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WHY AND HOW TO INCREASE SAFETY WHEN HANDLING HAZARDOUS CHEMICALS?

MANUAL FOR PROFESSIONALS HANDLING HAZARDOUS CHEMICALS

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INTRODUCTION

After some five years of teaching courses on handling poisons, and over twenty years of teaching courses on safe handling of chemicals for professionals, the need for additional training became evident, as earlier foreseen by the national legislation. The experience gained through lectures and exams, as well as through observations during subsequent field visits to a number of companies working with hazardous chemicals, especially chemicals harmful to human health and the environment, produced ample materials to complete the present manual. It was shocking to learn that there were virtually no reliable or coherent procedures in numerous companies, while the unsuitable choice of personal protective equipment (PPE) for the workers was even more shocking.

There were plenty reasons for writing a manual on further training in handling hazardous chemicals. It should be pointed out that, to be in line with the Chemicals Act and the EU definitions used therein, an effort was made to avoid using the term „poison“, at least in the title itself, but we remain supportive of the traditional toxicology conviction that anything harmful to human health constitutes a chemical dangerous for human health. To illustrate, sulfuric acid is a corrosive substance, and if someone drinks a glass of this chemical, their life will be at risk. The expression often used to describe this situation is poisoning, as evidenced in medical records. Naturally, this manual has attempted to fully adhere to the European regulations, and will try not to confuse the concepts in the heads of the attendees who have successfully completed toxicology courses, as defined by the former Poisons Act.

The basic concepts of the „harmful effects“ and „absorption of hazardous chemicals“ should be repeated, both because practice makes perfect in such a sensitive area, and because it introduces readers to new findings. It should be emphasized that the profession and science studying the effects of hazardous chemicals and protection against these advance rapidly, especially in terms of legislation. Therefore, it is necessary to hold supplementary courses at least every five years, if not sooner, and it is especially important to systematically update the literature and supplement course materials. This manual adheres to the global and EU tenets of lifelong learning.

1. BASIC CONCEPTS OF HARMFUL EFFECTS FOR HUMAN HEALTH AND LIFE

1.1. HARMFUL EFFECT AS A MEASURE OF HAZARD WHEN WORKING WITH CHEMICALS

Firstly, let us define the term „chemical“, according to the Croatian and EU regulations, as opposed to „substance“ or „mixture“. A „substance“ is any natural or synthesized chemical with a clearly defined structure, or matter with impurities obtained by isolation from nature (e.g. raw / unrefined oil), which is recorded in the relevant Chemical Abstract Service (CAS) Registry, under strictly defined numbers. Substances can be placed on the market as such (wholesale or retail), but, more often, „mixtures“ composed of two or more substances are marketed, whether as solutions or obtained by simply mixing two or more substances. „Chemicals“ include both substances and mixtures, and can be considered any material of natural (e.g. sand) or artificial origin (e.g. dishwashing detergent). Not all chemicals are dangerous to human health or the environment, but the problem is that dangerous properties are only known for a small number of substances and mixtures. To illustrate further, out of 110,000 substances coming to the EU market in annual quantities of more than 10 kg (for a total of about one million mixtures, based on said substances), dangerous properties of barely some 5,000 substances or ten times more mixtures are known and recognized. This does not mean that the remaining 105,000 substances are not dangerous. Far from it! It is believed that over 50 % of these are dangerous to human health and/or the environment, though there is no clear evidence that this is true (prescribed toxicological or other studies have yet to be performed). That the assumption of a large number of hazardous chemicals on the market is correct is also shown by the results of epidemiological research on a steady increase in CMR (carcinogenicity, mutagenicity, reproductive toxicity) effects or a significant increase in the frequency of allergies, compared to the situation some three or more decades ago. With Regulation (EC) No 1907/2006 (REACH), the EU has initiated an important process of identifying dangerous properties and the risk assessment for all chemicals on the EU market. The ultimate goal is to exclude any chemical substances from the EU market for which there are no data on potential dangerous properties (physico-chemical properties, effects on the human health and/or ecotoxicity).

Allergies are getting more common

1.1.1. WHAT IS MEANT BY SOMETHING BEING DANGEROUS AND/OR TOXIC?

Anything is poison in the wrong hands.

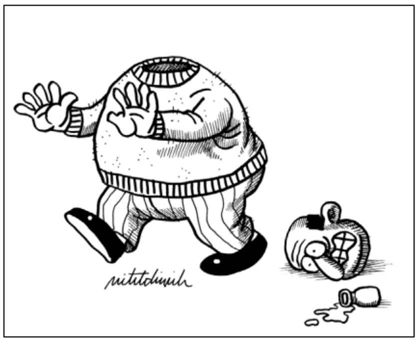
When we talk about toxicity, we refer to harmful effects to the body, or some part of it, due to external factors such as poisons. „Harmful effect“ is any temporary or permanent damage to the body or any part of it, whether it is a human or other organism Before moving on to types of damage, other terms from the above definition should be explained first.

1.1.2. TEMPORARY DAMAGE

Any such damage that will be repaired or will completely disappear on its own or with the application of suitable medical or other procedures. An example of a usual temporary damage is a skin injury (such as a scratch, burn, irritation) or other common problem (e.g. headache, dizziness, vomiting, diarrhea, etc.) that recedes after a short period and the injured person subsequently feels no unpleasant consequences of the effects of the chemical.

It will go away by tomorrow.

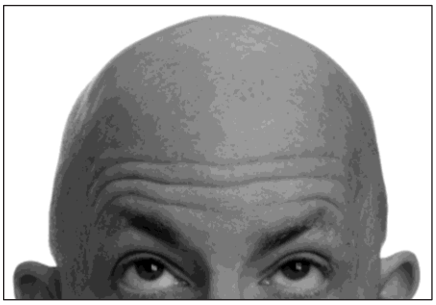
1.1.3. PERMANENT DAMAGE



Permanent effect

Any damage that cannot be completely undone or corrected, regardless of actions taken. If we use the above example, then permanent damage could be a scar on the skin. Although it may not be a major problem for the injured person, the scar is may present permanent damage. A much larger issue is any such permanent damage that makes life difficult (e.g. kidney failure or liver damage) or reduces its quality. The most severe is the permanent damage that leads to the death of an organism.

1.1.4. WHERE CAN DAMAGE OCCUR?



Baldness as a side effect in thallium poisoning.

Damage can occur anywhere, and the legislator makes a distinction in the type of damage according to its size or place of origin. Damage to the body (internal organs), skin and eyes is the most common type, which is why all relevant information concerning a hazardous chemical must be included in the accompanying safety data sheet, other supporting documentation, on the individual packaging or as a warning on visible places on the premise where the chemical is handled. The most important harmful effects will be discussed later, but it should be emphasized here that some chemicals are often associated with very specific effects, which need not be very important or even dangerous (e.g. the incidental occurrence of grey streaks on nails during poisoning by carcinogenic and extremely toxic arsenic compounds or temporary baldness in otherwise severe thallium salt poisoning).

All is green

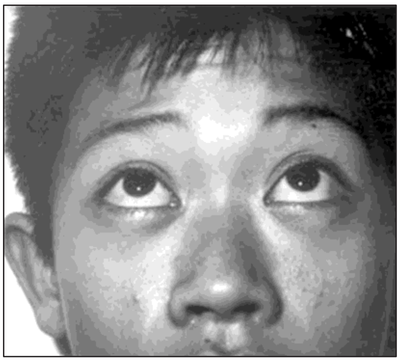
One of the interesting effects, which show what a hazardous chemical can do to the body, is visual field disorders. The phenomenon of green field of vision was documented in the great painter van Gogh. The fact is that his paintings were dominated by green tones, which certainly does not correspond with the landscapes he painted. The green color appeared due to a chronic abuse of absinthe, a herbal brandy popular at the turn of the 18th to the 19th century, due to whose frequent consumption, in one of his nervous wrecks, he cut off his ear. Today it is well known which plants cause this effect, as well as the effect of many other plants and medicines (e.g. digoxin). Whether the effect is harmful, tolerable or beneficial depends on the circumstances. For the great van Gogh, this undoubtedly had a detrimental effect on his health.

1.1.5. CAN A CHEMICAL HAVE BENEFICIAL EFFECTS?

Actually, it is a rare case that a chemical is used exclusively as a medicine for people who need it (e.g. toxic and explosive nitroglycerin as an antianginal). However, there are cases when a chemical that is not registered as a medicament happens to also possess certain (ambiguously) beneficial effects. There are numerous examples of substances that have certain effects of interest to drug addicts (e.g. amyl nitrite, previously used as an odorant for large halls and today as an antidote to cyanide poisoning, is a hallucinogen and aphrodisiac), while a typical misconception is the story on the usefulness of inhaling ammonia vapor to unclog the nose during a cold.

1.1.6. HOW TO DISTINGUISH HARMFUL FROM BENEFICIAL EFFECTS?

An example is given of the effect that some chemicals have on the vision field, but there are numerous similar examples. One is a substance called atropine. Atropine dilates the pupils when administered into the eye to prep the eye for medical examination of the ocular background. This is a useful effect as it allows diagnosis. Atropine extract was, in fact, used by ancient Roman beauties to make their eyes look more attractive. This could be said to be a desirable effect, although the resulting benefit to the organism is questionable. On the other hand, dilated pupils make life difficult for a person, since the eye is sensitive to the light and cannot function normally spatial orientation. This same atropine was once used as a remedy for stomach ulcers, as it reduced the secretion of gastric digestive juices, but, at the same time, it reduced the secretion of saliva and caused the mouth to dry. On the other hand, this saliva-reducing property was extremely useful in any upper airway or esophageal surgery, and atropine was administered before anesthesia to make it easier for the surgeon. To conclude, it all depends on what you consider to be a harmful or beneficial effect in a certain situation. Nevertheless, everyone can decide for themselves whether something is useful to them or not, even a medicament.



No iris. Only pupils.

1.1.7. RARE HARMFUL EFFECTS AND THEIR IMPORTANCE FOR PROFESSIONALS HANDLING CHEMICALS

A rare effect is one that occurs very rarely; e.g. among 10,000 or more people who come in contact with a chemical, only one person will have a detrimental effect and others will not, despite being exposed to the chemical in the same way. Croatian law very clearly stipulates that for every rare harmful effect of a chemical, the Ministry of Health must be informed, in order to prevent similar harmful effects in other people who may be exposed to it in the future. What is especially important to remember is that a chemical can have other undiscovered harmful properties in addition to those that must be on the label (pictograms). The reasons for rare harmful effects are numerous, the most common being hypersensitivity, resulting from a hereditary or acquired deficiency. A typical example is the rare persons who are not allowed to work with nitrates, nitrites or aromatic amines and hydrazines due to the poor function of the enzyme methemoglobin reductase. When working with similar substances, they experience constant headaches, dizziness and low blood pressure, as well as

I warned you about the rare harmful effects!

difficulties working, compared to the majority of people who are not sensitive to these substances. There are, naturally, many other examples of chemicals with rare effects, some of which may even seem useful

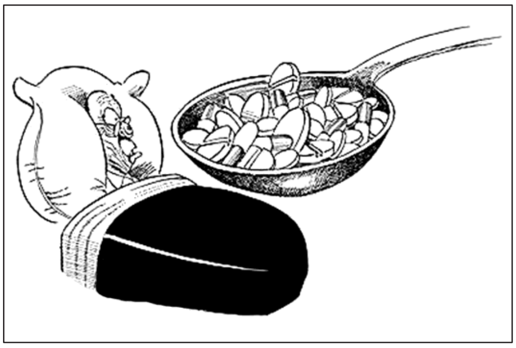
1.2. HAZARDOUS CHEMICAL AND DOSAGE

Regulations governing hazardous chemicals very carefully classify the related hazards, as will be shown later (e.g. toxins, corrosive and irritating substances, mutagens, carcinogens, reprotoxic or ecotoxic chemicals, etc.), but here, for simplicity reasons, the traditional toxicological definitions will be retained, focusing of the standpoint that a poison is anything that is harmful to human health or the environment. This toxicological approach does not violate the EU or the Croatian national regulations, and things are easier to explain.

1.2.1. WHAT CONSTITUTES A POISON OR A CHEMICAL DANGEROUS FOR HUMAN HEALTH?

A „poison“ to a living organism is any substance or mixture of substances which, when administered once or repeatedly in a given dose, causes temporary or permanent harmful effects in one of its parts or its entirety.

1.2.2. THE MEANING OF „DOSE“



The term **„DOSE“** is common in medical circles and refers to the amount of medicine a patient takes. However, the same term is used in toxicology to denote **the amount of a chemical** ingested, spilled on the skin or inhaled, in case of gaseous chemicals. Other routes of administration are also possible.

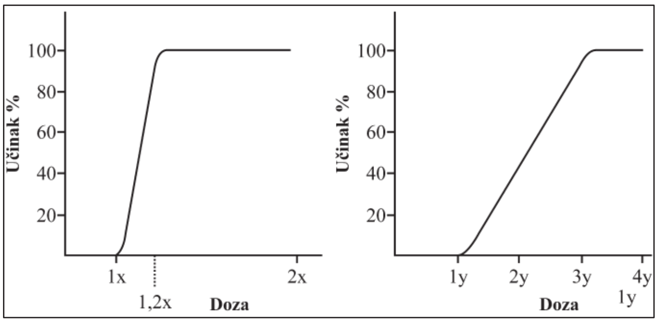
1.2.3. REAL-LIFE EXAMPLES OF THE RELATIVITY OF DEFINING SOMETHING AS A POISON OR A DANGEROUS SUBSTANCE

Even that which is essential for life can become toxic in certain circumstances. An environment composed of pure oxygen would be fatal, though in an environment without oxygen or with oxygen concentrations below 14 %, a person would die in a matter of minutes. The same can be said for other substances we consume. For example, table salt is not as necessary to us as oxygen or water, but without salt, life would be, at the very least, bland. This same table salt, consumed in large quantities, causes death due to cell dehydration (water leaves the cells). If table salt is ingested in increased amounts over a long period of time, severe harmful effects can be expected, such as kidney damage or chronic high blood pressure. Both types of table salt poisoning, resulting in a fatal outcome, have been recorded nationally. Table salt and oxygen are, nevertheless, not classified as poisons, but rather as substances necessary or, at least, important to sustain life.

The same occurs with other hazards, such as flammability. We all know that a significant number of chemicals in the environment are flammable, such as clothing.

However, we do not consider clothing a health hazard any more than we consider fried eggs toxic, except in people with high blood cholesterol levels. The legislator had to introduce a hazard assessment system, one that could determine, on the basis of real-life data, what needs special attention, whether in the workplace, the household or the environment. In general, this is not complicated when clear boundaries are set. In the case of flammable chemicals, the flash point or auto-ignition temperature at which a chemical becomes dangerous can be accurately determined, just as the level when a dose becomes toxic if limit values are clearly set (from the point of view of the legislator, a substance with a lethal dose (LD_{50}) higher than 2 g/kg, taken orally, no longer constitutes a poison).

1.2.4. DOSE-EFFECT RELATIONSHIP

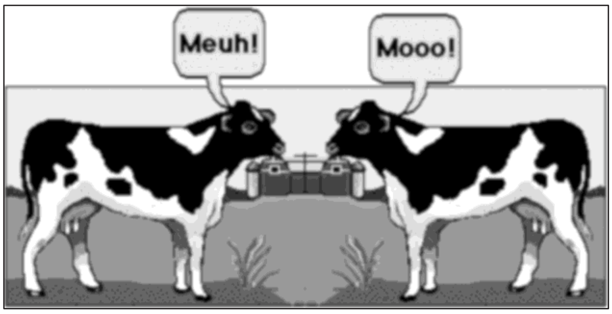


This is easily illustrated by a simple example of alcohol. With a very small amount of alcohol (e.g. a small glass of beer), most people will not feel any effects at all, but rather only the pleasure of quenching thirst. If one drinks a larger amount of beer, say a whole bottle, a significant number of people will feel some initial effects, such as improved mood, but also uncritical decision-making. Many may already notice a slowdown of movement or longer time needed to make a decision, which is why a person should not drive a car under the influence. If an even larger amount of beer has been drunk, the harmful effects will be more intense, even if the consumer does not understand or is not aware of it. The gait of the consumer is still normal, they may speak clearly and think they are sober, but they are no longer capable of performing demanding tasks such as operating an industrial machine. After an even greater amount of beer, the effects of alcohol are first observed on the gait, speech, speed of reaction, etc., while a still higher dose will constitute severe intoxication, which leaves at least temporary harmful effects on the person under the influence. Adverse effects can be so severe that they require hospitalization, while alcohol-related deaths are reported globally on a daily basis. In a similar way, any chemical can be harmful to the body, depending on the size of the administered dose.

This can best be seen from the dose / effect curve, where it can be observed that by increasing the dose, the observed effect also increases. At low doses, no effect is observed, while a certain (narrower or wider) range of doses causes the effects to be amplified to the maximum. Once the maximum effect is reached, a further increase in dose will have no effect on the body. It makes no difference whether the consumer takes one or three liters of spirits, if a single liter results in death. However, there are extremely low doses with no resulting effects whatsoever.

1.2.5. WHEN IS THE EFFECT OF A POISON STRONGER AND WHEN WEAKER?

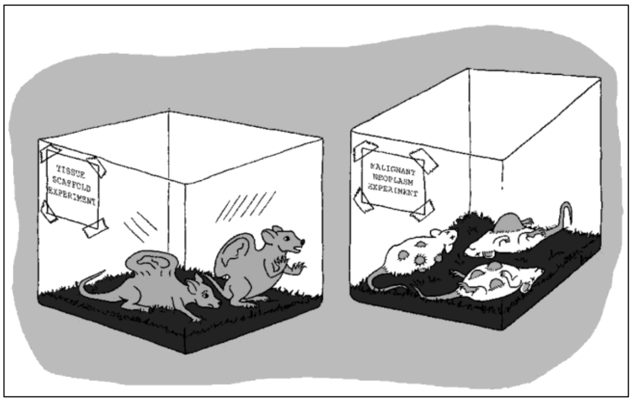
It is clear that a poison will not have the same effect on every person, because the effective dose will depend on many factors, such as age, gender, health, physique, resistance to the poison, etc. If we take the above alcohol example, it is easy to prove that children will be more sensitive to alcohol than adults, just as a sick person will be more susceptible than a healthy one. Sensitivity to alcohol will be affected by body mass, frequency of alcohol consumption, type of food eaten before consumption, and many other factors. Different people will demonstrate different susceptibility to alcohol, but, also, even the same person will manifest different levels of susceptibility in different cases. According to EU regulations, this does not classify alcohol as dangerous, except on account of its flammability. Clearly, it is difficult to predict how sensitive an organism will be to a hazardous chemical in different



No two sisters are identical.

circumstances. Ultimately, the best protection against the effects of poisons is avoiding exposure. Furthermore, not everyone is equally sensitive to hazardous chemicals at any given time of day, week, month or year. Humans are a part of nature and we are susceptible to our own biological rhythms (e.g. daily, monthly, annually, etc.). We are not equally susceptible to hazardous chemicals at all times of the day, nor will our body intake or excrete them in the same way. A special problem is the disruption of these rhythms, say, when someone who is a morning persons, used to working during the day and sleeping at night, is transferred to the night shift, or the infamous jetlag, when 12 or more hours are lost in a flight across different time zones, and one struggles for days adapting to the suffered physical stress.
It is not merely a psychological challenge to adapt to a stressful situation, it is also a dramatic physical exertion. One of the reasons for frequent accidents involving chemicals at night is the morning persons' difficulty to adapt to sporadic night shifts. There are numerous examples of the effect of biological rhythms on chemical absorption. One example is acetylsalicylic acid (the main ingredient of Andol and Aspirin), which, for the morning person, is excreted significantly faster in the morning than in the evening, and, hence, is more effective in the evening than before noon. Let us conclude with the example of the male hormone testosterone, which demonstrates the highest levels in autumn and winter, and contradicts the myth of May romance.

1.2.6. WHAT IS THE MEANING OF DATA ON SUBSTANCE TOXICITY?



Toxicity for an organism or some part of it does not automatically mean human toxicity. **Most toxicity data have been obtained from laboratory animal experiments**, involving rats, mice, rabbits, guinea pigs, dogs, pigs, etc. There are very few quantitative data on human toxicity for most substances. A person may be admitted to a hospital for
unintentional ingestion of a certain amount of ethylene glycol (an integral part of antifreeze), the concentrations of ethylene glycol in their blood can be measured and their oscillations with the application of suitable medical procedures may be monitored, and the course of recovery may even be compared against the damage caused in the patient. However, the dose-response relationship is still a mystery, due to unreliable data received from patients.
Therefore, a convention was agreed upon, and later legalized, to use animals for testing the harmful effects of substances or their toxicity. Though the obtained toxicity data does apply quite well to an animal, no one can be sure about toxicity for other species, or about the effect of the test substance on humans. Statistically, the test substance can be expected to have similar effects on humans but humans may also be more or less sensitive to the test substance than the experimental animal. These differences are unlikely to be large and the results from animal experiments can be a reliable approximation for alerting people about the dangers associated with a substance, but the data is still uncertain.
Traditionally, toxicity test results were obtained through experiments on rodents (e.g. rats, mice, guinea pigs), and today we understand that these species differ significantly from humans, especially in the structure of the digestive system. For testing of particularly important chemicals, such as

medications, experiments are done on pigs (today, a special breed of small pigs or "minipigs", which are very similar to humans in many ways) or dogs (e.g. the beagle species), but uncertainty about test results still remains.
Substances less dangerous for the health of humans than, say, for pigs, are less of a concern than substances not particularly dangerous for pigs being precarious for humans. More reliable data are obtained from epidemiological studies of people exposed to certain substances, most often in the workplace. These helps conclude when and how to improve the protective measures against the harmful effects of a substance. A typical example is vinyl chloride monomer (a raw material used in the preparation of the infamous PVC, widely used for the production of diverse general use items), which has long been known to cause liver tumors, as a result of prolonged exposure in the workplace, while dose and time exposures are associated with tumor incidence. Toxicologists were caught by surprise when this virtually harmless chemical proved to be carcinogenic. This example best explains why most national legislations insist on constant monitoring of the health of people exposed to chemicals, and it would be wise to be extremely careful when working with any chemical, always keeping in mind one’s health.

I’ll give you the information later. Cure me, first

1.2.6.1. Official classification




Until recently, a relatively simple classification of dangerous substances into three groups of poisons was used, and was, for the most part, considered user-friendly. However, the EU has long sought a different approach, focusing on hazard symbols, and, more recently, pictograms, to define hazards more precisely (not more user-friendly). For details, consult the Chemicals Act and CLP Regulation, as this is just an overview. Dangerous substances are classified as follows:

- explosive substances and mixtures,
- flammable gases,
- aerosols,
- oxidizing gases,
- pressurized gases,
- flammable liquids and solids,
- self-heating substances or mixtures,
- pyroform liquids and solids,
- self-reactive substances and mixtures,
- substances and mixtures which, in contact with water, release flammable gases,
- oxidizing liquids and solids,
- organic peroxides,
- substances and mixtures corrosive to metal,
- acutely toxic substances and mixtures
- substances and mixtures corrosive to the skin / that irritate the skin,
- substances and mixtures that cause severe eye damage / irritation to the

eye,
- substances and mixtures that cause respiratory / skin sensitization,
- substances and mixtures toxic to a target organ after single exposure,
- substances and mixtures toxic to a target organ after repeated exposure,
- substances and mixtures that pose a risk of aspiration
- mutagenic substances and mixtures,
- carcinogenic substances and mixtures,
- substances and mixtures toxic to reproduction,
- substances and mixtures dangerous for the environment,
- substances and mixtures dangerous for the ozone layer

It should be noted that this is not a definitive list of labeling elements and special warnings on chemicals. A good example is asbestos, which, due to its carcinogenicity, has been given a special place in the classification of chemicals and has a special hazard symbol. Asbestos has grown into a problem of the future on account of its massive prevalence in diverse building materials, machine parts and other places. Special warnings have also been foreseen by legislation, such as "contains isocyanates", etc.

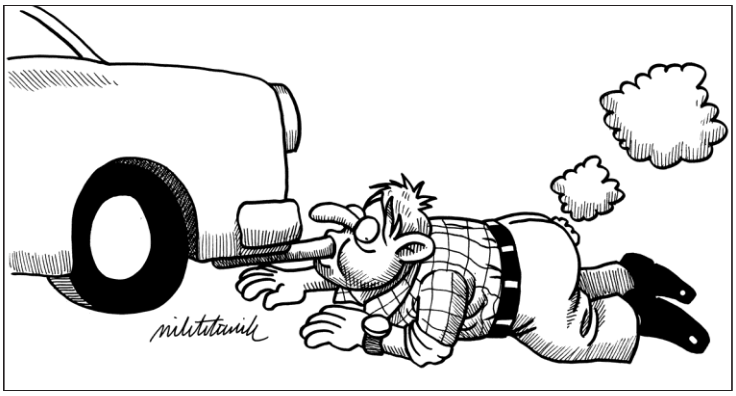
In the cards included in this manual and the safety data sheet for a particular chemical, all the special hazards associated with the chemical can be found.

1.2.7. ACUTE AND CHRONIC EXPOSURE TO A HAZARDOUS CHEMICAL

Acute exposure is considered to be any exposure of one day or less, while chronic exposure implies any period longer than three months. In fact, acute exposure is considered to be a single intake of a chemical, while chronic exposure is long-term exposure to a chemical (e.g. at work, in the environment, due to ingestion, etc.).

Dosage is only important in cases of accompanying harmful effects. In acute poisoning, effects occur quickly, after a single dose of the chemical applied over a short time, while in chronic exposure, harmful effects are observed only after long-term intake of the chemical. What does single-dose ingestion in a short period mean in practice? In case of ingestion, one swallowed dose is implied, whereas, for inhalation, a single-dose would cover one workday or the time spent in an environment contaminated with gaseous, aerosol, droplet or powdered chemicals. In any case, a period shorter than one day is defined. Chronic intake considers exposure to a poison on several occasions or continuously over a longer period.

There is a widespread misconception that a chemical hazard is determined solely by the LD_{50} (lethal dose for 50 % of exposed animals), which is not true.



This is ridiculous. Chronic exposure is more efficient.

LD_{50} is a mere starting point in assessing the hazards associated with a chemical. A number of other data must be taken into account. The fact is that all the animals that take part in an experiment are, eventually, sacrificed, and numerous experiments are performed on their organs in order to determine what kind of damage the chemical could cause, even if rare and minimal. What if a cataract is found in 0.01 % of the animals after chronic exposure? This must be taken into account and the effects of the chemical further studied. In addition to the toxicity to individual organs and systems, adverse effects on reproduction, mutagenic or carcinogenic potential, or any other adverse effects (e.g. endocrine disruptors) must also be closely monitored. Croatia, like other

European countries, has an expert commission responsible for studying the documentation on hazardous chemicals and deciding whether and under what conditions these can be placed on the EU market. Responsibilities are sky high, which is why such a stringent system of approval must exist.

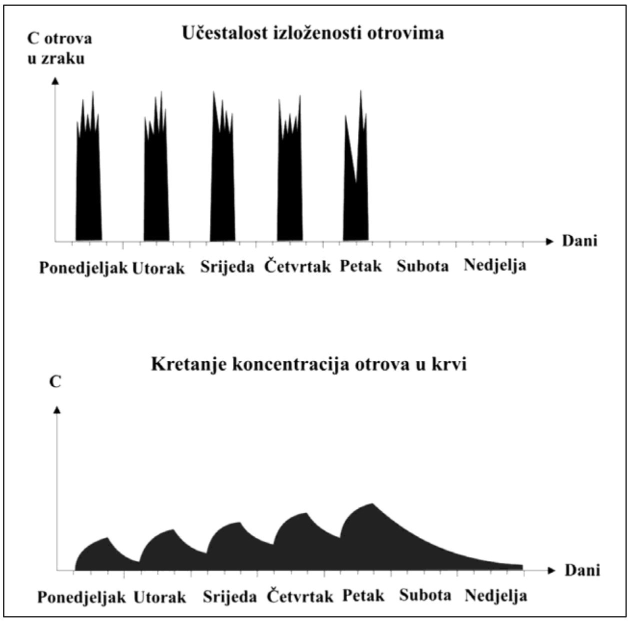
1.2.8. FREQUENCY OF EXPOSURE TO A HAZARDOUS CHEMICAL

In addition to the notion of exposure, frequency of exposure to a chemical is another term that requires explanation. The international term of „frequency of exposure“ to a chemical is associated with long-term (chronic) intake of a chemical on more than one occasion, i.e. a longer period of intake of a chemical interrupted by periods of no exposure after working hours. A typical example is exposure at the workplace, when the worker is exposed to the chemical during work, while the remaining time is spent away from work and the body is not exposed to the chemical.

This means that the worker will be exposed to the chemical every day from 7 am to 3 pm all workdays from Monday to Friday, while weekends break their exposure routine, as well as any workdays away from work. However, exposure to a chemical is not the same as exposure to the effect of the chemical after entering the body and circulating through the bloodstream. Such exposure depends on the length of retention of the chemical in the, its toxicokinetics

Early exposure.

1.2.9. ORGANISM EXPOSURE TO THE ACTIVITY OF A CHEMICAL



The notion of exposure to the intake and the action of a chemical should also be explained. Exposure to a chemical, as explained earlier, lasts as long as the chemical enters the body, while exposure to the action of the chemical takes as long as it remains in the body in doses high enough to achieve a harmful effect. The difference is significant, as exposure to the intake of a chemical does not necessarily mean poisoning, while the chemical is dangerous as long as the amounts at the site of interaction are high enough to cause harmful effects. To illustrate, inhalation ceases at the very moment when the worker leaves the area where the air is contaminated with the chemical or when they put on personal protective equipment (PPE) at work. Ingestion (e.g. swallowing a chemical) will last as long as the chemical is retained in the part of the digestive system from which it enters the bloodstream (absorption). However, the chemical has a specific route through the body, which will be discussed in more detail in the chapter on absorption. The chemical is likely to linger in the bloodstream or in one of the storage sites (very often, body fat, bones, bone marrow, etc.) for a very long time and have a harmful effect. The now long-banned (as of 1968) insecticide DDT can serve to illustrate. To this date, it can be found in our fatty tissues, because it is stored there permanently and is not excreted.

Certain unverified data show that it takes over 20 years for DDT concentrations in fatty tissues to drop to a half of their initial value, but its elimination half-time from those tissues seems to be significantly longer. Chemicals that remain in the body for a long time pose a special hazard, and DDT is one of them.

1.3. COMBINED EFFECTS OF SEVERAL SUBSTANCES

Two or more substances that are found in the body at the same time can have completely different effects on the body than they would each have one their own. Some of them may be normal constituents of the organism or substances that are not considered poisons at normal doses. However, there are very few reliable data on the combined effects of different chemicals in the human body, especially when it comes to long-term exposure in the workplace or the environment. This does not mean that interactions are not more numerous, but rather that they are difficult to prove or detect, especially if persons exposed to chemicals do not go for regular medical check-ups. The focus of study here is finding ways to defend against harmful effects intensified by chemical interaction. The combined adverse effects of two chemicals can be strengthened in the following ways:

– adding of effects (additive interaction),
– intensification greater than the sum of effects (synergistic interaction),
– disproportionate intensification of effects (exponential interaction)

The more – the worse!!

1.3.1. ADDING OF EFFECTS (ADDITIVE INTERACTION)

The simplest of interactions is the **adding of effects** that occurs when two chemicals have the same kind of effect on the body, e.g. raising blood pressure, but each in a different range. If such two chemicals are found in the body at the same time, then their effects will simply add up: for example, if each of them, in their respective concentrations, elevate the blood pressure by 20 %, then their combined effect will be a 40 % increase in blood pressure. This interaction is easy to understand, but does not occur very often.

When brothers join hands!

1.3.2. INTENSIFICATION GREATER THAN THE SUM OF EFFECTS (SYNERGISTIC INTERACTION)

An increase in effects greater than the sum of individual effects also occurs between two substances with the same harmful effect on an organism, but said increase will be significantly greater than the sum of their respective effects. If we take the previous example, the final blood pressure of the exposed person would increase by 100 % or more, although the expected sum of the interactions is lower. This type of combined interaction is, therefore, very unfavorable, especially so in the case of severe and permanent adverse effects of long-term exposure (e.g. cancer).

$$1 + 1 = 10$$

1.3.3. DISPROPORTIONATE INTENSIFICATION OF EFFECTS (EXPONENTIAL INTERACTION)

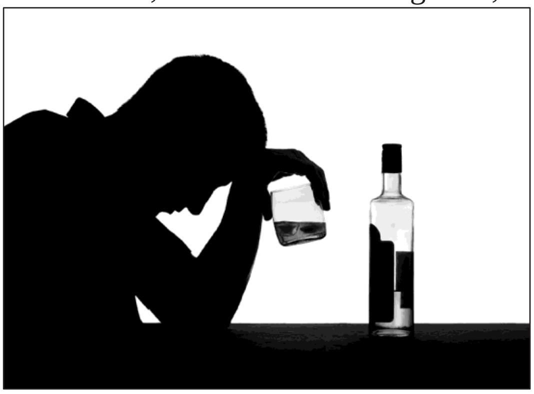
Finally, an increase in activity occurs when a substance with a harmful effect is found in the body in combination with another that does not show any such harmful effects, or not at a given dose, and yet there is a significant intensification of the harmful effect of the first substance, when the two meet inside the body. This interaction is particularly detrimental, as it is usually not expected, and is difficult to predict what may intensify the harmful effect of a poison, especially when it is just a regular constituent of the organism, food or drink, etc.

$$1 + 0 = 15$$

1.3.4. REASONS FOR INTERACTION

Interactions can occur at different levels, from facilitating the entry of chemicals into the body (enhancing absorption), to interactions at the cellular or molecular level. It is important to emphasize that most of these harmful phenomena remain unknown to this date. However, one thing is well known: the risk of adverse effects is reduced by limiting the entry of various harmful substances into the body. Let us analyze an example of interactions with alcohol. These can occur at different levels, from entering the body to interacting at the molecular level.

To illustrate, when alcohol is ingested, it will intensify the action of various chemicals (primarily, many insecticides), by enhancing their absorption from the digestive system, and thus result in a typical case of an effects boost. Alcohol will produce a variety of effects at the molecular level, from desirable to those extremely dangerous. The simplest way of avoiding multiple interactions with alcohol is not to consume alcohol and chemicals at the same time and, by extension, never to consume alcohol at the workplace when working with chemicals.



Unfortunately, in the case of alcohol, there is an additional problem to chronic use (alcoholism). Alcoholism significantly changes the metabolism in the human body and causes various harmful effects. Alcohol, for instance, accelerates the metabolism of many foreign substances due to increased synthesis of numerous metabolic enzymes. Another example is the case of accelerating the formation of free radicals of short halogenated hydrocarbons (such as chloroform, tetrachloroethylene, etc.), which are very toxic to the liver, which is why a chronic alcohol user should not work with said substances due to the risk of toxic hepatitis.

1.4. TYPES OF HARMFUL EFFECTS

The legislation foresees a specific classification for various types of toxicity. Here is a list of some:

- acute general toxicity,
- chronic general toxicity,
- corrosive activity,
- irritation and hypersensitivity,
- mutagenic effects,
- tumor induction (carcinogenicity),
- harmful effects on fertility,
- harmful effects on the fetus,
- harmful effects on offspring,
- ecotoxicity,
- other (e.g. severe hormonal disorders, developmental changes in a species, etc.).

1.4.1. ACUTE TOXICITY

The onset of signs of **acute toxicity** in connection with a chemical refers to a single high-dose intake and the consequences that occur in the body. Though the most fatal consequence is death, other harmful effects should not be neglected either. They are manifested in organ damage, which can lead to disability of the exposed person. Cases of acute poisoning are usually associated with accidents at work or with the (un)intentional ingestion of large amounts of toxic substances. At this point, it is not only a matter of how toxic the chemical is, but also the quantity that entered the body. Ethylene glycol (the main ingredient of antifreeze), for instance, is only classified as a harmful substance, but if swallowed in sufficient quantities can cause death or severe disability in humans due to kidney damage as a result of action of one of the metabolites of ethylene glycol (oxalic acid). It would be a mistake to think that it is dangerous to work only with very toxic or very corrosive chemicals, such as sulfuric acid, and that other chemicals can be handled carelessly. Even a substance not classified as dangerous can cause severe damage to the human body. And even if there are no permanent severe consequences, acute poisoning is an extremely painful and unpleasant experience.

Most common unspecific effect.

According to the regulations, acute toxicity is expressed by a dose of a chemical sufficient to cause death in 50 % of experimental animals (**LD_{50}, lethal dose for 50% of animals exposed to the poison**). LD_{50} is frequently mentioned in relation to ingestion, dermal exposure or inhalation of a chemical. Keep in mind that the differences in toxicity of most substances on humans and experimental animals are not that great. Significantly lower doses than LD_{50} will still affect the exposed organism severely.

Animal experiments show how a single intake of a chemical in different doses will affect individual organs or certain body functions. These data are valuable to clinicians for treatment of poisoned persons, and to the legislator for defining protection measures against a particular chemical. All workers should at least know the most important harmful effects of a chemical (e.g. damage to the kidneys, liver, central nervous system, heart, etc.) to estimate any consequences of their negligence when working with hazardous chemicals.

Typical injuries after swallowing strong acids or alkalis

Being familiar with the data on **corrosive or irritant effects that a chemical manifests in contact with the eye, skin and mucous membranes** is vital, because they will determine occupational safety measures, as well as information on vulnerable body parts that need special protection.
All information on the acute harmful effects of a chemical is given in the safety data sheet or other accompanying document, which must be supplied to each buyer at the first purchase, upon any update of the document and on special request.

1.4.2. CHRONIC TOXICITY

Chronic toxicity occurs with any long-term intake of a chemical in the body, with more or less regular frequency, and at different doses. Usually, the doses of chronic intake are much lower than in acute poisoning, but chronic exposure will still occur even when an individual dose is so small that it would otherwise, as a one-time incident, not cause any harmful effects.
Data on the chronic adverse effects on certain organs or body functions are obtained primarily from animal test models, but also from epidemiological studies on groups of people who were exposed to a chemical for a long time in the workplace or the environment. Special attention in these studies is paid to harmful effects on organs, such as central and peripheral nervous systems, heart and hematopoietic organs, lungs, digestive system, kidneys, liver, reproductive organs, endocrine glands, skin and mucous membranes, muscle tissue, eyes, etc. The European Union prescribes, in great detail, the methods of testing harmful effects, and the results are carefully studied, both at national level and at the European Chemicals Agency, to classify individual substances according to their toxicity by harmonizing them at the highest level.

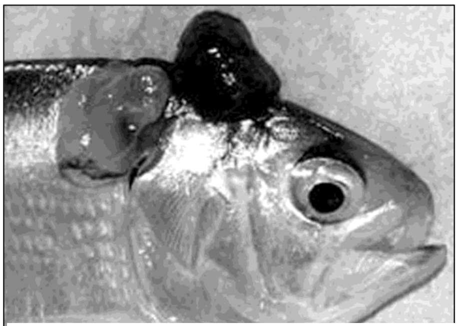
Typical gangrene in chronic exposure to arsenic.

Great attention is also paid to research in special effects, such as hypersensitivity or insensitivity to chemicals. Hypersensitivity to chemicals is an increasingly more common phenomenon in 10 % of European women who are hypersensitive to nickel, which is found in cheap jewelry, certain euro coins or in stainless steel cookware. Insensitivity is no less a problem, because exposed people miss a warning signal about excessive exposure to a hazardous chemical. Leaving aside the specific problem of allergenicity, which is not the subject of this manual, it must be said that the frequency of this phenomenon is growing dramatically across the EU, and is probably associated with increased exposure to all kinds of chemicals.

1.4.3. MUTAGENICITY AND CARCINOGENICITY (THE ABILITY OR TENDENCY TO CAUSE TUMORS)

These are very complex and often incomprehensible events. Mutagenicity is the occurrence of harmful effects on genetic material or DNA (deoxyribonucleic acid), with a very potent effect in the body. Chemicals can cause mutations by various mechanisms, either because they are reactive, by nature, or because their metabolites are reactive. Consequently, a mutation occurs by chemical alteration in the genetic material, whereby the affected DNA molecule changes its own properties in an unknown way. The key problem is that the cell affected by said change in the genetic material is no longer the same and no one can predict its future behavior. However, there are various mechanisms for correcting such damage and, by activating them, the genetic errors may very well be removed, which is, luckily, often the case and any consequences of the harmful event are thus prevented. A person can live with altered genetic material for a very long time, if the altered cell

does not replicate and a malignant tumor appears.
There are numerous external and internal factors that can stimulate the development of cancer or accelerate this process, but this will not necessarily make matters worse. The problem occurs when a tumor is differentiated and further develops with the onset of metastases. This phenomenon is called carcinogenicity. Despite numerous studies, it is difficult to monitor the process of carcinogenesis, which is typically long-term (takes over 20 years from exposure to a differentiated tumor), irreversible (once cancer occurs there is no going back), associated with chronic exposure to minimum doses of a chemical (acute exposure to a single dose equal to the sum of all doses in chronic exposure will, almost certainly, not cause cancer).


Fish can get cancer too.

The number of external or internal factors that can slow down or accelerate carcinogenesis is obviously extremely large and, in most cases, understudied.
Carcinogenicity is an extremely dangerous property, and it is imperative to determine which chemicals possess it. In the past, there had been several cases of late detection of carcinogenicity associated with various chemicals, and a typical example was the poor protection against vinyl chloride monomer. No special protection measures were taken in the plants for the production of this polymer, as vinyl chloride monomer did not manifest significant toxicological properties in acute exposure. Subsequently, workers began to develop liver tumors, especially those exposed to higher concentrations over a long period of time (e.g. in the maintenance of polymerization reactors), and only then were measures taken to enhance the protection of workers.
It should be kept in mind that carcinogens are divided into three groups / categories, according to their probability of causing cancer. The first group / category 1.A includes substances that have been proven to cause cancer in humans, such as benzene (a typical component of gasoline), vinyl chloride, asbestos, chromates, arsenic compounds, etc. The second group / category 1.B of carcinogens includes those substances for which there is no evidence that they can cause cancer in humans, but have been proved to cause it in at least two animal species, and are, hence, suspected to cause cancer in humans. These two groups / categories of hazardous chemicals are under constant monitoring, and long-term exposure should be avoided. They may only be used professionally on designated premises and for purposes allowed. Finally, the third group / category 2 includes such carcinogenic chemicals for which there is evidence that they are mutagenic in at least two laboratory models, but there is no evidence that they cause cancer in animals or, even less, in humans. However, they do pose a certain risk and this should be taken into account when handling said chemicals, as their carcinogenicity may be proven in the future as a result of more thorough research into the dangerous properties of chemicals.

1.4.4. REPRODUCTIVE TOXICITY

The findings about external factors having an effect on reproduction have long been known, but did not receive much attention until the "Thalidomide Tragedy". At the beginning of the second half of the twentieth century an analgesic (painkiller) called thalidomide appeared on the European market. It was deemed acceptable because of the few side effects it manifested, until it was discovered to have an antiemetic effect (against nausea and vomiting). Very soon after it was prescribed to pregnant women in their first trimester to help alleviate the nausea typical of that period of pregnancy. The result of this antiemetic medicine proved to be disastrous, as numerous children were born with absent or malformed limbs. The tragedy prompted toxicologists to study this horrific effect more closely and, subsequently, extend the research to other possible adverse effects on reproduction. Today, the EU regulations clearly stipulate research in the following types of reproductive toxicity:

a) harmful effects on fertility,
b) harmful effects on the fetus,
c) harmful effects on offspring,
d) other harmful effects (e.g. endocrine disruption, developmental changes in a species, etc.).

As with carcinogenic chemicals, reprotoxic chemicals must also be specially labeled under the category of reproductive toxicity. Chemicals proven to be reprotoxic are labeled »repro.cat.I / Repr. 1A«; the chemicals proven to be harmful only to animals are labeled »repro.cat II / Repr. 1B« and, finally, »repro.cat.III / Repr. 2« label is attached to such chemicals for which only laboratory research indicates reproductive toxicity.

Consequences of exposure to defoliants during the Vietnam War.

1.4.4.1. Effects on the gonadal function

It is most often a case of affecting the synthesis of sex hormones by different mechanisms, and the consequences can vary greatly, such as:

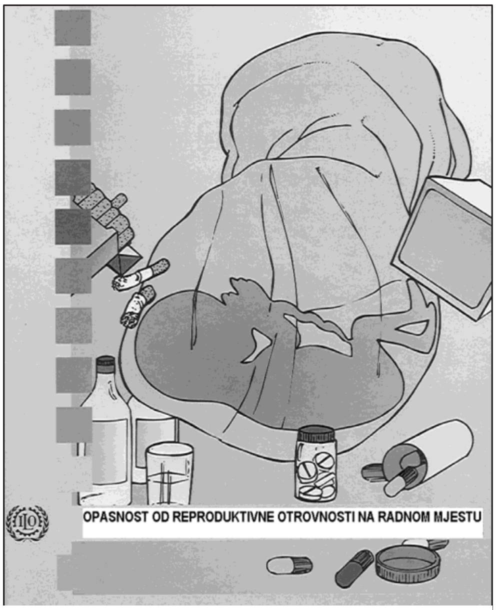
– inducing temporary or permanent sterility,
– changes in potency or libido (decrease or increase),
– impacts on biological cycles and their disturbances,
– other effects (e.g. endocrine disruptors, hirsutism, etc.).

Though the effect of reducing fertility has been vastly studied and quite a lot is known about it today, the area is still relatively unexplored. Various mechanisms reduce the fertility of men (e.g. by reducing sperm motility) or women (e.g. adverse effects on the ovum). The effects can be temporary or permanent, but the key is that they affect the couple together. There are many chemicals with such properties and those with well-proven effects are placed under restriction (e.g. lead compounds). The new approach to registration of chemicals increases the number of substances for which this effect has been proven and this will have a far-reaching impact on the work processes and protection methods for persons of reproductive ag

1.4.4.2. Harmful effects on the fetus

Another harmful reproductive effect, also called teratogenicity, is the most dangerous, according to current findings. The fetus is especially sensitive to any potential external effect, especially in the first trimester, because it undergoes amazing transformations. From one fertilized egg, a recognizable human figure is formed during this stage. First, the ovum splits into millions of new cells, creating a critical mass from which each cell will recognize what its role is. Some will turn into the heart, others into the limbs, still others into the brain, etc. After that, the cells begin to form organs, and these gradually take on their role. All of these events are extremely complex, while cells and organs are exceptionally sensitive to any external stimuli at this stage.

Chemicals that pass through the mother's bloodstream to the fetus can now have a lethal effect and the mother should, thus, refrain from taking any chemicals, drugs or addictive substances. Otherwise, the likelihood of fetal damage and the birth of a child with defects increases.



Unborn baby is exposed to whatever the mother is exposed to.

1.4.4.3. Harmful effects on offspring

The growing fetus receives chemicals from the mother's reserves (e.g. substances such as dioxins from her fatty tissue) or chemicals to which the mother is exposed during pregnancy (e.g. medication, drugs, chemicals from the workplace, etc.). The uptake of chemicals from the mother continues during breastfeeding, as many chemicals accumulate in the fatty breastmilk. These chemicals can be stored in the body of the fetus or can cause damage immediately after ingestion. What are the consequences?

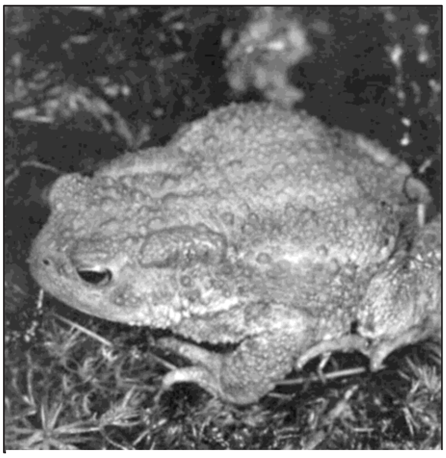
The consequences can vary. Early effects of hazardous chemicals have been demonstrated, from those that slow the child's growth and affect its memory or ability to learn, to those that may affect its reproduction (e.g. sterility) or carcinogenicity. Consequently, a daughter or granddaughter of an exposed person may get breast cancer at the age of 20. What alarms toxicologists and scientists is the fact that generational toxicity is being studied even on members of the third generation, i.e. great-grandchildren.

Is this your potential offspring?

1.4.4.4. Other harmful reproductive effects

There are many other adverse reproductive effects of chemicals, while a significant number cannot even be recognized or predicted. Our knowledge about the so-called endocrine
Disruptors have, in the meantime, gradually expanded. So far, such effects have only been found in frogs and similar amphibians. Due to the effect of chemicals, male frogs are becoming extinct and turning into hermaphrodites (intersex), thus, threatening the reproduction and survival of frogs. It has not been proven that similar harmful effects are possible in humans, but they should not be ruled out.

The effects of chemicals on the hormonal balance of humans and animals have been documented. One such phenomenon is hirsutism, mostly studied in women. This is not a particularly significant effect, in terms of impairing quality of life, because it is merely a question of enhanced hair growth. Though hirsutism is merely an aesthetic problem for sensitive women, it is still rather stressful.



Male frogs are dying out, while female frogs cannot extend the species on their own.

One of the most controversial adverse effects is a species change. Toxicologists fear that certain chemicals may cause a new species to develop, one closely related to man, but still different. To illustrate, horse and donkey are related species, but they are not the same. They can even mate, but their offspring will be a half-breed (mule or hinny). Though a new species has never been documented as a result of the impact of chemicals, theoretically, such a possibility exists. Fortunately, there is no evidence to support a similar evolutionary change in any of the mammalian species, but only in simpler organisms, such as bacteria or fruit flies. Lack of evidence, though, is not enough to rule out any similar effects of the chemicals on the human species.

1.4.5. ECOTOXICITY

Typical image of fishing mortality.

Ecotoxicity is the occurrence of adverse effects of chemicals in any living organism in the environment into which the chemical has been introduced. It should be emphasized that chemicals pose an environmental threat to humans in form of chronic exposure. This is reason enough to try to protect the environment from the introduction of chemicals into any part of it, since environmental pollution threatens both the person responsible for it and their offspring by virtue of long-term exposure. Moreover, chemicals in the environment are subject to various processes. A typical example of a chemical reaction is the combustion of PCBs (polychlorinated biphenyls) and other halogenated organic molecules, producing various byproducts, the most dangerous of which are dioxins or benzofurans (more precisely, polyhalogenated dibenzodioxins and dibenzofurans). According to the latest findings, some dioxins are, arguably, the most toxic small molecules that man has ever produced. The problem with dioxins is that they also occur during chemical reactions (e.g. synthesis of some pesticides), and pose a threat to man, when handling impure chemicals. Dioxins are also produced through microbial decomposition of municipal waste and other types of waste, so they are, obviously, dangerous to humans. An example of a biological transformation of a chemical can be best illustrated by mercury. When mercury is released into the sea, it enters fish, where it is metabolized into a much more dangerous substance, such as methylmercury. Methylmercury is very toxic to humans and, after long-term exposure, causes severe adverse effects, by saturating the body by consumption of fish contaminated with methylmercury. The most severe case of methylmercury poisoning occurred in a small Japanese town located in Minamata Bay, now known as the Minamata disease.

Why is it important to know the toxic effects of chemicals on different organisms in the environment? The reason is that every disturbance in a small part of the environment is reflected in all its segments, and the human species, like other living beings, are a part of that environment. Our species itself depends on this complex ecological equilibrium, much like our entire economy. Here is an example from the recent past of the globally significant application of an insecticide better known as DDT. Its application after WWII was extremely extensive and contaminated the global environment. Consequently, DDT was detected in fatty tissues of the Inuit population (though the Inuit had never used it) in higher concentrations than among the citizens of what was then West Germany. Though DDT has eradicated certain diseases, whose insect carriers were massively destroyed, the consequences are colossal and only partially evident. In the 1960s, for example, some birds became extinct because DDT affected them by making the shell of their eggs too fragile to stand the weight of the nesting birds. The decline in bird populations, in turn, favored the mass-reproduction of the insects that were food for these birds and were not affected by or were resistant to DDT. The damage to agriculture and forestry has been unprecedented. But these are just some of the consequences of the global use of DDT. The total tally of extinct species will probably never be known. A problem of particular concern is the fact that we use chemicals for a non-selective destruction of certain species in the environment (e.g. insects, plants, warm-blooded animals, bacteria, molds, etc.) and, in doing so, species that were not targeted in the first place eventually become seriously affected. This is why poisons must be given special attention and undergo systematic surveillance. Unjustified use of chemicals almost always indirectly harms the person responsible, while direct damage to the human body is caused by unintentional ingestion. Any and all means of protection of the human species and the environment are imperative when working with ecotoxic substances.

1.4.6. OTHER HARMFUL EFFECTS

Chemicals can be harmful in many ways and in many parts of the world. The adverse effects of chemicals on material and cultural goods cannot be disregarded because these are integral part of our civilization. The dry deposition from power plants destroys our stone artefacts, a typical example being the Zagreb Cathedral. Accidents involving chemicals, in addition to destroying life can cause severe material damage to important commercial and other establishments. Some chemicals destroy the ozone layer thus intensifying the penetration of dangerous UV radiation into certain areas of our planet. According to many scientists, carbon dioxide causes greenhouse effects and leads to climate change with unpredictable consequences. The range of possible adverse effects of chemicals is vast, but we are still not aware where their unwarranted use will take us.

1.4.7. A POSSIBLE CONCLUSION

Many adverse effects are not even discussed or investigated at all, although their occurrence can be presumed. This has been demonstrated with the side effects of drugs. Side effects are rare adverse effects caused by long-term use of medication. In most countries of the world, healthcare professionals are required to report all adverse reactions to the competent national authorities, who then communicate this to the central global database in Sweden.

Chemicals require more stringent controls.

Based on these data, the drugs are constantly re-evaluated and, at times, decisions are made to withdraw some of these from the market and ban them from use precisely because of the reported severe side effects. An adverse effect can also be psychological in nature, such as with harmless chemicals with an extremely unpleasant odor. Very often, people panic about a faint smell of rotten eggs which, in itself, puts no one in serious risk as no harm can be caused by a foul odor. Once again, all rare or particularly harmful effects of chemicals can be eliminated or prevented by adhering to protective measures against the introduction of chemicals into the body.
It should be pointed out that no precaution against the harmful effects of chemicals is ever excessive, especially when it comes to chronic exposure. What is crucial here is that the chemical will not interact until it reaches the site of interaction (e.g. on the skin). This is why it is especially important to adhere to all regulations concerning the protection from and prevention of chemicals entering the body, regardless of whether these are dangerous, deadly poisons or merely harmful chemicals. The greatest danger lies with substances that are not thought to be particularly dangerous, not until particularly severe effects are discovered retroactively, such as causing cancer or harmful reproductive effects.

1.4.8. IT IS VITAL TO ASSESS THE RISK AND TRY TO REDUCE IT

In the above text, only chemical hazards were discussed, while it is quite clear that danger is not the only criterion for predicting the consequences of exposure. The most toxic substances, such as botulinum toxin, can be kept in a well-secured safe without exposing anyone to any health risks. The key terms here are risk and safety.
„Risk" is the probability that someone will incur harm more or less due to working with a chemical, while „safety" is the probability that they will not feel any harmful consequences during their exposure to it.

Risk and safety depend on a number of factors, but these are not always easy to identify. The meteorite story can serve as an extreme example. While it is quite certain that a meteorite strike to the body would cause death, the description of the consequences is left to the reader's imagination. Still, no one is afraid of a meteorite because this is a rare phenomenon. The risk of death from a meteorite strike is virtually zero, despite pessimists saying that a meteorite striking Earth had caused severe destruction of most life at least once before.

1.4.8.1. OEL and MAC

Important variables in risk identification are **OEL (occupational exposure limits)** and **MAC** (**maximum allowable concentration**) of dangerous substances in different parts of the environment. When we talk about the workplace, we usually mean the concentrations of dangerous gaseous, powdered or aerosol substances suspended in the air. There is always the fundamental question of the meaning of and regulations on the magnitude determined for different substances. The question is whether the OEL represents a safety margin or a risk limit. In other words, is exceeding the OEL of a substance in the workplace a cause for panic or another type of reaction? OEL is a safety margin and guarantees that, at concentrations lower than it, a worker may be exposed to a certain chemical, for which the value is set, for eight hours daily during their lifetime. This is the same as when you arrive in front of a bridge bearing a 5 tones prohibition sign, banning all vehicles with a total weight greater than specified to cross the bridge.

This surpasses the allowed maximum!

However, nothing will happen to the bridge if an attempt is made to cross it with a load of 50 tons because the load capacity is calculated based on the safety factor. Still, guarantees are only valid if the person adheres to the set magnitudes. No harm will be done if the concentration of a chemical in the workplace air exceeds the OEL, but no exceedance should normally be allowed for safety reasons. There are situations when an OEL exceedance is allowed, but only in a clearly defined quantity and duration. Here, a new variable is introduced, the **STEL (short-term exposure limit)**. As a rule, the STEL for air, when allowed, is 50-100 % higher than the OEL, and is tolerable for a maximum of 15 min and four times a day during working hours, with minimum one-hour intervals between the incidents.
Consequently, in every workplace where vapors, dust or aerosols of a chemical are suspended in the environment, their concentrations should, as a rule, be monitored with a detector. More stringent controls based on similar important measurements are expected in the future.
The MAC (maximum allowable concentration) refers to basically the same thing as the OEL (i.e. safe concentrations of dangerous substances), but in different media with which people come into contact with, such as water, human and animal food, etc.

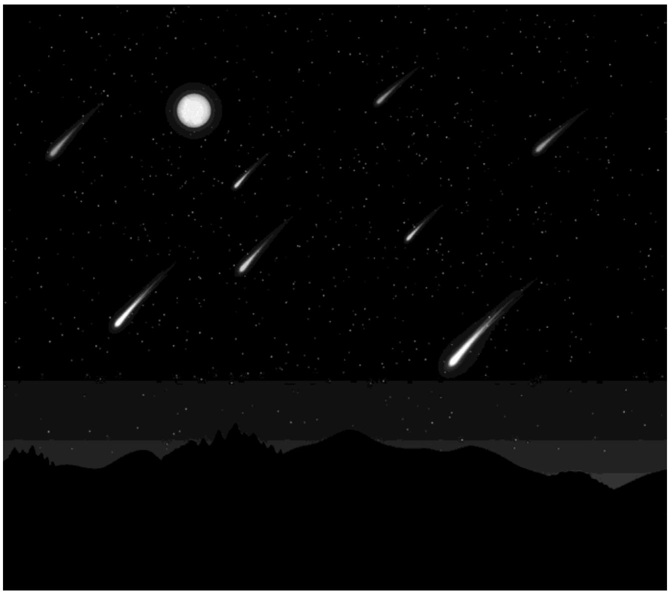
1.4.8.2. Risk assessment

There are a number of mathematical methods for assessing the risk of workers potentially exposed to a chemical, which should be monitored by those responsible at companies using chemicals. For the purpose of the present consideration, a demonstrative formula is applicable, not yielding any precise results:

$$R = H \times D \times T$$

where: R – risk, H – hazard, D – overall administered dose of a chemical, and T – exposure time.

It is quite clear that the H (hazard) of a chemical cannot simply be reduced if the chemical is needed for a particular job (e.g. if a job requires concentrated sulfuric acid, then diluted sulfuric acid cannot be used instead). It is also not possible to shorten working hours at a chemical plant from eight hours a day to less. The only thing that can be reduced is the intake dose, and there are many possibilities for that. This is the fundamental variable that can be altered, and the text following after this chapter will discuss just how to reduce the intake of hazardous chemicals in the body while the reasons for reducing the dose have been discussed in the present chapter.



2. ABSORPTION OF CHEMICALS

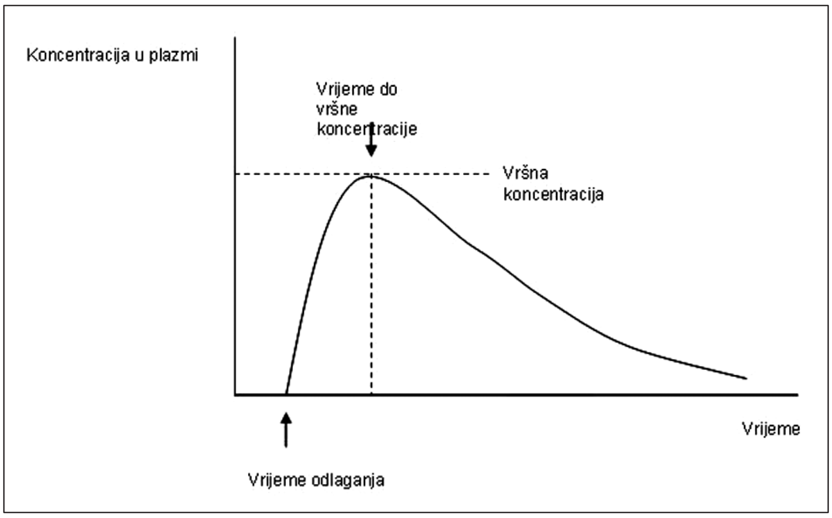
Chemicals can have a local effect, i.e. at the site where they are applied (e.g. spilled on the skin), or a systemic effect after they enter the bloodstream from the site of application and are then distributed throughout the body. The process of a chemical entering from the site of application into the bloodstream is called **absorption**. There are very rare cases at the workplace where the chemical enters the bloodstream directly without absorption (e.g. intravenous injection or a snake bite), so in most cases poisoning occurs after the chemical has penetrated the bloodstream. Therefore, special attention will be paid to this process.

2.1. GENERAL FACTORS OF ABSORPTION

How much of a chemical will enter the bloodstream from the site of application, and at which rate, will depend on:

- the body,
- the poison,
- other factors.

But, first of all, it is necessary to explain why the rate of absorption of chemicals is important, while the importance of the quantity of an absorbed chemical is self-evident. The rate of absorption of chemicals depends on the rate of onset of an effect and the time available to prevent absorption. If a chemical is absorbed very quickly into the body, then its effect is likely to occur quickly, and the time available to prevent absorption will be short. This also increases the risk for the exposed person. The rate of absorption is very well indicated by the time to achieve peak concentration. This is the time needed to reach the highest concentration of the substance in the bloodstream. The shorter the time, the faster the absorption and the effects can be expected sooner.



There is another important variable, and that is the time of delay of absorption before the hazardous chemical begins its entry into the bloodstream. Namely, certain processes of converting the chemical into a suitable state (e.g. dissolving in digestive juices) are required and this can take some time. This is the time, if allowed, to react by interrupting the process.

A third important piece of the puzzle has to do with the extent of absorption which refers to the quantity that was actually absorbed. In practice, the entire amount of a hazardous chemical (e.g. that was ingested) will never be absorbed, but only a larger or smaller part (e.g. salts are absorbed from the stomach with an efficiency or bioavailability of some 10 % in an adult). This should be kept in mind in case of a chemical poisoning.

2.1.1. GENERAL BODY FACTORS

The body is protected from the impact of the outside world by the skin and mucous membranes (mucosa), which, more or less, selectively release substances inside or out. Mucous membranes (e.g. along the digestive or respiratory systems) and the skin are barriers that prevent or allow the passage of chemicals into the blood capillaries from where they connect to the systemic circulation. This introductory text should, however, explain that barriers never completely prevent the entry of chemicals into the body and that chemicals can be absorbed in every conceivable site on the body, it is only a matter of extent. Each of the barriers has its own peculiarities, which will be discussed later, but there are also some general features or general factors affecting the absorption of a chemical, such as:

- thickness and quality of the barrier,
- barrier surface exposed to the poison,
- time the barrier is exposed to the poison,
- blood supply and blood flow below the barrier,
- composition of excreta at the site of absorption,
- other factors (e.g. temperature, presence of other substances, etc.).

2.1.1.1. Barrier thickness and quality

Elephant skin allows no absorption.

If we take a look at any of the barriers (e.g. skin, nasal, oral or gastric mucosas, alveolar barriers in the lungs, etc.), it is obvious that they are not equally thick or resistant in all their segments. When it comes to skin, uncovered parts are thicker than the covered ones (compare the skin of the palm with that of the abdomen, and it is clear that a chemical will penetrate better through the abdomen than the palm, which is why it is much more dangerous to spill a chemical on the abdomen than the palm).
The quality of the barrier changes in different circumstances such as disease, exposure to various chemicals or other circumstances (e.g. skin damage by friction or scratching, gastritis in the digestive system, etc.). The chemical will, obviously, penetrate more easily through damaged skin than through healthy skin. It is also clear that the chemical will penetrate more easily through the oral mucosa than through the skin on the back. This means that thinner, less resistant or damaged barriers should be better protected than thicker and more resistant ones.

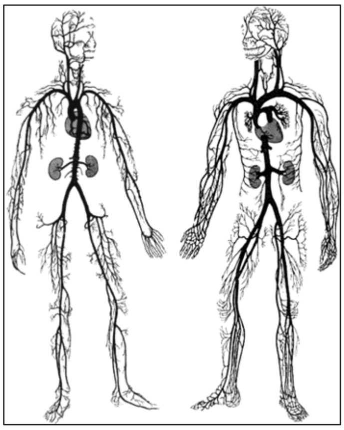
2.1.1.2. Barrier surface

The barrier surface exposed to the chemical is proportionate to the extent of absorption. The larger the exposure area, the more the chemical will be absorbed and enter the bloodstream. This is why absorption of chemicals in the digestive system largely takes place in the intestines, which have a huge surface area, and only a minor part in the stomach. This piece of information is pivotal when making a decision on whether to remove the chemical from the digestive system by vomiting before the chemical reaches the intestines. In case of the skin, the situation is clear-cut, but can change depending on additional factors such as clothing. If a person spills a chemical at the workplace, the clothing will permanently store it due to adhesion to the body. This is why it is vital to get clothes off the exposed person as soon as possible.

2.1.1.3. Barrier exposure time

The time a barrier is exposed to a chemical is of the same importance as the exposure itself. The longer the chemical is in contact with the barrier, the more of it will be absorbed. This ratio need not be linear, by doubling the exposure time, the amount of chemical absorbed will not necessarily double. This increase can be significantly higher if the barrier is damaged, and rarely will be lower. The conclusion is unequivocal: the chemical should be removed from the barrier as soon as possible. After a chemical spill, for example, both clothes and chemical should be removed from the skin immediately because every second counts.

2.1.1.4. Blood supply below the barrier



Blood supply on the other side of the barrier is different in different parts of the body due to physiological and other reasons. The better the blood supply and the faster the blood flow below the barrier, the faster and more extensive the absorption. This is easily tested from experience as bleeding is not the same if the cut is located at the tip of a finger or on the skin of the lower leg. The same is true of the mucous membranes, which have a much better blood supply in the intestines than in the stomach. Essentially, one might conclude that not all parts of the barrier, e.g. the skin, should be protected uniformly, since blood supply to different parts varies. However, there are additional factors that can affect the blood flow rate underneath the barrier. These can be physiological in nature, such as increased blood flow through the intestines after a meal (this is why we feel drowsy after a hearty meal – all the blood goes to the stomach). Blood flow can also be affected by disease (especially the heart, changes in body temperature due to a virus, etc.), interaction of the chemicals or weather changes at the workplace

2.1.1.5. Amount and composition of excreta

The amount and composition of the excreta at the barrier (e.g., sweat on the skin, saliva in the mouth, digestive juices in the stomach, etc.) will have a major impact on the absorption of certain chemicals through the barrier. This is a rather complex matter and the effects are different on different chemicals, but some powder chemicals, to illustrate, will be better absorbed through sweaty skin than dry skin.

Sweat is not a good thing when working with chemicals.

2.1.1.6. Other factors

Other factors are highly unpredictable but can have a significant impact on the rate and extent of absorption. The presence of another substance might increase or decrease the absorption of the chemical. If, for example, a powder chemical is dissolved in an organic solvent, it is the solvent that can increase its rate and extent of absorption in several ways. When applied on the skin, the increase is due to enhanced solubility and damage to the barrier by the action of the solvent. Increased outdoor temperatures will increase the extent of absorption of most chemicals, unless volatile liquids are removed from the application site (e.g. the skin) by evaporation.

2.1.2. CHEMICAL FACTORS

General factors affecting the rate and extent of absorption were already discussed earlier and will only be briefly described here due to their complexity. The main chemical factors are:
- physico-chemical properties,
- **the** amount of the chemical,
- other factors (e.g. local action of the chemical).

2.1.2.1. Physico-chemical properties of a chemical

It is the physico-chemical properties of a chemical that determine the chemical's solubility in the excreta or a solvent, its penetrability through a barrier, and any alternative absorption routes. If a chemical dissolves well in sweat, this does not imply it will equally easily penetrate through the skin and into the body. Arsenic trioxide, for example, will hardly, if at all, penetrate through undamaged skin, despite its instant solubility in sweat accumulated on the skin, while nitrobenzene will penetrate the skin in a flash, though it is not soluble in sweat, although liquid itself.

Watch out for gases and aerosols!

2.1.2.2. The amount of the chemical

The amount of the chemical is extremely important: the greater the amount of the chemical, the greater the extent of absorption.
Finally, the chemical can affect its own absorption by its local or central effects on the body. The simplest example of local action is barrier damage, which is often encountered with corrosive chemicals, which simply destroy the barrier and expose the capillaries. This also happens in cases of on-skin spills as well as swallowing. These are usually strong acids or alkalis, but there are a number of organic solvents that can also alter the properties of the barrier (e.g. by degreasing). A chemical can also alter its own absorption quality indirectly (e.g. by changing the blood flow below the barrier, causing such effects as vomiting or diarrhea, etc.).

Be wary of the

2.1.3. OTHER FACTORS

Other chemicals can significantly change the magnitude and rate of absorption of a chemical, as well as its effect. Very often, different chemicals are combined and certain interaction can be expected. Some were earlier discussed. Essentially, there are two types of interaction:
- direct interaction of two or more chemicals,
- indirect interaction with an effect on the organism

2.1.3.1. Direct interaction of two or more chemicals

The initial interaction consists in altering the properties of the chemical. Through interaction with another chemical, the result can be better solubility and penetrability through the barrier, altered physical state or immobilization of the first chemical by the action of the second one. The change in solubility of a chemical was described earlier. An example was also given illustrating a change in the physical state: the case of conversion of potassium cyanide to hydrogen cyanide through interaction with a mineral acid, thus allowing absorption of the chemical through the lungs (inhalation). Immobilization of a chemical by another substance is extremely important and will be studied in detail in the discussion on decontamination. One example is oral administration of activated carbon after swallowing a chemical.

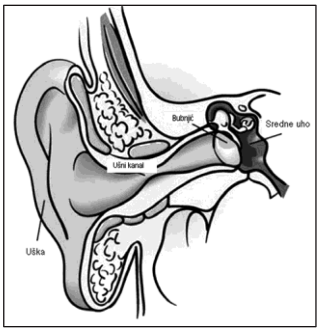
2.1.3.2. Indirect interaction

Indirect interactions were also described earlier, and are extremely numerous, which makes them highly unpredictable. Some chemicals can alter barrier properties (e.g. corrosive chemicals or organic solvents) and thus enhance their absorption. Decreased blood flow caused by toxic effects on the heart will reduce the absorption of the chemical through all routes and vice versa. Examples are numerous, but what is important to stress is that experts in this field are not able to predict all possible interactions of chemicals in the absorption phase or in other stages of the dangerous effects of a substance going through the body or its effect on the body, as explained in the first chapter.

Milk enhances the absorption of lipophilic substances.

2.2. PARTICULARLY IMPORTANT SITES OF CHEMICAL ABSORPTION

The main absorption sites, important for the workplace, are as follows:
- the digestive system,
- the respiratory system,
- the skin.



A chemical can also be absorbed through the ear (ear canal).

It should be kept in mind that the absorption of chemicals can also take place anywhere else and that, in certain circumstances, absorption can lead to poisoning. One example is the case of a pilot from South America who sprayed insecticides on a large farm. During the preparation of the organophosphorus insecticide solution, a single drop of the concentrate got into his eye and from there the chemical was absorbed into his bloodstream, causing symptoms of poisoning. Many similar examples can be listed and their primary purpose is to warn about the need of protecting all parts of the body from chemicals.
Absorption through the ear canal or the genitals should also be considered (e.g. penal absorption).

2.2.1. DIGESTIVE SYSTEM

The absorption of chemicals mostly takes place in the small intestine, but cases of poisoning through the mucous membranes of the oral cavity or through the stomach have also been recorded, especially with chemicals with extremely strong effects. The introduction of chemicals into the digestive system should be avoided at any cost.
In addition to (un)intentional swallowing, a chemical can also enter the body through the mouth in the following cases:
- non-compliance with airway protection measures from aerosols and dust,

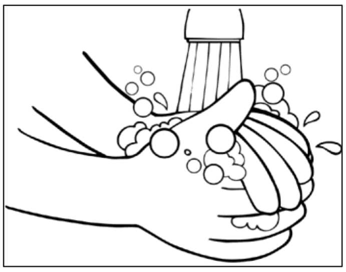
– non-compliance with the ban on smoking or eating and drinking while working,
– intake of chemicals using dirty hands,
– other routes.

2.2.1.1. Intake of chemicals from aerosols and dust

Although this will be further discussed in the section on the absorption of chemicals through the respiratory system, it should be noted here that, in case of aerosols or dust, a certain amount will stop inside the nose or throat, if airway protection equipment is not used. This way, the chemical reaches the digestive system by swallowing and is absorbed on the spot. Consequently, this is considered a case of chronic intake of chemicals that goes unnoted by the occupationally exposed person for some time before any signs of chronic exposure appear.

2.2.1.2. Intake of chemicals by smoking, eating or drinking while working, or using dirty hands

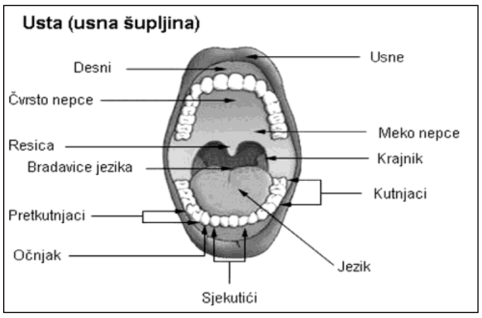
Intake of chemicals from a contaminated workplace environment by smoking, eating or drinking is a common route, as is any intake due to contamination by dirty hands or protective clothing. It is vital to adhere to safety measures at work (removing protective clothing and washing exposed parts of the body before going on holiday or leaving work). Daily quantities of this sort of chemical intake may appear to be insignificant, but over a period of several years of chronic exposure, the overall amount may turn out to be significant. Workers can often be seen handling chemicals as they go to the cafeteria or a restaurant without previously taking off their contaminated clothes or even washing their hands. This way they are not only endangering themselves, but everyone else around them.



Wash your hands before going to the bathroom and also before meals.

2.2.1.3. Chemical absorption mechanisms in the digestive system

As mentioned earlier, the absorption of chemicals in the digestive system takes place mostly in the small intestine. However, in some circumstances, the absorption or interaction will take place predominantly in other parts. An example is the ingestion of corrosive chemicals, such as strong acids or alkalis, when a chemical is activated as early as in the oral cavity, and absorption occurs in all parts of the digestive system, including the stomach. The mechanism of mucosal damage is the same for all corrosive chemicals, i.e. the barrier is removed and the capillaries are exposed, while any subsequent damaging mechanisms are different for acids and alkalis. To conclude, the most important thing when swallowing a corrosive chemical is to ingest a smaller amount of water and urgently get to the hospital, which will be discussed later.



The mouth too is a potential site of absorption.

Absorption usually takes place in the small intestine, but is theoretically possible in all parts of the digestive system through which the chemical passes. A particularly interesting site of absorption is the oral cavity with all its integral parts. The oral cavity has a rich blood supply, the barrier is thin and there is enough fluid (saliva) to dissolve the chemical. The only limiting factor is the short time the chemical remains in the mouth. However, if it is intentionally retained, e.g. under the tongue, as is the case with some drugs (e.g. nitroglycerin as an antianginal), the absorption will be extremely

fast and efficient. Absorption is also possible through the lips, because they have all the same properties as the oral cavity, and the chemical can be easily deposited on the lips in an environment contaminated with dust or aerosols. The chemical also gets in contact with the lips by touching them with contaminated hands, e.g. when smoking. The absorption discussed here is not significant in terms of amounts absorbed, but rather for long-term exposure, which is particularly important when it comes to CMR (carcinogenic, mutagenic and reprotoxic) substances.
The ingested chemical first enters the stomach, where it is retained for a period of time, and is then transferred through the duodenum into the small intestine. It is a process that takes some time and depends on a number of factors, typical of both the chemical and the organism. With relevance for the safety of workers handling the chemicals, it is important to know the following absorption specificities that have to do with the digestive system:

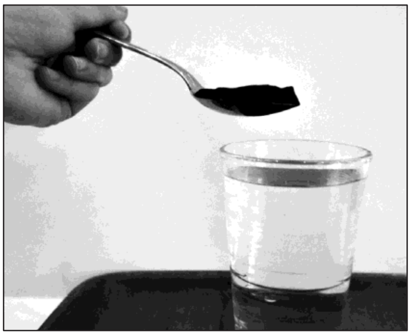
- A more extensive absorption will not occurs before the arrival of the chemical in the small intestine;
- The chemical must be available for absorption;
- The extent of absorption may be reduced or increased by factors that can partly be controlled.

2.2.1.4. Delayed absorption

The fact that the biggest part of absorption occurs in the small intestine and that it takes some time before the ingested chemical reaches that site is vital. This means that, for most chemicals (exceptions were given earlier, e.g. corrosive chemicals such as strong acids and alkalis), there is a delay that can be used to at least reduce the total quantity of the absorbed chemical by timely procedures. These measures will be discussed in the section on decontamination, but it is important to know now not to panic and how to at least partly correct the matter by reacting prudently. The exceptions are very strong chemicals, with which there is usually not much time to act.

2.2.1.5. Availability of a chemical for absorption

The chemical must be available for absorption to be able to cross the barriers of the digestive system and enter the bloodstream. This means that it must dissolve in digestive juices and be in such a physical state that allows it to pass through the barrier. Its solubility or conversion to a suitable state can be aided by other chemicals or, for example, foods such as milk. More about the properties of chemicals and favorable or unfavorable conditions for absorption from the digestive system can also be found in the safety data sheet.



2.2.1.6. Absorption control

There are controllable factors that have a significant impact on the absorption of a chemical from the digestive system. The absorption will decrease if:

- The chemical is not allowed to pass from the stomach into the intestine (vomiting, in cases where this is explicitly recommended);
- The chemical is immobilized so that it cannot be dissolved or absorbed (when explicitly recommended);
- The passage of the chemical is accelerated through the intestine, in cases when it had already reached the intestine (such a procedure may only be performed by medical staff).

2.2.1.7. Preventing the entry of chemicals from the stomach into the intestine

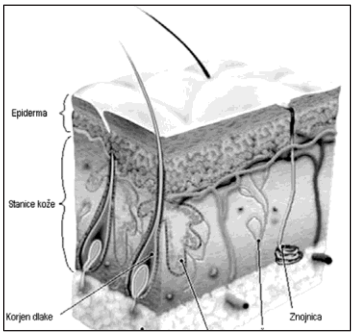
The easiest way to prevent a chemical from passing from the stomach to the gut is to induce vomiting, unless this is strictly forbidden for a particular chemical, which will be further discussed in the section on decontamination. It should be kept in mind that, though vomiting will never eliminate the entire amount ingested, it will certainly reduce the extent of absorption and, consequently, the damage to the body. Further gastric lavage can only be performed by a trained medical team in a hospital setting, but even this does not guarantee that the entire chemical will be removed from the body. The key thing is to remove the chemical as soon as possible after swallowing it, unless this is strictly forbidden.

2.2.1.8. Accelerating the passage and immobilization of the chemical in the intestine

Avoid laxatives.

The intestine has an extremely large surface area (like a tennis court) and the swallowed contents pass through it slowly. Aside from the general factors described earlier (blood supply and blood flow through the intestinal wall, presence of substances that may react with the chemical, acidity of intestinal fluids, condition and age of the mucosa, etc.), the extent of the absorption will also depend on the bowel contents (obstruction by food), the rate and manner of mixing the contents, etc. Due to the extremely large surface area of the intestine, the chances of absorption are high. Unfortunately, this also means that it is very difficult to perform decontamination, once the chemical has reached the gut. Absorption can only be reduced by increasing the rate of passage through the intestine (e.g. by administering a laxative) or by immobilization (e.g. adsorption to a sorbent or chemical binding to an inert substance).

2.2.2. ABSORPTION THROUGH THE SKIN



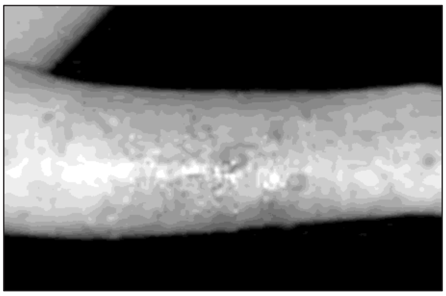
Normal skin

As mentioned earlier, the most important route of absorption through the skin is the stratum corneum (lipid barrier), which prevents the absorption of substances easily soluble in water. However, the skin allows the entry of such matter into the body through pores and glands or down the hair root. Some studies have shown that numerous water-soluble substances are absorbed some 200 times faster along a hair root than through the stratum corneum. Consequently, under certain conditions, even such substances considered unable to penetrate through skin barriers (e.g. metal salts) will be absorbed, which is why care must always be taken when exposing the skin to chemicals.

It should be emphasized that it is best not to allow any contact of a chemical with the skin, regardless of any assurance that it is not absorbed through the skin. Chemicals often have an effect on the skin, from simple irritation to causing severe injuries, which is reason enough to avoid any contact. However, in case of contact, the barrier is very often penetrated and the chemical can enter the bloodstream directly through the exposed capillaries.

Although stated earlier, it should still be reiterated that chemicals are not absorbed equally easily and in the same amount through all parts of the skin, as these vary in quality, blood supply below the barrier and other properties. Absorption is the most effective (almost 100 %) on the skin of the groin or underarms, very effective on the scalp, face or abdomen, and ineffective on the palms or soles of the feet. This should be considered both when choosing personal protective equipment (PPE) and for decontaminating procedures in case of severe chemical exposure.

The physical state of a chemical should not be disregarded. Gases are generally poorly absorbed through the skin and cause skin injuries (e.g. corrosive chemicals such as chlorine or ammonia). Solid chemicals cannot be absorbed until dissolved, and exposure to such a powdered chemical will not cause severe damage, other than corrosion or irritation of the skin (e.g. skin contact with ordinary cement or slaked lime). This does not mean that absorption cannot occur, e.g. due to the dissolution of a solid chemical in sweat. Solutions and liquids are most likely to be absorbed. Lipophilic solutions penetrate extremely well through the skin barrier, often degreasing the skin, while corrosive solutions facilitate their absorption by destroying the barrier (e.g. numerous alkalis and acids).

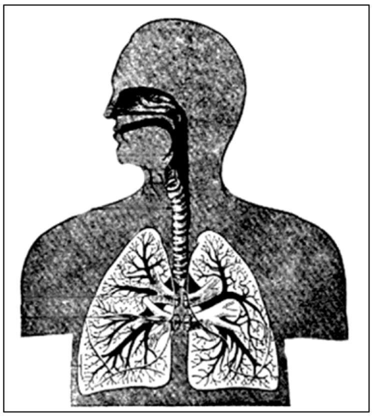


Damaged skin enhances absorption.

It is important to understand that clothing can be a reservoir of new quantities of fluid that keep absorbing through the skin over and over again. Therefore, decontamination always starts with immediate removal of all clothing. This also applies to other physical states of chemicals. Gases are readily adsorbed on clothing and, in the case of corrosive chemicals, can continue to have an effect on the skin long after the exposed person has left the contaminated area.

2.2.3. ABSORPTION THROUGH THE RESPIRATORY SYSTEM

Firstly, it should be pointed out that the airways begin with the nose and end with the alveoli, i.e. they cover all parts through which inhaled or exhaled air passes. Absorption can take place every step of the way, but the very site of absorption will depend mostly on the physical state of the chemical and its properties. The absorption of gases and vapors will be discussed separately from that of dust and aerosols.

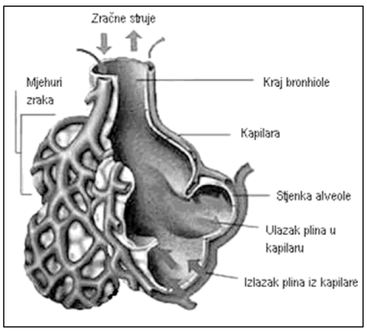


The respiratory system begins with the nose and ends with the alveoli.

2.2.3.1. Absorption of gases and vapors

Gases or vapors pass through the airways to the alveoli and, there, absorption takes place at a range and rate that depend on several key factors such as:

- concentration of the chemical in the air (preferred term is partial pressure in the air),
- time spent in the contaminated area,
- physico-chemical properties of the chemical,
- breathing intensity,
- other special factors.



Alveolus is ideally built for nearly 100 % absorption and process yield.

2.2.3.1.1. Concentration of a chemical in the air

The relationship between the concentration of a gaseous chemical in the air and the quantity that will be absorbed need not be linear, but any increased concentration of a chemical in the air will lead to an increase in the amount that will be absorbed in the lungs. At any workplace where chemical gases or vapors are suspended in the work environment, their concentrations should be measured and not exceed the occupational exposure limits (OEL) for an eight-hour period. Concentrations have been identified which guarantee that multiannual exposure over daily working hours will not cause harm to the exposed person.

The wise do not think about toxic concentrations in the air. They protect themselves

2.2.3.1.2. Time spent in the contaminated area

Exposure time is also directly associated with the amount of chemical absorbed. The concentration of the chemical in the air may be low, but, due to long exposure, absorbed amounts eventually add up. This is why air concentration and exposure time make a killer combination. The higher the concentration in the air, the shorter the exposure should be. Based on extensive data from epidemiological and other research, the legislator has foreseen such concentrations that are only allowed for a short time, i.e. the STEL. These determinants are vital and the worker should, for their own sake, insist on the measuring of concentrations of toxic gases or vapors in the air.

2.2.3.1.3. Physico-chemical properties of a chemical

The physico-chemical properties of chemicals significantly affect the extent and rate of their absorption, but their understanding requires knowledge of chemistry. It is easiest to look at the safety data sheet and/or mandatory written warnings concerning the chemical, which must be made available at every workplace involving (the possibility of) chemical exposure

2.2.3.1.4. Breathing intensity

Works like a slave and is exposed to chemicals, on top of that.

The factor of breathing intensity should not be disregarded. The harder the work, the more oxygen is needed to carry it out, which is why the breathing accelerates, and the amount of inhaled air increases. Naturally, a more extensive absorption of chemicals in the air can be expected. Many gaseous chemicals irritate the mucous membranes all the way they travel, from the nose to the alveoli and, at elevated concentrations, cause damage to the mucosa. The more strenuous the work, the greater the damage, and the consequences need not occur immediately after the exposure, or even up to 48 hours after the exposure has ceased. Consequent damage can range from spasms to suffocation (pulmonary edema), when it comes to irritant or corrosive chemicals (e.g. ammonia, chlorine, nitrous gases, sulfur dioxide, formaldehyde, etc.).

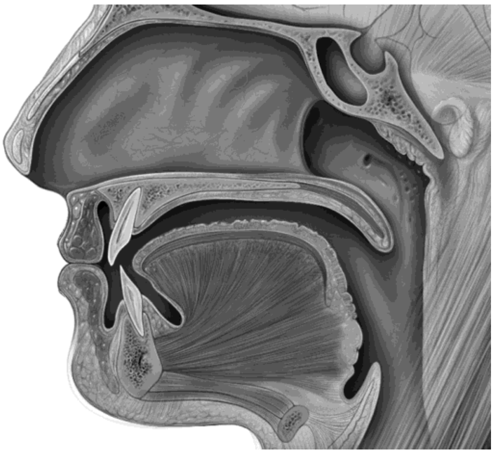
2.2.3.1.5. Other special factors

There are a number of other factors that can, in special cases, affect the extent and rate of absorption of a chemical, such as the weather or specific properties of certain chemicals. For example, elevated workspace temperature will enhance the absorption range in several ways. On the one hand, the evaporation range of volatile liquids will go up, as will their concentration in the air. On the other hand, the increased temperature will directly contribute to the passage of the chemical through the alveolar barrier. One example of the specific properties of chemicals is carbon monoxide that accumulates in the body by special mechanisms and is difficult to eliminate. The body has up to 200 times higher affinity for carbon monoxide than for oxygen, while the binding occurs in the same cell sites and in the red blood cells, and it is precisely due to this mechanism that the exposed person absorbs the chemical without excreting it from the body.

2.2.3.2. Absorption of aerosols and dust

Firstly, it should be explained that aerosols can be dust or droplets. The difference is that, in the case of droplets, the chemical is often dissolved in a liquid, most often water, and is thus more available for absorption than a solid aerosol. Another difference between dust and droplets is particle size: dust particles are significantly larger than droplets. Aerosol particles are considered to be smaller than 50 μm in diameter. Besides the size of particles dispersed in the air, the extent and rate of absorption through airways are affected by the same factors listed in the discussion on gases or vapors. Therefore, special attention will be paid here to particle size.

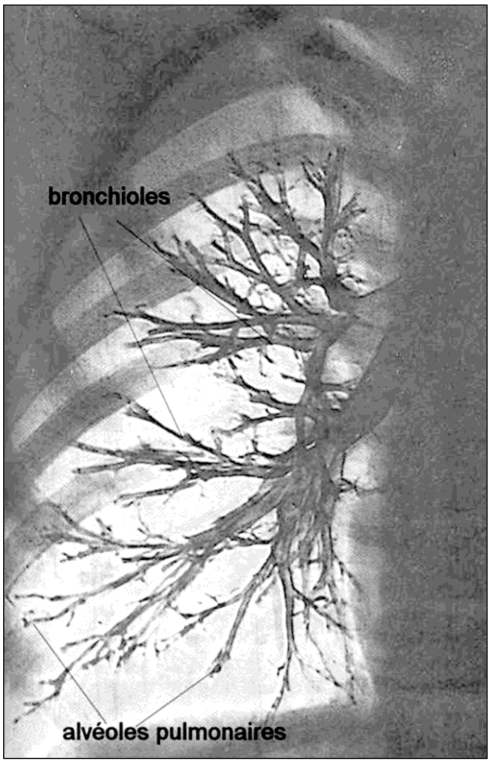
2.2.3.2.1. Journey of aerosols and dust



The nose is a good site for Absorption.

Inhaled air containing aerosols travels a long way from the nose to the alveoli, encountering numerous obstacles, often changing direction and speed and fighting the body's defenses. The first obstacles are located in the nose – the hairs and mucous membrane excreting mucus. Both are quite effective against dusts and aerosols and prevent them from entering the lungs. The following obstructive mechanism against dusts and aerosols in the nose is a change in the direction of air flow, where dusts and larger aerosols are deposited on the mucous membranes. The change of direction occurs several more times during the passage of air to the alveoli, but aerosols and what little remains of dust that was not detained in the nose are deposited anyway. Still, only the smallest aerosols (under 5 μm) reach the alveoli, where they can be absorbed by passing through a very thin barrier to the capillaries. To conclude, dust and aerosol particles will be deposited along the airways, depending on their size. The largest particles will be detained in the nose, while the smallest ones will reach the alveoli. Now, the question is what will be the extent of absorption and effect of such particles on the mucous membranes where they were detained.

2.2.3.2.2. Mucosa - both a barrier and a site of absorption



Bronchioles have a large surface area for absorption.

In the introduction to the chapter on absorption, it was explained that each mucous membrane (mucosa) can be both a barrier and a site of absorption of a chemical, and the same is true for the respiratory tract. The chemical deposited in the nose encounters a very weak barrier, which is, at the same time, well supplied with blood to be able to secrete mucus. Mucus will dissolve many chemicals, depending on their physico-chemical properties, and absorption can be high. A typical example is the absorption of cocaine through the nasal mucosa. It is considered to be one of the best routes of administration for this particular substance, much like tobacco was popularly administered by snorting through the nose. Though it is a less effective route for nicotine absorption than directly to the alveoli in smokers, the nasal mucosa may be an effective site of absorption for a large number of toxic substances. Poisons deposited at the root of the tongue will most often be swallowed and then absorbed through the digestive system, while poisons entering throughout the respiratory system will be absorbed at the place where they were deposited, with the greatest extent of absorption at the alveoli.

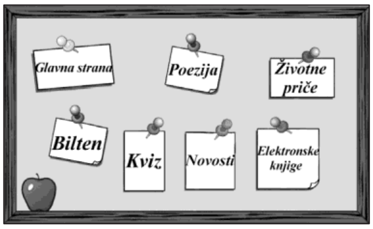
The greatest extent of absorption will take place in the alveoli, or possibly even sooner, in the bronchi. Whatever enters the alveoli will, most likely, be absorbed in a high amount, which is why gases and small particle aerosols are particularly dangerous. There is no way to decontaminate or slow down the absorption in the alveoli, as was the case with the skin or digestive system. What has entered this far will be absorbed to a greater or lesser extent, depending on the general factors of passage through the barriers. This is why the pulmonary system is particularly important, and there is no other way to prevent absorption than the use of personal protective equipment (PPE) or air purification in the workplace

Absorption is significantly less extensive because the worker is not doing hard work

3. PREVENTING ABSORPTION

Preventing the absorption of chemicals means preventing poisoning. There are two basic ways of preventing absorption:
1. not allowing the chemical to come in contact with or enter the body (skin, respiratory and digestive system
2. removing the chemical from the body as soon as possible.
Certainly, the first way is better, especially if a particularly hazardous chemical is involved. This chapter will discuss the preventive method of protection, while decontamination, i.e. the removal of chemicals from the body will be explained in the chapter on first aid.

3.1. WHERE TO FIND INSTRUCTIONS ON THE USE OF PROTECTIVE EQUIPMENT?



Have you ever noticed the instructions on the wall? They were written for you!

In areas where hazardous chemicals are handled, various notifications can be seen on bulletin boards or other visible places. These provide, among other things, detailed instructions on the use of protective equipment, i.e. the protective devices that serve to protect against chemicals used in the work process which can be production, storage, use, or other type of work that involves contact with hazardous chemicals. Unfortunately, very often, the workers, for whom these instructions were written, have no idea what the instructions say, most shockingly even those who have been working at the same workplace for decades pass by the bulletin boards without noticing the safety instructions. **Please read the instructions that were made for you.**

3.2. PROTECTION OF THE DIGESTIVE SYSTEM

Though there is no protective equipment specially designed for the digestive system. The best protection includes precautionary measures developed after studying the elementary causes of poisoning through the digestive system, such as:
- not wearing prescribed protective equipment;
- eating and drinking or smoking in places where chemicals dangerous for human health are handled;
- eating and drinking or smoking in isolated places without previously attending to basic hygiene;
- taking substances that enhance the absorption of hazardous chemicals;
- (un)intentional ingestion of hazardous chemicals

3.2.1. NOT WEARING PRESCRIBED PERSONAL PROTECTIVE EQUIPMENT

Protection measures implemented to protect the digestive system are, in principle, associated with the protection of other systems. A good part of the air is also inhaled protection of other systems. A good part of the air is also inhaled through the mouth, part of the air is also inhaled through the mouth, especially if the nose has become impassable, for example in case of a cold. Consequently, a part of the dangerous substances in the inhaled air can accumulate on the mucous membrane of the mouth and absorption begins there. Since the mouth is part of the digestive system, absorption will go through the digestive system. But the story does not end there. By secreting saliva, the deposited chemical can be washed down from the mucosa and as the saliva is swallowed, the chemical too will be swallowed and washed away with it. This way, the chemical is taken deep into the digestive system, where absorption is much faster and much larger in scope. In order to prevent this, measures are taken primarily to protect the respiratory system, as well as the digestive system.

Protective mask is something entirely different.

Another means of protection, which does not primarily target the digestive system, are protective gloves. Although they serve to protect the skin of the hands, they also play a key role in protecting the digestive system. First contact with chemicals is usually achieved through hands, and most physiological actions are performed using the hands (from wiping sweat, onwards). This way, chemicals are transferred from dirty hands to the lips and into the mouth, thus reaching deep into the digestive system. In addition, certain types of chemicals are very difficult to remove from the skin. One example is contact with greasy car engine parts or cleaning greasy ovens. What do hands look like after that and how much time and effort does it take to bring them back to their original condition?

This glove will not protect you from chemicals.

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There is always something left in the pores of the skin or underneath the nails. Since food, drinks and cigarettes are held with those hands, the remaining impurities will be transferred into the digestive system. This is why gloves constitute mandatory protective equipment when working with hazardous chemicals.

Since protective equipment used to prevent absorption through the digestive system primarily aims to protect other sites of absorption, this equipment will be further discussed while discussing its basic purpose.

3.2.2. EATING AND DRINKING OR SMOKING IN PLACES WHERE CHEMICALS DANGEROUS FOR HUMAN HEALTH ARE HANDLED

One of the more common types of poisoning is caused by consuming foods or drinks in places where hazardous chemicals are handled. By bringing foods or drinks into the contaminated area, these too will become contaminated through contact with dirty hands or, what is worse, with gloves.

As for cigarettes, besides holding them with dirty hands and placing them inside the mouth, there is another, perhaps even more illustrative reason.

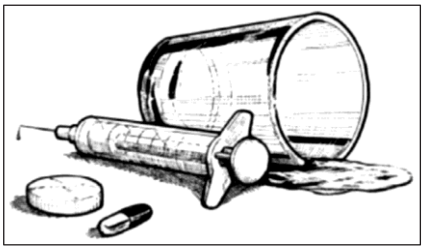
Namely, chemicals must be in a suitable form to be absorbed through the digestive system. They must be soluble in bodily fluids. Some substances may not be soluble in our bodily fluids, but, even so, if one such particle reaches the tip of a cigarette, where the temperature is high, it can be converted to a liquid or even gas, which then enhances its solubility and allows for easier penetration into the bloodstream. It is even not recommended to chew gum in a place where hazardous chemicals are handled. The reason is very simple: chewing gum increases salivation, which, in turn, means more frequent swallowing and greater chances of ingesting harmful substances together with the saliva.

3.2.3. EATING AND DRINKING OR SMOKING IN ISOLATED PLACES WITHOUT PREVIOUSLY ATTENDING TO BASIC HYGIENE

The situation is more or less identical as in the above case of a designated area, such as a restaurant, rest area or smoking area, without attending to basic hygiene beforehand. This means that said designated areas must not be entered wearing contaminated protective clothing and that those body parts that have been exposed to chemicals must be washed before entering. The entry of a contaminated person or the introduction of contaminated objects into said spaces is not only a hazard for the newly arriving exposed person, but also for all others who are currently residing in that space or will later enter, because a **contaminated area represents a permanent hazard to human health**.

3.2.4. CONSUMING SUBSTANCES THAT ENHANCE THE ABSORPTION OF HAZARDOUS CHEMICALS

It is particularly dangerous to eat or drink substances that can enhance absorption of chemicals through the digestive system in a place where chemicals hazardous for human health are handled. This especially applies to **alcoholic beverages**. In addition to alcohol, absorption through the digestive system can also be enhanced by other foodstuffs such as **fatty foods or milk**, especially when it comes to acute poisoning.



3.2.5. (UN)INTENTIONAL INGESTION OF HAZARDOUS CHEMICALS

Intentional ingestion of chemicals that can cause severe adverse effects is less common in the workplace than in other environments. Cases of unintentional or accidental ingestion are more common. Until recently, these mostly occurred due to lacking personal protective equipment (PPE) or inadequate procedures during the handling of chemicals. Today, a more common reason is ignorance. A special hazard has to do with transferring chemicals into containers that are identical or similar to containers for storing foods or drinks. The basic information source on the container

contents and substance properties is the product label (sticker). Instructions for use found on each individual packaging explain in detail how to protect oneself from the chemical content.
If this document is missing or incorrect, the chemical may be mishandled or treated as a completely harmless substance. The basic rule is that, **if possible, chemicals must be stored in their original packaging**. If they need to be transferred into some other containers, for example for processing, preparation, etc., then these **containers must be properly labelled** and must not resemble food storage containers

3.3. SKIN PROTECTION

Today, there is a very wide range of personal protective equipment (PPE) for the skin and mucosas on the market. Specialized protection is offered for different chemicals. All employees must be well aware that, after leaving a contaminated area, they are obliged to take off their clothes, wash them and any potentially contaminated skin and only then can they enter the rest area, smoking area or cafeteria. **Failure to use or the improper use of protective clothing is closely related to poisoning** cases and, even more so, to occupational diseases resulting from long-term exposure to hazardous chemicals.
It would be best to protect onself with disposable protective equipment. After work, protective clothing should be taken off, placed in a designated container and never be touched again, i.e. no contact should be made with its external parts.
Each chemical or group of chemicals requires special protective clothing. The difference is not only in the type and shape, but also the materials from which the clothing is made. Which kind of protective clothing should be used depends primarily on the type of chemicals with which one comes into contact with, their quantity (concentration) and physico-chemical properties (aggressiveness, reactivity, physical state, etc.). The selection of protective clothing is made by a responsible person, and it is **the obligation of every worker to use prescribed** personal protective equipment (PPE).
It is quite certain that all external body parts through which absorption could occur must be protected, and protective garments will, at this point, be described in detail, depending on the characteristics of the contact chemical

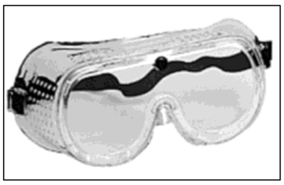
3.3.1. HANDS

Special attention should be paid to the protection of hands. The hands are the part of the skin through which one, necessarily, comes into contact with chemicals, containers, tools for handling chemicals, and all of these may be contaminated. It is very important that the gloves are resistant to chemicals, but also strong enough not to be damaged. It is vital (and this also applies to other personal protective equipment (PPE)) that the gloves are undamaged. Even the smallest damage (crack, tear, etc.) is a great hazard because the chemical can easily come into contact with the skin. **As soon as any damage or irregularity is observed, the gloves should immediately be replaced with new ones**.

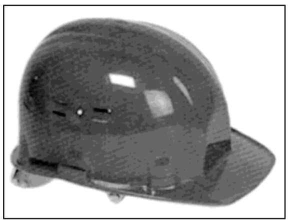
3.3.2. EYES

Eye protection is another key point, due to the sensitivity of the eyes, as well as for good control over the situation. If there is a danger of a chemical getting sprayed into the eyes, it is mandatory to use

safety goggles or a **visor** that, in addition to protecting the eyes, also prevents any contact of the facial skin with the chemical. In case of chemicals suspended in the working environment, such as gases, vapors, aerosols or even dust particles, the protective goggles must adhere well to the skin of the face so that the chemical cannot reach the eyes from the side.

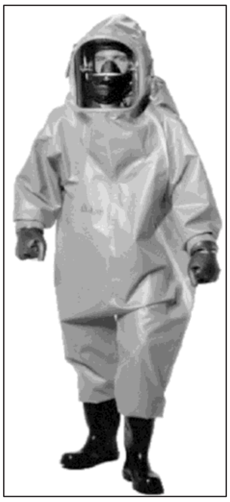


3.3.3. HEAD



The scalp can be protected with **hats, hoods** and any other forms of headgear suitable in given cases. Nevertheless, care should be taken of the quality of the barrier, as one of the basic factors of transdermal absorption. **The scalp is very sensitive**. Even a gentle scratch with a nail on the skin of the skull can damage it and remove the barrier that prevents the absorption of a hazardous chemical. A use of a **helmet** is advised wherever there is a risk of falls from a height or of heavy objects, but also wherever there is a risk of even the slightest scratch. This is especially important in field work, but also in confined spaces, i.e. anywhere where the head can get struck and the skin damaged. Such protective accessories as antiphons (noise protection) or visors can be mounted on the helmet.

3.3.4. BODY (TORSO)

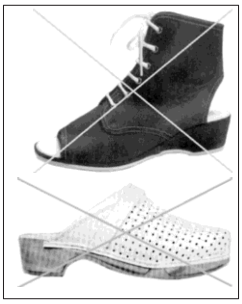


Insulation suite

Body protection equipment depends primarily on the properties and concentration of the chemical, but also the direction from which it is coming. Usually, **work clothes** made of cotton or some other natural material are used, or **multi-layer protective clothing**, i.e. overalls that can easily be put over one's clothes to provide additional protection. In a workplace where the workers may be sprayed with chemicals only from the front, a protective **apron** is preferred. However, if the risk of spillage threatens from any direction, then it is better to use a protective **hooded suit** or a **raincoat**. The hood also prevents the chemical being poured down the neck. If the chemicals that contaminate the environment do not move in a straight line and if their concentration is high, then **overalls** are advised, at the very least. With very high concentrations of hazardous chemicals in the environment, a hermetically sealed **insulation suit** must be used for complete protection. This will, most commonly, be needed when chemical concentrations are unknown or are expected to be high (e.g. in chemical accidents). The insulation suit completely protects from the surrounding environment. Contaminated air cannot reach the skin or the digestive or respiratory systems. In such situations, breathing air must be brought from another source, but this will be discussed at a later point.

3. 3.5. LEGS

Most suitable are, definitely, **boots**. There are no complications with untying or retying the laces, especially when it is very difficult to do so, for example, if one is wearing bulky protective hand gloves. If the footwear does not provide adequate protection, another option is special **shoe covers**. The materials



from which the shoes are made should be suitable for the contact chemicals and, especially so if aggressive chemicals are involved, whether the work area is contaminated or there is a permanent risk of contamination.

3.3.6. DECONTAMINATION

What is important is that the protective clothing is clean, i.e. decontaminated after use, if necessary. Poisoning from contaminated personal protective equipment (PPE) is very common. **Decontamination of clothes can be done either on the body**, especially if particularly hazardous chemicals are involved, **or after taking it off**. Bringing contaminated personal protective equipment (PPE) into the changing room is not allowed, as it can contaminate the area, as well as the personal clothes the workers go home in.

Skin decontamination should not be neglected either, because despite effective protection, a certain amount of chemicals can still penetrate to the skin, especially when undressing. This is why it is important to wash those body parts that have been exposed to chemicals. If skin protection is unsuitable or body contamination suspected, the complete protective equipment is taken off and full decontamination is carried out. Decontamination agents (decontaminants) depend on the properties of the contact chemicals. Neutralizing agents (acids for neutralizing alkalis or alkalis for neutralizing acids) must not be used for fear of a violent reaction, which can only worsen the condition, cause damage to the skin and further facilitate absorption. Most often, only plain water is used, and if chemicals do not mix with water (e.g. non-polar liquids such as organic solvents), soap is also advised, particularly liquid soap or soapy water. After washing up, it is necessary to rinse out the soap from the skin. No creams, lotions or similar substances should be applied to the skin that could increase the absorption of potential residual chemicals on the skin. All further treatment procedures are left to the doctor.

3.4. PROTECTION OF THE RESPIRATORY SYSTEM

The absorption of chemicals through the respiratory system depends on the type and concentration of chemicals, but perhaps mostly on their physical state. It makes a difference whether they are dust particles or tiny gas molecules. Only gaseous substances will reach the alveoli of the lungs to a greater extent. But with certain chemicals, even very small amounts of dust particles that manage to penetrate into the lungs are dangerous for the health. Such is the case with asbestos fibers (which cause asbestosis) or fine dust of quartz or silicon dioxide (which cause silicosis). This is why it is imperative to know which chemicals one is working with and what measures should be implemented to protect the respiratory system, especially if the working area is heavily contaminated.

The best way to protect the respiratory tract is to work in a clean environment. That is why it is vital to be careful around chemicals and not allow them to leave their designated area, where they do not pose a risk for human health or the environment.

There are two basic ways to protect the respiratory system:

1. purification of ambient air, i.e. the air from the working environment, or
2. supply of breathing air from other sources.

3.4.1. AMBIENT AIR PURIFICATION

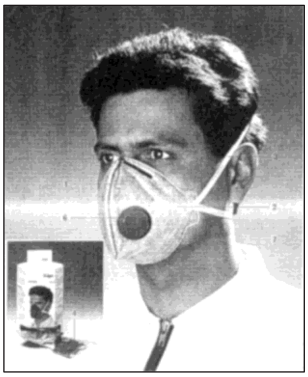
This method of protection includes two techniques:

1. filtration, and

2. adsorption.

The selection of technique primarily depends on the particle size of the dangerous substance. This is why it is very important to know the physico-chemical properties of the chemicals worked with.

3.4.1.1. Filtration



Generally speaking, ambient air purification seems to protect best against powdered substances and larger aerosol particles. Protection can be done with a simple filtration technique, most commonly used today, but also often neglected. It is highly unlikely on construction sites or in plaster plants, and especially so in slaked lime warehouses, to come across workers who use **filtering half masks for the protection against particles**. This type of protection is based on the principle of filtration. Even greater problems occur if this or a similar filtration technique is not used when working with fine quartz dust or asbestos fibers.

The filtering half mask for the protection against particles is mainly a disposable device, but can be used more than once as long as it allows effortless breathing. The filtering half mask must tightly adhere to the skin of the face so that no dust can come in from the side.

When removing the filtering half mask, it should be gently separated from the face so that no outside impurities reach the face, hands or the respiratory system.

Filtration is more effective if **half masks with particle filters** are used. The effectiveness of the half mask is directly associated with the filter. Particulate filters are white in color and are labeled as P1, P2 or P3. These filters must not be washed, purged with air or cleaned in any way, as this would enhance their permeability and render them ineffective.

3.4.1.2. Adsorption

When aerosols with particle size below 5 µm are detected in the working environment, especially vapors or gases, the adsorption technique must be applied. Often, workers who do not have sufficient prior experience in working with hazardous chemicals confuse the terms „absorption" and „adsorption".

In contrast to absorption, which implies the entry of dangerous substances into the bloodstream, adsorption is the binding of substances to a surface. Gas filters are used for this purpose. These are usually metal containers in which different adsorbents can be placed. Each adsorbent is marked with one color and a letter. A universal filter, one that contains several different adsorbents, is marked with colored stripes.

When a filter is marked with a white stripe and a letter P, it means that it also includes a particle filter at the front. Namely, some gases are combined with aerosols, and are most easily detained at the filter, which extends the service life of the adsorbent. When a filter uses both filtration and adsorption techniques simultaneously, it is called a **combined filter.**

These filters are attached to a **half mask** or a **full face mask**. Unlike the half mask, the full face mask includes additional cheek pieces that protect the skin of the face and goggles, or a visor. Both have straps for fastening to the head and a valve system – an inhalation valve and an exhalation valve. The valves are permeable only in one direction – the inhalation valve only inwards, and the exhalation valve only outwards. The full face mask solves this problem by including a half mask inside.

Before entering a contaminated area, a space where the concentrations of gases, vapors or aerosols of fine particles exceed the exposure limit value, a protective mask should be put on. Here is where the situation gets complicated. Workers often do not know how to use the mask, how to adjust it or check if it works correctly. Therefore, in work places where **personal protective equipment (PPE)** is obligatory, **instructions for use** should be consulted for safe entry into the contaminated area. Here is a brief overview of the instructions for using a protective mask with a filter.

Personal protective equipment (PPE) should be maintained properly for longer service life and to be immediate availability for next use. Filters should be attended to, especially their serviceability. Each filter has a shelf life guaranteed by the manufacturer. The manufacturer will specify the exact period in which the filter can be used, regardless of whether being stored or used. When the protective covers are removed from the filter (tearing the safety tape), the service life of the filter is significantly shortened. If the filter is used at high concentrations of hazardous chemicals, it can be so used for a very short time. That is why the concentration of chemicals in the working environment must be monitored and filter use time adjusted accordingly.

Maximum concentrations of hazardous chemicals a filter may be exposed to are strictly specified. If the chemicals' concentrations exceed the given values or if the concentration of oxygen in the working environment drops below 17 %, this protection method is rendered ineffective and cannot be applied. Breathing air should be supplied from another source.

Instructions for use of the protective full face mask

- Move the straps away from the body of the mask with your hands.
- Place the chin in the lower part of the mask and pull the straps over the head.
- Tighten the top and bottom pairs of side straps, and then the upper front strap.
- Cover the inhalation valve with the palm of your hand, breathe in air under the mask and wait to see if the negative pressure created under the mask is released.
- If yes, further tighten for better adherence of the cheek pieces to the face.
- If the air still penetrates under the mask, the mask is defective and needs to be replaced with a correct one - use only fully functional masks.
- If the mask is fully functional, attach the desired filter and tighten firmly.
- Cover the filter opening with your palm and repeat the permeability check.
- Only if the entire system functions properly can you enter the contaminated area.
- After finishing work, leave the contaminated area and do not take off the mask or separate the filter before you get to a clean environment.
- Decontaminate the mask (using an air current, water and soap, detergent or another agent).
- If the filter is still good for use, put the protective caps back on and have it decontaminated.
- Dry the personal protective equipment (PPE) and store it in a designated container (bag, cabinet, etc.), away from the contaminated area.

3.4.2. SUPPLY OF BREATHING AIR FROM OTHER SOURCES

There are two basic systems for supplying air from other sources:

1. hose breathing apparatus
2. self-contained breathing apparatus.

Both systems have their advantages and disadvantages.

3.4.2.1. Hose breathing apparatus

There are several different versions of the hose breathing apparatus, depending on the method of air supply (natural air current, fan-injected air) and whether the air is supplied from a clean area or a larger tank. These devices have a wide application in laboratories and industries, but also under field conditions. The device consists of a pipeline with connection valves into which air is injected at almost normal atmospheric pressure, only slightly higher.
A worker wearing an insulation suit is connected by a hose, which is an integral part of the suit, to the valves and air is injected inside the suit to allow normal breathing. Under field conditions, there is no pipeline, but the user is directly connected by the hose to an air tank. The advantage of a hose breathing apparatus is its availability in a contaminated area for an unlimited time, because there is a constant inflow of fresh air. The disadvantage of the device is low mobility. The worker's movement range is limited by the length of the hose. That is why this device is not suitable for a large range of movement, especially over longer distances, or in confined or maze-like spaces, where the hose can get tangled or caught. Also, it cannot be used in fire-affected areas or areas contaminated by aggressive chemicals, as the air supply hose could be damaged. In such situations, it is better to use a self-contained breathing apparatus.

3.4.2.2. Self-contained breathing apparatus

Here too, several versions are available. The basic division is into open-circuit and closed-circuit devices. The latter has to do with the air / oxygen supply method.
The self-contained open-circuit compressed-air breathing apparatus consists of an air tank, manometer, reduction valve, sound alarm, high and low-pressure hoses, a mouthpiece and protective mask. As the air in the bottle is pressurized at 200 to 300 bar, depending on the design, it is necessary to reduce this pressure to normal atmospheric pressure. The reduction valve has a **sound alarm** that reacts to the pressure in the tank. When the pressure falls below a certain value (usually set around 50 bar), the alarm sounds, letting you know that the air is running out and that you need to leave the contaminated area. In a safe area, the empty tank is replaced with a new, full one and then work can be continued. The sound of the alarm is quite loud and irritating to compel the worker to leave the contaminated area as soon as possible and close off the air supply, after which the beeping will stop. After the reduction valve, the low-pressure hose leads to the demand valve. This isa system of

valves (an inhalation valve and an exhalation valve) that respond to breathing. In other words, when one needs to inhale, negative pressure is created under the protective mask, which automatically opens the inhalation valve and blocks the exhalation valve and air is supplied from the low-pressure hose. When one needs to exhale, a slight positive pressure is created under the mask, which blocks the inhalation valve and opens the exhalation valve to let the air out. As with the protective mask, and all other protective equipment, instructions for use must be clearly displayed. These must describe in detail how to put on, check, use, take off, decontaminate, maintain and store the protective device. This protection method guarantees better mobility than for the hose apparatus, but its disadvantage is short availability in the contaminated area. One tank can last from 30 to a maximum of 40 minutes, and sometimes even shorter. It primarily depends on the difficulty of labor. During more strenuous tasks, breathing is faster and deeper, which consumes more air.
There is a system that can extend the time spent in a contaminated area. This is a regeneration device, i.e. a **self-contained close-circuit breathing apparatus**. Unlike in open-circuit devices, the exhaled air is not released here. The main purpose of this device is to collect residual oxygen in exhaled air. The only unusable ingredient of exhaled air is carbon dioxide. Instead of the air being released out through a hose connected to the exhalation valve, the air flows into a chamber with alkaline granulate where, after neutralization, carbon dioxide is deposited in form of carbonate, while all the remaining unchanged air is injected back into the regeneration chamber and the following chamber where it will be enriched with oxygen. This way, the maximum stay in the contaminated area can be tripled.

3.4.2.3. Self-contained self-rescue device, SCSR

The self-contained self-rescue device is used primarily when entering an area at risk of sudden contamination with hazardous chemicals that could be absorbed through the respiratory system and pose a serious threat to human health or survival. The performance of the self-rescuer depends primarily on the circumstances in which the device is used, the time spent in the contaminated environment, as well as the type and concentration of dangerous substances in the working environment. Such a device can work on the principle of filtering the ambient air or supplying air from another source.

3.5. HERMETICALLY SEALED ROOMS

The selection of the system to be used depends on the conditions in the working area. The method of supplying air from another source is used mainly when the concentrations of hazardous chemicals are (expected to be) very high. This is most often the case when some unforeseen accident happens, when a chemical leaks from its designated safe area beyond control, whether it is dispersed, spilled or evaporated. However, in such situations, the number of protective devices is usually limited and the number of workers is almost always greater.
This is why there must be sealed-off rooms in all the places where there is a risk of sudden outgassing of large quantities of dangerous substances. These are rooms that serve for the temporary protection of people and must be easily accessed from particularly dangerous places. There must be at least one antechamber in the building that is also hermetically sealed. This antechamber is used for safe entry into the main premise and, if necessary, for storing contaminated and decontamination of personal protective equipment (PPE). In hermetically sealed rooms, workers should have at their disposal personal protective equipment (PPE), a device for communicating with the outside world (e.g. a mobile phone or radio).
Communication devices are primarily used to communicate with expert teams in order to agree on the method of delivery of suitable personal protective equipment (PPE), which will guarantee safe exit from that area, or are used to notify about the outdoor concentration of hazardous chemicals falling below critical values and to announce it is safe to exit. After entry into the sealed-off room, workers

should limit their movement to a minimum and carefully follow the instructions given through the means of communication. When someone new enters the hermetically sealed shelter, they are first allowed into the antechamber, and into the main room only after the antechamber door is closed shut and secured from the outside environment. In case of penetration of contaminated air, personal protective equipment (PPE) is used.

If there are no hermetically sealed rooms in the building, **sealing can be done using temporary means** inside available rooms. The most important thing is to reduce the exchange of air from the sealed-off room with the outside air to the smallest possible extent. For this reason, said room should have as few openings as possible (e.g. windows or doors). Cracks are easiest to fill with putty. Openings in door or window frames can be secured using adhesive tape.

4. CHEMICAL ACCIDENTS AND DISASTERS

What are "chemical accidents" and what "chemical disasters"? The difference is very simple. During a chemical accident, there is a risk of chemicals being released from their tanks or reactors, thereby causing a potential danger to people, the environment and material or cultural goods. A disaster, on the other hand, kills people or causes great damage to their health, the environment or to material and cultural goods. These definitions are rather vague, as they do not cover all the potential consequences that chemicals can cause. For instance at first, it might seem that the evaporation of the chemical causes only minor damage, but the chronic consequences of human exposure may turn out to be catastrophic.

4.1. WHERE OR HOW CAN CHEMICAL ACCIDENTS OR DISASTERS OCCUR?

Both can occur during any procedure involving chemicals, i.e. during production, transport, storage, sale, use or disposal, and everyone who handles chemicals must at all times be prepared for an accident or a disaster. A much more important question is when do chemical accidents occur? The people involved in remediation after chemical accidents usually say that such accidents take place on the weekends and at night, which is not far from the truth, as will be shown later. The main causes of chemical accidents are:

- human error,
- technology,
- other reasons.

Memorial for the Bophal gas tragedy victims.

4.1.1. HUMAN ERROR

Unfortunately, most of the time human factor is to blame for chemical accidents, which ties in with the earlier presumption concerning weekends and nights. There are usually fewer workers on weekends and at night and they are often less qualified to work with hazardous chemicals, while fatigue also plays a part. Though this illustrates some of the causes of chemical accidents and disasters, an exhaustive list cannot be given. These constitute the most important causes of chemical accidents:

- ignorance,
- non-adherence to prescribed measures for handling chemicals,
- non-adherence to the emergency plan of action in the event of an accident,
- other factors.

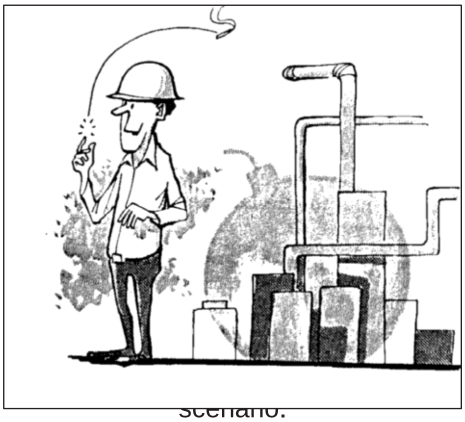

It couldn't have been me. Can't you see I'm drunk?

4.1.1.1. Ignorance

Everywhere in the world, ignorance is the main cause of accidents. All workers handling chemicals must have a good knowledge of both the chemical they are working with and the process they are involved in, or, otherwise, they will not know what to do when things go wrong or just how dangerous a chemical can be and in what way. This is why, in addition to general training in handling chemicals, it is vital to learn about all the chemicals used, their physical and toxicological properties, as well as all that is necessary for specific processes involving them. Detailed information on chemical properties is provided in the documentation accompanying the chemical and must be made available to workers at all times. This means that the safety data sheet and/or other equivalent document should be translated into Croatian, if written in a foreign language. The responsible person must provide the workers with detailed information about the processes involving chemicals. However, knowledge is only one segment of the skillset a worker must possess. Training in procedures to be undertaken in the event of an accident is another crucial element.

4.1.1.2. Non-adherence to prescribed chemical handling measures

All measures prescribed for handling chemicals must be clearly indicated at the workplace and followed. The instructions must state how the worker is protected from the effects of chemicals, but also what general technological measures should be applied during work to avoid accidents (e.g. maintaining the working temperature of a chemical process, rate of adding chemicals to the reaction vessel, ban on mixing certain chemicals with water or transporting chemicals in unfavorable weather conditions, etc.). Interestingly enough, non-adherence to these measures is, after ignorance, the second most common cause of chemical accidents, and precisely the key area where the most can be done to prevent them. Every worker must be warned about any unauthorized work on their part by their colleagues, because they are the ones that may be held responsible for a chemical accident caused by the unprofessional work of another.



Smoking is bad for your health.

4.1.1.3. Non-adherence to the emergency plan of action in the event of a chemical accident

When it becomes evident that things might lead to a chemical accident or disaster, it is crucial not to make further mistakes. However, a person in such a situation does not have much time to think. Panic sets in and wrong decisions are easily made. This is why it is extremely important to follow an emergency plan in the event of a chemical accident, which must be made available to every worker. It is equally vital that every worker knows the plan well and understands their personal role in it. The plan can not foresee every potential scenario or unpredictable event, but persons who are well trained in working with chemicals, who understand the work process well and are qualified to implement the emergency plan, will manage better in the event of a chemical accident. Again, the main focus is on education and training. In addition to the aforementioned, systematic drills are also important as the only way to detect possible intervention errors and amend the original emergency plan. Without practice, mistakes can be expected when an accident occurs and the already serious consequences may be additionally aggravated.

Go figure!

4.1.1.4. Other factors

We are fail-proof.

Finally, there are other factors that can render the worker incapable of making the right decision, such as temporary physical or mental incapacity caused by any factor (e.g. alcohol intoxication at work, fatigue, etc.). This need not be further discussed as it is already regulated by numerous national laws. However, two notions should be mentioned: fear and panic. Fear of the chemical that the worker is handling can be good motivation for suitable behavior in terms of adhering to chemical handling regulations, but inevitably becomes a bad thing when fear turns to panic. This sometimes happens even during normal work when a worker is unable to perform all the necessary measures to prevent an accident precisely due to progressed panic. In a situation of a chemical leakage threat or when an error occurs in the work process, it is extremely important to maintain composure and follow the emergency plan. This will be that much easier to achieve if the workers are well trained to carry out the plan.

4.1.2. TECHNOLOGICAL ERROR

Technological error is the third most frequent cause of chemical accidents and disasters, although it could be said that the human factor plays a part here too. The law and work instructions for each chemical and each process stipulate the use of correct tools or machines and their systematic surveillance. An accident most often occurs due to a technical malfunction, which was not duly noticed due to sloppy surveillance which, again, is a human factor. Sudden accidents due to an unforeseeable technical failures are much rarer, but they constitute a problem precisely because they are unexpected and often not even foreseen in the emergency plan. The company is obliged to comply with the rules on servicing and surveillance, as this reduces the frequency of mishaps. A decade ago, there were frequent accidents at chlorine stations due to valve failures or the falling off of the tank bottom, but since stringent controls were introduced, and since no tanks suspected of any damage are accepted for refilling, there have been no more chlorine release accidents. Simple as that!

4.1.3. OTHER REASONS FOR CHEMICAL ACCIDENTS

Various predictable and unpredictable external factors can cause a chemical accident or its consequences to be aggravated. The most common such factors are natural phenomena such as earthquakes, floods or strong storms. Though these cannot be controlled, they must be taken into account when designing and building chemical facilities. How difficult it is to predict the effects of various unexpected factors is evident from the case of a telecommunication system collapse in England during an accident when, due to thick smoke coming from a nearby plant, the panicking population blocked with their calls all city and provincial services, causing the collapse of the telecommunication system of the entire area, including all emergency services. In Croatia, most chemical accidents were caused by enemy war activities, especially in 1991. In such circumstances, little could be done to prevent accidents. The future may bring about terrorist attacks on strategic facilities, which is something we need to prepare for.

4.2. KEY ACTION AREAS IN CHEMICAL ACCIDENTS

There are three key areas of action in the event of a chemical accident, namely:

– prevention,
– reaction to a chemical accident
– remediation.

The following text will discuss the role of the worker and what to keep in mind in order to prevent a chemical accident, act in the event of its occurrence, and carry out suitable remediation.

4.2.1. PREVENTING ACCIDENTS

All segments of this manual, including the introduction to the chapter on accidents, reiterate the same basic idea: that chemical accident prevention is the most important thing and that success is guaranteed if all the know-how acquired through training courses on handling chemicals is applied and all regulations adhered to. In this regard, workers have the following obligations:

- regularly attend general courses on handling chemicals and specialized company courses on chemical accident prevention,
- training procedures in the event of a chemical accident, according to the local emergency plan in the event of a chemical accident (drills),
- adhering to all written instructions on handling chemicals
- adhering to all written instructions about the process being carried out, including the inspection of the working equipment used,
- maintenance and use of all prescribed personal protective equipment (PPE),
- making sure that suitable first aid kits are supplied at the workplace,
- regularly undergoing all prescribed health examinations

No unauthorized access

A lot has been said about the workers' obligations and this should be enough. Some of these obligations are defined by national laws and, if not adhered to, penalties are foreseen. When it comes to training courses, it is vital to know the chemical being used as well as the process in which it is used. After this, it becomes much easier to understand the importance of regular drill exercises in the event of a chemical accident. The emergency plan must include all urgent measures that must be taken, and in which order.


Drills save lives!

Regardless of the procedures and their order, the use of personal protective equipment (PPE) is always given priority because without protection one is unable to take other necessary steps. What measures will need to be taken on a case-by-case basis depends on the chemical and the process in which it is used. Sometimes, all energy sources in the system will need to be disconnected, when there is a risk of a chemical leaking, or certain valves closed. In other cases, further measures will need to be taken, depending on written instructions. For example, in most cases when transporting dangerous goods the vehicle will need to be stopped in addition to undertaking other legally defined measures, as to protect other road users, the population, the environment, or material assets and cultural heritage. However, stopping the vehicle precisely at the moment when realizing that an accident is imminent might not be wise, as the hazard might be reduced by driving on just a little further away from a potential high risk area.

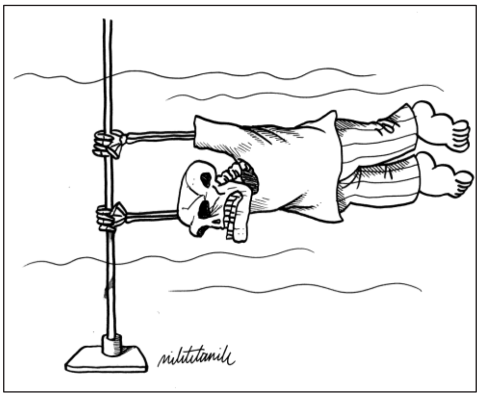
4.2.2. RESPONDING TO AN ACCIDENT

As pointed out earlier, the course of events in a chemical accident does not have to follow the order foreseen by the emergency plan. In practice, things will always turn out differently for numerous reasons, simply because all factors involved in an accident just cannot be predicted. However, a good plan will provide a framework for action. The most important segment being precisely the reaction of the workers in the first moments after the accident occurs. The first minutes are the key period when the most can be done to prevent an increase in the scope of harmful consequences, which is why the workers' on-the-spot reaction is crucial. By the time the special intervention team arrives, the situation will either be under control or huge efforts and specialized devices will be needed to keep the accident localized. This illustrates best the benefits of systematic worker training in the prevention of chemical accidents and quick reaction in the initial moments after a chemical accident / hazard. Once again, it is vital to keep a clear head and not let panic set in. This will be easier to do if the workers primarily focus on their own protection, because they are the first line of defense and if they are incapacitated, there will be no one left to carry out the necessary measures set out in the emergency plan.

4.2.2.1. Model action plan in the event of a chemical accident

The emergency plan can foresee different scenarios and all of them should be rehearsed because anything can happen in real life. Let us analyze the case of a tank truck carrying a chemical and overturning sideways, blocking all the valves for releasing the chemical. Firefighters who came to release the chemical had no training in similar cases, since their plan foresaw transferring the chemical from a tank truck standing upright on the road and burning or leaking chemicals. The emergency plan must foresee several extremely important factors such as:

- methods of protecting workers caught at the scene of the accident, including types of personal protective equipment (PPE),
- localizing the accident or at least slowing down and mitigating its potential consequences (e.g. closing off valves, turning off electricity, cooling an overheated tank, extinguishing fires, , etc.),
- exclusion of all external risk factors that could aggravate the scope of the accident (e.g. removal of other chemicals that could worsen the situation or extinguishing a fire that could spread to containers with potentially hazardous chemicals),



– methods of reporting to responsible persons by companies, services and institutions responsible for intervention in the event of a chemical accident (e.g. order of calling, means used to achieve communication, list of data that should be forwarded to responsible persons, institutions and services, etc.),
– methods of providing emergency aid to the poisoned or injured and their evacuation to a safe place, as well as instructions on what information and/or drugs and antidotes should be delivered to attending physicians,
– methods of informing the public about the accident and its possible harmful consequences and instructions on conduct (e.g. ordering urgent evacuation or withdrawal to hermetically sealed rooms),
– accident localization procedures, including a list of means and equipment to be used,
– all other data considered important for the case.

Don't exercise downwind!

Shovels and sand bags will solve many problems.

Public relations are vital and must be thoroughly planned. On the one hand, people are eager to watch accidents or even gather together at the scene, some even bringing children to watch from a close range. Clueless about the level of danger, they willingly expose themselves to potential chemical risks. Another problem is communication with citizens through the means of public communication. While citizens are impatiently waiting to hear the latest news, reliable data are scarce. Consequently, unconfirmed, or even untrue, sensationalist informations are often reported instead.

4.2.3. SANATION

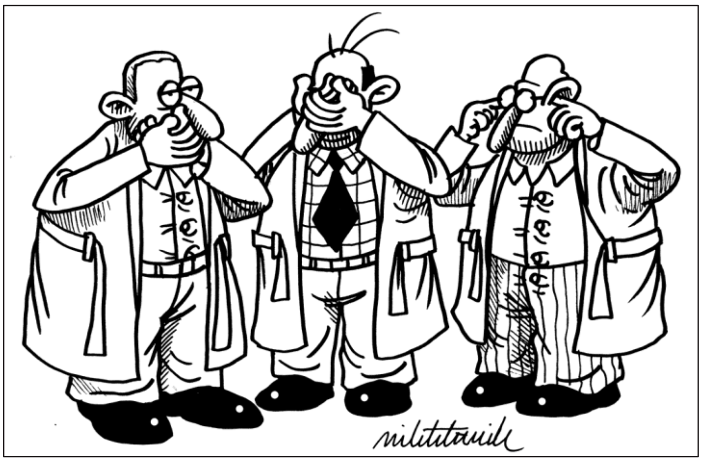
The consequences of a chemical accident depend on how successful the initial reaction was, especially in the first moments after the accident. These consequences are primarily reflected on human health, contamination of the environment and material and cultural assets. Sanation is usually extremely expensive and time-consuming and its cost by far exceeds the worth of the chemicals and property of the company involved in the accident. The inevitable tasks that must ensue after a chemical accident are as follows:

Water spray will solve many problems.

– treatment of poisoned or injured persons,
– analysis of the event,
– long-term monitoring of the health of everyone exposed to chemicals,
– identification of damage done to the environment and material and cultural goods,
– removal of contaminants done to the environment and material and cultural goods,
– long-term monitoring of chemicals in the environment.

4.2.3.1. Analysis of accident

The workers who take part in sanation will not be involved in all the above tasks, but their help or participation is extremely important. This refers to the analysis of accident, where every piece of information obtained from an immediate witness is invaluable for future reference. There is no chemical or other type of accident where mistakes or wrong moves were not made that are later difficult to explain to someone who was not at the scene. This is why it is vital to collect any and all data on the course of accident, the measures taken and their results. In this way, indispensable knowledge is acquired which will come in handy sometime in the future when someone else finds themselves in a similar situation.



Just don't overanalyze!

4.2.3.2. Monitoring human health

Monitoring of human health is intensified after an accident and is carried out over the course of many years. Harmful consequences on the human body do not have to appear immediately but can do so years later. Although monitoring the health of exposed persons is a long-term activity, as well as expensive and exhausting for both the attending physician and the exposed worker, it provides a guarantee that rare and/or delayed adverse effects will be noted in due time and treated accordingly. Today, the cost of monitoring the health of exposed persons is, most often, borne by the state, because the culprit is simply not able to cover the costs, much like the insurance companies are not willing to take on such risks. Now is a good time to remind again that the cheapest method of remediation is prevention.

4.2.3.3. Monitoring chemicals in the environment

Monitoring of the movement of chemicals through the environment is also important for the protection of the population living near the accident area. The chemicals that unintentionally leaked into the environment can now circulate freely depending on their properties and the properties of the local environment and can, eventually, reach the human body through contaminated food and water. Consequently, years later, the environment may become dangerous and a potential source of poisoning for the population. Monitoring of chemicals through the environment is extremely expensive but not as expensive as removing them from the environment, and these costs usually exceed by far the value of the company that caused the accident. Again, the cheapest and safest remediation is prevention, in keeping with all the procedures set out in the Croatian and EU legislation.

Being in control is everything.

5. DECONTAMINATION AND FIRST AID IN CHEMICAL EXPOSURE

The process of removing hazardous chemicals from the site of absorption (decontamination) must be applied if protective measures were not effective. It should be emphasized that by removing hazardous chemicals from the site of absorption, its entry into the body can never be completely prevented, so it is better to insist on the use of personal protective equipment (PPE). This section will discuss ways to remove hazardous chemicals from three potential absorption sites: the digestive system, the skin, and the respiratory tract. And another thing, the removal of hazardous chemicals from the site of absorption is not only done to prevent absorption, but also to prevent any local effects of the chemical, especially in case of aggressive and irritant chemicals.

5.1. GENERAL INSTRUCTIONS FOR ALL CHEMICAL EXPOSURE

Any contact with the skin or introduction of a chemical into the digestive or respiratory system can lead to unwanted consequences. This is why it is very important to take suitable and timely measures not to allow a chemical to have a harmful effect. If a person is in the area where the accident occurred or has yet to enter that area, it is necessary to follow the instructions to the letter. Cases of poisoning due to non-adherence to instructions on the use of personal protective equipment (PPE) before entering contaminated area are not rare. This is sometimes difficult to control when close or dear persons are the victims. At such time, one does not think clearly. Again, knowing the basic procedures in case of a chemical accident is vital, especially the procedures for decontamination and first aid.

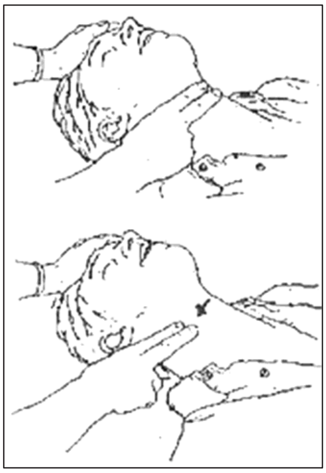
5.1.1. HOW TO BEHAVE IN AN ACCIDENT?

1. Firstly, use all available personal protective equipment (PPE).
2. Do not enter the contaminated area without personal protective equipment (PPE).
3. Perform decontamination as soon as possible.
4. Help the injured.

5.1.2. HOW TO HELP AN UNCONSCIOUS PERSON?

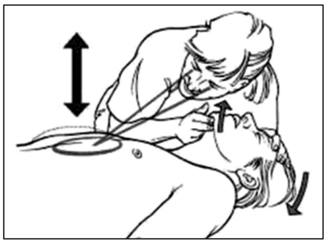
1. After taking the unconscious person out from the contaminated area, place them in a stable lateral position and clear their oral cavity from any solid objects.
2. Check their vital functions and act according to special instructions for specific types of exposure to hazardous chemicals.

5.1.3. HOW TO HELP A PERSON WITH A VITAL FUNCTION FAILURE?



1. After taking the victim out from the contaminated area, check their vital functions.
2. If the injured person is not breathing, clear their oral cavity from any obstructions and administer mouth-to-mouth resuscitation until they begin to breathe again.
3. In case of cardiac arrest and if the person is not breathing, administer chest-compressions and mouth-to-mouth resuscitation alternately (full CPR).

5.1.4. STRICT RULES WHEN TRANSFERING THE VICTIM TO A MEDICAL FACILITY



1. No contaminated person or object may be brought inside an ambulance or enter a medical facility.
2. The first to be brought inside an ambulance or enter a medical facility are the more seriously injured persons (with life threatening injuries), and only then persons with less severe injuries.
3. Entering a medical facility without the information prescribed by the general instructions on mandatory information and materials that must be submitted to the attending physician is strictly forbidden.

5.1.5. WHAT MUST BE DELIVERED TO THE MEDICAL FACILITY?

A clinician at the medical facility needs to make a simple and quick diagnosis and provide assistance to the patient. The main problem is that the clinician is usually not familiar with a large number of trade names of chemicals, nor do they recognize all the chemicals, their properties or treatment methods for all poisoning types. This is why it is crucial to deliver to the attending clinician:

– all accompanying documentation on the hazardous chemical (safety data sheet, label, instructions on providing first aid, etc.), as well as product composition, if supplied;
– the individual packaging of the chemical, including pictograms and hazard statements;
– information on how the chemical entered the body;
– information on the approximate amount of the chemical to which the worker was exposed (amount of swallowed chemical, size of the skin surface exposed to the chemical, concentration of the chemical in inhaled air and time spent in the contaminated environment, etc.);
– information on the procedures applied when providing first aid at the workplace,
– other data requested by the attending physician,
– specific agents from the first aid kit intended to be administered in case of a chemical poisoning that are not common in medical practice

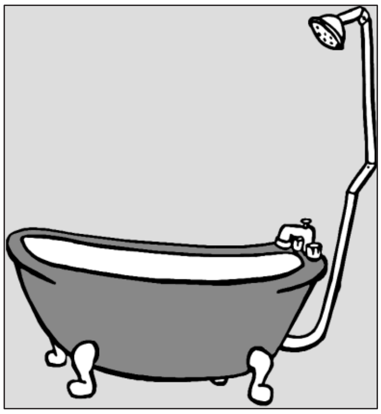
It is helpful if the poisoned person is accompanied to the medical facility by a worker present at the scene or while providing first aid, because the latter can often contribute with invaluable information. It must be pointed out that everyone who comes to a medical facility, including paramedics from an ambulance, must keep in mind the necessity of decontaminating all persons and objects involved in the accident, as this is too often disregarded.

5.2. REMOVING HAZARDOUS CHEMICALS FROM THE SKIN OR THE MUCOSA

As a rule, the removal of chemicals from the skin and mucous membranes of the eyes is utterly simple and easy to implement. Every medical facility where hazardous chemicals are handled should be able to provide this procedure. There are very rare specific cases when unusual methods of removing hazardous chemicals (decontamination) are used, but these must then be specified in the documentation supplied with the chemical.

5.2.1. WHAT TO DO FIRST?

The first and most basic thing to do when a worker is sprayed or spilled with a chemical is to take off the protective clothing and shoes. This will be done outside the contaminated zone, but in immediate vicinity. After that, rinsing with running water should be initiated as soon as possible. For these purposes, a shower with easily operable faucets for turning on the water flow and with a good drainage for contaminated water must be installed in areas adjacent to rooms where dangerous liquids or powders are handled. Rinsing is done with copious amounts of liquid and for as long as possible. It is considered that a minimum of 15 minutes of intensive showering is necessary before the exposed person may be taken to a doctor. In some cases, it is good to use special cleaning agents when washing up, such as alkaline soaps, in the case of chemicals that decompose under such conditions (e.g. certain organophosphorus compounds). When decontaminating by showering or under a stream of water, one must not forget to rinse out the chemicals from the eyes, where damage to the sensitive mucosas may be devastating. After decontamination, any excess water should be removed from the skin by dabbing with a clean gauze or similar material. No agents or medications whatsoever should be applied to the skin (e.g. creams or powders), and the skin should not be rubbed when wiping. The decontaminated person should be covered with a sterile gauze and in a semi-recumbent position urgently transferred to the nearest medical facility where all further tests and therapeutic procedures will be performed.



5.2.2. IMPROVISED AIDS FOR DECONTAMINATION

Under field conditions, when planning work with chemicals, every legal entity is obliged to provide sufficient quantities of water and all necessities for providing first aid. Decontamination can be done by pouring water from a barrel or using surface water. Small amounts of chemicals sprayed on a person’s skin can be removed by the so-called improvised aids. Ordinary paper tissues or gauze can be used to absorb drops of a chemical from the skin. No improvised aid may be utilized to wipe or rub the skin but rather to absorb the chemical by dabbing. Subsequently, the used paper tissue or gauze should be thrown away into a plastic or other bag and a fresh one taken for further absorption.
This kind of decontamination is insufficient and rinsing with water should ensue as soon as possible.

5.2.3. FIRST AID

Though this is only temporary decontamination and clearly insufficient, the first aid kit often also contains powdered materials (so-called sorbents) that can help with a specific group of chemicals (such as alkalized materials for the decomposition of organophosphates). The powder is sprinkled on the area of the skin where the chemical was removed from and a few minutes later the powder may be blown away from the skin. The procedure should be repeated after which the exposed person (with their contaminated clothes removed) should be immediately taken to the nearest place where they can be decontaminated by rinsing with water before they can be transferred to the hospital.

5.2.4. RINSING THE MUCOSA

The eyes and pertaining mucous membranes should always be rinsed out, even if there is only a vague suspicion of contamination. It is best to decontaminate the eyes with a light stream of running water. The eyelids should be spread with clean fingers and a gentle stream of running water directed into the eye, rinsing for as long as prescribed by the special instructions for a particular chemical or group of chemicals. For some chemicals, a few minutes is more than enough. But, with most chemicals, the recommended minimum is 15 minutes. With acids, it will take between 20 and 30 minutes, while with alkalis up to an hour. If the exposed person is unable to decontaminate their own eyes, a coworker should do so, paying attention to several important steps. The person performing decontamination must not be contaminated themselves and it is especially important that they have clean hands when coming in contact with the eyes of the injured person. If the victim is in such a condition that they cannot stand, they should be placed in a lying position on their back, while their eyes are carefully being rinsed, making sure that the water drips from the one eye down the cheek, and not into the other eye, contaminating it. Decontamination is done in a similar way when there is no running water at hand. The eyes will be rinsed with small amounts of water dripping or poured into the eye, making sure that the water drips from the eye down the cheek and not into the other eye. A similar procedure is used when the eye is irritated or exposed to a gaseous or powder chemical (for example, tear gas). Regardless of any eye pain or other form of discomfort, no medication or other agent should be applied to the eye, which is particularly dangerous prior to decontamination. After the eyes have been decontaminated, the injured person should be immediately transported to the hospital. Sterile gauze should be placed over their closed eyes, as to not strain their vision.
In conclusion, to make things easier, it is recommended to be familiar with the general instructions on providing first aid in case of exposure to chemicals through the skin and mucous membranes.

5.2.5. SHORT INSTRUCTIONS ON DECONTAMINATION OF THE SKIN AND EYES

5.2.5.1. How to help oneself in a chemical spill?

1. Leave the contaminated area immediately.
2. Take off clothes and shoes as soon as possible in a clean place.
3. Shower for at least as long as prescribed by the special instructions for a particular chemical or group of chemicals. Rinse out the eyes as well (see special instructions), even if they have not been sprayed, but wash your hands first.
4. After washing up, do not dry yourself off by rubbing, but rather dab using a towel, tissue or gauze to absorb the chemical. It is better to stay wet than rub the water off.
5. Do not use any creams or liquids on the injured areas.
6. With the help of uninjured persons, put on clean clothes or, if not possible, just cover yourself with clean linen cloth, e.g. a sheet or gauze.
7. Gather and take with you all materials and documents that the doctor will need to see.
8. Seek medical help. During transport, someone should accompany you, just in case.

9. Submit to the doctor all available documentation about the chemical and all relevant information about the event and the injured person.

5.2.5.2. How to help oneself in a chemical spill under field conditions with no running water?

1. Quickly move away from the contaminated area.
2. Take off your clothes as soon as possible, especially those heavily contaminated.
3. Disregard the quality of the water in water tanks for emergencies or of any standing or running water found and use it for decontamination.
4. Use any chemically clean container to catch water and pour over yourself generously. Rinse for at least as long as prescribed by the special instructions for a particular chemical or group of chemicals. In case of standing water or a river, get into the water and rinse out all the remaining chemical, paying attention to areas with more severe burns.
5. Only in cases when there is insufficient or no water nearby, use improvised aids to remove the chemical, such as paper tissues, gauze and similar chemically clean materials suitable for absorption. At the same time, do not rub, but dab to absorb. If you can find powder sorbents intended for decontamination in the first aid kit, use them after dabbing with a clean material. **Proper decontamination should ensue as soon as possible.**
6. After provisional or proper decontamination, do not wear any contaminated clothing, even if you have nothing to wear.
7. Urgently ask to be taken to the hospital and try to take with you all materials and documents that the doctor will need to see, according to general instructions.

5.2.5.3. What to do when a chemical is sprayed into the eyes?

1. Quickly leave the contaminated area and find the nearest tap or fountain for drinking water. The faucets should have a flexible rubber or plastic hose attached that can be bent and directed into the eyes. If you are not able to do it yourself, ask for help.
2. Wash your hands first.
3. Spread the eyelids using your thumb and forefinger and direct the stream of water into the eye. If both eyes were sprayed, rinse them out alternately, at first alternate the water current from one eye to the other and back quickly, later take one-minute turns. In total, each eye should be rinsed for at least as long as prescribed by the special instructions for a particular chemical or group of chemicals. If the faucet is not fitted with a flexible hose to direct the stream, lie under the faucet or kneel and tilt your head so that the water from the faucet can drip straight into your eyes.
4. After rinsing, the eyes should not be smeared with any creams or treated with any drops.
5. Ask somebody to take you to an ophthalmologist immediately or call an ambulance.
6. Take with you everything that the doctor will need to see.
7. During transport, put a clean gauze or tissue over your closed eyes, as to not strain your vision.
8. The doctor should be handed all available documentation about the chemical and all relevant information about the event and the injured person.

5.2.5.4. What to do when a hazardous chemical is accidentally sprayed into the eyes under field conditions?

1. Quickly move away from the contaminated area.
2. If you are able to help yourself or if there is no one else to help you, look for a source of surface water or a container with a larger amount of water and submerge your head so that only your eyes are in the water and your nose and mouth are not. Blink with your eyelids intensively, opening them wide and closing them again, or you can spread your eyelids with clean fingers. If the container is too small, change the water and submerge your head again, repeating the blinking process. Rinse out your eyes in this way for at least as long as prescribed by the special instructions for a particular chemical or group of chemicals.
3. Do not apply any creams or ointments or any other medicines.
4. Ask somebody to take you to an ophthalmologist immediately and take with you all materials and documents that the doctor will need to see.

5.2.5.5. How to help a victim of a hazardous chemical spill?

1. Quickly get the injured person out of the contaminated area.
2. Take off all their clothes and shoes.
3. If the injured person is unconscious or their vital functions are at risk, proceed according to the instructions for such cases.
4. Shower or rinse out the injured person using a stream of water for at least as long as prescribed by the special instructions for a particular chemical or group of chemicals, calming them down and making sure that harsh procedures do not aggravate their injuries or that water does not enter their lungs.
5. Wash your hands thoroughly and rinse out their eyes, just in case.

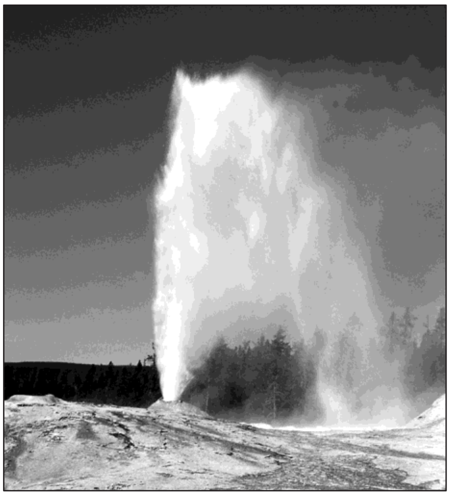
6. Do not wipe wet skin. Remove excess water by absorbing it with a towel, tissue or gauze.
7. Do not use any creams or ointments. Only cover the injured person with a clean sheet or cellulose wadding.
8. Gather and take with you all materials and documents that the doctor will need to see.
9. Get the injured person transferred to a dermatologist while constantly paying attention to whether the person is conscious. If the person is unconscious or loses consciousness during transport, they should immediately be placed in a stable lateral position.
10. The doctor should be handed all available documentation about the chemical and all relevant information about the event and the injured person.

5.2.5.6. How to help an unconscious victim of a chemical spill?

1. Take the injured person out of the contaminated area immediately and remove their clothes.
2. If the person is not breathing or is in a cardiac arrest, first restore their vital functions.
3. Shower the injured person for at least as long as prescribed by the special instructions for a particular chemical or group of chemicals under running water, taking care of their vital functions and preventing water from entering their lungs.

4. Perform eye decontamination with clean hands, if possible at the same time as body decontamination.
5. Constantly taking care to maintain vital functions, remove excess water from the injured person's skin by absorbing it and cover them with a sheet or gauze.
6. Do not use any ointments or creams on the skin or the eyes.
7. Prepare all needed materials for the doctor as specified by the special instructions.
8. Transport the injured person to a medical facility in a stable lateral position while continually monitoring their vital functions.
9. The doctor should be handed all available documentation about the chemical and all relevant information about the event and the injured person.

5.2.5.7. How to help a victim of a hazardous chemical spill under field conditions with no running water?



1. Take or carry the injured person out of the contaminated area.
2. Take off all their clothes and if they are unconscious or in case of vital functions failure, proceed according to the instructions on providing first aid.
3. Pour water (from a tank, river, lake or sea) over the injured person and, if prescribed for that particular chemical, apply a mild soap for washing. Disregard the quality of the water. Rinse for at least as long as prescribed by the special instructions for a particular chemical or group of chemicals. The person accompanying the injured person should also perform their own decontamination.
4. Try to find clean clothes to put on the victim or other fabric to cover them with, but in no case use the clothes contaminated with chemicals.
5. Quickly transfer the injured person to the nearest doctor or hospital, regardless of whether or not they are wearing clothes. Take with you everything the doctor will need for examination.
6. Give the doctor all the relevant information about the chemical, the event and the injured person.

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4. Try to find clean clothes to put on the victim or other fabric to cover them with, but in no case use the clothes contaminated with chemicals.
5. Quickly transfer the injured person to the nearest doctor or hospital, regardless of whether or not they are wearing clothes. Take with you everything the doctor will need for examination.
6. Give the doctor all the relevant information about the chemical, the event and the injured person.

5.2.5.8. How to help a victim of a hazardous chemical spill under field conditions with no water for decontamination?

1. Get the victim out of the contaminated site to a clean area and remove their clothes immediately.
2. If the person is unconscious or their vital functions are at risk, follow the general instructions for such cases.
3. Remove the chemical from the skin by dabbing using clean cellulose materials, e.g. paper tissues, gauze, etc. Clean gloves should be worn during decontamination not to contaminate the hands of the person performing the decontamination.
4. If the first aid kit includes special sorbents for the adsorption of the chemical, these should

be used.

5. Find at least a minimal amount of water (e.g. drinking water, fruit juices, etc.) to rinse out the chemical from the eyes and exposed body parts. Use clean materials (cellulose tissues, gauze or clean cloth) to absorb excess water from the skin.
6. Urgently inform emergency medical teams about the chemical accident or transport the injured person to the nearest facility for decontamination.
7. Take with you the relevant documents and materials for the doctor, as specified in the general instructions.

5.2.5.9. Rinsing out the eyes of another person with running water

1. Take or carry the injured person out of the contaminated area as soon as possible.
2. If the person is conscious, follow the special instructions. If, at the same time, aggressive liquid was spilled on the injured person, take off their clothes and carry out decontamination by showering. Decontaminate the eyes simultaneously.
3. If the injured person is able to stand, carry out decontamination by directing a light stream of water directly into the eyes, while spreading the eyelids of the injured person with thoroughly washed hands. Rinse alternately one eye and the other so that each eye is rinsed for at least as long as prescribed by the special instructions for a particular chemical or group of chemicals.
4. In the case of decontamination of an unconscious person, make sure that water does not enter the injured person's lungs when rinsing. Place the injured person on their back and under a gentle stream of running water, alternately rinsing out the eyes so that the water from each eye flows down the cheek, and not into the other eye.
5. After rinsing, do not apply any ointments or solutions to the eye, but place a clean gauze over the injured person's eyes and get them to a hospital, following the general instructions.

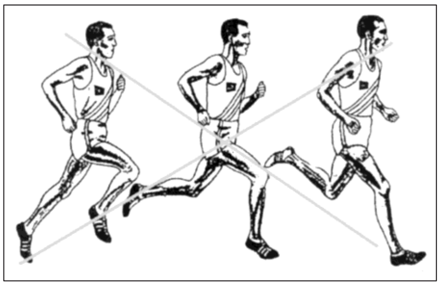
5.2.5.10. Rinsing out the eyes of another person under field conditions

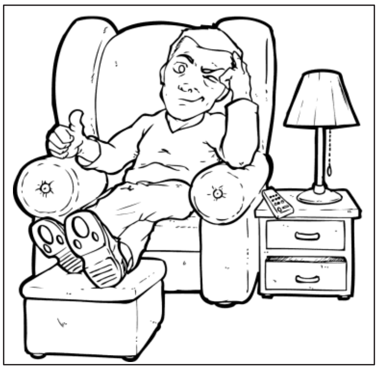
1. Take or carry out the injured person from the contaminated area.
2. In the injured person is unconscious or with failed vital functions, proceed according to the special instructions.
3. If the injured person was also spilled with a chemical, proceed as described for that specific case.
4. If the injured person is able to walk and understands the instructions, pour water into a large container and explain to them how to immerse the upper part of the head in the water and blink intensively to rinse out the chemical from the eyes.
5. If the injured person is unable to help themselves and is conscious, take them away from the accident site to a source of water and lay them on their back. After carefully washing your hands, take some water into a container and carefully start pouring it into one eye, while opening the eyelids using the thumb and forefinger. At the same time, make sure that the water from that eye flows down the cheek, and not into the other eye. If both eyes were sprayed, rinse them alternately for at least 15 minutes each. Pour water from the container generously

5.2.5.11. Special decontamination in case of water-reactive chemicals

With certain chemicals, it is not possible to use water or water-based agents. Such chemicals are, for example, phosphorus pentoxide, which reacts aggressively in contact with water, causing very severe damage to the skin. It is similar with phostoxin, which in contact with water develops highly toxic phosphine. Special decontamination rules apply to such chemicals and it is necessary to carefully study relevant documentation before undertaking any decontamination or first aid measures.

5.3. RESPIRATORY SYSTEM





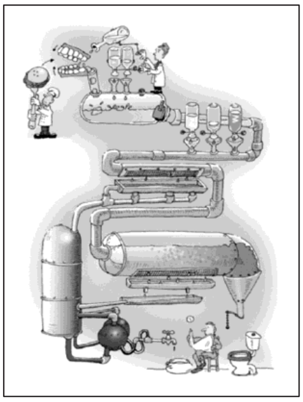
A person who has inhaled gases, vapors, dust or an aerosol chemical must immediately leave the contaminated environment and get out into clean air. While doing so, they must immediately put on a protective mask or apply another improvised aid (gauze or tissue, if soaked with water will prevent the penetration of a good part of the chemical into the respiratory system).

The contaminated area should be walked out of slowly, never by running. Running accelerates and deepens the breathing, allowing the chemical to get deep inside the respiratory system, as far as the alveoli, where absorption is most extensive. If it is not possible to walk slowly away from the contaminated area due to a large contaminated surface, a protective mask should be worn while waiting for evacuation. Decontamination itself, after getting the victim away from the contaminated environment, is reduced to cleaning the contents of the nasal cavity while the biggest problem is damage to the mucous membranes of the respiratory tract and lungs caused by an irritant chemical, which may lead to spasms or even swelling of the trachea and lungs. Very often, there is really nothing else to do but get the injured person to the nearest medical facility in a semi-recumbent position while calming them down to prevent a panic attack. Always follow the instructions on post-exposure procedures.

5.3.1. WHAT TO DO AFTER AIRWAY EXPOSURE TO A CHEMICAL?

1. Apply respiratory protection (protective half mask, mask or an improvised aid).
2. Get out into fresh air as soon as possible but without panicking or taking in too much oxygen.
3. In case of vital functions failure, proceed according to the rules on resuscitation.
4. With unconscious persons, proceed according to the instructions for unconscious persons.
5. Persons exposed to irritant chemicals should be calmed down and placed in a semi-recumbent position, regardless of whether they manifest pronounced symptoms of damage to the respiratory mucosa or not.
6. Call an ambulance or organize transport, and take with you all materials and documents that the doctor will need to see, according to special instructions.
7. Send the injured person to intensive care, and give the doctor all the documentation about the chemical and all relevant information about the event and the injured person.

5.4. DIGESTIVE SYSTEM



An important fact regarding the digestive system is that it is very difficult to remove a chemical once it reaches a certain point after ingestion and it is especially difficult to remove a chemical that has already reached the intestine. The organism defends itself against absorption of chemicals using two mechanisms: vomiting and diarrhea, both typical symptoms of poisoning. However, this is not the case with all chemicals. Some, for example, cause constipation and significantly slow down the bowel movement which, in turn, leads to an increase in the extent of absorption.

Medicine applies various techniques for removing chemicals from the body but the question remains who may apply these techniques and when. Some of the techniques may be performed by the victim themselves, a colleague or the responsible person, while others may only be applied by a clinician or a suitably trained nurse. This type of information should best be included for each individual chemical or a group of chemicals with the same properties in the mandatory instructions on first aid procedures.

5.4.1. REMOVING CHEMICALS FROM THE DIGESTIVE SYSTEM

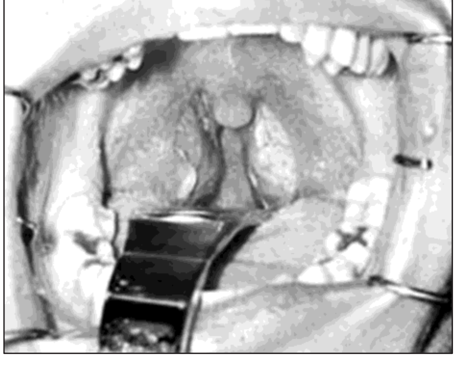
In what ways can a chemical be removed from the body? These are the following techniques:
– inducing vomiting,
– gastric lavage (clinician's discretion),
– use of laxatives (clinician's discretion),
– use of substances that will immobilize the chemical in the digestive system or change some of its properties.

Firstly, it should be warned when a chemical should not be removed from the site of absorption in the digestive system by vomiting. This is prohibited in the following cases:
– when swallowing strong acids or alkalis and all corrosive chemicals,
– with easily volatile liquids, especially those with low viscosity,
– with foaming agents,
– in other special cases.

5.4.1.1. General instructions in case of swallowing hazardous chemicals

1. Do not induce vomiting in case of swallowing aggressive chemicals (e.g. acids, alkalis or heavy metal salts), easily volatile organic solvents (e.g. thinners, oil derivatives, etc.) or detergents (especially, if they foam heavily).
2. Do not induce vomiting or apply any agents in a person who is unconscious or with failed vital functions. Act according to the special instructions for such situations.
3. See if the instructions on post-exposure conduct say anything in particular about swallowing the chemical, especially in case of fast-acting poisons or highly toxic substances.
4. In most cases, poisoning does not occur immediately after the chemical is swallowed, so you should keep your composure and not act rashly.
5. Regardless of the intended first aid procedures, a competent medical facility should be called immediately.
6. Do not leave the injured person unattended but provide assistance in performing the procedures described in the mandatory instructions.

5.4.2. AGGRESSIVE CHEMICALS



Ingestion of corrosive chemicals is associated with severe damage to all mucous membranes with which the chemical has come into contact. Acids and alkalis (e.g. glacial acetic acid, concentrated sulfuric or nitric acid, concentrated alkali solutions including concentrated ammonia solution, etc.) **will cause severe injuries to all the mucosas from the mouth through the esophagus to the stomach and beyond, wherever they get to**. The mechanisms of further damage and absorption of these chemicals are different, but in all cases perforations are possible anywhere from the esophagus to the intestines. Inducing vomiting could increase the damage due to strain, although in such cases the poisoned person very often vomits spontaneously. It is extremely difficult to give advice on what to do when someone has swallowed aggressive chemicals. It is wisest to drink some water in order to rinse out the particularly sensitive mucous membranes of the mouth and esophagus and dilute the chemical in the stomach. It is extremely dangerous to administer any chemical neutralization agent because of the violent reaction that can lead to damage of the barrier, as well as development of heat during neutralization. A poisoned person should be taken to a hospital immediately.

5.4.2.1. What to do after swallowing aggressive chemicals?

1. Give the injured person a glass or two (2.5 to 3 dl) of plain water to drink, place them in a semi-recumbent position and calm them down.
2. Immediately call an ambulance and transfer the injured person to the hospital.
3. Do not induce vomiting, but do not prevent it when it occurs spontaneously. After vomiting, give the injured person another glass of plain water.
4. Do not give the injured person any other liquids, especially neutralizing agents.
5. Take all the materials and documents to the hospital that are indicated in the special instructions.

5.4.3. ORGANIC SOLVENTS

With organic solvents or easily volatile liquids, in general, vomiting can cause one part of that liquid to reach the lungs and cause mild or severe damage there, pulmonary edema (suffocation) or even death. Gastric lavage is best performed by a well-trained medical professional, taking all necessary measures to protect the respiratory system. As with aggressive chemicals, it is necessary to take the poisoned person to the hospital as soon as possible, while calming them down and keeping them in a semi-recumbent position.

5.4.3.1. What to do after swallowing organic solvents?

1. Calm the injured person and place them in a semi-recumbent position.
2. Immediately call an ambulance.
3. Do not give the injured person anything to drink.
4. Take all the materials and documents to the medical facility that are indicated in the special instructions

5.4.4. FOAMING AGENTS

Foaming agents (e.g. various detergents) are dangerous due to their foaming effect that could increase when vomiting is induced. Foam reaching the lungs could cause suffocation or even death of the poisoned person. There are anti-foaming agents intended to counteract the effect of foaming agents, but these may only be swallowed in prescribed quantities and preferably under the supervision of a health professional.

5.4.4.1. What to do after swallowing detergents?

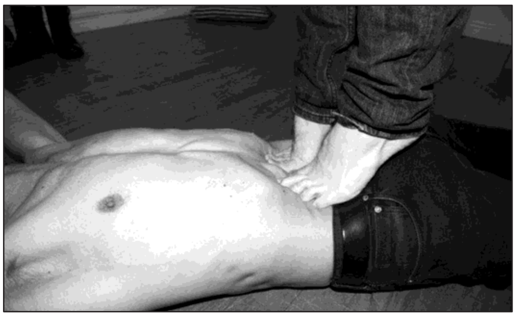
1. Urgently give the injured person an anti-foaming agent from the medicine cabinet, according to the instructions found therein, and if none, do not administer anything.
2. Do not induce vomiting.
3. Immediately call an ambulance.
4. Take all the materials and documents to the medical facility that are indicated in the special instructions.

5.4.5. UNCONSCIOUS STATE

Other cases when vomiting should not be induced are very rare and there must be a warning on the container with the chemical and/or on the posted instruction on the procedures after swallowing such a chemical. **Vomiting, in particular, should not be induced in an unconscious state**. In such a case, the general instructions on saving the vital functions of the injured person must be followed, i.e. they must be placed in a stable lateral position, their airways cleared up and the necessary measures applied (e.g. mouth-to-mouth resuscitation or chest compressions) when necessary. Sometimes, the victim starts vomiting spontaneously in an unconscious state. Their upper body should immediately be positioned to hang downwards. In this position, the content going up from the stomach is drained much faster from the upper part of the digestive system. This way, the danger of blocking the airways is eliminated faster than if the person were lying down. As in all other severe cases, the poisoned person should be sent to the hospital as soon as possible.

5.4.6. HOW IS VOMITING INDUCED?

It is best to induce vomiting mechanically by pushing a finger into the throat or to the root of the tongue, i.e. by stimulating the posterior soft palate. There are various means of inducing vomiting, but these should not be applied by an untrained amateur. The injured person, or a colleague, can best enhance the extraction of the chemical by swallowing water, preferably warm, and then mechanically inducing vomiting using a finger. **Once again, vomiting should not be induced if the injured person is unconscious or after swallowing corrosive chemicals, volatile solvents, detergents and other substances with an express warning against inducing vomiting.**



Whatever you do, don’t do this!

5.4.6.1. General instructions on inducing vomiting

1. Study when inducing vomiting is allowed, and check the instructions or other chemical specifications to confirm that vomiting is allowed.
2. It is recommended to take a glass or two of lukewarm water before inducing vomiting.
3. Vomiting is induced mechanically by pushing a finger down to the root of the tongue. It is recommended to repeat the procedure and take lukewarm water after each vomiting.
4. Remember that vomiting is not a guarantee that the total amount of the chemical will be expelled from the stomach, so it is advised to call an ambulance to get to

the hospital.
5. Gather and take with you all materials and documents that the doctor will need to see, as specified in the special instructions.

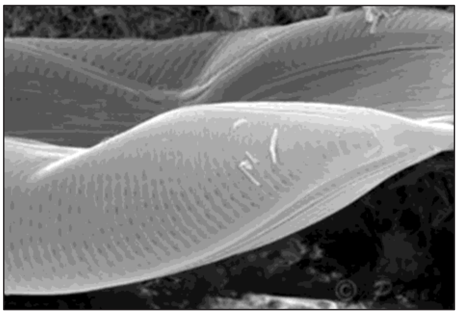
5.4.7. ADSORPTION ON AN INERT MATERIAL

Activated carbon.

The most suitable technique for the immobilization of chemicals is, without a doubt, adsorption onto a suitable inert material. Activated carbon is most often used as an inert material, since it will not be absorbed from the digestive system or cause any harm to the body and it adsorbs many chemicals strongly. It is very easy to apply, which is why it should be an integral part of any first aid kit. It usually comes in the form of powder or fast disintegrating tablets. A tablet or a spoonful of carbon should be dissolved in a glass of water and drunk. If necessary, more than once, if, say, a person vomits after taking the suspension of activated carbon. In addition to activated carbon, other sorbents are also used. One of the popular sorbents for quaternary ammonium bases (e.g. herbicides paraquat and diquat) is diatomaceous earth or Fuller's earth. Specific sorbents are indicated next to individual chemicals in the accompanying documentation and should also be an integral part of the first aid kit. If such a sorbent is used only in hospital settings, in case of poisoning, it should be brought together with the poisoned person to the medical facility.

5.4.7.1. When to use chemical binding agents (binders) after swallowing of a chemical?

1. Check to see which agent is used for adsorption (e.g. activated carbon) in the instructions on conduct after swallowing a specific hazardous chemical.
2. Take a suitable remedy from the medicine cabinet and prepare it for use.
3. Call an ambulance.
4. Gather and take with you all materials and documents that the doctor will need to see, as indicated in the special instructions.



Diatomaceous earth.