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EPOXY RESINS AND CURING AGENTS

Toxicology, Health, Safety and Environmental Aspects

July 2026

A Guidance Document

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1. Introduction

The manufacture, formulation and application of epoxy products involve a variety of separate substances, such as epoxy resins, hardeners, reactive diluents or solvents.

Considerable knowledge and experience has been gathered about their physical and chemical properties, hazards and risks to humans and the environment.

The aim of this document is to provide the reader with reference information concerning the main aspects of human health, occupational and environmental safety of epoxy products.

It is not intended to be fully comprehensive in answering all questions that might arise regarding the wide variety of products available. Rather it is intended as a useful reference guide for safe handling of products which due to their chemical nature have some toxicological properties requiring special precautions for human health and the environment.

In view of the increasing demand for information to producers, suppliers, converters and users of epoxy resin systems ,this document aims to help all parties in the supply chain disseminate the appropriate safety information for this group of chemicals.

For detailed information on specific products please consult the supplier's Safety Data Sheet or special product literature.

1.1. The Epoxy Europe Safety APP

Epoxy Europe has developed the "Safety App" as an online tutorial designed to provide expert information to epoxy users for working with epoxy resins safely. The app is divided into four chapters with a chapter dedicated to safety protocols for getting started (pre-use), actual application stage (while use) and post use. One chapter offers First Aid protocol to follow in case of accidents

Each chapter includes practise exercises at the end to help users memorise the information covered in the tutorial. Once a user has completed the tutorial, they can take the test provided at the end to check their knowledge of the safety protocols outlined in the app. On successful completion of the test the users are awarded a certificate as proof of completion. While there is no limit to the validity of the certificate, the users are encouraged to take the test annually to refresh their knowledge.

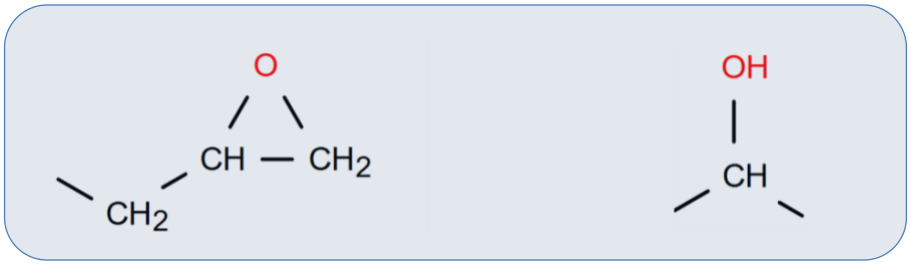
The app also includes a Frequently Asked Questions section to cover additional queries that a user might have about the app and on safe handling of epoxies.

The app can be accessed free of charge via the Epoxy Europe website:
www.epoxy-europe.eu/safety/safety-app/

or via the QR Code.

2. General Description and Properties of Epoxy Products

Epoxy resins are a family of synthetic resins, including products which range from viscous liquids to solids with a high melting point. The resin molecule contains one or more oxirane or epoxide groups as reactive site, usually in the form of the glycidyl group (below). In addition they often contain hydroxyl groups.



The most commercially important resin is the glycidyl ether of bisphenol A also known as BADGE (bisphenol A diglycidyl ether, CAS 1675-54-3), produced by the condensation of epichlorohydrin (ECH) and Bisphenol A

Epoxy resins with different characteristics are also produced commercially by reacting ECH with other materials.

For use the resins must be cross-linked with a curing agent or hardener. The choice of curing agent is of paramount importance in designing an epoxy resin formulation for a given application.

The main reactive groups in the resin – the epoxide or hydroxyl groups – can react with many other groups so that many types of chemical substances can be used as curing agents. These include acid anhydrides, aliphatic and aromatic amines and polyaminoamides. Some curing agents will react with and thus cross-link the resin at ambient temperature while others require the application of heat and/or catalysts.

However, the simple mixture of resin and curing agent rarely provides a material containing all the desired properties for a specific application. Other components are therefore added in formulating the system.

The major types of additives include:

- Cure accelerators
- Reactive Diluents
- Solvents
- Flexibilisers, plasticisers, toughening agents
- Fillers and pigments
- Reinforcements, particularly fibres

Epoxy Europe (EE) provides information covering residual ECH monomer. This is available from EE member companies or on the EE website.

3. The Terminology of Toxicology and Industrial Hygiene

Industrial hygiene and toxicology are important sciences that provide data to improve our understanding of the hazards posed by industrial products, and assess their risks to human health. The following chapter explains some of the most frequently used specialist terms and definitions encountered in literature and safety documentation such as Safety Data Sheets (SDSs).

3.1. Toxicity, Hazard and Risk

Toxicity is defined as the adverse effects that a chemical has on living organisms, including humans, animals and plants. It is an inherent characteristic of a substance like odour or colour or other physical and chemical properties.

Hazard is also determined by the inherent characteristics of a substance like physical and chemical properties or its toxicity. However, a health hazard can only become harmful if the exposure exceeds the threshold to cause a harmful or toxic effect on the organism. A typical hazard is the ability to cause irritation or corrosion. Therefore, a hazard requires exposure in order to result in risk.

Hazards are identified via in vivo or in vitro studies or in some cases modelling. The hazard of a substance is reflected by its classification. The Regulation 1272/2008 (CLP) on Classification & Labelling of Products sets the criteria and hazard classes for identifying the physical, health, and environmental hazards of chemical substances and mixtures of a substance and regulates hazard communication. It reflects the implementation of the Global harmonized System (GHS) in Europe.

Risk describes the probability or likelihood that a hazard will result in an adverse effect. While the hazard of a chemical cannot be changed, the risk can be minimized by controlling exposure.

3.2. Local Toxic Effects

A local toxic effect can occur if exposure to a substance causes direct damage at the point of contact. The effects of substances on the eyes, skin, and mucous membranes are a significant concern in the workplace.

A chemical's potential to cause local effects is determined through animal testing, as well as through tests using tissues or cell cultures only. However, such an effect may already be predictable based on the substance's physical or chemical properties (e.g., pH-value). Based on tests on laboratory animals, cell cultures or tissues, and depending on the degree and potential reversibility of the damage, substances are classified as non-irritants, irritants, or corrosives.

Irritating Substances cause local reactions resulting from single or multiple exposures. These reactions are characterised by redness and swelling. Depending on the degree of the inflammatory response, a substance may be classified as a mild, moderate, or severe irritant. An irritant reaction in tissue is generally reversible within hours or days.

Corrosive substances will cause necrosis or irreversible tissue destruction, especially in the eyes.

Skin

Occupational skin disorders are among the most common work-related illnesses. Direct skin lesions are "dose"- or "concentration"-dependent but should not occur if the correct personal protective equipment (PPE) and clothing are used.

Eyes and Mucous Membranes

The tissues of the eye and the surrounding mucous membranes around the eye are even more sensitive than the skin.

Furthermore, eye damage is more serious and can have graver consequences for the person involved. The effect of a substance on the eye is usually tested on laboratory animals or in animal-free test systems such as tissues or cultured cells. If the substance is already a proven skin irritant, the test is usually not performed, and an eye irritation potential is assumed by analogy.

3.3. Systemic Toxic Effects

Acute Toxicity

The acute toxicity of a chemical substance is determined by its ability to cause death after a single exposure.

This exposure is described as the 'lethal dose 50' or LD50. For classification purposes, regulatory authorities use the degree of toxicity based on the LD50 value. Exposure can occur through ingestion, dermal contact or inhalation.

The degree of toxicity of a single dose of a substance is expressed as the LD50 which is the lethal dose for 50 per cent of treated animals. The LD50 value is the amount of substance administered, normally expressed as a dosage in milligrams per kilogram (mg/kg) bodyweight that is likely to kill 50 per cent of test animals. Acute toxicity by inhalation is usually expressed as the LC50 value, or median lethal concentration.

LC50 values are usually expressed as the airborne concentration of a substance in milligrams per cubic metre (mg/m^3) air or milligrams per litre (mg/l) of air or in parts per million (ppm) in air and the length of exposure should be specified in hours or minutes. An example of a dose-response relationship is illustrated in the following graph on page 8.

Substances and preparations with an acute toxicity within the indicated ranges must carry the legally prescribed warning labels and the appropriate classification. Corrosive substances cause necrosis or irreversible tissue destruction, especially to the eyes.

The Regulation 1272/2008 (CLP) sets the cut-off values for the classification of the acute toxicity based on data from tests conducted on rats (see table below).

Exposure Route	Category 1	Category 2	Category 3	Category 4
Oral (mg/kg bodyweight) see: Note (a) Note (b)	5	50	300	2000
Dermal (mg/kg bodyweight) see: Note (a) Note (b)	50	200	1000	2000
Gases (ppmV) see: Note (a) Note (b) Note (c)	100	500	2500	20000
Vapours (mg/L) see: Note (a) Note (b) Note (c) Note (d)	0.5	2.0	10.0	20.0
Dusts and Mists (mg/L) see: Note (a) Note (b) Note (c)	0.05	0.5	1.0	5.0

Sensitisation

Sensitisation is an allergic reaction to a substance that can develop with repeated exposure, though a single exposure may also be enough to trigger the response. The degree of the sensitisation varies widely from person to person, as does the potency of sensitising substances. An allergic response can manifest as a skin rash or swelling in the case of dermal sensitisation, or as an asthmatic-type reaction in the case of respiratory sensitisation.

The extent of the sensitisation reaction does not depend solely on the degree of exposure. Contact with trace amounts of sensitising substances can cause an allergic reaction, if the individual is already sensitised or the substance is highly potent.

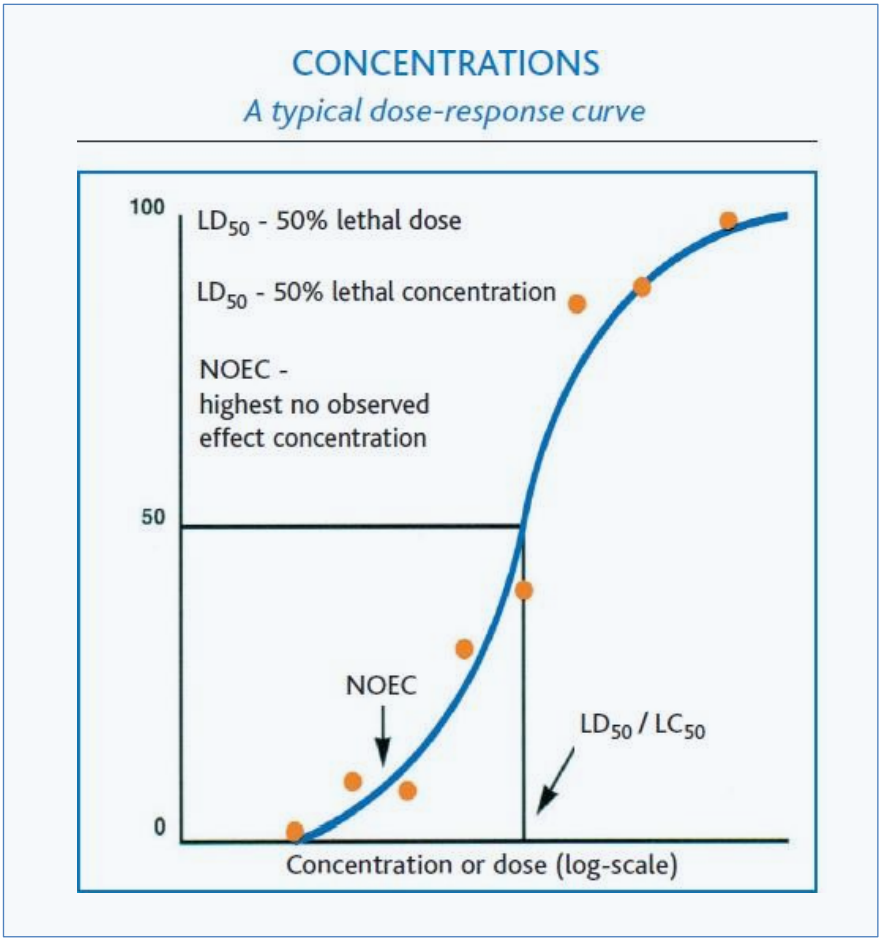
Subacute and Subchronic Toxicity

In daily working practice or when substances are used over a prolonged period, small quantities of substances in concentrations far below the acutely toxic range may enter the body. This can result in adverse effects, either through accumulation in target tissues or through prolonged stress to the liver or other organs. Specifically designed toxicity tests are performed to assess the hazards associated with this exposure duration.

The substance is administered at various dose levels to groups of test animals, so called cohorts, over a prolonged period (weeks or months). The information is most relevant when the administration of the dose corresponds to the likely route of exposure in humans.

The results provide dose-response information and form the basis for determining subacute/subchronic exposure:

- What are the possible safe levels in humans?
- What toxic levels might be in humans?
- What effects might occur in humans?



Chronic Toxicity

Chronic toxicity is defined as the occurrence of adverse health effects caused by exposure to a substance over a significant span of a lifetime. These effects can arise following repeated exposure to substances by dermal, oral or inhalation routes at dose levels far below those causing acute toxicity.

The aim of chronic toxicity testing is to determine the dose or exposure level at which no measurable, long-term toxic effects occur i.e., a level that would allow potential workplace exposure over a working lifetime with negligible risk of any negative health effects. The study will also provide information on chronic effects and the doses at which no effects occur (NOEL).

The most important long-term health effects investigated are mutagenicity, carcinogenicity and reproductive/developmental toxicity. Other effects, such as neurotoxicity and immunotoxicity can be the subject of further investigations.

Mutagenicity

Mutagenicity is the ability of a substance to cause mutations (permanent changes) in the genetic material of cells.

These mutations can occur in germ cells or somatic cells. Genetic changes in germ cells can have

an adverse effect on fertility and may lead to malformations or even death in the embryos. Currently science assumes that mutations in somatic cells are an initial step in pathways that can potentially lead to tumour induction in mammals. This provides an additional reason to understand the mutagenic potential of a substance.

The most frequently performed "in vitro" test for the mutagenicity of chemical substances involves Salmonella bacteria, also known as the "Ames test". It is sensitive, quick and relatively inexpensive for screening purposes. Other in vitro tests use mammalian cells in culture to screen for the mutagenic potential of a substance, providing information that may be relevant to its carcinogenic potential. More extensive mutagenicity testing is performed on animals (in vivo testing).

However, the outcome of a single test is not adequate or appropriate for establishing the mutagenic potential of a substance.

Carcinogenicity

Carcinogenicity is the ability of a chemical substance to cause or promote the growth of benign or malignant tumours. The current scientific consensus is that many types of cancer originate from genetic mutations in the body's cells that have not been (sufficiently) repaired. These genetic changes can have natural causes, such as excessive exposure to sunlight, but can also be induced by overexposure to synthetic chemical substances.

Chemical substances are normally classified as carcinogens when they have been shown to increase tumour formation in lifetime animal studies (usually in more than one species), or if there is reliable epidemiological evidence in humans. To interpret the results, and their significance for humans, additional information needs to be considered such as metabolism (which can be species-specific), mutagenicity, and the degree of exposure.

Reproductive Toxicity

Reproductive toxicity deals with the potential influence of chemical substances on complex reproductive processes, such as male and female fertility, and the development of offspring. The possible effects on humans are assessed based on the results of special animal experiments. Epidemiological studies can provide insights into the human relevance of animal studies to humans.

Multi-generation studies on animals are the most common way of investigating the potential reproductive toxicity of a substance. The results of these studies allow conclusions to be drawn about the possible effects on human reproduction and fertility.

Developmental Toxicity

Developmental toxicity describes the potential of a substance to cause toxicity in the developing embryo or foetus. This includes embryotoxicity, which is the potential of a substance to damage or kill the embryo. To test for developmental toxicity the following effects are studied in pregnant experimental animals:

- Embryo mortality (embryotoxic effects)
- Malformations (teratogenic effects)

- Growth retardation (developmental toxicity)
- Maternal toxicity (toxic effects)

3.4. Ecotoxicity and Environmental Behaviour

In addition to mammalian toxicity, the behaviour, the effects and the fate of chemical substances in and on the environment have attracted increased attention in the recent decades, developing into a significant discipline.

During the manufacture, processing and use of chemical substances one of the main potential routes of entry into the environment is through water; however, air and soil also represent significant routes. Consequently, testing for toxic effects on the environment (ecotoxicity) is generally conducted on aquatic organisms such as fish, daphnia, and algae, and terrestrial organisms such as earthworms and plants, as well as on microorganisms of both environmental compartments.

Acute Ecotoxicity

Acute ecotoxicity is investigated by exposing aquatic or terrestrial organisms (such as fish, earthworms, or plants) to a substance for a short period of time. The mortality of the organisms and the growth retardation of bacterial cultures are noted. These observations help to determine the concentrations at which 50 per cent of the test organisms are killed, e.g., the LC50 value "lethal concentration" for fish, the EC50 for reduced motility of Daphnia (water fleas) or the EC10 value for a 10 per cent retardation in bacterial growth. The results of these tests provide information about the potential for environmental damage following short-term accidental exposure. The data can also inform risk assessment for chronic exposure, when information on environmental behaviour/fate is available, e.g., biodegradability.

Chronic Ecotoxicity

Prolonged or chronic ecotoxicity testing provides information on the long-term behaviour of chemical substances in the environment. These tests provide data on no-effect concentrations for animals and plants and can help to determine the lowest chronic toxic concentration in water, air, and soil. In addition, the type of adverse effects on organisms can be determined. Together with degradability and accumulation data, the data are most important for environmental risk assessments.

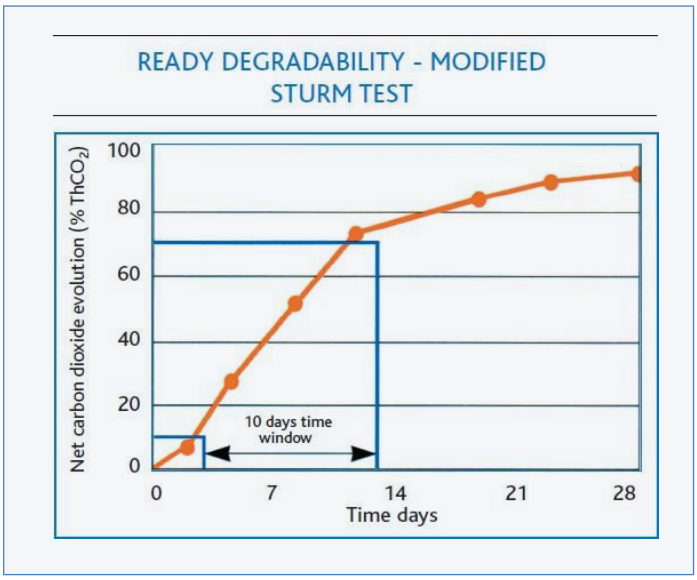
Long-term fish studies also include multigenerational studies which provide information on the potential reproductive effects of substances on aquatic organisms.

Classification categories			
Short-term (acute) hazard (Note 1)	*Long-term (chronic) hazard (Note 2)*		
	Adequate chronic toxicity data available		*Adequate chronic toxicity data not available (Note 1)*
	Non-rapidly degradable substances (Note 3)	*Rapidly degradable substances (Note 3)*	
Acute 1 $L(E)C_{50} \leq 1$ mg/L	**Chronic 1** NOEC or $EC_x \leq 0.1$ mg/L	**Chronic 1** NOEC or $EC_x \leq 0.01$ mg/L	**Chronic 1** $L(E)C_{50} \leq 1$ mg/L and not rapidly degradable and/or BCF ≥ 500, or if BCF is absent, log $K_{ow} \geq 4$
	Chronic 2 NOEC or $EC_x \leq 1$ mg/L	**Chronic 2** NOEC or $EC_x \leq 0.1$ mg/L	**Chronic 2** $1 < L(E)C_{50} \leq 10$ mg/L and not rapidly degradable and/or BCF ≥ 500, or if BCF is absent, log $K_{ow} \geq 4$
		Chronic 3 NOEC or $EC_x \leq 1$ mg/L	**Chronic 3** $10 < L(E)C_{50} \leq 100$ mg/L and not rapidly degradable and/or BCF ≥ 500, or if BCF is absent, log $K_{ow} \geq 4$
			Chronic 4 Safety-net category where data do not allow classification under Acute 1 or Chronic 1–3, but there are nevertheless grounds for concern. Example: no acute toxicity up to water solubility, not rapidly degradable and BCF ≥ 500, or if BCF is absent, log $K_{ow} \geq 4$.

Degradability

Apart from biodegradation, the environmental fate of a chemical substance is also influenced by physicochemical factors such as light, oxygen and temperature.

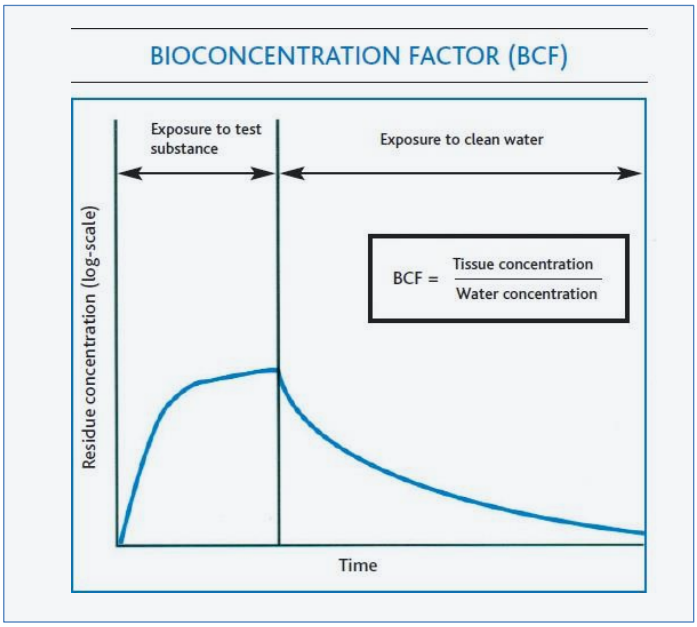
Biodegradation tests determine the extent to which a chemical substance entering an aquatic or terrestrial environment can be degraded by microorganisms. To this end, the substance is added to microorganisms extracted from sludge taken from municipal wastewater treatment plants. The decrease in substance concentration or the production of carbon dioxide is measured over time, and indicates the substance's potential for biological degradation. Low biodegradability means that the substance remains in the environment for longer. Full biodegradability means that the substance is likely to be eliminated through natural processes within a short period of time.



(Bio)Accumulation

Bioaccumulation, also known as bio-concentration, describes the ability of a substance to accumulate in living organisms.

The most common method used to predict ta material's potential to concentrate in aquatic organisms is the octanol/water partition coefficient, log P_{ow} or log K_{ow} which is the logarithmic ratio of the concentration of the substance in octanol to its concentration in water at equilibrium. A substance with a log P_{ow} greater than 3 may have the potential to bioaccumulate. However, these calculations do not consider the potential metabolic role of substances, which affect their log P_{ow} and thus their potential to bioaccumulate. Therefore, tests on animals or plants must be conducted to reliably establish the bioaccumulation potential of such chemicals, known as the bioconcentration factor (BCF).



More recently, bioaccumulation and persistence in the environment have become major issues in the EU and the USA. The EU treats PBT chemicals (persistent, bioaccumulative, and toxic) and vPvB (very persistent, very bioaccumulative) substances as dangerous and aims to eliminate them from the environment wherever possible. The new environmental classification "PMT" (Persistent, Mobile, and Toxic) has been introduced by the European Union through amendments to the CLP Regulation (EC) No 1272/2008. This regulation officially came into force on 20 April 2023. For substances that are new to the European market, companies have been required to classify and label them according to the new PMT hazard classes starting from 1 May 2025. For substances already on the market, compliance becomes mandatory from 1 November 2026.

The PBT (Persistent, Bioaccumulative, and Toxic) and PMT (Persistent, Mobile, and Toxic) criteria are both designed to identify substances that pose significant risks to human health and the environment, but they focus on different properties relevant to environmental concern.

PBT: The "B" criterion is bioaccumulation, the ability of a substance to accumulate in living organisms. PBT substances can concentrate up the food chain, posing long-term effects for wildlife and humans.

PMT: The “M” criterion is mobility, the ability of a substance to move quickly in water and soils, thus contaminating groundwater and drinking water sources. Mobility is typically assessed via the organic carbon-water partition coefficient (log K_{OC}), i.e., substances with a log K_{OC} smaller than 3 are considered mobile. This low value also means that they dissolve and travel easily with water, allowing them to pass through soil, sediments, and natural barriers. When combined with persistence, PMT substances can move with groundwater and surface water far from their original point of release, even into subsurface environments. This allows them to spread over extensive spatial and temporal scales, which can make it difficult to trace back to their source once detected and present challenges for environmental and drinking water protection.

4. Toxicology, Industrial Hygiene and Ecotoxicology Aspects of Epoxy Products

4.1. Toxicology and Industrial Hygiene

Bisphenol A and bisphenol F epoxy resins

Unmodified liquid epoxy resins based on bisphenol A or bisphenol F (with a molecular weight (Mn) of less than 700) have low acute oral toxicity (with an LD50 greater than 8 g/kg). They are mild to moderate primary irritants to the skin, eyes ,and mucous membranes.

Their sticky nature leads to prolonged skin contact, which increases their irritant potential. Solvents should not be used to remove them, as this increases the risk of skin irritation due to the "de-fatting" ability of the solvents. These resins are generally mild to moderate skin sensitisers and can cause an allergic reaction with repeated use. In vitro they exhibit mutagenic potential, which is absent in whole animal (in vivo) tests. No carcinogenic potential is associated with these epoxy systems. They are also not toxic to reproduction. Based on the extensive data available on Bisphenol A diglydicyl ether (BADGE), the risk of any in vivo mutagenic or carcinogenic potential associated with these unmodified liquid epoxy resins is negligible. BADGE has been evaluated for its reproductive and developmental effects in vivo in laboratory animals, including rats and rabbits, using guideline study designs in accordance with Good Laboratory Practices (GLPs). It has not shown specific toxicity to reproduction.

Unmodified solid resin grades (Mn >700) are not readily bioavailable, and their acute toxicity is very low (LD50 >30g/ kg). They present a low risk of skin irritation. Only direct contact with solutions of these resins can cause mild to moderate skin and eye irritation, primarily due to the solvents "de-fatting " the skin. While lower molecular weight liquid epoxy resins are dermal sensitizers, data for the higher molecular weight solid resins is mixed, likely due in part to impurities. When crushed to a fine powder the materials should be treated as potentially irritating dust. There is no in vivo mutagenic or carcinogenic potential associated with solid resin systems, and they are not expected to affect reproduction.

Modified liquid resin grades, for example through the addition of lower molecular weight epoxy components such as reactive diluents, are mild to moderate primary skin irritants. Low-molecular weight resins or reactive diluents present are moderate to strong sensitisers. Their sensitising potential increases with decreasing molecular weight. Epoxy components with significant volatility can irritate the skin, eyes and respiratory tract. Some of these epoxy resin systems exhibit a mutagenic potential "in vitro".

Reactive diluents

Certain low-molecular weight modifiers with epoxide functionality - so-called reactive diluents are added to epoxy resin formulations to decrease their viscosity. As epoxides they participate in the cross-linking reaction.

Reactive diluents and epoxy resins modified by the addition of these diluents are likely to cause more severe skin, eye, and mucous membrane irritation and to be more potent skin sensitizers than unmodified resins. Very low molecular weight reactive diluents, with increased vapour pressure present a higher risk of inhalation exposure, which can lead to irritation of the mucous membranes, eyes, and respiratory system.

In general, reactive diluents show the same toxicological profile as liquid epoxy resins but with more pronounced effects in humans. Some of the reactive diluents are mutagenic "in vitro" and in in vivo.

Details for individual products can be found in the Safety Data Sheet (SDS). However, it is essential to avoid exposure to this class of diluents, particularly via the dermal route.

In 2024 several reactive diluents have been subject to reclassification as reprotoxic substances category 1B in the European Union based on new toxicological data. The reclassified diluents include:

- 1,6 Hexanediol diglycidyl ether , HDDGE (CAS# 16096-31-4)
- 1,4-bis(2,3-epoxypropoxy)butane, BDDGE (CAS# 2425-79-8)
- Oxirane, mono[C12-14-alkyloxy)methyl]derivative (CAS#68609-97-2)

These reclassifications mean that mixtures containing these substances in concentrations equal or greater than 0.3% must now carry hazard labelling indicating reproductive toxicity (H360F) and the health hazard icon. This has major regulatory impact, particularly for the coatings, adhesives, and epoxy resin industries prompting many companies to develop safer substitutes to avoid the newly acquired hazard labelling.

Amines Curing Agents

Great majority of amine curing agents can be assigned to several groups based on similar chemical structures. These groups exhibit similarity in chemical properties and related risks for human health and environment.

Key building blocks used across these groups are aliphatic and cycloaliphatic amines, polyalkylenepolyamines, fatty acids, dimer fatty acids and epoxy resins. Main constituents in fatty acids are typically C18 unsaturated acids (oleic, linoleic).

The majority of volume of commercially available curing agents can be assigned to these groups:

- Aliphatic and Cycloaliphatic Amines as such
- Amine adducts = Amine + epoxy resin
- Reactive polyamides = Amine + Fatty acid + Dimer fatty acid
- Amidoamines = Amine + Fatty acid
- Mannich base = Amine + phenolic component + formaldehyde

Many materials in each group are registered under EU REACH in the high tonnage band. As a result we have available a significant number of good quality studies for each endpoint across the groups. This allows us to see similarity in properties of members in each defined group.

We can see that main driver of dangerous properties is typically the amine functional group and

when it is further reacted, we see less hazardous properties.

For many materials a Chemical Safety Assessment has been performed including exposure assessment for identified uses as part of the REACH registration. There are available defined conditions for safe use based on conservative assessments. This information is available through the safety data sheets of curing agent suppliers.

Aliphatic and Cycloaliphatic Amines

These products, such as isophoronediamine (IPDA), m-phenylenebis(methylamine) (MXDA), polyetheramine (PEA), diethylenetriamine (DETA), and triethylentetramine (TETA) are strong, low-molecular-weight bases. They are moderately toxic by ingestion, inhalation or skin contact, and are severe skin and eye irritants. In undiluted form, they can cause severe tissue damage to the skin, eyes and mucous membranes. You can also find skin sensitizers in this group or Specific Target Organ Toxicity effects.

Amine Adducts

Some aliphatic and cycloaliphatic amines are used as such (IPD) but the great majority is used in the reacted form. Large group are adducts of amines with epoxy resins. Adducts of IPD or MXDA are marketed in considerable volumes. Concentration of residual amine in these products can be significant. Those will be consumed during the final curing.

Typical properties for these materials are - non-toxic, corrosive to skin and eyes, skin sensitizing.

Reactive polyamides

Amines typically used in synthesis of materials in this group are polyalkylenepolyamines. Depending on raw materials ratios and reaction conditions, final products can be polymeric or non-polymeric. Concentration of residual amines in this group is typically not significant.

Typical properties for these material are – non-toxic, irritating to skin, damaging to eyes and skin sensitizing.

Amidoamines

Materials in this group are produced in large volume, but there are significant uses beyond the use as epoxy curing agents.

Typical properties for these material are - non-toxic, corrosive to skin and eyes, skin sensitizing.

Mannich bases

Properties of mannich base curing agents depend largely on the phenolic component used in the synthesis. Typical properties for materials based on phenol are - non-toxic, corrosive to skin and eyes, skin sensitizing. Use of other phenolic components (e.g. para-tertiary butyl phenol) may result in additional classification (reproductive toxicity, endocrine disruption).

Auxiliary Materials

Numerous auxiliary materials are used in the processing and application of epoxy resin systems. Due to the wide variety, only the two most common groups of products will be discussed. For other materials please refer to the SDS and the supplier's special instructions regarding safe handling and disposal.

Solvents

In addition to the flammability hazard, solvents and solvent blends commonly used in epoxy resin applications pose specific health risks.

Contact with organic solvents causes "de-fatting" and drying of the skin, which may result in dermatitis.

Some solvents are absorbed directly through the skin, and this process is accelerated if the skin is damaged or irritated. They can also dissolve other materials and carry them through the skin. Inhaling solvent vapours or mists can cause respiratory irritation and central nervous system depression . This may result in dizziness, sleepiness, lack of co-ordination, loss of equilibrium, unconsciousness, and even death in cases of severe over-exposure . When handling solvents and degreasing agents, proper safety and industrial hygiene measures must be observed.

Users should be fully aware of the precautions recommended by the solvent manufacturer for specific hazards associated with particular solvents, such as reproductive toxicity and mutagenicity, e.g. as indicated in the safety data sheet (SDS).

Fillers

The addition of fillers in powder form to resin formulations frequently presents a health hazard due to the potential for overexposure to dust. Inhaling filler dust – even so-called nuisance dust – can damage the respiratory tract. Processing glass fibres with epoxy resins and hardeners can pose serious risks. Glass fibres can irritate the skin, eyes, mucous membranes and respiratory system. They can cause skin lesions which may exacerbate the irritant effects of resins and curing agents and increase the risk of dermatitis or the penetration of other materials through the skin due to abrasion.

4.2. Environmental considerations

Ecotoxicology of Epoxy Products

Although liquid epoxy resins and some reactive diluents are not readily biodegradable; the epoxy functional groups are hydrolysed when they come into contact with water. However, they have the potential to bioaccumulate and are moderately toxic to aquatic organisms. They are generally classified as dangerous to the environment according to the European Union classification criteria.

In addition, certain resin formulations contain solvents that should be controlled when emitted into the air. The relevant SDS should be consulted for specific details.

Uncured solid resins on the other hand are not readily bioavailable, or toxic to aquatic or terrestrial organisms, and not readily biodegradable. However, they are hydrolysable, which reduces residence time in the air.

They present no significant hazard to the environment. No special precautions are required other than good industrial handling practice.

Where solvent-based resin systems are the only alternative, solvent vapour emissions to the atmosphere should be minimised. In most countries, solvent emissions are regulated, and legal limits must always be observed.

Waste Management

Production waste from epoxy resins and resin systems should be treated as hazardous waste in accordance with national regulations. Flame-retarded resins containing halogenated compounds should also be treated as special waste. Any accidental spills of resins, curing agents, and their formulations, should be contained and absorbed using special mineral absorbents to prevent them from entering the environment. Contaminated or surplus products should not be washed down the sink, they should be fully reacted to form cross-linked solids, which are easier to dispose of. Finished articles made from fully cured epoxy resins are hard, infusible solids that present no hazard to the environment. However, finished article made from flame-retarded material containing halogenated resins should be considered hazardous waste, and disposed as required by national laws. Articles made from epoxy resins, like other thermosets, can be recycled by grinding and used as fillers in other products. Another way of disposal and recovery is combustion with energy recovery

5. Workplace Organisation and Working Practices

Epoxy resins and curing agents are reactive compounds and should be handled sensibly and with considerable caution.

The risk to those who come into contact with epoxy products will highly depend on the process and operating procedures and will vary from job to job, task to task and workplace to workplace. However, the same general principles of control apply to all workplaces and are outlined below.

Special handling and control instructions are described in the following section or can be found in the respective SDS for individual products.

In general it can be stated that wearing appropriate clothing including gloves as well as proper personal hygiene goes a long way to preventing exposure and thus risk associated with epoxy use (link to study).

5.1. Hazard Elimination or Reduction

To insure optimum health and safety precautions for the workforce the least hazardous products or processes should be chosen, while still achieving the desired performance. Closed systems, low temperatures, appropriate tools and good ventilation at site of process will be of prime importance.

5.2. Epoxy Working Areas

In order to minimise hazards working areas should be designated and separated from other areas in the factory.

Rooms for eating, resting or changing clothes must be separate from the working area. Enclose and extract sources of emission which are likely to cause exposure or contamination of the workplace. General ventilation which effectively minimises the accumulation of vapours is essential in all areas where release to the work-room air occurs.

For operations with increased risk of forming hazardous vapours, such as spraying, lay-up or casting and curing of epoxy resins, local exhaust ventilation should be installed. The possible need to filter extracted air should also be included in the risk assessment.

5.3. Working Methods

Safety instructions and operating procedures for specified tasks must be written, communicated and enforced. These will include:

- Provision of hazard information and training of personnel based on previously described operating procedures and SDS, together with instructions on how to avoid exposure.
- Assessment of the risk of exposure and contact after reasonable practical steps have been taken to avoid exposure, selection and provision of suitable personal protective equipment.
- Provision of facilities for washing, storage of clothing and skin care, and promotion of their use.
- Close supervision to identify failure in the performance of process controls or in following operating instructions, the occurrence of irritation and inadequate use of personal protective equipment.
- Assessment should also be made of the need for industrial hygiene and medical surveillance, and provision of appropriate services.
- Provision of safety training of all workers involved in epoxy resin system handling.

6. Special Handling and Control Requirements of Epoxides

The following points cover some but not all particular health and safety aspects of epoxy products. Please always consult section 7. and 8. of the SDS of the respective product on handling, storage and exposure control.

6.1. Storage and Transportation

Epoxy products must be stored in closed and labelled containers and in case of solid epoxy resins in closed bags and the area should be designed and equipped for storing hazardous chemicals.

Resins, their formulations, curing agents and auxiliary materials should be stored in a cool place, in tight and well-designed containers away from open flames and sparks. Many epoxy products are classified as dangerous goods and are therefore subject to special transport regulations.

Details for individual products are given in the relevant SDS.

In the case of solid Epoxy Resins under certain conditions sintering of this product may occur, impacting the flowability of the solid product flakes. For detailed information on storage of solid Epoxy Resins contact your supplier for information beyond the one on the SDS.

6.2. Fire and Explosion Risk

Liquid and solid resins as supplied are not classified as flammable but will burn when applying an ignition source as many organic materials

Some formulated resin grades are classified as flammable or highly flammable depending on the solvent used. Adequate precautions must be taken to avoid vapour accumulation and ignition sources. Grounding, e.g. earthing, and bonding of the containers should be practised. Material transfer of solid resins in solution should take place preferably under oxygen reduced or inert atmosphere, e.g. with nitrogen blanket. Consider ATEX directive and apply risk assessment to control potential ignition sources. Storage requirements for this class of materials vary from country to country depending on the respective regulatory requirements and recommendations.

When solid resins are ground to a fine powder, dust clouds can form and result in a fire or explosion hazard, as with any other organic material of small particle size. The control of the formation of dust clouds is best accomplished by installing suitable grinding equipment and extraction systems.

There must be no source of ignition, such as open flames, welding arcs or equipment which could produce electric sparks near areas where finely divided resin is handled and where the risk of dust clouds exists. Even small sparks originating from not properly protected workplace electrical illumination may cause ignition.

The generation of static electricity presents another possible hazard. The buildup of static charges sufficient to produce incendiary sparks can occur when an operator insulated from earth is emptying paper or plastic bags of resin. In order to control these hazards it is recommended that operators wear antistatic footwear and stand on a conductive and grounded surface.

6.3. Personal Hygiene

The availability of certain facilities is a basic prerequisite for an effective personal hygiene programme. Workers handling epoxy resin systems should have access to:

- Separate lockers for work wear and personal clothes and effects
- A supply of clean overalls or other suitable working clothes
- Showers and washbowls with hot and cold water
- Soap, skin cleansing agents and paper towels in the work areas
- Protective cream for hands and face
- Suitable protective gloves

The use of these facilities should always be enforced. Eating, drinking and smoking in the working area should be prohibited. Employees should be instructed and understand the need for hand washing when leaving the working area, specifically before eating, drinking and smoking or before using the toilets. It is recommended that fingernails are kept short and clean.

Dermatitis presents the most common health hazard when working with epoxy resin systems. Workers should be trained and equipped to avoid skin contact with all components - resins, hardeners, solvents and formulated products.

Accidental contamination of the skin should immediately be countered by cleaning with soap and water. Organic solvents should never be used to cleanse the skin because of their "de- fatting" effect. Open cuts, abraded skin or irritated skin areas should under no circumstances be exposed to epoxy resin systems.

6.4. Personal Protection

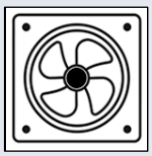
Special protection should be provided for operations where skin contact is likely to occur. Of particular concern when handling liquid epoxy resin products are hands, wrists, face and eyes. In case of vapour formation the eyes and the respiratory tract are likely to be affected. To minimise exposure the following protective equipment should be provided and used:

Rubber or plastic gloves and sleeves for operations where the possibility of skin contact arises. A variety of rubber and plastic materials have been tested for this purpose. It is of prime importance to select the most adequate gloves based on tensile strength, resistance to perforation, glove thickness, breakthrough time, flexibility at room and elevated temperature, and price. Examples of preferred glove barrier material include: butyl rubber or nitril/butadiene rubber (For further details refer to the literature references on page 31). Gloves should be removed by turning them inside out to avoid skin contact by removal.

Rubber or plastic coated aprons as additional protection if necessary.

Overalls, preferably **impermeable and disposable**, for all workers where body exposure is likely to occur, e.g. manual application. Additional **knee protection** as needed for specific tasks. **Closed shoes**.

Goggles or full face shields for eye protection wherever there is the possibility of splashes or aerosols, e.g. handling solvents or resin solutions.



General and local exhaust systems should be installed to remove vapours, aerosols and dusts that may occur in operations such as curing or formulation.

Respiratory protection is necessary in certain cases, such as short term spraying operations where local exhaust ventilation is inadequate to control exposure. A mask with A1-P2 filter should be worn in case of solvents used or in case of spraying.

Soiled protective equipment can be reconditioned by washing first with acetone or methylethylketone (MEK) and then with soap and water. Heavily contaminated or damaged gloves should be removed at once and discarded properly. Equipment made from plasticized PVC must not be cleaned with strong solvents.

Once contaminated, clothing should be immediately removed from the body to avoid contact with the skin. Overalls should be thoroughly laundered at least once a week. All contaminated protective equipment must be carefully cleaned before re-use.

Most important of all is professional training of the workforce. Operators must be instructed in the use of protective equipment and understand the need for it.

6.5. Selection and Training of Personnel

It is advisable to follow a careful assessment of pre-existing medical conditions of personnel to be working with epoxy resin systems. The following criteria should be seriously considered:

- People with chronic skin disease or a history of allergy should not be allowed to work with epoxy systems unless a doctor's permission has been obtained.
- It is most important that employees receive basic information about the materials they are working with and understand the nature of their hazards and the reasons for the recommended precautionary measures.
- It should be appreciated that dermatitis is an indication of improper handling.
- It is essential that all employees understand and diligently practise this recommended handling precautions and procedures. Compromise should not be permitted.

7. Chemical Exposure Limits

The recognition of potential health hazards to workers from exposure to substances during the full life cycle of a product (development, manufacture, use, storage, transport and disposal of chemical) has prompted industry and legislators to set Chemical Exposure Limits.

Most of Chemical Exposure limits are established for inhalation exposure. There are two main categories of atmospheric OELs. "Health-based" OELs are set on the basis that adequate evidence is available to ensure that exposure at levels below the standard will be free from adverse health effects for nearly all workers. "Technical" OELs, while representing an exposure which is not believed to be associated with adverse health effects, cannot be considered to be entirely free from risk.

In addition to these two main categories, most OEL systems distinguish between longer-term – usually 8 hours – "time-weighted average" (TWA) limits and "short-term" exposure limits (5- 30 minutes, but usually 10 or 15 min) TLV-STEL.

The longest established health-based OELs are the threshold limit values published by the American Conference of Governmental Hygienists (ACGIH). In the EU, non-binding Occupational Exposure Limits are derived by the EU Commission, based on the input from ECHA Risk Assessment Committee. Under the Carcinogens, Mutagens or Reprotoxic Substances Directive (CMRD, 2004/37/EC), the EU sets binding Occupational Exposure limits for substances identified by prioritisation, again starting from a health based OEL derived by RAC followed by a review process by the Working Party on Chemicals under DG Employment.

EU Member States continue to maintain own non-binding and binding OELs. These may be more stringent than the EU ones, but not less protective. .

Compliance with OELs is mostly determined by workplace air monitoring. For some substances, especially showing systemic health effects after dermal absorption, biological monitoring is performed. In relation to chemical exposure, biological monitoring is the measurement of the concentration of a chemical substance or its metabolite in a human biological media: e.g. blood, urine, saliva, exhaled air.

Atmospheric OELs are based upon mg/m3 or ppm. BEIs are based upon percent of haemoglobin for blood sample, milligrams or micrometers per gram of creatinine for urine sample or in ppm of exhaled air.

The biological monitoring should be considered complementary to workplace air monitoring.

Because of the uncertainties surrounding their effectiveness in protecting health there is normally a requirement to reduce exposure below the standard as far as practical. Where substances being handled in connection with epoxy resin systems have been assigned official or voluntary OELs care should be taken that these levels are not exceeded.

Where no OELs have been set by legislators internal exposure limits (IEL) can be set by the producer or user of a hazardous substance.

For substances registered under REACH Regulation in EU, when chemical safety assessment is required, Derived no Effect Levels (DNELs) are determined. DNELs should be understood as the

levels of exposure above which humans should not be exposed. They are determined for different routes of exposure (e.g. oral, dermal, inhalation), different duration of exposure and different human population. DNELs are calculated on the base of toxicological studies results for the substance, with following factors taken into account: the uncertainty arising, from the variability in the experimental data, the nature and severity of the effect, sensitivity of the human (sub-population).

Most of DNELs cannot be determined by measurement, however they are used to establish set of conditions: both risk management measures and operational conditions which ensure the substance is used in a safe way and exposure for considered population is controlled.

8. First Aid

When accidental exposures occur the following procedures must always be followed:

INGESTION

In the unlikely case of accidental swallowing, drink lots of water in small quantities. Do not try to induce vomiting or apply house remedies. Get medical attention immediately

EYES

Following accidental contamination the eye should be immediately and continuously washed under running fresh water for at least 10 minutes. The installation of eye showers for this purpose is strongly recommended. In any case of contamination the person should be referred to a doctor for examination of potential eye damage and follow up treatment.

SKIN

Contaminated clothing must be removed immediately to avoid contamination of yet none exposed skin. In case of skin contact first remove most of the resin with a clean cloth without rubbing, then wash all affected areas thoroughly with water and a suitable skin cleanser (mild soap). Never use solvents. Cover potential lesions with sterile material. Cured resins are not hazardous and will peel off after a short time. In case of severe contamination or effects seek medical attention.

INHALATION

In case of accidental inhalation remove the individual to fresh air and keep at rest until any symptoms of respiratory distress have disappeared. If rapid recovery does not occur or where there is a danger of unconsciousness, call an ambulance and obtain medical attention.

Consult section 4 of the SDS for details on first aid measures. Some specialised systems and applications which may require additional precautions or first aid support. In these cases it is recommended that technical information and special instructions are requested from the supplier.

9. Glossary of Terms and Values

Terms, values and abbreviations used within the document are briefly described as:

Allergy

Immune response built up against a particular substance by repeated exposure, causing allergic reactions upon exposure to minute amounts of the substance.

ACGIH – American Conference of Governmental Industrial Hygienists

An organisation of professional personnel in Governmental Agencies or educational institutions engaged in occupational safety and health programmes.

Bio-concentration

The buildup and accumulation of a chemical in plants, animals and man to levels higher than found in the immediate environment.

BOD – Biochemical Oxygen Demand

A test that measures the dissolved oxygen by microbial life and oxidising the organic matter present in organic waste discharges.

Ceiling Value

The maximum allowable human exposure limit for an airborne substance which is not to be exceeded at any time. See also PEL and TLV.

Dermatitis

Inflammation of the skin, also called skin irritation. Symptoms are rash, itching, blisters, swelling and crustiness.

Epidemiology

Science concerned with the study of a disease in a general or specific population. Determination of incidence and distribution of a particular disease which may provide information about its cause.

IEL – Internal Exposure Limit

Internal occupational standard set by the manufacturer in the absence of an official governmental standard.

In vitro

"in-glass" or "in-silico" experiments with cells, tissues or parts of cells from organisms, conducted outside of the organism.

In vivo

Experiments in life animals.

Irritant

A chemical which is not corrosive that causes a reversible inflammatory effect on living tissue by chemical action at the site of contact.

Irritation

A condition of irritability, soreness, roughness or inflammation of a body part.

LC50 – Lethal Concentration

The calculated or directly measured concentration of a material in air or water that is expected to kill 50 % of a group of test animals with a single exposure (normally 1-6 hours, aquatic organisms: 48 – 96 hours).

LD50 – Lethal Dose

The calculated or directly measured dose of a material that is expected to kill 50 % of a group of test animals with a single administration within a period of 14 days post treatment.

MAC – Value Maximale Aanvaarde Concentratie

Occupational standard of The Netherlands. Maximum permissible time weighted average concentration (mg/m3) at the workplace for a 40-hour working week.

MAK – Maximale Arbeitsplatz-Konzentration

German occupational standard Maximum permissible concentration in air at the workplace in the breathing zone for 8 hours per day and 5 days per week.

MEL – Value Maximum Exposure Limit

UK occupational standard. Maximum concentration of an airborne substance, averaged over a reference period, to which employees may be exposed by inhalation under any circumstances.

Mutagen

A substance or agent capable of chemically altering the genetic material in a living cell.

Necrosis

Tissue destruction or death of tissue. Corrosive materials may cause localised tissue damage at the site of contact which will lead to scarring.

NOEL – No Observed Effect Level

The dose of a substance used in a test which produces no substance-related adverse effects.

Sensitizer

A chemical that causes the development of an allergic reaction in exposed people or animals after repeated exposure. (See allergy).

Somatic Cells

Body cells except germ cells.

STEL – Short Term Exposure Limit

Defined as a 15-minute TWA exposure which should not be exceeded at any time during a workday even if the 8-hour TWA is within the TLV-TWA.

Subchronic

A health effect resulting from the repeated daily exposure of experimental animals to a chemical for part of their lifespan. Subchronic in rodents means 28 – 180 days.

Synergy

The combined action of chemicals so that their joint effect is greater than the sum of their individual effects.

Systemic Toxicity

Adverse health effects caused by a substance that affects the body in a general rather than local manner.

Target Organ Effect

The effect of a substance on an organ which is more sensitive than the remainder of the body.

TLV – TWA –: Threshold Limit Value – Time Weighted Average

Occupational guideline developed by the ACGIH in the USA. Concentrations in air for a normal 8-hour work- day and a 40-hour workweek, to which workers may be repeatedly exposed day after day without adverse effects.

TLV-C – Threshold Limit Value Ceiling

Occupational guideline developed by the ACGIH in the USA. The concentration that should not be exceeded during any time of the working exposure.

TLV-STEL – Threshold Limit Value – Short-Term Exposure Limit

Occupational guideline developed by the ACGIH in the USA. The concentration to which workers can be exposed continuously for a short period of time without suffering from (1) irritation, (2) chronic or irreversible tissue damage, or (3) narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency, provided that the daily TLV-TWA is not exceeded.

TRK – Technische Richt-Konzentration

German occupational guidance value. Established for dangerous chemical substances (especially carcinogens, mutagens and substances that strongly bioaccumulate) for which at present no MAK value can be defined.

TWA – Time Weighted Average

See also TLV. Average concentration over an 8-hour period.

10. Literature for Further Reading

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This guide has been developed by Technical Experts of company members of Epoxy Europe, a Sector Group of Cefic, the European Chemical Industry Council.

The user should always refer to the Safety Data Sheet of the supplier of the material for specific and updated information.

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