



Occupational Neurobehavioral and Respiratory Health Effects among Printing Press Workers: A Comprehensive Review

Sahar Abou El Magd Abou El Magd¹, Raghda Ali Abdelkhalek¹, Soad Abdelazeem Hassan¹, Heba Ahmed Abdelsalam²

1 Department of Occupational and Environmental Medicine, Faculty of Medicine, Zagazig University

2 Department of Psychiatry, Faculty of Medicine, Zagazig University

Corresponding Author: Soad Abdelazeem Hassan

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Abstract

Background: The printing industry remains an important occupational sector worldwide, employing millions of workers who are routinely exposed to a wide range of hazardous agents throughout pre-press, press, and post-press operations. Printing press workers encounter multiple occupational exposures, including volatile organic compounds, heavy metals, particulate matter, paper dust, adhesives, ultraviolet-curable compounds, excessive noise, heat, and ergonomic stressors. Although technological advances have modified several printing processes, many traditional hazards persist, particularly in small- and medium-scale enterprises where occupational health measures may be inadequate. Growing evidence suggests that chronic exposure to these workplace hazards may adversely affect both the nervous and respiratory systems, resulting in significant morbidity and impaired quality of life among exposed workers.

This review aims to provide a comprehensive overview of the occupational neurobehavioral and respiratory health effects associated with employment in the printing industry. It summarizes the major printing technologies and associated workplace exposures, explores the mechanisms through which solvents and heavy metals contribute to neurotoxicity, and examines the burden of respiratory disorders linked to inhalation of volatile chemicals and airborne particulates. Particular emphasis is placed on neurobehavioral manifestations such as cognitive impairment, memory deficits, attention disturbances, mood alterations, fatigue, and peripheral neuropathy, as well as respiratory outcomes including upper airway irritation, occupational asthma, chronic bronchitis, impaired pulmonary function, and chronic obstructive pulmonary disease. The review also highlights current approaches for health surveillance and early detection, including biological monitoring, neurobehavioral assessment tools, and spirometric evaluation.

Available evidence indicates that printing press workers represent a vulnerable occupational group requiring targeted preventive strategies. Implementation of engineering controls, substitution of hazardous substances, appropriate use of personal protective equipment, periodic medical examinations, and worker education programs are essential components of risk reduction. Strengthening occupational health services and conducting high-quality longitudinal studies are necessary to improve understanding of exposure–response relationships and to guide evidence-based interventions aimed at protecting the health and well-being of printing industry workers.

Keywords: Occupational, Neurobehavioral, Respiratory Health Effects, Printing Press Workers



Introduction

The printing industry has undergone remarkable technological evolution, expanding from traditional letterpress methods to modern offset, flexographic, gravure, screen, and digital printing technologies. Despite these advancements, workers in printing facilities continue to encounter a wide range of occupational hazards associated with various stages of the printing process. These hazards include exposure to solvents, inks, pigments, cleaning agents, particulate matter, excessive noise, and ergonomic stressors, particularly in workplaces where occupational safety measures are insufficient or inconsistently implemented. [1–3]

Among these hazards, chemical exposures remain a major concern. Printing press workers may be exposed to volatile organic compounds such as benzene, toluene, xylene, and n-hexane, in addition to heavy metals present in certain pigments and dyes. Owing to their neurotoxic properties, these substances have been associated with adverse effects on the central and peripheral nervous systems, leading to neurobehavioral manifestations including impaired attention, memory deficits, mood disturbances, fatigue, and reduced psychomotor performance. [4,5]

Respiratory disorders also represent an important occupational health issue in the printing industry. Airborne contaminants generated during printing activities, including volatile organic compounds, toner emissions, fine particulate matter, and paper dust, may contribute to upper and lower respiratory tract irritation, occupational asthma, chronic bronchitis, and deterioration in pulmonary function. The coexistence of multiple workplace exposures may further increase the burden of respiratory morbidity among printing workers. [3,6]

Although previous studies have investigated individual occupational exposures or specific health outcomes among printing workers, evidence integrating both neurobehavioral and respiratory consequences within a comprehensive occupational health perspective remains limited. Therefore, this review aims to summarize the current evidence regarding occupational neurobehavioral and respiratory health effects among printing press workers, discuss potential mechanisms underlying these outcomes, and highlight approaches for surveillance and prevention to support the protection of this vulnerable workforce.

Overview of the Printing Industry and Printing Processes

The printing industry remains an essential component of the global economy, serving diverse sectors including publishing, packaging, advertising, education, and commercial communications. Advances in technology have transformed traditional printing methods into highly specialized processes capable of producing high-quality outputs on a wide variety of substrates. Despite this evolution, many printing operations continue to involve manual handling of chemicals and prolonged worker interaction with printing equipment, creating opportunities for occupational exposures. Understanding the different printing processes is fundamental for identifying potential workplace hazards and implementing appropriate preventive measures. [7,8]

Printing operations are generally categorized into three main stages: pre-press, press, and post-press. The pre-press stage involves activities such as graphic design, image processing, plate preparation, and proofing. Historically, these processes required extensive use of photographic chemicals and developing solutions; however, newer technologies such as computer-to-plate systems have reduced the reliance on some hazardous substances. The press stage represents the actual transfer of images onto substrates and is often associated with exposure to inks, fountain solutions, solvents, and noise generated by printing machinery. The post-press stage includes cutting, folding, binding, laminating, and packaging operations, during which workers may encounter adhesives, dust, and mechanical hazards. [2,9]

Offset lithography remains one of the most widely used printing methods worldwide. This technique is based on the principle that oil and water repel each other, allowing the image area to selectively attract ink while non-image areas retain water. Offset printing commonly utilizes fountain solutions containing isopropyl alcohol and requires regular cleaning of rollers and blankets using organic solvents. Consequently, workers involved in offset printing may experience significant exposure to volatile organic compounds, particularly in facilities lacking adequate ventilation systems. [3,10]



Other important printing techniques include flexography, gravure, screen printing, and digital printing. Flexographic printing is extensively used in packaging industries and frequently employs fast-drying inks containing alcohols and other solvents. Gravure printing involves recessed image cells and traditionally relied on chemical etching processes during cylinder preparation. Screen printing utilizes mesh stencils and may involve ultraviolet-curable inks and photosensitive materials. In contrast, digital printing technologies, including laser and inkjet printing, offer improved efficiency and reduced setup requirements but can generate ultrafine particles and gaseous emissions during operation. Because each printing method has unique exposure profiles, occupational health risk assessments should consider the specific technologies employed within individual workplaces. [11–13]

Occupational Hazards in the Printing Industry

Chemical Hazards

Chemical exposures represent the most important occupational health concern in the printing industry because workers may encounter numerous hazardous substances simultaneously during different stages of production. These exposures occur during plate preparation, ink formulation, printing operations, machine maintenance, and post-press activities. The major chemical agents include organic solvents, printing inks, fountain solutions, cleaning agents, adhesives, ultraviolet-curable compounds, and heavy metals contained in pigments and dyes. Exposure occurs predominantly through inhalation of vapors and aerosols, although dermal absorption is also an important route, especially among workers handling solvents and inks without adequate personal protective equipment. The magnitude of exposure depends on several factors, including the type of printing technology employed, workplace ventilation, duration of exposure, and adherence to occupational safety practices. [14,15]

Organic solvents constitute one of the most extensively studied hazards among printing workers. Benzene, toluene, xylene, ethyl acetate, glycol ethers, and n-hexane are frequently encountered in solvent-based inks, thinning agents, and cleaning products used to remove ink residues from rollers and blankets. These compounds are highly volatile and readily evaporate into workplace air, resulting in substantial inhalational exposure. Acute exposure may produce mucosal irritation, headache, dizziness, nausea, and impaired concentration, whereas chronic exposure has been associated with neurobehavioral dysfunction, hepatotoxicity, nephrotoxicity, hematological abnormalities, and respiratory impairment. Several studies have demonstrated measurable concentrations of volatile organic compounds in printing environments, emphasizing the need for effective engineering controls and exposure monitoring programs. [16–18]

Printing inks themselves are complex mixtures composed of pigments, binders, solvents, oils, waxes, and various performance-enhancing additives. Although advances in printing technology have reduced the use of certain hazardous constituents, some pigments still contain heavy metals such as lead, cadmium, chromium, and mercury. Long-term occupational exposure to these metals may result in bioaccumulation and subsequent adverse health outcomes affecting the nervous, renal, hematopoietic, and respiratory systems. Heavy metal exposure among printing workers has therefore emerged as an area of increasing concern, particularly in settings where environmental monitoring and industrial hygiene measures remain inadequate. [19,20]

Cleaning solvents used during routine maintenance procedures are another important source of occupational exposure. Frequent cleaning of printing machinery is necessary to maintain print quality and prevent the accumulation of dried inks and paper debris. However, manual cleaning practices often involve the use of open containers and solvent-soaked cloths, facilitating the release of volatile compounds into the workplace atmosphere. Workers performing these tasks repeatedly throughout the workday may therefore experience cumulative exposure levels that contribute substantially to their overall toxic burden. The implementation of enclosed cleaning systems, substitution with less hazardous alternatives, and reinforcement of safe handling practices are critical preventive strategies. [15,18]

Physical Hazards

In addition to chemical exposures, printing press workers encounter numerous physical hazards that may adversely affect health and safety. Noise is among the most prevalent occupational hazards in printing facilities, generated by printing presses, compressors, folding machines, cutting devices, and ventilation



systems. Continuous exposure to elevated noise levels may result in noise-induced hearing loss, tinnitus, impaired communication, and reduced work performance. Importantly, recent evidence suggests that co-exposure to organic solvents and occupational noise may exert synergistic ototoxic effects, thereby increasing the risk of auditory dysfunction beyond that attributable to either exposure alone. [21,22]

Mechanical hazards also contribute substantially to occupational injuries in the printing industry. Workers frequently operate machinery containing rapidly moving rollers, rotating cylinders, gears, cutting blades, and binding equipment. Inadequate machine guarding, improper maintenance, and unsafe work practices may lead to traumatic injuries including lacerations, crush injuries, fractures, and amputations. The implementation of machine safety protocols, lockout-tagout procedures, and comprehensive worker training programs is therefore essential to reduce injury risks within printing facilities. [23]

Heat exposure constitutes another relevant concern, particularly in workplaces utilizing drying ovens, ultraviolet-curing systems, or heat-generating printing equipment. Prolonged exposure to elevated temperatures may lead to dehydration, fatigue, reduced concentration, and heat-related illnesses. Moreover, excessive heat may indirectly increase occupational accident risk by impairing cognitive performance and decision-making capacity. Adequate environmental controls, proper hydration practices, and scheduled rest periods should therefore be integrated into workplace health programs. [24]

Biological Hazards

Although biological hazards receive less attention than chemical and physical risks, they remain important considerations in certain printing environments. Paper storage areas characterized by poor ventilation and elevated humidity may support the growth of moulds and fungi. Workers exposed to airborne fungal spores may develop allergic reactions, rhinitis, conjunctival irritation, and respiratory symptoms, particularly among susceptible individuals with underlying atopic conditions. In addition, some fungal species are capable of producing mycotoxins that may exert immunological and systemic effects following prolonged exposure. [25,26]

The risk of microbial contamination is heightened in facilities with inadequate housekeeping practices, water leakage, or insufficient environmental control measures. Consequently, maintaining appropriate humidity levels, ensuring adequate ventilation, and implementing regular cleaning protocols are important preventive measures aimed at minimizing biological hazards in printing workplaces. [26]

Psychosocial Hazards

Psychosocial factors are increasingly recognized as important determinants of occupational health within industrial settings, including the printing industry. Production deadlines, high workload demands, repetitive tasks, prolonged working hours, and shift schedules may contribute to psychological stress and occupational fatigue. These factors not only affect workers' mental well-being but may also impair concentration, increase the likelihood of human error, and elevate the risk of workplace accidents. [27]

Rotating shift work, commonly encountered in large-scale printing operations functioning around the clock, may disrupt circadian rhythms and adversely affect sleep quality. Sleep disturbances have been associated with impaired cognitive performance, mood changes, reduced productivity, and increased susceptibility to chronic diseases. Therefore, comprehensive occupational health programs should extend beyond traditional hazard control measures to incorporate strategies addressing psychosocial well-being, work organization, and employee support systems. Recognition of psychosocial hazards as integral components of workplace risk assessment may ultimately contribute to healthier and safer printing environments. [27]

Neurobehavioral Health Effects among Printing Press Workers

Neurobehavioral disorders represent one of the most important yet frequently underrecognized occupational health consequences among printing press workers. During routine printing activities, workers may experience repeated exposure to neurotoxic agents, particularly organic solvents and heavy metals, through inhalation and dermal absorption. Owing to their lipophilic nature, many organic solvents readily cross the blood-brain barrier and accumulate within lipid-rich neural tissues, thereby interfering with normal neuronal function. Similarly, certain heavy metals used in pigments and printing materials possess the ability to bioaccumulate and exert long-lasting toxic effects on both the central and peripheral



nervous systems. Consequently, prolonged occupational exposure in printing environments has increasingly been associated with adverse neurobehavioral outcomes affecting cognition, mood, sensory function, and motor performance. [28–30]

Organic solvents remain among the most extensively investigated neurotoxic agents in the printing industry. Benzene, toluene, xylene, and n-hexane are commonly encountered in solvent-based inks, cleaning agents, and thinners used throughout printing operations. Acute exposure to these compounds may manifest as headache, dizziness, fatigue, nausea, impaired concentration, and transient alterations in psychomotor performance. However, chronic exposure appears to pose a greater threat because repeated low-level exposure may lead to cumulative neurotoxic effects that evolve gradually and remain clinically unrecognized during the early stages of disease development. [31–33]

Among aromatic hydrocarbons, toluene has been particularly implicated in occupational neurotoxicity. Following inhalation, toluene is rapidly distributed to highly perfused and lipid-rich tissues, including the brain. Experimental and epidemiological evidence suggests that toluene exposure disrupts neuronal membrane integrity, induces oxidative stress, and interferes with neurotransmitter systems involved in attention, learning, and emotional regulation. Workers chronically exposed to toluene have reported symptoms such as unusual fatigue, irritability, memory difficulties, sleep disturbances, and reduced concentration, while prolonged exposure has been linked to measurable impairments in neuropsychological performance. [34–36]

Similarly, xylene exposure has been associated with disturbances in cognitive and behavioral functioning. The proposed mechanisms include oxidative stress, neuroinflammation, and alterations in dopaminergic and serotonergic neurotransmission. Clinical manifestations reported among exposed individuals include headache, dizziness, impaired memory, emotional instability, and difficulties in maintaining attention. Although some effects may improve following removal from exposure, prolonged occupational contact may contribute to persistent neurological dysfunction and reduced quality of life. [37,38]

N-hexane deserves particular attention because of its established association with peripheral neuropathy. Hepatic metabolism of n-hexane generates the neurotoxic metabolite 2,5-hexanedione, which induces axonal degeneration through interactions with neurofilament proteins. Workers with prolonged exposure may develop numbness, paresthesia, muscle weakness, reduced reflexes, and impaired coordination. In severe cases, progressive sensorimotor neuropathy may interfere substantially with occupational performance and activities of daily living. The occurrence of these manifestations underscores the importance of early recognition and exposure prevention in workplaces utilizing n-hexane-containing products. [39,40]

Heavy metals encountered in printing environments may also contribute to neurobehavioral impairment. Lead, cadmium, mercury, and manganese have all been implicated in neurological toxicity through mechanisms involving oxidative stress, mitochondrial dysfunction, disruption of calcium homeostasis, and interference with neurotransmitter synthesis and release. Lead exposure, for example, has been associated with deficits in attention, executive functioning, reaction time, and mood regulation. Mercury toxicity may manifest as tremors, irritability, insomnia, and emotional instability, whereas manganese accumulation has been linked to parkinsonian features characterized by bradykinesia, rigidity, and impaired motor coordination. [30,41]

The neurobehavioral manifestations observed among exposed workers encompass a broad spectrum of clinical symptoms and functional impairments. Frequently reported complaints include chronic fatigue, headache, forgetfulness, reduced attention span, irritability, anxiety, depressed mood, sleep disturbances, and difficulties performing complex cognitive tasks. Motor impairments involving reduced manual dexterity, slower reaction times, and diminished psychomotor speed have also been documented. Because these manifestations often develop insidiously and may overlap with symptoms arising from psychosocial stressors or aging, they are frequently overlooked in routine occupational health practice. [29,42]

Several epidemiological investigations have demonstrated an association between occupational solvent exposure and objective deficits in neurobehavioral performance. Neuropsychological assessments have identified impairments in domains including memory, attention, perceptual speed, motor coordination, and



executive functioning among exposed workers compared with unexposed populations. Importantly, some studies have reported adverse effects even at exposure levels below currently accepted occupational exposure limits, suggesting that existing standards may not fully protect susceptible individuals from subtle neurotoxic effects. These findings highlight the necessity of integrating neurobehavioral surveillance into occupational health programs serving printing industry workers. [33,43]

Given the potentially irreversible nature of chronic neurotoxicity, prevention and early detection remain critical components of worker protection. Comprehensive strategies should include substitution of hazardous chemicals whenever feasible, optimization of local exhaust ventilation systems, routine exposure monitoring, worker education, and appropriate use of personal protective equipment. Periodic health assessments incorporating symptom questionnaires and standardized neurobehavioral testing may facilitate the identification of affected workers before the development of advanced neurological impairment. Such interventions are essential for minimizing the long-term neurobehavioral burden associated with employment in the printing industry. [15,44]

Respiratory Health Effects among Printing Press Workers

Respiratory disorders constitute a major occupational health concern among printing press workers because of their frequent exposure to airborne contaminants generated during printing operations. The printing environment contains a complex mixture of volatile organic compounds (VOCs), particulate matter, toner emissions, paper dust, isocyanates, ozone, and various chemical aerosols released during ink preparation, printing, equipment cleaning, and finishing processes. The nature and magnitude of respiratory exposure vary according to the printing technology used, the degree of automation, environmental conditions within the workplace, and the effectiveness of existing control measures. Prolonged inhalation of these agents may result in both acute respiratory symptoms and chronic pulmonary diseases that adversely affect workers' quality of life and productivity. [45–47]

Volatile organic compounds represent one of the most important categories of respiratory hazards in the printing industry. Solvents such as toluene, xylene, benzene, and other hydrocarbon mixtures readily evaporate into the workplace atmosphere, particularly during cleaning procedures and the use of solvent-based inks. Acute exposure to elevated concentrations of these compounds may produce irritation of the eyes, nose, and throat, accompanied by coughing, chest discomfort, and shortness of breath. Repeated exposure contributes to persistent airway inflammation and may exacerbate pre-existing respiratory conditions. The risk is particularly pronounced in workplaces characterized by inadequate ventilation and limited implementation of industrial hygiene practices. [46,48]

Particulate matter generated during printing activities has also emerged as an important contributor to respiratory morbidity. Airborne particles may originate from toner powders, pigments, paper dust, and emissions from digital printing equipment. Fine particles (PM_{2.5}) and ultrafine particles possess the capacity to penetrate deeply into the lower respiratory tract, reaching the bronchioles and alveolar spaces. Following deposition, these particles stimulate inflammatory pathways, oxidative stress responses, and macrophage activation, potentially leading to chronic respiratory symptoms and progressive deterioration of lung function. Because smaller particles remain suspended in the air for prolonged periods, workers may experience substantial cumulative exposure during routine occupational activities. [49,50]

Paper dust exposure represents another significant hazard, particularly among workers involved in paper handling, cutting, folding, and finishing operations. Chronic inhalation of paper dust has been associated with increased prevalence of cough, wheezing, breathlessness, and upper airway irritation. The biological mechanisms underlying these effects involve mechanical irritation of respiratory mucosa and induction of inflammatory responses within the airways. Although paper dust is sometimes perceived as relatively harmless compared with chemical exposures, accumulating evidence indicates that sustained exposure may contribute meaningfully to respiratory morbidity among industrial workers. [51]

Occupational asthma is among the most important work-related respiratory disorders encountered in printing environments. Sensitizing agents such as isocyanates and acrylates used in ultraviolet-curable inks and adhesives have been implicated in the development of occupational asthma through immunologically mediated mechanisms. In sensitized individuals, even low levels of exposure may provoke



bronchoconstriction, wheezing, chest tightness, and dyspnea. In contrast, certain irritant chemicals encountered in printing settings may induce non-immunologic asthma through direct injury to the airway epithelium. Early recognition of occupational asthma is crucial because continued exposure following symptom onset is associated with poorer clinical outcomes and irreversible airway remodeling. [52,53]

Chronic respiratory diseases may also develop following prolonged occupational exposure. Persistent inhalation of chemical vapors and airborne particulates contributes to chronic inflammation, mucus hypersecretion, and structural alterations within the respiratory tract. Over time, these pathological processes may manifest clinically as chronic bronchitis and progressive airflow limitation characteristic of chronic obstructive pulmonary disease (COPD). Epidemiological investigations have demonstrated an increased prevalence of respiratory symptoms and reduced pulmonary function among workers exposed to printing-related emissions, emphasizing the need for long-term respiratory surveillance in this occupational group. [50,54]

Respiratory manifestations reported among printing workers include chronic cough, sputum production, wheezing, nasal congestion, sore throat, chest tightness, exertional dyspnea, and recurrent upper respiratory tract infections. Although these symptoms are frequently dismissed as nonspecific or attributed to smoking and environmental pollution, their occurrence in occupational settings warrants careful evaluation. Failure to recognize work-related respiratory disease may delay diagnosis, prolong harmful exposures, and diminish opportunities for effective intervention. Occupational history-taking therefore remains an indispensable component of respiratory assessment among individuals employed in the printing industry. [47,55]

Preventive measures play a pivotal role in reducing respiratory risks among printing workers. Effective interventions include substitution of hazardous substances with safer alternatives, installation of local exhaust ventilation systems, regular maintenance of printing equipment, optimization of workplace housekeeping practices, and implementation of comprehensive respiratory protection programs when engineering controls are insufficient. Worker education regarding exposure risks and early symptom recognition should complement environmental control measures. In addition, periodic medical surveillance incorporating respiratory questionnaires and pulmonary function testing may facilitate early identification of disease and improve long-term health outcomes. [15,56]

Investigations and Health Surveillance for Neurobehavioral and Respiratory Disorders among Printing Press Workers

Early identification of work-related neurobehavioral and respiratory disorders is a cornerstone of occupational health practice because many adverse health effects associated with printing industry exposures are initially subtle, nonspecific, and potentially reversible if recognized promptly. Comprehensive surveillance programs should therefore integrate exposure assessment, biological monitoring, clinical evaluation, and functional testing to identify workers at increased risk before irreversible damage occurs. Such programs not only facilitate early diagnosis and intervention but also provide valuable information regarding the effectiveness of workplace control measures and the adequacy of existing occupational health policies. [57,58]

Biological Monitoring of Occupational Exposures

Biological monitoring provides an objective approach for evaluating internal doses of hazardous substances absorbed by workers through inhalation, dermal contact, or ingestion. In the printing industry, where employees are frequently exposed to mixtures of organic solvents and heavy metals, biomonitoring serves as an important complement to environmental measurements. Unlike air sampling, biological monitoring reflects the total amount of a substance entering the body from all exposure routes and may therefore provide a more accurate estimate of individual exposure burden. [59]

Urinary metabolites are among the most commonly used biomarkers for assessing exposure to organic solvents. Hippuric acid has traditionally been used as an indicator of toluene exposure, whereas methylhippuric acids serve as biomarkers of xylene exposure. Studies involving printing workers have demonstrated higher urinary concentrations of these metabolites among exposed individuals compared with non-exposed controls, confirming the occurrence of occupational absorption even in settings where



environmental concentrations may comply with regulatory limits. Biomonitoring data can therefore support risk assessment activities and guide interventions aimed at reducing workplace exposures. [60] Heavy metals possess relatively long biological half-lives and tend to accumulate in tissues over time, making biological surveillance particularly valuable in exposed populations. Blood, urine, and scalp hair have all been utilized for the assessment of occupational heavy metal exposure. Urinary measurements generally reflect more recent exposures, whereas hair analysis may provide information regarding cumulative exposure over extended periods. Previous investigations among printing workers have identified elevated concentrations of selected metals among employees directly involved in production processes, highlighting the usefulness of these methods for identifying high-risk groups within industrial settings. [61,62]

Neurobehavioral Assessment

Because neurotoxic effects often develop gradually and may initially present as subtle cognitive or emotional disturbances, standardized neurobehavioral testing constitutes an essential component of occupational health surveillance. Such assessments enable the detection of early functional changes before the appearance of overt neurological disease and facilitate monitoring of trends over time among exposed workers. The use of validated instruments is therefore recommended in occupational settings characterized by potential exposure to neurotoxic substances. [63]

The World Health Organization Neurobehavioral Core Test Battery (WHO-NCTB) is one of the most widely recognized tools for evaluating neurobehavioral performance in occupational studies. The battery assesses several domains, including attention, memory, motor speed, manual dexterity, perceptual function, and affective status. Its standardized format allows comparisons across different populations and facilitates the identification of exposure-related impairments. The WHO-NCTB has been applied extensively in studies investigating neurotoxicity associated with pesticides, heavy metals, and organic solvents. [64]

Evidence from occupational studies indicates that workers exposed to organic solvents may exhibit deficits in psychomotor speed, attention, and memory when compared with non-exposed populations. Computerized neurobehavioral assessments have demonstrated reduced finger tapping performance, slower reaction times, and impaired concentration among solvent-exposed workers. Additionally, symptom-based screening instruments such as the Q16 questionnaire have proven useful in identifying workers experiencing neuropsychological complaints warranting further clinical evaluation. Although these tools are not diagnostic in isolation, they represent valuable components of comprehensive surveillance strategies aimed at early detection of occupational neurotoxicity. [65–67]

Respiratory Assessment

Respiratory surveillance is equally important among printing press workers because occupational respiratory diseases often progress insidiously before becoming clinically apparent. A comprehensive respiratory evaluation should begin with detailed occupational and medical history-taking, focusing on respiratory symptoms, smoking status, temporal relationships between symptoms and workplace exposures, and previous respiratory diagnoses. Particular attention should be directed toward identifying symptom improvement during weekends or holidays, which may suggest an occupational etiology. [68]

Spirometry remains the most widely used and validated method for evaluating pulmonary function in occupational health practice. It provides objective measurements of lung function parameters, including forced vital capacity (FVC), forced expiratory volume in one second (FEV₁), and the FEV₁/FVC ratio. These indices facilitate the identification of obstructive and restrictive ventilatory abnormalities and enable longitudinal monitoring of respiratory status among exposed workers. Standardization of testing procedures and adherence to international guidelines are essential to ensure reliable interpretation of spirometric findings. [69,70]

Serial pulmonary function testing may be particularly valuable in industries characterized by ongoing respiratory exposures because repeated measurements permit the detection of accelerated declines in lung function before severe impairment develops. Workers exhibiting persistent respiratory symptoms or abnormal spirometric findings should undergo further evaluation to establish the nature and severity of the



underlying condition. Such investigations may include bronchodilator responsiveness testing, specialist referral, and additional diagnostic procedures when clinically indicated. [68]

Importance of Periodic Medical Surveillance

Periodic medical examinations constitute an integral component of occupational health programs for printing press workers. Surveillance activities should be tailored to the specific hazards present within individual workplaces and should incorporate both neurobehavioral and respiratory evaluations where appropriate. The results of surveillance programs should inform workplace interventions, including modification of work practices, enhancement of engineering controls, and reinforcement of personal protective measures. Importantly, health surveillance should not be viewed merely as a regulatory obligation but rather as a proactive strategy aimed at preserving worker health and preventing occupational disease. [57,71]

Prevention and Control Strategies for Occupational Neurobehavioral and Respiratory Disorders among Printing Press Workers

Prevention of occupational diseases in the printing industry requires a comprehensive approach that addresses the diverse hazards encountered throughout printing operations. Given that workers are often exposed simultaneously to multiple chemical, physical, and psychosocial stressors, isolated interventions are unlikely to provide adequate protection. Instead, effective occupational health programs should adopt the hierarchy of controls framework, prioritizing elimination and substitution of hazards, implementation of engineering controls, administrative interventions, and appropriate use of personal protective equipment. Integrating these strategies within routine workplace practices is essential for reducing exposure levels and minimizing the burden of neurobehavioral and respiratory disorders among printing press workers. [72]

Elimination and Substitution of Hazardous Agents

The most effective preventive strategy involves eliminating hazardous substances whenever feasible or replacing them with safer alternatives. Technological advancements have facilitated the development of water-based inks, low-VOC formulations, alcohol-free fountain solutions, and digital printing technologies that substantially reduce worker exposure to toxic chemicals. Similarly, replacement of cleaning agents containing highly volatile solvents with less hazardous products can significantly decrease inhalational risks. Although economic and technical considerations may influence the feasibility of substitution, continuous evaluation of available alternatives should constitute an integral component of occupational risk management within the printing industry. [73,74]

Engineering Controls

Engineering controls represent the primary line of defense when hazardous exposures cannot be completely eliminated. Local exhaust ventilation systems are particularly important in printing facilities because they capture airborne contaminants at their source before dispersion into the general work environment. Enclosed cleaning systems, automated ink dispensing technologies, and modifications to production equipment can further reduce direct worker contact with hazardous substances. Regular maintenance of ventilation systems and periodic evaluation of their effectiveness are essential to ensure sustained protection. In addition, adequate general ventilation contributes to reducing background concentrations of volatile organic compounds and airborne particulates within the workplace. [75,76]

Advances in industrial hygiene engineering have also emphasized the importance of considering worker movement patterns and workstation design when evaluating ventilation performance. The effectiveness of local exhaust systems may be compromised by inappropriate placement, inadequate airflow, or work practices that disrupt contaminant capture. Consequently, engineering interventions should be designed collaboratively by occupational hygienists, engineers, and workplace managers to maximize exposure reduction under actual operating conditions. [76]

Administrative Controls

Administrative measures constitute important complementary strategies aimed at minimizing exposure duration and promoting safer work practices. Such measures include implementation of standard operating procedures, scheduling of high-exposure tasks during periods of reduced occupancy, restriction of access



to hazardous areas, and establishment of preventive maintenance programs. Periodic environmental monitoring and routine occupational risk assessments facilitate the identification of emerging hazards and support timely corrective actions. [77]

Worker education and training are equally critical components of administrative control programs. Employees should receive regular instruction regarding the health risks associated with workplace exposures, proper handling and storage of chemicals, recognition of early symptoms of occupational illness, and emergency response procedures. Educational interventions have been shown to improve workers' knowledge and safety practices, thereby enhancing compliance with recommended protective measures. Continuous reinforcement of safety culture within the organization remains essential for sustaining these improvements over time. [78]

Personal Protective Equipment

Although personal protective equipment (PPE) occupies the lowest tier within the hierarchy of controls, it continues to play an important role in situations where residual exposures cannot be adequately controlled through other means. Appropriate respiratory protection should be provided to workers involved in activities associated with elevated airborne contaminant concentrations, particularly during equipment cleaning, maintenance procedures, and tasks generating dust or aerosols. Selection of respirators should be based on hazard assessment findings and accompanied by fit testing, training, and maintenance programs to ensure effectiveness. [72]

Chemical-resistant gloves, protective clothing, and eye protection should also be utilized when handling solvents, inks, adhesives, and other hazardous substances capable of causing dermal or mucosal injury. However, reliance on PPE alone is insufficient and may provide a false sense of security if higher-level control measures are neglected. Therefore, PPE should be regarded as one component of a broader occupational health strategy rather than the primary means of hazard control. [77]

Medical Surveillance and Health Promotion

Periodic medical surveillance programs provide valuable opportunities for early detection of work-related disorders and evaluation of preventive interventions. Workers exposed to neurotoxic agents should undergo regular assessments focusing on neurobehavioral symptoms and functional status, whereas individuals at risk of respiratory disease may benefit from serial pulmonary evaluations. Surveillance findings should be reviewed systematically to identify exposure trends, emerging health concerns, and priorities for workplace intervention. [79]

Beyond disease surveillance, workplace health promotion initiatives may contribute to enhancing overall worker well-being and resilience. Smoking cessation programs, encouragement of healthy lifestyles, stress management interventions, and facilitation of access to occupational health services represent important supportive strategies. Because smoking may exacerbate respiratory morbidity and confound interpretation of occupational health findings, targeted smoking prevention initiatives should be incorporated into comprehensive worker health programs whenever appropriate. [80]

Future Directions in Occupational Health Protection

The dynamic nature of printing technologies necessitates continuous adaptation of occupational health practices. Emerging digital printing methods and novel chemical formulations may introduce previously unrecognized hazards requiring further investigation. Future efforts should prioritize longitudinal studies capable of clarifying exposure–response relationships and identifying susceptible populations. In addition, greater integration of biological monitoring, exposure science, and occupational epidemiology may facilitate the development of evidence-based preventive strategies tailored to the specific needs of the printing workforce. Strengthening occupational health infrastructure, particularly in low- and middle-income countries where regulatory oversight may be limited, remains an important global public health priority. [74,81]

Ultimately, effective prevention of neurobehavioral and respiratory disorders among printing press workers depends upon a proactive and multidisciplinary approach involving employers, workers, occupational health professionals, industrial hygienists, and policymakers. Sustained commitment to hazard reduction, worker education, and health surveillance is essential to safeguarding the health and



productivity of this vulnerable occupational population.

Conclusion

Printing press workers are exposed to a wide range of occupational hazards that may adversely affect both neurobehavioral and respiratory health. Accumulating evidence indicates that chronic exposure to organic solvents, heavy metals, particulate matter, and other workplace contaminants contributes to cognitive impairment, mood disturbances, peripheral neuropathy, respiratory symptoms, occupational asthma, and deterioration in pulmonary function. Given the often subtle onset and progressive nature of these disorders, early recognition through appropriate health surveillance is essential. Implementing comprehensive preventive strategies, including substitution of hazardous substances, engineering controls, worker education, use of personal protective equipment, and periodic medical evaluations, is critical to reducing occupational risks. Strengthening occupational health practices and promoting safer printing environments will not only protect workers' health and well-being but also enhance productivity and sustainability within the printing industry.

References

1. Hellinga L. The Gutenberg Revolutions. In: Suarez MF, Woudhuysen HR, editors. *A Companion to the History of the Book*. Oxford: Wiley-Blackwell; 2019:377-392.
2. Kasikovic N, Djurdjevic S, Novakovic D. Printing process parameters identification system. *Teh Vjesn*. 2021;28(5):1782-1789.
3. Dikshit M, Tiwari RC. A review on occupational health hazards and future challenges in the printing industry. *World J Pharm Res*. 2024;14(3):214-222.
4. Juárez-Pérez CA, Aguilar-Madrid G, Sandoval-Ocaña J, Cabello-López A, Trujillo-Reyes O, et al. Neuropsychological effects among workers exposed to organic solvents. *Salud Publica Mex*. 2019;61(5):670-677.
5. Rostami R, Fazlzadeh M, Babaei-Pouya A, Abazari M, Rastgho L. Exposure to BTEX concentration and the related health risk assessment in printing and copying centers. *Environ Sci Pollut Res Int*. 2021;28:31195-31206.
6. Pongboonkhumlarp N, Jinsart W. Health risk analysis from volatile organic compounds and fine particulate matter in the printing industry. *Int J Environ Sci Technol*. 2022;19(9):8633-8644.
7. Kalilu RO, Abiodun DA. An analysis of the strengths and challenges of Direct Imaging and Computer to Plate offset printing technologies: the Nigerian experience. *Art Des*. 2023:40-53.
8. Abusaq Z, Zahoor S, Habib MS, Rehman M, Mahmood J, et al. Improving energy performance in flexographic printing process through lean and AI techniques: a case study. *Energies*. 2023;16(4):1972.
9. Shah MA, Lee DG, Lee BY, Hur S. Classifications and applications of inkjet printing technology: A review. *IEEE Access*. 2021;9:140079-140102.
10. Florian C, Serra P. Printing via laser-induced forward transfer and the future of digital manufacturing. *Materials (Basel)*. 2023;16(2):698.
11. Tsai CJ, Mao IF, Ting JY, Young CH, Lin JS, Li WL. Quality of chemical safety information in printing industry. *Ann Occup Hyg*. 2016;60(3):361-370.
12. Su M, Sun R, Zhang X, Wang S, Zhang P, Yuan Z, et al. Assessment of the inhalation risks associated with working in printing rooms: a study on the staff of eight printing rooms in Beijing, China. *Environ Sci Pollut Res Int*. 2018;25:17137-17143.
13. Alabdulhadi A, Ramadan A, Devey P, Boggess M, Guest M. Inhalation exposure to volatile organic compounds in the printing industry. *J Air Waste Manag Assoc*. 2019;69(10):1142-1169.
14. Abdulateef Z, Talib A. Impacts of printing presses emissions upon occupationally exposed workers health. *Int J Curr Microbiol App Sci*. 2016;5(4):757-771.



15. Sirinara P, Patarapongsant Y, Nilyai S, Sooklert K, Dissayabutra T, et al. Assessing exposure of printing factory workers in Thailand to selected heavy metals using urine and hair as non-invasive matrices. *BMC Public Health*. 2023;23(1):31.
16. Alabdulhadi A, Devey P, Boggess M, Guest M. Personal noise exposure assessment of Kuwaiti printing industry workers. *Int J Occup Saf Ergon*. 2021;27(2):578-588.
17. Cabello-López A, Chávez-Gómez NL, Torres-Valenzuela A, Aguilar-Madrid G, Trujillo-Reyes O, et al. Audiometric findings of printing press workers exposed to noise and organic solvents. *Int J Audiol*. 2021;60(1):8-15.
18. Agbenorku P, Owusu DJ, Nyador E, Agbenorku M. Traumatic injuries among printing press workers in Kumasi (Ghana). *J Med Med Sci*. 2010;1(9):426-432.
19. Ibrahim AS, Fouad NA, Elkodoos RF. Assessment of occupational health hazards among printing press workers. *Egypt Nurs J*. 2024;21(2):198-210.
20. Robbins CA, Swenson LJ, Nealley ML, Kelman BJ, Gots RE. Health effects of mycotoxins in indoor air: a critical review. *Appl Occup Environ Hyg*. 2000;15(10):773-784.
21. Hänninen OO. WHO guidelines for indoor air quality: dampness and mold. In: Johanning E, ed. *Fundamentals of Mold Growth in Indoor Environments and Strategies for Healthy Living*. Wageningen Academic Publishers; 2011:277-302.
22. Fischer FM, Morata TC, do Rosario Latorre M, Krieg EF, Fiorini AC, Colacioppo S, et al. Effects of environmental and organizational factors on the health of shiftworkers of a printing company. *J Occup Environ Med*. 2001;43(10):882-889.
23. Shi B, Su S, Wen C, Wang T, Xu H, et al. The prediction of occupational health risks of benzene in the printing industry through multiple occupational health risk assessment models. *Front Public Health*. 2022;10:1038608.
24. Khan A, Kanwal H, Bibi S, Mushtaq S, Khan A, et al. Volatile organic compounds and neurological disorders: from exposure to preventive interventions. In: Gupta RC, ed. *Environmental Contaminants and Neurological Disorders*. Springer; 2021:201-230.
25. Ayu PS, Tualeka AR, Arini SY, Russeng SS, Rahmawati P, Ahsan A, et al. Relationship between toluene concentration, malondialdehyde level and health complaints in workers of Surabaya printing industry. *Indian J Forensic Med Toxicol*. 2020;14(4).
26. Ningrum DP, Tualeka AR, Jalaludin J, Russeng SS, Rahmawati P, et al. Correlation of toluene safe duration and glutathione concentration, malondialdehyde and neurotoxic symptoms. *Indian J Forensic Med Toxicol*. 2020;14(4):868-931.
27. Hormozi M, Mirzaei R, Nakhaee A, Payandeh A, Izadi S, et al. Quantification of urinary metabolites of toluene and xylene isomers as biological indices of occupational exposure in printing industry workers. *Health Scope*. 2019;8(1):e62465.
28. Dehghan Haghighi J, Hormozi M, Payandeh A. Blood serum levels of selected biomarkers of oxidative stress among printing workers occupationally exposed to low levels of toluene and xylene. *Toxicol Ind Health*. 2022;38(5):299-307.
29. Hu L, Chen M, Zhong Q, Chen H, Cai X, et al. The prediction of occupational health risks of n-hexane in small and micro enterprises within China's printing industry using five occupational health risk assessment models. *Front Public Health*. 2024;12:1399081.
30. Kumar B, Deak C. Occupational and environmental risks of n-hexane in industries: a review on risk and regulatory perspectives. *Chem Eng Trans*. 2025;115:37-42.
31. Vellingiri B, Suriyanarayanan A, Selvaraj P, Abraham KS, Pasha MY, et al. Role of heavy metals induced neurotoxicity. *Chemosphere*. 2022;301:134625.
32. Sripathy L, Hariprasad BN, Vinay G, Vinaykumar C, Venkatesh T. Effect of lead on employees working in flux and printing press. *Rasayan J Chem*. 2014;7:207-213.
33. Moussa A, Brahim D, Mechergui N, Ziedi H, Ayed W, et al. Neuropsychological effects of occupational exposure to organic solvents: a study of 37 cases. *Eur Psychiatry*. 2023;66(S1):S962.



34. Kang SK, Rohlman DS, Lee MY, Lee HS, Chung SY, et al. Neurobehavioral performance in workers exposed to toluene. *Environ Toxicol Pharmacol.* 2005;19(3):645-650.
35. Voliotis A, Karali I, Kouras A, Samara C. Fine and ultrafine particle doses in the respiratory tract from digital printing operations. *Environ Sci Pollut Res Int.* 2017;24:3027-3037.
36. Lyu L, Li Y, Ou X, Guo W, Zhang Y, et al. Health effects of occupational exposure to printer emissions on workers in China: cardiopulmonary function change. *NanoImpact.* 2021;21:100289.
37. Tafese A, Kumie A, Moen BE, Abegaz T, Deressa W, et al. Respiratory symptoms and paper dust exposure among workers in the paper industry in Ethiopia: a comparative cross-sectional study. *Int J Environ Res Public Health.* 2024;21(10):1331.
38. Dao A, Bernstein DI. Occupational exposure and asthma. *Ann Allergy Asthma Immunol.* 2018;120(5):468-475.
39. Tarlo SM. Update on work-exacerbated asthma. *Int J Occup Med Environ Health.* 2015;29(3):369-374.
40. Aarhus L, Skare Ø, Nordby KC, Gulsvik A, Vikjord S, et al. Occupation and 11-year lung function decline in the HUNT Study. *Occup Med (Lond).* 2024;74(9):676-683.
41. Elango N, Kasi V, Vembhu B, Poornima JG. Chronic exposure to emissions from photocopiers in copy shops causes oxidative stress and systematic inflammation among photocopier operators in India. *Environ Health.* 2013;12:78.
42. Nakhaee S, Amirabadizadeh A, Nakhaee S, Zardast M, Schimmel J, et al. Blood lead level risk factors and reference value derivation in a cross-sectional study of potentially lead-exposed workers in Iran. *BMJ Open.* 2019;9(7):e023867.
43. Tefera M, Alemu M, Destaw B, Wubet W, Abebe Y, et al. Occupational exposure assessment of heavy metals in human scalp hair among tannery workers in Bahir Dar, Ethiopia: indication of pollution. *J Hazard Mater Adv.* 2024;16:100505.
44. Pawestri IN, Sulistyarningsih E. Neurobehavioral performance of Indonesian farmers and its association with pesticide exposure: a cross-sectional study. *Clin Epidemiol Glob Health.* 2021;11:100754.
45. Saha A, Tripathi SR. A study on neurobehavioral performance of workers occupationally exposed to solvent in synthetic resin manufacturing. *Toxicol Int.* 2014;21(3):264-269.
46. Graham BL, Steenbruggen I, Miller MR, Barjaktarevic IZ, Cooper BG, et al. Standardization of spirometry 2019 update. *Am J Respir Crit Care Med.* 2019;200(8):e70-e88.
47. Attarchi M, Majlesi B, Ildari S, Eslami-Kenarsari H. Quality of spirometry tests in the field of occupational health. *BMC Res Notes.* 2024;17(1):1-5.
48. Carlsson L, Holm M, Edlund M, Ekström M, Torén K, et al. Ever smoking is not associated with performed spirometry while occupational exposure and respiratory symptoms are. *Int J Chron Obstruct Pulmon Dis.* 2023;18:341-348.
49. Lyon BK, Popov G. Risk treatment strategies: Harmonizing the hierarchy of controls and inherently safer design concepts. *Prof Saf.* 2019;64(5):34-43.
50. Radermacher K. Environmental and safety issues of polymers and polymeric material in the printing industry. In: Kipphan H, ed. *Printing on Polymers: Fundamentals and Applications.* Springer; 2016:397-415.
51. Mahaki M, Mattsson M, Salmanzadeh M, Hayati A. Experimental and numerical simulations of human movement effect on the capture efficiency of a local exhaust ventilation system. *J Build Eng.* 2022;52:104444.
52. Badoozadeh ES, Arefi MF, Babaei-Pouya AM. Job safety risk assessment in the printing industry using job safety analysis method and offering control recommendations. *Pak J Med Health Sci.* 2021;14(4):1785-1789.
53. Ibrahim AA, El Magrabi NM, Abd El-aty NS. Effect of educational program on knowledge and practices regarding occupational safety measures among photocopy and printing workers at Assiut University. *Assiut Sci Nurs J.* 2023;11(39):47-57.
54. Ozobu CO, Adikwu FE, Odujobi O, Onyekwe FO, Nwulu EO. A conceptual model for reducing occupational exposure risks in high-risk manufacturing and petrochemical industries through industrial hygiene practices. *Int J Soc Sci Except Res.* 2022;1(1):26-37.
55. Takala J. Burden of injury due to occupational exposures. In: Korb G, ed. *Handbook of Disability, Work and* Cuest.fisioter.2024.53(3):7721-7735



Health. Springer; 2019:1-22.

56. Tziaferi SG, Rachiotis G, Hadjichristodoulou C. Neurotoxicity in occupational exposure to organic solvents: an overview of current evidence. *Arch Hell Med*. 2011;28(6):798-806.
57. Tualeka AR, Jalaludin J, Adriyani R, Russeng SS, Rahmawati P. Relationship between toluene concentration and RQ toluene with neurotoxic symptoms among exposed workers. *J Posit Sch Psychol*. 2022;6(9):2409-2418.
58. Davidson CJ, Svenson DW, Hannigan JH, Perrine SA, Bowen SE. A novel preclinical model of environment-like combined benzene, toluene, ethylbenzene, and xylenes (BTEX) exposure: behavioral and neurochemical findings. *Neurotoxicol Teratol*. 2022;91:107076.
59. Dou J, Zhou L, Zhao Y, Jin W, Shen H, Zhang F. Effects of long-term high-level lead exposure on the immune function of workers. *Arch Environ Occup Health*. 2022;77(4):301-308.
60. Kim DY, Kim HS, Lim DS, Kim KY. Benzene exposure assessment of printing workers treating petroleum-based cleaner in South Korea. *Ind Health*. 2023;61(4):283-290.
61. Thetkathuek A, Polyong CP, Jaidee W. Benzene health risk assessment for neurological disorders of gas station employees in Rayong Province, Thailand. *Rocz Panstw Zakl Hig*. 2023;74(2):231-241.
62. Parinduri AI, Ashar T, Nurmaini I, Siregar AF, Manalu SM. Measurement of benzene levels in decrease hemoglobin levels among printing industry workers. *J Occup Health*. 2020;62(5):234-240.
63. Prayogi AR, Tualeka AR, Rahmawati P, Russeng SS, Susilowati IH. The determination of safe concentration of non-carcinogenic toluene in Surabaya printing workers. *Indones J Occup Saf Health*. 2020;9(3):360-368.
64. Nurmaini S. Chemical pressures: assessing toluene exposure and central nervous disorders risk in printing workers. *Int J Med Sci Clin Res*. 2023;3(12):1-6.
65. Fei L, Lu K, Wang B, Xu F, Ca N, et al. Occupational health risk assessment of n-hexane based on four risk assessment models. *J Environ Occup Med*. 2024;41(6):655-660.
66. Ilychova SA, Zaridze DG. Cancer mortality among female and male workers occupationally exposed to inorganic lead in the printing industry. *Occup Environ Med*. 2012;69(2):87-92.
67. Kumari S, Jain MK, Elumalai SP. Assessment of pollution and health risks of heavy metals in particulate matter and road dust along the road network of Dhanbad, India. *J Health Pollut*. 2021;11(29):210305.
68. Nayak L, Mohanty S, Nayak SK, Ramadoss A. A review on inkjet printing of nanoparticle inks for flexible electronics. *J Mater Chem C*. 2019;7(29):8771-8795.
69. Chan FL, House R, Kudla I, Lipszyc JC, Rajaram N, Tarlo SM. Health survey of employees regularly using 3D printers. *Occup Med (Lond)*. 2018;68(3):211-214.
70. Haruna U, Mohammed MA, Ajibade YA. Evaluating the impacts of printing operations on indoor air quality in a printing press. *Facilities*. 2024;42(13-14):989-1014.
71. Paste V, Tiwari RR, Kamath R. Evaluation of respiratory health of polyester dyeing and printing workers. *Indian J Physiol Pharmacol*. 2023;67(4):277-282.
72. Graham BL, Steenbruggen I, Miller MR, Barjaktarevic IZ, Cooper BG, Hall GL, et al. Standardization of spirometry 2019 update. An official American Thoracic Society and European Respiratory Society technical statement. *Am J Respir Crit Care Med*. 2019;200(8):e70-e88.
73. Attarchi M, Majlesi B, Ildari S, Eslami-Kenarsari H. Quality of spirometry tests in the field of occupational health. *BMC Res Notes*. 2024;17(1):1-6.
74. Carlsson L, Holm M, Edlund M, Ekström M, Torén K, et al. Ever smoking is not associated with performed spirometry while occupational exposure and respiratory symptoms are. *Int J Chron Obstruct Pulmon Dis*. 2023;18:341-348.
75. Lyon BK, Popov G. Risk treatment strategies: harmonizing the hierarchy of controls and inherently safer design concepts. *Prof Saf*. 2019;64(5):34-43.
76. Radermacher K. Environmental and safety issues of polymers and polymeric material in the printing industry. In: Kipphan H, ed. *Printing on Polymers: Fundamentals and Applications*. Berlin: Springer; 2016:397-415.
77. Mahaki M, Mattsson M, Salmanzadeh M, Hayati A. Experimental and numerical simulations of human



- movement effect on the capture efficiency of a local exhaust ventilation system. *J Build Eng.* 2022;52:104444.
78. Badoozadeh ES, Arefi MF, Babaei-Pouya AM. Job safety risk assessment in the printing industry using job safety analysis method and offering control recommendations. *Pak J Med Health Sci.* 2021;14(4):1785-1789.
79. Ibrahim AA, El Magrabi NM, Abd El-aty NS. Effect of educational program on knowledge and practices regarding occupational safety measures among photocopy and printing workers at Assiut University. *Assiut Sci Nurs J.* 2023;11(39):47-57.
80. Takala J. Burden of injury due to occupational exposures. In: Korb G, editor. *Handbook of Disability, Work and Health.* Cham: Springer; 2019:1-22.
81. American Conference of Governmental Industrial Hygienists. *TLVs and BEIs: Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices.* Cincinnati, OH: ACGIH; 2019.