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OCCUPATIONAL SAFETY AND HEALTH IN THE WORKING ENVIRONMENT

ОХОРОНА ПРАЦІ ТА ЗДОРОВ'Я У ВИРОБНИЧОМУ СЕРЕДОВИЩІ

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The textbook describes the characteristics of the international legislative and regulatory framework on life safety and occupational health and safety, describes the system of legal, socio-economic, organizational-technical and medical-prophylactic measures and means aimed at preserving the health and working capacity of a person in the process of work, harmful and dangerous factors of the production environment and labor process, the impact of the latter on human health and working capacity were considered, measures and means aimed at creating safe and harmless working conditions were proposed.

Intended for full-time and part-time students of all specialties.

Наведено характеристику міжнародної законодавчої та нормативно-правової бази з питань безпеки життєдіяльності та охорони праці, описано систему правових, соціально-економічних, організаційно-технічних і лікувально-профілактичних заходів та засобів, спрямованих на збереження здоров'я і працездатності людини в процесі праці, розглянуто шкідливі та небезпечні чинники виробничого середовища і трудового процесу, вплив останніх на здоров'я та працездатність людини, запропоновано заходи та засоби, спрямовані на створення безпечних і нешкідливих умов праці.

Призначено для студентів денної та заочної форм навчання всіх спеціальностей.

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PART I

LEGAL SAFETY LIFE

TOPIC 1. LEGAL SAFETY LIFE

1.1 Introduction

Life safety have considerable value for the employee and employer alike. As work processes become more flexible, this branch of knowledge becomes more important for society as a whole. This knowledge is both fascinating and complex, encompassing achievements in the technical, biological and social sciences fields, which have experienced rapid growth during the past decade. Practical use of this body of knowledge – due to globalization of production and deregulation of labour markets – should be similar among individual countries.

Occupational safety is generally defined as the science of the anticipation, recognition, evaluation and control of hazards arising in or from the work place that could impair the health and well-being of workers, taking into account the possible impact on the surrounding communities and the general environment.

Occupational health and safety are factors and conditions that can affect the well-being of persons within the workplace, i. e. employees, contractors, temporary workers and visitors.

Safety is the freedom from unacceptable risk from harm.

Dangerous factor is the industrial factor, the impact of which on the employee under certain conditions can lead to injury or other sudden health deterioration.

Harmful factor is the industrial factor, prolonged exposure of workers to which in certain conditions can lead to a disease or a decrease in efficiency.

Accident at work is the result of dangerous industrial factor effect on a worker while performing job duties or job supervision.

Occupational disease is the result of long term effect of harmful industrial factor.

Danger zone is a space in which the effects on the running of hazardous and (or) harmful factors are possible.

Workers' abilities are limited due to the requirements of homeostasis, that is, the need to maintain a constant internal environment of parameters such as the internal temperature or pH of the blood. These parameters must be at a constant level in order for biochemical and enzymatic processes, which are necessary for health and life (Figure 1), to occur. In the living environment, and especially in the work environment, humans are exposed to extreme levels of factors such as temperature (from -20°C to $+70^{\circ}\text{C}$) and noise (up to 140 dB). In the course of phylogenetic development, our bodies have developed mechanisms to prevent an imbalance in the internal environment by physiological processes such as increasing heart rate, breath rate and sweating and changing the placenta of the peripheral blood vessels. These mechanisms, however, have a limited ability to compensate for harmful factors in the work environment. Moreover, longterm involvement of these mechanisms results in a substantial increase in the physical work capacity, which, in turn, leads to chronic fatigue.

These processes influence the development of *occupational diseases*, defined as diseases associated with exposure to harmful work conditions. *Paraoccupational diseases* are those associated indirectly with work conditions (the so-called civilisation diseases such as hypertension, obesity, diabetes) and are often rooted

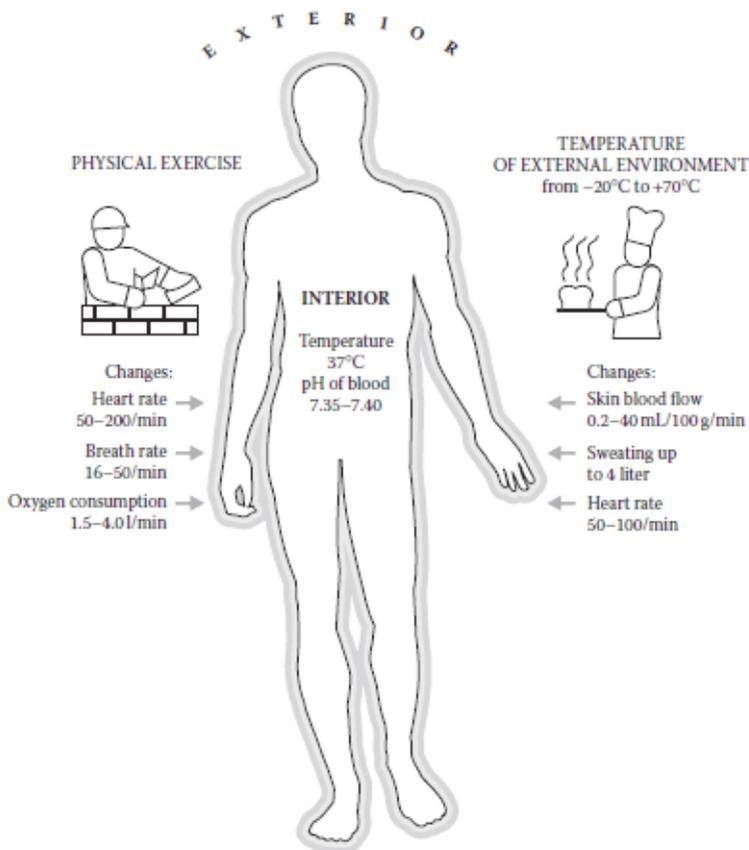


Figure 1.1 – Response of an organism to maintain homeostasis

indirectly in unsuitable work and living conditions. We often assume that work conditions may constitute a ‘trigger mechanism’, which increases the onset of diseases to which the human body has a genetic predisposition and which would not have developed under different conditions (e.g., carcinogenic diseases).

We tend to perceive the conditions of work and life of humans from a broader perspective because of these factors. This is consistent with the definition provided in the Constitution

of the World Health Organization, which states that health is the state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. In our efforts to meet the requirements resulting from such a perception of health in the work environment, ergonomics brings us closer to the objective. *Ergonomics* is defined as an adaptation of workstations, work processes and the work environment to the psychophysical abilities of the human body.

At present, ergonomics aims to optimise the adaptation of workstations, processes and the work environment to the psychophysical abilities of humans, not only to protect human life and health, but also to provide humans with an opportunity to maximally develop their personality.

Questions often arise about the relationship between ergonomics and occupational safety. The simplest answer is that occupational safety protects the workers' life, whereas ergonomics protects the workers' health.

Another term very close to the concept of *occupational safety and ergonomics* is the concept of *occupational safety and health*, used often in legislation. Ensuring occupational health means shaping work conditions and the work environment in a manner that ensures health protection. This includes a full range of physical, biological and chemical factors. Shaping the psychophysical climate at work is important, in addition to being able to participate in planning tasks and available support – everything that makes up the beautiful, traditional concept of *well-being*.

1.2 Legal Labour Protection

A national OSH system comprises all the infrastructures, mechanisms and specialized human resources required to translate the principles and goals defined by the national policy into the

practical implementation of national OSH programmers. In turn, one of the main aims of national OSH programs should be to strengthen national OSH systems. An OSH system must respond to the effects of both socio-economic and technological changes on working conditions and environment, and so is not built just once but must be to be strengthened, reorganized and reoriented through a permanent cyclical process of reviews, performance evaluations, and readjustments of objectives and programs or creation of new ones to meet new needs.

While legislation, tripartite collaboration, inspection and enforcement are the core components of any national OSH system, other elements are needed to make the system function adequately. For example, most employers, particularly those of small and even medium-sized enterprises, need assistance to understand and comply with OSH regulatory requirements, such as providing training to workers handling hazardous substances, conducting technical inspections of dangerous machinery or making OSH-related information available in the enterprise. Further support and services are required to promote good practice covering many other aspects of occupational safety and health that lie outside the legal sphere. According to Convention No. 187, to be functional and effective in addressing the OSH needs of both employers and workers, a national system must include at the least the following key elements:

- laws, regulations, collective agreements where appropriate, and any other relevant instruments on occupational safety and health;
- an authority or authorities responsible for occupational safety and health, designated in accordance with national law and practice;
- mechanisms for ensuring compliance with national laws and regulations, including systems of inspection;
- arrangements to promote, at the level of the undertaking, cooperation between management, workers and their

representatives as an essential element of workplace-related prevention measures;

- a national tripartite body on occupational safety and health;
- information and advisory services on occupational safety and health;
- the provision of OSH training;
- the provision of occupational health services in accordance with national law and practice;
- research on occupational safety and health;
- mechanisms for the collection and analysis of data on occupational accidents and diseases, taking into account relevant ILO instruments;
- provisions for collaboration with relevant insurance and compensation schemes covering occupational accidents and diseases;
- support mechanisms for a progressive improvement of occupational safety and health conditions in micro-, small and medium-sized enterprises and in the informal economy.

1.3 The International Labour

Law is of major importance for Safety life law. Almost all countries are members of several international organizations that issue regulations with great significance in OSH requirements. The most important of these are the International Labour Organization (ILO), the Council of Europe, and the European Union.

The ILO was founded in 1919. Since its inception, the ILO has been dealing intensively with the creation of work conditions, especially by performing normative activities. According to the Constitution of the ILO, the organization creates norms of law in the form of international conventions and recommendation. These

conventions are resolutions of the General Conference of the ILO, which contain norms regulating issues in the areas of working relations, social securities, and social policy. The conventions are also regulations of International Law, which come into force in any given country after their ratification by the member country. Recommendations are resolutions of the General Conference of the ILO, passed in cases that are not yet regulated by any type of conventions or that constitute a supplement or development of the general norms included in conventions. Recommendations do not have legal force, while the conventions do, but are nevertheless crucial components of law adopted by the ILO. Conventions and Recommendations on occupational safety and health may serve several purposes, acting as:

- fundamental principles to guide policies for promotion, action and management;
- general protection measures, for example, guarding of machinery, medical examination of young workers or limiting the weight of loads to be transported by a single worker;
- protection in specific branches of economic activity, such as mining, the building industry, commerce and dock work;
- protection of specific professions (for example, nurses and seafarers) and categories of workers having particular occupational health needs (such as women or young workers);
- protection against specific risks (ionizing radiation, benzene, asbestos); prevention of occupational cancer; control of air pollution, noise and vibration in the working environment; measures to ensure safety in the use of chemicals, including the prevention of major industrial accidents;
- organizational measures and procedures relating, for example, to labour inspection or compensation for occupational injuries and diseases.

According to the Treaty of the European Union, the legal acts of the European Union are regulations, directives, decisions, recommendations, and opinions. Regulations have general

applications and concern all member states of the European Union. They are binding in their entirety and are directly applicable to all member states after they are published in the Official Journal of the European Union or on the date indicated in the regulation.

Directives are binding to each member state to which they are addressed with reference to the result to be achieved, but shall leave the choice of the form and methods to the corresponding national authorities.

Decisions are binding in their entirety upon those to whom they are addressed. These legal acts are directed to particular institutions, enterprises, or member states.

Recommendations and opinions are not legal acts because they have no binding force, but they do have political implications. Only the institutions of the European Union are authorized to take a position on particular issues.

A directive is the basic legal act of the European Union regarding OSH. According to the treaty that established the European Union, a lack of transposition of the directive within the deadline determined by the European Union (usually included in the same directive), or erroneous transposition, can have directly binding legal consequences in the member state, despite the fact that the directive is a legal act that is only applicable after it has been transposed into the national. The most important OSH directive adopted by the European Union is the framework directive 89/391/EEC of 12 June 1989, regarding the introduction of measures to encourage improvements in the safety and health of workers at work, as well as 19 individual directives based on Article 16 of the framework directive. These directives constitute the core OSH legislation for the protection of workers but are not the only directives adopted by the European Union concerning this topic. The framework directive emphasizes reducing the likelihood of health and/or life risks for employees and not on reducing the occupational accidents and diseases, as was the case

previously. Hence, the prevention, reduction, and elimination of occupational risks have great significance in the directive concerning risks that cannot be avoided in a workplace. The general principles for prevention listed in the directive are as follows:

- Preventing occupational risks.
- Informing workers of such risks.
- Training workers to facilitate the reduction or elimination of the risks.
- Providing appropriate means and organization of work.

Detailed directives regulate OSH principles depending on the workplace, methods of performing the work, and factors related to the work environment.

1.4 Occupational Safety Management

Main principles of Implementation of Occupational safety management:

- priority of human (employees) health and life over the enterprise's production performance;
- implementation of the accident prevention principle;
- joint discussion of labor safety issues and personal responsibility for decisions and their implications;
- regularity of labor protection management;
- publicity of control and managerial decisions.

Each company possesses (whether consciously or not, whether documented or not) an overall occupational health and safety management system (OHSMS). This management system is the sum of the management subsystems as well as their interrelationships.

Occupational Health and Safety Assessment Series (OHSAS) Standard and the accompanying OHSAS 18002, Guidelines for the implementation of OHSAS 18001, have been developed

in response to customer demand for a recognizable occupational health and safety management system standard against which their management systems can be assessed and certified.

Conventions and Recommendations on occupational safety and health may serve several purposes, acting as (Figure 1.2):

- fundamental principles to guide policies for promotion, action and management;
- general protection measures, for example, guarding of machinery, medical examination of young workers or limiting the weight of loads to be transported by a single worker;
- protection in specific branches of economic activity, such as mining, the building industry, commerce and dock work;
- protection of specific professions (for example, nurses and seafarers) and categories of workers having particular occupational health needs (such as women or young workers);



Figure 1.2 – OHSMS Evolution

- protection against specific risks (ionizing radiation, benzene, asbestos);
- prevention of occupational cancer; control of air pollution, noise and vibration in the working environment; measures to ensure safety in the use of chemicals, including the prevention of major industrial accidents;
- organizational measures and procedures relating, for example, to labor inspection or compensation for occupational injuries and diseases.

There is emphasis on continual improvement and systematic elimination of underlying or root causes of deficiencies (Figure 1.3).

Plan Do Check Act (PDCA) cycle includes next components.

Plan: identify and analyze the problem: aspects, impacts, legal requirements, objectives, and metrics.

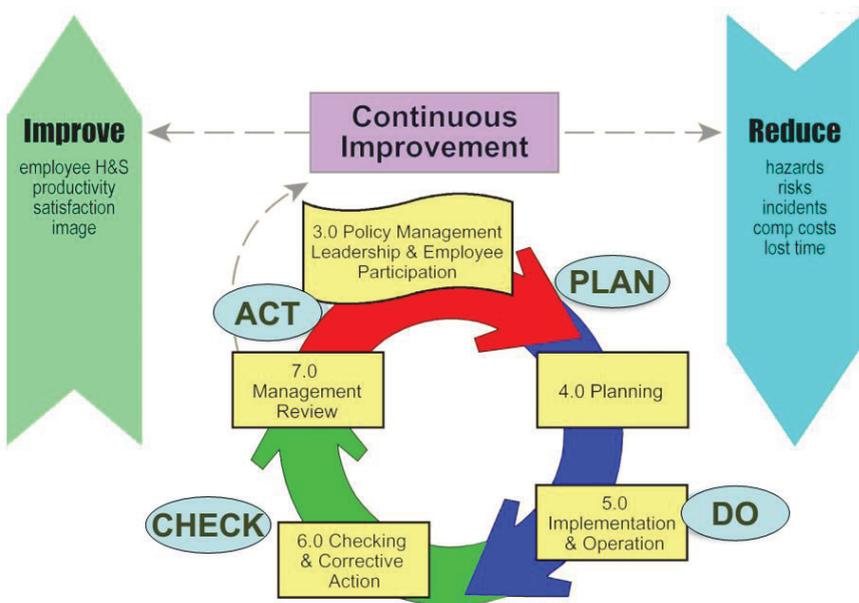


Figure 1.3 – The Z10 OHSMS Model

Do: developing and testing a potential solution: for example changes to organizational structure, processes, procedures, documentation, controls.

Check: measure effectiveness of solution and whether it can be improved. Assess through monitoring, evaluation, recordkeeping, audits.

Act: implement the improved solution fully.

All ISO standards follow the philosophy: say it, do it, document it.

Continual improvement is recurring process of enhancing the OH&S management system in order to achieve improvements in overall OH&S performance consistent with the organization's OH&S policy.

Many organizations manage their operations via the application of a system of processes and their interactions, which can be referred to as the "process approach". ISO 9001 promotes the use of the process approach. Since PDCA can be applied to all processes, the two methodologies are considered to be compatible.

The organization shall establish, document, implement, maintain and continually improve an OH&S management system in accordance with the requirements of OHSAS Standard and determine how it will fulfill these requirements. Top management shall define and authorize the organization's OH&S policy and ensure that within the defined scope of its OH&S management system. The organization shall establish, implement and maintain a procedure(s) for the ongoing hazard identification, risk assessment, and determination of necessary controls.

PART II

BASIC HAZARDS

IN THE WORK ENVIRONMENT

TOPIC 1. HARMFUL CHEMICAL AGENTS

IN THE WORK ENVIRONMENT

1.1 Introduction

Due to the high level of industrialization in the contemporary world, humans are increasingly exposed to dangerous chemicals in their work and living environments. Chemicals cause many diseases, including insufficient respiratory ability, inflammatory skin conditions, psychoneurological disorders, and neoplastic diseases. Studies conducted by the European Foundation of Living and Working Conditions in Dublin on the work conditions in the countries of the European Union (EU) 18% of workers are exposing to or coming in contact with chemical agents, including 20.5% through the respiratory tract. One in three occupational diseases recognized every year in the 15 EU countries is caused by exposure to chemical agents.

According to the European Agency for Safety and Health at Work in Bilbao (is a city in northern Spain), about 16 million chemicals are available on the market and 10,000

are manufactured in amounts exceeding 10 tons per year. In the last few decades, sciences that investigate the effects of chemical substances on human health and the environment have seen rapid development. Still, sufficient data to classify these chemicals according to their toxic and physicochemical properties are available for only 14 % of commonly used compounds. Research units active in industrial toxicology therefore attempt to identify the hazards to human health posed by chemical substances and preparations present in the work and living environments.

An important element for the safe use of chemicals in the work environment is the occupational exposure limit (OEL) – the main criterion for assessment of occupational exposure. The American Conference of Governmental Industrial Hygienists (ACGIH), a nongovernmental organization of industrial hygienists and safety specialists, created one of the first systems for establishing and revising OELs. ACGIH was formed in 1938 and released its first list of OELs in 1941 (Paustenbach 2000). In Europe (Commission Decision 95/320/EC), the Scientific Committee for Occupational Exposure Limits to Chemical Agents (SCOEL) has been developing indicative occupational exposure limit values (IOELVs) for chemical agents in the work environment since 1995. Directives 98/24/EC, 91/322/EWG, 2000/39/EC, and 2006/15/EC of the Environmental Working Group European Commission contain the current lists of IOELVs for 104 chemical substances and binding occupational exposure limit values (BOELVs) for 10 substances (98/24/EC, 99/38/EC, directive 2003/18/EC). France, Germany, Sweden, and Finland have national systems for establishing admissible concentrations of chemicals in the workplace air.

Definitions

Chemical substances are chemical elements and their compounds either in their natural state or obtained by a manufacturing process, including by using any additives

necessary to preserve their stability and any impurities derived from the process used; they do not include solvents that may be separated without affecting the stability of the substance or changing its composition. *Preparations* are mixtures or solutions composed of two or more substances (Registration, Evaluation, Authorization, and Restriction of Chemicals [REACH] regulation).

Dangerous substances and *dangerous preparations* are substances and preparations that pose a hazard to human health or the environment. These are classified into at least one of the following categories: highly toxic, toxic, harmful, corrosive, irritant, sensitizing, carcinogenic, mutagenic, toxic for reproduction, flammable, extremely flammable, explosive, oxidative, and dangerous to the environment.

1.2 Effects of Harmful Chemicals in the Work Environment on Humans

1.2.1 Types of Poisoning

Poisoning occurs when exposure to chemical substances or preparations exceeds the limits of human capacity, that is, when the body cannot remove these substances either by digestion or excretion. Poisoning can be divided into the following groups according to the exposure and duration:

- *Acute*: Harmful effects are induced by a substance absorbed into the body in a high dose or on one occasion; occurs in a relatively short period of time (within 24 hours).
- *Chronic*: Harmful effects occur after prolonged exposure to low doses or concentrations of substances present in the industrial or living environment, such as contamination of air, water, or food.

Occupational poisonings are usually chronic. The body's response to chemicals depends on the chemicals

physicochemical properties and absorption route, the health, sex, and age of the exposed person, and the condition of both the endocrine and immune systems, in addition to external factors such as temperature, exposure period and humidity.

1.2.2 Effects of Harmful Chemicals on Humans

The effects of chemicals on the human body are divided into local (corrosive and irritant), systemic, and remote (genotoxic, carcinogenic, embryotoxic, fetotoxic, and teratogenic) effects.

Corrosive and Irritant Effects

Local effects of chemical substances occur at the site of contact with the substance, such as on the skin or in the respiratory tract. Corrosive substances or preparations may induce burns of the skin and mucosal membranes. Acids, alkalis, and solvents are examples of irritant substances.

Sensitisation

Allergic contact eczema appears in workers who are in contact with substances that provoke sensitizing effects. Allergic reactions of the skin are often similar to symptoms of inflammation: itching, burning, erythema, and popular, vesicular or exfoliated epidermis, mainly on the hands, forearms, and face. Allergic contact eczema has recently been the most frequently occurring occupational skin disease.

Chemical allergies cause about 70 % of skin inflammation. The course of allergic contact eczema depends on the type of contact with the sensitizer. Allergies resulting from permanent, long-term contact with such substances are resistant to treatment. Only completely preventing contact with the allergen allows the person to recover. Aromatic amines, turpentine, epoxy resins, triethyltetramine, rubber, chromium VI, nickel, cobalt, tetracycline, formalin, aniline dye, and essential oils are the most frequent substances that produce allergies.

Systemic Actions

The human body is made up of many tissues and organs forming different types of systems. Chemicals can have various effects on these systems that lead to morphological and functional changes in some organs or groups of organs.

Nitro compounds (nitrotoluene), chloroalkanes, and chloro- and bromobenzene derivatives affect the liver. The symptoms of liver injury caused by such substances, such as a yellow color of the eyes, are sometimes misdiagnosed as liver inflammation. Substances such as carbon tetrachloride, ethylene glycol, and carbon disulphide affect the kidney's ability to eliminate toxic substances from the body. Other substances, such as cadmium, lead, turpentine, methanol, toluene, and xylene affect the kidneys more slowly. Attention recently has been focused on the harmful effects of chemicals on the reproductive systems of both women and men.

Carcinogenic Effects

Exposure to some chemicals can cause an uncontrolled growth of cells, leading to cancerous lesions. Most carcinogenic substances are nonthreshold compounds, that is, those for which safe exposure levels cannot be determined.

Cancerous lesions may occur many years after the first exposure to the chemical substance. This period is called the latency period and can range from 4 to 40 years. Cancers that develop due to occupational exposure can be localised in different places in the body, and are not necessarily limited to those areas that were in direct contact with the chemical substance. Substances such as arsenic, asbestos, chromium, and nickel may cause lung cancers. Chromium, nickel, isopropyl oils, wood dust, and dust from tanned leather can cause neoplasms of the nasal cavity and nasal sinuses.

1.3 Admissible Concentrations of Chemical Agents Harmful to Health in the Work Environment

An admissible concentration of a substance in the air exists for all harmful chemical agents. Workers may be exposed to chemicals without any adverse health effects at levels below these concentrations. The list of exposure limits for chemical substances in the work environment has the following criteria:

- *Maximum admissible concentration (MAC-TWA)*: The TWA concentration, for a conventional 8-hour workday and a work week as defined in the Labour Code, to which workers may be exposed during their whole working life, without any adverse effects on their health (also when retired) or that of the next generations.

- *Maximum admissible short-term concentration (MAC-STEEL)*: The average concentration to which workers may be exposed without any adverse health effects if the exposure does not last longer than 15 minutes, does not occur more than twice during a workday, and occurs at intervals not shorter than 1 hour.

- *Maximum admissible ceiling concentration (MAC-C)*: A concentration that should not be exceeded even for an instant because of the threat to workers' health or life.

1.4 Testing and Measuring Chemical Substances in the Workplace air for Occupational Exposure Assessment

Supervision of the hygiene conditions of a work environment and assessment of occupational exposure to chemical substances are the most important elements of workers' health protection. When the concentrations and absorbed doses of harmful airborne substances are known, the health effects of exposure can be predicted and preventive measures applied early to reduce the

occupational risk. The principal obligation of an employer should be the systematic identification and assessment of hazards connected with chemicals in the work environment.

Methods for Measuring Chemical Agents in the Workplace Air

The concentration of chemical substances in the workplace air should be measured by accredited laboratories in accordance with regulations on testing and certification. The measurements should use determination methods characterised by selectivity, adequate sensitivity, and precision.

Measurement procedures for the quantitative determination of chemical substances in workplace air involve taking and analysing air samples. The chemical substances should be quantitatively separated from air, and their concentrations should be measured.

Strategy of Measurements for Inhalation Exposure Assessment

Proper air sampling using the above-mentioned methods is necessary for occupational exposure assessment of chemical agents. Air samples should be taken in each worker's breathing zone during his or her entire stay at a workstation, using individual dosimetry.

Assessment of Occupational Inhalation Exposure

The main criteria for assessing inhalation exposure are the results of the measurement of chemical substance concentrations in the workplace air and the relevant MACs. Exposure is assessed based on these results and also by using calculated exposure indicators, that is, concentration, the upper and lower limit of the confidence interval for a real-time average or concentration

1.5 Protection of Harmful Chemical Agents in the Work Environment

Different types of measures are used to protect people from harmful substances.

1. *Technical measures:*

- replacement of toxic substances with non- or less toxic;
- automation, mechanization, application of remote control in order to eliminate the contact of the employee with toxic substances;

- hermetization of the equipment using local and general ventilation.

2. *Sanitation measures:*

- systematic control of toxic substances concentration in the air;

- use of individual protection means;
- keeping scheduled work-rest regimen.

3. *Medical preventive measures:*

- preliminary and periodical medical examinations;
- treatment at health resorts.

Safe storage of chemicals and other hazardous materials begins with the separation, segregation or isolation of incompatible materials. The degree to which this process needs to be done depends upon the laboratory's size, the quantities and types of materials used, the durability of the storage containers and the potential for spills or leakage.

Separation, segregation and isolation are defined by NFPA standards as follows:

Separation – storage within the same fire area but separated by as much space as practicable or by intervening storage from incompatible materials.

Segregation – storage in the same room but physically separated by space from incompatible materials. This usually requires some type of physical barrier such as sills, curbs or safety cabinets.

Isolation – storage away from incompatible materials in separate rooms, vaults or buildings.

There are various types of chemical storage systems. These include storage lockers, cabinets, vaults and pallets. Many models

can be purchased with built-in ventilation, fire suppression systems and spill alarms.

The following recommended practices will also aid in ensuring safe storage of chemicals:

1. Fitting of storage shelves with shelf lips on all sides.
2. Use of caged shelving units.
3. Purchase and utilization of commercially available ventilation systems which include ventilated storage cabinets.
4. Use of storage cabinets with self-closing doors.

Storage cabinets should be labeled according to their contents. In addition, storage cabinets should always be labeled with an appropriate hazard warning.

Flammable and combustible liquids storage cabinets should be labeled: FLAMMABLE – KEEP FIRE AWAY. Each container in the cabinet should be labeled.

Some hazardous materials have special symbols associated with them (i. e., radioactive, biohazard, etc.). These symbols must be displayed prominently in the storage area and on the storage containers.

Over toxic substances control methods:

- 1) express method: colorimetric (change of color); gas analyzers UG-2, GH-4;
- 2) laboratory method (taking air samples in work area and its physical and chemical laboratory analysis);
- 3) continuous method (gas analyzers and detectors): FKG-3M for chlorine; “Syrena-2” for ammonium; “Photon” for hydrogen sulfide.

TOPIC 2. DUSTS

2.1 Introduction

Dusts are among the most significant harmful agents present in the work environment. Human exposure to dusts can cause mechanical injury of the mucosa or skin, allergic reactions and diseases, pneumoconiosis, and cancer.

Production plants and service outlets emit the greatest amount of harmful dusts to the work environment; their concentrations and harmful effects on human health depend on the work processes. Although dust concentrations in office space air are much lower than in industrial facilities, concentrations and particle size distributions are still significant in the context of ‘sick building syndrome’.

Definitions

Particle: A small, separate part of a solid or liquid substance (ISO 4225 1994).

Nanoparticle: Nano-object with all three external dimensions in the nanoscale (ISO/TS 27687 2008).

Particle aerodynamic diameter: The diameter of a sphere of a density 1 g/cm^3 with the same terminal velocity due to gravitational force in calm air as a particle under the prevailing conditions of temperature, pressure, and relative humidity.

Dust: A general term that refers to solid particles of varying size and origin, which remain suspended in a gas for a period of time.

Dust emission: Liberation of dust into the atmosphere. The point or area from which such liberation takes place is known as the ‘emission source’.

Dust concentration: The mass or number of particles of a solid substance in a unit volume of gas, grams per cubic metre, or the number of particles per cubic metre.

Breathing zone: The space from which humans directly inhale air. This is a radius of about 3 dm (decimetres) around the face; its centre lies in the middle of the line joining both the ears. The base of the hemisphere is the plane running through this line and the top of the head and the larynx.

Exposure index: A number describing employees' exposure to a harmful substance, calculated based on the substance's concentration in the air and compared to the appropriate admissible value.

Maximum admissible concentrations (MAC-TWA): The time-weighted average concentration for a conventional 8-hour workday and a work week, as defined in the Labour Code, to which workers may be exposed during their whole working life without any adverse effects on their health (even when retired) or on the next generations.

Filter: A device on which particles are deposited in a porous medium.

Collective protection against dust: The simultaneous protection of a group of people against harmful dusts at work, applied as technical solutions in workplaces, machines, and devices.

Equipment for personal protection against dust: Equipment used by the employee for protection against harmful dusts in the work environment, including all accessories and additional elements designated for this purpose.

General mechanical ventilation: Ventilation of the entire room or a complex of rooms.

Local mechanical ventilation: Ventilation of a specific space in a room, a workstation, or a production device.

Filtration and ventilation device: The device used to remove pollutants from the air at a workstation.

2.2 Dusts in the Work Environment

Dusts emitted at workstations can have various properties depending upon the emission source. The degree of human exposure and a selection of collective and personal protection equipment can be estimated based on the following parameters:

- Dust concentration (concentration of various size fractions of dust particles).
- Particle size (coarse-, medium-, and fine-dispersed dusts).
- Particle shape (fibrous and nonfibrous dusts).
- Chemical composition and crystal structure (e.g. crystalline silica or amorphous silica).
- Explosive properties of the dust (e.g. wood dusts or flour dusts).

Dust emission sources in workplaces include the following:

- Technological processes (in typical production spaces).
- Personnel handling machines and equipment (e.g. in ‘clean rooms’).
- Air supplied from the outside by forced air ventilation unit or by infiltration (in production spaces, office spaces, or in ‘clean rooms’).
- Nanotechnological processes (in rooms in which nanoparticles are produced or used for production).

Production Spaces

During the production process, emissions usually occur from point sources. The size distributions of the emitted particles and the concentration of harmful dusts in the workstations depend upon the type of technological process.

The particles generated in production processes like the grinding of brittle materials (milling, cutting, or crushing of solids) are dispersed and suspended in the air and usually form a polydispersive aerosol (containing particles of various sizes). Particles originating from the solidification of vapours of metals

or other compounds, which assume the form of solids at room temperature, constitute the dispersed phase of regular particles and form a monodispersive aerosol (containing particles of similar sizes).

During the production process, particles of various sizes usually are present in the air (polydispersive aerosols). The particles' suspension period in the air (suspended particles) and their ability to become suspended near their settlement location (settled dust) depends upon factors such as the size, shape, and specific gravity of the particles and the velocity, humidity, and temperature of the air.

The most significant dust-generating technological processes, such as milling, crushing, sieving, transportation, mixing of loose materials, sharpening, cutting, polishing, and smoothing, emit substantial quantities of dust particles that may be inhaled by employees and may cause occupational diseases. Figures 2.1 and 2.2 present the mass and number concentration of some dust particles emitted at various workstations in the furniture industry and at a construction site, respectively.

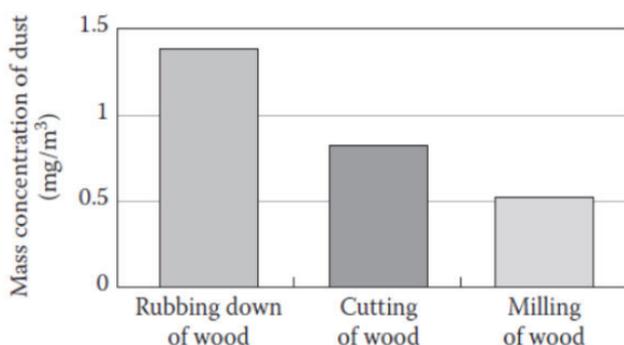


Figure 2.1 – Total dust concentration at workplaces in the furniture industry; measurements conducted using the filtration-gravimetric method

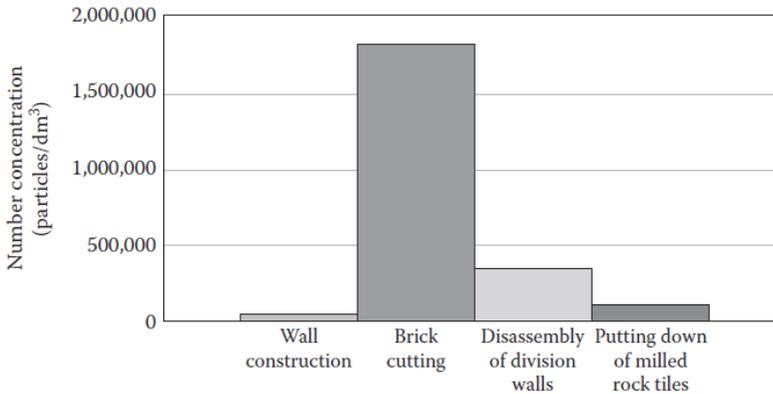


Figure 2.2 – Number concentration of dust particles within the range of 0.3–3 μm at construction site workstations; measurements conducted using the particle counting method

Local ventilation systems are usually used to capture dust from point source emissions (e.g. production spaces and some service outlets), along with auxiliary general mechanical ventilation systems, in work spaces in which point sources of dust are present. However, some dust emitted from point sources, particularly fine and very fine particles, disperse throughout the room, which may lead to dust exposure (usually at concentrations higher than that in the outdoor air) among not only the employees occupying the dust-emitting workstations, but also those who are at other workstations or pass through the room. Attention should be given to rooms in which point-emission dust sources are located and local ventilation systems are absent, because they generate significant concentrations of particles in the room as both as suspended and settled dust, depending upon the production process.

Office Spaces

The dust concentration in office space air is lower than that in typical industrial production spaces and usually lower than the concentration in the outdoor air (Figure 2.3). The concentration

and size distribution of particles entering the room are determined by the room ventilation method (natural or mechanical). The quality of the air supplied to the rooms is controlled by using appropriate air filters, cleaning the ventilation systems, and so on.

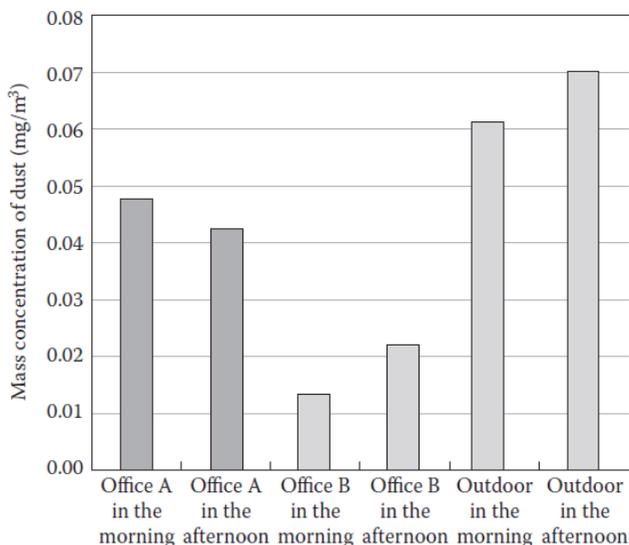


Figure 2.3 – Mass concentration of dust in the air outside the building and in office spaces A and B; measurements conducted using the photometric method

The presence of a large number of people in a room, the finishing material and equipment room, the type of work performed (e.g. administrative work), and smoking may also be internal emission sources, mainly of fine and very fine particles. Although the particle concentrations in office spaces are much lower than those in industrial production spaces, the influence of particles from external and internal emission sources and the air parameters (velocity, humidity, and temperature) upon the concentration and size distribution of the particles is significant. Dusts are believed to be one of the most harmful agents present in

the office spaces, causing SBS, which affects a number of people in postindustrial society.

Nanotechnological Processes

The production and use of nanoparticles in work processes has resulted in intense worldwide research to assess the harmful effects of nanoparticles on humans. The analysis of exposure to nanoparticles is significant to the protection of human health because these particles may be suspended in the air for a long time even after the completion of the process, posing a threat not only to persons occupying the workstations directly associated with the process, but also to those near these workstations, as well as the general population, if, for example, improper air filters are used in the exhaust mechanical ventilation systems. Nanoparticles may settle in the alveoli of the human respiratory system and cause diseases, and, due to their size, may also get into the blood of exposed persons, causing other diseases that have not yet been recognised.

Knowledge on the emission of nanoparticles during various stages of their production or application is very limited; therefore, research in this field is a significant priority. Large plants producing or using nanoparticles in technological processes protect against their harmful effects mainly by air-tight sealing of processes or effective mechanical ventilation, whereas employees of most small- and medium-sized companies are usually unprotected against the harmful effects of nanoparticles.

2.3 Methods of Determination of Dust Parameters

The quantities of dust entering the human respiratory system from the air depend upon the dust's properties, the velocity and direction of the air's movement in the surrounding area, breathing frequency, and whether the particles are inhaled through the mouth or the nose. These parameters are measured using various

research methods depending on the size of dust particles emitted at the workstations. At typical production spaces, dust samples are collected using the filtration-gravimetric method or the microscopic method. In office spaces and in nanotechnological processes, dust samples are examined mainly using optical methods, such as photometers and particle counters.

The basic parameters of the air are determined during the analysis of the concentration and size distribution of dust particles. These include temperature, humidity, and velocity, which may significantly influence the movement and number of particles suspended in the air. Analyses should also determine the basic harmful chemical substances in the dust—particularly in dust fractions that enter the area of gaseous exchange.

Production Spaces

The European and the international standards recommend that exposure to dust at production spaces is measured using methods that ensure selection at the entry due to aerodynamic effects. The following dust fractions of specific aerodynamic diameters of suspended particles in the air are collected from workstations:

- *The inhalable fraction:* The mass fraction of total airborne particles inhaled through the nose and mouth
- *The thoracic fraction:* The mass fraction of inhaled particles penetrating beyond the larynx
- *The respirable (alveolar) fraction:* The mass fraction of the inhaled particles penetrating to the unciliated airways

Office Spaces and Nanotechnological Processes

Filtration-gravimetric methods cannot be used to measure the concentration of dusts in the air in office space and nanotechnological processes because the results are not accurate and the dusts measured cannot be related to the strictly defined fractions of suspended particles in the air. To determine the concentration and size distribution of these particles, optical methods, including photometers (for measuring mass concentrations of dust) and optical and condensation counters

(for measuring the number concentrations and size distributions of dust particles), are used. Various photometers and particle counters that allow for measurements within a very broad range of particle sizes from nanometric diameters (condensation counters) to several dozen micrometers (photometers, optical counters) are currently available.

Although the concentration and size distribution of particles determined using photometers and various particle counters cannot be directly compared, these devices gather multidimensional data on the parameters of dust suspended in the air within a specified range of particle sizes and indicate the type of particle fractions present in the air. These measurements are particularly significant to determine the presence of fine dust particles and nanoparticles in the air.

Dust exposure in office space is usually estimated by analysing and comparing the mass concentration values or number concentration values, specified for individual rooms using photometer or counters to measure size fractions of particles similar to those determined by filtration-gravimetric methods, that is, sets of dust particles of a size under 10 μm or under 4 μm , as well as fine particles of the size below 1 μm in the surrounding air.

Research conducted at present assesses the real threat resulting from human exposure to nanoparticles.

2.4 Collective Protection Against Dust

Collective protection against dust includes general mechanical ventilation systems, local mechanical ventilation systems, and devices equipped with air filters.

The purposes of ventilation systems, based upon continuous or periodical air exchange in rooms, are as follows:

To improve the condition and composition of the air at the workstations in accordance with specified requirements for human

health protection and the technology necessary to manufacture products with specific properties.

- To regulate air parameters in rooms, including pollution concentrations, temperature, humidity, velocity, and direction of air movement.

For industrial buildings where substantial amounts of dusts are emitted at individual workstations, the most beneficial solution in local exhaust ventilation (LEV) is to ensure the air-tight sealing of processes, that is, air-tight encasing of the pollution emission sources. When fully encasing the technological processes is not possible, partial encasing or local ventilation systems are used, which are connected to the dust extraction systems or to filtration–ventilation equipment. The types of LEV systems according to the degree of encasing of the pollution emission source are illustrated in Figure 2.4.

Each LEV system should be accompanied by a general mechanical ventilation system. The type of LEV system depends on both the location of the emission source and the type of dust emitted. The direction and velocity of dust dispersion are also significant.

In office space, general room ventilation systems are usually used; the system layout significantly influences the air quality, including the concentrations of particles. Appropriate air flow should be ensured particularly in large open-space offices. Although the air streams are supplied to rooms as required by legal provisions, improper distribution of ventilation openings, for example, a large number of openings located close to windows and walls, may lead to draughts at the located nearby, while proper air flow is not ensured in the central part of the room, resulting in higher dust concentrations.

In both general ventilation systems and local ventilation equipment, purification systems (single or multistage) equipped with the appropriate air filters will ensure the required quality of the air is extracted from or supplied to the rooms.

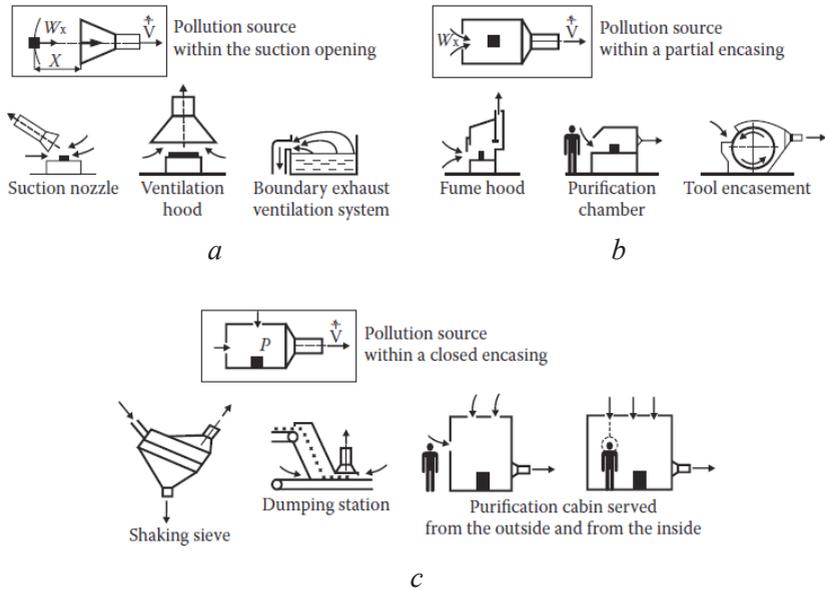


Figure 2.4 – Types of local exhaust ventilation systems according to the degree of encasing of pollution emission source:

- (a) within the suction opening, (b) within a partial encasing, and (c) within a closed encasing

The basic indicators of air filter usability are filtration efficiency and pressure drop; these parameters depend upon dust properties, air properties, and the structural parameters of the filter.

Filtration efficiency is the capacity of the filter to remove from the air pollution particles of a specified size range. The *pressure drop* (pressure difference) largely influences the selection of equipment responsible for the air movement during its flow through the filtration media.

The required level of purity for the air leaving the system (for specific pollutant particle sizes or the filtration–ventilation device) is significant for the selection of the number of filtration stages in the purification system and their classes, which are

determined based on the appropriate standardised testing methods. Air filters are classified based on their filtration efficiency, which is determined using the appropriate test aerosols. If collective protection against dust does not ensure the required level of air purity in the workplace, then appropriate personal protection equipment should be selected workstations.

TOPIC 3. VIBROACOUSTIC HAZARDS

3.1 Introduction

Vibroacoustics is a field of science that deals with vibration and acoustic processes observed in nature, engineering, machines and equipment, means of transport, and communication, that is, in the entire work and life environment. It is useful in reducing vibroacoustic disturbances to the minimum level attainable with the current knowledge and technology. Vibroacoustic hazards related to exposure to noise and vibration in a work environment lead to its degradation.

Oscillation motion or-in short-*oscillation (vibration)* is a process that periodically changes any physical quantity specific to this process. This chapter focuses on mechanical system vibrations. A mechanical system is a set of interconnected solid bodies; an acoustic system is an area filled with gas, or sometimes liquid, and limited by surfaces (such as room walls). Mechanical and the acoustic systems often form a whole unit, referred to as a *vibroacoustic system*.

Vibration has three correlated vibratory quantities: displacement, velocity, and acceleration.

Another term applied to vibroacoustic hazards is *noise*. Noise is all adverse, unpleasant, strenuous, or harmful oscillations of the elastic medium, acting through the air on the hearing organ and other parts of the human body.

3.2 Physical characteristics and classification of vibration

Mechanical vibration transferred from oscillatory systems to the human body may have a negative impact on individual systems and organs, or it may cause vibration of the whole body or its parts and its cellular structures. Long-term exposure to vibration may lead to many disorders and cause permanent and irreversible pathological changes; these changes depend upon the type of vibration to which an individual is exposed—whole-body or hand-arm vibration.

At low frequencies (3–100 Hz) with large amplitude (0.5–0.003 mm) a human perceives oscillation as a **vibration**.

According to the presence 6 degrees of freedom in the simplest single-mass systems vibration is generally implemented in six ways (Figure 3.1).

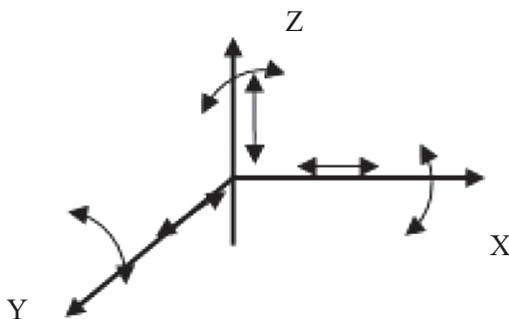


Figure 3.1 – Forms of vibrations implementation

Vibration is a movement of point or mechanical system in which there is an increase or decrease alternately in time value of at least one coordinate.

The causes of vibration can be:

1) unbalanced forceful actions (gears, crank mechanism in engines and compressors);

2) unbalanced elements that rotate: uneven product distribution in the mills, centrifuges, separators, rotating. Non-symmetrical wear causes beating. Imbalance is due to casting defects, non-symmetrical mass distribution, and others;

3) wind resonance (on the cause of up to 50-ies of the last century was not brought to notice).

Types of vibration regarding the influence on a person:

a) local (brings into oscillation motion only separate parts of the body);

b) general (causes shaking of a person).

Types of general vibration regarding the sources of its origin:

- transporting (during the motion of the machines);
- transporting and technological (during the work of the machines which execute technological operations in the stationary position or move on the specially prepared surfaces);

- technological (during the work of the stationary machines or transmitted to the working places that do not have any sources of vibration).

Vibration is characterized by absolute parameters:

1) amplitude of displacement (X), m, is the magnitude of the rejection that fluctuates from the equilibrium position;

2) amplitude of speed (V), m/s;

3) amplitude of acceleration (A), m/s²;

4) the period of oscillation (T), s;

5) frequency (f), Hz.

3.3 Impact of Vibration on the Human Body

Mechanical vibration transferred from oscillatory systems to the human body may have a negative impact on individual systems and organs, or it may cause vibration of the whole body or its parts and its cellular structures. Long-term exposure to vibration may lead to many disorders and cause permanent and

irreversible pathological changes; these changes depend upon the type of vibration to which an individual is exposed—whole-body or hand-arm vibration.

Hand-Arm Vibration

Exposure to vibration transferred to the organism through the upper limbs—

hand-arm vibration—results mainly in pathological changes in

- The circulatory system
- The nervous system
- The osteoarticular system

Epidemiological research has shown a strict causal relationship between pathological changes in these systems and work conditions. Therefore, a set of these changes, known as *vibration syndrome*, is considered an occupational disease in many countries.

The vascular form of vibration syndrome is the most frequent and is characterized by changes mainly in peripheral blood circulation in the form of paroxysmal vasospastic disorders of the upper extremities (white fingers). Paroxysmal vasospasms are indicated by one or more fingertips turning pale. This form of vibration syndrome is often confused with Raynaud's disease.

Vasospastic disorders are often accompanied by nervous disorders and osteoarticular changes. Changes in the nervous system caused by exposure to hand-arm vibration mainly include pallesthesia, apselaphesia, loss of sense of temperature, and associated problems such as numbness or tingling of fingertips. If exposure to vibration continues, these changes develop further, decreasing the ability to work and perform other life functions.

Osteoarticular changes in the hand are caused mainly by hand-arm vibration of frequency below 30 Hz. These include the deformity of articular spaces, calcification of articular capsules, and changes in the periosteum and the woven bone, leading to the emergence of characteristic cysts in the small bones,

particularly in the wrist. Operators of manual vibration tools are the main group exposed to hand-arm vibration.

Whole-Body Vibration

The negative consequences of occupational exposure to whole-body vibration are mostly related to

- The skeletal system
- The internal organs

In the skeletal system, pathological changes emerge mainly in the lumbar segment of the spine, and less often in the cervical segment. Spinal pain syndrome resulting from pathological changes occurring in persons occupationally exposed to wholebody vibration has been recognised as an occupational disease–like vibration syndrome caused by hand-arm vibration–in some countries, such as Belgium and Germany.

Internal organ disorders caused by whole-body vibration are mainly due to the resonance excitation – of individual organs (the frequency of natural vibrations of most organs is between 2 and 18 Hz). This causes adverse changes in the functioning of the alimentary system organs, mainly the stomach and the oesophagus; however, tests conducted on large groups occupationally exposed to whole-body vibration show that disorders are also found, for example, in the vestibulocochlear organ, the organs of the thorax, the female reproductive system, and the nasopharyngeal cavity.

The main groups of employees exposed to whole-body vibration are car drivers, tram drivers, engine drivers, and construction and road machine operators. In these cases, vibration is transmitted to the body from the vehicle seat through the pelvis, the back, and the sides. However, occupational exposure to whole-body vibration often affects persons who handle fixed equipment and machines operated in various work areas in a standing position. In such cases, vibrations penetrate the employee's body through the feet from the vibrating base of the workstation. The effects of these vibrations are similar to those transmitted by seats.

The biological effects of hand-arm and whole-body vibrations on the human body are usually accompanied by functional effects, which include the following:

- Prolonged motor response time
- Prolonged visual response time
- Movement coordination disturbances
- Excessive fatigue
- Irritation
- Sleep disorders

Adverse functional changes lead to a decrease in the effectiveness and quality of the work performed, sometimes making it impossible to work at all.

Because mechanical vibration and its effects are common in the work environment, it should be measured to assess occupational risk and to reduce the risk level.

3.4 Common protective methods against harmful effects of vibration

The main directions of solving the problem of vibration protection are the automation of production and the introduction of robotics.

Ways of protection against vibration:

- 1) reduction of vibration in the source of its origin;
- 2) vibration damper;
- 3) vibration extinction;
- 4) vibration isolation.

Reduction of vibration in the source of its origin:

- the replacement of the percussive processes by non-percussive;
- the static and dynamic balancing;
- the replacement of metallic details by plastics with the significant internal friction;

- an application of the resilient insertions and gaskets in the connections;
- the greasing of the connecting and passing machine knots.

Vibration damper is a reduction of the vibration level of the protected object by converting the energy of mechanical vibrations of this system, fluctuates in other types of energy (Figure 3.2).



Figure 3.2 – Vibration damper

Increasing energy losses in the system can be by:

- 1) using vibration absorbents with the significant internal friction (plastics, soft rubbers, mastics, thick felt);
- 2) using materials with greater internal friction allows lowering vibration in the range of mean and high frequencies between 8–10 dB.

Vibration extinction is the reduction of vibration level of machines and aggregates by placing it onto the vibration isolation bases.

Vibration isolation is the process of isolating an object, such as a piece of equipment, from the source of vibrations (rubber, spring and combined) (Figure 3.3).

1. Vibration isolation between the stationary equipment and the foundation by means of rubber gaskets, springs, rubber and metal shock absorbers (Figure 3.4).

Spring insulators in comparison with rubber have a number of advantages: they can be used for isolation of both low and high frequencies; they retain the constancy of elastic properties in time longer, resist the effects of oils and heat, relatively small. But

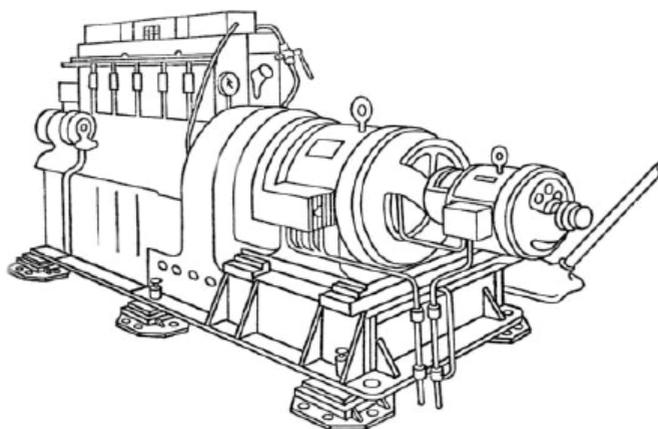


Figure 3.3 – System with the vibration isolation

they can skip high frequency vibrations, as the spring material (steel) has small internal losses. Therefore, in this case it is recommended to install spring vibration isolators on gaskets made from elastic materials such as rubber (combined cushioning).

2. Acoustic joints of the foundations of buildings (emptiness is left on the foundation of the building).

3. Basement vibration insulation from the ground.

4. Elastic inserts between the load-bearing elements of buildings and structures (the fans are separated by an elastic insert from the air ducts).

5. When working with a hand-operated mechanized tool, personal protective equipment is used against vibration.

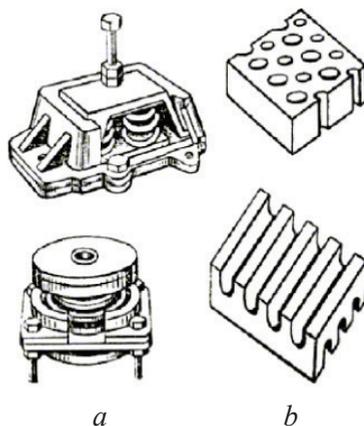


Figure 3.4 – Vibration isolated supports (shock absorbers):
a – springs; *b* – rubber vibroinsulator

Personal protective equipment includes:

- a) anti-vibration gloves;
- b) anti-vibration pads or plates, which are secured by fastening to the handle;
- c) special shoes on a high elastic sole.

To prevent vibration disease for workers with vibrating equipment it is recommended to carry out a set of preventive measures:

- 1) water treatment;
- 2) massage;
- 3) physical therapy;
- 4) vitaminization (Vitamins B₁, B₁₂, B₆, PP).

Periodic medical examinations are realized not rarer than once in 12 months with participation of internist, neurologist, otolaryngologist. At the inspection it is necessary to realize capillaroscopy, measuring of skin temperature, cold test, to explore vibration, pain sensitiveness, if necessary radiography of hands, spine.

When working with vibrating equipment a duty cycle processing operation not related to vibration is included. If this is not possible, it is necessary to provide for 10–15 minute breaks after every hour of operation.

It is noted that the adverse effects of exposure to vibration are enhanced in cold conditions. Therefore, in the wintertime it is necessary to provide workers with warm mittens.

3.5 Basic Terms and Quantities of Noise

Noise is defined as all adverse, unpleasant, irritating, annoying, or harmful sound that reaches the hearing organ and influences other senses and parts of the human body. In physical terms, sound is a mechanical vibration of an elastic medium (gas, liquid, or solid). The vibration may be considered to be an

oscillatory movement of the particles of the medium in relation to the equilibrium condition, resulting in a change in the medium static (atmospheric) pressure.

Noise is usually the sum of a large number of sinusoidal vibrations. The frequency distribution of these vibrations is called the frequency spectrum of noise.

The propagation of an acoustic wave in a medium is associated with the transmission of acoustic energy, which has the following quantities:

- *Sound power of the source*: The measure of the amount of energy (in watts [W]) radiated by the source in a unit of time
- *Sound intensity*: A vector quantity, defined as the value of the stream of energy (in watts per meter squared) flowing through the surface area in the same direction as the acoustic velocity at this point

As in the case of sound pressure, a logarithmic scale and decibels are used due to the wide range of changes in sound power and sound intensity. Acoustic power level and sound intensity level are used to describe the transmission of acoustic energy.

The sound power level is the basic quantity of noise emission from the source. It is therefore used for the assessment of noise generated by machines. It is usually the A-weighted sound power level.

Apart from the terms and quantities discussed, other terms related to various methods of noise classification should also be familiar.

Noise is divided according to its influence on people into *annoying*, which has no permanent effects on the human body, and *harmful*, which has permanent effects or poses specific risks to humans. It can be steady or variable (interrupted) in time. For example, impulse noise is variable in time, as it rises sharply to high levels and is of a short duration.

Based on the frequency range, noise is categorized as follows:

- *Infrasonic noise*, with a spectrum of components of infrasound frequencies from 1 to 20 Hz

- *Audible noise*, with a spectrum of components of audible frequencies from about 16 to 16,000 Hz
- *Ultrasonic noise*, with a spectrum of components of high audible frequencies and low ultrasound frequencies, that is, from 10 to 40 kHz

There are other noise classifications as well, based, for instance, on its causes or sources. For example, aerodynamic noise is caused by a flow of air or other gases, while mechanical noise results from friction and impacts of solids, mainly machine parts. Noise can also be classified by the environment in which it is observed. Noise in an industrial environment is known as industrial noise; noise in residential areas, public spaces, and recreational areas is known as community noise; and noise generated during transport is known as transport noise.

There are next basic parameters of the noise:

1. *The amplitude of the oscillation* is the maximum deviation from the initial position of the particles of the environment that conduct sound.

2. *Sound pressure* is a variable pressure that occurs in addition to the atmospheric pressure in the environment through which the sound waves are spread.

3. *The speed of sound* is the distance at which the wave process can spread in one second.

4. *Wavelength* is the distance between two adjacent condensation or liquefaction in the sound wave.

5. *The power of sound (intensity)* is the amount of energy that passes in the result of sound spread through an area of 1 m² per unit of time.

6. *The frequency content of noise* is a collection of sounds frequencies contained in it.

Interference is the process of imposition of the sound waves of the same frequency.

Diffraction is the process of sound waves rounding of the finite size obstacles.

Resonance is the process of a sharp amplitude increase due to the coincidence of the sound frequency with the natural frequency of oscillation.

7. *Sound volume or noise.* Unit volume is fon.

Only at frequency of 1000 Hz units in dB match with units in fon.

8. *Sound power of the sound source P* is the total amount of sound energy radiated by a source of noise into the environment per unit of time.

Hearing threshold (auditory threshold) is the minimum amount of sound energy that a person perceives as sound. The hearing threshold is $I_0 = 10^{-12}$ W/m². Sound pressure corresponding to this value is equal to $P_0 = 2 \dots 10^{-5}$ N/m².

Pain threshold is sound energy at which the sound already causes painful sensations. It corresponds to the strength of $I = 10^2$ W/m², and a sound pressure $P = 20$ N/m².

Bel (B) is the logarithm of the ratio of the actual sound parameter to accepted limit value in acoustics.

$$L_p = \lg \left(\frac{P_{act}}{P_{lim}} \right),$$

where L_p – sound pressure level;

P_{act} – the actual value of sound pressure;

P_{lim} – the limited value of sound pressure.

The whole range from auditory to pain threshold is concluded in the 14 B or 140 dB.

Sound is usually measured with microphones responding proportionally to the sound pressure. The power in a sound wave goes as the square of the pressure. (Similarly, electrical power goes as the square of the voltage.) The log of the square of x is just 2 log x, so this introduces a factor of 2 when we convert to decibels for pressures. Sound pressure levels in decibels are caused by some common sources (table 3.1).

Table 3.1 – Situation examples of sound pressure level

Example	Sound pressure level, dB
The explosion of the atomic bomb (fatal threshold)	200
The clock process	30
Quiet conversation	30
Normal working conditions for our classrooms	60
Loud music	110
The turning machine	100

3.6 Effects of Noise on Humans

The adverse effects of noise on humans are associated mainly with the hearing organ, however, nonauditory effects can also be observed in the entire body. The effects of noise on hearing are the best known and documented, whereas nonauditory effects have not been fully examined.

Some undesirable effects of the noise on human health:

- specific damage of hearing organs;
- psychiatric disorders;
- neurosis;
- hypertension;
- function disorders of gastrointestinal tract;
- cardiovascular system disorders.

Noise disease is an occupational disease associated with a combination of occupational hearing loss and disorders of the central nervous system and the cardiovascular system in workers in noisy environments.

As well as permanent and temporary hearing loss, noise-related conditions include: tinnitus (ringing in the ears), which can be painful and may lead to sleep disturbance; acoustic trauma; perforated eardrum; and hyperacusis (which can develop

after sudden exposure to high sound levels and the sufferer may then find certain sounds uncomfortably or even painfully loud). Exposure to noise has been linked to heart disease and high blood pressure, especially in pregnant workers, and noise may affect the hearing of the unborn child. Noise plus exposure to solvents has a synergistic effect, causing greater noise-induced hearing loss than exposure to noise alone.

Exposure to noise reduces our ability to hear higher frequencies and so interferes in our ability to hear human speech clearly, resulting in noise-induced hearing loss (which differs from age-induced hearing loss). The inability to hear what is being said, to use a telephone or take part in conversation in social situations can lead to social exclusion and additional health risks.

Noise at work can cause other problems such as disturbance, interference with communications, difficulties with concentration, fatigue, tension and irritability – all of which may also cause stress.

An emerging problem is voice loss due to the necessity to speak in noisy environments and may affect, for example, teachers, lecturers and call center workers.

3.7 Methods of Preventing, Eliminating, and Limiting Noise Exposure

State-of-the-art methods for preventing, eliminating, or limiting noise exposure are based upon the simultaneous application of technical, administrative, and organizational solutions, which are selected based on a detailed analysis of the acoustic conditions at workstations with excessive noise.

The most significant technical solutions that limit noise include the following:

- Use of low-noise technological processes.

- Mechanization and automation of technological processes including remote and automatic control devices for noisy machines.
- Construction and application of low-noise or noiseless machines, devices, and tools.
- Proper layout of the plant and adaptation of rooms, taking into account the acoustic aspects.
- Use of noise control devices such as silencers, enclosures, screens, and sound-absorbing materials and systems.
- Use of structure-related sound insulation (vibration isolators and vibroisolated foundations of machines and devices).

The application of low-noise technological processes, as well as their mechanization and automation, is among the most significant requirements faced by designers and managers of production processes and manufacturing plants. Manufacturers should also use low-noise machines, devices, and tools.

Only at the design and construction stage of a plant can all of the available noise control measures be used. Noise reduction after the construction of the plant and the installation of machines and devices or during the full-scale operation stage is not only much more difficult, but also much less efficient, leading to only a slight reduction of noise at a relatively high cost. Moreover, the necessary alterations or adaptations are not always favourable to the technological process applied.

Hearing Protectors

The use of hearing protectors is the simplest and quickest way to protect the hearing organ against the effects of noise exposure. However, hearing protectors should be used only if all available technical and organisational methods for limiting noise at the workplace have been applied and the permissible values of noise are still exceeded.

Hearing protectors can be divided into noise reduction earmuffs and earplugs. Earmuffs can be worn separately or fixed to protective helmets. Earplugs can be disposable or reusable.

Noise-reduction earplugs can be factory-made, formed by the user, or customised by the manufacturer for the needs of individual users, taking into account specific features of the employee's external ear canal. Hearing protectors can be equipped with electronic systems, which are divided into three groups: hearing protectors with active noise reduction, level-dependent hearing protectors, and hearing protectors equipped with wired or wireless communication systems.

Protective methods from ultrasound:

- sound-proofing;
- protective shields (shelter materials are steel, duralumin, acrylic resin, cloth laminate added to the acoustical absorbents);
- the use of the booths of remote control;
- vibration isolation (vibration isolation coverage, rubber mittens, carpets).

Ways of protection from infrasound:

- reduction of the infrasound level in its origin;
- removal of the infrasound causes;
- medical prophylaxis;
- increase of frequency of mechanism rotation;
- increase in construction inflexibility;
- mufflers installation of the resonance type, resonance and chamber.

TOPIC 4. ELECTROMAGNETIC HAZARDS IN THE WORKPLACE

4.1 Introduction

Electromagnetic fields (EMFs) have existed since the dawn of history. Geostatic Magnetic fields, the electric fields of Earth's atmosphere, and low-frequency magnetic fields exist in the natural environment. The development of science and technology at the turn of the nineteenth and twentieth centuries has led to a massive use of electric energy in all areas of the economy and in households, as well as to the use of electromagnetic waves of various frequencies in wireless communications (Figure 4.1).

Artificial EMFs are common and humans are exposed to complex EMFs composed of various frequencies. Workers who operate these devices may be exposed to relatively high-level EMFs; the conditions of their exposure should be controlled. The ubiquitous presence of EMFs in the work environment requires employees, inspectors and workers to identify the sources and characteristics of the fields they generate, assess the severity of workers' exposure in the context of occupational health and safety and reduce identified hazards where necessary. The principle of avoiding unnecessary exposure also means limiting EMF exposure wherever possible.

The highest priority should be given to technical activities aimed at eliminating or reducing EMF levels in the vicinity of devices. Identifying and assessing electromagnetic hazards when designing devices and designing and organizing the workplace

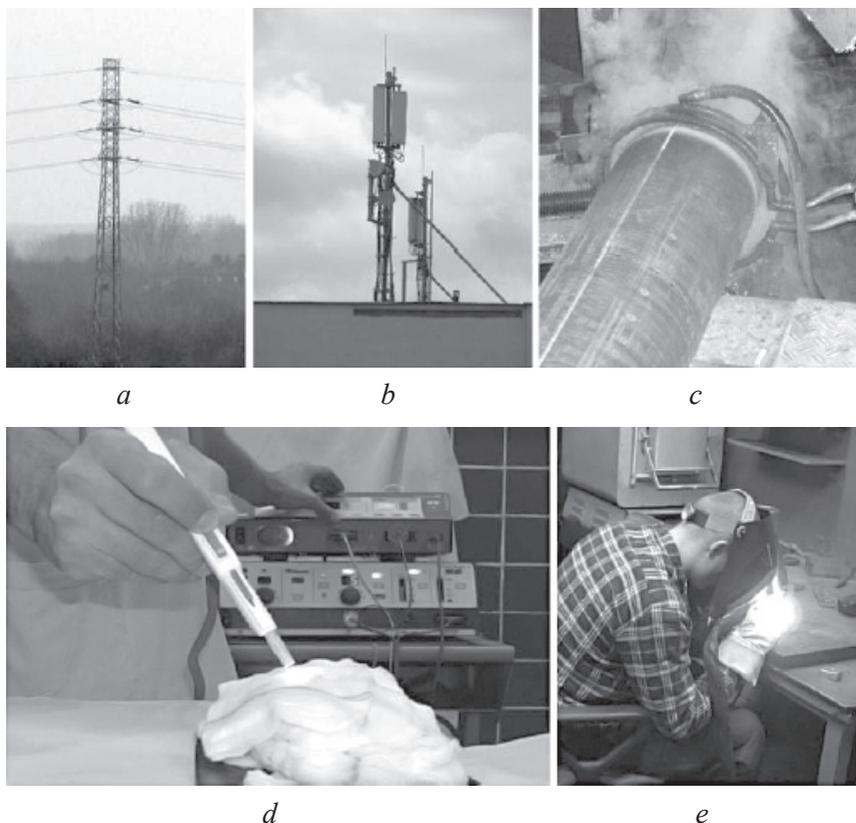


Figure 4.1 – Examples of electromagnetic field sources:
(a) a high-voltage power line; (b) antennas of mobile phone base stations;
(c) an induction heater; (d) an electrical surgery device;
and (e) an arc welding device

to reduce these levels are the most efficient methods to do this, in terms of both reducing the costs of protective measures and improving their effectiveness.

The frequency of time-varying EMFs is unlimited. EMFs of frequencies exceeding several megahertz (MHz) are also called electromagnetic radiation. The electromagnetic spectrum

(Figure 4.2) includes the fields and radiation of various frequencies and biophysical properties, such as EMFs and optical radiation (nonionising), as well as X-ray, gamma, and cosmic radiation (ionising radiation). In occupational health and safety, the term *electromagnetic field* is used to describe static electric and static magnetic fields (invariable in time) and time-varying fields of frequencies less than 300 GHz, that is, fields produced by sources emitting waves of a length exceeding 1 mm. Such radiation cannot be directly perceived by human senses and does not cause the ionisation of the medium of its propagation.

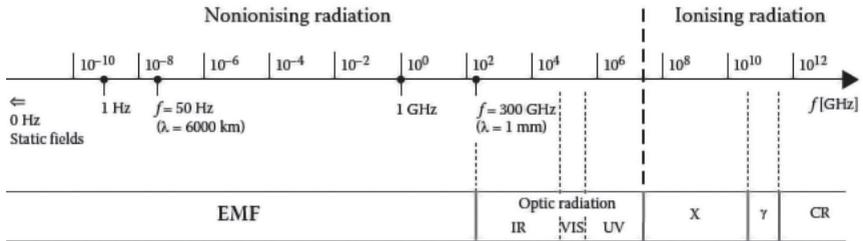


Figure 4.2 – Frequency spectrum of electromagnetic fields and radiation:
 IR = infrared radiation, VIS = visible radiation,
 UV = ultra-violet radiation, X = roentgens’s ray, γ = gamma radiation,
 CR = cosmic radiation

The properties of the EMF are usually analysed with regard to its two components: the electric field and the magnetic field. The magnetic field is present around the moving electric charges (creating an electric current) or as a result of the magnetization of some materials. The electric field exists around both the moving and motionless charges. The exposure level is usually described by the electric field strength (E), magnetic field strength (H), and frequency (f) of those fields present in the workplace (affecting the worker’s body). The level of electromagnetic hazard depends on the polarisation and spatial distribution of the field in relation to

the human body and the relationship between the strengths of the electric field and the magnetic field.

The energy of electric fields affects both moving and motionless charges, whereas that of magnetic fields affects only the moving charges. The static electric field is present around motionless charges, and the static magnetic field exists in the vicinity of conductors of direct current (DC) or permanent magnets.

Definitions

Wavelength (λ): This is the distance between two points in space, in which the wave is in the same phase of its oscillations (e.g. the distance between two adjacent peaks). The wavelength expressed in metres can be estimated by dividing 300 by the field frequency expressed in MHz; for example, for fields of frequency 100 kHz (i.e. 0.1 MHz), the wavelength (λ) is 3 km.

Electric field strength (E): This is a vector quantity representing the force affecting a unit electrical charge situated at a given point in the electric field. Its unit is volts per metre (V/m). For example, the electric field strength in a parallel plate capacitor, expressed in V/m, can be determined by dividing the difference in electrical potential on its plates, expressed in volts, by the distance between the plates, expressed in metres. An electric field strength of 25,000 V/m (i.e. 25 kV/m) exists in the centre of the plates of an air-spaced capacitor, separated by a distance of 1 cm and supplied by 250 V.

Magnetic field strength (H): This is a vector quantity representing the force affecting a unit electric charge moving at unit speed in the direction perpendicular to that vector measure. Its unit is ampere per metre (A/m). A magnetic field is also characterised by magnetic flux density (B), expressed in tesla (T). In the air, a magnetic field of 1 A/m is characterised by a magnetic flux density of about 1.25 μ T. For example, the magnetic field strength, expressed in A/m, in the surroundings of a straight electric cable, can be determined by dividing the current,

expressed in amperes, by double the π constant (about 3.14) multiplied by the distance from the cable, expressed in metres. At a distance of 15 cm from a single cable with a 100 A current, the magnetic field strength is about 106 A/m and the magnetic flux density is about 132 μ T.

Near field (or near field area): A field directly adjacent to the field source, up to a distance approximately equal to one wavelength (if the size of the source is small compared with the wavelength), in which the electric and magnetic field strengths are independent of each other.

Far field (or far field area): A field that extends to distances exceeding approximately three wavelengths from the field source (if the size of the source is small compared with the wavelength), where the orientations of the electric and magnetic fields are perpendicular to the direction of radiation propagation and perpendicular to each other (i.e. they create a 'plane wave').

Specific absorption rate (SAR): The rate at which energy is absorbed in the unit mass of an exposed body, expressed in watts per kilogram (W/kg). The SAR, averaged over the whole body, is a widely accepted measure of the thermal effects of exposure to radio-frequency fields. Local SAR is used to assess the level of energy absorbed in small parts and resulting from specific exposure conditions. Local SAR should be assessed, for example, for a grounded person exposed to a radio-frequency field of a frequency in the low megahertz (MHz) range or persons exposed to near field in the immediate surroundings of the source.

Current density (J): The current in a voluminous conductor (e.g. the human body) flowing through a unit cross-sectional area, perpendicular to the direction of current flow. The unit is ampere per square metre (A/m^2).

Permissible values of internal measures of exposure: The parameters derived to protect workers against adverse consequences of thermal effects and the effects of induced

currents during exposure to EMF, expressed as limit values of the SAR and the density of the induced current (J).

Permissible values of external measures of exposure: The parameters measurable in the real-work environment, expressed as electric field strength (E), magnetic field strength (H), magnetic flux density (B), and power density (S). If the permissible values of external measures are defined in order to fulfil the requirements regarding the permissible values of internal measures of exposure in the most unfavourable exposure conditions (e.g. exposure to a homogeneous field), then exceeding the permissible values of external measures is not always equivalent to the excess of the permissible values of internal measures (i.e. in the case of local exposure to a heterogeneous fields of a relatively high level).

Values related to parameters of EMFs are often presented using the following submultiple and multiple units:

n – Nano $\times 10^{-9}$ ($\times 0.000\ 000\ 001$)

μ – Micro $\times 10^{-6}$ ($\times 0.000\ 001$)

m – Milli $\times 10^{-3}$ ($\times 0.001$) $\times 100$ ($\times 1$)

k – Kilo $\times 10^3$ ($\times 1,000$)

M – Mega $\times 10^6$ ($\times 1,000,000$)

G – Giga $\times 10^9$ ($\times 1,000,000,000$)

4.2 Mechanism of Influence of an Electromagnetic Field on the Human Body

An EMF may affect the body of an exposed person directly or indirectly due to the absorption of field energy by exposed objects and its influence on the human body.

Most indirect effects are caused by contact currents, which flow through the body of a person who touches a metal object with a different electrical potential. The difference of potentials results from exposure to EMF. This phenomenon, which is linked with hazards of serious burns, needs attention in fields

of frequencies less than 100 MHz, whereas in the case of fields of frequencies below 100 kHz, it can stimulate electrically sensitive tissues such as muscles or nerves and cause pain. The intensity and the spatial distribution of contact currents depend on the frequencies of the EMF, the dimensions of the exposed object, and the area of contact between the object and the human body.

An EMF also may be hazardous to people due to an impact on the technical infrastructure, as currents induced by EMFs in devices may cause interference with automatic control devices or detonations of electrically controlled explosion equipment.

The ignition of flammable or explosive materials by sparks produced by the flow of an induced current or the discharge of an electrostatic charge can also cause fires and explosions. Induced or contact currents flowing through the body may also interfere with the function of active medical implants (such as pacemakers) and mechanical implants in the body.

EMFs are not usually perceived by human senses. In some situations, however, EMFs can be sensed directly; for example, in strong magnetic or electric fields of low frequencies (several or tens of hertz), a person may have visual sensations, called magneto- or electrophosphenes. Exposure to pulsed microwave fields can cause hearing sensations, called the Frey effect.

The direct effects of EMF exposure include stimulation of electrically sensitive tissues as a result of the flow of currents induced directly in the body (this is the most significant interaction mechanism for EMFs of frequencies not exceeding hundreds of kilohertz) and heating of tissues, including serious burns, caused by the energy of field absorbed in (this mechanism is the most significant for EMFs of frequencies exceeding 1 MHz). The effects of the current induction and rise of temperature in an exposed body are the basis for internal measures of exposure, whereas electric or magnetic field strengths, representing the level of fields in which a person is present, are called external measures of exposure.

The health consequences of various interactions of EMFs with the human body are not yet established. The following mechanisms of human interaction with EMF have been found:

1. Established mechanisms of human interaction with EMF:
 - Synapse activity alteration by membrane polarisation (phosphenes).
 - Peripheral nerve excitation by membrane depolarization.
 - Muscle cell excitation by membrane depolarisation (skeletal).
 - Electroporation.
 - Resistive (joule) heating.
 - Audio effects by thermoelastic expansion (Frey effect).
 - Magnetohydrodynamic effects.
2. Proposed mechanisms of human interaction with EMF:
 - Soliton mechanism through cell membrane proteins.
 - Spatial or temporal cellular integration.
 - Stochastic resonance.
 - Temperature mediated alteration of membrane ion transport.
 - Plasmon resonance.
 - Radon decay product attractors.
 - Rectification by cellular membranes.
 - Ion resonance.
 - Ca²⁺ oscillations.
 - Nuclear magnetic resonance.
 - Radical pair mechanism.
 - Magnetite interactions.

Other undesirable effects can also appear and significantly reduce working ability. Such effects, related for example to movements in the high-level static magnetic field, can include vertigo, magnetophosphenes, nausea, a metallic taste in the mouth, and difficulties with eye–hand coordination.

Occupational exposure to EMFs extended over many years may affect health and the ability to work. So far, results of investigations have not excluded the possibility of adverse health

effects from chronic exposure, especially to EMF of high levels. Possible adverse health effects from EMF exposure include the development of tumours or malfunctions of the cardiovascular, nervous, and immunological systems. Research continues in this respect.

At present, the scientific background for the assessment of health risk from such exposures is not adequate, especially in relation to exposure to static fields and intermediate frequency fields. Further investigation is a research priority. The wide use of technical or organisational measures to reduce workers' exposure to the lowest possible level is necessary. There are many examples of such measures with a high efficiency and low cost.

4.3 Worker's Exposure to Electromagnetic Fields

Any electrical device is a source of EMF, which can be generated intentionally or as a side effect of its operation. The most popular sources of EMFs encountered in a work environment are devices and installations used to distribute electric power, wireless communication and radars, electrothermal devices for thermal processing of metal or dielectric elements, and therapeutic or diagnostic medical equipment.

An estimated several million workers are subject to exposure to EMFs throughout Europe, but such data can be significantly underestimated because of the lack of relevant registers.

Most workers are exposed to weak EMFs, which can occur near the following:

- Electrical appliances available also for the use of the general public, for example, office or computer equipment that is not located directly on the body of the worker.
- Lighting equipment, except for some types of specialised radio frequency – energised lighting.

- Wireless or cordless phone systems and base stations, except when work is performed directly on the active antennae.
- Power supplying devices, such as high-voltage power lines, transformer stations, and switch yards, except for workers performing work on the living devices (e.g. at a live high-voltage power line).
- Medical devices, except magnetic resonance imaging (MRI) scanners, physiotherapy diathermies, and electrical surgery devices.

Exposure to strong EMFs can occur near the following:

- Electrothermal devices, such as arc furnaces for melting scrap steel, induction furnaces, and heaters for thermal processing of steel elements (e.g. in hardening, forging).
 - Dielectric heaters and presses for joining plastic elements.
 - Resistance welders for connecting metal elements.
 - Industrial magnetisers and demagnetisers
- Radio- and telecommunication devices, such as radio and television broadcasting antennas and radars.
- Medical and laboratory devices, such as physiotherapy diathermies, electrical surgery devices, MRI scanners, NMR spectrometers, and magnetic therapy devices.
 - Electrochemical devices, such as electrolytic vats.
 - Magnetic separators for capturing metal elements from loose and fragmented materials.

4.4 Protective measures against Electromagnetic Fields

Measures for the protection of workers include engineering and administrative controls, personal protection programs, and medical surveillance. Appropriate protective measures must be implemented when exposure in the workplace results in the basic restrictions being exceeded. As a first step, engineering controls should be undertaken wherever possible to reduce device

emissions of fields to acceptable levels. Such controls include good safety design and, where necessary, the use of interlocks or similar health protection mechanisms.

Administrative controls, such as limitations on access and the use of audible and visible warnings, should be used in conjunction with engineering controls. The equipment emitting EMF must be placed in working areas dedicated to the sole use of that equipment and at an appropriate distance from other working areas where the personnel stands for extended periods of time. Moreover, in order to prevent indirect effects, interferential problems and undue exposure, it is of basic importance to avoid that metallic objects of any kind and electrical equipment are placed next to EMF sources, except if an appropriate previous technical assessment has been performed.

In general, the distance between the installation area of the equipment, which we will define as the restricted access area with relation to the risk of EMF exposure, and the other working areas, which are free access areas, depends on the technical features of the equipment and should be estimated by the person who is in charge of risk assessment.

In application of the optimization principle, it will be appropriate to aim, where possible, at obtaining that the exposure to electromagnetic fields in the areas dedicated to prolonged stay of the non-professionally exposed personnel is below the maximum limits established in the current regulations for the general public.

The work areas where the exposure values can be higher than the reference levels for the general public established in the European recommendation 1999/519/EC, should be delimited by using electromagnetic fields alerting signs, which have to be compliant to the current regulations for warning signs (Figure 4.3).

Personal protection measures, such as protective clothing, though useful in certain circumstances, should be regarded as a last resort to ensure the safety of the worker; priority should

be given to engineering and administrative controls wherever possible. Furthermore, when such items as insulated gloves are used to protect individuals from high-frequency shock and burns, the basic restrictions must not be exceeded, since the insulation protects only against indirect effects of the fields.

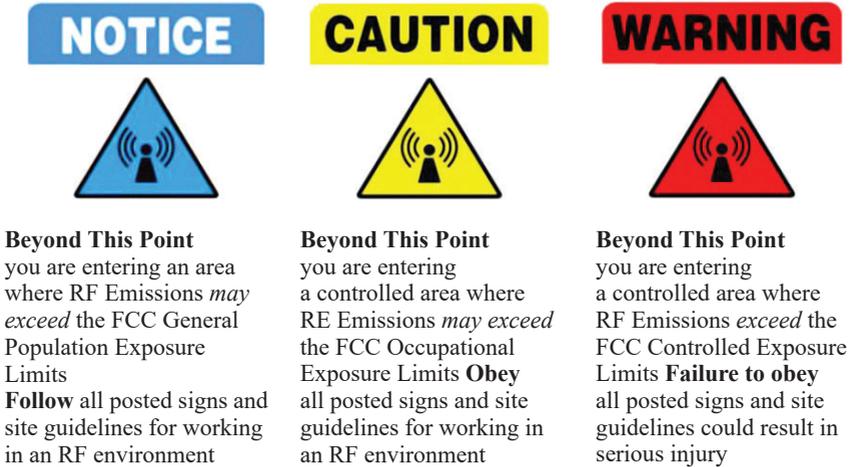


Figure 4.3 – Electromagnetic fields safety signs

With the exception of protective clothing and other personal protection, the same measures can be applied to the general public whenever there is a possibility that the general public reference levels might be exceeded.

It is also essential to establish and implement rules that will prevent:

- a) interference with medical electronic equipment and devices (including cardiac pacemakers);
- b) detonation of electro-explosive devices (detonators);
- c) fires and explosions resulting from ignition of flammable materials by sparks caused by induced fields, contact currents, or spark discharges.

TOPIC 5. ELECTRIC LIGHTING FOR INDOOR WORKPLACES AND WORKSTATIONS

5.1 Introduction

Lighting is the use of light (visual radiation) to make places, objects, and their environments visible. Lighting directly influences the speed and reliability of vision and determines how forms, figures, colours, and features of the surface (e.g. texture) of objects are seen. Lighting is very important to maximising visual performance and visual work efficiency and, at the same time, minimising visual fatigue and the risk of perception mistakes. Lighting has three main functions:

- Ensure safety for people in interior environments.
- Ensure proper conditions for performing visual tasks.
- Assist in creating a proper luminous environment.

Light is an important stimulator of not only eyesight but the entire organism as well. For a human being day and night, light and darkness determine biorhythm, periods of vivacity and sleep. Thus, lack of illumination or its excess cause a reduction in central nervous system excitation and, naturally, reduce the intensity of all vital processes.

It is common knowledge that 90 % of all information is perceived visually, thus its quality absolutely depends on illumination. Rational illumination is an important factor in general industrial culture.

The lighting condition of industrial area plays an important role in occupational injury prevention. Foreign researchers have established that more than 20 % of occupational accidents are result of poor illumination.

5.2 Lighting Principles

Three conditions are essential for visual comfort:

1. Full ability to distinguish details
2. Efficient perception, without any risk for the observer
3. Perception without any discomfort or excessive fatigue

There are three main groups of lighting principles: physiological, aesthetic, economic.

Physiological principles are the most important for the visual system:

- Sufficient luminance in relation to the visual task
- Sufficient contrast between the visual task and its surroundings
- Avoidance of details with too-small angular dimensions and a too-short time for perception
- Uniform luminance of the surroundings

Excessive deviation from these rules for lengthy visual work leads to visual fatigue and a decrease in work efficiency.

Aesthetic principles are derived from analysis of the influence of light on the mental state of man. There are two main aesthetic principles:

1. Increasing the attractiveness of the picture
2. Creating a mood

The selection of luminaires with similar lighting characteristics but different prices and the selection of energy-saving light sources and ballasts depends on the employer's economic principles, which often focus on reducing excessive costs.

All of the above-mentioned principles are linked with one another and, depending on the visual work, the difficulty of the visual task, and the purpose of the lit interior, each has different groups of principles that are most important. Physiological principles are the most significant in designing indoor lighting. These principles must be followed, especially for interiors where visual tasks are difficult and lengthy.

5.3 Basic Light Engineering Notions

The illumination of industrial buildings is characterized by quantitative and qualitative parameters (Figure 5.1).

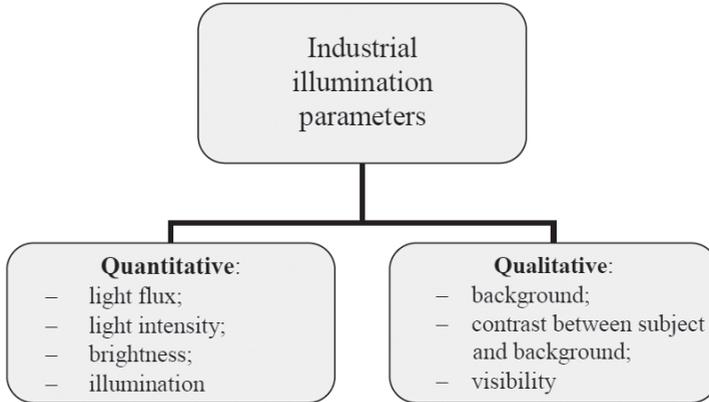


Figure 5.1 – Parameters of the industrial illumination

Light flux (F) is the intensity of light that is evaluated by human eyesight in accordance with light sensation. Unit of light flux measurement is lumen.

Light intensity (I) is a magnitude defined by the ratio between light flux (F) and solid angle (W) within which light flux is equally allocated:

$$I = F / W, \text{ cd (candela)}$$

Brightness (B) is the ratio of light intensity that is emanating from surface element into proper direction to shining surface area:

$$B = \frac{I}{S} \cdot \cos \alpha, \text{ nit}$$

where I is light intensity emanating from surface into proper direction, cd;

S is surface area, m^2 ;

α is angle between normal of surface element S and direction to which the brightness is determined.

Illumination (E) is the ratio of light flux (F) that falls on surface element to surface area of this element (S):

$$E = \frac{F}{S}, \text{ lx (lux)}$$

Background is the surface adjacent to the object of distinction on which it is observed. Background is considered in next way: light when $p > 0.4$, medium when $p > 0.2-0.4$ and dark when $p < 0.2$.

Contrast between subject and background is characterized by the balance of the brightness of the observed object (dot, line and sign) and background.

$$K = \frac{B_0 - B_f}{B_f},$$

where B_0 and B_f are brightness of object and background, nit.

Contrast is defined as: big when $k > 0.5$, medium when $k = 0.2-0.5$ and small when $k < 0.2$.

Basic Illumination Hygienic Requirements consist of: optimal brightness of the workplace; uniformity of illumination; absence of sharp difference between the brightness of working surface and that of the environment; absence of lighting source dazzle.

5.4 Artificial Illumination

There are next types of artificial illumination:

- a) general – even and uneven;
- b) combined – consists of general and local;
- c) local – concentrates light flux at workplaces.

Local illumination is forbidden to use since it creates the danger of industrial injuries or occupational diseases.

Artificial illumination is divided into working, emergency, evacuation, security and telltale light according to purpose.

Working illumination facilitates the industrial process, people movement, transport movement and is necessary in all industrial buildings.

Emergency illumination ensures work continuation when switching on working illumination can cause explosion, fire or poisoning. The minimal illumination of working surfaces under emergency illumination has to be 5 % of working illumination, but no less than 2 lx.

Evacuation illumination is to ensure people evacuation from the building when there is an emergency shutdown of working illumination. The minimal illumination is 0.5 lx indoors and no less than 0.2 lx in open areas.

All the buildings must have natural illumination. Illumination norm depends on optical work whose accuracy is defined by the smallest object of distinction.

It is advisable to use combined illumination during different kinds of works: lamps of local illumination create high illumination of the working surface and lamps of general illumination even brightness in the field of vision.

5.5 Improper Lighting as a Hazardous Factor in Work Environment

Factors that can cause visual fatigue can be divided into external (environmental) and internal (visual system) factors. External factors include the following:

- Too- low or too-high illuminance.
- Glare.
- High luminance contrasts and colour contrasts in the visual field or no contrast.
- Flicker.
- Simultaneous use of natural and artificial light in a spectrum that is not properly adjusted to daylight.

- Lengthy visual effort.
- Incorrect placement of the visual task area in relation to the location of the luminaires.

Internal factors include the following:

- Uncorrected or inadequately corrected refractive errors.
- Accommodation and convergence disorders.
- Binocular vision disorder.
- Eye diseases.
- Other diseases.

Visual fatigue occurs when the visual system is strained and can be manifested as the following:

- Ocular symptoms (sore, tired, itchy, dry, burning eyes).
- Visual symptoms (blurred, double vision) headaches, tiredness).
- Transient changes in visual functions, such as a decrease in the amplitude of accommodation and a longer distance of near point of convergence.

People with any of the above internal factors experience greater visual fatigue more frequently compared to people without internal factors. Working in incorrect lighting conditions for a long time weakens the visual system and refractive disorders can emerge or become more severe.

5.6 Artificial Illumination Sources

There are different types of lamps as sources of artificial illumination depending on light extraction element (Figure 5.2).

Incandescent, discharge and LED lamps are widespread as artificial illumination sources.

Incandescent lamps are characterized by simple construction and production, low price, easy exploitation, wide voltage and power ranges (Figure 5.3).

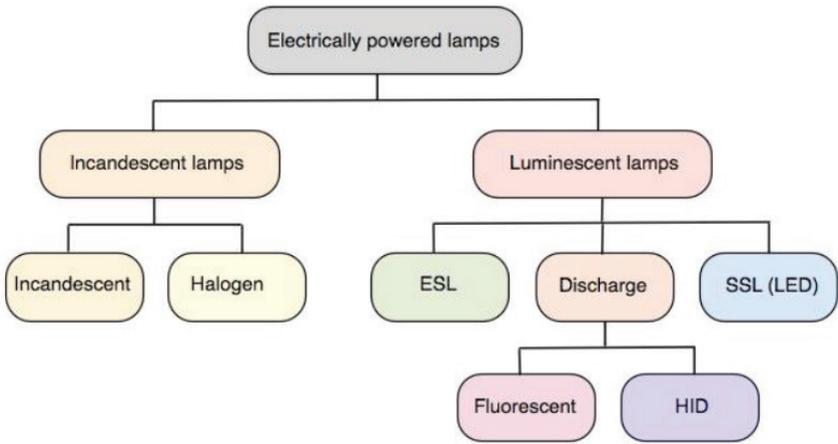


Figure 5.2 – Illustration of different types of lamps

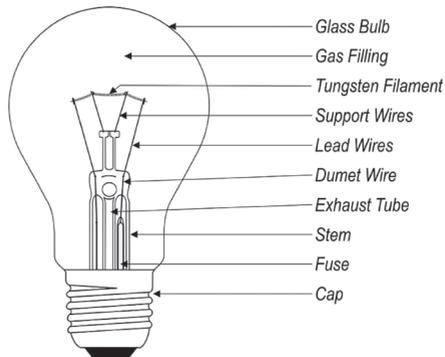


Figure 5.3 – Shapes of bulb incandescent lamp

There are next drawbacks of incandescent lamps: high brightness (dazzle effect); low light efficiency (7–20 lm/W); relatively low operation life (to 2.5 thousand hours); yellow–red rays domination comparatively with natural light; high reheat temperature (to 140 °C that makes them fire hazardous).

Incandescent lamps are usually used for local illumination and for areas where personnel stay temporarily.

Gas-discharge lamps emanate optical range light resulting from an electric discharge in rare gas and metal steam environment as well as luminescence.

Advantages: economy, light efficiency 40–100 lm/W; operation life up to 10 thousand hours; any spectrum guarantee; reheat temperature – 30–60 °C.

Drawbacks: light flux pulsation that can cause stroboscopic effect and the optical effect of moving objects; complicated switching system; relatively expensive; a significant period between switching on and striking. Gas-discharge lamps can be of high (fluorescent) or low pressure (Figure 5.4).

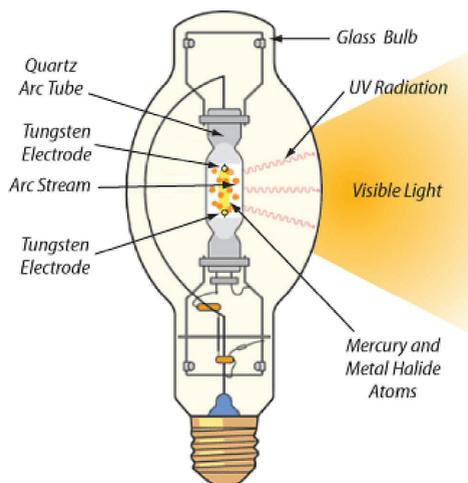


Figure 5.4 –High-intensity discharge lamp

Fluorescent lighting is used for doghouse and industrial building illumination (Figure 5.5). However, they cannot be used in conditions of low temperature. Gas-discharge lamps of high pressure are used if there is a need of high light efficiency, light source compactness and stability despite adverse environment conditions.

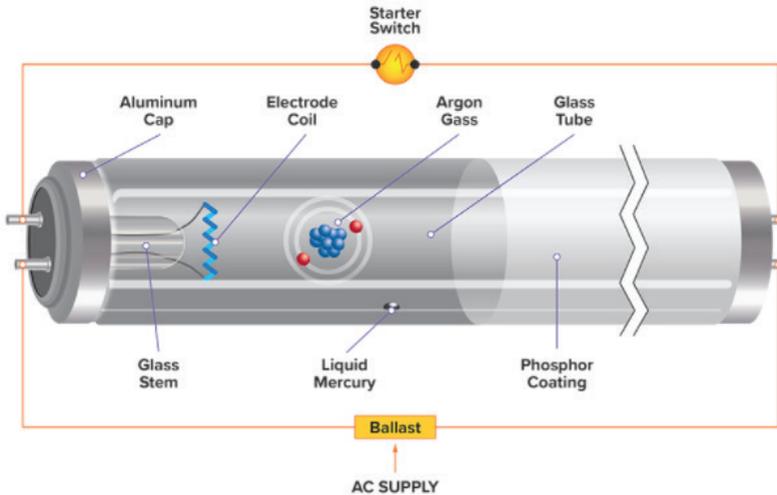


Figure 5.5 –Fluorescent light bulb diagram

In order to avoid the dazzle effect, the bulb is placed into the fitting that prevents excessive brightness of the source and protects it from the effect of fire- and explosion-hazardous and reactive environment, mechanical failures, dust, dirt and atmospheric precipitates.

Depending on construction, there are the following types of lamps: open (the bulb is not separated from the environment), protected (the bulb is separated with a shell that is no barrier for free air penetration), closed (the shell protects the lamp from large dust particles), dust-tight lamps, water proof lamps, explosion-hazardous lamps, lamps of improved reliability against explosion.

Lamps can be of general and local illumination. The system of general or combined illumination is designed for all industrial buildings. Working surface illumination represented by lamps of general illumination in the system of combined illumination must be no less than 10 % of normal for combined, but not lower than 150 lx at gas-discharge lamps and 50 lx at incandescent lamps.

5.7 Designing Artificial Illumination Systems

Design involves: choice of the system of illumination; type of lighting source; lamp type; choice of location of lighting devices; calculations; definition of lamp and bulb power.

A system of general or combined illumination is designed for all industrial buildings. The lighting of the working area by lamps of general lighting in the system of combined lighting has to be no less than 10 % of combined lightning standard but not lower than 150 lx for gas-discharge lamps and 50 lx for incandescent lamps.

From the economic point of view luminous tube lamps of LB type are the best as they have the highest light efficiency. The minimal height from the floor at which the lamps are to be installed is 2.6 m for a 4-bulb lamp and 3.2 for lamps with 4 and more bulbs. The selection of a lamp depends on workplace characteristics. For buildings whose walls and ceiling have low reflecting capacity, lamps of direct effect are used. For buildings whose walls and ceiling have high reflecting capacity, lamps mainly of direct effect are used.

In administrative and office buildings, lamps of diffused illumination are common. Lamps must have a proper protection level from conditions of the environment where they are fixed.

TOPIC 6. ELECTRICAL SAFETY

6.1 Introduction

Today, in power supply systems of receivers in industry, civil engineering, agriculture, and other branches of industry, electrical energy is usually transferred by applying a voltage of 400/230 alternating current (AC) with a frequency of 50 Hz (hertz). However, the risk of electric shock is inherent, and is the most important hazard posed, in such cases. Electric shock is the most frequent cause of accidents, and is fourth in the list of most fatal accidents, after falling down, losing control over a car, or being hit with a falling object. The consequences of electric shock are usually tragic, often resulting in death. Protection against electric shock is therefore crucial. To ensure effective protection against electric shock, safety principles should be followed when using electrically powered systems and only the devices that have been designed according to the requirements given in the standards and rules should be used.

Definitions

Live part: A conductor or conductive part intended to be energised in normal use and that conducts electric current; for example, socket pins, cable phase wires (also neutral conductor N), switchgear conductor bars, motor windings, electrical equipment, and so on.

Exposed conductive part: A conductive part of electrical equipment, but not a part of the working equipment; for example, electrical machine enclosures, switchgear enclosures, motor enclosures, luminaires, and so on.

Extraneous conductive part: A conductive part, not a part of electrical equipment and liable to introduce a potential, generally the earth potential; for example, all pipelines, building structure elements, belt conveyors, and so on.

Direct contact: The contact of persons or livestock with live parts that may result in electric shock.

Indirect contact: The contact of persons with exposed or extraneous conductive parts, which could become live under fault conditions or other disturbances.

6.2 General Characteristics of Electric Shock Hazards

Electric shock is a shocking current flow through a human body when it comes into contact with two points of different electric potentials. The difference between potentials may be a touch voltage, which appears when a shocking current flows through the following paths: upper extremity–upper extremity (hand–hand), upper extremity–lower extremity (hand–leg), hand–torso, and leg–leg.

Direct contact can cause electric shock to a human; that is, touching a live part, which, by definition, operates normally under a voltage higher than the safe one relative to the reference potential (Figure 6.1). Direct contact usually happens when work safety requirements are not satisfied, for example if one does not follow the instructions, if the design or use of the device is improper, if the device has not been adapted to environmental hazards, if a damaged or incomplete device is used, and so on.

Electric shock can also be caused by indirect contact (Figure 6.2), that is, contact with the exposed conductive elements (the elements of an electrical system or electrical equipment that are not live parts) or extraneous conductive parts (i.e. metal objects not connected to the electrical circuits). When the voltage in such an element or between the elements, relative

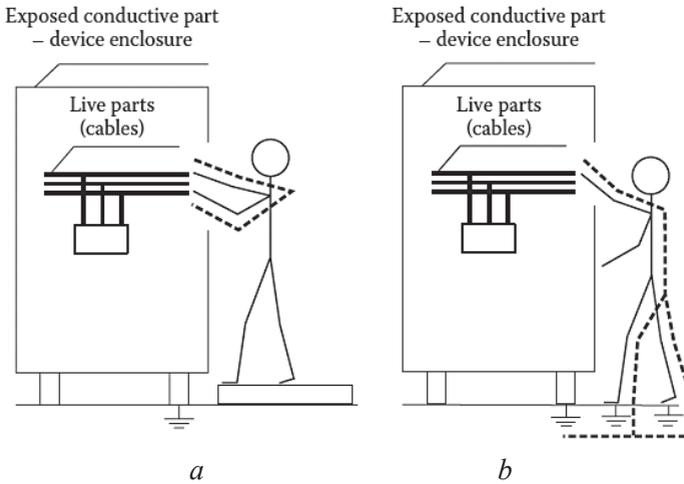


Figure 6.1 – Electric shock due to direct contact:
 (a) shock current flowing along the hand–hand path,
 (b) shock current flowing along the hand–leg path

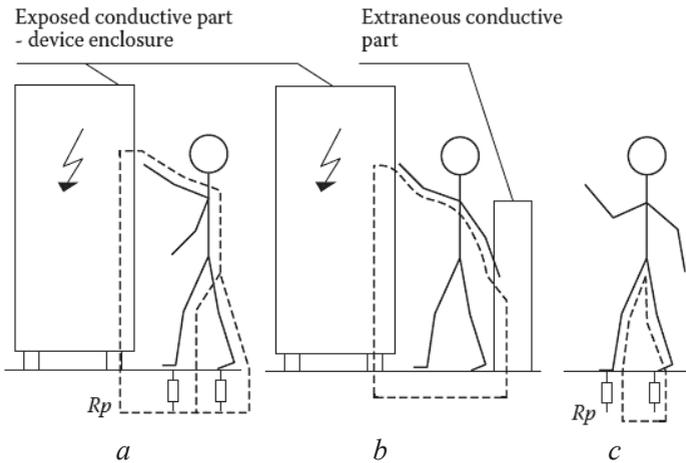


Figure 6.2 – Electric shock due to indirect contact:
 (a) shock current flowing along the hand–leg path,
 (b) shock current flowing along the hand–hand path,
 and (c) shock current flowing along the leg–leg path

to the earth, exceeds the safe voltage, the person touching the element will receive an electric shock. This usually happens when a fault appears in the insulating system, and is accompanied by an earth fault.

Some extraneous causes of electric shock include the propagation of currents after atmospheric discharge, stray currents approaching other objects, or a step voltage accumulating between the feet of a person standing on a conductive floor.

6.3 Protection against Electric Shock

Protection against electric shock requires the following three elements:

- Protection against direct contact
- Protection against indirect contact
- Additional safety measures

Technical Protection against Direct Contact

Protection against direct contact involves the prevention of contact between the human body and the live part of the device. Based on the designs of electrically powered devices and their environmental hazards, protection against electric shock can be executed using the following:

- *Insulation of the live parts:* Application of basic insulation protects against both intended and unintended contacts. Replacement of the element with a new one is required if the insulation capacity is lost or if there are mechanical damages.

- *Application of guards, enclosures, and barriers:* This includes placing live parts inside casings or fences that allow protection level, or the use of guards that prevent contact with the energised elements. The casing and fences should be fixed as firmly as possible and made up of materials that ensure their functionality within the lifetime specified by the manufacturer. The disassembly of casings, fences, and guards should be difficult

(e.g. require special tools) or be possible only after eliminating the hazards against which they protect.

- *Application of obstacles, portable barriers, and placing live parts outside the reach of the operator*: This reduces the risk of electric shock only when contact with energised elements results from deliberate action. The means of protection can be disassembled relatively easily. It is very rare in solid designs, which are not moveable, but is used very often in maintenance and repair works executed in electrical installations.

- *Application of residual current protective devices (additional safety measures)*: Using switches with a low residual current response ($\Delta I \leq 30 \text{ mA}$) improves efficiency against direct contact if the protective means are ineffective. This method cannot prevent the risk of electric shock due to direct contact, but can reduce its consequences; therefore, this should not be the only protective measure.

Technical Measures of Protection against Indirect Contact

Protection against indirect contact is the prevention of electric shock when a person touches exposed conductive parts, which are energised due to insulation damage.

The following measures can be applied:

- *Automatic disconnection of supply*: Short circuits are created through the protective conductors, connecting the exposed conductive parts with a neutral point or the earth (depending on the network structure), combined with protective means ensuring that the supply is disconnected. This task may be executed using overcurrent protection means or residual current protective devices.

- *Protection by provision of class II equipment or by equivalent insulation*: This protection prevents dangerous energising of the exposed conductive parts in case there is basic insulation damage. Double insulation, reinforced insulation, or equivalent insulation is used. Class II equipment is commonly used as an additional safety measure, especially when dealing with moving equipment or hand tools such as power tools.

- *Insulation of a workstation:* Preventing simultaneous contact with parts that may have different potentials. The surroundings of a given device should be completely insulated and at the same time no earthed objects or protective conductors should be connected.

- *Application of electric separation in power supply:* A receiver is actuated through a separating transformer or separating converter for a DC. When using this type of protective means, no electric shock can happen because there is a one-point contact with the live part. However, its application is strictly limited.

- *Application of equipotential bonding not being earthed:* This prevents Dangerous touch voltage. All exposed and extraneous conductive parts are connected using unearthed local equipotential bonding.

Organisational Safety Measures for Protection against Electric Shock

Besides technical safety means, organisational safety measures also play an important role in reducing hazards posed by electrical energy, electrostatic energy, or the exploitation of machines and devices. The following organisational safety measures may be followed:

- Ensure that the safety requirements have been satisfied.
- Ensure that the persons operating or maintaining the specified machines and devices have the relevant permissions.
- Ensure that the relevant instructions on the machine and device operation are available.
- Spread knowledge of the safe operation of electrical machines and devices and focus attention on initial and periodic employee training.
- Perform a periodic medical examination of employees.

Good Practices

Good practices in the operation of electrically powered equipment include keeping the equipment in a good technical

condition and following the schedules for periodic measurement of its protection against electric shock. The following aspects of work organisation should also be emphasised:

- Periodic training of employees.
- Appointing only the persons with relevant permissions to perform all operations of electrical installations and devices.
- Ensuring that the equipment is used for what it was intended.
- Displaying tables and warning signs about the hazards of electric shock (Figure 6.3).
- Performing periodic inspection of nonmobile electrical devices at least once a month and in the following cases:
 - Before starting the device after changes have been made to its electrical and mechanical parts or after any repairs have been done.

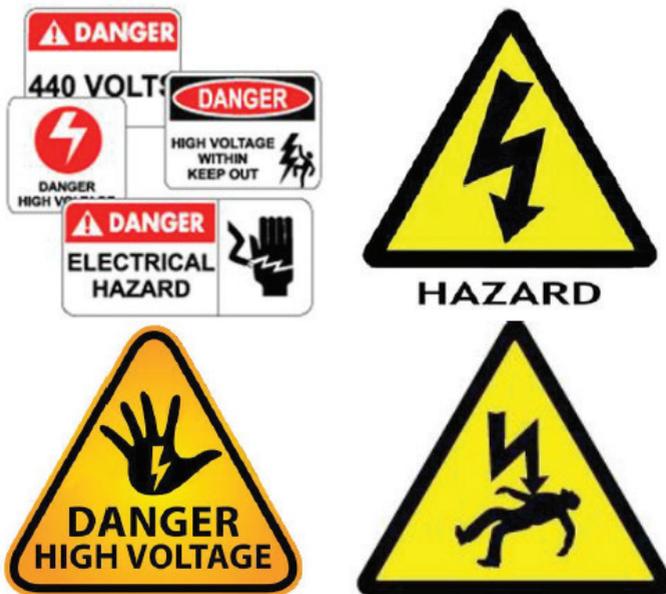


Figure 6.3 – Electrical Safety signs

- Before starting the device after a one-month (or longer) break in its operation.
- Before starting the device after it has been transferred.
- While reporting all the repairs and inspections in the device maintenance book.

When operating electrically-powered devices, the following rules should be followed:

- Use the plugs that fit into the sockets on the receivers.
- Avoid direct connection of the conductors with the socket (without a plug).
- Use only the devices for which the enclosures reveal at least an IP44 protection level.
- Apply the separating transformers when using the devices.
- Carefully follow the manufacturer's recommendations concerning the use of the devices.
- Try to avoid exposing the electrical equipment to rain or using it under explosive, humid, or damp environmental conditions.
- Use special tools designed for industrial applications when a long-lasting continuous task needs to be executed.
- Use the conductor only for what it was intended.
- Do not move the device by grabbing its conductors or disconnect the plugsocket combination by pulling the conductor.
- Protect the conductors against high temperatures, oils, lubricants, and sharp edges.
- Cut off the power supply to a device that is not operating or on which replaceable equipment is mounted.
- Make sure that the device is in the 'off' state before connecting it with a power supply.
- Do not make any changes in the electrical system or in the design of electrical devices without professional help.

Obeying the aforementioned rules will considerably reduce the possibility of dangerous events when operating electric devices.

6.4 Actions to Be Taken in Case of Electric Shock

Special protection equipment is typically not used in the operation of electrically powered devices. Protection against electric shock can be provided by using other methods. Contact with a source of electric current may cause skin burns, syncope, cardiac standstill, or even death. When a person is subject to an electric shock of a voltage lower than 1 kV for a short time, there is no harm to the human body; however, when the time of exposure is longer, it might be dangerous. The injured person should be freed from the electric current as soon as possible, however, the person under electric shock is as dangerous as the source of current itself. To free the injured person from an electric current of voltage lower than 1 kV, the following should be done:

1. Disconnect the proper electric circuit.
2. Open the proper switching devices.
3. Take the cutouts from the power supply circuit.
4. Cut out or tear the conductors from the power supply side using special tools.
5. Make a short circuit of conductors from the power supply side.
6. Take out the cutouts using special holders.

When the aforementioned actions cannot be taken, the following should be done:

7. Drag the injured person out of the energised device using special tools or objects made of dry wood or plastic.
8. Prevent the injured person from falling down, which can result from cutting off the power supply.

TOPIC 7. IONISING RADIATION

7.1 Introduction

Radiation protection refers to all the actions and activities necessary to prevent the exposure of humans and the environment to ionising radiation, and if prevention of such exposure is not possible, these actions should endeavour to reduce the harmful influence of this radiation on the health of future generations in the form of genetic consequences.

In 1980, the International Commission on Radiation Units and Measurements (ICRU) approved doses for ionising radiation under the international system of units (SI system): for absorbed doses, the gray (Gy) replaced the earlier rad (radiation absorbed dose [rd, rad]); for dose equivalent, the sievert (Sv) replaced the former rem (roentgen equivalent man [rem]). In 1990, changes in the recommendations (ICRP-60) raised the dose limits to a stricter level of 20 mSv/year for occupational exposure.

The ICRP's recommendations formed the basis for the *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources* formulated and published collectively by the organisations affiliated with the United Nations, namely the International Atomic Energy Agency (IAEA), the World Health Organization (WHO), the International Labor Organization (ILO), and the Food and Agriculture Organization (FAO), as well as the Organisation for Economic Cooperation and Development (OECD), the Nuclear Energy Agency (NEA/OECD), and the Pan American Health Organization (PAHO). National regulations on radiation protection in most countries are based on the ICRP

recommendations of 1990 (ICRP, 1990). The directives of the European Union are also based on these documents.

The ICRP uses all available sources of scientific information in its work, especially the periodic reports of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000, UNSCEAR, 2006), issued every 3 to 5 years. Exposure to ionising radiation is of three basic types:

1. *Occupational exposure*: This refers to hazards relating to work and applies solely to persons employed in conditions where they face a threat of exposure to ionising radiation.

2. *Public exposure*: This refers to the presence of ionising radiation sources in the environment, for example, in potable water, air, or soil, and in objects of everyday use. It also refers to sources other than those naturally encountered in the given environment that are responsible for the radiation level in the natural environment.

3. *Medical exposure*: This includes all medical uses of radiation for diagnostic tests and in radiation therapy.

7.2 Physical Basis of Radiation

Ionising radiation is electromagnetic radiation (gamma, γ ; roentgen, X) or molecular radiation (corpuscular, e.g. α ; β), which, when passing through matter directly or indirectly produces ions (other than photons of ultraviolet radiation). Radiation is related to the emission and transfer of energy. When a body is said to radiate, this means that it emits energy. Sources of ionising radiation include the following:

- Radioactive substances (elements or their chemical compounds) such as radium (^{226}Ra).
- Equipment, for example, X-ray apparatus.

Radioactivity is the independent disintegration of the atomic nuclei of certain isotopes associated with the emission of the

rays α , β and γ . Radioactive nuclides are often referred to as radionuclides. The nucleus of the newly created element can be stable or radioactive. The penetration of α radiation (a stream of fast-moving helium nuclei) is very small. In air, its maximum range does not exceed 10 cm, and in tissue only fractions of millimetres. It can hardly penetrate through a single sheet of ordinary paper.

The ionisation caused by β radiation (a stream of fast-moving electrons or positrons), which consists of particles smaller than α particles and of a lower electrical charge, is small; hence, its range is much greater (in air, almost 60 times greater than α radiation of the same energy), and can reach distances of several metres. This radiation can even penetrate a metal shield of a several-millimetre thickness.

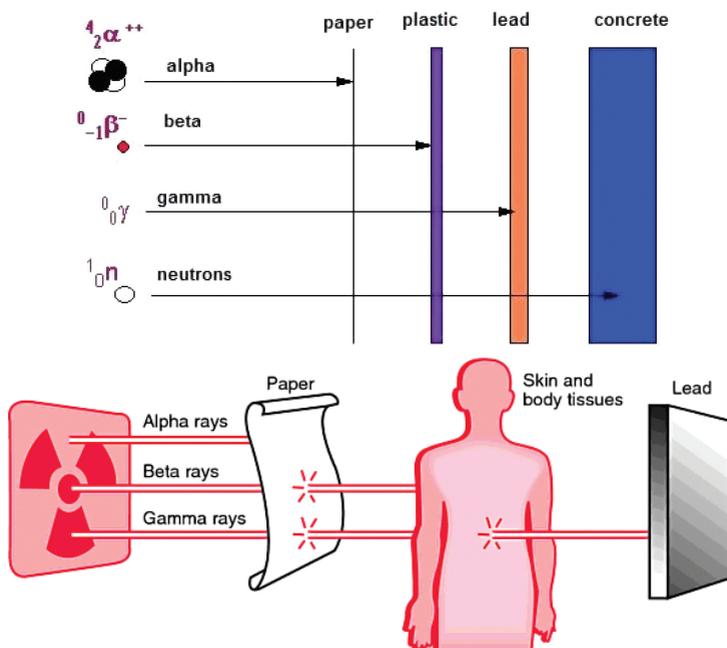


Figure 7.1 – Comparison of main types of ionizing radiation

Gamma or X radiation (electromagnetic radiation) is very powerful and can penetrate very thick layers of concrete or steel. It is very difficult to define its range in matter. Consequently, the thickness of this layer of matter is usually expressed in terms of the thickness that is needed to weaken the intensity of this radiation by half (the so-called half-value layer).

7.3 Biological Effects of Ionising Radiation

The interaction of ionising radiation with a live organism over time can be broken down into several phases occurring subsequently, for example, *physical interactions* (energy deposition, excitation or ionisation, initial particle tracks; time: 10⁻¹⁵–10⁻¹² seconds), *physico-chemical interactions* (radical formation, diffusion, chemical reactions, initial DNA damage, DNA breaks or base damage; time: 10⁻⁹–10⁻³ seconds), *biological responses* (repair processes, damage fixation, cell killing, mutations, transformations, aberrations; time: 1 second–1 day), and *medical effects* (proliferation of ‘damaged’ cells, promotion or completion, teratogenesis, cancer, hereditary defects; time: 10 days–100 years).

The allowed exposures from specific radioactive sources to the public are limited to 100 mrem. Medical X-rays generally deliver less than 10 mrem. All kinds of ionizing radiations produce health effects. The damages incurred by different kinds of tissue vary with the type of radiation to which the person is exposed and the means of exposure. Non-ionizing radiations do not affect at molecular levels. They may cause electrical shocks and burns. Prolonged exposure to microwaves radiation, which is non-ionizing, may cause cataracts.

The biological effect of ionizing radiation on human health is divided into two types: direct and indirect. Direct exposure to radiation and radiation emitters (radionuclides) can affect the

whole body while inhalation or ingestion affects tissues inside the body.

The body attempts to repair the damage caused by the radiation. However, at times the damage is so severe and widespread that repair is impossible. Radiations can damage the process of normal cell division leading to cancers (Figure 7.2).

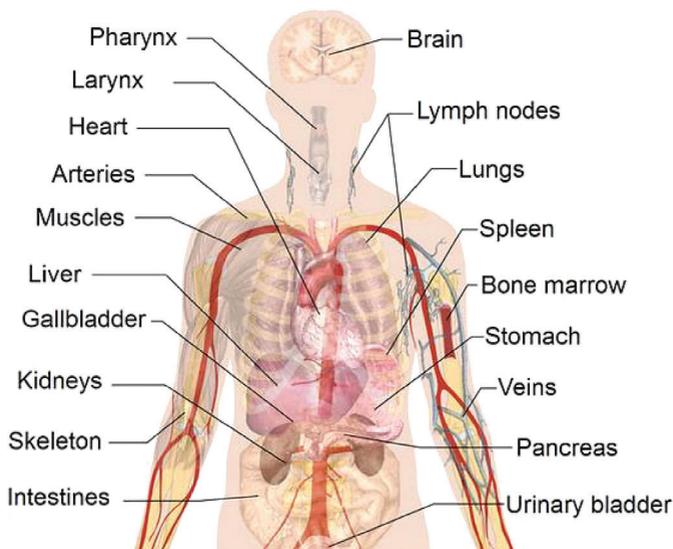


Figure 7.2 – Biological consequences of ionising radiation

The irradiated organism sometimes does not demonstrate any identifiable symptoms for a prolonged period following exposure. The consequences of such irradiation could exist in latent form and develop gradually, manifesting themselves even after dozens of years.

There are two categories of biological consequences of ionising radiation:

1. *Deterministic effects (nonstochastic)*: The radiation effects for which a threshold dose generally exists, above which the severity of the effect is greater. These include all of the

well-known complications in radiation therapy.

2. *Stochastic effects*: Radiation effects that generally occur without a threshold dose level, whose probability is proportional to the dose and whose severity is independent of the dose. These include malignant carcinomas.

Biological effect of IR depends on:

a) the dose of radiation. For example:

0–25 Rem – tangible violations are absent;

25–50 Rem – possible changes in the blood;

80–120 Rem – change of blood cells (initial signs of radiation sickness);

up to 120 Rem – working infringement;

250–450 Rem – disability;

300 Rem – the death, 50 % of the damage;

600 Rem – 100 % of the death;

b) the IR type, because different types of IR have different penetrating potential;

c) the age (children are more susceptible);

d) the sensitivity of the organism to IR.

7.4 Sources of Ionising Radiation and Their Applications

The source of ionising radiation is any radiation source or device that produces ionizing radiation. In industry, meters employing radiation isotopes are used to measure various values, control production processes, and so on. These include meters that measure material thickness and density, the levels of solids or liquids in tanks, or the thickness of a top layer on a base, and meters that measure the concentrations of acids, dustiness of the air, and so on. These devices employ mainly closed sources of γ or β radiation, and their functioning is usually based on the absorption of radiation passing through matter or of radiation dispersion. A very popular method of ‘nondestructive’ testing is

industrial radiography, which uses γ - or X-rays to inspect items such as welded elements.

Radiation techniques are used in various areas of industry. They are used to sterilize disposable medical equipment, to modify polymers, materials, and semiconductor-based devices, and to colour fabrics, glass, and artificial—and sometimes even natural—stones. There are millions of tons of products manufactured or modified with radiation worldwide, and this is constantly on the rise. Radiation techniques are based on irradiation of raw materials and finished products with an electron beam or γ radiation. An interesting example of these techniques is thermoshrink tubes and tapes, which provide perfect electrical insulation. They are used wherever durable and hermetic joints of construction elements are required, for example, in assembly of ventilation ducts, conduits, and electrical cables. Radiation techniques are also employed in cleaning exhaust fumes from installations that burn fuels such as coal. Irradiation of the gas with an electron beam causes reduction of the Sulphur dioxide (SO₂) emission by 95 %, and nitrogen oxides (NO_x) by 80 %.

Radioactive tracer methods are used most frequently for analysis of objects and various states of matter. Tracing methods are used to establish the flow of materials and determine their speed and trajectory dispersion. These methods are also used in the glass, paper, chemical, and metallurgy industries. Radioactive tracers are also used to analyse the degree of wear on materials and tools, diagnose corrosion processes, analyse greases and lubricants, and locate and measure leaks in tanks and pipelines.

One of the most important ionising radiation methods is *activation analysis* – nuclear analysis of the composition of materials. This method enables identification of contaminants in semiconductors, luminophores, and other materials of high purity. Activation analysis is also used to determine the residual amount of heavy metals in waste (e.g. in ashes) and nitrogen in grain, fertilisers, and the like.

In the food and pharmaceutical industries, large doses of radiation are used for food preservation and sterilisation of medical equipment, syringes, and dressings. The source of the radiation used for these purposes is primarily cobalt (^{60}Co), with an activity of dozens thousands terabecquerels (TBq), in doses of several dozens of kilograys, or electron accelerators. In geological research, neutron-emitting sources are used to search for mineral deposits and to measure the humidity (or density) of soil.

The use of radiology and radioactive isotope techniques in medical diagnostics and radiotherapy (X-ray tests, computer tomography, nuclear medicine, radiotherapy) is a great success of science. These techniques enable the identification of flawed structures or activity of the organs. The test results are often crucial to forming the right diagnosis. Radiotherapy used to fight carcinomas often proves decisive in patients' survival. Ionising radiation currently dominates scientific applications in various fields, especially physics, chemistry, and biology.

7.5 Rules of Radiation Protection

Regulations for protection from ionising radiation cover only the types of sources and situations that submit to measurement. Radiation from sources such as natural radionuclides within the human body (e.g. potassium-40 K, radium-226 Ra) or cosmic radiation cannot be limited. Radiation protection is currently based on two systems: licensing and supervision and dose limitation.

The licensing system requires that the purchase of radioactive substances (sources of ionising radiation), and their possession, usage, and removal be allowed only for specific purposes, in appropriately prepared locations, and solely by authorized persons.

Regulations for radiation protection are formed based on three fundamental rules: justification, optimisation, and limitation. These principles are defined as follows:

- *The principle of justification:* Any decision that alters the radiation exposure situation should do more good than harm.

- *The principle of optimisation of protection:* The likelihood of incurring exposure, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and societal factors.

- *The principle of application of dose limits:* The total dose to any individual from regulated sources in planned exposure situations other than medical exposure of patients should not exceed the appropriate limit.

Adherence to the following rules can reduce absorbed doses of ionising radiation:

- The shorter the time spent near an ionising radiation source, the smaller is the radiation dose absorbed.

- The farther from an ionising radiation source one is, the safer it is.

- Use of shields is beneficial; they weaken radiation.

Radiation types vary in hardness and in the ways they interact with matter. Shields are therefore made of different materials. For example, shields that afford protection from X and γ radiation are made of heavy materials (lead and depleted uranium), and those that afford protection from β radiation are made of light materials (aluminium and plastics). In practice, shields for protection from α radiation are not needed because its hardness is negligible.

Radiation shields can be *permanent* (e.g. a wall), *movable* (e.g. screens, containers for storage of sources), and *personal* (e.g. protective goggles, rubber gloves, aprons of lead rubber).

For persons working in conditions of ionising radiation hazards, the dose limit, expressed as the effective dose, amounts to 20 mSv per calendar year. This dose can rise to the level

of 50 mSv in the course of a given calendar year if within the subsequent five calendar years its cumulative level does not exceed 100 mSv. The values of dose limit, expressed as equivalent dose, within a calendar year when the aforementioned condition for effective dose is met, are as follows:

- 150 mSv for the lens of the eye;
- 500 mSv for the skin (averaged over any 1 cm² area of exposed part of skin);
- 500 mSv for the hands, forearms, feet, and ankles.

The current radiation protection standards are based on three general principles:

1. Justification of a practice, i. e. no practice involving exposures to radiation should be adopted unless it provides sufficient benefit to offset the detrimental effects of radiation.

2. Protection should be optimized in relation to the magnitude of doses, number of people exposed and also to optimize it for all social and economic strata of patients.

3. Dose limitation, on the other hand, deals with the idea of establishing annual dose limits for occupational exposures, public exposures, and exposures to the embryo and fetus.

The international radiation symbol (also known as the trefoil) first appeared in 1946, at the University of California, Berkeley Radiation Laboratory. The sign is commonly referred to as a radioactivity warning sign, but it is actually a warning sign of ionizing radiation.



Figure 7.3 – Warning signs of radiation hazards

TOPIC 8. THERMAL LOADS AT WORKSTATIONS

8.1 Introduction

Designers of workstations and employers alike have made considerable efforts to provide optimal work conditions suited to workers' capabilities. Nevertheless, there are still environments that subject individuals to thermal loads of various types. A hot environment is particularly strenuous if heat sources are large and/or when a work activity requires a considerable expenditure of energy, that is, one that is performed mainly in protective clothing. A cold environment, on the other hand, is strenuous when work tasks are performed in the open air, usually in winter and in windy conditions. Such an environment can also be present when work activities are carried out indoors where the ambient temperature is below the values established for the 'thermal comfort zone', that is, 17 °C–21 °C.

The impact of thermal environments on workers' health and, consequently, on their productivity and physical and intellectual capabilities is determined by adaptation abilities of an individual and by the solutions the employer applies to reduce the harmful influence of the thermal environment.

Numerous European and international standards address the impact of workplace thermal environments on the individual. These assessment methods first determine specific indices of thermal load and then compare them with limit values. If the values are exceeded, the standards suggest specific solutions aimed at reducing the risk.

8.2 General Characteristics

The *predicted mean vote* (PMV) index classifies the thermal environment into three categories: hot, moderate, and cold. A PMV index ranging between -2 and $+2$ is the ‘comfort zone’. A hot environment is one in which the PMV index is higher than $+2$. A cold environment is one in which the PMV index is lower than -2 .

Determinations about the thermal environment’s influence on a human body are based on the heat balance equation. This formula provides the parameters that influence the thermal equilibrium between a human and the environment, that is, between endogenic heat and exogenic heat. The body’s metabolic processes generate the former, while the latter is derived externally, that is, from food intake. Energy loss resulting from the intensity with which one performs a work task is an example of the endogenic factor. Exogenic factors include heat transfer resistance through clothing and air parameters such as air temperature, mean radiant temperature, water vapour pressure, and air velocity. All of these factors influence the rate at which the body emits heat into the environment in order to maintain homothermy.

Fanger developed the thermal balance equation, and after numerous modifications, its form is as follows:

$$M - W = (C + R + E_{sk}) + (C_{res} + E_{res}) + (S_{sk} + S_{cr}),$$

where M is the rate of metabolic heat production (in watts per square metre [W/m^2]), W is the rate at which mechanical work is accomplished (W/m^2), $C + R$ is the rate of convective and radiation heat loss from skin (sensible heat loss; W/m^2), E_{sk} is the rate of evaporative heat loss from skin (latent heat loss; W/m^2), C_{res} is the rate of convective heat loss from respiration (W/m^2), E_{res} is the rate of evaporative heat loss from respiration (W/m^2), S_{sk} is the

rate of heat storage in the skin compartment (W/m^2), and S_{cr} is the rate of heat storage in the core compartment (W/m^2).

In addition to the variables presented in the thermal balance equation, many other factors affect thermal response and comfort at the workplace. They are divided into two major categories:

1. Environmental parameters:
 - Air temperature.
 - Air velocity.
 - Relative humidity.
 - Radiant temperature asymmetry.
2. Individual (personal) parameters:
 - Thermal insulation of clothing.
 - Metabolic rate.
 - Age.
 - Acclimatisation.

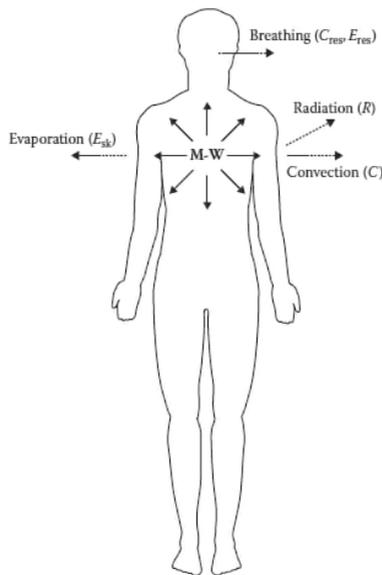


Figure 8.1 – Human–environment heat exchange

Inviromental Parameters

The temperature of the air greatly influences thermal comfort. High temperatures can cause severe psychophysiological dysfunctions. When the temperature rises above 25 °C, the following symptoms can appear: dissatisfaction, lack of concentration on work activities, an increase in the number of mistakes made, and a decline in dexterity in work tasks requiring precision. When the temperature rises above 30 °C, physiological dysfunctions occur, including fluid-electrolyte imbalance, an excessive load on the heart and the circulatory system, and considerable fatigue that could lead to exhaustion.

Studies by Traczyk and Trzebski revealed that exposure to an air temperature higher than 21 °C reduces psychophysical perception by about 60 % in relation to the neutral temperature (16 °C–21 °C). Furthermore, they noted that when the 26 °C threshold is considerably exceeded, attention level, perception, and reflexes are impaired to a great extent, in particular during short exposures, that is, those lasting not longer than 120 minutes. The fall in perception was about 16 %. Prolonged exposure to temperatures below the comfort level causes vasoconstriction. Not only does blood flow in the limbs decrease, but also the temperature of the legs decreases by as much as 10 °C. The lowest permissible skin temperature is 20 °C and the lowest core temperature is 36 °C. A further decrease in the core temperature leads to many dysfunctions: when the core temperature falls below 36 °C, the metabolic rate rises; when it falls below 35 °C, severe shivering occurs; below 33 °C, severe hypothermia occurs; at 32 °C, consciousness is clouded, shivering ceases, and blood pressure becomes difficult to measure; and at 30 °C, muscle rigidity increases and pulse and blood pressure are difficult to measure.

Air Velocity

Air velocity and the difference between the skin temperature (t_{sk}) and the ambient air (t_a) determine the thermal sensation temperature, which increases with an increase in the difference ($t_{sk} - t_a$). Furthermore, an increase in air temperature causes an increase in the amount of heat transferred to the environment by convection. Hence, maintaining the air temperature of the room at one level results in a thermal sensation of cold when compared to thermal effects in an environment without perceptible air flow. For instance, air velocity below 0.1 m/s most often occurs in naturally ventilated buildings; the threshold for strong sensations is 0.2 m/s; for perceptible movement, 0.25–0.5; for air flow causing hair to wave, 0.5–1.0; and for normal walking speed, 1.0–2.0.

Relative Humidity of the Air

The relative humidity of the air affects the comfort of the workers. Its influence is greater in higher air temperatures, that is, at values higher than the set point for thermal comfort, it produces intensive sweating episodes. High relative humidity (about 70 %) hinders heat dissipation from the skin surface and creates conditions favourable to the growth of indoor bacteria and mould. Low relative humidity in heated rooms can cause dryness of skin and nasal mucous membranes. It can also cause throat aches and headaches and contribute to air pollution. Hence, for health reasons, indoor relative humidity should be between 40 % and 70 %.

Asymmetry in Air Temperature

The presence of a vertical temperature gradient in a room may cause different thermal sensations in the parts of the body, such as a thermal sensation of cold at the feet or head and a comfortable thermal sensation in other parts of the body. Thermal radiation asymmetry should not exceed 10 °C, and the

ground temperature should not exceed 24 °C. Overheating of the feet may lead to vasodilation or even to swelling.

8.3 Impact of Thermal Load Effect on the Human Body

Changes in the Circulatory System

The basic response of the human body to hot environments is vasodilation, which is the increase of blood flow to the skin from 5% in conditions of thermal comfort to as much as 20% in a very hot environment. The body can then transfer more heat to its surface, the skin. Simultaneously, the body stimulates the sweat glands and secretes sweat onto the surface of the skin.

Further exposure to hot surroundings exceeds the adaptive capabilities of the human body and may lead to unfavourable reactions such as a rise in the heart rate (to above 140 beats per minute), lowered blood pressure following an increase in the circular resistance of blood vessels, and finally to ischaemia of internal organs and circulatory collapse.

In a cold environment, stress results in vasoconstriction that reduces cutaneous and subcutaneous blood flow to some areas of the body, in particular to the peripheral regions. Blood is directed to the blood vessels located deeper in the body, which increases central blood volume and, at times, causes a rise in blood pressure.

Sweat Glands

When the body temperature or the ambient temperature rises above 28 °C–32 °C, sweat is secreted all over the body to increase cooling by evaporation. However, the intracellular and extracellular volumes of body fluids are reduced with heat loss. Due to the body's need to maintain fluid-electrolyte balance, secreted sweat should not exceed the limit value of 5 % of the body mass.

Skeletal Muscles

The human body reacts to a cold environment through shivering and nonshivering thermogenesis. Stimulation of the

reflex skeletal muscles provokes an increase in the metabolic rate, which is the source of heat for the human body. Consequently, tension in resting muscles increases, causing shivering, a source of heat. The amount of heat generated by this reaction depends on the ambient temperature and the duration of its influence. In extreme conditions, the basic metabolic rate can rise by 4 or even 5.5 times.

Heat Disorders

Extreme ambient temperature conditions and impairment of the body's thermoregulatory mechanism can cause excessive heat loss. This results in a cooling of the body (hypothermia) or insufficient heat loss leading to overheating.

In extremely cold conditions, the body's core temperature falls below 35°C and leads to a decrease in performance, reduction in muscle contraction power, and physical and behavioural disorders such as a prolonged reaction time. Further hypothermia results in decreased heart output and stroke volume.

In a hot environment, where the amount of heat absorbed by or created in the body exceeds the amount of heat lost, hyperthermia occurs. Dehydrated persons suffering from sweating dysfunctions may experience heat stroke, which can cause death due to thermal shock at a core temperature of 42°C–43°C.

Failure to balance a loss of electrolytes leads to dysfunctions of the alimentary canal and contracture of skeletal muscles. Hyperthermia may occur even with sufficient sweat secretion. It causes apathy, fatigue, behavioural and physiological changes, and, in extreme cases, death due to cardiovascular collapse.

8.4 Assessment of Workers Exposure to Thermal Loads

Numerous national, European, and international standards have addressed the problems workers experience due to workplace exposure to hot or cold environments. These

documents examine and determine thermal loads based on indices characteristic of a given work environment, that is, wet bulb globe temperature (WBGT) for hot environments and twc and required clothing insulation (IREQ) for cold environments. The standards also include reference values (the ‘permissible’ values of the aforementioned indices), which are the levels of hot or cold conditions to which almost all individuals could be exposed without suffering any adverse health effects. The indices are based on the typical effects of a given environment on an individual over prolonged periods, excluding peak loads, that is, temporary extremes of cold or hot or work that is more or less intense than usual.

When the permissible threshold of temperature is exceeded in a hot environment, the thermal load should be reduced by modifying the work environment or the level of load. Reflective shields between radiant sources and workers, limiting exposure or work time and using heat reflective clothing or reducing thermal insulation of clothing are effective methods of reducing thermal load. A detailed analysis of the thermal load should also be carried out by measuring core temperature and the volume of evaporated sweat. The ISO 7933 standard describes the method for assessing these values.

8.5 Examples of Good Practice in Preventing the Adverse Effects of a Hot or Cold Environment on the Human Body

Differences in perception of heat, thermoregulation processes, and considerable differentiation in the time and space of thermal conditions at workstations mean that each worker’s load or risk must be individually assessed at each workstation. Proposed solutions to reduce thermal load can be categorised by hot and cold environments and are described in the next section.

Solutions Falling within the Scope of Health Care Prevention

Solutions for hot environments include:

- Ensure workers are acclimated to heat and that water loss is replaced. Provide access to fluids supplemented with salt (where the diet is by low in sodium) and balance electrolyte shortages caused by intensive sweating.

- Frequently replace the protective clothing of workers to eliminate the risk of skin infections, as fabrics stiffened with salt secreted with sweat can damage the epidermis.

- Assess physical fitness in the preliminary medical examination of workers required to wear protective clothing. Measuring the ability to maximise oxygen use per minute, enables the selection of individuals fit to work in this type of clothing. Procedures should also include annual medical examinations and entail measurements of physiological parameters that assess the efficiency of the thermoregulatory system.

- Solutions for cold environments include:

- Provide access to hot drinks (except caffeinated drinks) and hot, highcalorie meals.

- Replace wet innerwear or wet clothes due to their lowered thermal insulation parameters.

Collective Protection

An appropriately designed workstation effectively reduces the hazards present in cold or hot surroundings. The following aspects should be considered at the design stage:

- Ensuring control of hot or cold temperature sources.
- Ensuring control of air parameters in the working areas.

Solutions appropriate to a hot environment include:

- Using production processes, machinery, and equipment that do not generate heat or generate only a small amount of heat.

- Automating technological processes.
- Isolating equipment that are sources of heat by providing separate rooms or situating them outside the building, by cooling

and shielding with water shields or shields made of insulation materials, aluminium sheets, aluminium foil, or absorptive glass, or by shielding with heat exchangers, where the shield is cooled internally with air or water.

- Installing local ventilation or air conditioning and suspended or ventilated ceilings.

- Eliminating ventilation leaks or installing local steam-shaft elements.

- Increasing the coefficient of partition heat resistance if work is performed in rooms where the cause of high temperature is excessive heat gain through nontransparent partitions (walls, ceilings). To this end, the following solutions can be attempted: adding more layers of insulation, installing suspended ceilings, installing shields outside buildings, or coating external surfaces of the walls with solar reflective material.

- Using double- or triple-glazed windows filled with noble gas (most frequently argon) to reduce the heat transfer coefficient in buildings where large wall areas are occupied by transparent partitions (windows).

TOPIC 9. FIRE SAFETY

9.1 Introduction

Burning is the exothermic reaction of substance oxidization, which is accompanied by flame, luminescence, and smoke.

Four things must be present at the same time in order to produce fire:

- enough oxygen to sustain combustion;
- enough heat to raise the material to its ignition temperature;
- some sort of fuel or combustible material;
- the chemical, exothermic reaction that is fire.

Oxygen, heat, and fuel are frequently referred to as the “fire triangle” (Figure. 9.1).

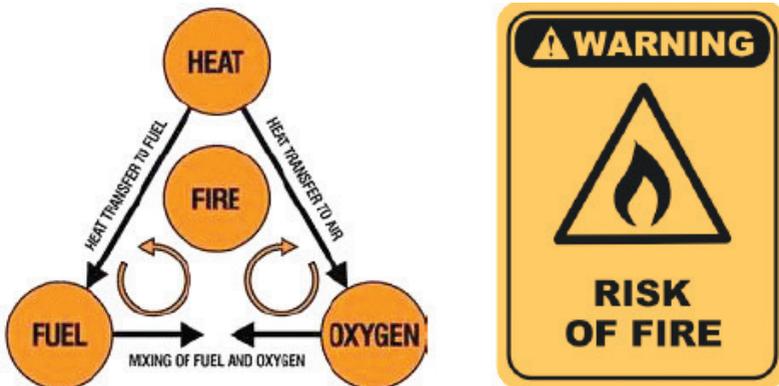


Figure 9.1 – Basic of burning process – fire triangle

Add in the fourth element, the chemical reaction, and you actually have a fire “tetrahedron”. The important thing to remember is: take any of these four things away, and you will not have a fire or the fire will be extinguished.

Burning can be divided into the following processes:

- flash;
- ignition;
- inflammation;
- spontaneous combustion;
- spontaneous ignition.

Definitions

Flash is a rapid combustion of combustible substance, which is not accompanied by formation of constrained gas.

Combustion is the initial stage of burning under the influence of the inflammation source.

Inflammation is the ignition which is accompanied by flame.

Spontaneous combustion is a phenomenon of the speed acceleration of exothermic reactions, which causes a sudden temperature increase and burning of matters in default of any inflammation source.

Spontaneous ignition is a spontaneous combustion which is accompanied by appearance of flame.

Burning can be accompanied by: *fire and explosion*.

Explosion is a rapid transformation of matter (explosive burning) which is accompanied by the burst of energy and formation of shock wave (speed is of 330 m/s).

Explosion-proof indexes of substances and materials are used for:

- the analysis of the fire danger;
- classification of dangerous freights;
- the choice of category of rooms and buildings pursuant to the requirements of norms of the technological design;

- the purpose of the realization of technical supervision on materials.

Main causes of fires are:

1. Improper heat-producing machine installation – 20 %
2. Faulty or improper installation of electrical installations and electrical systems – 16 %.
3. Poor training equipment for repairing – 13 %.
4. Auto-ignition materials – 10 %.
5. Violation of production process (especially at the end of the month).
6. Discharge static electricity.
7. Lighting strike.

Indexes of fire explosiveness of substances and materials:

- the combustibility group;
- flash temperature;
- combustion temperature;
- the lower and upper concentration borders of flame distribution;
- the conditions of thermal combustion.

Due to combustibility, matters and materials are divided into three groups:

1. Noncombustible (cannot be burned). Under fire effect or high temperature they do not flash, rot and char.
2. Heavily burnt. Under the fire effect or high temperature they flash, smolder, char and when the ignition source is available they continue to burn, smolder or char.
3. Combustible (can be burnt). Under the fire effect or high temperature they flash, smolder, and char.

Groups of materials according to flash temperature:

- *inflammable liquids* are the ones whose flash temperature does not exceed 45 °C (in closed crucible), and they are able to burn after the removal of the ignition source on their own;
- *flammable liquids* are the ones whose flash temperature is more than 45 °C, and they are able to burn after the removal of the ignition source on their own.

Fire safety signs can be used to identify flammable materials and other fire hazards (Figure 9.2). „Flammable“ signs should be placed alongside any potential ignition points or fuel sources as part of a larger fire safety management plan.



Figure 9.2 – Fire safety warning signs

Groups of compatible preservation of substances and materials:

1. Substances that are apt to the formation of explosive mixtures: potassium nitric acid, potassium chlorate etc.
2. Constrained and fluid gases:
 - burnt and highly explosive – acetylene, hydrogen, propane;
 - inert and not put out – argon, nitrogen, helium;
 - gases which sustain burning – oxygen, compressed and liquidized air.
3. Self-igniting from water and air substances: potassium, sodium, aluminum dust, zincs dust etc.
4. Flammable burnt substances:
 - liquids – petrol, acetone, alcohol;
 - solid substances – celluloid, naphthalene.
5. Substances that can cause combustion: bromine, sulphur acid, potassium aluminate.
6. Easily burnt substances – cotton, hay, peat, sulphur, vegetable and animal soot.

9.2 Classification of the category of buildings, structures and premises for fire and explosion hazards

The fire and explosion hazard areas and warehouse purposes, regardless of their functionality are divided into the following categories:

- 1) high explosive (A);
- 2) explosive (B);
- 3) fire risk (B1–B4);
- 4) a moderate fire risk (D);
- 5) reduced fire risk (D).

Categories of premises for fire and explosion hazards are based on the premises of the type of flammable substances and materials, their quantity and fire properties, and based on the space-planning decisions and premises characteristics. Definition of the categories of premises should be carried out by sequential testing facilities belonging to the categories of the most dangerous (A) to the least dangerous (D).

The category A includes areas in which there are (treated) flammable gases, flammable liquid with a flash point of more than 28 degrees Celsius in a quantity that can form explosive mixtures steam and gas, in the ignition which develops the design pressure of explosion in the room of more than 5 kPa, and (or) substances and materials that can explode and burn at contact with water, oxygen, or with each other, in a such amount that the design pressure of explosion in the room is more than 5 kPa.

The category B includes areas in which there are (treated) combustible dust or fibers, flammable liquid with a flash point above 28 °C, flammable liquids in such a quantity that can form explosive dust-air or vapor-air mixture, which, when ignited, develop the design pressure of explosion in the room of more than 5 kPa.

The categories B1–B4 are areas in which there are (treated) flammable and nonflammable liquids, solids flammable and

nonflammable materials and supplies (including dust and fibers), substances and materials capable of contact with water, oxygen, air, or with each other only to burn, provided that the premises in which they are located (address), are not category A or B.

The assignment of the room to the category B1, B2, B3 or B4 is dependent on the amount and method of placement of fire load in this area and space planning characteristics, as well as the fire properties of materials that make up the fire load.

The category D includes the areas in which there are (treated) non-combustible substances and materials in the hot or molten state, the processing of which is accompanied by radiant heat, sparks and flame, and (or) fuel gases, liquids and solids that are burned or recycled as fuel.

The category D also includes the areas in which there are (treated) combustible media and materials in a cold state. Categories of buildings and structures for fire and explosion hazards are based on the proportion and summed area of the hazard category premises in the building and construction.

The building belongs to the category T in case of all the following conditions: the building is not classified as A, B or C and in total area of the premises in categories A, B, B1, B2, B3 and r is greater than 5 percent of the summed area of all premises. The building does not belong to the category T, if we sum up floor space in categories A, B, B1, B2, B3 and C in the building, which does not exceed 25 percent of the summed area of all within the container premises (but not more than 5 000 square meters) and the spaces of category A, B, B1, B2 and B3 are equipped with automatic fire extinguishing installations.

The building belongs to the category A if it does not apply to category B, C or D. Methods for determining the classification criteria for inclusion of the facilities and warehouse assignment to the categories of fire and explosion hazards are set regulations on fire safety. Categories of buildings, structures and premises and warehouse destination for fire and explosion hazards are

specified in the design documentation for capital construction and renovation.

Common fire hazards are:

- 1) electrical systems that are overloaded, resulting in hot wiring or connections, or failed components;
- 2) combustible storage areas with insufficient protection;
- 3) combustibles near equipment that generates heat, flame, or sparks;
- 4) candles, smoking (cigarettes, cigars, pipes, lighters, etc.), flammable liquids;
- 5) chimneys of fireplace that are not properly or regularly cleaned; cooking appliances – stoves, ovens;
- 6) heating appliances – wood burning stoves, furnaces, boilers, portable heaters;
- 7) electrical wiring in poor condition; batteries; personal ignition sources – matches, lighters;
- 8) electronic and electrical equipment; exterior cooking equipment – BBQ, campfires.

9.3 Fire protection requirements to ensure the forced evacuation from the building

Fire safety is the set of practices intended to reduce the destruction caused by fire. Fire safety measures include those that are intended to prevent ignition of uncontrolled fire, and those that are used to limit the development and effects of the fire after it starts.

Fire safety measures include those that are planned during the construction of a building or implemented in structures that are already standing, and those that are taught to occupants of the building.

The system of fire-prevention is the total of organizational measures and hardware directed to prevention of influence on the people of dangerous fire factors and limitation of material losses.

Fire safety protection is achieved by:

- the proper choice of the necessary degree of fire-resistance of building constructions;
- proper volume design of buildings;
- room and factory location in compliance with the fire safety requirements;
- the installment of the fire-prevention barriers in buildings, ventilation systems, fuel and cable communications;
- the limitation of the effluence and spread of combustible liquids during the fire;
- the off-take installment;
- planning evacuation routes;
- taking measures for successful fire extinguishing.

Measures of preventing fire spread into the house while planning and building industrial enterprises:

- division of houses into fire-prevention compartments by fire-prevention walls or a fire-prevention ceiling;
- division of houses into sections by fire-prevention partitions;
- installment of fire-prevention barriers for the limitation of the fire spread over constructions and combustible materials (ridges, skirting boards, peaks, belts etc.);
- installment of fire-prevention doors and gates;
- installment of fire-prevention breaks between the houses.

Fire Doors. Fire barriers play an integral role in managing a fire by preventing the spread of smoke, toxic gases, and fire itself from one area to another. Fire doors are fundamental to the integrity of fire barriers, because any time there is an open doorway to a compartment; a fire barrier is temporarily broken. To prevent breaks in fire protection, fire doors must be self-closing and be equipped with proper latching devices in order to provide as much resistance as possible to the spread of fire, smoke and toxic gases. Fire exit doors are often held open for the convenience of employees and visitors, creating a significant

fire hazard for all building occupants due to the break created in the fire barrier. Doors that are designed to be fire exit doors can be held open, but only if they automatically release when the building fire alarms are activated. Fire doors may only be held open by a device that automatically releases when the fire alarm is activated (such as an electromagnetic hold-open device).

Fire doors are needed:

- where a door has an „EXIT“ sign on or around it;
- where a door leads to exit stairwells and horizontal exits;
- where a door leads to a hazardous area such as flammable storage;
- where a door leads to a hallway or from one fully-enclosed room to another.

Hazards to avoid with fire doors:

- a) fire doors should never be tied open or held open by devices such as door wedges or blocks;
- b) when closed, fire doors should never have their latches taped over. During a fire, hot gases can easily build up enough pressure to cause fire doors to blow open.



Figure 9.3 – Fire action

Fire action signage is essential to clearly communicate to anyone on your premises what action should be taken in the event of a fire. It is a legal requirement that visitors and employees know the fire evacuation procedure in the event of a fire and alarm activation.

9.4 Fire extinguishing methods

There are following methods of fire extinguishing:

- a) removal of combustible material on fire or hearth reducing its percentage content;
- b) removal of oxidant or reducing its concentration in the combustion zone (reducing the percentage of oxygen in the air to 14–15 % leads to the cessation of burning);
- c) lowering the temperature of combustible environment to the point where further combustion is not possible (below the ignition temperature).

The majority of portable fire extinguishers located throughout every University building consists of multi-purpose, dry chemical extinguishers that will be effective on any type of fire you may encounter:

- ordinary combustibles, such as paper, cardboard, cloth and wood;
- energized electrical equipment;
- flammable liquids (except for flammable metals).

If you discover a fire, you must immediately set off the building fire alarm system by activating a manual fire alarm pull station to warn building occupants.

Only attempt to extinguish the fire if it is **very small, not more than 2 feet high**. Keep your escape route behind you. Should you decide to try to extinguish the fire, use the following acronym to help you (Figure 4):

P. A. S. S.

Pull safety pin from handle.

Aim at base of fire.

Squeeze the trigger handle.

Sweep from side to side.



To operate an extinguisher

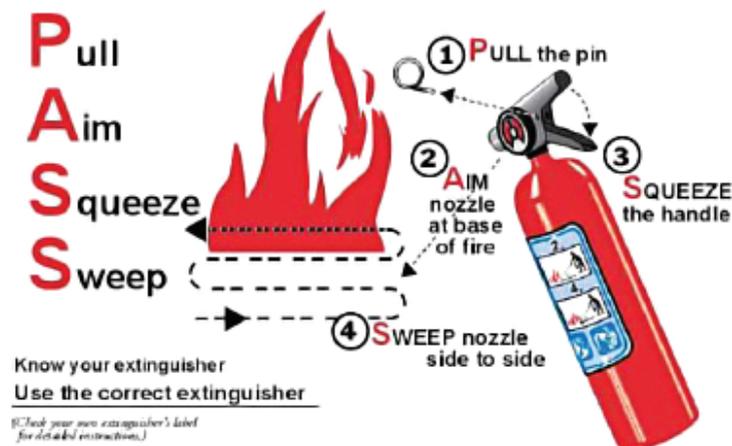


Figure 9.4 – Fire extinguisher

Not all fires are the same. Different fuels create different fires and require different types of fire extinguishing agents.

Class A fires are fires in ordinary combustibles such as wood, paper, cloth, trash, and plastics.

Class B fires are fires in flammable liquids such as gasoline, petroleum oil and paint. Class B fires also include flammable gases such as propane and butane. Class B fires do not include fires involving cooking oils and grease.

Class C fires are fires involving energized electrical equipment such as motors, transformers, and appliances. Remove the power and the Class C fire becomes one of the other classes of fire.

Class D fires are fires in combustible metals such as potassium, sodium, aluminum, and magnesium.

Class K fires are fires in cooking oils and greases such as animals fats and vegetable fats.

Some types of fire extinguishing agents can be used on more than one class of fire. Others have warnings where it would be dangerous for the operator to use a particular fire extinguishing agent.

If you decide not to fight the fire, try to close the door to the fire area, if it is safe to do so. This will help to prevent heat, smoke and toxic gases from entering the egress corridors. Then evacuate the building via the closest exit.

A periodic check of the extinguishers should be performed to ensure:

- a) the extinguisher is not being used inappropriately (for example, to prop a door open);
- b) the extinguisher pressure gauge needle is in the green zone;
- c) there are no visible indications that the extinguisher has been damaged, discharged, or removed from its proper location;
- d) that the inspection tag is attached to the fire extinguisher.

The inspection tag must be stamped with a month and year indicating the extinguisher was inspected within the past twelve months.

PART III

THE EFFECTS OF HAZARDS ON WORK PROCESSES

TOPIC 1. OCCUPATIONAL DISEASES

1.1 Introduction

Awareness of the influence of work conditions on human health has its beginnings in antiquity. The first mentions of the subject are found in the ancient Egyptian encyclopedia dating back to 1800 bc. Descriptions of pain and injuries of the spine in pyramid builders are found in Egyptian papyruses. Hippocrates (460–377 bc.) in his treatise *Airs, Waters and Places* described symptoms that occurred in workers extracting nonferrous metal ores. In this treatise he explicitly stressed the need to observe the patient in his or her work environment, including identifying work environment conditions as risk factors of many diseases.

The first observations of diseases in miners were described by Agricola (Georg Bauer; 1494–1555) and Paracelsus (1493–1541). In his book *On the Nature of Metals*, Agricola described diseases affecting metal ore miners in Bohemia. In his monograph on occupational diseases, Paracelsus presented a similar problem in miners of gold, silver, and other metals in the region of Villach

in Austria. In his treatise *Twelve Books on Mining and Smelting* (1557), Agricola described a number of aspects of mining, smelting, and refining of gold and silver. He also advocated the use of ventilation and personal protective equipment such as leather shoes and gloves and loose veils to protect the miners from dust.

Bernardino Ramazzini (1633–1714), a professor of medicine at Modena and Padua, pioneered scientific research in the areas of occupational hygiene and medicine. He is regarded as the father of occupational medicine because of his masterpiece on occupational diseases entitled *Diseases of Workers*. The quintessence of Ramazzini's school is his advice to doctors, which was 'To the questions recommended by Hippocrates, he should ask one more—What is your occupation?' (Gochfeld 2005). Ramazzini presented a comprehensive approach to workers' health problems, embracing epidemiology, hygiene, and certain aspects of ergonomics. His areas of interest covered many occupational groups, 69 of which he described in his works, including miners, apothecaries, locksmiths, glaziers, painters, mirror manufacturers, tanners, and bakers.

The first institutions dealing with the protection of workers' health were established at the turn of twentieth century. In 1898, Great Britain appointed the first medical factory inspector, Thomas Morison Legge (1863–1932; Waldron 2004). In the twentieth century, research progress in the field of occupational pathology, epidemiology and toxicology contributed significantly to the advancement of occupational hygiene and medicine. Achievements in these disciplines led to the implementation of practical solutions for the protection of workers' health.

In the 1920s, the first lists of occupational disease were developed, making it possible for workers to obtain compensation for work-related health impairment. This process was preceded by the establishment of the International Labour

Organization (ILO) convention in 1925, which included the first list of occupational diseases and toxic substances and the types of industry and manufacturing processes that could give rise to occupational diseases.

The second half of the twentieth century saw significant progress in occupational medicine, along with the tempestuous development of industry and the introduction of new production technologies, machines and work tools, automation, chemicalisation of agriculture and, most recently, informatics and computerisation. New harmful factors whose health effects were not known before began to emerge, as well as psychosocial factors resulting from work organization and the mechanisation and automation of production processes. Their effects were connected with the time pressures and increased mental stress. Psychosocial effects are no longer confined to the workplace environment but are carried over to the external environment and probably modify the incidence and course of some chronic diseases.

1.2 Identification of an Occupational Disease and a Rationale for Diagnosis

Occupational disease is a medical-legal term. In order to label a disease occupational, the causal relationship of the disease with work conditions must be established and the disease must be included in the list of occupational diseases. The latter is a prerequisite for obtaining the benefits stipulated in relevant legal regulations.

The probability of various occupational diseases having a causal relationship with work conditions is differentiated. The definition of occupational disease requires this relationship to be indisputable or highly probable. For some diseases, the causal relationship with work conditions may be established with almost

absolute certainty, for example, pneumoconiosis and a majority of acute or chronic poisons. Another group lists diseases for which occupational exposure is the most probable causal factor, for example, hearing loss in persons exposed to noise exceeding the permissible level over a long period of time or vibration syndrome in persons exposed to mechanical vibration. In these cases, occupational disease certification requires only high probability and not certainty because the symptoms of the disease are not absolutely specific, that is, similar symptoms sometimes result from causes other than exposure to noise or vibration.

Most countries have their own lists of occupational diseases; in Europe, only two countries – Sweden and the Netherlands – have no such lists. In these countries, each case of suspected occupational disease is assessed on an individual basis. Such a solution may create a problem by allowing discretion in decision making by different teams medically certifying similar cases.

Occupational diseases must be diagnosed based on definite criteria that consider many factors in order to justify the causal relationship between the disease and occupational exposure. The most important criteria are as follows:

- Symptoms must correspond to the clinical presentation of the disease in question. The extent of diagnostic difficulties varies depending on the specificity of symptoms of the given disease.
- The occupational exposure level must be high enough. This is determined based on the characteristics of harmful factors such as concentration, intensity, and length of exposure. When permissible values for these factors are exceeded, the health risk for the worker increases accordingly.

When assessing occupational exposure to diagnose an occupational disease, a number of aspects should be considered:

- *Chemical and physical factors*: Type of factor, concentration level or intensity (when compared to the maximum admissible concentration or maximum admissible intensity), and the duration of occupational exposure.

- *Biological factors*: Type of and duration of contact with the factor and the mechanism of its effects or dissemination paths. It is not necessary to determine the concentration.

- *Sensitising factors (allergens)*: Type of factor and an ability to determine that the contact took place during work and that the factor was present in the environment, raw materials, or semifinished or finished products. It is not necessary to determine the concentration.

- *Manner in which the work is performed*: Degree and type of physical load (static, dynamic, repetitive) and timing of activities that could impose excessive load on certain organs or systems of the human body.

When diagnosing a disease, the evaluating doctor should always obtain the necessary data on the worker's level of exposure and his or her medical history from the employer and/or the organisation's preventive health care doctor. It should be noted that this information might be different and should be treated with caution.

- Some diseases manifest after a latency period. The length of the latency period is important for correct diagnosis. Due to the fact that the disease manifests after exposure has ceased, long latency periods occur with diseases such as cancers and pneumoconiosis.

- A differential diagnosis should be performed in each case. This is especially important for diseases that can be effectively treated and are diagnosed as occupational.

1.3 Prevention of Occupational Diseases

Civilised countries all over the world are engaged in multidirectional activities created to limit the incidence rate of occupational diseases. The WHO, highlighting the need to protect the health of working people, described its aim as 'achieving

a state in which the level of general morbidity of different occupational groups will not exceed the level of morbidity of the general population’.

This rule has not yet been fully realised in any country, and the effectiveness of occupational disease prevention varies from country to country. Employers, health care services and, to a great extent, the workers themselves must take the necessary preventive actions. There are three types of prevention:

1. Primary prevention.
2. Organisational prevention.
3. Medical prevention.

Primary prevention, or technical prevention, aims to ensure safe work conditions and is the task of engineers and technicians. Primary prevention starts at the design stage for machines, equipment, and production technologies. Design defects in technologies are very difficult to eliminate once production has started. It is essential to involve a health care physician at the design stage who can assess health risks arising from the introduction of new technologies. In many branches of the national economy, workers are exposed to different harmful or noxious factors. The employer must ensure that these factors are restricted to the limits permitted by hygienic norms. This can be achieved through solutions such as hermetising production processes, using local exhaust ventilation and general ventilation at the workplace, and replacing high-risk technologies with safer ones.

Personal protective equipment such as protective clothing, masks, ear protectors, goggles, and gloves may be placed at the border of technical and medical prevention. However, some protective gear reduces work comfort and can be used for limited durations only. A better solution may be to give up high efficiency in favour of work comfort. Disposable masks used in mining are an example; their efficiency is assessed at 50%, but they are tolerated in underground mining conditions.

Organisational prevention in high-risk conditions and rotating jobs can reduce health risk by shortening working time and lengthening total employment time. The benefits obtained result not only from shortening the time of exposure, but also facilitate the processes of disturbed defence mechanisms, such as eliminating dust from the respiratory tract or detoxification processes.

Medical prevention involves a broadly understood protection of the workers' health at the workplace. The main task of doctors of occupational medicine is to conduct prophylactic examinations—preplacement, periodic checkups, and control. Preplacement examinations cover newly hired employees or those transferred from another post and should detect any health contraindications. Periodic examinations systematically check the employees' health status and assess their fitness for the job. They are particularly helpful in detecting the health effects of exposure to harmful and noxious factors at as early a stage as possible. Periodic examinations also detect diseases not associated with work that appear during employment and which may constitute a contraindication to work at the present job.

In order to prevent occupational diseases, it is very important that the employer inform employees about the conditions in the work environment, the potential effects of exposure to these conditions, and the ergonomic principles of safe work. An employee should know what his or her workstation should look like, so that he or she can ask for modifications from the employer. Worker training should be conducted in the form of lectures and practical training at workstations.

TOPIC 2. ACCIDENTS AT WORK

2.1 Introduction

Accidents can happen at home, at school, on sports fields and playgrounds, and while playing, travelling, and working. Injuries suffered in association with work are included as accidents at work. According to statistical information from the International Labour Organisation, the annual average number of accidents at work recorded in the last decade was 270 million, including 350,000 fatal accidents. According to European Union data, each year 4 out of 1000 employees die because of accidents at work.

Accidents lead to suffering and losses. Light accidents hinder the performance of current plans and goals, serious accidents lower the quality of life, and the gravest lead to death. Therefore, accident prevention is the subject of many analyses, statistical records, and preventive measures. This chapter presents an overview of accidents, events that are classified as accidents at work and their causes, as well as ways to limit occurrences and consequences.

2.2 Accidents at Work

The major feature of an accident at work is that the injury occurs during performance of occupational or work-related tasks. A material loss or bodily injury in itself that is not related to work cannot be considered an accident at work, since such events do not satisfy all the legal criteria associated with accidents at work. Such events are treated as nonoccupational accidents, also known as unfortunate accidents or events attributed to fate.

Accident at work is a sudden event due to an external cause that results in injury or death and that takes place in association with work under one or more of the following conditions:

- While the employee performs his or her ordinary tasks or the orders of superiors.
- While the employee performs activities for the benefit of the employer, even without being ordered to do so.
- While the employee remains at the employer's disposal, including travelling between the employer's place of business and a place of performance of duties.

Accident at work may also include an injury suffered by an employee during a lunch break, while changing or taking a shower at work, or en route between the office building and the workstation. However, there are occasions when a direct correlation with work may not exist. This can occur if employees perform work during working hours that is not related to their employment or that is contrary to the objectives of employment. An accident that takes place during performance of activities not related to the employer cannot be considered an accident at work. An accident is the total event and not just a feature of the event.

Accidents are classified by the number of persons subjected to the traumatic consequences of the event, such as individual and collective accidents, as well as—depending on the extent of seriousness of the injuries suffered—fatal accidents, accidents leading to serious bodily injury, and other accidents. An individual injury is one that results from occurrence of a dangerous event and causes a single person to suffer trauma. A collective accident is an event that causes at least two persons to suffer trauma. A fatal accident is an accident that leads to the death of a person who suffers an injury during or within six months after the accident. Accidents may result in a serious body injury, leading to loss of vision, hearing, speech, limbs, reproductive capacity, or an incurable illness, including life-threatening illnesses. These effects result in an inability to perform occupational work or in

permanent serious disfiguration or deformation of the body. Accidents that result in reversible health effects are commonly referred to as ‘light’ accidents.

2.3 Accident Rate

The accident rate is the total number of accidents occurring within a given time, usually one year, presented using specific indices. In some companies, accidents occur frequently; in others, they are rare. Depending upon the related hazards and the specific nature of occupational risk, some injuries are serious and require prolonged treatment, while others have no significant consequences. The number and seriousness of accidents in a given company depend upon many factors; these include the hazards methods of control present, the duration of exposure to hazards, the number of employees, and so on. Multiple sources of accidents may lead to a situation in which the accident rate for two companies differs significantly, even if the total number of accidents per year is almost identical, because the number of employees is different.

Accident rate indicators illustrate the relationship between the number of accidents and work conditions. Assessments and comparison of accident rates, frequency rates, severity rates, and accident cost rates are applied to compare safety levels in companies.

The most widely used accident rate indicators are presented in Table 2.1. Indicators W , $W1$ and $W2$, called incidence rates, denote the frequency of accidents. W denotes the number of accidents recorded per 1000 employees.

$W1$ denotes the number of accidents in relation to the duration of exposure to the hazards per 100,000 working hours.

$W2$ relates the number of accidents to the production size; in the ‘mining’ version, the number of accidents is determined

per million tonnes of coal extracted. It may also relate accidents to other dimensions of production, such as the number of pieces of products manufactured, the number of kilometres of roads constructed, and so on.

W_3 and W_4 relate to the severity of accidents. W_3 shows how many working days are lost due to one accident; W_4 shows the number of employees killed for every thousand who suffer an accident. The last indicator, W_5 , is obtained by dividing the total cost of all accidents by their number and shows the average accident-related loss. Other indicators can be constructed by carrying out modifications. For instance, the absence rate, which shows the average absence per 1000 employees or 100,000 work hours, relates the severity of accidents to their frequency.

Table 2.1 – Accident Rate Indices

Name, Content	Mode of Assessment of Accident Rate
Incidence rate: number of accidents per 1000 employees	$W = \frac{\text{Number of accidents (injuries)}}{\text{The number of employees}} \times 100$
Incidence rate: number of accidents per 100,000 working hours	$W_1 = \frac{\text{Number of accidents (injuries)}}{\text{Number of work hours}} \times 100,000$
Incidence rate: number of accidents per 1 million tonnes of product	$W_2 = \frac{\text{Number of accidents (injuries)}}{\text{Amount of product (tonnes)}} \times 1,000,000$
Severity rate: number of working days lost due to a single accident	$W_3 = \frac{\text{Total absence caused by accidents}}{\text{Number of injuries}}$
Severity rate: number of fatal accidents per 1000 total accidents	$W_4 = \frac{\text{Number of fatalities}}{\text{Total number of accidents (injuries)}} \times 1000$
Accident cost rate: average loss suffered due to a single accident	$W_5 = \frac{\text{Total cost of accidents}}{\text{Number of accidents}}$

Frequency rates can be calculated for all accidents recorded at work, or they can be determined separately for fatal and serious accidents. Rates are usually calculated annually, although they are also useful when calculated in 3- or 5-year periods. Multiannual rates are useful for comparing fatal accident rates of establishments, trades, or countries.

2.3 Causes of Accidents

Identifying the causes of accidents is a prerequisite for formulating preventive action programmes. The legal provisions that require maintenance of accident records define the cause of accident as any flaws and errors which contribute directly or indirectly to the occurrence of the accident. This can be related to material (technical) factors, general work organisation, or organisation of the work station, or can be associated with the employee.

The term 'causality' is an expression of the principle that every effect has a cause that precedes it. *Simple causality* is when events result from a single cause. *Complex causality* is when the observed effect arises from several causes. Accidents are events with many causes. Most correlations between events that lead to an accident have a complex causality. Therefore, causes of accidents must be treated as coexisting events preceding the injury.

TOPIC 3. MAJOR INDUSTRIAL ACCIDENTS

3.1 Introduction

Major accidents often have catastrophic results and pose serious problems, particularly in industrialised countries. Major accidents are failures of technological and storage systems or transport devices that result not only in explosions or fire but also in the release of large quantities of hazardous chemicals found in such facilities into the environment. The consequences of industrial and transport accidents for people and the environment, as well as the scope of material losses, mean that many international organisations and states have adopted environmental programmes and incorporated certain tasks in order to protect the life and health of workers, protect the environment, and maintain the safety of the work environment.

Issues associated with preventing major industrial accidents and limiting their consequences were regulated in the European Union (EU; EEC at the time) as early as in 1982. Council Directive 82/501/EEC on the major accident hazards of certain industrial activities, also called the Seveso Directive, was the applicable document at the time, along with amendments introduced by Council Directives 87/216/EEC, 88/610/EEC and 91/692/EEC.

The EU's current legal regulations on the control of major accident hazards consist of two fundamental legislative acts:

1. Council Directive 96/82/EC on the control of major accident hazards involving dangerous substances, also called the Seveso II Directive.

2. Directive 2003/105/EC of the European Parliament and of the council amending the Seveso II Directive.

The following decisions govern their detailed provisions:

- Commission Decision 98/433/EC of 26 June 1998 on harmonised criteria for dispensation according to Article 9 of Council Directive 96/82/EC.

- Council Decision 98/685/EC of 23 March 1998 on the conclusions of the Convention on the transboundary effects of industrial accidents.

As defined by the Seveso II Directive, a major accident is ‘an occurrence such as a major emission, fire, or explosion resulting from uncontrolled developments in the course of the operation of any establishment covered by this directive, and leading to serious danger to human health and/or the environment, immediate or delayed, inside or outside the establishment, and involving one or more dangerous substances.

- A *major accident* is an event, in particular, an emission, fire, or explosion, which occurs during industrial processes, storage or transport, involving one or more dangerous substances and leading to an immediate threat to the lives or health of people or the environment or to a delayed emergence of such threat.

- A *major industrial accident* is a major accident at an industrial establishment.

3.2 Conclusions from Analysis of Major Accidents in Europe

The Joint Research Centre, within the ambit of activities coordinated by Major Accident Hazards Bureau (MAHB), conducted an analysis of past major accidents as ordered by the European Commission. This was an identification study and

intended to gather information on the production of hazardous chemicals and their release into the environment during industrial accidents. Analyses of the results contain a wealth of information on the significant aspects of the emergence, course, and nature of major industrial accidents.

The authors of this study analysed data on 550 accidents, which occurred mostly between the 1950s and 1990s, gathered from the following databases: ARIA (France), FACTS (The Netherlands), MHIDAS, (Great Britain), MARS, and CDCIR (MAHB–UE).

There were 406 accidents involving dangerous chemicals in which additional hazardous chemical substances were or could have been created, and in total, the analysed industrial accidents involved more than 350 chemical substances. Conclusions from an analysis of the data based on the type of accident, that is, fires, explosions, and releases of hazardous substances to the environment, are presented in Figure 3.1.

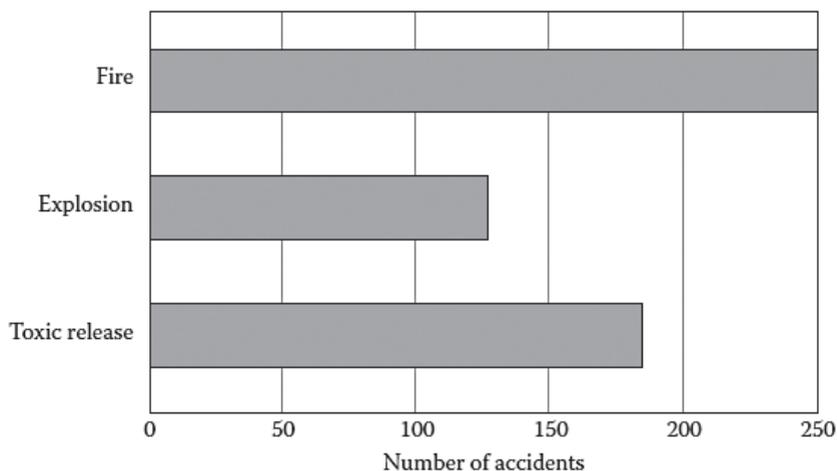


Figure 3.1 – Numbers and types of industrial accidents

Based on this data, the percentage of each type of major industrial accidents in the total number of events analysed was determined as follows:

- Fires – about 45 %
- Explosions – about 22 %
- Release of toxic substances – about 33 %

The analyses determined the specific causes of these major accidents and their frequency. The two most significant causes were ‘operator error’ (about 20 % of all accidents) and ‘component failure’ (about 10 %). In most cases, accidents caused by operator error were due to insufficient training and lack of clear procedures and instructions.

According to the official records of the EU, the immediate causes of most major accidents were management and/or organisational shortcomings; inefficient management systems contributed to more than 85 % of accidents. Analyses of accidents show that the scenario that leads to production of hazardous chemical substances greatly influences the extent of each type of effect. Most effects, such as evacuation of the population, transport bottlenecks, and some fatalities, result mainly from release of toxic substances produced in adverse reactions during accidents. Therefore, the production and release of toxic substances when loss of control occurs during an accident is the most significant cause of fatalities and environmental damage. Figure 3.2 presents a summary of the consequences of accidents to society and the environment depending upon the accident scenario. As the diagram indicates, there is no single dominant cause for the evacuation of employees. Fires are the most frequent reason for evacuation of the local population and for transport bottlenecks.

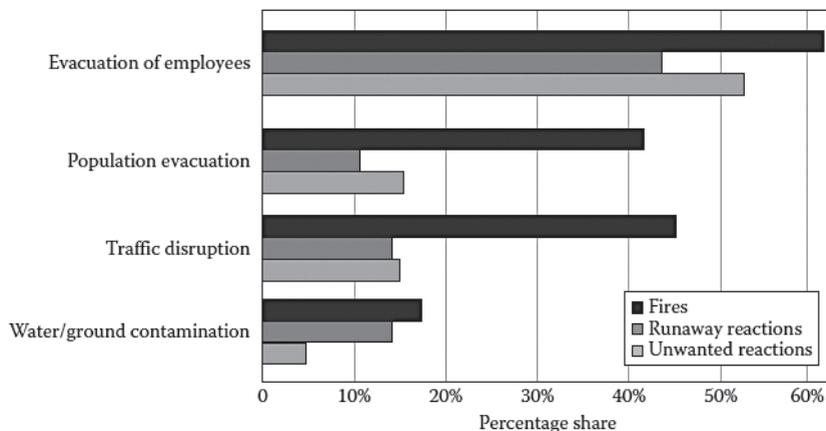


Figure 3.2 – Percentages of accidents, by scenario, causing various consequences for people, infrastructure and the environment

3.3 Shaping Employee Attitudes and Behaviours in Plants Posing Major Industrial Accident Hazards

EU legislation (the Seveso II Directive) and domestic regulations on the programmes for preventing major industrial accidents, safety management systems, and internal emergency action plans serve as the basis for shaping employee attitudes and behaviours in order to prevent major industrial accidents. Undoubtedly, appropriate training for employees of LTEs, UTEs, and other establishments and organisations that pose a risk of major industrial accidents is imperative.

Such training should create awareness of the threats present and convince employees of the compelling necessity to observe the special rules of safety and procedures designed to prevent accidents and limit their consequences. The training programme should list the specific risks, such as the hazardous substances, nature of threats, technologies in use at the establishment, nature

of work performed, and safety-oriented tasks and objectives, and should stress the importance of avoiding actions or behaviour that might trigger major accidents or events.

It is important that employees are prepared to perform various tasks in the case of an emergency: chemical rescue, technical rescue, first aid, measuring chemical contamination levels, performing evacuation tasks, firefighting, and many other activities specified in emergency action plans. Training is an essential means of disseminating complete and detailed information on such plans to the employees designated to participate in rescue activities.

The planning and implementation of tasks to shape employee attitudes and behaviours should ensure that the employees:

- Are appropriately and sufficiently informed of the threats associated with specific hazardous installations and the probable consequences of accidents.
- Are informed of the orders, instructions, and recommendations issued by the appropriate authorities and the establishment's management.
- Participate in consultations to formulate the following documents:
 - A programme for the prevention of major accidents and for the SMS
 - A safety report.
 - Emergency action plans and procedures.

TOPIC 4. PERSONAL PROTECTIVE EQUIPMENT

4.1 Introduction

Personal protective equipment (PPE) belongs to the group of protective devices that directly protect a worker against hazards in the work environment. Before deciding to use PPE, all possible technical and organisational measures to eliminate the risk at the source must be undertaken. When efforts to completely eliminate hazards to life and health or to reduce their admissible values do not succeed, that is, the concentration or intensity values of harmful factors present at workstations are still higher than is permissible, the use of PPE is the final barrier for the worker. European Union legislation has two areas of regulations. The first is included in directive 89/656/EEC (1989) and determines the obligations of the employer relating to the safe use of PPE. The second area, included in directive 89/686/EEC (1989), covers the rules for placing these products on the internal market, that is, assessment of conformity to basic health and safety requirements.

4.2 Rules for Safe Use of Personal Protective Equipment

Ensuring the safe use of PPE is the duty of every employer, who should:

- Provide PPE free of charge.
- Select suitable PPE considering the nature and magnitude of hazards.

- Organise training on the appropriate use of PPE.
- Ensure appropriate storage, cleaning, disinfection, maintenance and necessary servicing for PPE.

The appropriate selection of PPE is fundamental. PPE should meet selection criteria that consider the hazards and work environment conditions and at the same time conform to the basic requirements of safety and ergonomics. Conformance to CE markings as well as the manufacturer's declaration and the instructions for use confirm the PPE's conformity to regulations.

Before selecting the PPE, all hazards in the work environment should be identified and occupational risk assessment should be carried out. The extent of dangerous and harmful factors should be measured, if necessary, and the findings compared with admissible values such as maximum admissible concentration (MAC) for chemical factors and dusts or maximum admissible intensity for physical factors, noise, vibration, and electromagnetic fields. The number of times an admissible value is exceeded will be the guideline for selecting the protection level. Knowledge about harmful factors activity will indicate the necessary extent of protection.

PPE can be categorised as follows, based on the scope of protection:

- Protective clothing
- Hand and foot protection
- Head protection
- Hearing protection
- Eye and face protection
- Respiratory protection
- Equipment protecting against falls from a height

The first stage of PPE selection is the analysis and assessment of hazards. A technical solution should then be based on additional information related to the following:

- Workstation organisation
- Climatic conditions

- Additional hazards not related to the necessity to use PPE
- Characteristics of the user
- Working time and other conditions that could have adverse effects on a worker's health and well-being

The employer is responsible for determining the terms of use for PPE. While determining the terms of use, the level of hazard, and frequency of exposure to the hazard, the employer should consider workstation characteristics and the efficiency of the PPE. If more than one hazard occurs and the situation calls for use of more than one PPE, the equipment must be designed in such a way that it can be adjusted without reducing its protective properties. The employer is also responsible for training, information and consultations related to the safe use of PPE. Both the employees and the personnel responsible for supervising the use of PPE should be aware of the following:

- The PPE's protective properties
- The consequences of not using the PPE
- How to use the PPE correctly
- How to keep the PPE clean and when it should be discarded

Protective Clothing

Protective clothing is the most commonly used type of PPE; it protects the worker from dangerous and harmful factors that occur in the work environment. The type of protective clothing depends on the type of harmful or dangerous factors occurring at the workstation. Therefore, clothing should be classified based on its protective properties. Clothing is classified as that providing protection against mechanical, thermal, chemical and biological agents, high visibility warning clothing, and as providing protection from electric shock, electromagnetic radiation, or drowning.

Clothing for protection against mechanical hazards protects the worker from mechanical injuries caused by cuts, punctures, entanglement in the moving parts of devices, and the effects of

impact. Clothing made of metallic materials such as wire mesh or appropriately jointed metal elements protects against puncture by hand knives, and multilayer fillers are used to protect against injuries by chain saws. Contact with a chain saw causes the fibres to entangle themselves with the chain in the driving system, block its movement and stop the saw.

The properties of clothing for protection against chemical agents should be adapted to the aggregation of the chemical substance, its type and the concentrations, and the intensity of its effect on the clothing. Clothing that completely isolates the body from the outside environment—so-called gastight clothing—belongs to this group, as does clothing that protects only against accidental low-volume splashes of chemical substances. Such clothing can be made of textiles, knitwear, or nonwovens coated with plastics or impregnated textiles as well as foil, depending on its intended use.



Figure 4.1 – Safety protection suit

Hand and Arm Protection

Protective gloves provide basic hand and arm protection. Gloves ensure the protection of the hands, and if their cuffs are long enough they can also protect part of the forearm and the arm. It is particularly important that gloves have the appropriate protective properties but do not restrict the dexterity, accuracy, and firmness of the user's grip when working and thus add to the risk of accidents at work caused by inappropriate or manual work that is too slow. Gloves must ensure protection of the hand against many different harmful and dangerous substances. When seeking to assure protection against several hazards, combinations of different materials are typically used, limiting the comfort. It is essential to strike a balance between protective and usability properties. Because of the hazardous situations in which gloves are used, the time needed to put on and take off the gloves should be the shortest possible. It is also crucial to fit the size of the glove to the user's hand. Gloves that are too tight not only cause discomfort, but also hasten the loss of protective properties, whereas gloves that are too large do not ensure the necessary protection and additionally make work difficult. Depending on the precision required, gloves with one, three or five fingers can be chosen.

Gloves for protection against minor and average mechanical injuries are often made of combinations of leather and fabric, and fabrics and knitted fabrics partly or wholly coated with plastic or rubber or with polymer dots.



Figure 4.2 – Example of gloves made of chain mail

Foot Protection

At many workstations, for example, construction sites, metallurgical and machinery industries, and mining, workers are exposed to risks of injury to the lower limbs, especially the feet. The risks are directly related to the work performed as well as to the harmful effects of the floor's surface or the environment. Footwear selected according to the risks provides foot protection. Footwear, depending on the design and materials used, as well as additional protective components, offer protection against various mechanical damages, such as punctures of the sole of the foot, injury or crushing of the toes or metatarsus, thermal injuries caused by excessively high or low temperatures, electric shock, and so on.

According to the European standards (ISO 20345:2011; ISO 20346:2014; ISO 20347:2012), the following categories of footwear are ranked as PPE for the lower limbs:

- *Safety shoes*: Equipped with toecaps to protect toes against impact up to 200 joules (J) and compression up to 15 kilonewtons (kN; safety toecaps).
- *Protective footwear*: Equipped with toecaps to protect toes against impact up to 100 J and compression up to 10 kN (protective toecaps).
- *Occupational shoes*: Has protective properties but without toe protection.

As for the materials used, classification I footwear includes footwear made from leather and other materials (excluding all-rubber and all-polymeric footwear), and classification II includes all-rubber entirely vulcanised and all-polymeric entirely moulded footwear.

Additional protective elements of footwear include:

- Safety and protective toecaps protecting the toes
- Penetration-resistant inserts fixed on the bottom of the shoes protecting the foot against punctures
- Metatarsal protection fixed on the inside or outside of safety or protective footwear

- Ankle protection to absorb impact
- Flaps protecting the metatarsus, preventing sand, stones, sparks, and splashes of melted metal from entering the shoe

Head Protection

In many workstations in industry, for example, mining, power, construction, and forestry, the risk of head injury for workers is constantly present. The most serious are mechanical injuries, which can be the result of the impact of falling objects or collision with fixed objects at the workstation. Because of the nature of these work activities, it is not always possible to eliminate such risks with appropriate organizational solutions or collective protective equipment. Therefore, the only way to ensure the safety of workers is by using safety helmets. The type of helmet depends on the specific nature of mechanical risk.

If the risk is of impact by hard, fixed objects, which can cause superficial head injuries, industrial bump caps can be used. Workers exposed to a risk of falling objects, which can cause serious injuries to the skull, brain or cervical vertebrae, require industrial safety helmets. Examples of designs of this type of helmets are presented in Figure 4.3. Workers exposed to a risk of impact to the head by extremely heavy falling objects from heights and with sharp edges as well as blows to the top of the head by dangerous objects at the workstation (Baszczyński, 2002) should be equipped with a helmet. Examples of designs of this type of helmets are presented in Figure 4.4.

Eye and Face Protection

Natural protective mechanisms protect the eye against external factors. For example, a thin layer of slightly oily lachrymal fluid produced by the conjunctiva protects it against less intensive pollution. Eyelids and lashes ensure the protection of the eye against fine foreign bodies. However, this natural protection of the eye against external factors is often insufficient in workplaces as well as in everyday life. In such situations,

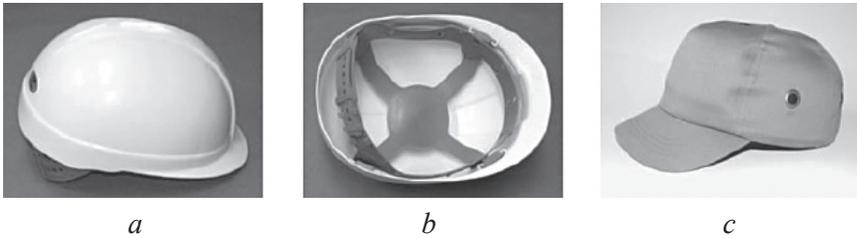


Figure 4.3 – Examples of designs of industrial bump caps:
(a) industrial bump cap with a polyethylene shell;
(b) construction of the internal part of an industrial bump cap;
and (c) industrial bump cap with a shell covered by a textile material



Figure 4.4 – Example of a design of a highly efficient safety helmet

extra eye protection is required. It should be used in places where the following hazards may occur:

- Impact (e.g. fragments of solids).
- Optical radiation (e.g. radiation related to welding, sun glare, laser radiation).
- Dusts and gases (e.g. coal dust or aerosols of harmful chemical substances).
- Droplets and splashes of fluids (e.g. splatter occurring when pouring fluids).
- Molten metals and hot solid bodies (e.g. sparks of molten metal during metallurgical processes).
- Electric arc (e.g. occurring while working on high-tension equipment).

The eye can be protected against the aforementioned hazards using eye protection equipment falling in the following four basic categories:

1. Spectacles.
2. Protective goggles.
3. Face shields.
4. Welder's face shields (includes hand screens, face screens, goggles, and hoods).

To ensure eye protection and vision, the PPE of the aforementioned categories is equipped with vision systems, oculars, meshes, or filters. Filters include welding filters, UV filters, infrared filters, sun glare filters, and filters protecting against laser radiation. Eye protection equipment may be part of respiratory protective devices (full masks that have vision systems) or head protection equipment (face shields mounted in industrial protective helmets). Eye protection equipment of all categories is composed of a transparent part (vision systems, oculars, meshes, or filters) and a frame (spectacles and goggles) or housing with a harness (shields).

Spectacles are the most widely used eye protection equipment. They should provide forehead protection against dangerous splatters of fluids or fragments of solid bodies. A model of such spectacles is presented in Figure 4.5.

If the worker requires a higher degree of eye protection, he or she can use protective goggles. Their construction ensures tight adhesion to the user's face, which enables them to protect against biological factors. The ventilation systems of goggles often differ greatly from one from another and are also very important. Figure 4.6 presents goggles with direct and indirect ventilation systems. Goggles with indirect ventilation systems ensure better protection against droplets and splashes of harmful substances. If the hazards require protection of the entire face, face shields should be used.

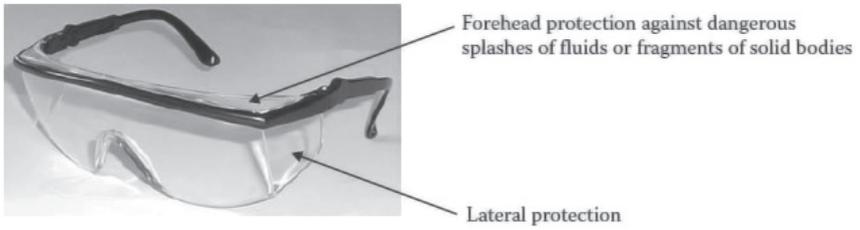


Figure 4.5 – Spectacles



Figure 4.6 – Protective goggles with (a) direct and (b) indirect ventilation systems

Face shields protect the entire face; their large protective surface minimises the probability of penetration of dangerous fluid splatter. Face shields may be used with spectacles, corrective glasses, goggles, and some respiratory protection devices.

The last of the basic categories of protective eye equipment are *welder's face shields*, that is, devices protecting the user against harmful optical radiation and other specific hazards arising during welding and/or related techniques. Welder's face shields include face screens, hand screens, goggles, spectacles, and hoods.

Respiratory Protective Devices

Respiratory protective devices are divided into two basic categories: (1) filtering devices and (2) breathing apparatus. Filtering devices include filters, gas filters, combined filters,

filtering half masks, filtering half masks protecting against gases and particles, powered filtering devices, and power-assisted filtering devices (Figure 4.7). The second category includes self-contained open-circuit compressed-air breathing apparatus and self-contained closed-circuit breathing apparatus, compressed-oxygen or compressed-oxygen-nitrogen types, and continuous-flow compressed air line breathing apparatus.



Figure 4.7 – Powered filtering device incorporating a helmet or a hood and powerassisted filtering device incorporating full face mask, half mask, or quarter mask

The different types of filtering devices are classified based on their protection parameters, such as filtration efficiency and sorption capacity, determine their use. There are three classes of protection for filters, filtration half masks and gas filters: lowest, medium, and highest. Combined filtering elements are classified by their purpose: devices protecting against organic

gases and vapours of organic substances of temperatures above 65 °C, against organic gases and vapours of organic substances of temperatures below 65 °C, against nonorganic gases; excluding carbon monoxide, against sulphur dioxide and other acid gases and vapours, against ammonia and organic ammonia derivatives, and against specific gases and vapours. Combining different types of gas filters results in multitype gas filters, and combining gas filters with filtering elements results in combined filtering devices.

There is also a separate group of respiratory protective devices intended specially for escape in case of sudden hazard, for example, major accidents, explosions, fires, accidents related to the transport of dangerous substances, and terrorist attacks.

These types of devices include lung-governed demand self-contained open-circuit compressed air breathing apparatus with a full face mask or mouthpiece assembly for escape, self-contained closed-circuit breathing apparatus for escape, and filtering elements with a hood. One of the basic requirements of respiratory protective devices intended for evacuation is that they must supply the user with breathable air and that they can be worn easily and quickly.

Equipment Protecting against Falls from a Height

Data on work accidents published annually in many European countries indicate that work at a height is still one of the most dangerous types of work. Working at a height in such areas as construction, power engineering, and telecommunications means that often the personal systems protecting against falls are the only method of workers' protection. The systems, depending on the function, can be categorized into three types:

1. Intended for arresting falls.
2. Intended for positioning work.
3. Intended for restraining falls.

Fall arrest systems are intended for use at workstations whose configuration does not allow for elimination of the risks of free fall. The major functions of the system are that it arrest the fall,

mitigate its effects by limiting the forces acting on the human body, protect it against collision with dangerous objects on the soil or workstation, and position the body during the fall and after the arrest it in a way that enables the worker to safely wait for help. An example of a personal fall arrest system is presented in Figure 4.8. A fall arrest system is composed of three basic subsystems, namely anchoring, connecting and shock-absorbing as well as full-body harness. The anchor subsystem (Baszczyński et al., 1999) is the first link of the system and is directly connected to the workstation. It enables linking the connecting and shock-absorption subsystems with the bearing structure of the workstation to arrest the fall. (Baszczyński and Zrobek, 1998).

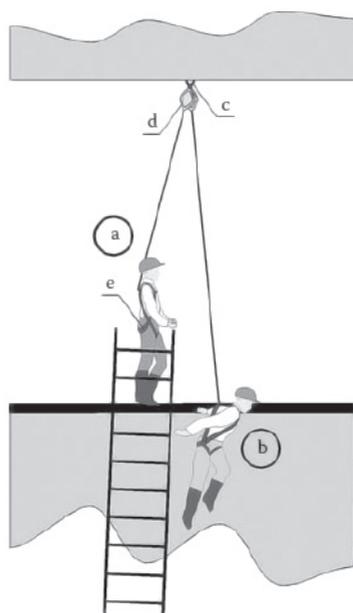


Figure 4.8 – Fall arrest system:
(a) the state before free fall; (b) the state after fall arrest;
(c) anchor element on the structure of the workstation;
(d) retractable-type fall arrester; (e) full-body harness

PART IV

THE LIFE SAFETY AND HEALTH ON SHIPBUILDING AND SHIP REPAIR ENTERPRISES

TOPIC 1. THE LIFE SAFETY AND HEALTH ON SHIPBUILDING AND SHIP REPAIR ENTERPRISES

1.1 Introduction

There is a major manpower requirement to process production in shipyard industry under hard working conditions with hazardous material. Most of the processes such as welding, painting, blasting, fiberglass production has direct effect on workers health, i.e. exposure to volatile organic compounds (VOCs), fumes resulting from burning through base metal and from burning the interior and exterior coatings, as well as a significant generation of NO_x gases during welding and cutting processes that are often left in place can cause acute and chronic health problems.

Production processes of shipyards may be discussed in two main categories: New shipbuilding and ship repair industry. Production methods of these two divisions are similar. New ship construction and ship repairing involve the usage of several

processes. Some of these processes surface preparation, painting and coating, solvent cleaning, degreasing, welding, machining and metalworking and fiberglass manufacturing. Ship repairing generally includes all ship conversions, overhauls, maintenance programs, major damage repairs, and minor equipment repairs. Raw material inputs to the shipbuilding and repair industry are primarily steel and other metals, paints and solvents, blasting abrasives, and lubrication and cutting oils. In addition, a variety of chemicals, such as solvent degreasers, acid and alkaline cleaners, and plating solutions containing heavy metal and cyanide ions, are used for surface preparation and finishing. Pollutants and wastes generated include volatile organic compounds (VOCs), chromium, hexavalent chromium, styrene, manganese, nickel, lead, tin, zinc, etc. as hazardous air pollutants (HAPs), particulate matters (PMs), waste solvents, oils and resins, metal bearing sludge and wastewater, waste paint, waste paint chips, and spent abrasives.

In recent years some researchers have focused on health of shipyard workers related to working conditions. These researchers studied mostly on the effects of the process outcomes such as welding fumes and asbestos on human respiratory system in detail and their impact to worker mortality (Barhad, B. et al., 1975, Buerke, U. et al., 2002, , Kilburn, K., H. et al., 1985, Puntoni, R. et al., 2001). There are some additional studies on environmental effects such as noise, dust, VOCs, on shipyard workers health.

1.2 Basic Shipyard Processes

Surface Preparation Processes Wastes and Affects on Worker Health

Surface preparation is an important step in the shipbuilding industry. Common surface preparation methods adopted by the shipyards are dry abrasive blasting, wet abrasive blasting,

hydroblasting, thermal stripping, chemical stripping and mechanical stripping. Material inputs used for preparing surfaces include, abrasive materials such as steel shot or grit, glass, garnet, copper, or coal slag; cleaning water, detergents, and chemical paint strippers (e.g., methylene chloridebased solutions, caustic solutions, and solvents). In the case of hydroblasting only water and occasionally rust inhibitors are required. Air emissions from surface preparation operations include particulate emissions of blasting abrasives and paint chips (Celebi, U.B. et al., 2010).

Potential exposure to dust and air contaminants is the primary health hazard associated with abrasive blasting. Abrasive blasting can generate large quantities of dust that can contain high levels of toxic air contaminants. Table 1 summarizes hazards of air contaminants associated with abrasive blasting in shipyards.

Table 1.1 – Hazards of Air Contaminants Associated with Abrasive Blasting in Shipyards

Contaminant	Potential Health Hazards
1	2
Aluminum	Respiratory irritation.
Arsenic (metal)	skin, lung and possibly lymphatic cancers and lead to peripheral neuropathy and vascular disease
Cadmium	degeneration of the renal tubules (kidney damage) manifested by increased protein in the urine; increased blood pressure contributing to hypertension; obstructive lung diseases like chronic bronchitis, pulmonary fibrosis and emphysema; and increase the risk of lung and prostate cancer.
Chromium (VI)	Lung cancer and asthma, damage nasal tissue and cause allergic dermatitis with skin contact.
Cobalt	Chronic lung inflammation and pulmonary fibrosis, increase the risk of lung cancer, and cause allergic contact dermatitis with skin contact.
Copper	Respiratory irritation.
Iron	siderosis (mildly fibrotic lung disease)

Continuation of Table 1.1

1	2
Lead	subclinical and clinical peripheral neuropathy [muscle weakness, pam. and paralysis of extremities], disruption of hemesynthesis and anemia, loss of kidney function, increased blood pressure, nephropathy, reduced sperm count and male sterility, and increase the risk of cancer.
Manganese	Subclinical/clinical manganism, a 'Parkinson's -like' movement disorder manifested by reduced reaction tune, loss of steadiness, walking difficulties, and emotional instability.
Nickel	Lung and nasal cancers, asthma and allergic dermatitis with skin contact.
Crystalline Silica	Chronic lung disease, silicosis, and increase the nsk of lung cancer.
Tin (organic)	Headaches and subclinical neurological disturbances.
Titanium	Lung inflammation and pulmonary fibrosis.
Zinc and Copper	Metal fume fever (acute 'pneumonia-like' symptoms).

1.3 Painting Processes Wastes and Affects on Worker Health

Painting is a major process in shipyards which provides corrosion protection and/or improves appearance of the substrate, and is generally distributed throughout the yard. Painting activity can be divided into two major categories, painting and equipment cleaning, both of which result in emissions of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs). Painting wastes are believed to be the largest category of hazardous wastes produced in a shipyard. In a typical shipyard it may account for more than half of the hazardous wastes produced. This may include leftover paint, overspray, paint that is no longer usable, rags, and other materials contaminated with paint. In many cases the amount of paint can be reduced through the use of improved

equipment, alternative coatings, and good operating practices. Equipment cleaning also generates hazardous waste in the form of solvents, thinners, and acids. Painting activity involves significant air emissions. Volatile organic compounds and hazardous pollutants result from painting operations that are of concern (Celebi, U.B. et al., 2010).

The nature of shipbuilding and repair requires several types of paints to be used for a variety of applications. Paint types range from water-based coatings to high-performance epoxy coatings. Antifouling paints are used to prevent the growth of marine organisms. Copper-based and tributyltin (TBT)- based paints are widely used as antifouling paints, though TBT may only be used on vessels longer than 25 m and with regulatory authority approval. Most of these toxic agents are heavy metals or organometallic compounds, such as cuprous oxide, lead oxide, and tributyl tin compounds.

Employees exposed to methylene chloride are at increased risk of developing cancer, adverse effects on the heart, central nervous system and liver, and skin or eye irritation. Exposure may occur through inhalation, by absorption through the skin, or through contact with the skin. (Shipyards Employment e-Tool).

Organic solvents are useful to dissolve and disperse lubricants, oils, waxes, paints, varnishes, rubber and so on, and are widely used in many industrial processes. Most of them are also recognized as extremely hazardous chemicals and some of them might cause Alzheimer's disease, leukoencephalopathy, multiple sclerosis, neurobehavioral disorders etc. Solvent vapors comprised of VOCs and HAPs are significant pollutant outputs of cleaning and degreasing operations. Both halogenated and nonhalogenated solvents are used, and mixtures of different solvents are common. Typical cleaning and degreasing solvents include mineral spirits, aromatic hydrocarbons (e.g., xylenes, toluene, etc.), aliphatic hydrocarbons, ketones, esters, alcohols, phenols, turpentine, and various halogenated solvents.

1.4 Welding Processes Wastes and Affects on Worker Health

Various types of welding processes are used to join the different types of metals used in the construction of ships. Fusion welding, in particular, is performed at almost all locations in the shipyard. An important factor in welding processes is shielding. In most welding processes, this shielding is accomplished by addition of a flux, a gas, or a combination of the two. The waste generally depends on the methods and magnitude of welding employed. The waste generated by welding of thin metals by any method is the used diluted acids. The wastewater is sent for on-site/off-site treatment and other wastes such as slag are disposed as solid wastes. Welding rod stubs, wire stubs contaminated with flux and welding wire spools are the solid wastes that come from these activities. Welding fumes and particulate emissions are the potential air emissions from these operations.

Welding is a common and a highly skilled occupational specialty. Welding processes involve inhalation exposures, which may lead to acute or chronic respiratory disease. The primary source of inhaled particulate material in most welding processes is a consumable electrode of filler metal, which is partially vaporized. Metal fume is formed when vaporized metal condenses in air as metal oxide particles. These particles are particularly hazardous component of welding fumes because they are small enough to deposit in the terminal bronchioles and alveoli, distal to mucociliary cleaning mechanisms. Welding has been associated with many respiratory problems, which vary from acute or chronic respiratory symptoms, such as malaise, cough, dyspnea, chronic bronchitis, interstitial lung disease, pneumonitis, asthma, pneumoconiosis, and lung cancer.

Hexavalent chromium has been designated as a priority pollutant due to its ability to cause genetic mutations and cancer. Various studies have reported a greater incidence of lung cancer

in chromate workers than in other industrial workers. However, it may take around 15-20 years for the lung cancer to develop, so the disease may not immediately appear after exposure.

1.5 Identification of Occupational Accident Relations of Shipyard Labour in terms of Individual and Workplace Factors

The whole process in the shipyard must be done correctly and in a timely manner. According to Heinrich, the highest chance of industrial accidents is caused by human activities (88 %), 10 % caused by unsafe working environment, and 2 % of work accident caused by the unreasonable factor. The result of his research shows that 98 % of accidents can be avoided and can be controlled by human capabilities. Currently, many industrial accidents are caused by human factors. Therefore, it is an important issue to avoid and control human habits in preventing accidents from happening.

Workplace accidents are unforeseen and unintentional incidents, which occur in economic activity, causing one or more workers to be injured or lost their lives. An accident is a preliminary event, after which an injury may result, material damage, or environmental damage. Common causes of occupational accidents include altitude, toxic materials, flammable and explosive materials, fire, rotating machinery, harmful gases, frivolous work, equipment misuse or equipment failure, improper work, poor lighting at a place, electrical hazards, and clothing that does not comply with safety standards. Worker carelessness, lack of training and education about work safety, human error in operation, and insufficient workspace are major factors in workplace accidents. Every 15 second, one worker passed away due to work accident or occupational illness. 160 workers suffer from occupational accident every 15 seconds. More than

2.3 million deaths per year are caused by occupational accidents, and there are more than 336 million accidents each year.

Every worker must be granted protection for the safety of doing work for the welfare of life and to increase national production and productivity, and every other person at work needs to be assured of his safety. Mentioned in this regulation that the requirement of occupational safety is to prevent and reduce accidents; prevent, reduce and extinguish fires; prevent and reduce the dangers of blasting; provide an opportunity or a way to save themselves when a fire occurs or other dangerous circumstances; giving help to accidents; provide selfprotection tools to workers; prevent and control the emergence or spread of temperature, humidity, dust, dirt, smoke, vapor, gas, wind, weather, light or radiation, sound and vibration; prevent and control the onset of illness due to physical or psychological work, poisoning, infection and transmission; obtain sufficient and appropriate lighting; maintaining good air temperature and humidity; maintaining sufficient air refreshment; maintain hygiene, health, and order; obtaining harmony between the workforce, the work tool, the environment, the way, and its work processes; secure and facilitate the transportation of persons, animals, plants, or goods; securing and maintaining all types of buildings; securing and expediting loading and unloading, treatment and storage of goods; prevent exposure to dangerous electrical current; adjusting and perfecting security in jobs where the danger of accidents grows higher.

Psychologists conduct research on what the definition of occupational safety is and relate the relationship between occupational accidents and factors related to occupational safety cultures, such as heavy workload, emotional stability, and internal or external safety control. Workplace safety is defined by Zohar as a basic perception of the worker about how safe his work environment is. Work safety consists of eight factors: the importance of conducting safety training, safety attitudes from management, the impact of safety culture on promotion,

the severity of risks arising from the workplace, the effects of the speed of work on safety, the status of the occupational safety manager, the influence of safety culture on social status, and the status of the safety committee. According to Griffin and Neal, work safety is defined as a climate that exists in organizations that an individual feels toward the organization that he or she is following. Work safety consists of five factors: the meaning of management, communication, safety implementation, education/training, and safety tools.

Prevention of occupational injuries can be done because according to previous research, 98% of accidents can be prevented, and only 2% of workplace accidents cannot be prevented. Prevention of workplace factors are done in various ways as follows: for falling from height accident use and check safety equipment to work at heights, build handrails at elevated workplaces, inspect work surfaces at slippery heights and install web if needed, provide safety training, place warning signs at workplace, for electric exposure use insulated shoes and appropriate work clothes, plug ground electrical systems and switches for electrical leakage, check cables regularly, for fire and or explosion check gas regularly and strictly control, create a hot work action report when needed, make good ventilation, for being struck by object accident cause always work with a rigger, follow the rules of crane use, use appropriate support items, and for squeezed between accident Create an appropriate environment for work, install a sound warning system on the shipyard, use a border for steel sheets.

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Навчальне видання

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**OCCUPATIONAL SAFETY AND HEALTH
IN THE WORKING ENVIRONMENT**

**ОХОРОНА ПРАЦІ ТА ЗДОРОВ'Я
У ВИРОБНИЧОМУ СЕРЕДОВИЩІ**

Навчальний посібник

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