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HANDBOOK OF OCCUPATIONAL SAFETY AND HEALTH

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Introduction

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Introduction

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1.1 Historical review of OSH (Before the industrial revolution)

It is important for students of occupational health and safety to first study the past. Understanding the past can help safety and health professionals examine the present and future with a sense of perspective and continuity. Modern developments in health and safety are neither isolated nor independent. Rather, they are part of the long continuum of developments in the safety and health movement. The continuum begins with the days of the ancient Babylonians. During that time, circa 2000 BC, their ruler, Hammurabi, developed his Code of Hammurabi. The code encompassed all the laws of the land at that time, showed Hammurabi to be a just ruler, and set a precedent followed by other Mesopotamian kings. The significance of the code from the perspective of safety and health is that it contained clauses dealing with injuries, allowable fees for physicians, and monetary damages assessed against those who injured others.3 This clause from the code illustrates Hammurabi's concern for the proper handling of injuries: "If a man has caused the loss of a gentleman's eye, his own eye shall be caused to be lost."4 This movement continued and emerged in later Egyptian civilization. As evidenced from the temples and pyramids that still remain, the Egyptians were an industrious people. Much of the labor was provided by slaves, and there is ample evidence that slaves were not treated well—that is, unless it suited the needs of the Egyptian taskmasters. One such case occurred during the reign of Rameses II (circa 1500 BC), who undertook a major construction project, the Ramesseum. To ensure the maintenance of a workforce sufficient to build this huge temple bearing his name, Rameses created an industrial medical service to care for the workers. They were required to bathe daily in the Nile and were given regular medical examinations. Sick workers were isolated.5 The Romans were vitally concerned with safety and health, as can be seen from the remains of their construction projects. The Romans built aqueducts, sewerage systems, public baths, latrines, and well-ventilated houses.6 As civilization progressed, so did safety and health developments. In 1567, Philippus Aureolus produced a treatise on the pulmonary diseases of miners. Titled On the Miners' Sickness and Other Miners' Diseases, the treatise covered diseases of smelter workers and metallurgists and diseases associated with the handling of and exposure to mercury. Around the same time, Georgius Agricola published his treatise De Re Metallica, emphasizing the need for ventilation in mines and illustrating various devices that could be used to introduce fresh air into mines.7 The eighteenth century saw the contributions of Bernardino Ramazzini, who wrote Discourse on the Diseases of Workers. Ramazzini drew conclusive parallels between diseases suffered by workers and their occupations. He related occupational diseases to

the handling of harmful materials and to irregular or unnatural movements of the body. Much of what Ramazzini wrote is still relevant today. The Industrial Revolution changed forever the methods of producing goods. According to J. LaDou, the changes in production brought about by the Industrial Revolution can be summarized as follows:
- Introduction of inanimate power (i.e., steam power) to replace people and animal power
- Substitution of machines for people
- Introduction of new methods for converting raw materials
- Organization and specialization of work, resulting in a division of labor

These changes necessitated a greater focusing of attention on the safety and health of workers. Steam power increased markedly the potential for life-threatening injuries, as did machines. The new methods used for converting raw materials also introduced new risks of injuries and diseases. Specialization, by increasing the likelihood of boredom and inattentiveness, also made the workplace a more dangerous environment.
Occupational Safety and Health: From the Past, through the Present, and into the Future Post-twentieth century society is convinced of the unique position of our civilisation, and we are proud of the scientific and technical progress in shaping work processes. At the same time, we are amazed at the discoveries of work processes solutions and products from many centuries or even millennia ago, such as the ergonomic handles of axes or stone tools, the aqueducts in Rome or Istanbul that we still admire, and the way the mighty pyramids were built. People remain somewhat in the background of these achievements, although building the magnificent structures of Egypt, China or Persia took the lives of tens of thousands. Skeletons from those times reveal pathological changes associated with the work people did, for example, simple tasks in the Neolithic period (about 3000 years ago), when human societies shifted from hunter– gatherer to farming civilisations. During a 1972–1973 archaeological excavation in Aber-Hureyra (today's northern Syria), Andrew M.T. Moore found the remains of 162 people from two settlements. An analysis of the women's bones showed work- Related changes (Molleson 1994). Many hours of daily monotonous work, for example, grinding grain using a saddle quern-stone, were performed in a kneeling and flexed posture. This led to significant degenerative changes in the lumbar spine (as a result of flexion while the body is bent forward), knee joints (caused by the pressure of the ground) and big toes (as a result of hyperextension while kneeling). Carrying loads on their heads led to changes in the first cervical vertebra—the addition of lateral processes of the vertebrae to stabilise the position of the neck. Changes caused by daily forced postures over a long period of time gradually resulted in degenerative changes in other organs; these can be considered work-related pathological changes. These changes intensified with a decrease in the egalitarianism of communities— people began to specialise in specific tasks in order to increase the quantity of goods produced and the associated income. People who performed the same type of work all the time reached a high level of excellence in that work; however, the price was often high, with the work resulting in deterioration of health or even death (Chapanis 1951). These hazards did not disappear with industrialisation; their types simply changed. Excessive dynamic physical workload was replaced with static workload, excess of signal stimuli (Paluszkiewicz 1975),

noise and chemical hazards and, later, radiation. Automation, introduced thanks to technical progress, has resulted in monotonous work tasks and mental processes, which are dangerous for the musculoskeletal system (Rahimi and Karwowski 1992). In the past decade, we have been experiencing another revolution in workstations and work processes (Ozok and Salvendy 1996). Computerisation, while increasing

1.2 General view of OHS

The possibilities for controlling and carrying out work processes, has made work even more monotonous and has increased the eye strain and static workload associated with a forced sitting posture (Strasser 2007). Computerisation has also increased the overload of some muscle groups (Christensen 1960; Dul and Hildebrandt 1987; Grandjean and Hunting 1977; Kidd and Karwowski 1994). Occupational risk is also associated with biological factors. Biotechnologies are yet another challenge for humankind. All of these hazards and cases of strain are inherently accompanied by stress, which is universal among workers who are striving to be the best in order to maintain their position at work or even just to keep their jobs (European Agency for Safety and Health at Work 2002). When stress is too great, workers may become passive and escape into alcohol or the world of 'wonder' pills. Thus, substantial technical progress has not solved the problems of occupational safety and health, but has only shifted the core of the problems from chemical and physical hazards to psycho physical and biological ones. Labour protection—like art in the Renaissance—must now focus on people with limited psycho physical abilities in the workplace. 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 -20C% to + 70C%) 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 (Astrand and Rodahl 1977). These mechanisms, however, have a limited ability to compensate for harmful factors in the work environment (Koradecka 1982). Moreover, longterm involvement of these mechanisms results in a substantial increase in the physical work capacity (Brouha 1962; Lehmann 1962), which, in turn, leads to chronic fatigue. These processes influence the development of occupational diseases (Ramazzini 2009), defined as diseases associated with exposure to harmful work conditions. Paraoccupational diseases are those associated indirectly with work conditions (the so-called civilization diseases such as hypertension, obesity, diabetes) and are often rooted 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’ (Stellman 1998). 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 (Stanton 2005). Ergonomics is defined as an adaptation of workstations, work processes and the work environment to the psychophysical abilities of the human body.

The concept of ergonomics has its own history and methodological bases (Franus 1991). The term ’ergonomics’ was first used by Wojciech Jastrzebowski in 1857 in his treatise An Outline of Ergonomics, or the Science of Work, Based upon the Truths Drawn from the Science of Nature. Here we find many thoughts consistent with modern knowledge on modifying work conditions (Jastrzebowski 2004). I would like to show the timeless nature of the problems of shaping work conditions by commenting on a quotation from the treatise. Jastrzebowski writes: . . . for it is well-known that our vital forces grow weak and impoverished as much by the lack of their exercise as by their abuse; and they are maintained in their proper condition, growing and increasing by their proper and moderated exercise, which we call work.’ This quotation illustrates the very popular—and often disregarded—principle of planning work processes in a way that reduces excessive effort and monotonous work tasks. Wojciech Jastrzebowski defines ergonomics as follows: ‘By the term Ergonomics, derived from Greek word ergon work, and nomos principle or law, we mean the Science of Work, that is the use of Man’s forces or faculties with which he has been endowed by his Maker.’ He also praises training and education: "The second chief advantage which we draw from work is that through it we acquire the skill to perform work itself more and more easily and with an ever-growing satisfaction, accuracy, and liking for it. In other words that we can are able to undertake work at the expense of a lesser and lesser amount of toil and drudgery, but to the ever-increasing gain of ourselves and the common good". Jastrzebowski also mentions the need to develop one’s personality through work, which is emphasised so often these days: ‘Perfection on the other hand, the advantage now under discussion, is always seen as one of our inner properties, a thing strictly connected with us and a direct consequence of Ability (. . .) Apart from their absolute value, by which our being is endowed with a similar value, these Perfections also have a relative value, which concerns the objectives of our active, improving and productive life.’ Thus, we have made a full circle in the causes and effects of actions, going back to the term ‘perfection called health’, which does not differ substantially from the World Health Organization’s definition of health. 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 (Kim 2001). 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 (Karwowski 2006). 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 (Alli 2001). 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. To sum up the analysis of these definitions, the somewhat artificial division between occupational safety, ergonomics, and occupational health is not very significant from the perspective of a practitioner. In fact, the logical sequence of tasks undertaken to protect a worker's health and life in modern complex work processes is more important (Koradecka 1997). First, the highest admissible concentrations and intensities of harmful agents (chemical, physical and dusts) in the work environment must be established to protect workers' health and that of the next generations. In individual member states of the European Union (EU), admissible values have been established for an average of 500 harmful chemical substances (in Poland, the list now contains 523 items).

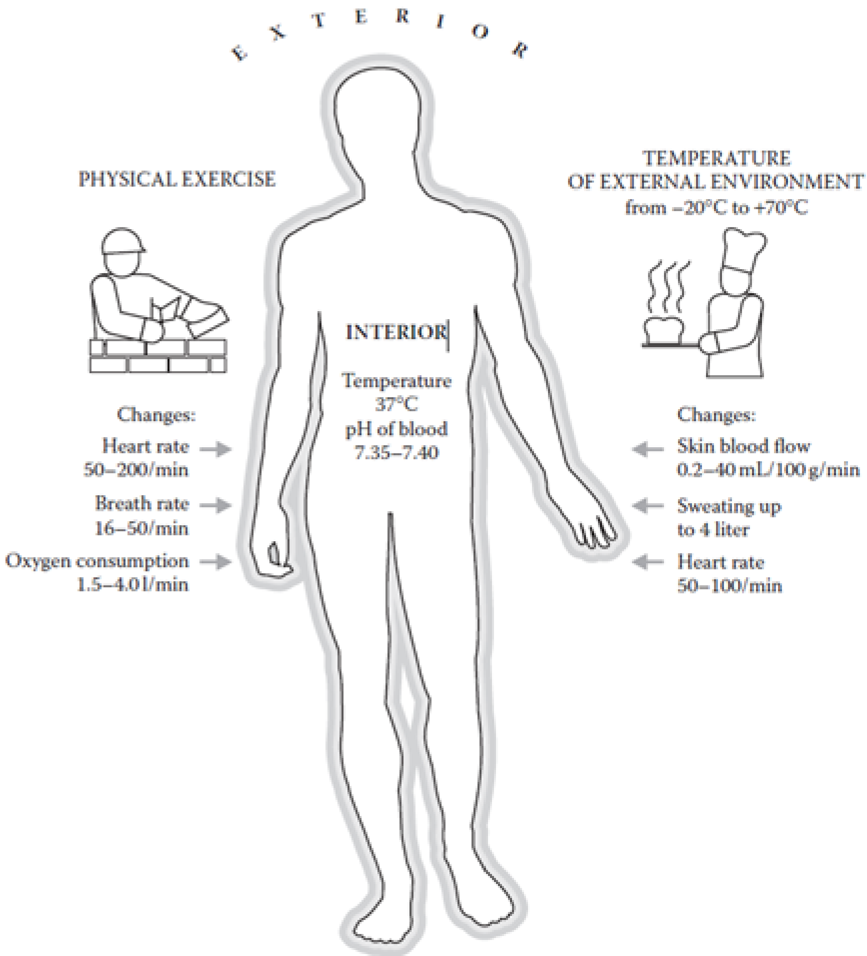

FIGURE 1.1: Response of an organism to maintain homeostasis.

At present, there are only 104 substances on the list, agreed upon by all of the member states of the EU. This is mainly due to lack of knowledge about aspects of the harmfulness of chemical agents (e.g., their carcinogenic and mutagenic nature) and the associated difficulties in occupational risk assessment (Koradecka and Bugajska 1999). Apart from the health aspect, the economic aspect, associated with the cost of decreasing concentrations to the recommended values, should also be considered. Of course, placing an agent on the list along with the value of the highest admissible concentration or intensity is not enough, since this only constitutes information on the threat. To prevent hazards, information serving as a basis for establishing of the highest admissible concentration values should be obtained from expert documentation. The next stage in creating an environmental safety and protection system is the development of standardised methods for determining harmful agents. These methods are necessary to control pollution of the environment by chemical and physical agents and dusts and to undertake preventive actions (Koradecka et al. 2006). Then at the design stage the values of harmful agent emissions resulting from the application of specific technologies must be determined (Benczek and Kurpiewska 1996). After exhausting the possibilities for protecting health and life through proper, modern design of products, workstations, and work processes, compliance with the basic safety requirements must be supervised (Salvendy and Karwowski 1994). EU directives on testing and certification of products with regard to their compliance with safety and health and environmental protection requirements have enforced mandatory CE marking of products, which confirms their conformity with European standards, since 1995. A declaration from the manufacturer is sufficient for simple products; however, prior to marking personal and collective protective equipment and particularly dangerous machinery, listed in Appendix IV of directive 89/392/EEC, compliance with complex procedures is required throughout the several stages of creation of the product, such as design and approval of the prototype. Products must comply with these rules in order to be exported to the EU and to be approved for marketing in all member states. After verifying whether testing laboratories and bodies certifying products and quality systems meet the requirements listed in European standards, they can be accredited. Poland has used the European certification system since January 1994; it was officially introduced by an act of 3 April 1994. The implementation of this system at research and testing laboratories in our country is invaluable. The EU recognises the test results and facilitates the export of Polish products into the European Economic Zone. Thus, compliance with the requirements of occupational safety and ergonomics is of economic significance. Economic stimuli are equally important for stimulating healthy work conditions. In pre–World War II Poland, economic stimuli took the form of differentiated insurance premium rates. These are currently used in many developed countries (e.g., Germany and France). The European Foundation for the Improvement of Living and Working Conditions has also prepared a list of modern economic stimuli to motivate companies to comply with the requirements of occupational safety and health (Bailey et al. 1995; Rzepecki 2007). Poland has differentiated insurance premiums depending on occupational risk since 2003 (DzU no. 199, item 1673, with amendments). Compliance with the requirements of occupational safety and ergonomics is thus no longer perceived as a humanitarian gesture of good will; it has become an economic category, indicating the further development of the science and practices associated with these issues. In our research we have compared national statistics data on exposure to harmful physical and chemical factors in a population of 9225 persons. The data was obtained from two sources: the results of a survey on subjective assessment of the working environment, covering 1001 persons, and from measurements taken in the working environment, covering 823 persons selected out of this population (Figure 2). Note that there are considerable differences between an objectively measured amount of exposure and the subjective perception of this exposure by workers, the latter being considerably worse. Against this background, national statistics based on employers' reports turned out to be significantly underestimated. In light of the fact that subjective exposure assessment is dependent on the individual features of an employee, the psychosocial conditions of the work tasks performed, and the workers' perception of health hazards, the need to carry out risk assessment in the work environment by means of both objective and subjective methods is fully justified. It is difficult to make reliable forecasts for the future; we can only identify opportunities for development. In occupational safety and

health, globalisation brings not only new technical risks, but also new problems associated with different models of employment. Conditions for the protection of life and health are also increasingly different. Associated risks, however, are due not only to changing work conditions but also to improper risk management (Karwowski 2003). Thus, we can forecast the following: • Maintenance of the downward trend from the manufacturing sector towards the sector of services
• A high level of variability of entities on the labour market (particularly small- and medium-sized enterprises)
• An increase in the level of part-time employment and remote employment
• An increase in workers' age
• An increase in the number of women employed At the same time, societies are undergoing many lifestyle changes and feeling consequences such as an increase of obese people, people addicted to alcohol or other substances, people suffering from sleep disorders or depression. These general social changes—in opposition with transformations in the world of work—will result in tensions and hazards not only to life and health, but also to socioeconomic development (Koradecka 1997). For instance, in the United Kingdom, according to the health and safety executive data, there will be 13 million new workers in the workplace by 2015; inexperienced workers are 40 percent times more likely to have accidents than experienced workers. Also in the United Kingdom, by 2010 most of the present small- and medium-sized enterprises will cease to exist, and 4.5 million new ones will replace them. Small organisations have a higher number of accidents; the risk decreases if the organisation has operated for a long period of time. The number of older workers will also increase; they are absent from work less often, but their absences are longer. Obesity will increase, which is conducive to increased absenteeism due to musculoskeletal disorders and heart disease. New technologies are another significant challenge for occupational safety and health, including:
• Nanotechnologies
• Biotechnologies
• Spatial computing
• Alternative sources of energy Work processes will need to become more effective. This will probably lead to the following:
• More frequent monitoring of the workplace
• Equipping workers with microchip ID cards A need to increase interactions between humans and independently
• working Robots Under such supervision, workers' levels of stress and depression will grow. Workers will react to these enhanced requirements by using risky medications more frequently to increase their efficiency, as these can improve memory and eliminate fatigue for up to 36 hours. On the other hand, technological progress will be substantial, for example, in the following fields:
• Hydrogen infrastructure in households and in transport
• Robotisation, including in offices
• New-generation nuclear reactors
• Wind power
Trust in technologies will increase, and a new generation of workers will be highly independent.

This may lead to changes in the perceptions of issues related to occupational safety and health.

Topic 1

CHAPTER 2

Safety legislation

2.1 Introduction

Appropriate legislation and regulations, together with adequate means of enforcement, are essential for the protection of workers' safety and health. Legislation is the very foundation of social order and justice; without it, or where it is not enforced, the door is wide open to all forms of abuse. Each country should therefore take such measures as may be necessary to protect workers' safety and health. This may be done by enacting laws or regulations, or by any other method consistent with national conditions and practice, undertaken in consultation with the representative organizations of employers and workers concerned. The law directly regulates certain components of working conditions and the work environment, including hours of work and occupational safety and health. There are also provisions relating to trade unions and collective bargaining machinery, which establish conditions for negotiations between employers and workers.One of the greatest problems regarding labour legislation in many countries is its application in practice. It is therefore important for govern-ments to take the necessary steps to ensure that there is an effective system of labour inspection to make certain that statutory requirements are met. This is often difficult because of a shortage of trained personnel. Another problem relates to the difficulty of dealing with new hazards, bearing in mind the speed at which technology is changing. In some cases such problems can be solved by employers and workers through collective bargaining. These two complementary approaches are outlined below.

2.2 Labour inspection

The enforcement of legal provisions concerning occupational safety and health and the working environment should be secured by an adequate and appropriate system of inspection. The system should be guided by the provisions of the relevant ILO instruments,2 without prejudice to the obligations of the countries that have ratified them. As provided in Article 3(1) of the Labour Inspection Convention, 1947 (No. 81), the functions of the system of labour inspection should be:

- to secure the enforcement of the legal provisions relating to conditions of work and the protection of workers while engaged in their work, such as provisions relating to hours, wages, safety, health and welfare, the employment of children and young persons, and other connected matters, in so far as such provisions are enforceable by labour inspectors;
- to supply technical information and advice to employers and workers concerning the most effective means of complying with the legal provisions;
- to bring to the notice of the competent authority defects or abuses not specifically covered by existing legal provisions.

For inspection to be taken seriously, labour legislation must be enforced systematically and forcefully. This may be a tall order in many countries because:

- legislation may not be sufficiently realistic;

• labour inspectors may have difficulty in imposing their authority;
• infrastructure facilities essential for inspection, such as adequate means of transport or communication, may not be available;
• procedures may be lengthy and costly.
It is therefore imperative to broaden national labour inspection activities to involve employers and workers more actively (see box 15), and to make greater efforts in the field of training. It should be stressed that any further duties which may be entrusted to labour inspectors should not be such as to interfere with the effective discharge of their primary duties or to prejudice in any way the authority and impartiality that are necessary to inspectors in their relations with employers and workers. Also, the need for the labour inspectorate staff to be well trained cannot be overemphasized.
In view of the crucial role of labour inspection in implementing national OSH programmes, government authorities must strive to strengthen the in-spectorate. Depending on national approaches and circumstances, appropriate measures necessary to achieve the above objectives may include:

Apart from the provisions of the LC and the executory provisions of the LC, there are other rules concerning workplace safety and health that regulate obligations in administrative relations. These can be found in the Act on Chemical Substances and Preparations, the Construction Law, the Atomic Law, and the Geological and Mining Law, among other laws.

Collective labour agreements and workplace regulations should also be enumer-ated as sources of labour law, that is, OSH law. In the event of collective labour agreements, the requirements concerning OSH included therein shall not be less favourable than the provisions included in the generally binding law. The case of workplace regulations is somewhat different. Workplace regulations shall specify the organisation and order of the work process and the associated rights and duties of both employers and employees. According to the provisions of the LC, workplace regulations must be introduced by any employer who employs more than 20 persons. According to the LC, OSH issues are crucial among all the matters that should be defined in workplace regulations. The following matters are part of OSH: providing employees with personal protective and hygienic equipment; listing types of work forbidden to adolescent workers and female employees; listing types of work and work posts allowed to adolescent workers to complete vocational training; listing types of light works allowed to adolescent workers employed for a purpose other than vocational training; knowledge of duties relating to OSH and fire protection, including the method of informing the employees of the occupational risks involved in the work performed.

2.3 International Law

OSH as a discipline of law is subject to frequent changes due to scientific progress in the field of technology, medicine, and work organisation. The International Labour Law is of major importance for OSH law. Poland is a member of several international organisations that issue

Box 15 Cooperation between inspectors and workers

The Labour Inspection Convention, 1947 (No. 81) lays down standards for cooperation between inspectors and workers. In Article 5, the Convention states:

The competent authority shall make appropriate arrangements to promote ... collaboration between officials of the labour inspectorate.

In addition, Article 5 of the accompanying Recommendation (No. 81) states that representatives of the workers and the management should be authorized to collaborate directly with officials of the labour inspectorate. improving the capacity to secure the enforcement of legal provisions;

supplying technical information and advice;

identifying new needs for action;

increasing the number of inspectors;

improving the training of inspectors in support of their enforcement and advisory roles;

integrating separate inspection units or functions and using multidisciplinary inspection teams;

fostering closer cooperation between labour inspectors and employers, workers and their organizations;

improving systems for gathering and reporting statistics on occupational accidents and diseases, and the inclusion of the resulting data in the annual inspection report;

Improved support facilities, institutions and other material arrangements.

The labour inspectorate must have an adequate and well-trained staff, be provided with adequate resources, have an effective presence at the workplace, and be capable of taking decisive action by being severe, persuasive or explan-atory, depending on the case.

It must be stated in conclusion that the conditions for an effective labour inspectorate, set out above, are very hard to attain in many countries of the world (see box 16). The reasons are not difficult to understand, and include scarce resources, especially in countries undergoing various programmes of economic reform, and the low priority given to OSH issues in the face of other competing demands. There is therefore very little justification for maintaining two parallel inspection systems, a practice that is still being observed in some countries. It is certainly more cost-effective to have an integrated system of inspection, whereby labour inspectors are also trained in safety and health issues. The mechanisms for achieving this process should be embodied in the national policy on occupational safety and health.

FIGURE 2.1: Cooperation between inspectors and workers

Box 16 Some problems of labour inspection

A meeting of labour inspection experts dealing with child labour, organized by the ILO in 1999, made some broad observations of general interest to labour inspectors. The first problem identified was the lack of resources:

In developing countries generally there was a great shortage of human and material resources to carry out the functionsof labour inspection.There were perhaps genuine intentions to apply the law,but performance failed to measure up to these intentions. Posts existed but qualified inspectors could not be found and there were insufficient funds for training and purchasing equipment.

Another problem was interference from vested interests:

Although Article 4 of Convention No. 81 was clear in stating that labour inspection should, if national law and practice so permitted, come under one central authority, some countries varied in the extent to which labour inspection was organized under a central, regionalor local body. The further labour inspection was removed from this central authority, the greater the risk of involvement of vested interests in decisions affecting its independence. Pressure to change the manner of organizing had often occurred because of the perceived costs of running labour inspection without highlighting the benefits also in economic terms. This had been a particular issue in developing countries because of the regular requirement of many structural adjustment programmes to cut public expenditure and reduce public service smore or less drastically. The impact on the independence and operation of labour inspection was therefore largely negative,with obvious consequences also for the ability of inspectors to meet the challenge of combating child labour.

Source: ILO: Labour inspection and child labour, Report of the Meeting of Experts on Labour Inspection and Child Labour, Geneva, 27 Sept.1 Oct. 1999, pp. 56, para. 27; p. 8, para. 38.

FIGURE 2.2: Some problems of labour inspection

regulations with great significance in Polish OSH require-ments. The most important of these are the International Labour Organisation (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 norma-tive activities. According to the Constitution of the ILO, the organisation creates norms of law in the form of international conventions and recommendations (Article 19, point 1 of the Constitution). 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 (Florek and Seweryn´ski 1988).

The ILO conducts intensive legislative activity in the area of OSH: 187 con-ventions, including 42 directly concerned with OSH, have been enacted from the foundation of the ILO in 1919 through 2006. The ILO conventions are ratified after consent is obtained per a separate act of law (Article 89, point 1 of the con-stitution). In the event that the ratified convention contradicts national legal acts, the convention is superior to the national legal acts. The convention is ratified only after the national law has been transposed to the requirements included in the convention.

The basic ILO convention concerning OSH and the work environment is con-vention no. 155, adopted in 1981. It obliges the signatory countries to formulate, implement, and periodically review their national policy on OSH in the work environment. The representative organisations of employers and employees should be consulted regarding the contents of the policy before putting the policy into practice. Convention no. 155 set the criteria to be met in order to guarantee the creation of a proper national OSH policy. The most important criterion is the determination of the functions and responsibilities of public authorities, employers, and workers, as well as their participation in the formulation of the policy.

Equally important for OSH is ILO convention no. 187, adopted in 2006 on the promotional framework for OSH. The member states that ratified convention no. 187 are obliged to formulate a national policy that promotes OSH and to lay out, develop, and implement a national system for OSH. Each country shall also formulate, implement, monitor, evaluate, and periodically review a national OSH programme.

The Council of Europe is an international organisation that was founded in 1949 to protect human rights, pluralist democracy, and the rule of law. The council aims to find common solutions to the challenges facing European society and to consolidate democratic stability in Europe by backing political, legislative, and constitutional reforms. The Council of Europe has 47 member countries. These acts are in force in the member states after ratification. From an OSH point of view, the most important act is the European Social Charter, adopted in 1961 and revised in 1996. OSH protection issues are regulated in points 2 and 3 of the first part and in Articles 2 and 3 of the second part of the charter (Henczel and Maciejewska 1997).

The framework directive emphasises 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 organisation of work.

CHAPTER 3

Workers compensation and Record keeping

3.1 Introduction

The surveillance of workers' health entails medical examinations of workers to ensure that their state of health is compatible with their job assignment and that their occupational exposure to hazards does not have any detrimental effects on their health. Health examinations also help to identify conditions which may make a worker more susceptible to the effects of hazardous agents and to detect early signs of health impairment caused by them. Their main purpose is primary prevention of work-related injuries and diseases. Surveillance should be carried out in consultation with the workers or their representatives, and should not result in any loss of earnings for them. Furthermore, medical examinations should be free of charge and, as far as possible, should take place during working hours. Workers' health surveillance at national, industry and enterprise levels should be organized so as to take into account several factors, including:

- the need for a thorough investigation of all work-related factors;
- the nature of occupational hazards and risks in the workplace which may affect workers' health;
- the health requirements of the working population;
- the relevant laws and regulations and the available resources;
- the awareness of workers and employers of the functions and purposes of such surveillance; and
- the fact that surveillance is not a substitute for monitoring and control of the working environment.

3.2 Occupational health surveillance

3.2.1 Medical examinations, health assessments and biological tests

Workers who are or have been exposed to occupational hazards, such as asbestos, should be provided with such medical examinations as are necessary to supervise their health in relation to those occupational hazards, and to diagnose occupational diseases caused by exposure to them. Surveillance of workers' health in the form of medical screening or periodic medical examinations often leads to the identification of occupational hazards or diseases. It has been shown that special prescriptive surveys to detect ill health among the working population generally prove more rewarding in terms of avoiding or controlling hazards than a series of medical tests performed at a later stage to identify or confirm suspected occupational disease. Cases of occupational disease often remain "latent" (silent) among the labour force. As a condition slowly develops, workers adapt to it, and are often unwilling to report illness that may result in the loss of their jobs.
Health examinations of workers frequently reveal the existence of health hazards in the workplace, and in such cases the necessary environmental evaluation and control measures must be implemented.
The importance of workers' health surveillance is clearly stated in paragraph 11 of the Occupational Health Services Recommendation, 1985 (No. 171), which provides as follows:

• Surveillance of the workers' health should include, in the cases and under the conditions specified by the competent authority, all assessments necessary to protect the health of the workers, which may include:
• health assessment of workers before their assignment to specific tasks which may involve a danger to their health or that of others;
• health assessment at periodic intervals during employment which involves exposure to a particular hazard to health;
• health assessment on resumption of work after a prolonged absence for health reasons for the purpose of determining its possible occupational causes, of recommending appropriate action to protect the workers and of determining the worker's suitability for the job and needs for reassignment and rehabilitation;
• health assessment on and after the termination of assignments involving hazards which might cause or contribute to future health impairment.
Pre-assignment medical examinations are carried out before the placement of workers in jobs or their assignment to specific tasks which may involve a danger to their health or that of others. The purpose of such an examination is to determine in what capacity the prospective employee can be utilized most

3.3 Fundamental principles of occupational health and safety

Fundamental principles of occupational health and safety efficiently without detriment to himself or herself or to fellow workers. The scope of pre-assignment medical examination is influenced by such factors as the nature and location of the industry, as well as by the availability of the services of physicians and nurses. Regardless of the size of the enterprise, it is advisable to conduct such examinations for all prospective employees. In the case of young people, such pre-assignment medical examinations are prescribed by specific ILO Conventions.
The pre-assignment medical examination provides clinical information and laboratory data on the worker's health status at the moment of entering employment. It is also important with regard to the worker's subsequent occupational history,as it provides a baseline for the evaluation of any changes in health status that may occur later on. The results of pre-assignment medical examinations should be used to help place workers in jobs which are compatible with the status of their health, and not to screen out workers. In some cases, prospective employees who are found to be HIV-positive may be refused employment on the basis of their health status, or those already in employment may be summarily dismissed. These practices should not be condoned.
Periodic health evaluations are performed at appropriate intervals during employment to determine whether the worker's health remains compatible with his or her job assignment and to detect any evidence of ill health attributed to employment. Their objectives include:
• identifying as early as possible any adverse health effects caused by work practices or exposure to hazards; and
• detecting possible hazards.

Changes in the body organs and systems affected by harmful agents can be detected during the periodic medical examination, usually performed after the worker has been employed long enough to have been exposed to any such hazards in the workplace. The worker may be physically fit, showing no signs of impairment and unaware of the fact that the substances he or she works with daily are slowly poisoning his or her system. The nature of the exposure and the expected biological response will determine the frequency with which the periodical medical examination is conducted. It could be as frequent as every one to three months, or it could be carried out at yearly intervals.

3.3.1 A return-to-work health assessment

is required to determine whether a worker is fit to resume his or her duties after a prolonged absence for health reasons. Such an assessment might recommend appropriate actions to protect the worker against future exposure, or may identify a need for reassignment or special rehabilitation. A similar assessment is performed on a worker who changes job, with a view to certifying him or her fit for the new duties.

3.3.2 Post-assignment health examinations

are conducted after the termination of assignments involving hazards which could cause or contribute to future health impairment. The purpose is to make a final evaluation of workers' health and compare it with the results of previous medical examinations to see whether the job assignments have affected their health.

In certain hazardous occupations, the competent authority should ensure that provision is made, in accordance with national law and practice, for appropriate medical examinations to continue to be available to workers after the termination of their assignment.

At the conclusion of a prescribed health assessment, workers should be informed in a clear and appropriate manner, by the attending physician, of the results of their medical examinations and receive individual advice concerning their health in relation to their work. When such reports are communicated to the employer, they should not contain any information of a medical nature. They should simply contain a conclusion about the fitness of the examined person for the proposed or held assignment and specify the kinds of jobs and conditions of work which he or she should not undertake, for medical reasons, either temporarily or permanently.

When continued assignment to work involving exposure to hazardous substances is found to be medically inadvisable, every effort, consistent with national conditions and practice, should be made to provide the workers concerned with other means of maintaining an income. Furthermore, national laws or regulations should provide for the compensation of workers who contract a disease or develop a functional impairment related to occupational exposure, in accordance with the Employment Injury Benefits Convention, 1964 (No. 121).

It must be mentioned that there are limitations to medical examinations, especially in developing countries, where generally the provision and coverage of health services is poor and there are relatively very few doctors. In these conditions, the heavy workload and other limitations often inhibit the thoroughness of medical examinations.
Where workers are exposed to specific occupational hazards, special tests are needed. These should be carried out in addition to the health assessments described above. The surveillance of workers' health should thus include, where appropriate, any other examinations and investigations which may be necessary to detect exposure levels and early biological effects and responses. The analysis of biological samples obtained from the exposed workers is one of the most useful means of assessing occupational exposure to a harmful material. This analysis may provide an indication of the amount of substance that has accumulated or is stored in the body, the amount circulating in the blood, or the amount being excreted. There are several valid and generally accepted methods of biological monitoring which allow for the early detection of the effects on workers' health of exposure to specific occupational hazards. These can be used to identify workers who need a detailed medical examination, subject to the individual worker's consent. Urine, blood and saliva are the usual body fluids examined for evidence of past exposure to toxic (harmful) agents. Lead concentrations in the urine or blood have long been used as indices of lead exposure.
Most biological monitoring measures are invasive procedures which may be undertaken only with legal permission. Moreover, many countries lack the laboratory facilities and other resources necessary to carry out such tests. Consequently, priority should be given to environmental criteria over bio-logical criteria in setting exposure limits, even though biological monitoring has certain advantages over environmental sampling. Biological monitoring takes account of substances absorbed through the skin and gastrointestinal tract (stomach), and the effects of added stress (such as increased workload resulting in a higher respiration rate with increased intake of the air contaminant) will also be reflected in the analytical results. Furthermore, the total exposure (both on and off the job) to harmful materials will be accounted for. Biological monitoring should not, however, be a substitute for surveillance of the working environment and the assessment of individual exposures. In assessing the significance of the results of biological monitoring, values commonly found in the general public should be taken into account.

3.3.3 Sickness absence monitoring

The importance of keeping a record of absence from work because of sickness is well recognized in various countries. Monitoring sickness absence can help identify whetherthere is any relation betweenthe reasonsfor ill health or absence and any health hazards which may be present at the workplace. Occupational health professionals should not, however, be required by the employer to verify the reasons for absence from work. Their role is rather to provide advice on the health status of the workforce in the enterprise and on medical problems which affect attendance and fitness for work. Occupationalhealth professionalsshould not become involved in the administrative management and control of sickness absence, but it is acceptable for them to provide advice on medical aspects of sickness cases, provided that medical confidentiality is respected.

3.3.4 Reporting of occupational accidents, injuries and diseases

One of the tasks of the competent authority is to ensure the establishment and application of procedures for the notification of occupational accidents and diseases by employers and, when appropriate, insurance institutions and others directly concerned, as well as the production of annual statistics on occupational accidents and diseases. Consequently, national laws or regulations in many countries provide for:

- the reporting of occupational accidents and diseases to the competent authority within a prescribed time;
- standard procedures for reporting and investigating fatal and serious accidents, as well as dangerous occurrences; and
- the compilation and publication of statistics on accidents, occupational diseases and dangerous occurrences.

This compulsory reporting is usually carried out within the framework of programmes for the prevention of occupational disease and injury or for the provision of compensation or benefits. In other countries there are voluntary systems for reporting occupational injury and disease. In either case, the competent authority is responsible for developing a system of notification of occupational diseases, in the case of asbestos for example. It must be acknowl-edged that occupational diseases are usually less well recorded than occupational accidents since the factors of recognition set out in the list of notifiable diseases differ from one country to another. Countries could use the ILO code of practice Recording and notification of occupational accidents and diseases (1995) as a basis for developing their own systems.

Whatever the system developed, it is the responsibility of the employer to present a detailed report to the competent authority within a fixed period of any accident or disease outbreak that results in a specified amount of lost working time (in many countries, three or four days). After a major accident, for example, the employer must submit a report containing an analysis of the causes of the accident and describing its immediate on-site consequences, as well as indicating any action taken to mitigate its effects. It is equally the responsibility of the employer to keep records of relevant occupational accidents and diseases. In this respect, it is worth pointing out that good record-keeping is beneficial to the company in many ways (see box 3.1).

In many countries, lists of notifiable occupational diseases have been established by statute. The records of notified diseases give administrators some idea of the extent and types of occupational pathology. This presupposes that medical practitioners are sufficiently well informed to make such diagnoses accurately and are prepared to cooperate with the authorities, which unfortunately is not always the case: some doctors may try to cover for employers for fear of losing their own jobs. Workers' compensation schemes operated by ministries of labour also have lists covering occupational injuries for which compensation may be claimed.

Where an occupational disease has been detected through the surveillance of the worker's health, it should be notified to the competent authority, in accordance with national law and practice. The employer, workers and workers' representatives should be informed that this notification has been carried out. Specifically, the labour inspectorate, where it exists, should be notified of industrial accidents and occupational diseases in the cases and in the manner prescribed by national laws and regulations.

> Box 21 Some benefits of good record-keeping
>
> The company is able to assess the economic impact of accidents in terms of production time lost, damage to machinery or raw materials, product liability and increased premiums paid to the workers compensation insurance fund.
>
> Having assessed the economic consequences and the types of accidents that most frequently occur at its workplace, the company can identify high-risk occupations and processes and devise better accident prevention strategies in future to minimize or eliminate accidents at work.
>
> An accident-free workplace enhances worker morale,improves worker-management relationships, and leads to increased productivity and fewer industrial disputes.
>
> The public image of a company improves if there are few or no accidents, and this will have a positive effect on the sale of its products.
>
> If a proper register of accidents is kept, the company will have nothing to fear when inspectors visit to inspect or investigate accidents.

Figure 3.1: Some benefits of good recordkeeping

CHAPTER 4

Prevention and protection measures

4.1 General considerations

The incidence of accidents and work-related diseases and injuries in most occupational sectors is still regrettably high; there is therefore an urgent need for preventive and protective measures to be instituted at workplaces in order to guarantee the safety and health of workers. Occupational accidents and diseases not only cause great pain, suffering and death to victims, but also threaten the lives of other workers and their dependants. Occupational accidents and diseases also result in:

• loss of skilled and unskilled but experienced labour;

• material loss, i.e. damage to machinery and equipment well as spoiled products; and

• high operational costs through medical care, payment of compensation, and repairing or replacing damaged machinery and equipment.

Occupational health problems arise largely from hazardous factors in the working environment. Since most hazardous conditions at work are in principle preventable, efforts should be concentrated on primary prevention at the workplace, as this offers the most cost-effective strategy for their elimination and control. The planning and design of workplaces should be aimed at establishing working environments that are conducive to physical, psychological and social well-being. This means taking all reasonable precautions to avoid occupational diseases and injuries. Workplace safety and health programmes should aim at eliminating the unsafe or unhealthy working conditions and dangerous acts which account for

Box 27 Duties of employers when workers are exposed to occupational hazards

In situations where workers are exposed to occupational hazards, employers have the duty to:

inform the workers of all the known hazards associated with their work, the health risks involved and the relevant preventive and protective measures;

take appropriate measures to eliminate or minimize the risks resulting from exposure to those hazards;

provide workers with suitable protective equipment, clothing and other facilities where adequate protection against risk of accident or injury to health, including exposure to adverse conditions, cannot be ensured by other means; and

provide first aid for workers who have suffered from an injury or illness at the workplace, as well as appropriate transportation from the workplace and access to appropriate medical facilities.

FIGURE 4.1: Duties of employers when workers are exposed to occupational hazards

nearly all occupational accidents and diseases. This can be achieved in a number of ways: engineering control, design of safe work systems to minimize risks, substituting safer materials for hazardous substances, administrative or organizational methods, and use of personal protective equipment. How particular occupational hazards are prevented depends on the nature of the various causal agents, their mode of action and the severity of the risk. In prescribing measures for the prevention and control of such hazards, the competent authority should take into consideration the most recent ILO codes of practice or guidelines and the conclusions of relevant meetings of experts convened by the ILO, as well as information from other competent bodies. In taking preventive and protective measures the employer should assess the risks and deal with them in the order of priority set out in box 13. In situations where workers are exposed to physical, chemical or biological hazards, the employer is bound to fulfil a number of duties: these are set out in box 27.

4.2 Engineering control and housekeeping

Engineering control involves controlling the hazard at the source. The com-petent authority should ensure that exposure to hazardous substances (such as asbestos, for instance), is prevented or controlled by prescribing engineering controls and work practices which afford maximum protection to workers. One type of engineering control involves built-in protection as part of the work process concerned. These engineering controls should be built in during the design phase; they may be implemented later, but this tends to be more costly. Engineering controls may be more expensive to implement than methods which depend on continual vigilance or intervention by the worker, but they are safer. Examples include erecting guards around machines to prevent accidents or encasing a noise source with a muffler. Another form of engineering control is the mechanization process. This involves the use of a machine to do dangerous work rather than exposing a worker to the hazard. An example is the use of an automatic parts dipper on a vapour degreaser rather than having dipped parts into the tank by hand. Where the elimination of hazardous substances is not practicable in existing plants and processes, employers or managers should apply technical measures to control the hazard or risk by changing the process, so that the job is done in a completely different and safer way, or by enclosing the process completely to keep the hazard from reaching the worker. If the problems still cannot be solved by these methods, then methods such as local exhaust ventilation could be used to control the hazard. These and other appropriate measures should be taken so that the exposure level is reduced to a level which, in the light of current knowledge, is not expected to damage the health of workers, even if they should go on being exposed at the same level for the duration of their working lives. Good work practices and working methods can ensure that hazardous materials are contained before they become a problem. Where complete containment has not been achieved, strict housekeeping and personal hygiene are absolutely essential to ensure workplace and personal safety. In the pres-ence of toxic chemicals, for instance, strict personal hygiene must always be observed so as to prevent local irritations or the absorption of such chemicals through the skin. Where hazardous substances such as lead dust in a storage battery plant or asbestos dust in brake shoe manufacture are involved, inadequate housekeeping can result in toxic materials circulating in the air. There are several ways of maintaining good housekeeping; for example:

- vacuuming is the best way of cleaning up dust, as dry sweeping often makes the problem worse

by pushing dust particles back into the air; and
• regular and thorough maintenance of machines and equipment will reduce dust and fumes.

4.2.1 Substitution

Where necessary for the protection of workers, the competent authority should require the replacement of hazardous substances by substitute materials, in so far as this is possible. For example, in the case of asbestos or products containing asbestos, national laws or regulations must provide for its replacement, if technically practicable, by other materials and products, or for the use of alternative technology, scientifically evaluated by the competent authority as harmless or less harmful. The use of asbestos, or of certain types of asbestos, or of products containing asbestos, may be totally or partially prohibited in certain work processes. It is, however, necessary to ensure that the substitute is really safer.

4.2.2 Work practices and organizational methods

Where the evaluation of the working environment shows that elimination of risk and total enclosure of machinery are both impracticable, employers should reduce exposure to hazard as much as possible, through administrative or organizational measures, so as to:
• reduce the source of the hazard, so that risks are confined to certain areas where engineering control measures can be applied effectively;
• adopt adequate work practices and working-time arrangements so that workers' exposure to hazards is effectively controlled; and
• minimize the magnitude of exposure, the number of workers exposed and the duration of exposure, e.g. carry out noisy operations at night or during the weekend, when fewer workers are exposed.

4.2.3 Personal protective equipment

When none of the above approaches is feasible, or when the degree of safety achieved by them is considered inadequate, the only solution is to provide exposed persons with suitable personal protective equipment and protective clothing. This is the final line of defence and should be used only as a last resort, since it entails reliance on active cooperation and compliance by the workers. Moreover, such equipment may be heavy, cumbersome and uncomfortable, and may restrict movement. Employers should consult workers or their representatives on suitable personal protective equipment and clothing, having regard to the type of work and the type and level of risks. Furthermore, when hazards cannot be other-wise prevented or controlled, employers should provide and maintain such equipment and clothing as are reasonably necessary, without cost to the workers. The employer should provide the workers with the appropriate means to enable them to use the individual protective equipment. Indeed, the employer has a duty to ensure its proper use. Protective equipment and clothing should comply with the standards set by the competent authority and take ergonomic principles into account. Workers have the obligation to make proper use of and take good care of the personal protective equipment and protective clothing provided for their use.

4.3 Technological change

Technological progress can play an important role in improving working conditions and job content, but it can also introduce new hazards. Great care should therefore be taken in both the choice and the international transfer of technology in order to avoid potential hazards and ensure that the technology is adapted to local conditions. Management should consult with workers' representatives whenever new technology is introduced. The hazards associated with technologies (equipment, substances and processes) used at the work site must be identified and effective measures taken to eliminate or control them. This means that safety factors should be built in, and that working conditions, organization and methods should be adapted to the characteristics and capacities of workers. The introduction of new technology should be accompanied by adequate information and training. Furthermore, potentially dangerous machinery, equipment or substances should not be exported without adequate safeguards being put in place, including information on safe use in the language of the importing country. It is the duty of the governments of importing countries to review national legislation to make sure that it includes provisions to stop the import of technology detrimental to occupational safety and health or working conditions.

CHAPTER 5

Ergonomics andm safety

5.1 Introduction

A number of key principles underpin the field of occupational safety and health. These principles and the provisions of international labour standards are all designed to achieve a vital objective: that work should take place in a safe and healthy environment.

CHAPTER 6

Psychosocial risk in the workplace and its reduction

6.1 Introduction

The past few decades have brought significant changes to the characteristics and conditions of performed work. The significance of heavy manual labour, performed in extremely tough external environments using imperfect—at least compared to the contemporary—tools and machines has decreased, while the importance of clerical work and service sectors has increased. These types of work are often per-formed in huge, sometimes international organisations, and usually require a level of cooperation among various categories of coworkers, supervisors, and customers. The market's globalisation and greater competition among related companies have a significant impact on the characteristics of work. This competition forces a constant growth in work intensity, as well as an organization's continued transforma-tion to accommodate its newest needs. It may cause employees to feel overwhelmed with work and unable to follow ongoing changes with regard to the job's insecurity. Moreover, companies striving to achieve more flexibility have been searching for new forms of employment: fixed-time employment, part-time contracts, outsourcing, and temporary employment. Such new forms of employment usually have lower security and stability.The above situation is one in which the social and organisational layer of work is the main source of stress, rather than the physicochemical work conditions. The fourth European survey of work conditions, conducted by the European Foundation for the Improvement of Living and Working Conditions (Parent-Thirion et al. 2007), reported stress to be the second most common cause of ailments, dwarfed only by musculoskeletal disorders. Among the employees of the 27 countries of the European Union (EU), 22percent have suffered stress (25percent reported musculoskeletal disorders). Stress-related problems occur more often in countries that have recently joined the EU. Moreover, a comparison of Eurofund surveys from 1995, 2000–2001, and 2005 shows they are on the rise in new member states (NMS), including Poland. The relevant data are shown in Table 6.1. As shown in the table, in 2000–2001, the level of stress was similar in both old member states (OMS) and NMS of the EU (28percent each). However, in 2000–2005, this level decreased to 20percent in OMS. At the same time, the levels of fatigue, irrita-tion, and headaches also decreased. A reverse trend was found to exist in NMS. The prevalence of stress grew slightly in these countries in 2001–2005 (from 28 percent to 30percent). Some stress-related problems also increased; for example, sleeping problems and headaches increased from 8 percent and 15 to 12 and 24 percent, respectively. Due to (Table 6.1 Stress and Stress-Related Symptoms: Trends over Time).

The reversal of previous trends, the difference in stress prevalence between OMS and NMS in 2005 also grew compared to 2000–2001. In 2005, stress prevalence in NMS was markedly higher than that in the EU 15—work-related stress was reported by 20 percent of OMS and 30 percent of NMS. Other stress-related conditions (except for anxiety) were also found at higher levels in NMS. According to the same survey, around 35 percent of the employees in Poland suffered stress at the workplace.

Question	EU-15			CC-12	NMS-10
	1995[a]	2000[a]	2005[b]	2001[c]	2005[b]
Does your job influence your health? (% yes)	57	60	31	69	56
Stress (% yes)	28	28	20	28	30
Fatigue (% yes)	20	23	18	41	41
Headaches (% yes)	13	15	13	15	24
Irritation (% yes)	11	11	10	11	12
Sleeping problems (% yes)	7	8	8	8	12
Anxiety (% yes)	7	7	8	7	7

Sources: [a] Paoli, P., and D. Merllie. 2001. *Third European Survey on Working Conditions 2000.* European Foundation for the Improvement of Living and Working Conditions. Luxembourg: Office for Official Publications of the European Communities.

[b] Fourth European Working Conditions Survey. 2005. Statistical annex. http://www.eurofound.eu.int/docs/ewco/4EWCS/4WCS_Annex%20statistical%20annex.pdf (accessed August 8, 2008).

[c] Working conditions in the acceding and candidate countries. 2001. Polish language version. http://www.eurofound.eu.int/publications/htmlfiles/ef0306.htm (accessed August 8, 2008).

Note: CC = candidate countries.

FIGURE 6.1: Stress and Stress-Related Symptoms: Trends over Time

6.2 Why Psychosocial Job Characteristics Are a Source of Risk—the Mechanism of Stress

The mechanism of stress is the psychosocial property that explains the influence of work on the organisation's health. It justifies the usage of the term 'psychosocial risks'.

6.2.1 Concept of Stress

The concept of stress was introduced in the 1930s by physiologist Hans Selye, who defined it as 'the non-specific response of the body to any demand placed upon it' (Selye 1977, 14). This concept of stress works in both physiology and psychology. Its definition has undergone variations, not only as a reaction of the organism as the author would suggest, but also as the incentive to the reaction, as well as the interaction between entities and environments (see reviews by Reykowski 1966; Heszen-Niejodek 1996; Widerszal-Bazyl 2003). On the basis of the various approaches and studies, the meaning of the term here will be as follows: Stress in the workplace is a psychophysiological response to a situation in which the environment's requirements exceed the employees' capabilities or border such limits.
Because stress is a psychophysiological response, it can be described in terms of physiology and psychology.

6.2.2 Stress at the Physiological Level

At the physiological level, the three following axes are the most characteristic of stress (Everly and Rosenfeld 1992): The first axis—direct agitation of internal organs by the autonomic nervous system. Brain impulses (from the hypothalamus) agitate the autonomic nervous system, innervating the internal organs. The autonomic nervous system consists of the sympathetic and parasympathetic parts, which are antagonistic to each other. The sympathetic circuit is especially impor-tant (although not exclusively) in relation to stress mechanics. Its agitation causes, among other effects, the following symptoms:

- Pupil dilation
- Sweat-gland agitation
- Heart-rate acceleration
- Musculoskeletal blood vessel extension
- Stenosis of the blood vessels of the skin
- Extension of gills (acceleration of respiration rate)
- Decomposition of glycogen and release of cellohexaose in the liver

The second axis—neurohormonal (also called the hypothalamic-adrenal axis). Impulses are delivered to the hypothalamus from the tonsillar body (a part of the limbic system), and then pass through the autonomic nervous system to the core of the adrenal capsule, which in turn releases adrena-line and norepinephrine, sometimes called the 'stress hormones', into the blood circulation. Their effects are often similar to those brought on by stimulation of the first axis, however, those are more delayed and tenacious. Adrenaline and norepinephrine create, among other symptoms, the follow-ing effects:

- Increase in arterial blood pressure
- Increase in cardiac output
- Increase of free fatty acids, cholesterol, and triglycerides in the blood plasma
- Increase in muscle tension

The third axis—hormonal (also called the hypothalamic–pituitary–adrenal axis). This axis consists of three circuits that are more or less separate. We will focus on the hypothalamus, the most substantially diagnosed and described. The hypothalamus, through the hormonal canals, agitates the most important vessel for internal incretion, the pituitary gland. The gland then releases adrenocorticotropic hormone (ACTH) into the blood circu-lation, stimulating the adrenal capsule's crust to release glucocorticoids (the most recognisable is cortisol). Glucocorticoids cause the following symptoms:

- Increase in glucose production
- Increase in levels of free fatty acids in the blood
- Inhibition of immunological functions

6.2.3 Stress at the Psychological Level

At the psychological level, the emotional reactions most often caused by stress are anger, fear, and frustration. Cognitive reactions are strongly linked to emotional reactions and can be described as our feelings about the situation ultimately over-whelming and threatening us, thereby lowering our self-esteem or even causing us to find hostility all around us. The efficiency of rendition, observed on the behavioural level, varies in accordance with general emotional agitation in agreement with the classical rule of Yerkes–Dodson, which claims that the efficiency of performance is subject to agitation. With a slight increase in emotional agitation, we can observe an increase in performance efficiency (in terms of insight, memory, focus, motor skills, and intellect), whereas a large increase in emotional agitation is followed by a decrease in efficiency. Important psychological factors come into play in the stress reaction, and must be considered in the process of restoring balance between entities and environments. Ways of restoring balance, or in other words, ways of dealing with stress in the workplace, can differ significantly. The solutions are as diverse as the threatening situations and human characters. However, various authors offer certain general cat-egories of ways to deal with stress (Heszen-Niejodek 1996; Wrzesniewski 1996). We shall cite herein the classification offered by Lazarus and Folkman (1984), who detailed four ways of dealing with stress.

Seeking information: Information is sought so that one may be more effec-tive in reaching a goal or in dealing with failure or an existing threat more easily (e.g., one would gather information to indicate that the failure is not as big or the goal is not as attractive as first presumed). Taking direct actions: This category includes almost an infinite number of possible actions. The actions are aimed at either changing the surroundings to better suit the entity's abilities and values or at changing the entity itself to lessen the divergence between the entity and the surroundings.

Holding back actions: Lazarus regards this category to be an important countermeasure. In the modern world, it is sometimes best not to take action to most effectively dispose off the threatening stress.

Intrapsychic methods: These are based on changes in the perception of the environment or ourselves in order to mitigate the divergence between the surroundings and the entity. Their significance lies mostly in their sedative

activity and ability to reduce feelings of emotional upset. We include defensive mechanisms such as distancing the mind (erasing from aware-ness the problems causing the stress), projection (assigning our emotions and traits to other people), perfunctory reactions (disregarding real motives while acknowledging opposite and fake motives), repression (disregard-ing thoughts or motives that may cause feelings of guilt), and many others (Grzegolowska-Klarkowska 1986).

6.2.4 Stress and Diseases

Either long-lasting or especially intense stress may bring on damage to an organ or even a whole system, thereby leading to disease. Almost every disease can be a derivative of stress to some extent. On the contrary, we cannot say that there is a definite connection between even a strong

stress and any disease. Such a situation is a nondirect state and is also connected to many secondary factors, such as genetic inclination, type of the cause of stress, acquired habits of reaction under various situ-ations, and many others (Everly and Rosenfeld 1992). All these elements together decide whether the disease occurs and, if yes, how is it going to manifest. Connections between psychosocial stress and the ailments described next are often observed.
Cardiovascular diseases (especially coronary heart disease, heart failure and hypertension): Chronically high levels of catecholamines and gluco-corticoids lead to arteriosclerosis (a significant reduction in the capacity of blood vessels, including coronary vessels) and increased blood pressure, causing heart attacks and heart failure.
Distortion of the digestive system (especially peptic ulcers): The inordi-nate release of gastric juice caused by stress in addition to some genetic
inclinations may cause gastric erosion.
Musculoskeletal disorders: Stress causes an increase in the tension in stri-ated muscles. If the duration of the contraction is too long, less blood flows through the muscle, while the number of metabolic by-products simultane-ously increases. Consequently, pain occurs. Some headaches have a similar mechanism.
Decrease in immunological resistance: The immunological system has long been acknowledged to be fairly independent of the central nervous system, while reacting mainly to intruding antigens (foreign bodies). Current research, however, clearly shows that the brain—and through it, received psychoso-cial signals—has an impact on the immunological system. The cause lies either in the autonomic nervous system (which innervates the organs of the autonomic nervous system such as the marrow, thymus, and lymph nodes) or in the hormones secreted. The T and B lymphocytes, playing a major part in the organism's immunological capabilities, have stress-sensitive receptors, reacting to adrenaline, norepinephrine, glucocorticoids, and other hormones. Psychosocial stress is a possible cause of a decrease in various aspects of the immunological response, such as maturation and partition of some forms of T lymphocytes. The new, exciting field devoted to the relationship among psychic topics, the nervous system, and immunol-ogy is called psychoneuroimmunology (Maier et al. 1997; Sheridan and Radmacher 1998). A decrease in immunological resistance increases the chances for various viral, microbial, and degenerative diseases. A decrease in immunological resistance under the influence of the psychosocial stresses listed below is also perceived as an important mechanism of tumour generation (Sheridan and Radmacher 1998; Zakrzewska 1989).
•States of anxiety and depression
•Professional burnout
Professional burnout was first described in 1974 by psychiatrist H. Freudenberger and later popularised by research papers published by Ch. Maslach, a social psychol-ogist, and her formulation of the measurement tool. In the beginning, burnout was connected to jobs related to direct services or helping other people; thus, it included nurses, teachers, doctors, social workers, and so on. The high emotional demands necessitated by such professions might have led to the first strong symptoms of stress. According to Maslach, they can be included under three main categories:

Emotional exhaustion: Subject appears to be in a depressed mood, anxious, dejected, disillusioned; may have feelings of helplessness and frustration, as well as constant fatigue and somatic ailments.
Depersonalisation: This term is used to describe a lukewarm or even a hostile position towards a charge, and means that they are treating somebody more as an object than as a sensitive person. Such effects have been acknowledged to be the outcome of an objectionable manner of dealing with stress, caused by high demands in the workplace, but mainly resulting from use of defensive techniques such as distancing. Depersonalisation causes the person to back down from tough emotional problems, as well as intellectualise the issue (think about patients in medical terms only), use professional parlance or offensive language ('they behave like animals'), and escape physical contact (dodge eye contact).
Sense of lack of accomplishment at work: The subject shows pessimism towards the possibility of helping a charge, low professional self-esteem and feelings of underestimation and failure.
Burnout is most often observed among young people with no more than 2–3 years of professional experience, especially among those who begin their work with high, usually idealistic, expectations of their role in the company and the significance of their work (Schaufeli and Enzmann 1998). Later versions of the burnout concept (Maslach and Leiter 1997) pertain to the effect not only to jobs devoted to helping or service but also to many other professions. The three symptom groups described above can be classified under three general categories: exhaustion, cynicism, and ineffectiveness. A scale of measurement of such general phenomena was developed (Schaufeli and Enzmann 1998) but has not been adopted in Poland so far. However, vast empirical resources have been gathered thus far regarding the burnout effect, and the majority of jobs described involve the service fields

6.2.5 Consequences of Stress at the Organisational Level

Stress on employees affects the functioning of the whole company, which can lead to the following:
• Increased absences: According to data gathered in the United States, American industry has been losing 550 million labour days annually due to absences, with 54percent of absences said to be caused by stress. Similar data were gathered in the United Kingdom; the industry there has been losing 360 million labour days annually, with half that number caused by stress in the workplace (Cooper et al. 1996).

• Lowered productivity: Productivity declines when stress increases. Even if the employees are present at work, the quality of their services and products is lower.

• More accidents: Inordinate stress levels increase the probability of a mis-take and, consequently, an accident. Some experts estimate that stress is responsible for 60–80 percent of accidents in the workplace (Cooper et al. 1996).

• Higher job turnover: Results of research over the burnout effect among nurses show that (Schaufeli and Enzmann 1998) depersonalisation was associated with job turnover 2 years later. Similarly, positive associations were found between emotional exhaustion and job turnover among teachers within 1 year, and among general practitioners within 5 years (Schaufeli and Enzmann 1998). However, the percentage of variation in fluctuation explained by the range of burnout, although significant, was not high and ranged between 1 and 5 percent.

• Increase in costs related to higher morbidity rate: Treatment costs for dis-eases that are a consequence of stress are best visible in United States, where an employer is directly charged with treatment of his or her employees. In European countries, such costs are more hidden, which does not mean that they are nonexistent. According to the British Health Foundation, the evalu-ated loss of companies employing 10,000 people due to cardiovascular dis-orders (where we recognise stress as an important risk factor) can be split up as follows:

• 2.1 million pounds lost due to lowered productivity of male employees and 340,000 pounds due to lowered productivity of female workers.

• Loss of 35 men and 7 women (due to coronary heart disease among others).

• Truancy of 59,000 labour days for men and 14,000 for women.

The full evaluation of costs must include a whole range of other diseases we men-tioned previously, significantly increasing the above numbers. According to the British evaluation, if we scale the results to the whole country, the costs of stress in the workplace in the United Kingdom reach 10 percent of the gross national income (Cooper et al. 1996).

6.3 Psychosocial Risk Factors in the Workplace

In literature, one may find various classifications of stress-causing factors pres-ent in the workplace or, in other words, classification of psychosocial risk types. Cooper and Marshall (1987) name five categories of factors: those related to work itself, to the role of the employee in the organisation, career development, rela-tions among the employees, the organisational structure, and the work climate. Below is a different classification, which mirrors the main directions of research in the field.

6.3.1 bextbfVery High Quantitative and Qualitative Demands

The most common problems in modern work environments are too much work and pressure that the work be done quickly. According to the European Agency for Safety and Health at Work, the intensity of work is one of the major types of psychosocial risk (European Agency for Safety and Health at Work 2007). In surveys on European work conditions, conducted between 1991 and 2005, there is a continuous growth in the number of respondents who report that they work at a very high speed at least three-fourths of their time (Figure 6.1). In 2005, 46 percent of respondents selected this answer (in the EU-25), whereas in 1990, 35 percent selected this answer (for the EU-12). The same survey also shows that there is a rise in the number of workers who report working under tight deadlines around three-fourths of the time or more. Intensive work can become a source of satisfaction and personal development when there is a significant amount of autonomy. Nonetheless, there are many epidemiological research articles showing high quantitative demands at work are

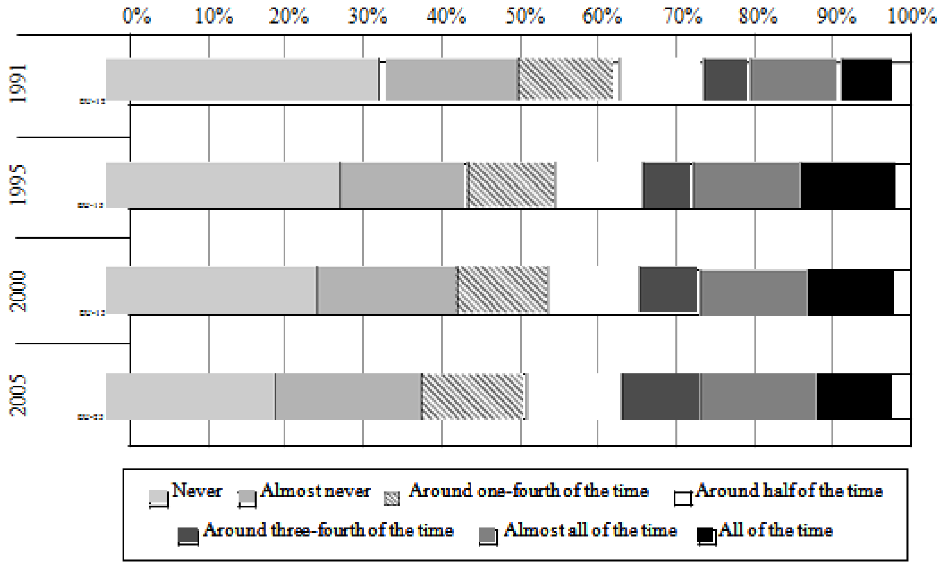

FIGURE 6.2: Figure 6.1 Percent of workers working at a very high speed.

connected with the health loss in employees. Previous and current research leads to the same conclusion. Margolis et al. (1974) surveyed a representative number of employees in the United States aged 16 and over, for a total of 1496 people. The authors found that work overload was related to the following indicators of stress: excessive use of alcohol, work absenteeism, and lower self-esteem.

A more recent study reported by Dutch researchers (de Jonge et al. 2000) involved a sample of 1700 workers; it showed that high demands were significantly related to lower job satisfaction, higher emotional burnout, a slightly higher level of depres-sion, and more frequent psychosomatic symptoms.

Psychosocial risks can also be caused by excessive qualitative demands at the workplace, meaning work that is too hard or complex. Caplan et al. (1975) surveyed representatives from 23 countries and certified that the higher the subjective com-plexity of work (in terms of employee preference), the greater are the symptoms of depression among the surveyed people. Excessive qualitative demands may also involve an excessive amount of work: someone who has to perform a difficult task will have to work longer and more intensively.

6.3.2 Very Low Quantitative and Qualitative Demands

Psychosocial risks may be also caused by situations totally opposite to those men-tioned previously, that is, a very low level of stimulation or satisfaction from the performed work. Such situations involve performing jobs that may seem dull, repeat-able, and are usually very much below the employee's potential abilities. Risks are also related to jobs that require physical isolation, for example, in Arctic stations, in submarines, or during wardenship. Even professions commonly described as highly demanding and connected, with a high level of stimulation, may lack stimulation over a longer period of time, for example, among guards or pilots. In psychology, an effect of 'solitary altitude' is described among pilots (Terelak 1995). It occurs above certain heights and is usually recognised as losing touch with reality and a feeling of abruption from the Earth. It is accompanied by feelings of anxiety, apathy, and an urge to break out of the situation. The current part-time professions, considered dull, not only refuse to vanish but, on the contrary, their range has been increasing due to ongoing automation and com-puterisation, embracing even broader social areas related to production, services, and administration.

6.3.3 Emotional Demands

Emotional demands are a significant source of stress, especially in jobs that entail frequent contact with other people, that is, predominantly in the service sector. The role of this sector has been steadily growing in all the developed economies of the world. In 2005, this sector made up 66 percent of the labour force in the EU (Parent-Thirion et al. 2007). Consequently, the importance of psychosocial risk, such as high emotional demands, has also been growing. Contact with other people, such as cli-ents, students, patients, and so on, is frequently a source of negative emotions such as sadness, helplessness (e.g., when faced with suffering or an incurable disease), anger (e.g., toward a tedious client), irritation, and impatience (e.g., toward a lazy student). Generally accepted standards do not permit display of emotions; people who help are expected to be composed and friendly. Thus, they are penalised twice: not only are they more prone to experiencing negative emotions compared to those doing other jobs, but they are also expected to suppress these feelings and display emotions that are incompatible with those they are actually experiencing. A high level of emotional demand is related to a low level of mental well-being (Zapf 2002); it is conducive to professional burnout and behaviours incompatible with the standards of the organi-sation or profession (Bechtoldt et al. 2007).

6.3.4 Low Job Control

Job control is the possibility of influencing one's work (its methods, pace, breaks, and so on) and the conditions in which it is performed. The importance of job control has been underlined in psychology for a long time. Having control, not using it, is the most important (Glass et al. 1971). Control of an employee in the work environment is being reassessed in two aspects—job autonomy and participation in decision making. Although these terms are similar, they refer to slightly different effects. We can use 'autonomy' if this person is in charge of the assigned tasks and their results. In other words, no one is expected to interfere with the employee's job; he or she is self-reliant. We can use 'participation' if an employee shares the responsibility of

the work-place decision-making process more broadly, not only in relation to his or her duties. Limitations in both forms of control should be considered psychosocial risk factors. As early as the 1960s, Kornhauser (1965) pointed to the negative mental effect of limited control as related to the necessity to work at a pace imposed by a machine. In his study, only 13 percent ofworkers working at a pace imposed by a machine were mentally healthy, whereas 29 percent of workers doing repetitive work at their own pace were mentally healthy.
The latest British research confirms the negative health effects of lack of control. The British Whitehall II project (Marmot et al. 2002) has been going on for more than 10 years, with over 10,000 civil servants as subjects. The results indicate that new cases of ischaemic heart disease (registered over a period of 5 years) are sig-nificantly more common in workers with low job control compared to workers with high job control. It is worth pointing out that the results were the same regardless of whether the worker or the supervisor was assessing the level of control (Bosma et al. 1998). Polish studies conducted in a group of more than 300 managers at the Central Institute for Labour Protection—National Research Institute (CIOP-PIB) also proved that perceived job control was a predictor of certain symptoms of mental health, such as an increased level of anxiety and a decreased level of curiosity on Spielberger's State-Trait Personality Inventory (STPI) scale, a higher score when measured with the Beck Depression Inventory, a lower assessment of the quality of life on the Cantril ladder, and a higher frequency of somatic complaints (Widerszal-Bazyl 2003).
Jackson (1983) conducted sedulous research in the workplace. Two groups of hospital staff participated. In the experimental group, the surveyed people were given a chance to participate in the decision-making process in their department. Supervisors were trained and instructed to organise meetings with employees at least twice a month. The control group was not given such a chance. Tests conducted half a year after the experiment clearly showed that participation in decision making decreased role conflict and ambiguity (see below), which in turn led to lowered ten-sion and higher satisfaction.
The results of research on the psychological outcome of participation in the decision-making process are not consistent. This is due to the fact that participation itself has various forms: formal and informal, voluntary and coercive, and direct and indirect. The possibility of each of these forms leading to specific results should not be ruled out. On the contrary, research seldom diversifies individual types of participation.
Spector (1986) has conducted a meta-analysis of 88 studies containing participa-tion results. Just three (totalling N = 213 of respondents) measured subjective physical ailments. Their average correlation with participation equalled r = 34. Therefore, an average correlation of participation with bad mood equalled r = 18; the equation was based on research from four groups (where N = 300). The relationship between participation and satisfaction is stronger. Spector (1986) reviewed 17 studies of the relationship between participation and satisfaction and observed an average correlation equal to r = 44. The relationship between participation and behavioural measures of stress is not strong; however, it is noticeable. Based on his analysis and research review, Spector derived the following average correlations for participation at various levels:

- r = 0.23—study level (6 studies, 1343 people)
- r = 0.20—intention of leaving the job (4 studies, 1451 people)
- r = 0.38—actual job switch (3 studies, 358 people)

6.3.5 Job Insecurity

Job insecurity as related to the dynamic changes in the job market is an important stress-causing factor in many work environments. In a survey conducted in the 27 EU member states by the European Agency for Safety and Health at Work, 11.3 percent of 'old Europe' respondents and 25.6 percentof 'new Europe' respondents agreed with the following statement: 'I can lose my job within the next 6 months'. Insecurity was especially visible in Poland, with 26.6 percentof respondents agreeing, outpaced only by the Czech Republic and Slovenia.
Empirical research has shown a lot of evidence for job insecurity as an important risk factor for employees' health. A meta-analysis by Sverke et al. (2002) covered 37 studies on this topic conducted between 1980 and 1999; 14,888 subjects were involved. Analysis showed the correlation between job insecurity and poorer mental health to be r = 0.24. This relationship was also confirmed by longitudinal analy-ses, which unambiguously showed that job insecurity should be considered a cause of poor mental health, whereas the inverse relationship, the effect of poor mental health on the perception of job insecurity, although theoretically possible, was not statistically significant (Hellgren and Sverke 2003). The relationship between job insecurity and physical health has been analysed less frequently. Another meta-analysis of Sverke et al. (2002) covered 19 such studies with a total of 9704 subjects. It showed that the mean correlation was r = 0.16, which means that the greater the insecurity, the poorer is the physical health. Usually, researchers include the sub-jects' opinions regarding their health, which form a basis for the statement that high insecurity is related to a lower assessment of one's own health, higher frequency of somatic disorders (such as headache and back pain), and an onset of chronic dis-eases. It is important to point out that the longitudinal studies did not confirm the effects of job insecurity on somatic disorders experienced a year later (Hellgren and Sverke 2003). However, the authors are right in pointing out that the cause-and-effect relationship between job insecurity and physical health should be considered open for the time being because it is impossible to say whether one year is too short a period to reveal somatic disorders. A few researchers have studied the physiological indicators of health and claim that job insecurity may be related to higher systolic and diastolic blood pressures, ischaemic heart disease, and elevated body mass index (BMI*; Ferrie et al. 1998, 2001).

6.3.6 Role Conflict and Ambiguity

A person has plenty of important social roles in the workplace: a charge, supervisor, colleague, mentor, and so on. Some aspects of these roles may be important sources of psychological stress. A lot of focus has been devoted to two parameters of jobs: role clarity and role conflict. The basics of knowledge in this field were laid more than 30 years ago by Kahn et al. (1964) and there has been a lot of interest in this topic since then. The clarity of a role can be described as a 'level of clarity in communicating goals and responsibilities to employees and a level of comprehending processes needed to achieve goals by employees' (Sawyer 1992, 130).

Usually, lack of clarity is a problem for high-level staff in an organisation (Schuler 1975). Fisher and Gitelson (1983), who conducted a meta-analysis of 42 studies on role clarity and its causes and results, observed that lack of clarity is mostly a prob-lem to people who perform complex tasks and are well educated. In a study by Kahn et al. (1964), the lack of clarity in a role is a reason for either lower job satisfac-tion or leaving the job. This dependence was not too strong, although statistically noticeable.

Margolis et al. (1974) conducted a study in the United States in a representative sample of subjects (N = 1496); they found that unclear roles were related to depres-sion, lower self-esteem, dissatisfaction with both life and job, and the intent to quit work. However, though these relationships are statistically significant, they are not very strong.

Exhaustive research has been done regarding the importance of role clarity and its relationship to the burnout effect. A meta-analysis of 38 studies concerning this problem (Pfenning and Husch 1994; cited after Schaufeli and Enzmann 1998) clearly showed a strong correlation between the two. Lack of role clarity has a lot in common with the professional burnout effect (14 percent of collective variation), dep-ersonalisation (8 percent of collective variation), and lack of achievement at work (10 percent of collective variation), thereby possessing all major components of the professional burnout effect.

Another important parameter of the professional role as a source of psychosocial risk is called role conflict. This term can be described as a 'coincidental appear-ance of at least two role transmissions', or demands made by the environment to the employee performing a certain performing one task certainly excludes the possibil-ity of performing the other because the assignments are clearly adverse (Katz and Kahn 1979, 286).

Employees bordering the organisation who are in contact with other companies as well, are especially vulnerable to role conflict. Internal workstations are less vulner-able to such risk, although employees working for more than one department may feel more threatened than others.

New roles, usually developed to break stereotypes of behaviour and ways of deal-ing with problems in a given environment, are more at risk for role conflict. The scale of conflict depends on two factors: (1) who is transmitting the message that delivers the conflict and (2) the concerned person's position in the organisation and influence on other employees. The bigger this influence, the greater the conflicts may become. Role conflicts may lead to mental and physical health losses.

6.3.7 Mobbing

According to the Polish labour code, mobbing is an 'act or behaviour aimed at or against an employee, especially resting upon a long-lasting and systematic harass-ment, and threatening an employee, causing his professional self-evaluation to decrease, as well as aimed at humiliating

and gibing an employee, keeping him or her away from other employees, or eliminating him or her from the team of employees' (Labour Code 2009, article 94).
Although mobbing sometimes means an act of physical aggression, it is most often seen as psychological violence. Some authors distinguish mobbing as (1) personal, such as yelling, offending, gibing, threatening, ignoring, or nasty jokes, and (2) that related directly to the work aspect: unrealistic task deadlines, too much work to do, tasks below abilities, constant control, and hiding important information. Some of the above-mentioned behaviours may be very discreet and indiscernible by other employees.
Polish labour code requires employers to counteract mobbing in their workplace (Labour Code 2009, article 94). An employee who suffers health loss due to mobbing can come forward with financial demands of his or her employer, as well as request compensation if he or she chooses to terminate the contract due to mobbing (Labour Code 2009).
Mobbing has consequence for both an employee and the organisation. A victim of abuse usually suffers high stress, which may lead to physical and mental health losses if it is long lasting. Post-traumatic stress disorder (PTSD) is also possible. PTSD is usually diagnosed if a victim of abuse lasting for at least a month constantly suffers upsetting flashbacks and feelings related to the violence, is trying to run away from thoughts, feelings, and places related to the abuse and seems to be constantly agitated. Such syndromes are often accompanied by depression, anxiety, fear, addic-tion, or even suicide attempts.

6.3.8 Interpersonal Relations and Social Support

We all know that good relationships with other people at work are important to our well-being. Not only should those in the work environment try to avoid conflicts, but should also actively support employees. Such support may take various forms. Usually, we can distinguish the following (House 1981) types of support:
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6.3.9 Stages of Occupational Career as a Source of Risk

Successive stages in a person's professional career can be a source of characteristic forms of stress. A considerable amount of focus has been devoted to the beginner's stage. Potential stress-causing factors at this stage are often related to shock caused by a difference between naïve expectations and the reality of work, confusion, lack of confidence, and the need to determine one's work and role in the company, strike up relations with superiors and workmates, and understand the rules and prize systems in the workplace (Burke 1988). Professional burnout is most likely to show up at this stage of the career and objectionable work conditions only fuel its strength. Cherniss (1980) names five sources of stress likely to appear in jobs related to helping other people: lack of confidence in professional skills, lack of appreciation from custom-ers, bureaucratic procedures that aggravate work, lack of stimulation followed by a feeling of monotony, and lack of teamwork and support from colleagues.
The current focus is on older employees beyond the peak of their careers, between 50 and 65 years old. The most important stress-causing factors in this period are (Burke 1988) the need to deal with new technology, lack of promotion possibili-ties, likelihood of decrease in efficiency, need for additional training, discrimination, financial problems, and health problems for the employee and his or her spouse.

6.4 Models of Psychosocial Stress at Work

Discussions and studies on psychosocial risk at work have resulted in several interesting models (Siegrist 1998) that reveal the most important mechanisms of this phenomenon. The two that have had the greatest influence on contemporary thinking on psychosocial risk and have inspired the greatest number of studies are the demand–control–support (DCS) model and the effort–reward imbalance (ERI) model. A third model, demand–resources, is a synthesis of those two.

6.4.1 Demand–Control–Support Model

American researcher Robert Karasek (1979) formulated the first version of the DCS model. He assumed that two dimensions of the work environment, demand and control, have basic significance for the workers' perception of stress. Karasek understood that demand primarily involves quantitative demands* (a lot of work, tight deadlines) and demands that result from role conflict. Control was explained as a component of two subdimensions: skill discretion (the level of skill and creativity required on the job) and decision authority (the possibility for workers to make decisions about their work).

- Emotional support: Showing sympathy, interest, kindness, and so on.
- Instrumental support: Concrete forms of support, for example, solving a difficult problem.
- Informational support: Delivering information crucial to solving problems.
- Evaluational support: Giving opinions on a person's appearance, behaviour, and speech.

Social support can have many effects on the employees' health. First, the kindness of the environment may become a shield that keeps out stress-causing factors. As a result, there are no stressful reactions, with no health consequences to follow. In a harmonious workplace, employees are unlikely to be unfairly punished.

Second, if the surrounding environment has many stress-causing factors, social support may become a buffer that shields employees from any negative impact on their health. The reason for this effect is probably 'blunting of the blade', which allows the person to deal with problems more effectively by lowering both stress and the negative impact on health.

Third, there are direct relations between an employee's well-being and social support. A person surrounded by kindness feels better and more confident even if working under the influence of other stress-causing factors.

Many studies have indicated a relationship between the amount of support received and an employee's health. An example can be found in the following Swedish undertaking:

Hoog and Eriksson (1993) conducted research on 150 female computer opera-tors, trying to identify factors that play an important part in the occurrence of skin diseases. One such factor appeared to be their superior's support when given a lot of work. With stronger support, a lesser chance for skin disease was observed. However, given a small amount of work, no relation between the superior's support and the probability of skin disease was observed.

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In his model, Karasek identified the following four main situations (Figure 6.2), which differed in two critical dimensions: High demand–low control is the most stressful situation. Workers are faced with high demand, but are not given adequate latitude or means to meet those demands. This creates psychophysiological stress, which, if extensive, leads to anxiety, depression, and risk of a somatic illness. High demand–high control creates conditions for personal development. Workers are faced with difficult tasks, but they can model their behaviour in such a way that they can meet their goals. Low demand–low control neither stimulates activity, because demands are low, nor allows action or control. This causes passivity both in occupational life and in the way free time is spent. Seligman (1975) described similar phenomena as 'learned helplessness'. The individual has no opportunity to develop. Low demand–high control is the

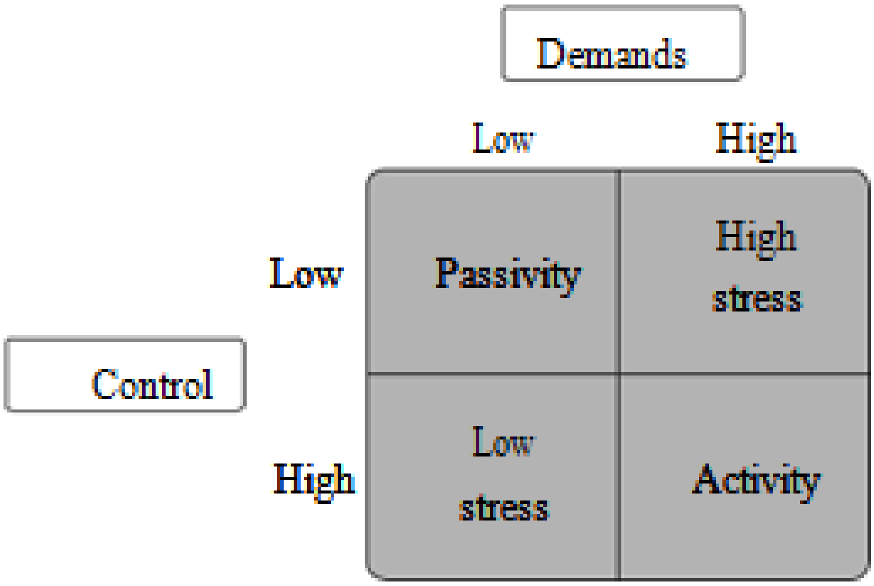

Figure 6.3: Karasek's demand–control model.

most relaxing situation, causing the least stress. High control makes it possible to react optimally to every unchal-lenging demand. The risk of poor mental well-being or a psychosomatic illness is low. Many studies have confirmed the demand-control model, proving that when demands are high and control is low, mental, cardiovascular, musculoskeletal, or immunologi-cal disorders are significantly more frequent. An example of this type of research is an epidemiological study conducted in Stockholm (Theorell et al. 1998) involving men ages 45 to 64 who had their first myocardial infarction between 1992 and 1994. The results were as follows: consider-ing the ratio of demand to control and forming a subgroup from the upper quartile of this index (namely, people who perceive their demands as high when compared with the possibilities of control), the risk of infarction in this subgroup is almost one and a half times higher than that in the other subgroups (relative risk [RR] = 1.4). After eliminating many possible confounding variables, such as smoking cigarettes, hypertension, cholesterol level, social class, and so on, the rate of infarction risk was slightly lower but still significant (RR = 1.3). Johnson and Hall (1988) and Karasek and Theorell (1990) further developed the DCS model. They pointed to a third important dimension of the psychosocial work environment, which determined the level of stress—social support. According to this model, stress is highest when high demands coexist with low levels of control and social support. A few studies have confirmed this extended model (cf. reviews by De Lange et al. 2003; Widerszal-Bazyl 2003).

6.5.2 Job Demands–Resources Model

The job demands–resources (JDR) model was proposed by Demerouti et al. (2000) and Bakker et al. (2003); it is a synthesis of the DCS and ERI models. The JDR model distinguishes two categories of work conditions: demands and resources. According to Demerouti, 'job demands refer to those physical, social, or organisational aspects

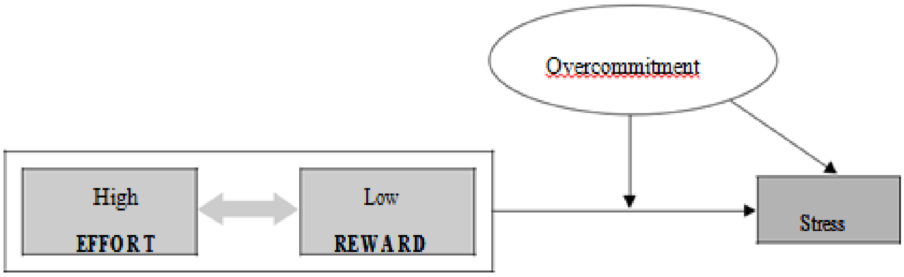

FIGURE 6.4: The effort–reward imbalance model.

of the job that require sustained physical and/or psychological (i.e. cognitive or emotional) effort on the part of the employee and are therefore associated with cer-tain physiological and/or psychological costs. Job resources refer to those physical, psychological, social, or organisational aspects of the job that either/or: (1) reduce job demands and the associated physiological and psychological costs; (2) are functional in achieving work goals; (3) stimulate personal growth, learning, and development' (Demerouti et al. 2000, 395).

Thus, the JDR model is a more general model, though it has much in common with the aforementioned models. The demands in this model are not quantitative demands as in the DCS model; rather, they comprise emotional demands, equipment problems, changes at work, and so on. Resources are not just control and support (as in the DCS model) or just rewards (as in the ERI model), but all of these elements together. The essence of the JDR model lies in the assumption that every organisa-tion has its own characteristics, which can be classified into two main categories: demands and resources. According to the authors of this model, it is best to begin a study with a qualitative analysis, which will make it possible to extract the most important demands and resources in a given environment. Only then should one conduct a quantitative analysis of the influence of those dimensions on the result variables (such as health and absenteeism) and use those particular questionnaires that consider resources and demands especially significant in an environment. The problem with the JDR model is that it does not state precisely what characteristics of the work environment produce the most stress. People responsible for psychoso-cial work conditions may therefore not know what they should pay attention to first. However, this flaw of the model is also its advantage; the model is thus more flexible and can be adapted to specific organisations that are being analysed.

6.6 Psychosocial Risk Management and its basic steps

Following the European Commission's guidance (Levi and Levi 2000), the psycho-social risk-management process should involve the following steps:

Define the risk factors and their severity, range of prevalence, causes, and relationship to overall health. The aim of this step is to determine through surveys, interviews, and other techniques which psychosocial properties of work are the most stressful in a group. It also evaluates the hardening of potential health consequences of existing psychosocial risk types.
Analyse the connection between risk factors and their results in terms of employees' health and organisational outcome. The goal of this step is to gain an understanding about which of the risk factors identified in step 1 are exceptionally strongly connected to entities' and organisation's health.
Social partners (employers and employees' representatives, experts, and other important organisations active within the company) work together to project an intervention set of rules aimed at limiting existing psychosocial risk and implementing the project.

Evaluate the direct and long-term consequences of enforcing sets of rules. The evaluation embraces the level of risk factors, level of physical health and well-being, quality and quantity of manufactured goods, and performed services. Economic analyses of costs and earnings related to such enforce-ment are also expected.

Many factors decide if applying a set of rules aimed at lowering psychosocial risks will be effective. Two factors are especially important:

- Social support of organisational change
- Active participation of employees in the process

In European states, labour unions are an important source of support for the improve-ment of work conditions. In the United States, where the number of unions is very low, a lot of pressure is exerted on superiors to support changes. Even in places where unions are strong, however, it is also crucial to receive support from superiors. With no such support, even the most rational changes have hardly any chance of success. A very important and valuable source of support is a mutual agreement between the union or unions and the company's management team. The recently signed European Framework Agreement (2004) opens a window of opportunity and provides a good formal basis for stimulating such cooperation. It obligates the main social partners (governments as well as representatives of employers and employees) to cooperate in the limitation of psychosocial risks in the workplace.

Agreements and contracts should be also formed among the lower stages of the management structure and union officials in consultation with employer's representatives. Mid- and low-level managers, who might initially support changes, can become uneasy with possible threats in later stages as an increase in the
employee's decision-making power lessens the impact of managers. However, man-agers must understand and support changes so that the changes can be effectively applied. In other words, it is imperative to confirm the sets of rules and ideas of change at many levels of the organisation to ensure they prevail and bring results, or, as Karasek and Theorell (1990) aptly observed, that they have to come to the 'critical organisational bulk'.
Active participation from regular employees is another critical condition for the successful application of new rules and changes. The discipline of participation ergonomy particularly relies upon this participation (Noro and Imada 1991). The foundation of participation ergonomy lies in

the theory that efficient work condi-tions (including psychosocial aspects) is not possible without employee support. The advantages of including employees in the process are as follows:

Psychosocial risk factors occur in many fields, and their origins may vary; an effective diagnosis of such a state given by a broad and miscellaneous body usually shows factors that might be missed by a single observer or even a sole management team.

Participation in the decision-making process, leading to solving problems, increases involvement in applying a solution previously accepted as valid.

6.6.1 Forms of Prevention

Three forms of psychosocial risk prevention are usually distinguished (e.g. Murphy 1988):

Limitation of the sources of psychosocial risk

Limitation of physical and physiological reaction to risks

Treatment of health losses caused by long-lasting stress resulting from psychosocial risks

Each of these forms can be aimed at either an entity or an organisation. The main goal is to strengthen resistance to stress, while the organisation benefits from the possibility of applying changes aimed at reducing or eliminating existing sources of stress or developing mechanisms that counteract the creation of stress. The primary condition to any action lies in monitoring stress at the workplace.

6.6.2 Monitoring Psychosocial Risk at Work

Monitoring psychosocial work conditions means simply finding the risk factors in the psychosocial area of work. It requires observing both work conditions and the staff's health level. The basic tools useful in such monitoring processes are check-lists and questionnaires.

Checklists are simple in form; an example can be found in the 19-question list prepared by the European Foundation for the Improvement of Living and Working Conditions (Kompier and Levi 1994) to monitor the content of work tasks. The respondent answers the questions by marking yes or no. Respondents can be picked from among either employees or management teams, and have a chance to report problems in their fields through such a list.

A more advanced form of stress monitoring is applied, along with an inquiry form surveying employees' feelings and opinions regarding their work. In the Psychological Workroom of CIOP, an inquiry form for stress monitoring was developed and named Psychosocial Conditions of Work (Widerszal-Bazyl and Cies´lak 1999).

Figure 6.5

Figure 6.6

CHAPTER 7

Basic Hazards in the Work Environment

7.1 Harmful Chemical Agents in the Work Environment

Due to the high level of industrialisation 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, inflamma-tory 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) in 2005–2006 showed that 18 percent of workers were exposed to or came in contact with chemical agents, including 20.5 percent through the respiratory tract (Parent-Thirion et al. 2007). In 2007, more than 74,000 deaths due to chemical exposure were recorded in the EU-27 member states (Takala et al. 2009; Musu 2007). One in three occupational diseases recognised every year in the 15 EU countries is caused by exposure to chemical agents (Eurostat 2004).According to the European Agency for Safety and Health at Work (2006) in Bilbao, about 16 million chemicals are available on the market and 10,000 are manu-factured 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 proper-ties are available for only 14 percent 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 organisation 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. Poland has had such a system since 1983—the Interdepartmental Commission for Maximum Admissible Concentrations and Intensities of Agents Harmful to Health in the Working Environment is its core element. The commission develops new

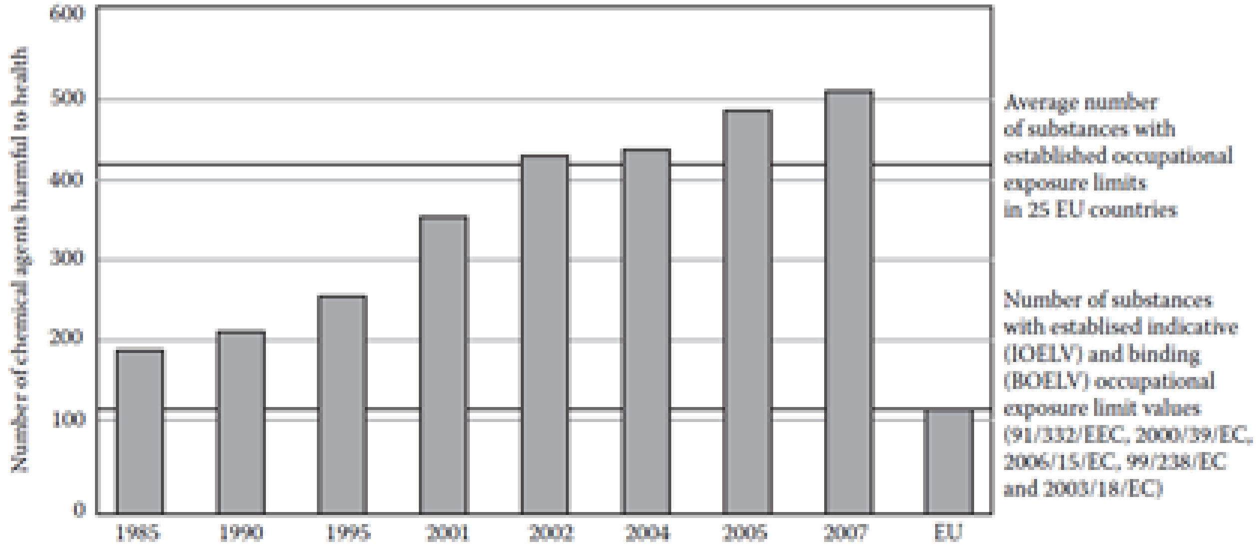

FIGURE 6.1 Establishment and verification of the maximum admissible concentrations in workplace air in Poland (1985–2007) and in the European Union (2007) for chemical agents harmful to health.

FIGURE 7.1: Establishment and verification of the maximum admissible concentrations in workplace air in Poland (1985–2007) and in the European Union (2007) for chemical agents harmful to health.

values and systematically revises the existing values of maximum admissible con-centrations (MACs) of chemical and aerosol agents in accordance with the provisions of the EU directives (Council Directive 89/391/EEC, Council Directive 99/38/EC, Council Directive 98/24/EC) and national regulations (labour code, together with the executive provisions).In the more than 20 years Poland has been using the national system, more than 300 new items have been added to the list of MACs (Figure 7.1). The list currently in force in Poland includes 514 chemical substances and aerosols, along with their OELs, which are legally binding in all national economy sectors.An integral part of the documentation of MACs for chemical substances involves the use of analytical methods that measure concentrations of substances at the workplace. The Polish Committee for Standardisation has developed these meth-ods over more than 40 years as standards for air-purity protection at the workplace (Koradecka 1999).

7.2 General Characteristics of Chemical Agents Harmful to Health

Basic Definitions

Chemical substances are chemical elements and their compounds either in their nat-ural 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 stabil-ity of the substance or changing its composition. Preparations are mixtures or solu-tions composed of two or more substances (Registration, Evaluation, Authorisation, and Restriction of Chemicals [REACH] regulation). Dangerous substances and dangerous preparations are substances and prepara-tions 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, sensitising, carcinogenic, mutagenic, toxic for reproduction, flammable, extremely flammable, explosive, oxidative, and dangerous to the environment.

The skin is the outer covering of the body; it protects the body against the envi-ronment. Some chemicals destroy the skin, but others can be absorbed through it. There are two ways chemicals can be absorbed through the skin:

- Diffusion through the skin layers (the transepidermal routes)
- Diffusion through skin appendages—hair follicles, oil glands, or sweat glands (the transfollicular routes)

Organic chemicals with a high partition coefficient in oil or water emulsions and a small degree of ionisation can be absorbed by passive diffusion (the transepidermal route). Aliphatic and aromatic hydrocarbons, nitric compounds and amines, phe-nols, phosphor-organic insecticides, carbon disulphide, and tetraethyl lead can be absorbed this way.The role of absorption of organic solvents or pesticides through skin is often underestimated.The transfollicular route has a less important role in absorption, because skin appendages occupy only a small surface of the skin—from 0.1 to 0.01percent.

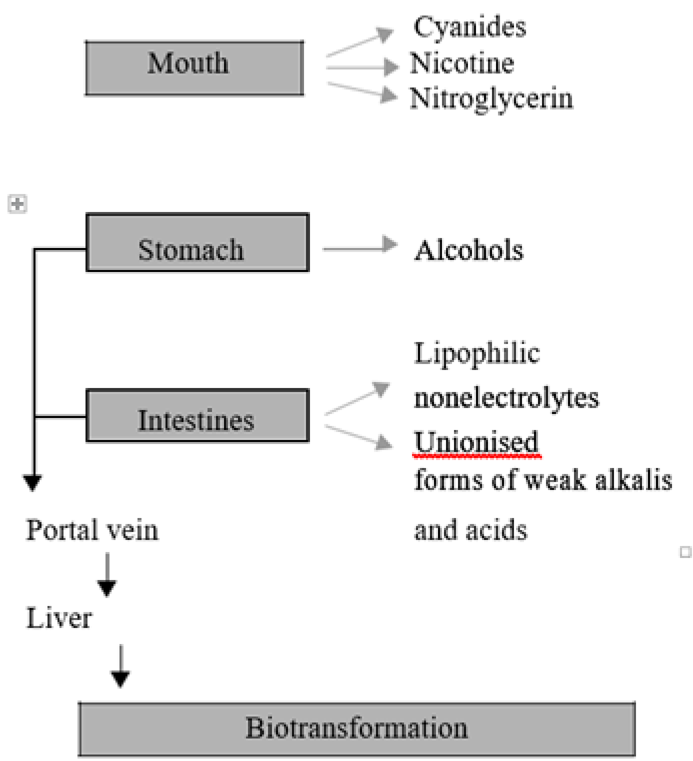

Figure 6.3 Absorption of chemicals in the gastrointestinal tract.

FIGURE 7.2: Absorption of chemicals in the gastrointestinal tract

Electrolytes, metals, and their organic compounds are absorbed through this route.Absorption of chemicals through the skin from the workplace air is not very important for most substances, apart from phenol, nitrobenzene, and aniline. The absorption rate through the skin for these substances can increase to about 30 percent of the volume present in the work environment. Different factors can change the absorption efficiency; among them are the state of the skin, anatomic differences, age, tempera-ture, and humidity (Czerczak and Kupczewska 2002).Absorption of chemicals through the gastrointestinal tract can occur in differ-ent sectors, from the mouth through the oesophagus and stomach to the intestines (Figure 7.2). Chemicals are absorbed from the gastrointestinal tract when they are in a nonionic form. Weak acids are absorbed mainly in the stomach, while weak bases are absorbed in the intestines. Dangerous chemicals undergo resorption very quickly in the intestines because the intestinal mucosa is physiologically adapted to absorp-tion. Metals can also be absorbed by the gastrointestinal tract, but the mechanism and efficiency of this process are not well known. Knowledge of the chemical form of the metal is important, for example, methyl mercury is absorbed by the gastro-intestinal tract with an efficiency of 90–100 percent, whereas inorganic mercury com-pounds are absorbed with only 10 percent efficiency and metallic mercury is not absorbed in this way. The absorption efficiency also depends on the person's diet. Low levels of calcium, ferric ions, and proteins in the diet cause an increase in the absorption of toxic metals such as lead and cadmium.

7.2.1 Combined Effects of Chemicals

In industrial conditions, situations in which the same population is exposed to differ-ent substances or preparations are the rule rather than the exception. When humans are exposed to two or more chemicals, the combined toxic effects may be one of the following types:Independent: The mechanisms of the substances are different and therefore induce different effects. The combined effects are the same as if the person was exposed to each substance individually. Additive: The mechanisms of the substances are the same and the volume of the effects is quantitatively equal to the sum of the effects caused by each substance individually. Synergistic: The toxic effects of one substance are intensified by the other. Strengthened (potentialisation): The chemical substance itself does not cause a harmful effect, but it intensifies the harmful effects of another substance.
Antagonistic: The toxic effect of a given substance is reduced or cancelled by another substance (Skowron et al. 2000).

7.3 Effects of Harmful Chemicals in the Work Environment on Humans

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.

7.3.1 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.

7.3.2 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.In the occupational environment, acute poisonings are often considered accidents at work. Corrosive substances or preparations may induce burns of the skin and mucosal membranes. Direct eye contact with irritant chemicals may cause health effects of different intensities, ranging from temporary stinging and lacrimation to permanent corneal damage. The rate and intensity of the damage depend on the quantity of the substance to which the eyes were exposed and the time elapsed before the administration of first aid. Acids, alkalis, and solvents are examples of irritant substances.When a chemical come in contact with the skin, damage to the protective skin layer may occur and, consequently, the skin will become dry, rough, and sore. This condition is called irritant or toxic eczema. The substances that cause this type of skin lesion are called primary irritants. Alkalis, acids, organic solvents, soaps, and washing agents are the most important primary irritants. Chemicals irritate the respiratory tract and cause inflammatory lesions in different parts of the tract. The gases and vapours of some substances, such as hydrogen fluoride, hydrogen chlo-ride, ammonium, formaldehyde, and acetic acid, usually cause lesions in the nose, pharyngonasal cavity and larynx. Substances such as chlorine, arsenic trichloride, and phosphorus trichloride cause lesions in the upper respiratory tract and bron-chi. Irritant chemicals cause cough and sneezing and can provoke spasms of the epiglottis and bronchi in high concentrations. Phosgene or nitrogen oxides directly cause lesions of the lung, which may be the cause of pulmonary oedema and pleural inflammation. Such inflammation may occur immediately after exposure or within a few hours after exposure, that is, after the latency period. In this case, the clinical symptoms of poisoning include cough, cyanosis (oxygen-deficiency symptom), and coughing up large amounts of mucus (Sen´czuk 2007).Substances that irritate the respiratory tract also damage its defence mechanisms, decreasing immunity and increasing susceptibility to asthma and pulmonary oedema.

The effects of irritating substances on the respiratory tract depend upon a num-ber of factors, including the concentration of the substance, duration of exposure, and individual susceptibility. Another important factor is the manner of breathing— through the mouth or through the nose. People who are exposed to irritants over a long period often have an impaired sense of smell and cannot detect the presence of these substances in the workplace air.

7.3.3 Sensitisation

Allergic contact eczema appears in workers who are in contact with substances that provoke sensitising effects. Allergic reactions of the skin are often similar to symptoms of inflammation: itching, burning, erythema, and papular, 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 percent of skin inflammation. The course of allergic contact eczema depends on the type of contact with the sensitiser. 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.Asthma is caused by sensitising changes in the respiratory tract arising from exposure to allergens in the occupational environment. The characteristic signs of asthma are a cough, especially at night, and respiratory difficulties such as gasp-ing and shortness of breath. Occupational asthma is caused by both macro- and microparticles in the work environment, often in concentrations that do not exceed the exposure limits or exceed them minimally (Górski 1997). Macroparticles include flour and its impurities, animal allergens, resin (especially colophony), antibiot-ics (especially beta-lactam antibiotics), latex, grains of oil plants, and detergents. Microparticles include isocyanines, platinum salts, nickel, chromium, cobalt, alu-minium, dyes, persulphates, henna, disinfection agents, and acid anhydrides.An allergy specialist can conduct many types of examinations to diagnose occu-pational asthma, such as the skin-patch test and testing for antibodies. To prevent allergies, contact with sensitising substances should be avoided by: (1) eliminating such substances from the environment, (2) using personal protective equipment, or (3) changing the work location (Górski 1997).

7.3.4 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 morpho-logical and functional changes in some organs or groups of organs.Exposure to neurotoxic substances can disturb the process of external inhibi-tion or the stimulation of nerve conduction in the central and peripheral nervous systems. It can lead to functional disturbances in the central (encephalopathy) or peripheral (peripheral neuropathy) nervous systems. Depression or stimulation of the nervous system may also occur, which indicates a correlation of the toxic action of the substance with the adaptation mechanism. This can lead to normalisation of
the activity of this system. The rate of these changes and the time needed to elicit them depend upon the concentration or dose of the neurotoxic substance. Small functional changes in the central and peripheral nervous systems are often a serious result of exposure to lower concentration of chemicals. Chloroalkanes, carbon disul-phide, and mercury vapours and lead are substances that affect the nervous system. Alkanes (hexane), aliphatic ketones, and carbon disulphide show a strong action onthe peripheral nervous system. Exposure to phosphoro-organic compounds, such as parathion, can obstruct and destroy the functioning of the central and peripheral nervous systems.Nitro compounds (nitrotoluene), chloroalkanes, and chloro- and bromoben-zene derivatives affect the liver. The symptoms of liver injury caused by such sub-stances, such as a yellow colour 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 sub-stances, 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. Toxicology has focused on the mech-anisms of the toxic effects of substances on the entire reproductive cycle, includ-ing the production of reproductive cells in both sexes, fertilisation of the ovum, its implantation, embryo or organogenesis, foetal development, delivery, and growth until sexual maturity. Fertility impairment in men may be connected with exposure to chemicals such as ethylene dibromide, benzene, anaesthetic gases, chloroprene, lead, organic solvents, and carbon disulphide. Miscarriages may follow exposure to anaesthetic gases, ethylmercury oxide, glutaraldehyde, chloroprene, lead, organic solvents, carbon disulphide, and vinyl chloride.

7.3.5 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. Bladder cancer is associated with exposure to benzidine, 2-naphthylamine, or dust of tanned leather, whereas skin cancer is associated with exposure to arsenic, coal tar, and petroleum derivatives containing polycyclic aromatic hydrocarbons. Vinyl chloride may cause cancerous lesions in the liver and benzene in the bone marrow (Szadkowska-Stan´czyk and Szeszenia-Dabrowska 2001).Exposure limits for certain carcinogenic substances are not established in many countries because safe exposure levels cannot be determined. Instead of proposing an exposure limit, agencies or organisations determine the risk caused by a definite exposure level. Government agencies and national or international organisations use the concept of acceptable risk for establishing or proposing admissible exposure lev-els for carcinogenic substances. The level of acceptable risk depends on commonly accepted social and economic criteria; in developed countries, three interest groups, made up of representatives of employees, employers, and state administrators whose task is to perform law-enforcement surveillance, make decisions regarding this topic (Czerczak 2004b). Enterprises having carcinogenic or mutagenic substances should strive to elimi-nate them from their technological processes or maintain their concentrations at lev-els below the maximum admissible values, preferably at a very low level. Exposure to nonthreshold carcinogenic substances should also be minimised.

		TWA	TWA	TWA		
Chemical Name	CAS	(mg/m3)	(ppm)	(fibres/ml)	Notation a	Directive
Asbestos actinolite	77536-66-4	-	-	0.1	-	2003/18/EC
Asbestos	77536-67-5	-	-	0.1	-	2003/18/EC
anthophyllite						
Asbestos chrysotile	12001-29-5	-	-	0.1	-	2003/18/EC
Asbestos grunerite	12172-73-5	-	-	0.1	-	2003/18/EC
(amosite)						
Asbestos	12001-28-4	-	-	0.1	-	2003/18/EC
crocidolite						
Asbestos tremolite	77536-68-6	-	-	0.1	-	2003/18/EC
Benzene	71-43-2	3.25	1	-	Skin	99/38/EC
Hardwood dust	–	5	-	-	-	99/38/EC
Lead and its	7439-92-1	0.15	-	-	-	98/24/EC
inorganic						
compounds						
Vinyl chloride	75-01-4	7.77	3	-	-	99/38/EC
monomer						

Note: CAS = chemical abstract service number; TWA = time-weighted average concentration measured or calculated for an 8-hour workday exposure; mg/m3 = milligrams per cubic metre of air at 20°C and 101.3 kPa; ppm = parts per million by volume in air (ml/m3).

aA skin notation identifies the possibility of significant uptake through the skin.

FIGURE 7.3: Binding Occupational Exposure Limit Values for Chemical Substances as Established by the European Union

Establishment of a list of priority substances for which IOELVs should be set by the Directorate General for Employment, Social Affairs, and Equal Opportunities
Adoption of the priority list of chemical substances by SCOEL
Evaluation of recent published scientific data on the toxicology of the chemicals by SCOEL
Preparation of a draft recommendation summary document (SCOEL/SUM) by SCOEL
Six months of public consultation through the contact points

Collation of comments about the document and the proposed IOELVs; amendments to the document

Publication of the document together with a justification of the values by the commission

Development of a proposal for a directive based on the SCOEL recommen-dation by the commission

Consultation with the Advisory Committee on Safety and Health at Work about the commission's proposal

Adoption of the directive by the Technical Committee when establishing IOELVs for chemical substances or by the Council and European Parliament for BOELVs (Employment and Social Affairs 2008; Skowron´ 2007b)

7.4 Admissible Concentrations in the Biological Medium or Biological Limit Values

Biological monitoring measures the amount of a substance or its metabolites con-tained in a biological medium and assesses its biological effects. Biological limit values (BLVs) are reference values used to assess potential hazards to the workers' health. These values are established based on available scientific data. Concentrations of a substance equivalent to its BLV should not cause adverse health effects in people exposed in the workplace (8 hours per day, 5 days per week). Toxic substances or their metabolites are measured mainly in blood, urine, and exhaled air. Biological monitoring makes it possible to assess exposure to a substance absorbed from the living and work environments through various routes, such as the respiratory tract, the digestive system, or the skin; hence, large individual differences are observed in the exposure indices (Jakubowski 1997). SCOEL determines BLVs based on the following items: (1) currently avail-able scientific data from studies on humans (epidemiological or volunteer stud-ies); (2) extrapolating the IOELVs established for a substance, taking into account the toxicokinetics of the substance (if the IOELV for a substance is established because of its corrosive effects, the BLV may be based on systemic adverse effects; then these values will not correspond to each other); and (3) the results of the sub-stance's effects (e.g. acetylcholinesterase inhibition in serum); the BLV can be directly derived from suitable studies in humans (European Commission, Report EUR 19253 EN 1999). In Poland, persons exposed to lead in the work environment must be tested for lead in the blood. The recommendations of the Interdepartmental Commission for MAC and MAI include conditions for taking samples of the biological medium and an interpretation of results for 29 chemical agents (Jakubowski 2004; Augustyn´ska and Pos´niak 2007).

7.5 Information Sources on Hazards Related to the Use of Chemical Agents in the Workplace

Safety Data Sheets for Chemical Substances and Preparations

Chemical substances and preparations are potentially hazardous for human health and life, not only in the work environment, but also in the natural environment. Comprehensive information about the dangerous properties of chemical substances and preparations, the type and dimension of hazard they pose, and the rules to be followed when handling them allows for rational and efficient prevention in the

workplace and for the protection of people and the natural environment outside the workplace. Essential information about chemical substances and preparations, intended for the general public, is presented in the form of safety data sheets.

Chemical substances and preparations with explosive, oxidising, flammable, highly toxic, toxic, harmful, corrosive, irritating, sensitising, carcinogenic, and mutagenic properties, as well as those that can impair reproduction and are destruc-tive to the environment, are classified as dangerous. Guidelines for the compilation of safety data sheets for a substance or preparation are included in Annex II to the regulation (EC) No. 1907/2006 (REACH).

A safety data sheet contains the date of issue and the following items:

- Identification of the substance or preparation and of the company
- Identification of hazards
- Composition or information on ingredients
- First-aid measures
- Firefighting measures
- Accidental release measures
- Handling and storage
- Exposure controls or personal protection
- Physical and chemical properties
- Stability and reactivity
- Toxicological information
- Ecological information
- Disposal considerations
- Transport information
- Regulatory information
- Other information

Toxicological information includes the relevant derived no-effect level (DNEL), at which the agent does not cause adverse effects in different groups of exposed pop-ulations (e.g. workers, consumers, and small children, reflecting the likely routes, duration, and effects of exposure) and a predicted no-effect concentration (PNEC), at which the agent does not cause adverse effects in the environment. These are required in safety reports for chemical substances introduced to the market in amounts exceeding 10 tons/year (Gromiec 2008). The supplier of a substance or

a preparation shall also provide the recipient with a safety data sheet compiled in accordance with the following regulations:
If a substance or preparation meets the criteria for classification as dangerous
If a substance is persistent, bioaccumulative, and toxic or is very persistent and very bioaccumulative (vPvB) in the environment according to criteria laid down in Annex XIII of the REACH regulation
If a substance is included in the list established in accordance with Article 59(1) for reasons other than those referred to in point 1, that is, the sub-stance meets the criteria for classification as carcinogenic of category 1 or 2
in accordance with directive 67/548/EEC or the substance meets the criteria for classification as mutagenic of category 1 or 2 in accordance with directive 67/548/EEC.

7.6 EU Policy Regarding Chemical Agents—REACH Regulation

7.6.1 REACH Regulation Provisions

The December 2006 REACH regulation no. 1907/2006 of the European Parliament and of the Council of 18 is the governing act of the new European chemicals policy, which ensures a high level of environment and human health protection, especially workers' health, and enhances the competitiveness of the European chemical indus-try. The regulation set specific duties and obligations for manufacturers, importers and downstream users of substances to be used for their own reference and in prepa-rations and articles. The biggest shortcoming of the previous regulations was an unnatural division between new and existing substances; this meant that 99 percent of new agents on the market are not tested, and therefore the information on most of them is not sufficient. The REACH system will increase the interest in test results and their use in industry; this should translate to an increase in innovation and thereby in the competitiveness of the European chemical industry against other great world economies (Miranowicz-Dzierz˙awska 2007). The REACH regulation began in all EU countries on 1 June 2007.

7.6.2 Main Elements of REACH

The REACH system is based on the following four pillars:]**Routes of Absorption of Chemicals into the Body**
Chemical substances occur as gases, vapours, liquids, or solid bodies. They are absorbed into the body mostly through the respiratory tract and skin or from the gastrointestinal tract.Substances such as gases or vapours form a homogeneous mixture with air. Two phase system solid gases or liquid gases are called aerosols. Aerosols can be divided into dusts, fumes, and mists. Dusts are suspensions of solid particles in the air, arising from mechanical disintegration. Fumes are also suspensions of solid particles in the air, arising from processes such as combustion, calcination, or sublimation. Mists are suspensions of liquid droplets in the air formed during liquid

spraying and fume condensation. Aerosols of oil fumes arise during machining and solvent fumes during spray painting. These substances are absorbed in the respiratory tract mainly as gases, vapours, and aerosols.The respiratory tract is the anatomical part that governs the process of respiration, that is, brings in oxygen and excretes the products of metabolic changes, such as carbon dioxide. The major function of the respiratory system is to exchange gas between the external environment and the organism's circulatory system. In humans and other mammals, this exchange facilitates the oxygenation of blood by removing carbon dioxide and other gaseous metabolic wastes from the circulation. The respiratory tract is divided into upper and lower respiratory tracts; the skin also plays a minimal role in gas exchange. The upper respiratory tract includes the nasal passages, pharynx, and larynx. The lower respiratory tract includes the trachea, right and left bronchi, and lungs. The trachea divides into the left and right air tubes, called bronchi; the bronchi in turn connect to the lungs. Within the lungs, the bronchi branch into smaller bronchi and even smaller tubes called bronchioles. Bronchioles end in tiny air sacs called alveoli, where the exchange of oxygen and carbon dioxide actually takes place. Each lung contains about 300–400 million alveoli. The lungs also contain elastic tissues that allow them to inflate and deflate without losing shape and are encased by a thin lining called the pleura. This network of alveoli, bronchioles, and bronchi is known as the bronchial tree (Aleksandrowicz 1994).The respiratory tract is covered with an epithelium, the type of which varies down the tract. The respiratory tract also contains smooth muscle, elastin and cartilage, and glands in parts of the tract that produce mucus.There is no cartilage or smooth muscle in the bronchi. Each of the segmental bronchus supplies a bronchopulmonary segment. A bronchopulmonary segment is a division of the lung separated from the rest of the lung by a connective tissue septum. The left lung is divided into two lobes and the right into three lobes.

The bronchial tree continues branching until it becomes terminal bronchioles, which lead to the alveolar sacs. Alveolar sacs are made up of clusters of alveoli, similar to individual grapes in a bunch. The individual alveoli are tightly wrapped in blood vessels, and the gas exchange actually occurs here. Deoxygenated bloodfrom the heart is pumped through the pulmonary artery to the lungs, where oxygen diffuses into the blood and is exchanged for carbon dioxide in the haemoglobin of erythrocytes. The oxygen-rich blood returns to the heart via the pulmonary veins to be pumped back into the systemic circulation.The alveoli consist of an epithelial layer and extracellular matrix surrounded by capillaries. There are three major alveolar cell types in the alveolar wall.Each alveolus is wrapped in a fine mesh of capillaries that covers about 70 percent of its area. The blood brings carbon dioxide from the rest of the body to be released in the alveoli; then, the blood in the alveolar blood vessels takes up the oxygen from the alveoli to be transported to the cells in the body. An adult alveolus has an average diameter of 0.2–0.3 mm (Pabst and Putz 2007). Together, the lungs contain approxi-mately 1500 miles (2400 km) of airways and 300–500 million alveoli, with a total surface area of about 70 m2 in adults. An adult at rest breathes in about 5 litres per minute and during work about 20 litres or more.Gases and vapours are absorbed into the body directly through the respiratory tract, depending on the physical activity. Fumes in the liquid phase can be absorbed directly by the alveolar epithelial layer. Aerosols (dusts and fumes) are not totally absorbed some dusts can be eliminated with mucus, coughed up with sputum, or swallowed.The contribution of the respiratory-tract segments (nasopharyngeal, tracheobronchial, and pulmonary) to aerosol absorption depends on the particles' aerodynamic diameter. Particles less than 7 m (the respirable fraction) are the most dangerous, because they are most easily deposited in the lungs and are also easily distributed throughout the body (Figure7.2).

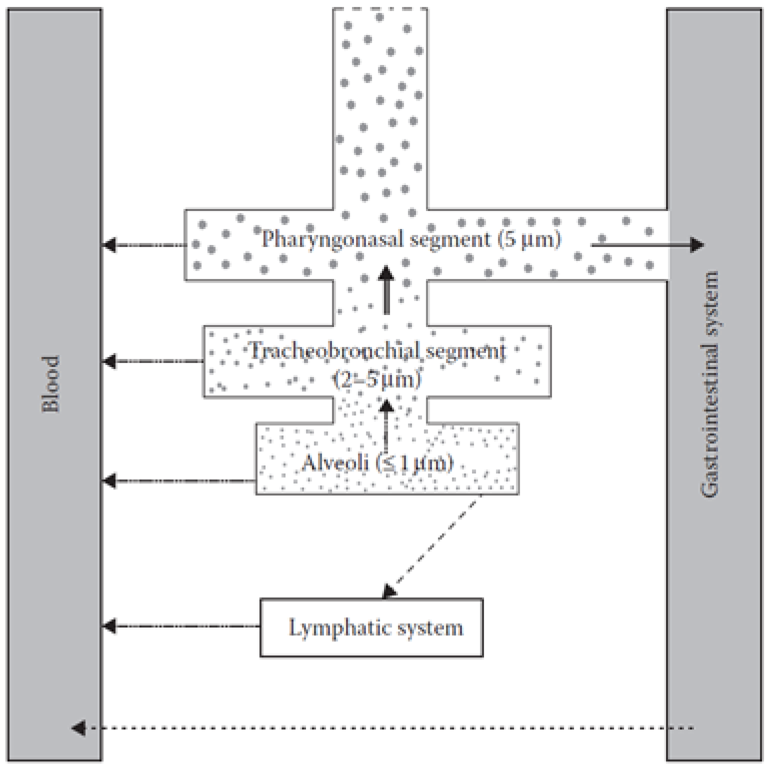

FIGURE 6.2 Absorption and distribution of chemicals in the lungs.

FIGURE 7.4

The skin is the outer covering of the body; it protects the body against the envi-ronment. Some chemicals destroy the skin, but others can be absorbed through it. There are two ways chemicals can be absorbed through the skin:

- Diffusion through the skin layers (the transepidermal routes)
- Diffusion through skin appendages—hair follicles, oil glands, or sweat glands (the transfollicular routes)

Organic chemicals with a high partition coefficient in oil or water emulsions and a small degree of ionisation can be absorbed by passive diffusion (the transepidermal route). Aliphatic and aromatic hydrocarbons, nitric compounds and amines, phe-nols, phosphor-organic insecticides, carbon disulphide, and tetraethyl lead can be absorbed this way.The role of absorption of organic solvents or pesticides through skin is often underestimated.The transfollicular route has a less important role in absorption, because skin appendages occupy only a small surface of the skin—from 0.1 to 0.01percent.

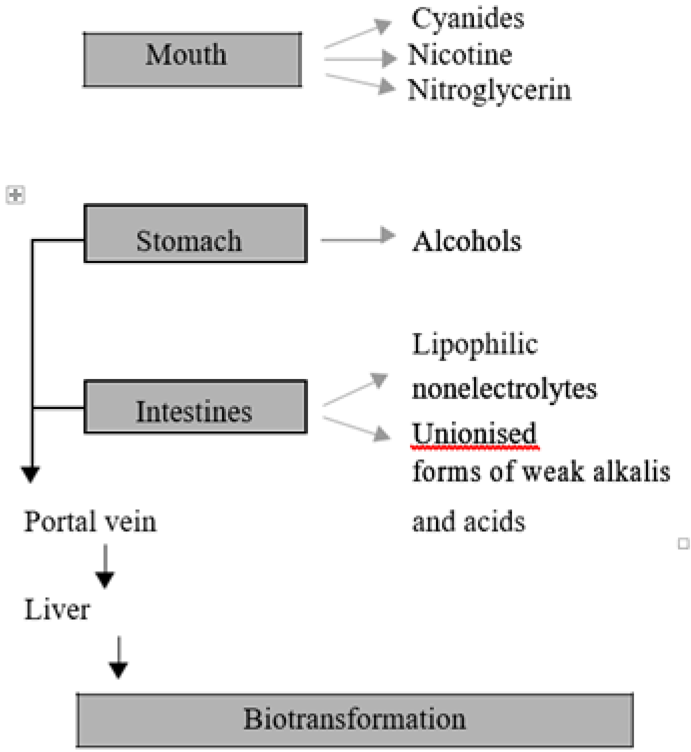

Figure 6.3 Absorption of chemicals in the gastrointestinal tract.

Figure 7.5: Absorption of chemicals in the gastrointestinal tract

Electrolytes, metals, and their organic compounds are absorbed through this route.Absorption of chemicals through the skin from the workplace air is not very important for most substances, apart from phenol, nitrobenzene, and aniline. The absorption rate through the skin for these substances can increase to about 30 percent of the volume present in the work environment. Different factors can change the absorption efficiency; among them are the state of the skin, anatomic differences, age, tempera-ture, and humidity (Czerczak and Kupczewska 2002).Absorption of chemicals through the gastrointestinal tract can occur in differ-ent sectors, from the mouth through the oesophagus and stomach to the intestines (Figure 7.2). Chemicals are absorbed from the gastrointestinal tract when they are in a nonionic form. Weak acids are absorbed mainly in the stomach, while weak bases are absorbed in the intestines. Dangerous chemicals undergo resorption very quickly in the intestines because the intestinal mucosa is physiologically adapted to absorp-tion. Metals can also be absorbed by the gastrointestinal tract, but the mechanism and efficiency of this process are not well known. Knowledge of the chemical form of the metal is important, for example, methyl mercury is absorbed by the gastro-intestinal tract with an efficiency of 90–100 percent, whereas inorganic mercury com-pounds are absorbed with only

10 percent efficiency and metallic mercury is not absorbed in this way. The absorption efficiency also depends on the person's diet. Low levels of calcium, ferric ions, and proteins in the diet cause an increase in the absorption of toxic metals such as lead and cadmium.

7.6.3 Combined Effects of Chemicals

In industrial conditions, situations in which the same population is exposed to differ-ent substances or preparations are the rule rather than the exception. When humans are exposed to two or more chemicals, the combined toxic effects may be one of the following types:Independent: The mechanisms of the substances are different and therefore induce different effects. The combined effects are the same as if the person was exposed to each substance individually. Additive: The mechanisms of the substances are the same and the volume of the effects is quantitatively equal to the sum of the effects caused by each substance individually. Synergistic: The toxic effects of one substance are intensified by the other. Strengthened (potentialisation): The chemical substance itself does not cause a harmful effect, but it intensifies the harmful effects of another substance.
Antagonistic: The toxic effect of a given substance is reduced or cancelled by another substance (Skowron et al. 2000).

7.7 Effects of Harmful Chemicals in the Work Environment on Humans

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.

7.7.1 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.

7.7.2 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.In the occupational environment, acute poisonings are often considered accidents at work. Corrosive substances or preparations may induce burns of the skin and mucosal membranes. Direct eye contact with irritant chemicals may cause health effects of different intensities, ranging from temporary stinging and lacrimation to permanent corneal damage. The rate and intensity of the damage depend on the quantity of the substance to which the eyes were exposed and the time elapsed before the administration of first aid. Acids, alkalis, and solvents are examples of irritant substances.When a chemical come in contact with the skin, damage to the protective skin layer may occur and, consequently, the skin will become dry, rough, and sore. This condition is called irritant or toxic eczema. The substances that cause this type of skin lesion are called primary irritants. Alkalis, acids, organic solvents, soaps, and washing agents are the most important primary irritants. Chemicals irritate the respiratory tract and cause inflammatory lesions in different parts of the tract. The gases and vapours of some substances, such as hydrogen fluoride, hydrogen chlo-ride, ammonium, formaldehyde, and acetic acid, usually cause lesions in the nose, pharyngonasal cavity and larynx. Substances such as chlorine, arsenic trichloride, and phosphorus trichloride cause lesions in the upper respiratory tract and bron-chi. Irritant chemicals cause cough and sneezing and can provoke spasms of the epiglottis and bronchi in high concentrations. Phosgene or nitrogen oxides directly cause lesions of the lung, which may be the cause of pulmonary oedema and pleural inflammation. Such inflammation may occur immediately after exposure or within a few hours after exposure, that is, after the latency period. In this case, the clinical symptoms of poisoning include cough, cyanosis (oxygen-deficiency symptom), and coughing up large amounts of mucus (Sen´czuk 2007).Substances that irritate the respiratory tract also damage its defence mechanisms, decreasing immunity and increasing susceptibility to asthma and pulmonary oedema.

The effects of irritating substances on the respiratory tract depend upon a num-ber of factors, including the concentration of the substance, duration of exposure, and individual susceptibility. Another important factor is the manner of breathing— through the mouth or through the nose. People who are exposed to irritants over a long period often have an impaired sense of smell and cannot detect the presence of these substances in the workplace air.

7.7.3 Sensitisation

Allergic contact eczema appears in workers who are in contact with substances that provoke sensitising effects. Allergic reactions of the skin are often similar to symptoms of inflammation: itching, burning, erythema, and papular, 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 percent of skin inflammation. The course of allergic contact eczema depends on the type of contact with the sensitiser. 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.Asthma is caused by sensitising changes in the respiratory tract arising from exposure to allergens in the occupational environment. The characteristic signs of asthma are a cough, especially at night, and respiratory difficulties such as gasp-ing and shortness of breath. Occupational asthma is caused by both macro- and microparticles in the work environment, often in concentrations that do not exceed the exposure limits or exceed them minimally (Górski 1997). Macroparticles include flour and its impurities, animal allergens, resin (especially colophony), antibiot-ics (especially beta-lactam antibiotics), latex, grains of oil plants, and detergents. Microparticles include isocyanines, platinum salts, nickel, chromium, cobalt, alu-minium, dyes, persulphates, henna, disinfection agents, and acid anhydrides.An allergy specialist can conduct many types of examinations to diagnose occu-pational asthma, such as the skin-patch test and testing for antibodies. To prevent allergies, contact with sensitising substances should be avoided by: (1) eliminating such substances from the environment, (2) using personal protective equipment, or (3) changing the work location (Górski 1997).

7.7.4 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 morpho-logical and functional changes in some organs or groups of organs.Exposure to neurotoxic substances can disturb the process of external inhibi-tion or the stimulation of nerve conduction in the central and peripheral nervous systems. It can lead to functional disturbances in the central (encephalopathy) or peripheral (peripheral neuropathy) nervous systems. Depression or stimulation of the nervous system may also occur, which indicates a correlation of the toxic action of the substance with the adaptation mechanism. This can lead to normalisation of

the activity of this system. The rate of these changes and the time needed to elicit them depend upon the concentration or dose of the neurotoxic substance. Small functional changes in the central and peripheral nervous systems are often a serious result of exposure to lower concentration of chemicals. Chloroalkanes, carbon disul-phide, and mercury vapours and lead are substances that affect the nervous system. Alkanes (hexane), aliphatic ketones, and carbon disulphide show a strong action onthe peripheral nervous system. Exposure to phosphoro-organic compounds, such as parathion, can obstruct and destroy the functioning of the central and peripheral nervous systems.Nitro compounds (nitrotoluene), chloroalkanes, and chloro- and bromoben-zene derivatives affect the liver. The symptoms of liver injury caused by such sub-stances, such as a yellow colour 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 sub-stances, 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. Toxicology has focused on the mech-anisms of the toxic effects of substances on the entire reproductive cycle, includ-ing the production of reproductive cells in both sexes, fertilisation of the ovum, its implantation, embryo or organogenesis, foetal development, delivery, and growth until sexual maturity. Fertility impairment in men may be connected with exposure to chemicals such as ethylene dibromide, benzene, anaesthetic gases, chloroprene, lead, organic solvents, and carbon disulphide. Miscarriages may follow exposure to anaesthetic gases, ethylmercury oxide, glutaraldehyde, chloroprene, lead, organic solvents, carbon disulphide, and vinyl chloride.

7.7.5 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. Bladder cancer is associated with exposure to benzidine, 2-naphthylamine, or dust of tanned leather, whereas skin cancer is associated with exposure to arsenic, coal tar, and petroleum derivatives containing polycyclic aromatic hydrocarbons. Vinyl chloride may cause cancerous lesions in the liver and benzene in the bone marrow (Szadkowska-Stan´czyk and Szeszenia-Dabrowska 2001).Exposure limits for certain carcinogenic substances are not established in many countries because safe exposure levels cannot be determined. Instead of proposing an exposure limit, agencies or organisations determine the risk caused by a definite exposure level. Government agencies and national or international organisations use the concept of acceptable risk for establishing or proposing admissible exposure lev-els for carcinogenic substances. The level of acceptable risk depends on commonly accepted social and economic criteria; in developed countries, three interest groups, made up of representatives of employees, employers, and state administrators whose task is to perform law-enforcement surveillance, make decisions regarding this topic (Czerczak 2004b). Enterprises having carcinogenic or mutagenic substances should strive to elimi-nate them from their technological processes or maintain their concentrations at lev-els below the maximum admissible values, preferably at a very low level. Exposure to nonthreshold carcinogenic substances should also be minimised.

		TWA	TWA	TWA		
Chemical Name	CAS	(mg/m3)	(ppm)	(fibres/ml)	Notation a	Directive
Asbestos actinolite	77536-66-4	-	-	0.1	-	2003/18/EC
Asbestos	77536-67-5	-	-	0.1	-	2003/18/EC
anthophyllite						
Asbestos chrysotile	12001-29-5	-	-	0.1	-	2003/18/EC
Asbestos grunerite	12172-73-5	-	-	0.1	-	2003/18/EC
(amosite)						
Asbestos	12001-28-4	-	-	0.1	-	2003/18/EC
crocidolite						
Asbestos tremolite	77536-68-6	-	-	0.1	-	2003/18/EC
Benzene	71-43-2	3.25	1	-	Skin	99/38/EC
Hardwood dust	–	5	-	-	-	99/38/EC
Lead and its	7439-92-1	0.15	-	-	-	98/24/EC
inorganic						
compounds						
Vinyl chloride	75-01-4	7.77	3	-	-	99/38/EC
monomer						

Note: CAS = chemical abstract service number; TWA = time-weighted average concentration measured or calculated for an 8-hour workday exposure; mg/m3 = milligrams per cubic metre of air at 20°C and 101.3 kPa; ppm = parts per million by volume in air (ml/m3).

aA skin notation identifies the possibility of significant uptake through the skin.

FIGURE 7.6: Binding Occupational Exposure Limit Values for Chemical Substances as Established by the European Union

Establishment of a list of priority substances for which IOELVs should be set by the Directorate General for Employment, Social Affairs, and Equal Opportunities
Adoption of the priority list of chemical substances by SCOEL
Evaluation of recent published scientific data on the toxicology of the chemicals by SCOEL
Preparation of a draft recommendation summary document (SCOEL/SUM) by SCOEL
Six months of public consultation through the contact points

Collation of comments about the document and the proposed IOELVs; amendments to the document
Publication of the document together with a justification of the values by the commission
Development of a proposal for a directive based on the SCOEL recommen-dation by the commission
Consultation with the Advisory Committee on Safety and Health at Work about the commission's proposal
Adoption of the directive by the Technical Committee when establishing IOELVs for chemical substances or by the Council and European Parliament for BOELVs (Employment and Social Affairs 2008; Skowron´ 2007b)

7.8 Admissible Concentrations in the Biological Medium or Biological Limit Values

Biological monitoring measures the amount of a substance or its metabolites con-tained in a biological medium and assesses its biological effects. Biological limit values (BLVs) are reference values used to assess potential hazards to the workers' health. These values are established based on available scientific data. Concentrations of a substance equivalent to its BLV should not cause adverse health effects in people exposed in the workplace (8 hours per day, 5 days per week). Toxic substances or their metabolites are measured mainly in blood, urine, and exhaled air. Biological monitoring makes it possible to assess exposure to a substance absorbed from the living and work environments through various routes, such as the respiratory tract, the digestive system, or the skin; hence, large individual differences are observed in the exposure indices (Jakubowski 1997). SCOEL determines BLVs based on the following items: (1) currently avail-able scientific data from studies on humans (epidemiological or volunteer stud-ies); (2) extrapolating the IOELVs established for a substance, taking into account the toxicokinetics of the substance (if the IOELV for a substance is established because of its corrosive effects, the BLV may be based on systemic adverse effects; then these values will not correspond to each other); and (3) the results of the sub-stance's effects (e.g. acetylcholinesterase inhibition in serum); the BLV can be directly derived from suitable studies in humans (European Commission, Report EUR 19253 EN 1999). In Poland, persons exposed to lead in the work environment must be tested for lead in the blood. The recommendations of the Interdepartmental Commission for MAC and MAI include conditions for taking samples of the biological medium and an interpretation of results for 29 chemical agents (Jakubowski 2004; Augustyn´ska and Pos´niak 2007).

7.9 Information Sources on Hazards Related to the Use of Chemical Agents in the Workplace

Safety Data Sheets for Chemical Substances and Preparations

Chemical substances and preparations are potentially hazardous for human health and life, not only in the work environment, but also in the natural environment. Comprehensive information about the dangerous properties of chemical substances and preparations, the type and dimension of hazard they pose, and the rules to be followed when handling them allows for rational and efficient prevention in the
workplace and for the protection of people and the natural environment outside the workplace. Essential information about chemical substances and preparations, intended for the general public, is presented in the form of safety data sheets.

Chemical substances and preparations with explosive, oxidising, flammable, highly toxic, toxic, harmful, corrosive, irritating, sensitising, carcinogenic, and mutagenic properties, as well as those that can impair reproduction and are destruc-tive to the environment, are classified as dangerous. Guidelines for the compilation of safety data sheets for a substance or preparation are included in Annex II to the regulation (EC) No. 1907/2006 (REACH).

A safety data sheet contains the date of issue and the following items:

- Identification of the substance or preparation and of the company
- Identification of hazards
- Composition or information on ingredients
- First-aid measures
- Firefighting measures
- Accidental release measures
- Handling and storage
- Exposure controls or personal protection
- Physical and chemical properties
- Stability and reactivity
- Toxicological information
- Ecological information
- Disposal considerations
- Transport information
- Regulatory information
- Other information

Toxicological information includes the relevant derived no-effect level (DNEL), at which the agent does not cause adverse effects in different groups of exposed pop-ulations (e.g. workers, consumers, and small children, reflecting the likely routes, duration, and effects of exposure) and a predicted no-effect concentration (PNEC), at which the agent does not cause adverse effects in the environment. These are required in safety reports for chemical substances introduced to the market in amounts exceeding 10 tons/year (Gromiec 2008). The supplier of a substance or

a preparation shall also provide the recipient with a safety data sheet compiled in accordance with the following regulations:
If a substance or preparation meets the criteria for classification as dangerous
If a substance is persistent, bioaccumulative, and toxic or is very persistent and very bioaccumulative (vPvB) in the environment according to criteria laid down in Annex XIII of the REACH regulation
If a substance is included in the list established in accordance with Article 59(1) for reasons other than those referred to in point 1, that is, the sub-stance meets the criteria for classification as carcinogenic of category 1 or 2
in accordance with directive 67/548/EEC or the substance meets the criteria for classification as mutagenic of category 1 or 2 in accordance with directive 67/548/EEC.

7.10 EU Policy Regarding Chemical Agents—REACH Regulation

7.10.1 REACH Regulation Provisions

The December 2006 REACH regulation no. 1907/2006 of the European Parliament and of the Council of 18 is the governing act of the new European chemicals policy, which ensures a high level of environment and human health protection, especially workers' health, and enhances the competitiveness of the European chemical indus-try. The regulation set specific duties and obligations for manufacturers, importers and downstream users of substances to be used for their own reference and in prepa-rations and articles. The biggest shortcoming of the previous regulations was an unnatural division between new and existing substances; this meant that 99 percent of new agents on the market are not tested, and therefore the information on most of them is not sufficient. The REACH system will increase the interest in test results and their use in industry; this should translate to an increase in innovation and thereby in the competitiveness of the European chemical industry against other great world economies (Miranowicz-Dzierz˙awska 2007). The REACH regulation began in all EU countries on 1 June 2007.

7.10.2 Main Elements of REACH

The REACH system is based on the following four pillars:
Registration: Each substance manufactured or imported into a community in quantities exceeding 1 ton/year must be registered with the European Chemicals Agency. The level of detail and the date the registration must be prepared depend on the total yearly tonnage of the substance. Substances should be registered over an appropriate period of time as it is shown below, depending on the quantity marketed:
Above 1000 tons/year + substances of very high concern (SVHC)— over 3.5 years
100–1000 tons/year—over 6 years

1–100 tons/year—over 11 years
Chemical substances can also be preregistered, allowing transition periods for the manufacturers and importers. At preregistration, the registrant must submit the following basic information to the agency: The identity of the substance as specified in Section 2 of Annex VI of the regulation
The identity and contact details of the producer or importer who should be contacted
The prospective deadline for registration or tonnage band
These data must be submitted between 1 June 2008 and 1 December 2009. The producer must complete prereregistration. Substances exceed-ing 1 ton/year require submission of a registration dossier. Substances exceeding 10 tons/year require a chemical assessment, and a chemi-cal safety report must be prepared if the substances are classified as vPvB or persistent, bioaccumulative and/or toxic (PBT; Miranowicz-Dzierz˙awska 2008).
Evaluation: Both the industry (within registration obligations) and the com-petent authorities in the member states will evaluate the substance's poten-tial risk. The agency will also evaluate the registration dossier, perform preliminary verification of the technical dossier, and send it to the compe-tent authorities in the relevant country for a detailed evaluation.
Authorisation: Certain substances will require authorisation from the European Commission. The authorisation procedure covers SVHC because some agents have very serious and often irreversible effects on humans and the environment, regardless of their tonnage. These substances are classified as carcinogenic, mutagenic, or harmful to reproduction or PBT or vPvB.
Restriction: Some dangerous substances will be subject to restrictions on their manufacture, marketing and use. The list of substances subject to these restrictions is specified in Annex C to the regulation, and will be established and modified as necessary at the request of the European Commission or member states.
The regulation also established a new institution, the European Chemicals Agency, based in Helsinki, which will be responsible for the implementation of the REACH system at the community level.
REACH introduces substantial changes to the system for developing and com-municating information about chemical substances. The most important changes are as follows:

- Shifts the obligation to prove that a substance is dangerous from the state authorities to the manufacturer or importer.
- Creates a uniform legal system for placing chemical substances on the market.
- Updates information about chemical substances according to an established schedule.
- Imposes an obligation to evaluate the chemical substance to intermediate users.
- Disseminates information about registered chemical substances.

7.11 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 obli-gation of an employer should be the systematic identification and assessment of haz-ards connected with chemicals in the work environment.

7.11.1 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. This can be methods specified in Polish and inter-national standards or other equivalent methods that are consistent with the general requirements of the European standard PN EN 482 2006.
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 mea-sured (ideally at the level 0.1 MAC and at least 0.25 MAC). The specifics of the air samples have a considerable influence on the results of the measurements and the assessment of exposure to harmful chemical substances in the work environment, and therefore should be taken with great precision regarding the volume of air and quan-titative identification of the tested substances. The method of taking the air sample is selected depending on the substance's properties and the analytical techniques used. The person selecting the appropriate methods should know the technological process and physicochemical properties of the substances they are hoping to quantify. The main methods of taking air samples are the isolation method and the integration method. The isolation method is used to take samples of air containing gases and vapours of low-boiling liquids. It involves taking a definite amount of air in a special container, for example, gas pipettes, cylinders, glass or plastic syringes, or even plastic bags. Although this method is simple, its applications are limited due to the small amount of air taken, which is often not sufficient to determine the MAC. Moreover, adsorption of the container walls can cause losses of the substance being measured. This method should not be used for taking air samples that contain reactive or easily adsorbing materials. In the integration method, a definite amount of air flows through sorbents that quantitatively absorb the tested substances. Air samples are enriched by the absorp-tion of substances into solutions or by adsorption of solid sorbents. The kit for taking samples includes the following:
An absorber, which may be an impinger filled with an absorbing solution, a tube filled with

a solid absorber, or a filter placed in a fitting An air pump to ensure a constant flow rate A rotameter

For liquid sorbents, the determined substances either dissolve in the sorbent or enter into the chemical reaction, resulting in a colour change. The absorption efficiency

depends on the sorbent type and absorption conditions such as the velocity and volume of airflow and the column height of the liquid in the impinger temperature. For chemisorption, that is, absorption as a chemical reaction between the substance and the surface liquid sorbent, the airflow velocity should be adapted to the speed of this reaction. Prolonging the time the two phases are in contact and enlarging the con-tact surface by using washers with sintered glass increases the absorption efficiency.

While using solid sorbers to separate the substances from the air, the substances are adsorbed on the sorbent surface. Different materials with well-developed sur-faces may be used as sorbents, for example, activated carbon, silica gel, alumin-ium oxide, molecular sieves, a mixture of aluminium oxide and magnesium oxide, Florisil, modified diatom soil (e.g. chromosorbs), and plastics (Amberlite XAD res-ins, tenax, resins, chromosorbs of series 100, and porapak).

Depending on the physicochemical properties of the substance being separated from the tested air, suitable solid sorbents can be used. The sorption ability of the substance depends mainly on its polarity, particle size, and vapour pressure. Polar compounds adsorb more easily on polar sorbents such as activated carbon, and non-polar compounds on nonpolar sorbents such as silica gel.

Adsorbing tubes are most frequently used for taking air samples. They are usually made of glass and contain the sorbent in two layers (10 and 100 mg) separated by dividers of glass fibre or polyurethane foam and closed with plastic plugs.

Substances adsorbed on solid sorbents in adsorbing tubes are separated quantita-tively, using a process reverse to adsorption, desorption. Two types of desorption may be used in the analysis of air: desorption with a suitable solvent (eluent) and thermal desorption into a gaseous phase. However, desorption with a solvent is commonly used in standardised methods to determine harmful substances, using gas chromatography as a measuring technique. The procedure should ensure quantitative desorption with the highest possible efficiency. Usually the efficiency is lower than 100 percent and there-fore it is necessary to determine the desorption coefficient, which should be taken into account when calculating the content of determined substances in the air sample. Chemisorption is also used to separate and determine the substances on solid sor-bents. In these cases, the solid sorbents are covered with special reagents that react with the tested substances during absorption and form special products that are the basis for further determination. Taking air samples on solid sorbents has many advantages: it allows enrichment and long-term storage of samples, easy transport, and easy service. The integra-tion method to separate air contaminants uses pumps that allow constant airflow through the sorbents. Different types of pumps can be used for this purpose, but membrane pumps powered by a battery or main supply are most frequently used. Portable battery pumps are the most convenient, as they enable airflow with different velocities—from 0.02 to several litres per minute, for at least 12 hours. Nonexplosive battery pumps are also produced for use in explosive conditions.

7.11.2 Strategy of Measurements for Inhalation Exposure Assessment

Proper air sampling using the above-mentioned methods is necessary for occupational exposure assessment of chemical agents, and should be performed in accordanc
with existing rules that govern the assessment of the compatibility of work condi-tions with MAC-TWA, MAC-STEL, and MAC-ceiling (MAC-C).

Air samples should be taken in each worker's breathing zone during his or her entire stay at a workstation, using individual dosimetry. Taking air samples with this method requires suitable equipment, either samplers with individual battery pumps or passive dosimeters without pumps. Laboratories without such equipment can use stationary measurements, in which air samples are taken at permanent measurement points, as close to the workstations as possible. Samples must be taken randomly, and the time of each sampling depends on the determination method that is being used.

In occupational exposure assessment, personal samplers are placed in the worker's breathing zone for at least 75 percent of the work shift. The assessment should cover all workers whose jobs involve contact with harmful substances. To assess the compat-ibility of work conditions with MAC values, two to five samples should be taken continuously using pumps with a sampler, and one sample should be taken using a passive dosimeter.

At least two 15-minute samples should be taken when the concentration is the highest, to determine the 'short-term concentration' and its compatibility with MAC-STEL values. For stationary measurements, the rules for taking air samples depend on the timing of the tasks.

If the chemicals in the work environment cause acute irritation, act quickly, or have a disagreeable smell, and have MAC-C values established, then air samples should be taken as quickly as possible. Continuous monitoring of substance concen-trations may be performed at stationary posts localised in the workers' area or by individual analysers placed directly on the work clothing.

Because there are no devices for making continuous measurements, the samples should be taken in a short amount of time, or, the measurements should be taken at regular intervals and in all periods of expected high concentrations. The time span between successive measurements depends upon the homogeneity of the technologi-cal process and the changeability of concentrations. The time spans are as follows:

30 minutes for nonhomogenous technological processes of high concentra-tion changeability

1 hour for technological processes of low concentration changeability

The concentration should not exceed the MAC-C in samples taken as mentioned above or in other samples taken for exposure assessment.

Devices such as portable analysers and tube indicators can be used for this type of measurement, rather than using methods that yield results only after the sample has been analysed.

Gas and absorption chromatography are most frequently used to determine the chemicals in air samples taken at workstations. Visible, infrared, and ultraviolet spectrophotometry and high-performance liquid chromatography are used less often.

7.11.3 Assessment of Occupational Inhalation Exposure

The main criteria for assessing inhalation exposure are the results of the measure-ment 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, TWA concentration Xg, the upper and lower limit of the confidence interval (UC and LC) for a real-time average or TWA concentration (PN-Z-04008-7 2002; Gromiec 2005; PN-EN 689 2002).
If the TWA concentration or the upper limit of the confidence interval of real-time average does not exceed the MAC-TWA value, then work conditions are considered to be compliant with the requirements. If the MAC-TWA value is in the confidence interval for the geometric mean of the measurement results, then the data are not sufficient to determine if work conditions comply with exposure limits. Additional tests of the work environment should then be conducted, and measurements should be made over 30 days on two randomly chosen work shifts, taking at least five air samples at each shift. If the results of more than half of the samples are over the MAC-TWA, the work conditions are considered harmful. If the results for half of the samples are equal to or below MAC-TWA, the work conditions are considered safe.
If several chemical substances are present simultaneously in the workplace air, then combined exposure should also be assessed by summing up the toxic effects of all chemicals.
Work conditions are considered safe if, for both samples taken intentionally in the periods of highest emission of substances and samples taken randomly, the concen-tration in any of the 15-minute air samples taken does not exceed the MAC-STEL for the given substance.
Work conditions are considered harmful in the following cases:
The concentration in any 15-minute sample is higher than the MAC-STEL.
A concentration equal to the MAC-STEL is in the work environment for more than 15 minutes or occurs more than twice.
The interval between two 15-minute periods when the concentration is equal to the MAC-STEL is shorter than 1 hour.
Work conditions can be considered safe if the determined concentration does not exceed the MAC-C for the given substance. If a chemical agent harmful to workers' health is present in a workplace, the employer must carry out tests and periodical measurements of this agent within the following time frames:
At least every 2 years if, in the last test, the concentration of the harmful agent was 0.1–0.5 inclusive of the MAC-TWA set out in the regulations.
At least once a year if the concentration of the harmful agent is between 0.5 and 1.0 inclusive of the MAC-TWA set out in the regulations.
When a carcinogenic or mutagenic agent occurs in workplace air, the employer must measure

this agent in accordance with the regulations:
In all cases when the conditions of using the agent have changed
At least once every 3 months if the concentration of carcinogenic or muta-genic agent is between 0.5 and 1.0 inclusive of the MAC-TWA value
At least once every 6 months if the concentration of carcinogenic or muta-genic agent is between 0.1 and 0.5 inclusive of the MAC-TWA value
If the MACs of an agent harmful to workers' health are exceeded, the employer must determine the causes and introduce the necessary technical, technological, or organisational changes immediately.
Periodical measurements of harmful chemical agents are not obligatory if the results of the last two measurements do not exceed 0.1 MAC-TWA and no changes in the technological process that could affect the concentration of the harmful agent are foreseen. This also applies to measurements of carcinogenic or mutagenic agents.

7.11.4 Strategy for Dermal Exposure Assessment

Dermal exposure occurs when a substance is in contact with the epidermis, can be absorbed dermally, and shows systemic effects and/or causes local effects, that is, effects on the skin's surface. Contact of chemical substances with the skin may lead to irritation, rashes, acne, and even ulceration or subcutaneous haemorrhage, burns and damage of the skin's protective properties due to long-term exposure.
Dermal exposure causes dynamic interaction between environmental contami-nants and the skin. Unlike inhalation exposure, dermal exposure is not currently considered in general occupational risk assessment, although the harmful effects and occupational skin diseases it can cause are documented in literature and in the results of epidemiological and statistical studies (Marquart et al. 2006).
In accordance with recommendations of European directives and national reg-ulations, the assessment of exposure to chemical substances in the work environ-ment should take into account many parameters of dermal exposure. These include the quantities of the chemical substances deposited on the skin, the surface area of exposed skin, the duration of the deposition on the skin, and the amount of the substance that is absorbed through the skin under normal occupational exposure conditions.
Methods to measure the concentrations of chemical substances and assess der-mal exposure increasingly have been the subject of research. CEN TC 137 has dealt with this problem as well and has started developing standards. Workplace exposure—Measurement of dermal exposure—Principles and methods proposes principles and methods for measuring occupational dermal exposure (presented in Table 7.2).Selecting a method by which to measure chemical substances on the skin or on work or protective clothing depends on physicochemical properties and quantity of the deposited substance. However, basing the method on the determination of mass will fail when the results of the measurement are used to calculate and evaluate the quantity of

chemical substance absorbed into the body, mainly due to the lack of limit values for chemical substances deposited on the skin. Surrogate skin and biomonitoring of the chemical substances or their metabolites in out-breathing air of the worker, in urea, blood, or in other biological materials can

CHAPTER 8

Violence in the workplace

8.1 Workplace violence

Work place violance has emerged as a critical safety and health issue. According to the Bureau of Labor Statistics, homicide is the second leading cause of death to American workers, “accounting for 16 percent of the 6,588 fatal work injuries in the United States. Although more than 80 percent of workplace homicide victims are men, workplace violence is not just a male problem. In fact, workplace homicide is the leading cause of death on the job for women in the United States.
Almost 1 million people are injured or killed in workplace-violence incidents every year in the United States, and the number of incidents is on the rise. In fact, according to the U.S. Department of Justice, the workplace is the most dangerous place to be in the United States. Clearly, workplace violence is an issue of concern to safety and health professionals.

8.2 OCCUPATIONAL SAFETY AND WORKPLACE VIOLENCE: THE RELATIONSHIP

The prevention of workplace violence is a natural extension of the responsibilities of safety and health professionals. Hazard analysis, records analysis and tracking, trend monitoring, incident analysis, and prevention strategies based on administrative and engineering controls are all fundamental to both concepts. In addition, emergency response and employee training are key elements of both. Consequently, occupational safety and health professionals are well suited to add the prevention of workplace violence to their normal duties.

WORKPLACE VIOLENCE: DEFINITIONS

Safety and health professionals should be familiar with the language that has developed around the issue of workplace violence. This section contains the definitions of several concepts as they relate specifically to workplace violence.

- Workplace violence. Violent acts, behavior, or threats that occur in the workplace or are related to it. Such acts are harmful or potentially harmful to people, property, or organizational capabilities.
- Occupational violent crime. Intentional battery, rape, or homicide during the course of employment.
- Employee. An individual with an employment-related relationship (present or past) with the victim of a workplace-violence incident.
- Outsider. An individual with no relationship of any kind with the victim of a workplace-violence incident or with the victim’s employer.
- Employee-related outsider. An individual with some type of personal relationship (past or present) with an employee, but who has no work-related relationship with the employee.
- Customer. An individual who receives products or services from the victim of a workplace-violence incident or from the victim’s employer.

Each of these terms has other definitions. Those presented here reflect how the terms are used in the language that has evolved around workplace violence.

WORKPLACE VIOLENCE: CASES

This section contains numerous cases of workplace violence that occurred in the United States during a one-year period. These cases are provided to give students of occupational safety and health a better understanding of the types of violent incidents that occur frequently in today's workplace. The names of individuals involved have been changed, but the incidents are real.

1. Jackson, Mississippi. A 32-year-old firefighter shot his wife through the head and then proceeded to a firehouse. Using an assault rifle, the man shot six coworkers—all supervisors—killing four of them and seriously wounding another two. He then fled the scene and exchanged fire with a police officer, wounding the officer, before being shot in the head himself and critically injured. The president of the union representing the shooter described him as "a time bomb waiting to go off."

Fort Lauderdale, Florida. Shouting "Everyone is going to die," a maintenance employee who had been fired walked into a meeting of his former coworkers and began shooting, killing five people and injuring another. The employees were inside a temporary trailer office when the disgruntled former employee showed up with two handguns. Police say that he chased workers around the office and shot them methodically, pausing only to reload.

3. Honolulu, Hawaii. An employee returned to his former workplace after being fired from his job. He held five coworkers hostage—including his former boss—for up to six hours. During the incident, the disgruntled former employee shot and seriously wounded his former supervisor. He was eventually killed by police after he held a shotgun to the head of one coworker for several hours while negotiating with officers. Prior to being shot by police, the perpetrator threatened to kill the coworker and started a countdown to pulling the trigger of the gun. The countdown prompted the hostage to grab the barrel of the gun and gave police the opportunity to shoot. The perpetrator died of his wounds.

4. Waterville, Maine. A former patient of a mental institution was accused of beating and stabbing four nuns, killing two of them. Police said that they caught the perpetrator in the convent's chapel Saturday evening, standing over one of the nuns and beating her with a religious figurine. Officers said that they had to pull him off the woman and that he had also beaten and stabbed three others in an adjacent part of the convent. Nuns at the convent of the Servants of the Blessed Sacrament said that the man had applied for a job but had been turned down. Nuns had just finished a prayer service when the perpetrator smashed the glass on a locked door, opened it, and walked inside. The perpetrator was described as an accomplished musician who had played trumpet in a local jazz combo and studied at the University of Maine at Augusta.

5. Evensdale, Ohio. A male in his early fifties returned to the office from which he had recently been fired. Brandishing two pistols, he shot and killed three employees and wounded a fourth. A witness quoted the perpetrator as saying he was "going after someone who had screwed him over." After the murders, he surrendered quietly to authorities.

SIZE OF THE PROBLEM
Violence in the workplace no longer amounts to just isolated incidents that are simply aberrations. In fact, workplace violence should be considered a common hazard worthy of the attention of safety and health professionals. In a report on the subject, the U.S.
Department of Justice revealed the following information:
• About 1 million individuals are the direct victims of some form of violent crime in the workplace every year. This represents approximately 15 percent of all violent crimes committed annually in America. Approximately 60 percent of these violent crimes were categorized as simple assaults by the U.S. Department of Justice.
• Of all workplace violent crimes reported, over 80 percent were committed by males;
40 percent were committed by complete strangers to the victims; 35 percent by casual acquaintances, 19 percent by individuals well known to the victims, and 1 percent by

8.2.1 relatives of the victims

• More than half of the incidents (56 percent) were not reported to police, although 26 percent were reported to at least one official in the workplace.
• In 62 percent of violent crimes, the perpetrator was not armed; in 30 percent of the incidents, the perpetrator was armed with a handgun.
• In 84 percent of the incidents, there were no reported injuries; 10 percent required
medical intervention
• More than 60 percent of violent incidents occurred in private companies, 30 percent in government agencies, and 8 percent to self-employed individuals.
• It is estimated that violent crime in the workplace caused 500,000 employees to miss 1,751,000 days of work annually, or an average of 3.5 days per incident. This missed work equates to approximately $55 million in lost wages.5
The Society for Human Resource Management periodically surveys its members on the issue of workplace violence. One such survey produced the following results:6
Regarding violent incidents in the workplace:
• 33 percent of all managers surveyed experienced at least one violent incident in the workplace.
• 54 percent of these managers reported between two and five acts of violence in the five years prior to the survey.
Regarding the type of violence experienced:
• 75 percent of the reported incidents were fistfights.
• 17 percent of the incidents were shootings.

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Regarding the type of violence experienced:
• 75 percent of the reported incidents were fistfights.
• 17 percent of the incidents were shootings.
• 8 percent of the incidents were stabbings.
• 6 percent of the incidents were sexual assaults.
Regarding the victims of the incidents:
• 54 percent of the incidents were employee against employee.
• 13 percent of the incidents were employee against a supervisor.
• 7 percent of the incidents were customer against worker(s).

Regarding the gender of the perpetrator:
• 80 percent of all violent acts were committed by males.
Regarding the injuries sustained by the victims:
• 22 percent of the incidents involved serious harm.
• 42 percent of the incidents required medical intervention.
Regarding the reasons for the violent incidents:
• 38 percent were attributed to personality conflicts.
• 15 percent were attributed to marital or family problems.
• 10 percent were attributed to drug or alcohol abuse.
• 7 percent were nonspecific as to attribution.
• 7 percent were attributed to firings or layoffs.
Regarding crisis management programs:
• 28 percent of the organizations had a crisis management program in place prior to the violent incident.
• 12 percent of the organizations implemented a crisis management program after the violent incident occurred.
Regarding the effect of a violent incident on the workplace:
• 41 percent of the organizations reported increased stress levels in the workplace after a violent incident.
• 20 percent reported higher levels of paranoia.
• 18 percent reported increased distrust among employees.
LEGAL CONSIDERATIONS
Most issues relating to safety and health have legal ramifications, and workplace violence is no exception. The legal aspects of the issue revolve around the competing rights of violent employees and their coworkers (Figure 8–1). These conflicting rights create potential liabilities for employers.

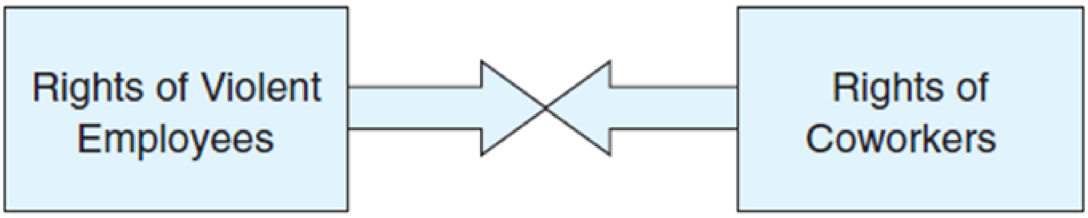

FIGURE 8.1

8.3 Rights of Violent Employees

It may seem odd to be concerned about the rights of employees who commit violent acts on the job. After all, logic suggests that in such situations the only concern would be the protection of other employees. However, even violent employees have rights. Remember, the first thing that law enforcement officers must do after taking criminals into custody is to read them their rights.

8.3.1 Employer Liability for Workplace Violence

Having to contend with the rights of both violent employees and their coworkers, employers often feel as if they are caught between a rock and a hard place. Fortunately, the situation is less bleak than it may first appear primarily due to the exclusivity provision of workers' compensation laws. This provision makes workers' compensation the employee's exclusive remedy for injuries that are work-related. This means that even in cases of workplace violence, as long as the violence occurs within the scope of the victim's employment, the employer is protected from civil lawsuits and the excessive jury
verdicts that have become so common.
The key to enjoying the protection of the exclusivity provision of workers' compensation laws lies in determining that violence-related injuries are within the scope of the victim's employment—a more difficult undertaking than one may expect. For example,
if the violent act occurred
at work but resulted from a non-work-related dispute, does the exclusivity provision apply? What if the dispute was work-related, but the violent act occurred away from the workplace?
Making Work-Related Determinations
The National Institute for Occupational Safety and Health (NIOSH) developed the following guidelines for categorizing an injury as being work-related:
• If the violent act occurred on the employer's premises, it is considered an on-the-job event if one of the following criteria apply:
The victim was engaged in work activity, apprenticeship, or training.
The victim was on break, in hallway, restrooms, cafeteria, or storage areas.
The victim was in the employer's parking lots while working, arriving at, or leaving work.
• If the violent act occurred off the employer's premises, it is still considered an on-the job event, if one of the following criteria apply:
The victim was working for pay or compensation at the time, including working at
home. The victim was working as a volunteer, emergency services worker, law enforcement officer, or firefighter.
The victim was working in a profit-oriented family business, including farming.
The victim was traveling on business, including to and from customer-business
contacts.
The victim was engaged in work activity in which the vehicle is part of the work
environment (taxi driver, truck driver, and so on)10.

8.4 RISK-REDUCTION STRATEGIES

Figure 8–2 is a checklist that can be used by employers to reduce the risk of workplace violence in their facilities. Most of these risk-reduction strategies grow out of the philosophy of crime reduction through environmental design (CRTED).11 CRTED has the following four major elements, to which the author has added a fifth (administrative controls).

- Natural surveillance
- Control of access
- Establishment of territoriality
- Activity support
- Administrative controls

The following explains how these elements can help avoid workplace violence:

1. Natural surveillance. This strategy involves designing, arranging, and operating the workplace in a way that minimizes secluded areas. Making all areas inside and outside the facility easily observable allows for natural surveillance.
2. Control of access. One of the most common occurrences of workplace violence involves an outsider entering the workplace and harming employees. The most effective way of stopping this type of incident is to control access to the workplace. Channeling the flow of outsiders to an access-control station, requiring visitor's passes, issuing access badges to employees, and isolating pickup and delivery points can minimize the risk of violence perpetrated by outsiders.
3. Establishment of territoriality. This strategy involves giving employees control over the workplace. With this approach, employees move freely within their established territory but are restricted in other areas. Employees come to know everyone who works in their territory and can, as a result, immediately recognize anyone who shouldn't be there.
4. Activity support. Activity support involves organizing workflow and natural traffic patterns in ways that maximize the number of employees conducting natural surveillance. The more employees observing the activity in the workplace, the better.
5. Administrative controls. Administrative controls consist of management practices that can reduce the risk of workplace violence. These practices include establishing policies, conducting background checks, and providing training for employees.

- ✓ Identify high-risk areas and make them visible. Secluded areas invite violence.
- ✓ Install good lighting in parking lots and inside all buildings.
- ✓ Minimize the handling of cash by employees and the amount of cash available on the premises.
- ✓ Install silent alarms and surveillance cameras where appropriate.
- ✓ Control access to all buildings (employee badges, visitor check-in and check-out procedure, visitor passes, and so on).
- ✓ Discourage working alone, particularly late at night.
- ✓ Provide training in conflict resolution as part of a mandatory employee orientation.
- ✓ Conduct background checks before hiring new employees.
- ✓ Train employees how to handle themselves and respond when a violent act occurs on the job.
- ✓ Develop policies that establish ground rules for employee behavior and responses in threatening or violent situations.
- ✓ Nurture a positive, harmonious work environment.
- ✓ Encourage employees to report suspicious individuals and activities or potentially threatening situations.
- ✓ Deal with allegations of harassment or threatened violence promptly before the situation escalates.
- ✓ Take threats seriously and act appropriately.
- ✓ Adopt a *zero-tolerance* policy toward threatening or violent behavior.
- ✓ Establish a *violence hot line* so that employees can report potential problems anonymously.
- ✓ Establish a *threat-management team* with responsibility for preventing and responding to violence.
- ✓ Establish an *emergency response team* to deal with the immediate trauma of workplace violence.

Figure 8.2

who works in their territory and can, as a result, immediately recognize anyone who shouldn't be there.

4. Activity support. Activity support involves organizing workflow and natural traffic patterns in ways that maximize the number of employees conducting natural surveillance.

The more employees observing the activity in the workplace, the better.

5. Administrative controls. Administrative controls consist of management practices that can reduce the risk of workplace violence. These practices include establishing policies, conducting background checks, and providing training for employees.

6. Another way to reduce the risk of workplace violence is to ensure that managers understand the social and cultural factors that can lead to it. These factors fall into two broad categories: individual and environmental factors.

Discussion Case

What Is Your Opinion?

A man walks into an office building and asks to see his wife. The man is well known to the other employees, one of whom escorts him to his wife's workstation. Suddenly, the man pulls a gun and shoots his wife and another employee who tries to intervene. Is this an on-the-job event? Is the employer at fault? What is your opinion about this incident involving an employee-related outsider?

Another way to reduce the risk of workplace violence is to ensure that managers understand the social and cultural factors that can lead to it. These factors fall into two broad categories: individual and environmental factors.
Individual Factors Associated with Violence
The factors explained in this section can be predictors of the potential for violence. Employees and individuals with one or more of the following factors may respond to anger, stress, or anxiety in a violent way.
1. Record of violence. Past violent behavior is typically an accurate predictor of future violent behavior. Consequently, thorough background checks should be a normal part of the employment process.
2. Membership in a hate group. Hate groups often promote violence against the subjects of their prejudice. Hate-group membership on the part of an employee should raise a red flag in the eyes of management.
3. Psychotic behavior. Individuals who incessantly talk to themselves, express fears concerning conspiracies against them, say that they hear voices, or become increasingly disheveled over time may be violence prone.
4. Romantic obsessions. Workplace violence is often the result of romantic entanglements or love interests gone awry. Employees who persist in making unwelcome advances may eventually respond to rejection with violence.
5. Depression. People who suffer from depression are prone to hurt either themselves or someone else. An employee who becomes increasingly withdrawn or overly stressed may be suffering from depression.
6. Finger pointers. Refusal to accept responsibility is a factor often exhibited by perpetrators of workplace violence. An employee's tendency to blame others for his or her own shortcomings should raise the caution flag.
7. Unusual frustration levels. The workplace has become a competitive, stressful, and sometimes frustrating place. When frustration reaches the boiling point, the emotional explosion that results can manifest itself in violence.
8. Obsession with weapons. Violence in the workplace often involves a weapon (gun, knife, or explosive device). A normal interest in guns used for hunting or target practice need not raise concerns. However, an employee whose interest in weapons is unusually intense and focused is cause for concern.
Safety Fact
Eight Steps for Preventing Workplace Violence
• Complete a risk-assessment survey of the entire workplace.
• Review existing security procedures.
• Develop and publish a policy statement that explains expectations, rules for behavior, roles, duties and responsibilities.

• Develop work-site-specific prevention procedures. • Train all managers, supervisors, and employees.
• Establish incident-reporting and investigation procedures.
• Establish incident-follow-up procedures (trauma plan, counseling services, and disciplinary guidelines).
• Monitor, evaluate, and adjust procedures.
9. Drug dependence. It is common for perpetrators of workplace violence to be drug abusers. Consequently, drug dependence should cause concern not only for all the usual reasons but also for its association with violence on the job.

Environmental Factors Associated with Violence

The environment in which employees work can contribute to workplace violence. An environment that produces stress, anger, frustration, feelings of powerlessness, resentment, and feelings of inadequacy can increase the potential for violent behavior. The following factors can result in such an environment:
1. Dictatorial management. Dictatorial, overly authoritative management that shuts employees out of the decision-making process can cause them to feel powerless, as if they have little or no control over their jobs. Some people respond to powerlessness by striking out violently—a response that gives them power, if only momentarily.
2. Role ambiguity. One of the principal causes of stress and frustration on the job is role ambiguity. Employees need to know for what they are responsible, how they will be held accountable, and how much authority they have. When these questions are not clear, employees become stressed and frustrated, factors often associated with workplace violence.
3. Partial, inconsistent supervision. Supervisors who play favorites engender resentment in employees who aren't the favorite. Supervisors who treat one employee differently from another or one group of employees differently from another group also cause resentment. Employees who feel that they are being treated unfairly or unequally may show their resentment in violent ways.
4. Unattended hostility. Supervisors who ignore hostile situations or threatening behavior are unwittingly giving them their tacit approval. An environment that accepts hostile behavior will have hostile behavior.
5. No respect for privacy. Supervisors and managers who go through the desks, files, tool boxes, and work areas of employees without first getting their permission can make them feel invaded or even violated. Violent behavior is a possible response to these feelings.
6. Insufficient training. Holding employees accountable for performance on the job without providing the training that they need to perform well can cause them to feel inadequate. People who feel inadequate can turn their frustration inward and become depressed or turn it outward and become violent.

The overriding message in this section is twofold. First, managers should establish and maintain a positive work environment that builds up employees rather than tearing them down. Second, managers should be aware of the individual factors that can contribute to violent behavior and respond promptly if employees show evidence of responding negatively to these factors.

CHAPTER 9

Electromagnetic Hazards in the Workplace

Introduction

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 elec-tromagnetic waves of various frequencies in wireless communications (Figure 9.1). 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

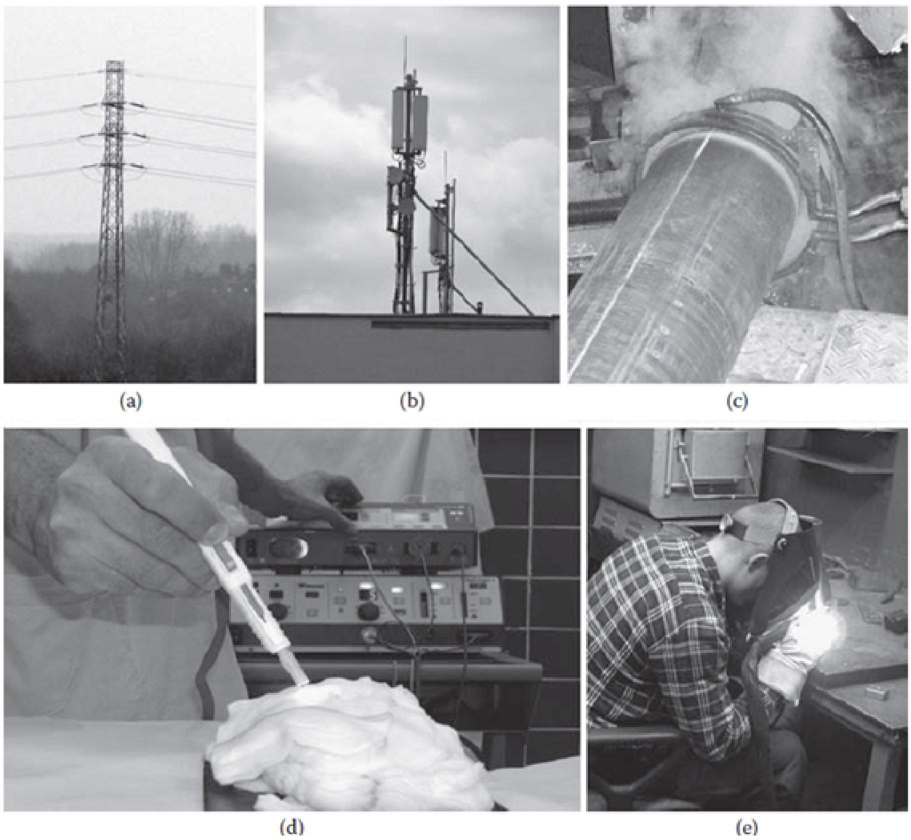

FIGURE 9.1: Examples of electromagnetic field sources: (a) a high-voltage power line; antennas of mobile phone base stations; (c) an induction heater; (d) an electrical surgery device; and (e) an arc welding device.

Figure 9.1 workplace 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.

9.1 General Description

The frequency of time-varying EMFs is unlimited. EMFs of frequencies exceeding several megahertz (MHz) are also called electromagnetic radiation. The electromag-netic spectrum (Figure 9.2) 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 (gigahertz), 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.

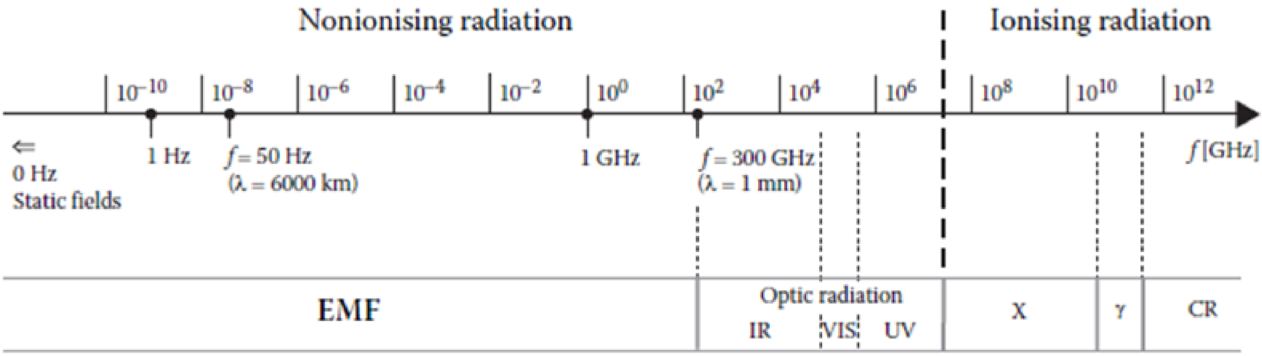

FIGURE 9.2: Seven segments

Frequency spectrum of electromagnetic fields and radiation. IR = infrared radiation, VIS = visible radiation, UV = ultra-violet radiation, X = roentgens's ray, = 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 mag-netisation 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.

9.2 Definitions and Related Terms

Wavelength : 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 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 elec-tric 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 mag-netic flux density of about 1.25 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 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 µT.
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 spe-cific 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 immedi-ate 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/m2).
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 measur-able 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).

n – Nano	$\times 10^{-9}$	(×0.000 000 001)
μ – Micro	$\times 10^{-6}$	(×0.000 001)
m – Milli	$\times 10^{-3}$	(×0.001)
	$\times 10^{0}$	(×1)
k – Kilo	$\times 10^{3}$	(×1,000)
M – Mega	$\times 10^{6}$	(×1,000,000)
G – Giga	$\times 10^{9}$	(×1,000,000,000)

Figure 9.3: Prefixes

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

9.3 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 (ICNIRP 1998; IEEE 2002, 2005; Reilly 1998; WHO 1993, 2006, 2007).
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 (ICNIRP 1998; IEEE 2002, 2005; Reilly 1998; WHO 2007). The intensity and the spatial distribu-tion 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 equip-ment. The ignition of flammable or explosive materials by sparks produced by the flow of an induced current or the discharge of an electrostatic charge (WHO 2006; IEEE 2002) 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 hear-ing sensations, called the Frey effect (Reilly 1998; IEEE 2005).

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 frequen-cies exceeding 1 MHz; ICNIRP 1998; Reilly 1998; WHO 1993). 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 (Directive 2004/40/EC; ICNIRP 1998; Karpowicz et al. 2006).

The health consequences of various interactions of EMFs with the human body are not yet established (Karpowicz and Gryz 2007a; WHO 1987, 1993, 2006, 2007). The following mechanisms of human interaction with EMF have been found (Reilly 1998):

1. Established mechanisms of human interaction with EMF:

- Synapse activity alteration by membrane polarisation (phosphenes)
- Peripheral nerve excitation by membrane depolarisation
- 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 (Karpowicz et al. 2007; WHO 2007).

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 possi-bility 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 inter-mediate 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.

9.4 Methods of Assessing the Electromagnetic Field

Investigations of EMFs in work environments are conducted to identify the sources of fields, which can produce a potential hazard to workers, and to assess the severity of the hazards caused by such fields. The investigations are conducted by making measurements or calculations of the parameters of the fields affecting the workers and of the technical objects present in the work environment (Gryz and Karpowicz 2000, 2008; Karpowicz and Gryz 2007a). These measurements are mostly used to assess the level of the electric or magnetic fields present in the workplace (Figure 9.3). The measurements of induced or contact currents may be a complement to electric and magnetic field measurements (Figure 9.4).

To obtain standardised and repetitive results, the quantities of the unperturbed field (i.e. not interfered with by human presence) are used to determine the EMF affecting the human body or the environment. Therefore, measurements are taken at the location of normal work activities, but in the absence of workers.

Measurement devices are composed of exchangeable measurement probes with magnetic or electric field sensors and a battery-powered monitor containing an indi-cator. Electric dipoles are usually used as the electric field sensors, whereas the mag-netic fields are measured by multiturn coils or Hall sensors.

The calculations that are usually performed when assessing electromagnetic hazards in the work environment are focused on the internal measures of exposure effects (J and SAR) in the worker's body (Figure 9.5; Karpowicz and Gryz 2007a). This may lead to being able to determine the distribution of external measures of exposure as well (e.g. when the unperturbed field cannot be properly measured or when there are problems with the assessment of EMF of highly heterogeneous spa-tial distribution in the workplace; Figure 9.6; Karpowicz and Gryz 2007a).

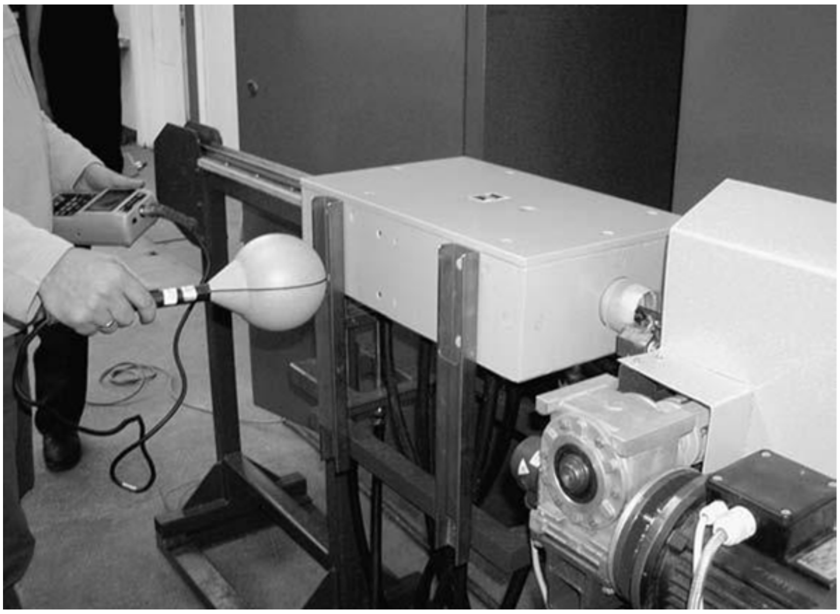

FIGURE 9.4: Assessing the worker's exposure based on the magnetic field strength in the operation of an induction heater

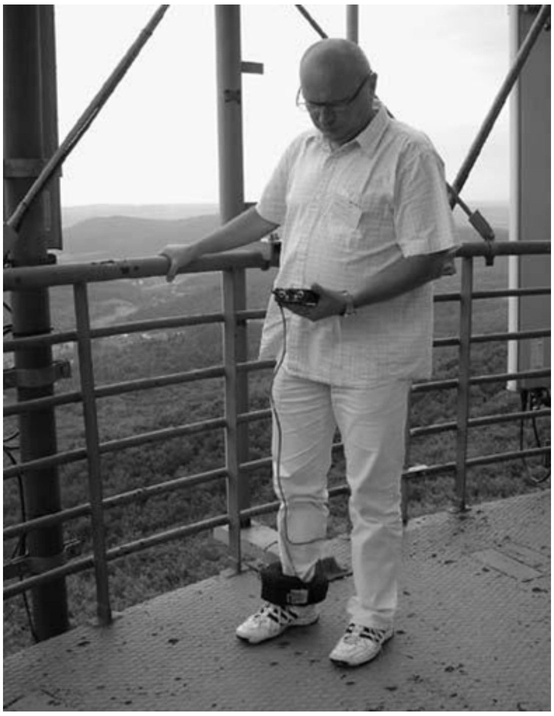

FIGURE 9.5: Assessing the worker's exposure based on the induced or contact current in the workplace while touching conductive objects exposed to an electromagnetic field

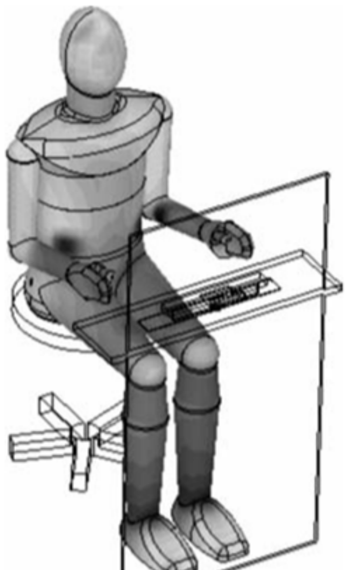

FIGURE 9.6: Assessing the worker's exposure by calculating internal measures of exposure; an example of simulation of the specific absorption rate (SAR) distribution in the body of a worker sitting in front of a dielectric heater (darker grey represents higher values).

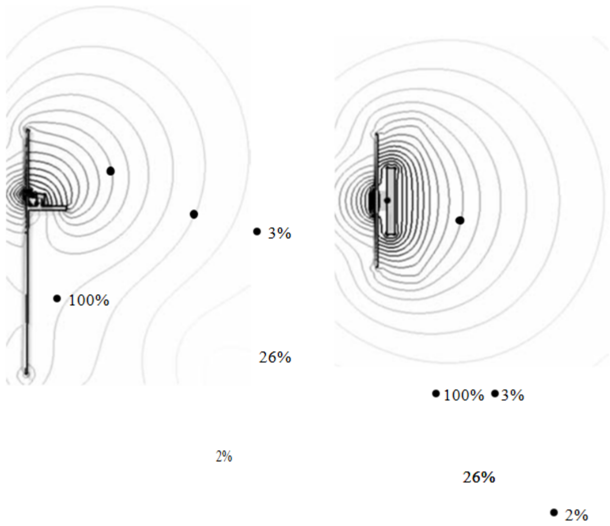

Figure 9.7: Assessing the level of the worker's exposure by calculating external measures of exposure; an example of spatial distribution of the electric field strength near a dielectric heater

Computer simulations use digital models that realistically represent exposure con-ditions in the workplace being investigated. This would include the geometry of the investigated area, the objects present there, the electrical properties of the materials, and models of the worker's body. To accurately determine the distribution of internal measures in a human body, the model should take into account details of the anatomy. The model can be simplified, and a homogeneous model (with simple geometric forms, such as cylinder, ellipsoid, or sphere) can be used where integral parameters are stud-ied, for example, SAR averaged over the whole body or contact and induced current.

Workers' exposure level should be assessed in the highest risk conditions. That is, the worst-case assessment in which the worker is affected by the fields of the highest level should be performed by measurements or calculations. Alternatively, the pos-sibility of exposures higher than as investigated should be considered in analysing the obtained results.

9.5 Parameters Representing the Exposure Level

Two types of quantities are used to assess the level of exposure to EMFs (Gryz and Karpowicz 2000; Karpowicz 2007; Karpowicz and Gryz 2007a,b; Karpowicz et al. 2006; Koradecka et al. 2006):

Internal measures of exposure (J and SAR) cannot be measured in a work environment, but their permissible values define the maximum level of exposure to EMFs.

External measures of exposure (E, H and B) can be measured in a work environment. They determine whether the exposure level in the workplace should be controlled and if preventive measures should be undertaken.

These are supplemented by permissible values of contact and induced currents that are related to the internal measures but measurable in a work environment. The lim-its for permissible internal measures of exposure should never be exceeded.

Widely accepted international documents providing guidelines on the permis-sible level of workers' exposure were published by ICNIRP, IEEE, and the European Parliament (Directive 2004/40/EC; ICNIRP 1998; IEEE 2002, 2005). Many countries use slightly modified values of the abovementioned limit values for their national occupational safety and health (OSH) policy (e.g. in Poland; Karpowicz et al. 2006). In the European Union OSH legislation system, the highest priority should be given to national legislation. International guidelines should be used for research or for OSH engineering where there is no national legislation.

Limits on the density of induced current refer to the head and torso (Table 9.1). Limits on the SAR ratio are defined as values averaged for the entire body (0.4 W/kg), local values in the head and torso (10 W/kg), and separate, local values in the limbs (20 W/kg), for frequencies between 100 kHz and 10 GHz (Directive 2004/40/EC; ICNIRP 1998) or for frequencies between 100 kHz and 3 GHz (IEEE 2005). The permissible values for induced and contact currents are specified in Tables 9.2 and 9.3 for assessing the exposure level of limbs.

Internal measures, correlated with the effects of exposure inside the body, were used in creating these guidelines to determine the limits of external measures, which can ensure compliance with limits of internal measures even in the most unfavour-able conditions of exposure (i.e. in the worst case of exposure to constant homoge-neous fields, with the highest level of interaction of the worker's body with the field, for example, the exposure of a grounded worker in an electric field of vertical polari-sation). Permissible values of external measures may be exceeded in a workplace if it is demonstrated that no risk exists when permissible internal measures are exceeded. Analysing this requirement usually involves assessing the level of internal measures based on the results of numeric simulations and is of little practical significance. Therefore, the current system is to manage health and safety in the work environ-ment containing EMFs sources by investigating and assessing the levels of external

Table 9.1

Permissible Values (RMS) of Current Density in Head and Torso

Frequency Range	Current Density in Head and Torso, J (mA/m^2)
Up to 1 Hz	40
1–4 Hz	40/*f*
4–1000 Hz	10
1 kHz–10 MHz	*f*100

Note: *f* = frequency in Hz.

Source: Data from Directive 2004/40/EC; and ICNIRP. 1998. *Health Phys* 74(4):494–522.

FIGURE 9.8: Permissible value of Current density in head and Torso

Table 9.2

Permissible Values of Induced Current

Document	Frequency	Induced Current (mA)
IEEE Std C.95.6, 2002; IEEE Std C 95.1, 2005	Up to 3 kHz	6 (both feet)
		3 (each foot)
	3–100 kHz	2*f* (both feet)
		1*f* (each foot)
	0.1–110 MHz	200 (both feet)
		100 (each foot)
Directive 2004/40/EC; ICNIRP 1998	10–110 MHz	100 (limb)

Note: *f* = frequency in kHz.

FIGURE 9.9: Permissible value of Induced Current

Table 9.3

Permissible Values of Contact Current

Document	Frequency	Contact Current (mA)
IEEE Std C.95.6, 2002; IEEE Std	Up to 3 kHz	3
C95.1, 2005–grasp		
	3–100 kHz	1*f*
	0.1–100 MHz	100
IEEE Std C.95.6, 2002; IEEE Std	Up to 3 kHz	1.5
C95.1, 2005–contact		
	3–100 kHz	0.5*f*
	0.1–110 MHz	50
Directive 2004/40/EC; ICNIRP,	Up to 2.5 kHz	1.0
1998–contact		
	2.5–100 kHz	0.4*f*
	0.1–110 MHz	40

Note: *f* = frequency in kHz.

FIGURE 9.10: Permissible value of contact Current

measures of exposure in the workplace. Relatively high uncertainties of EMF-related measurements and simulations, reaching 10%–50% in the case of measurements or more in the case of calculations, should be taken into account in the EMF-related OSH-management system.
Because bioelectrical parameters of the human body depend on the field fre-quency, permissible values of external measures also depend on the frequency (Figure 9.7).
Examples of EMF-related regulations can be found in OSH legislation in Poland. Detailed provisions are available from various Web pages (e.g. http://www.ciop. pl/EMF) or research papers (e.g. Gryz and Karpowicz 2000; Karpowicz 2007;

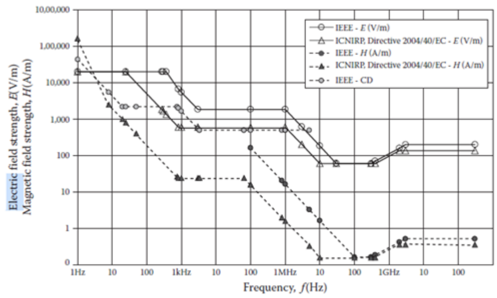

Figure 9.7 Permissible values of external measure, electric and magnetic field strength.

FIGURE 9.11: Permissible valuesof external measure, EMF strength

Karpowicz and Gryz 2007b; Karpowicz et al. 2006, 2008; Koradecka et al. 2006), in which the following limits are specified:

• Level of exposure permissible during an 8-hour shift, in the case of occupa-tional exposure, expressed in electric and magnetic field strengths (external measures)

• Principles for shortening the duration of exposure to fields of higher levels, expressed as the

exposure factor
• Threshold of prohibited exposure, acceptable for an exposure of only a few minutes per shift, expressed in electric and magnetic field strength
• Conditions in which it is permissible to work in fields at a prohibited level:
• when using a protective suit, (2) when low-frequency magnetic fields affect the limbs only
• Permissible exposure to pulse microwave fields
• Definition of occupational and nonoccupational exposures, related to vari-ous groups of workers and various conditions and permissible levels of their exposure
For EMF, permissible exposure conditions were stated to ensure that the influence of a field on a worker over the period of his or her work life, up to 40 years dura-tion, should not cause adverse changes in his or her health or the health of future generations.
Measurements should be performed in accordance with the standards harmo-nized with particular documents regarding the permissible conditions of exposure in the workplace. Polish standard PN-T-06580:2002, harmonized with the above-mentioned regulations on occupational exposure limitation, defines the terminology
and principles of measurement and assessment of workers' exposure to EMFs. The maximum permissible level of fields affecting workers are specified to ensure that the permissible values of internal measures are not exceeded in typical, realistic conditions of exposure in the workplace, and when such exposure does not exceed the threshold of prohibited exposure.
International guidelines available are as follows: measurement standard IEEE C95.3, 2002, harmonized with exposure limitations from standards IEEE C95.1, 2006 and IEEE C95.6, 2002. A detailed measurement methodology is not avail-able for ICNIRP recommendations, and standards harmonized with the require-ments of directive 2004/40/EC are being prepared by CENELEC, leaving practical problems calling for interpretation of the directive provisions (Hansson Mild et al. 2009).

9.5.1 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 perfomed directly

on the active antennae
• Power supplying devices, such as high-voltage power lines, transformer sta-tions, 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, induc-tion 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 broad-casting 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 frag-mented materials

9.6 Good Practices for Preventing Electromagnetic Hazards

To avoid the aforementioned adverse effects of chronic exposure, EMF affecting employees should be minimised using the available technical and organisational measures, regardless of the exposure level. To eliminate the exposure of workers to strong EMFs in the work environment, it is compulsory to apply diverse technical or organisational protective measures. The most effective good practices can be deter-mined by reviewing the solutions and tools used in various industries. Occupational and nonoccupational exposures are differentiated in the assess-ment of EMFs (Karpowicz and Gryz 2007a). Occupational exposure is exposure to high-level fields prohibited for the general public and results from operating devices generating strong EMFs (Figure 9.8). Nonoccupational exposure is exposure to weak EMFs in the area far from the source of a strong EMF. Such exposure is not restricted, regardless of the status of the worker or public members. Particular pro-tection is extended to young workers and pregnant women, for whom only nonoccu-pational exposure is allowed. The level of nonoccupational exposure is harmonized with the level of exposure acceptable for the general population, specified by regula-tions for public environments.

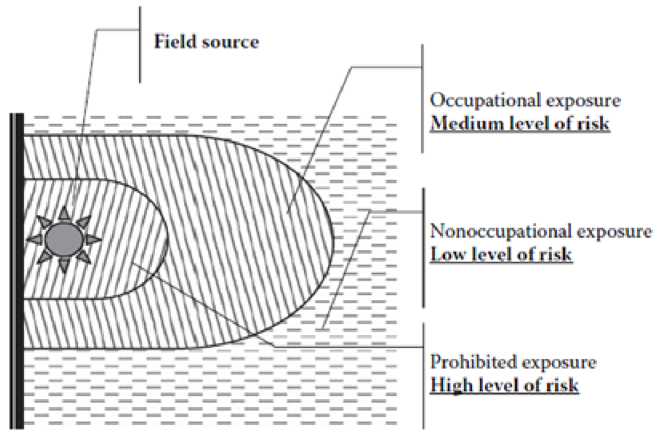

Figure 9.8 Principles for evaluating the occupational risk of exposure to electromagnetic fields.

FIGURE 9.12: Principles for evaluating the occupational risk of exposure to electromagnetic fields

Identification of groups of workers who are subject to occupational exposure and analysis of whether these groups can be minimised are key to the prevention of elec-tromagnetic hazards in the work environment.

Occupational exposure is allowed if the sources of EMFs are identified and marked (Figure 9.9) and workers have been informed about possible hazards in their surroundings. They also must be subject to medical surveillance (especially where excessive exposure has been found), and periodic training must be conducted on the principles of working safely in EMFs. Labelling EMF sources and the areas of high-level EMFs is necessary to warn workers of the presence of a hazard, particularly people with increased sensitivity, such as pregnant women or workers with medical implants.

Persons with a higher sensitivity to EMFs, for example, those with electronic imp lants, may require increased protection even in fields of nonoccupational exposure level. Following international recommendations, persons with active implants should not be in static magnetic fields exceeding 0.5 mT (millitesla) or in time-varying fields of a power frequency of 50 Hz, exceeding 100 T or 1 kV/m (ACGIH 2009, IEEE 2002, WHO 2007). They should not stay near the sources of radio-frequency radia-tion, for example, in the vicinity of antitheft gates; they should not use a cordless or cellular phone handset at a distance less than 15 cm from the pacemaker.

Before assessing the level of workers' exposure, the field source and the profile of electromagnetic hazards around it should be identified. Devices can be considered sources of weak EMFs if the exposure level of workers near the devices is much less than the limits stated by the regulations on the permissible exposure of workers. For example, electrical appliances for common office or home use, including office and

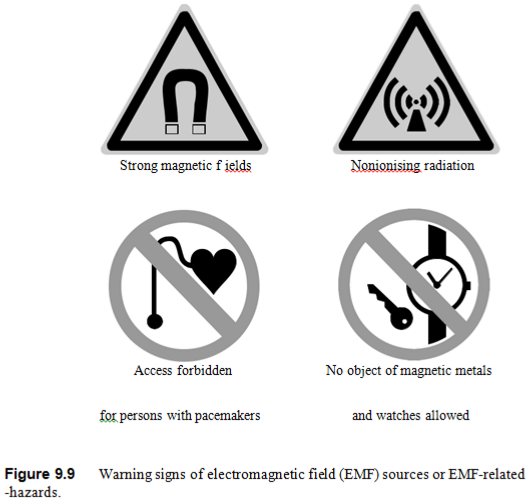

FIGURE 9.13: Warning signs of EMF sources or EMF related-Hazards

computer devices meeting European requirements of exposure to the general public (Recommendation 1999/519/EC) and that are not present directly on the worker's body, do not require periodic inspection of the worker's exposure level. According to provisions of directive 2004/40/CE, the assessment of EMFs in the area acces-sible to the general public is not required in the case workers are affected by above-mentioned EMF sources only. If workers stay close to such devices, they may be exposed to stronger fields. The most effective method to avoid such exposure is to organise the workplace in such a way that the sources of the fields are not in direct proximity of the workers' body.

While planning the installation or construction of a new device, electromagnetic safety requirements and information on the levels of fields that may be generated around it during its operation should be analysed. The personnel directly operating the devices should not be within the areas of strong fields, and the workers must be exposed to the least possible levels. Workers should be as far as possible from the EMF-emitting devices, or either the devices or the workplaces near the devices should be shielded.

Measurements of fields at the time of installing and test operation allow determi-nation of the spatial distribution of the field level around the devices. These results are necessary for the proper assessment of workers' exposure, which covers both the environment of the use of EMF-emitting device and the nature activities performed by workers while operating that device. They also help in formulating recommenda-tions and principles for safety. A detailed description of the principles of limiting the exposure of workers can be found at the Web page of CIOP-PIB (http://www.ciop.pl/ EMF) and in quoted publications on the topic.

9.7 Collective Protective Equipment

Collective protection measures against EMFs include two kinds of shielding: local-ising (shielding of the EMF source) or protective (shielding of the workplace). Localising shielding is preferred, as it reduces the field level in a larger area, ensures more protection of the people within the surroundings of the source, and prevents the possibility of accidental exposure. The effectiveness of the shielding depends on various physical phenomena that take place in the shielding material (usually a metal mesh or sheet) and its geometric shape and galvanic connections. The field is partly attenuated at the surface due to surface reflection. The part that is not reflected at the surface is attenuated when it passes through the shield, due to an absorption loss. Further attenuation may happen when the field reflects towards the inside of the shield and multiple reflections (called internal reflection) occur inside it (Figure 9.10).

The efficiency of shielding is a function of the frequency and type of field and the current technical condition of the shield; the technical condition of the shield must be controlled and the efficiency of the shielding must be periodically measured.

EMF exposure can also be reduced by changing the technology that is used, for example, by reducing the output power of the device to the minimum level allowing normal operation. Similarly, the using manipulators and automatising the device operation so that the workplace is far from the area of strong EMFs protect workers from electromagnetic hazards. Changes in the device design, such as reducing the

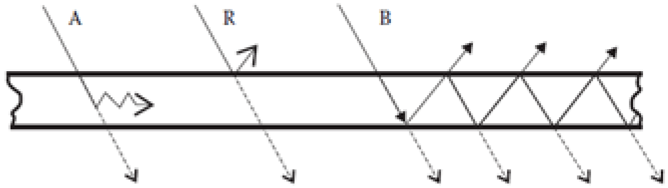

Figure 9.10 Interaction of an electromagnetic field with a shield. A = absorption; R = external reflection; B = internal reflection.

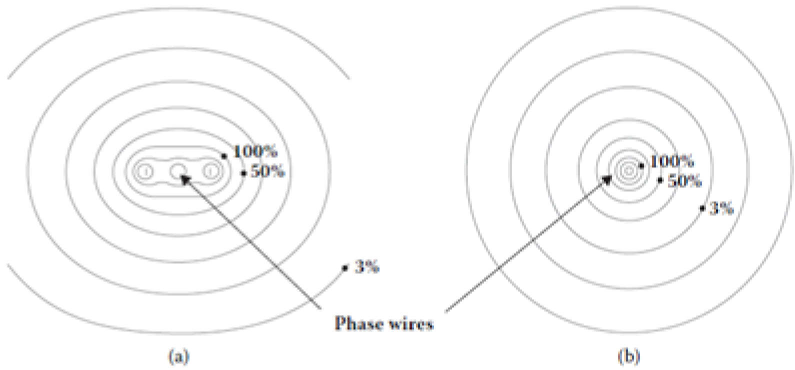

Figure 9.11 Magnetic flux density around three-phase wires: (a) 50 cm distance between wires; (b) 3 cm distance between wires. Calculations performed for equal current, in each of the phase wires, the phase shift is 120° and the centre of the coordinates is located in the axis of the central wire.

FIGURE 9.14: Magnetic Flux density around three-phase wires

sizes of elements that generate EMFs or keeping them closer to each other, can be alternatives to electromagnetic shielding. For example in three-phase electric instal-lations, when closing cables and bus bars on each other, magnetic fields generated by such a set of cables might be significantly lowered as a result of the interaction of vector quantities shift in phase (Figure 9.11).

9.8 Personal Protective Equipment

The use of protective clothing, which shields workers from EMF, is an alternative method for reducing the level of exposure. This option is the best for situations in which the workers must work in strong EMFs and in direct proximity to the field source, which cannot be switched off during the workers' presence, for example, when performing repairs or maintenance on broadcasting or radar devices. In such situations, protective clothing might protect workers from hazardous, excessive exposure to electromagnetic radiation (Figure 9.12). However, the main problem is the limited availability of clothing that is efficient enough to reduce many kinds of EMF exposures.

CHAPTER 10

Static Electricity

10.1 Introduction

Static electricity is the formation, accumulation, and disappearance of an unbal-anced electric charge Q. The unbalanced charge is usually formed on the surface of solid or liquid objects, which can be compact or broken up (e.g. dust and haze particles), of low electrical conductivity (dielectrics, semiconductors), and can con-duct objects insulated from the ground. Also, the external electric field induces the electric charge on the surface of conducting object. In the electrified object, there is at least a local lack of equilibrium between the number of elementary positive and negative charges.

Gas particles can be electrified or ionised only by ionising radiation or electrical discharges. Gases (e.g. atmospheric air) carry aerosol particles, such as dust, smoke, ice crystals, or haze electrified by other mechanisms.

The change in the charge is equivalent to the electric current flow. The intensity of the electric current flow is proportional to the speed of the charge change. The current pulse intensity during the electrostatic discharge (ESD) may be up to a few dozen amperes.

The separation of positive and negative charges requires working against the coulomb (C) force. This work is converted into the potential energy of the electric field. When the unbalanced charge disappears, the energy of the field is converted into other forms, such as thermal (above 90 percent of the local energy), mechanical (e.g. acoustic), and electromagnetic (Gajewski 1987).

The unbalanced charge can decay slowly and continuously (taking from millisec-onds to many hours and according to an exponential dependence on time) or rapidly (from tens of nanoseconds to a few hundred microseconds). In the first case, the neu-tralisation of excess charge via the conduction of a material is called the dissipation

of the charge. In the second case, ESD, the discharge can be in the form of an electric current pulse in a gas, especially in the air, between the objects (which have enough electric potential difference to ionise the air), or in the form of a direct current pulse when the objects touch (contact discharge), if the potential difference is not enough to ionise the air.

10.2 Types of Electrostatic Discharges

ESDs are the main sources of electrostatic hazards. They occur when the intensity of the electric field locally achieves a strength of about Es = 3 MV/m, the strength that is necessary to cause an avalanche ionisation of the air. ESDs can be classified as:

Corona discharge: Occurs around the edge and point of conducting blades or thin conductors when their radii of curvature are smaller than 5 mm and the electrical potential is high in relation to the surroundings. The onset voltage Us for a corona discharge depends on the radius of the curvature (e.g. for r = 0.1 mm, Us is about 2 kV and for r = 1 mm, Us is about 6 kV). The current intensity of this discharge can be from picoamperes to a few hundred microamperes. The ignition potential of this discharge is generally very low, but it can ignite sensitive media for which the minimum ignition energy (MIE; see Section 10.3) is around several microjoules (e.g. hydro-gen, carbon disulfide, acetylene). At a current intensity higher than 200 A, a corona discharge can ignite the vapours of some hydrocarbons (Britton 1999). They are also used as an ion source to neutralise the electrostatic charge.

Spark (capacitive) discharge: Occurs between the conducting electrodes when the radii of curvature are above 50 mm and the voltage between them exceeds 320–350 V (Jones and King 1991; Kaiser 2006). The conducting liquid can also act as an electrode. The duration of a spark discharge is from the tens up to hundreds of nanoseconds, depending on the resistivity of the electrodes. It can ignite vapours, flammable gases, explosives, most of the combustible dusts, and about 90 percent of the dusts caused by ESDs (Jones and King 1991). Their energy is close to the energy accumulated in the electric capacity between objects:

$$W = \frac{CU_2}{2} = \frac{QU}{2}$$

(10.1)

where C is the electric capacity of both the conducting objects or one conducting object in relation to the ground, U is the potential difference between the conducting objects or between the conducting object and the ground, and Q = UC is the charge accumulated in capacity C. Theoretically, this energy is unlimited, but in practice, it is between a few dozen up to a few hundred millijoules (mJ). This discharge can be prevented by bonding and earthing all of the conducted objects.

Table 10.1

Approximate Values of the Electric Capacities of Some Unearthed Metallic Objects Commonly Used in Industry

Metallic Objects	Capacitance, pF (Order of Magnitude)
Small screw	1
Coin	2
Shovel	10
Small hand tools	10–20
Small container (up to 0.05 m_3), hopper	10–100
Medium container, drum, vessel (up to 0.5 m_3)	50–500
Flange connection (unbonded)	10–500
Some elements of plant equipment	100–1000
Human body	70–300
Filter elements	10–100
Large machine, large container or vessel	100–1000
Vehicle	300–1000
Road tanker	~1000
Large silo with dielectric lining, rail tanker	up to 100,000
Sphere with radius *R*, far from the ground	~110 × *R* (m)

FIGURE 10.1: Approximate Values of the Electric Capacities of Some Unearthed Metallic Objects Commonly Used in Industry

Spark discharge risk assessment is relatively simple and can be made by comparing the energy accumulated in the capacity C with the MIE. The risk is negligible if the stored energy (Equation 10.1) does not exceed 0.1 MIE.

The electric capacities of commonly used metallic objects, measured to the ground, are shown in Table 10.1.

Brush discharge: Occurs between conductors when the radius of the cur-vature of the smaller electrode is between 5 and 50 mm and the electro-static field intensity exceeds 0.5 MV/m. It more often appears between the conductor and the electrified dielectric, solid, or liquid. This discharge ignites most flammable gases and vapours, including hydrocarbons (MIE about 0.2 mJ). The minimum electric potential differences that initiate brush discharge is around a dozen kilovolts (for a liquid, between 20 and 60 kV [Cross 1987]). The charge neutralisation during a single discharge occurs only on a limited surface of the dielectric (up to a few dozen square centimetres). The energy of the discharge is as follows (Cross 1987 after Masuda):

$$W = K(U_1 q - q^2/2C_d)$$

(10.2)

where K is the experimentally determined coefficient (approximately 0.08), U1 is the initial potential of the dielectric surface, q is the charge transferred by the discharge, and Cd is the capacity equal to the transferred charge q divided by the potential drop at the surface during discharge. Applying a charge neutraliser (particularly passive ionisers) or reducing the speed of the technological processes that cause the electrification can prevent this discharge.
Propagating brush discharge (PBD): A multichannel discharge (with plasma channels radially coinciding) occurring along the surface of the highly elec-trified, thin dielectric layer and backed by the conducting surface (the flat capacitor) if the conducting object (e.g. the worker's finger) approaches the dielectric surface or as a result of the electric breakdown of the dielectric layer. This is the strongest ESD, in which energy can exceed 1 J, and it can ignite all flammable vapours, gases and hazes, and most combustible dusts, and can be dangerous for humans. PBDs occur when the dielectric layer thickness is between 0.1 and 8 mm, the surface density of accumulated energy is more than 10 J/m_2 and the surface density sigma of the accumulated charge is more than 0.25 mC/m_2. PBDs can be prevented by avoiding plac-ing the dielectric layers (or paint covers) on the metal surfaces, increas-ing the thickness of these dielectrics above 10 mm, reducing this thickness below 0.5 mm, or applying a dielectric for which the breakdown voltage is smaller than 4 kV. Some authors (Jones and King 1991; Cross 1987, after Heidelberg) recommend the following dielectric thicknesses, depending on the accumulated charge density σ:

- $If\sigma 0.25mC/m_2$, the dielectric should be much thinner than 1 mm.
- $If\sigma 0.25mC/m_2$, the dielectric should be much thicker than 1 mm.

Cone discharge (Maurer's discharge, bulking brush discharge): Occurs along the conical surface of the electrified heap of the dielectric material towards the walls of the vessel or silo. According to Glor (1988), this type of discharge is possible during the intensive inflow of a coarse (particle diam-eter more than 1 mm), highly insulating (volume resistivity v more than $10_{10}\Omega$m), and charged loose material into the vessel or silo. Its maximum effective energies are probably not more than 20 mJ. It can ignite flammable gases, vapours and some sensitive dusts.
Lightning-like discharge: This type has not been observed in industrial practice, but occurs from the dust clouds during tornadoes, dust storms, and volcanic eruptions (Britton 1999). It cannot occur in silos smaller than 60 m3 or of diameter less than 3 m (Boschung et al. 1977). Examples of pos-sible discharges in silos are shown in Figure 10.1.
The accidental introduction of a conducting and grounded object into the interior of a filled silo can cause a spark discharge between the objects and the silo. The intro-duction of thin (diameter smaller than 3 mm) and grounded wires or rods into the silo before starting its filling can neutralise the electric charge of the poured mate-rial, because of corona discharges from the wires.

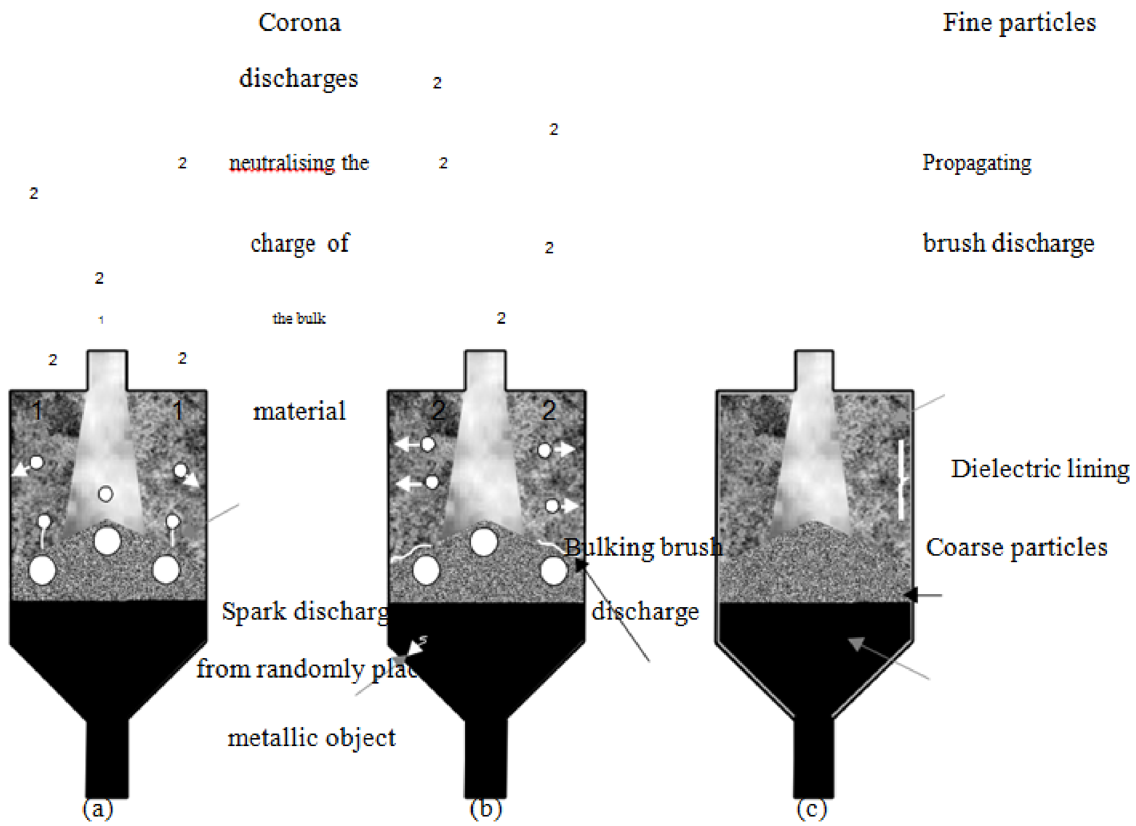

FIGURE 10.2: The potential electrostatic discharges that can occur while filling up the silo with dielectric bulk material: (a) coarse and fine particles are charged in reverse—corona discharges occur and neutralise the charge of heap; (b) coarse and fine particles have the same charge polarity—cone discharges occur, not grounded piece of metal inside the heap can cause the spark discharge; and (c) dielectric lining at the conducting walls can cause propagating brush discharge.

10.3 Electrostatic Hazards

If the dissipation rate of the electrostatic charge is insufficient, the accumulation of the charge leads to a strong electric field and an incendiary discharge; these can occur due to the widespread processing and application of nonconducting synthetic or natural materials and flammable dielectric liquids and dusts, which can be electri-fied easily and can store the accumulated charge for a long time. The three groups of hazards caused by the ESDs are as follows:

- Initiation of deflagration or explosion of explosive atmospheres and materials
- Shocks to humans
- Damage to the semiconductor electronic devices

The ESD energy, usually in the range of several microjoules to a few hundred mil-lijoules (seldom a few joules), sometimes exceeds the ignition energy of the explo-sive atmospheres and explosive materials. ESDs cause about 9 percent of dust explosions. According to the Polish National Headquarters of the State Fire Service 105 fires were caused by ESDs from 1999 to 2000.
Explosive atmospheres are categorised by their MIE, which is defined as the minimum energy

that can ignite a mixture of specified flammable material with air or oxygen, and is measured according to the standard procedure.

The typical MIE ranges of flammable and explosive materials are as follows:

- Primary explosives: 0.001–0.1 mJ
- Mixture of gases and vapours with the air: 0.0004–1.0 mJ
- Sensitive dust clouds: 1–10 mJ
- Dust clouds: 10–5000 mJ

MIE values in atmospheres with increased concentrations of oxygen can be of a smaller magnitude.

ESDs from the charged human body do not create direct health or life physiologi-cal risk, but they can cause involuntary responses resulting in falls or injuries. The human response to ESD is dependent on the gender, age, physical characteristics, and skin moisture and sensitivity. The electrical capacity of the body is also significant; it is usually in the range of 70–300 pF (picofarad). The electrostatic potential of the body, which is the perception threshold, varies from person to person from 0.6 up to 7 kV depending on the surface in contact with the conducting object and the method of contact. The perception threshold is commonly agreed to be about 2 kV. With respect to these potentials, the energy thresholds range from 0.05–0.8 mJ (Guderska 1981) up to 0.5–2 mJ (Britton 1999), which exceed the MIE of the majority of the mixtures of flammable gases and vapours with the air. ESDs are rated as unpleasant for the range of 1–15 mJ, 15–40 mJ as very unpleasant, 40–100 mJ as painful, and 100 mJ as a severe shock. According to Britton (1999), unconsciousness is possible at 1–10 J and cardiac arrest at above 10 J. Frequent ESDs occurring on a limited area of the skin surface can cause local irritation and dermatitis. Usually, the electric potential of an electrified human does not exceed 20 kV (more often 10 kV), and the energy of the ESD from the body does not exceed 100 mJ, which can be painful but not dangerous. Discharge through the body from different electrified objects of higher potentials and accumulated energies can be dangerous to life. Such energies sometimes have PBDs and spark discharges from objects, whose potential is of the order of dozens or more kilovolts and that have capacities above 1000 pF. The con-tact of the human body with the electrodes of charged capacitors or with the wires supplying high-voltage direct current (DC) is very dangerous, even some time after disconnecting the wire from the DC supplier.

Human exposure to an electrostatic field is not harmful if it does not cause dis-charges from the body due to electrostatic induction (see Section 10.4). The electro-static field does not penetrate the body and is suppressed by the skin about 1012-fold (Polk and Postow 1996).

Electronic semiconductor devices, especially those made by metal oxide semi-conductor technology, magnetoresistive and thin-layer devices, or printed boards, are particularly sensitive to ESDs. ESD (through-unit or nearby) can cause thermal damages to the thin conducting lattices or voltage breakdowns of thin insulating lay-ers inside the semiconductor devices. This may happen during production, transpor-tation, service, and usage of ready-made devices. ESDs can disturb the function of electronic devices, so in some cases, such as medical electronic diagnostic apparatus and data centres, antielectrostatic equipment of rooms (especially the floors) is obligatory to prevent the formation and accumulation of electrostatic charge. ESDs from the human body cause damage to electronic devices and also ignition of explosive atmospheres, even if the discharge is invisible and imperceptible by humans.

CHAPTER 11

Course assignment

11.1 Course Assignmnets

1. Family OSH history paper 2. Case study project 3. Case study discussion 4. Problem sheets