Social Distribution of Occupational Hazards 10

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Contents

Abstract

In the present chapter, an overview of the social distribution of major occupational hazards is provided. To this end, the prevalence and/or incidence rates of selected chemical, physical, and organizational hazards across occupational categories are presented. The chapter focuses on chemical substances related to cancer and allergic reactions; physical hazards such as noise, biomechanical forces, and ultraviolet radiation; and organizational hazards related to job demands, decision latitude, working time arrangements, and leadership. In addition, several mediators and moderators of exposure to occupational hazards are discussed which encompass occupational inequalities of hazard control, simultaneous exposure to multiple hazards, and behaviors and attitudes toward safety procedures. The chapter ends with some concluding remarks for future research and practice.

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Introduction

The social distribution of occupational hazards captures the rate with which health hazards occur within and between occupational categories in the labor force. The likelihood of being exposed to specific health hazards is directly associated with specific occupations and results from a series of complex social processes involving technology, systems of economic production, definition of products and services, and several mediators and moderators of exposure to hazards. The aim of the present chapter is thus to provide a general overview of (i) the occupation-specific prevalence and/or incidence of major groups of occupational hazards (chemical, physical, organizational), (ii) some mediators and moderators of exposure to those hazards, and (iii) emerging occupational hazards.

Socioeconomic Determinants of Occupational Hazard Distribution

From a historical perspective, the occupational structure of society is not a simple classification of human activities; it is rather the result of economical and political processes determining not only the kind, scope, and intensity of those activities but also the group of individuals carrying them out. Two examples may be illustrative of these processes: the labor allocation system of ancient Rome and the free-market system of the eighteenth century in North America and Europe. In the former case, economic production was performed by free workers, semi-dependent workers, freed workers, soldiers, and slaves in a wide array of occupations including crafts, agriculture, education, and services (Verboven and Laes 2017). However, for the ancient elite writers like Cicero, the social status of most occupations was low, since they implied performing "dirty" job tasks. According to Cicero, for instance, certain occupations (artes) such as crafts (opifices) and fishery (piscatores) were per nature "dirty" (sordidae) and, therefore, not appropriate occupations (liberales) for the noble and "free" (liber) Romans (Cicero 1852, Lib 1, Ch. 42). On the other hand, in the free-market ideology of the eighteenth century, as represented by the writings of Adam Smith, the distribution of occupations in society is due to a natural "propensity to truck, barter, and exchange one thing for another" (Smith 2007, Ch. 2, p. 16), which results in a specialization of human labor, i.e., an occupational structure. In the free-market ideology, "free servants" must pay themselves for the wear and tear of their labor capacity (Smith 2007, Ch. 8, p. 67), according to the "cleanliness or dirtiness, the honorableness or dishonorableness" arising from the nature of the occupation itself (Smith 2007, Ch. 10, p. 83).

Nonetheless, in both instances, the distribution of occupations parallels the hierarchy structure of society, whereby social groups with less power and social status, i.e., free workers, slaves, or "free servants," perform job tasks which are per se "dirtier" and thus "less honorable." This reasoning presupposes the belief that the conditions of work cannot be changed and belong to the inherent "dirtiness or cleanliness" of occupations. Thus, it is perhaps only with the advance of public health concerns and the increase of social struggles in the early eighteenth century in Western Europe that the notion of the "natural dirtiness" of occupations began to be challenged at the level of social policy. In this regard, the seminal work of Bernardino Ramazzini on the occupational diseases (*De Morbis Artificum Diatriba*) at the beginning of the eighteenth century represents a first systematic account on the relationship between production processes and disease incidence. Ramazzini's work focuses not only on the physical and chemical properties of work materials but also on the whole context of production. Ramazzini's approach is certainly pointing out to occupational hazards, i.e., the sources of potential adverse effects on workers' health, which, in the context of production and services processes, are amenable to elimination or reduction.

In the period between the late eighteenth and the end of the nineteenth century, the pace of technological and socioeconomic innovations triggered not only unprecedented changes in the working conditions in the larger world economies but also new areas of research on the nature and scale of occupational hazards, especially in Western Europe. With the expansion of the modern state bureaucracy, the creation of health surveillance institutions (e.g., factory inspectorates across Europe), and the collection of statistical data on occupational diseases and accidents, it was possible to estimate, at least to some extent and for the first time in history, the scale of the distribution of occupational hazards in the major industrial sectors and occupational groups by the beginning of the twentieth century in some European and North American industrial centers.

Despite the increased knowledge of the nature and magnitude of work-related hazards, the improvements in the operational safety of industrial machinery, and the implementation and enforcement of worker protection policies (e.g., Health and Safety at Work etc. Act 1974), large inequalities regarding health and occupational hazards persist across occupations (Mackenbach et al. 2003). As discussed in the sections to follow, these inequalities obey to a series of constraints imposed by social, technological, and physical properties of complex work systems. As depicted schematically in Fig. 1, the observed distribution of occupational hazards can be conceptualized as the consequence of the interplay between (i) the technology required to bring about products and services, (ii) the definition of products and services which in turn may bring about technological innovations, (iii) the resulting job tasks and job goals within the boundaries of the organizational structures and processes, (iv) and a set of mediators or moderators reducing or aggravating the magnitude and intensity of occupational exposures. The specific products and services resulting from a certain technology lay the fundamental framework defining specific occupations (work tasks, routines, etc.) and set the overall conditions of work and the magnitude and quality of risks. Technology encompasses not only

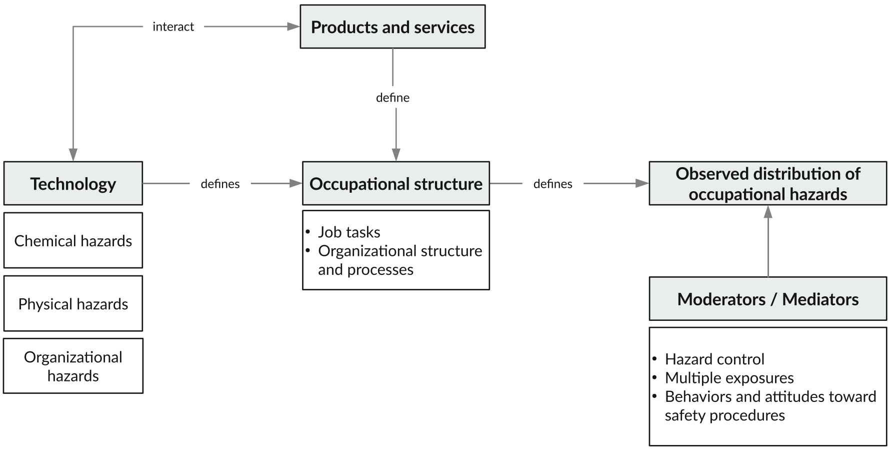

Fig. 1 Major socioeconomic factors determining the observed distribution of occupational hazards. Schematic representation

work devices, substances, and physical properties but also specific production or service processes (e.g., division of labor), managerial approaches, and business models. The set of mediators and moderators can be specific to a certain society, or even involve global conditions, and may be related to key factors such as simultaneous exposure to multiple hazards, different hazard control approaches, or more complex social-psychological and organizational phenomena concerning safety behaviors and attitudes.

In order to provide an overview of the vast literature on occupational hazards, the present chapter will focus on the distribution of selected occupational hazards which either have serious health adverse effects, such as cancers, allergies, respiratory symptoms, musculoskeletal disorders, or mental health symptoms, or account for a relatively large proportion of exposures. In the present chapter, the occupational structure will be often described by the International Standard Classification of Occupations (ISCO) 2008, which operationalizes an occupation as an aggregation of jobs with highly similar main tasks and duties. By considering the skill levels and skill specialization of occupations, the highest level of aggregation results in ten occupational categories. A more detailed description of the occupations subsumed in these general categories is provided in Table 1 as a reference for the subsequent sections.

Technology, Products, and Services

Chemical Hazards

Hazards resulting from the use of chemical compounds in work processes are extremely large. By May 2019, the total number of hazardous substances registered under the European REACH legislation (Registration, Evaluation, Authorization

Table 1 ISCO 2008 major and sub-major occupational groups (ILO 2012)

ISCO	Major group	Subgroups
1	Managers	Chief executives, senior officials and legislators, administrative and commercial managers, production and specialized services managers, hospitality, retail, and other services managers
2	Professionals	Science and engineering professionals, health professionals, teaching professionals, business and administration professionals, information and communications technology professionals, legal, social, and cultural professionals
3	Technicians and associate professionals	Science and engineering associate professionals; health associate professionals; business and administration associate professionals; legal, social, cultural, and related associate professionals; information and communications technicians
4	Clerical support workers	General and keyboard clerks customer services clerks, numerical and material recording clerks, other clerical support workers
5	Service and sales workers	Personal service workers, sales workers, personal care workers, protective services workers
6	Skilled agricultural, forestry, and fishery workers	Market-oriented skilled agricultural workers; market-oriented skilled forestry, fishing, and hunting workers; subsistence farmers, fishers, hunters, and gatherers
7	Craft and related trades workers	Building and related trades workers, excluding electricians, metal, machinery, and related trades workers, handicraft and printing workers, electrical and electronic trades workers, food processing, wood working, garment, and other craft and related trades workers
8	Plant and machine operators and assemblers	Stationary plant and machine operators, assemblers, drivers, and mobile plant operators
9	Elementary occupations	Cleaners and helpers; agricultural, forestry, and fishery laborers; laborers in mining, construction, manufacturing, and transport; food preparation assistants; street and related sales and service workers; refuse workers; and other elementary workers
0	Armed forces occupations	Commissioned armed forces officers, noncommissioned armed forces officers, armed forces occupations, other ranks

and Restriction of Chemicals) comprises about 22,000 different substances (from more than 140,000 in the market according to the Classification and Labelling Inventory), from which around 7,300 have widespread use by professional workers (European Chemicals Agency 2019). Even though regulations such as the European REACH (EC 1907/2006) or the American Toxic Substances Control Act in the United States aim to improve the protection of human health, the number of substances and their widespread use in particular occupations and economic sectors account for persistent inequalities of hazard exposure around the globe. Since a full assessment of all potential health adverse effects of each chemical compound is not feasible, occupational physicians and researchers concentrate on about 1,400 chemical substances associated with particularly severe health outcomes such as cancer (carcinogenic substances), sensitization of airways or the skin (sensitizers), systemic intoxication, pregnancy toxicity, and cell germ mutagenicity (reprotoxic and mutagenic substances) (Deutsche Forschungsgemeinschaft (DFG) 2018). For this kind of chemical substances, however, a scientifically based estimate of the maximum workplace concentration values, i.e., concentration with “no observed adverse effect level” NOAEL, has been determined for only about 209 substances by the German Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area (Deutsche Forschungsgemeinschaft (DFG) 2018). Under the REACH legislation, manufacturers, importers, and downstream users of chemical compounds are required to provide estimates of the so-called derived no-effect level (DNEL), i.e., the level of exposure above which human populations (e.g., workers, consumers) should not be exposed. In spite of the limited knowledge on toxicity, maximum concentration values, and potential exposure scenarios of each chemical compound, several epidemiological studies have estimated the degree of exposure inequality across occupations for some substances or compound groups (for a review see Montano 2014a).

In the 2010 SUMER study in France (Havet et al. 2017b), a random sample of occupational physicians was asked to perform an assessment of employees’ exposure during 1 week to 28 carcinogenic, mutagenic, and reprotoxic (CMR) agents. Assessment of exposure was performed for substances which are known or presumed to have CMR effects on workers’ health according to the International Agency for Research on Cancer (IARC) and the Council Directive 67/548/ECC. A total of 47,983 randomly selected employees consented to participate in the study. In a series of logistic regression analysis, Havet et al. (2017b) investigated the prevalence of exposure to at least one CMR agent, the exposure duration, and exposure intensity (i.e., whether short-term exposure limits were exceeded or not). The most common exposures comprised diesel engine exhaust, mineral oil, wood dust, crystalline silica, and formaldehyde. The results indicated large exposure differences across ISCO occupational categories. In comparison to managers and professionals (ISCO 1 and ISCO 2), the odds ratio (OR) for each exposure indicator (i.e., prevalence, duration, and intensity) is higher for workers in the other ISCO categories, in particular among technicians (ISCO 3), services workers (ISCO 5), and skilled and unskilled blue-collar workers (roughly ISCO 7, 8, and 9) (Havet et al. 2017b). Moreover, trend analyses performed with data from two waves of the SUMER study (2003 and 2010) indicated that these exposure inequalities persist in spite of the overall decline of exposure rates across occupations during that period in France (Havet et al. 2017a).

Similar results were obtained from data of the Italian Information System on Occupational Exposure to Carcinogens (SIREP), a database of measurements of exposure to airborne carcinogens. The most common carcinogenic agents such as hardwood dust, benzene, polycyclic aromatic hydrocarbons (PAH), 1,3-butadiene, and acrylonitrile are usually concentrated among carpenters, chemical processing plant operators, and asphalt workers (Scarselli et al. 2007). Further analyses of the

SIREP database confirmed an elevated odds ratio of being highly exposed to carcinogenic agents among clerical and craft workers (ISCO 4 and 7), machine operators (ISCO 8), and the elementary occupations (ISCO 9) (Scarselli et al. 2018). The increased likelihood of exposure among these occupational groups may partially explain the increased risks at specific cancer sites reported in epidemiological studies. In a large population-based case-control study in Italy, for example, adjusted odds ratios of lung cancer were higher among mostly male workers in the ceramic and refractory brick sector and the occupations within the nonferrous basic industry (Consonni et al. 2010).

The inequality of exposures across occupations reflects to a large extent the type of products, services, and technologies used in the economic activities. Analyses based on the European and Canadian Information System on Carcinogen Exposure (CAREX and CAREX Canada) have revealed that about 32 million workers in the 15 countries of the European Union and 16 million in Canada, respectively, may be exposed to carcinogens, especially to solar radiation, crystalline silica, diesel exhaust, radon, wood dust, lead and inorganic lead compounds, benzene, asbestos, and formaldehyde (Kauppinen et al. 2000; Peters et al. 2015). However, single and multiple exposures pertain primarily workers in construction, manufacturing, transportation and warehousing, retail trade, and agriculture. In a large cross-sectional survey of 27,157 adults in the United States, prevalence rates of dermal exposure to chemicals and frequent exposure to vapors, gas, dust, or fumes at work were most common in the mining industry, construction, manufacturing, agriculture, waste management, accommodation, and food services (Calvert et al. 2012).

Similarly, exposure to sensitizing substances, i.e., substances which can cause allergies mostly of the skin and the respiratory airways (Deutsche Forschungsgemeinschaft (DFG) 2018), is highly concentrated on certain occupational titles and industrial sectors. In Germany, the majority of confirmed cases of occupational obstructive airways disease due to sensitizers in 2003 were found among bakers, hairdressers, wholesalers, retailers, purchasers, and chemical workers (Latza and Baur 2005). Results from a systematic review on occupational exposure to vapors, gas, dust, and fumes and chronic obstructive pulmonary disease confirmed not only increased risks of disease for exposed workers but also dose-response relationships for workers involved in cotton textile, jute processing, farming, grain and animal feed, wood processing, welding, foundry work, coal mining, and non-mining industrial dust (Omland et al. 2014). For hand eczema, a relatively common disease in the population (approx. 9.7% prevalence) associated with burning, stinging, and soring of the skin (Diepgen et al. 2009), occupational exposures have been estimated at 51% of cases in a multicenter study with 319 patients (Diepgen et al. 2009). Moreover, a more detailed analysis with a sample of 1466 chronic hand eczema patients in Switzerland and Germany indicated large associations between hand eczema and several exposures including wetness, detergents, disinfectants, wearing gloves, solvents, industrial oils, and lubricants (Cazzaniga et al. 2017). These associations were frequently observed in the healthcare sector, hairdressing, cleaning, food processing, and catering, among female workers, and in the construction and metal and chemical sector among male workers (Cazzaniga et al. 2017). The occupational distribution of exposure to sensitizers leading to hand eczema is also confirmed in patch testing studies (i.e., clinical diagnostic studies) showing larger risks among hairdressers, beauticians, bricklayers, stonemasons, nurses, precision workers in metal and related materials, and health professionals (e.g., Pesonen et al. 2015). Even though job tasks are the major conditions of exposure to allergens leading to contact dermatitis, there are several product- or service-related factors which account for the actual level of exposure. For example, exposure to allergenic rubber chemicals (e.g., thiurams) or biocides and preservatives (e.g., methylisothiazolinone) is not directly related to specific job tasks such as cleaning or laundry work, or painting and varnishing, but to the usage of rubber gloves as protective devices in wet work or paints containing allergenic preservatives, respectively (Pesonen et al. 2015).

Physical Hazards

Occupational physical hazards can be classified according to the nature of exposure in (1) noise; (2) biomechanical forces, e.g., carrying or moving heavy loads, tiring or painful positions, sitting, and traumas; (3) ionizing radiation, e.g., X-ray and particle radiation; (4) electromagnetic radiation (not ionizing), e.g., lasers, ultraviolet, or infrared radiation; (5) temperature (including high or low temperatures of solids and liquids); and (6) electricity. In occupational settings, noise, biomechanical forces leading to injuries, musculoskeletal disorders or neurological symptoms, and electromagnetic radiation such as solar radiation are the most common exposures (EU-OSHA 2009, 2010). In the United States, prevalence estimates based on self-reported data of hazardous workplace noise exposure (measured as "speaking in a raised voice") resulted in high rates among vehicle and mobile equipment mechanics, construction and mining workers, transportation and material moving, warehousing, and utilities (e.g., Tak et al. 2009). In another study from Norway investigating the associations of occupation and disabling hearing loss of more than 35 dB hearing threshold elevation, the age-adjusted prevalence ratios of hearing loss for men were largest among wood workers, miners, linemen, construction workers, and workshop mechanics (Engdahl and Tambs 2009). For women, high prevalence rates were observed among bakers, nursing care workers, engineers, and technicians. Moreover, the positive associations between occupation, noise exposure, and hearing loss have been also observed in prospective studies. With data from a sample of construction workers in the United States in a 10-year follow-up period, it was found that the hearing threshold levels increased by approximately 2.5–3 dB for an additional 10 dB noise exposure (Seixas et al. 2012). Similar results were obtained with a large sample of construction workers in Denmark in which not only the overall hearing threshold levels increased but also were more pronounced at higher frequencies from 0.19 dB to 0.99 dB per year at 2 kHz and 8 kHz, respectively, in a 4-year follow-up period (Leensen and Dreschler 2014).

Trend analysis of data from the European Working Conditions Survey (EWCS) between 1995 and 2010 reveals that the inequalities of exposure to physical risk factors remain consistent and highly concentrated in specific occupational groups. Workers in the EWCS reporting being exposed “all the time” and “almost all the time” to either low or high temperatures, working in tiring or painful positions, carrying or moving heavy loads, repetitive hand or arm movements, and vibrations from hand tools and machinery are usually agricultural workers (ISCO 6), craft workers (ISCO 7), plan and machine operators (ISCO 8), and elementary occupations (ISCO 9) (Montano 2014b). A comparable pattern of exposure to biomechanical hazards such as carrying heavy loads, repetitive work, painful or tiring postures, and uniform arm or hand movements was observed in Switzerland where the prevalence exposure rates among the lowest social class (i.e., occupations in production and low education) in comparison to the highest social class (i.e., supervisors and managers with high education) were approximately fivefold (Hämmig and Bauer 2013). Additional analyses of the EWCS data on the prevalence ratios of back pain and neck/upper limb pain indicate higher risks among mobile plant operators; market-oriented skilled agricultural and fishery workers; extraction and building trade workers; precision, handicraft, printing, and related trade workers; and drivers (Farioli et al. 2014). Similarly, a large population-based Norwegian study revealed higher cross-sectional prevalence ratios of low-back pain, neck-shoulder pain, and arm pain among routine manual workers, skilled and unskilled workers, and workers usually performing heavy physical job tasks (Mehlum et al. 2008).

Even though the results obtained from studies based on self-reported musculoskeletal symptoms may under- or overestimate the level of exposure, they agree to some extent with studies based on physician diagnoses. For example, in a physician-based study in the United Kingdom, diagnoses of musculoskeletal diseases reported by occupational physicians and rheumatologists were analyzed by occupation, anatomical region, and job task (Chen et al. 2006). For upper limb diseases, higher rates were observed among clerical, craft-related (e.g., builders, decorators, fitters, welders, and textile machinists), and machine work. For neck and back disorders, craft-related and machine workers had higher prevalence rates, together with professional workers, especially nurses. Tasks associated with upper limb disorders were fine hand work (e.g., keyboard work) and forceful grip (e.g., guiding/holding building tools), neck/back with heavy lifting, and lower limb disorders with standing and walking and heavy lifting. From these results it can be seen that the incidence of musculoskeletal diseases is higher for job tasks which characterize the major occupational groups with higher exposure rates to biomechanical forces.

Furthermore, excessive exposure to ultraviolet radiation (UVR), i.e., electromagnetic radiation of wavelength 100–400 nm, is considered by the IARC to cause different types of skin cancer. Common sources of UVR are solar radiation and some technologies used in dye and paint-drying techniques, microbial inactivation in the food industry, in welding processes (e.g., arc welding and gas welding), and tanning devices (EU-OSHA 2009). In a meta-analysis of cohort and case-control studies investigating the relationship between occupational UVR exposure and cutaneous squamous cell carcinoma, it was found that workers exposed to UVR have increased cancer risk in comparison with nonexposed workers (Schmitt et al. 2011). For the labor force in the EU-15 countries, the exposure estimates of the CAREX database to solar radiation in the period 1990–1993 amount to approximately 8.9 million exposures, with workers employed in agriculture and hunting, construction, public administration and defense, and land transport accounting for about 5.7 million exposures (Kauppinen et al. 1998). In more detailed analysis of occupational UVR exposure, large differences across occupational groups have been identified (for a review see Modenese et al. 2018). In a population-based study in France, UVR exposure assessed by satellite data and self-reported information on time, duration, and place of outdoor work for 889 individuals resulted in larger URV doses among gardeners and landscapers, construction workers, agricultural workers, culture and social workers, and industrial workers (Boniol et al. 2015). On the contrary, lowest UV exposure levels were estimated for managers (ISCO 1), professionals (ISCO 2), and clerical and support workers (ISCO 4) (Boniol et al. 2015).

Concerning occupational injuries, reported estimates from North America and Europe indicate an overall decline of injury incidence rates. In the United States, the incident rates of injury and illnesses show a steady decline from about 80 in 1992 to about 55 injuries in 2002 per 1000 full-time workers (Subramanian et al. 2006). In France and Germany, the long-term trends of incidence of occupational accidents per 1000 workers decreased from 118 in the year 1955 to 38 in 2008 (Serres 2010) and from 110 in the year 1960 to about 23 in 2016 (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin 2017), respectively. Global estimates for the years 1998, 2001, and 2003 suggest that the incidence rates of fatal and nonfatal occupational accidents have been decreasing in regions such as Western and Eastern Europe, and the Eastern Mediterranean, but less so in Southeast Asia and Africa (Hämäläinen et al. 2009). Nevertheless, detailed analyses on the distribution of injuries indicate large differences of the incidence rates across occupations. In the European Union, for instance, the number of workers reporting one or more accidental injuries at work in the years 1997 and 2007 is higher among the skilled and low-skilled manual workers (about 5.5%) than among the highly skilled nonmanual workers (1.8%) (European Commission 2010). Moreover, accidents are most frequently reported in agriculture, hunting and forestry, mining and quarrying, manufacturing, construction, transport, and health and social work. Most occupational accidents in the European Union involving more than 3 days of absence correspond to wounds and superficial injuries; dislocations, sprains, and strains; and concussion and internal injuries, especially in the upper and lower extremities, the back, and head (European Commission 2010). Comparable findings were obtained in the United States where the number of nonfatal occupational injuries of the upper extremities and the back in the years 2000–2002 is usually observed among operators, fabricators, laborers, workers in precision production, craft and repair workers, and services (Subramanian et al. 2006).

Organizational Hazards

Organizational technology can be understood in very general terms as the set of norms and procedures by means of which collective labor is coordinated in production processes toward the creation of products or services in socio-technical systems

(Child 2015). The concept "technology" implies here that the structure of organizations as such may be regarded as an instrument for the attainment of organizational goals and, therefore, be modified to improve the efficacy and efficiency of collective labor. In the context of occupational health, the hazardousness of specific organizational technologies is commonly assessed by the subjective perception of workers on important aspects of the work environment and processes such as decision latitude, control of work tasks, role and task conflict, working time arrangements, job tasks, promotion opportunities, and labor contract conditions. Thus, organizational hazards can be identified with those characteristics of the organizational structure and processes which can have potential adverse effects on the physical and/or mental health of workers. Previous research has identified several organizational characteristics resulting in health adverse outcomes such as (i) the combination of high job demands and low decision latitude (i.e., job strain), (ii) the combination of high efforts and low rewards, (iii) long working hours and night work, (iv) inadequate leadership styles, and (v) unstable employment conditions.

Due to the fact that organizational hazards may be found in every occupational category, since they are related to general principles of labor allocation and coordination, structural characteristics of the organization and labor contract conditions have a pivotal role in the distribution of these kinds of hazards. In a large case-control study with register data in Denmark, the distribution of work strain, i.e., high job demands and low decision latitude, reveals larger prevalence rates among construction and craft workers, health workers, machine and plant operators, and cleaners than among managers, professionals, and teachers (Wieclaw et al. 2008). These findings reflect the top-down line of command in most organizations, whereby the extent of individual decision latitude decreases from the managerial and administrative levels to the shop-floor levels of the organization. A similar observation has been made for workers in France and Germany. In the SUMER French study of 2003, managers and professional workers report more frequently being exposed to external demands requiring immediate action (65,6%) than unskilled workers (26%); in contrast, unskilled workers have lower control over their work pace than managers (38.3% vs. 11.7%, respectively) (Arnaudo et al. 2004). Moreover, in the year 2010, a gradient of job strain was observed among French workers: Professionals and managers had the lowest prevalence rates, while service and blue-collar workers the highest (13.6%, 24.8%, 22%, respectively) (Niedhammer et al. 2018). In the German Socio-Economic Panel, a gradient of decreasing job efforts and, at the same time, decreasing job rewards was observed, with workers in the higher service class reporting more efforts, but also more rewards, in comparison to skilled and unskilled manual workers who report less efforts but also less rewards (Götz et al. 2018).

From the perspective of larger occupational categories and single dimensions of job demands such as pace of work (intensity), long working hours or days (extensity), handling emotionally disturbing situations (emotional hazards), and harassment and discrimination (social hazards), a distribution pattern of hazards can also be identified. For workers in the European Union in 2015 (Eurofound 2019), for instance, a higher prevalence of extensive work was observed among the elementary occupations (ISCO 9), whereas craft workers (ISCO 7) and plant and machine operators (ISCO 8) reported more frequently intensive and extensive work. In contrast, professionals (ISCO 2), technicians (ISCO 3), and service and sales workers (ISCO 5) reported higher levels of emotional demands and social hazards, while managers (ISCO 1) were exposed to higher levels of extensive work. On the other hand, the interaction of job autonomy (i.e., whether workers can change the order of tasks, methods of work, or work pace) and work intensity (i.e., whether work involves working at high speed and tight deadlines) reveals also a clear pattern of hazard distribution across occupations. With data from EWCS 2010, it has been shown that managers experience more often a higher work intensity and, at the same time, higher job autonomy, followed by professionals and technicians. On the contrary, craft workers, workers in elementary occupations, and especially plant and machine operators report lower job autonomy and, at the same time, a higher work intensity (Eurofound 2012).

Concerning working time arrangements, available prevalence estimates indicate that the distribution of hazards such as long working hours and night work usually depends on the constraints of manufacturing systems (e.g., continuous mass production), the sector and business model (e.g., utilities, health, or security services), or specific job commitments (e.g., accountability or failure risks). Data from the SUMER French study in the year 2010 revealed higher prevalence rates of frequent night work (i.e., > 45 days per year) for technicians and machine operators (31% for skilled workers and 17.5% for unskilled), security personnel (29.7%), sailors and fishers (27.4%), and police workers and firefighters (20%) (Vinck 2014). The largest numbers of exposed workers were found in the transportation and warehousing sector, healthcare, the food sector, and the hospitality and restaurant industry (Vinck 2014). A similar distribution has also been reported in Germany for the year 2012: Shift work is more frequently experienced in occupations in the manufacture sector (23%), transport and warehousing (20%), the hospitality and restaurant industry (20%), and the health sector (21%) (Lohmann-Haislah 2012).

Even though leader behavior has been identified as an important predictor of several indicators of subordinates' mental health such as stress, burnout, affective symptoms, and general health complaints (Montano et al. 2017), evidence on the prevalence rates of single leadership behaviors is limited. In particular, the so-called destructive leadership, i.e., harmful behavior against the organization or subordinates, is a genuine organizational hazard which is seldom collected in large surveys. Some estimates with a Norwegian sample of employees ($n = 2{,}539$) resulted in 8.8% of employees exposed to the so-called derailed leadership (i.e., anti-organizational and anti-subordinate leadership) and 3.4% to tyrannical leadership (i.e., humiliating, belittling, or manipulative leadership behavior) (Aasland et al. 2010). In a sample of 2,829 workers in the United States, the prevalence of aggression at work originating from the supervisor or boss resulted in higher rates among construction, extraction, farming, and fishing workers (16.5%); installation, maintenance, and production workers (16.1%); and managers (15.5%) (Schat et al. 2006). At least for workers in the European Union, there is some evidence from the EWCS 2010 suggesting a gradient of higher to lower leadership quality along the ISCO occupational categories. By considering whether the supervisor gives feedback on work, shows respectful behavior, has a good ability to solve conflicts and plan work activities, and encourages employees to participate in decisions, it was found that managers and professionals (ISCO 1 and 2) report higher levels of leadership quality than operators and workers in elementary occupations (ISCO 8 and 9) (Montano 2016). An occupational gradient of exposure to bullying in the last 6 months from supervisors or co-workers has also been observed in a German sample ($n = 4{,}143$). Unskilled workers reported more frequently having being bullied by supervisors or colleagues (19.1% and 10.2%, respectively) than academics and managers (9.4% and 5.3%, respectively) (Lange et al. 2018). Moreover, in the same sample, severe bullying by one's supervisor, i.e., exposure to bullying once a week for at least 6 months, was more frequently reported by unskilled workers (8.1%) than academics and managers (3.1%). In general, for the year 2001 in Germany, the number of mobbing cases were larger among clerks, service, and sales workers (17.5% of mobbing cases) and skilled healthcare and social workers (6.9% of mobbing cases) (Meschkutat et al. 2002).

Mediators and Moderators

The actual level of exposure to occupational hazards in specific work environments depends on diverse context factors such as the hazard control procedures in organizations, the extent of simultaneous exposure to multiple hazards, and the attitudes and behaviors of workers and employers toward occupational health and safety issues (Hale and Borys 2013). Thus, in real work situations, the health outcomes resulting from exposure to particular occupational hazards can be attenuated or aggravated given the level of certain mediators or moderators of exposure. A salient research finding in this context is related to occupational-specific differences in the level of hazard protection. In France, for instance, the probability of obtaining engineering control measures such as ventilation systems to reduce the exposure to carcinogenic, mutagenic, or reprotoxic agents (see section "Chemical Hazards") is substantially lower among clerical workers (ISCO 4), service and sales workers (ISCO 5), machine operators, agricultural, and workers in elementary occupations (ISCO 6, 8, and 9) than among managers and professionals (ISCO 1 and 2) (Havet et al. 2018). Since engineering controls are much more effective in reducing exposure than personal protective equipment, the magnitude and frequency of occupation-specific hazards may be increased. Moreover, studies investigating how organizations manage occupational safety and health (OSH) risks have pointed that the awareness of risks does not imply action to reduce them (EU-OSHA 2017). This may depend, for instance, on the belief that certain risks are intrinsically associated with the profession, e.g., working under pressure or dealing with angry or aggressive clients and customers. Hence, it is unlikely that organizations take action to reduce the level of exposures which are deemed "unavoidable" per se. Moreover, by considering the intensity of exposure to occupational risks (here psychosocial risks) and the extent of risk management, as reported by enterprises in the European Survey of Enterprises on New and Emerging Risks (ESENER), it could be observed that the risk awareness and risk management differ across economic sectors: from low levels of both risk awareness and management observed in the agriculture, construction, and wholesale and retail trade sectors to high levels in the health sector (EU-OSHA 2017).

Furthermore, the prevalence and health effects of exposure to multiple hazards of the same or different type (e.g., chemical and organizational hazards) have received less attention in occupational health research, even though they should be a rather common phenomenon in real work environments. Nonetheless, some studies have investigated how different types of hazards may interact to increase the likelihood of adverse health effects in employed populations. In a large Danish register-based study with a cohort of hospital and administrative workers ($n = 69{,}200$), the probability of injury was higher for workers in the evening and night work shifts than for workers in the day shift (Nielsen et al. 2018). These results and similar studies (Uehli et al. 2014) provide support for the association linking shift work with sleep disorders (Boivin and Boudreau 2014), which in turn lead to a higher probability of work injuries (Uehli et al. 2014). Another example of multiple exposures and increasing likelihood of health adverse outcomes is related to multiple exposures to carcinogens. In spite of the difficulties and limitations associated with the assessment of actual concentrations of carcinogens in the work environment, the estimation of the effects of multiple exposures to carcinogens on health has been attempted in a lung cancer case-control study in Central and Eastern Europe and the United Kingdom (‘t Mannetje et al. 2011). In that study, the working lifetime exposure to dust and fumes/mist of chromium, nickel, cadmium, and arsenic was assessed on the basis of expert cut points for cases and controls. Whereas exposure to at least one metal was associated with an odds ratio of 1.28 (95% Cl 1.07–1.86), simultaneous exposure to all four metals yielded an odds ratio of 3.38 (95% Cl 1.25–9.12). Moreover, the distribution of exposures was mainly concentrated in the sectors of construction and metal manufacturing industries, agriculture, and specific occupations such as blacksmiths, toolmakers, painters, plumbers, welders, and sheet metal workers.

A very important moderator of actual exposure which has received less attention in the occupational health literature so far is the degree to which safety rules and procedures interact with the distribution of hazards across occupations (see Hale and Borys 2013 for an extensive review on safety rules). Commonly, two approaches to safety management are discussed: (1) a behavioral approach based on the identification of critical behaviors and their modification by means of feedback conditioning and (2) a cultural approach based on organizational and social-psychological models of norms, values, beliefs, and behaviors related to safety in organizations (DeJoy 2005). However, in both approaches it is assumed that the actual exposure to hazards is to some extent the consequence of failures at single hazard control levels (e.g., ignoring warning and usage rules of chemical substances) or at the level of the organizational culture (e.g., ignoring safety rules is usual practice in the organization) (DeJoy 2005). From a more general perspective, occupational risks and safety issues at the workplace are embedded in complex social-psychological decision processes occurring within organizations.

Previous investigations focusing on the causes, motives, or mental models involved in the violation of safety rules suggest a wide array of factors responsible for this type of norm violation. This can be briefly illustrated by considering the results from a focus group study with employees at a large steel manufacturing company in Sweden which gives some insight into the social-psychological processes involved in occupational risk exposure (Nordlf et al. 2015). From the perspective of the interviewed workers, employees (1) held the belief that risks associated with their work were unavoidable (fatalism); (2) were convinced that the individual worker has the largest responsibility for safety, and not the company; (3) had little trust in the company's commitment to safety; (4) experienced that communication and collaboration with colleagues were very important for safety; and (5) believed that some degree of nonchalance toward risks was prevalent due to effort reduction and getting used to a risky environment. In a literature review of similar studies conducted in the health, aviation, mining, rail transport, and construction sectors, Alper and Karsh concluded that violation to safety procedures involves several factors: characteristics of the individual workers (e.g., experience, age, gender), the work system (e.g., task demands, complexity, time demands, department goals), organizational factors (e.g., policies, rules, goals), and the external environment (e.g., standards, legislation) (Alper and Karsh 2009). In the context of the distribution of occupational hazards, these findings suggest that the observed magnitude and frequency of actual exposure are in some instances rather a consequence of the interaction between the different components of the whole work environment and not just the nature of specific job tasks. Hence, by the same token, in spite of the presence of unavoidable risks given by the nature of the production and service processes themselves, it seems that exposure reduction or elimination should still be attainable in working environments.

Conclusions and Future Directions

The findings briefly discussed in the preceding sections indicate that occupational hazards are substantially higher among service and sales workers (ISCO 5), skilled agricultural and fishery workers (ISCO 6), craft and related trades workers (ISCO 7), plant and machine operators (ISCO 8), and workers in elementary occupations (ISCO 9). Despite the fact that it is very difficult to accurately estimate the contribution of these hazards to the total incidence of disease in the population, the higher prevalence of chemical, physical, and organizational hazards for workers in these occupational categories is to some extent reflected in the distribution of recognized occupational diseases. Available results for the European Union in 2001 reveal that the incidence per 100,000 workers of overall occupational diseases by occupation is highest among craft and related trades workers (106.3), plant and machine operators (90), elementary occupations (74.3), skilled agricultural and fishery workers (35.2), and service and sales workers (13) (Karjalainen and Niederlaender 2004). In contrast, the incidence rates among managers, professionals, technicians, and clerks are less than 6 per 100,000 workers, i.e., approximately 17 times lower than for craft and related trades workers (Karjalainen and Niederlaender 2004). The most frequent occupational diseases follow the pattern of exposure to biomechanical (hand or wrist tenosynovitis, epicondylitis of the elbow, Raynaud's syndrome or vibration white finger, carpal tunnel syndrome), physical (noise-induced hearing loss), and chemical hazards (mesothelioma, asthma, asbestosis, and coal worker's pneumoconiosis). Nonetheless, these estimates largely underestimate the true burden of occupational hazards on workers' health, since they correspond to "recognized" occupational diseases, i.e., a selected group of diseases whose clinical features are aligned with the health effects following exposure to a single, specific agent (European Commission 2009), and fulfill the evidential criteria required by the insurance policies in the different jurisdictions of the European Union. As an illustration, from the 80,163 reported cases for social insurance compensation in Germany in the year 2016, only 22,320 were "recognized" as an occupational disease, i.e., an overall recognition rate of approximately 27% (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin 2017). In countries where reporting of cases is not mandatory, the underestimation of occupational disease incidence should be even larger.

As discussed in section "Socioeconomic Determinants of Occupational Hazard Distribution," there is no natural "dirtiness or cleanliness" of occupations; instead, the deliberate development and use of products, services, and production technologies set the general conditions on the type, magnitude, and frequency of occupational exposure to hazards. As new technologies at the production and organizational level develop and the magnitude of globalization of production and consumption patterns increases, it is to be expected that the type and distribution of hazards across occupations will accordingly change. Some global and regional trends can already be observed. The spreading of digital and automation technologies, for instance, increases the scale of production and the labor market in the manufacturing of electronic devices, electronic waste, and related industries and, thus, the number of workers exposed to substances such as organic solvents, cadmium, mercury, or nickel, especially in Eastern Asia (e.g., Friesen et al. 2014). Similarly, the intensification of global trade, market liberalization, and the consolidation of regional production clusters in sectors such as textiles and clothing may potentially increase the rates of exposure to carcinogenic, mutagenic, or reprotoxic agents, especially in Southern and Southeast Asia (e.g., Khan et al. 2015). On the other hand, in North America and Europe, the occupational structure has shifted from manufacturing to the services sector, and, accordingly, the type and distribution of hazards in several occupations are more related to organizational characteristics associated with factors including sitting and standing, irregular work, long working hours, working under pressure, tight deadlines, high-speed work, and low job control (e.g., Doubleday et al. 2019; Eurofound 2019). Even though it can also be expected that current management approaches such as lean and agile management will continue expanding, the consequences of these approaches on workers' health have not been assessed in occupational health research. To some extent, this knowledge gap is due to the traditional focus of occupational health research on individuals and not on individuals *within organizations.* Nonetheless, some basic principles of work organization in the lean and agile management approaches seem to indicate an increase in the exposure to organizational hazards. Work organization principles such as just-in-time production, strict cost-saving work procedures, reduction of operating and personnel costs, increased work specialization and standardization, and tighter deadlines, among others, suggest an increase of the exposure to psychosocial hazards associated with lower job control and autonomy, increased work intensity, longer working hours, and increased job demands (Koukoulaki 2014).

Finally, in a series of expert reports commissioned by the European Agency for Safety and Health at Work (EU-OSHA), several chemical, biological, psychosocial, and physical hazards have been identified for future research and occupational safety and health measures. Among the new chemical hazards, it is estimated that nanoparticles, diesel exhausts, man-made mineral fibers, epoxy resins, isocyanates, and crystalline silica-based products may pose unknown or increasing health risks for European workers. Regarding biological risks, the most important emerging occupational hazards identified by the experts concern global epidemics, zoonoses, drug-resistant organisms, and endotoxins. Concerning psychosocial hazards, it is expected that job insecurity, aging of the workforce, work intensification, high emotional demands at work, and poor work-life balance will account for increasing levels of exposure. Among the most important emerging physical hazards, the experts identified lack of physical activity, combined exposure to musculoskeletal hazards and psychosocial factors, poor design interfaces, thermal discomfort, ultraviolet radiation, and vibrations. Future research is needed to assess the impact of these emergent hazards both on the distribution of occupational hazards and the occupation-specific mortality and morbidity rates.

Cross-References

► Effort-Reward Imbalance and Occupational Health
► Impact of the Digitization in the Industry Sector on Work, Employment, and Health
► Job Intensity
► Occupational Noise: A Determinant of Social Inequalities in Health
► Shift Work and Occupational Hazards
► The Demand Control Support Work Stress Model

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