently to carbon dioxide and nitrogen by adding an oxidant with a pH of 8–9.



Alternatively, cyanide can be oxidized with an approximately 5 % solution of hydrogen peroxide in an alkaline medium to form ammonia and carbon dioxide. The excess of hydrogen peroxide can be detected by means of potassium iodide starch. Undestroyed cyanide in the reaction mixture can be detected by the Prussian blue reaction. If this test is negative, then the mixture can be safely discarded.



■ Ethidium Bromide

Ethidium bromide, a powerful mutagen, is widely used in biochemical research laboratories for visualizing DNA fragments.

Aqueous solutions or gels of ethidium bromide and other materials contaminated with ethidium bromide can be detoxified using ultraviolet light (UV lamp or in the sun). Residual ethidium bromide can be readily detected on account of its fluorescence.

■ Liquid Mercury

Toxic elemental mercury can be stabilized as mercury sulfide (Hg S) by a reaction with sulfur in a sealed, temperature-controlled vacuum mixer. Mercury sulfide is non-toxic for humans, safe for the environment and can be disposed of in accordance with the applicable legislation.

■ Mercury distillation

Metallic mercury of poorer quality can be processed to reach a defined technical purity simply by distillation.

By repeated distillation in high vacuum, mercury purities of 99.99 % (4N-grade) up to 99.999999 % (8N quality) are attainable. The required purity will depend upon the intended use of the recycled mercury (physical, chemical or medical applications).

■ Osmium Tetroxide

Osmium tetroxide solutions can be converted to a less volatile (safer) form in a variety of ways, all of them involving reduction of tetroxide to the non-volatile dioxide or to a cyclic osmium (VI) ester. A freshly prepared solution of sodium sulfite (sodium sulfite slowly oxidizes to sulfate during prolonged storage) is added to a solution containing osmium tetroxide. A black or purple turbidity indicates the reduction of the tetroxide to dioxide.

Alternatively, corn oil is added to the osmium tetroxide solution and shaken. This method takes advantage of the double bonds of the unsaturated oil to form a cyclic osmic ester. The reaction may be slow since corn oil is not miscible with water, but the method is easy and effective. The solution becomes dark and a suspension will form, indicating that reaction has taken place.

Appendix 8:

Chemical disinfection – categories of decontaminants and their properties

■ Alcohols

- Ethyl or isopropyl alcohol at a concentration of 70–85 %
- Denature proteins
- Longer contact times are required when treating fungi and mycobacteria
- Variable effectiveness against non-enveloped viruses
- Not effective against bacterial spores
- Easy to use, non-corrosive
- Readily evaporated
- Extremely flammable
- Easily inactivated by organic matter, no cleansing properties

■ Formaldehyde

- Broad spectrum of activity against all classes of microorganisms
- Less susceptible to inactivation by organic material
- Prolonged contact times are required (up to 3 h against bacterial spores)
- Loss of activity at refrigeration temperatures
- Pungent, irritating odour
- Expensive
- Can cause hypersensitivity
- Low storage life

■ Phenolic compounds

- Effective against enveloped viruses
- Variable effectiveness against fungi and mycobacteria (depending on the product)
- Limited effectiveness against non-enveloped viruses
- Not effective against bacterial spores
- Toxic
- Causes skin irritation
- Unpleasant odour
- Sticky, gummy residue on treated surfaces

■ Quaternary ammonium compounds (Quats)

- Cationic detergents attach to proteins
- Strongly surface-active, therefore good surface cleaners

- Odourless
- Non-staining
- Non-corrosive to metals
- Inexpensive
- Relatively non-toxic
- Effectiveness reduced by anionic soaps and organic material (proteins)
- Ineffective against gram negative bacteria, spores, mycobacteria and many viruses

■ Hypochlorite

- Universal decontaminant against all microorganisms including bacterial spores
- Corrosive to metals
- Diluted solutions are unstable, therefore it is important to prepare fresh solutions frequently (short storage life)
- Effectiveness reduced by organic matter (protein)
- Irritation to skin and eyes

■ Glutaraldehyde

- Broad spectrum of activity against all classes of microorganisms
- Rapidly bactericidal, but requires longer contact times for mycobacteria and bacterial spores (at least 3 h)
- Non-corrosive
- Adverse health effects (mucous membrane irritation, contact dermatitis, occupational asthma)

■ Hydrogen peroxide and peroxy acids

- Broad-spectrum agent against all classes of microorganisms
- H₂O₂ can be used for the decontamination of work surfaces (laboratory benches, biosafety cabinets)
- Use of vaporized hydrogen peroxide (VHP) requires special (and expensive) equipment
- Can be corrosive to some metals (aluminium, copper, brass and zinc)
- Can decolourize fabrics, hair, skin and mucous membranes

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38116 Braunschweig
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Responsible

Dr. Marion Stoldt
+49 531 592-9300
marion.stoldt@ptb.de
www.ptb.de/9.3/en

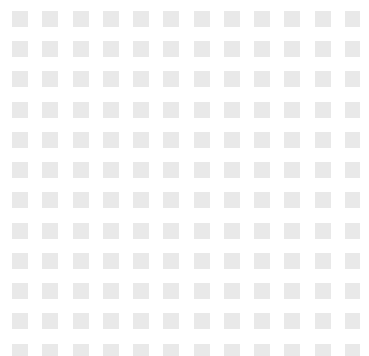
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Dr. Roswitha Meyer

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Contact

Physikalisch-Technische Bundesanstalt

International Cooperation

Dr. Marion Stoldt

Phone +49 531 592-9300

Fax +49 531 592-8225

marion.stoldt@ptb.de

www.ptb.de/9.3/en