Paper 14 Proceedings of 8th International Engineering Symposium at Bánki [PDF] (ISBN: 978-615-5460-95-1), 2016

Occupational Exposure to Hazardous Substances in Printing Industry

M. Prica[1], V. Kecić[1], S. Adamović[1], J. Radonić[2] and M. Turk Sekulić[2]

[1]University of Novi Sad, Faculty of Technical Sciences, Department for Graphic Engineering and Design, Trg Dositeja Obradovića 6, 21000 Novi Sad, Serbia
[2]University of Novi Sad, Faculty of Technical Sciences, Department for Environmental Engineering and Occupational Safety and Health, Trg Dositeja Obradovića 6, 21000 Novi Sad, Serbia

Abstract. The rapid development of modern society involves the use of various technologies, new materials and other products, whose practical use often overshadows the quality and production method. In that way, the individual, as well as a society, become witnesses of the presence of a growing number of potential hazardous substances and compounds that threaten human health and the environment, regardless their toxicity, carcinogenic properties or complex methods, as well as the long time required for degradation to less harmful products. Printing industry within its production process uses a wide range of different materials and substances in the form of paints, varnishes, surfactants and solvents, depending both on the selected technology and final product. If this substances are not handled properly, they can become very dangerous contaminants for living and work environment, which primarily reach to the air of the work environment or into surface and ground water through industrial effluents. A growing concern is about the concentration levels of potentially harmful pollutants that can be emitted during the various printing process into the ambient air of work environment. Basic sources of emission in an interior spaces within offset printing are cleaning agents, inks, alcohol and other solutions for the dampening of printing plates, plastics, paint and other construction materials. In that case a volatile organic compounds, such as benzene, toluene, ethylbenzene, m, p-xylene, o-xylene isopropyl and formaldehyde are major air pollutants and exert serious adverse effects on human health. On the other hand, digital printing (precisely photocopying), although the most effective, also achieves its role in indoor pollution due to emissions of various gases during the printing. Pollutants like ozone, volatile organic compounds, nitrogen dioxide, carbon dioxide, carbon monoxide, ammonia, non methane hydrocarbons, perchloroethylene, sulfur dioxide, toner and paper particles, nanoparticles and ultralow-frequency electromagnetic fields are easily transmitted into the photocopying surroundings and worsen the atmosphere of the industrial environment. In addition, environmental conditions such as poor ventilation, high temperature and humidity can contribute to the retention of emitted hazardous gases. Based on the mentioned above, management of hazardous substances within printing industry must be a priority and in that way the entire quality of work environment will be improved.

Keywords: indoor pollution; work environment; hazardous substances; volatile organic compounds; printing industry, occupational exposure

1 Introduction

A significant growth in scientific and technological development has led to an increased level of basic natural resource pollution. The importance of environmental protection and its improvement is a key issue that modern society needs to deal with. A large contribution presents the raise of environmental awareness, creating a solid foundation for a new generation, with the aim of becoming environmentally responsible and healthy people. Alongside these, a systematic study and monitoring of pollution and environmental protection must be a priority. Within this it is necessary to define the legal regulations and inspections, modeling and forecasting the state of the environment and developing appropriate plans for improvement, with emphasis on the identification and quantification of pollutants in various environmental media [1].
Nowadays, work environment pollution present a growing problem affecting all aspects of life. Since the 1960s, modern society has experienced dramatic work environment degradation, including air and water pollution, as a by-product of rapid economic development and industrialization [2]. The presence of polluting materials and noises within a workplace where people perform their jobs and are exposed to various hazardous substances dangerous to human health, is defined as a work environment pollution. The exposure to hazardous materials can occur in several ways: including the air breathing, direct contact with toxic and/or corrosive materials or accidental ingestion of toxic chemicals or polluted water/liquids. Described work environment may negatively affect worker's health, especially if exposure continues over longer periods of time, even at low concentration levels. A significant point of view in the system of work environmental monitoring is taken by control of atmospheric air, where industrial enterprises are traditionally seen as the most polluted indoor air environments. It is established that the presence of hazardous substances either as gases (fumes) or particulate matter dispersed in the air contribute the most to the work environment pollution. Other type of human exposure to hazardous substances may occur involving skin contact, ingestion, and/or ijection. Due to emission of a huge number of contaminating substances, air media of an workplace is the most vulnerable component of indoor environment [3].

2 Printing industry as a polluter

The entire printing process, which includes input material in terms of raw material, energy, and water consumption, as well as the production of semi-finished products, contributes to the creation of wastes. Each printing technique present a diffuse and permanent environmental polluter with certain characteristics of waste flows.

Classification of pollutants generated in the printing industry is carried out trough solid (damaged plates, developed film and paper waste, empty containers and canisters), liquid (waste paint, cleaning solvents, film developing chemicals, acids, alkalis, and metals such as silver, iron, copper, and chromium) and gaseous wastes (volatile organic compounds (VOCs) emitted mainly by using the cleaning agents, inks, alcohol and other solutions for the dampening of printing plates, nitrogen dioxide, ammonia, carbon monoxide, carbon dioxide, non-methane hydrocarbons, etc.) [4]. The composition of wastes from each printing type varies, but source reduction will benefit printers by reducing raw material needs and disposal costs, and by lowering the long term liabilities associated with waste disposal [5].

2.1 VOCs emission

Since the industrial revolution, many activities have emitted anthropogenic pollutants, including toxic gases and volatile organic compounds. Printing industry, within various printing techniques (pad, offset and screen printing), is abundant with a specific source and processes that commonly emit high levels of VOCs, such as carbonyls, alcohols, alkanes, alkenes, esters, aromatics, ethers, and amides. Although necessary and required as components of inks, cleaners, solvents, emulsions, thinners, retardants and de-emulsifiers, the increased emissions of VOCs and their resulting impact on the air quality are now considered as a major environmental concern [6].

Studies have shown that concentrations of VOCs are much higher indoors than outdoors (up to 10 times higher) and it is estimated that up to 300 different VOCs may be detected in the air of printing work environment. Considerable amounts of vaporized toluene, ethylbenzene, xylenes, alcohols, and other airborne organic compounds are emitted to the indoor printing air. Surely, the type of printing machines, cleaning and drying process, working conditions, substrates and end-use application requirements affect the chemical vapor composition [7].

Volatile organic compounds are characterized by high vapor pressure, great flammability and low water solubility properties. As chemical species with varying chemical reactivity, VOCs are very difficult to control. In the presence of oxygen, OH radicals, and UV radiation, VOCs can easily participate in the series photochemical reactions formatting smog as a final product. In the presence of nitrogen oxides (NOx), secondary contaminants, such as ozone, aldehydes, nitrates, can also be easily generated [8 - 12].

Studies have confirmed the potential hazardous effects and adverse effects of VOCs on human health, even at low (sub-ppb) concentrations. The well-known example is

benzene, which belongs to the group of carcinogenic compounds with a high potential to damage humans, both specifically (e.g., the liver, kidneys, spleen, and stomach) and systematically (e.g., the nervous, circulatory, reproductive, immune, cardiovascular, and respiratory systems). Sick building syndrome and building related illness are both directly related to VOCs emission and affect a large working population. Many VOCs, such as xylenes, ketones, alcohols and aliphatic compounds, if present in higher concentrations in indoor environments, are considered to be toxins, carcinogens, or mutagens or to be responsible for allergic symptoms, such as asthma or eczema [13]. This fact precisely present the main reason for establishing guidelines to limit the exposure of humans to VOCs in indoor and workplace air by a number of major environmental safety agencies, such as Occupational Safety and Health Administration (OSHA), National Institute of Occupational Safety and Health (NIOSH) and Environmental Protection Agency (EPA) [14 - 16]. Although the implementation of volatile organic compounds has been utilized in global industries and continues to be used, effective methods to monitor VOCs have been in demand for atmospheric environmental measurement and control, as well as human well-being. Besides that, a great achievement will be reached with the introduction of adequate eco-friendly replacements for certain toxic substances. In that way, the physical and chemical characteristics of the materials will have a positive impact on the efficiency of technological processes, as well as on the quality of life and the work environment [11].

2.2 Digital printing pollution

Due to the improved living standard and digitalization of printing process, electronic equipment such as laser printers, photocopier and fax machines are more common in an office environment. From the standpoint of environmental protection and given the fact that digital printing process uses water-based inks which contains up to 80% of water, environmental pollution is minimal comparing to other printing process. On the other side, digital printing process (specifically photocopying process) can be an emitter of various primary and secondary pollutants. Nitrogen dioxide, carbon dioxide, carbon monoxide and sulfur dioxide can be emitted directly from the stack or process equipment and they are categorized as primary pollutants. On the other hand, gaseous and vapor phase compounds formed during the reactions between primary pollutants in the atmosphere, or between a primary pollutant and naturally occurring compounds in the atmosphere are called secondary pollutants, and they include ozone and photochemical oxidants generated during the sunlight initiated reactions of nitrogen oxides, volatile organic compounds, and carbon monoxide, as well as free radicals and ions (O^-, O_2^-, O_3^-, N_2^-, N^-, H^-, OH^-, etc.) [17 - 19].

Many studies have investigated the health effects of photocopier toner dust and concluded that various diseases like sick building syndrome and sarcoidosis-like pulmonary diseases are associated with human exposure to photocopier toner dust, particulate matter, toner and paper particles, nanoparticles and ultralow-frequency electromagnetic fields. Also, materials such as plastics, paint and other construction materials are sources of emissions in an interior space. An important role of work environment air pollution is attached to inadequate working conditions, such as insufficient ventilation with a high temperature, relative humidity and light intensity [20].
As copying is becoming an independent service, the number of copy centers is increasing and significant air pollution can be expected in the coming years. In that way, people spending most of the time in indoor environment, can be exposed to the influence of various hazardous substances.

2.3 Wastewater

A great amount of wastewater can easily be generated during the printing process, due to the usage of chemicals that are either toxic or difficult to decompose: ink residues (containing zinc, chromium, barium, lead, manganese, benzene, dibutyl/ethyl acetates); waste fountain and cleaning solutions (spent organic solvents, including trichloroethane, methylene chloride, carbon tetrachloride, acetone, methanol); and other solvents and container residues (toluene, xylene, glycol ethers, methyl ethyl ketone, and ethanol). The greatest attention in printing industry deserves a purification and regeneration of wastewater [21].
Heavy metals, such as zinc and copper, are the most common pollutants that can act toxic, hazardous and fatal for human health. The growing trend of these metal concentration levels achieved negative consequences for all parts of the environment and the living world.
Considering the fact that harmful influences of such pollutants on human health through acute and chronic exposure is undeniable, it is necessary to take technical and organizational measures in terms of more efficient elimination. Therefore, great attention is directed towards the removal of pollutants from wastewater directly prior to their disposal or discharge in the effluent [22 - 24].

3 Conclusions

Given that most people spend about 90% of their time indoors, it can easily be concluded that air quality of work environment has become an important issue in

modern times. Depending on the nature of the business, a various kind of pollutants can be find in work environment. It has been established that work places that deal with dangerous toxins (manufacturers, chemical plants, hospitals, auto repair places etc.) pose significant health threats and are closely monitored by government agencies. Office environments, however, also pose air pollution problems that have been mostly underestimated and less effectively dealt with, probably because of the subtlety of the pollutants involved.

One of the biggest polluters is surely printing industry. During the various basic operations, such as printing plates production, image processing and final graphic processing, a different kind of waste can be generated: photographic films, waste photochemical baths, water for rinsing and coatings, developers and waste printing plates. In that way, work printing environment is certainly impaired in terms of health of individual worker. In order to reduce generated waste, companies have to take better care of waste management. This requires a change in attitudes and practices of companies with a focus on preventing and reducing waste rather than on the treatment and elimination of the same. Also, many regulations in work environment, starting with safety procedures and preventive regulations, must be followed. Pollution prevention at workplace involves wearing protective equipment if contact with hazardous materials may not be avoided otherwise, good air ventilation indoors and deployment of safety procedures. Besides that, production of adequate eco-friendly replacements for certain toxic substances must be a priority. In that way, the profitability and efficiency of technological processes, as well as the quality of life and the work environment will be improved.

References

[1] Čvoro, D.: *Monitoring and selfmonitoring in Serbia*, Republic of Serbia, Ministry of Agriculture and Environmental Protection, Environmental Protection Agency, 2012

[2] Knezović, Z., Trgo, M., Sutlović, D.: Monitoring mercury environment pollution through bioaccumulation in meconium, *Process Saf. Environ*., 101, 2-8, 2016

[3] Bespalov, V.I., Gurova, O.S., Samarskaya, N.S.: Main Principles of the Atmospheric Air Ecological Monitoring Organization for Urban Environment Mobile Pollution Sources, *Procedia Engineering*, 150, 2019 – 2024, 2016

[4] Andrade, L.C., Míguez, C.G., Gomez, M.C.T., Bugallo, P.M.B.: Management strategy for hazardous waste from atomised SME: application to the printing industry, *J. Clean Prod*., 35, 214-229, 2012

[5] Environmental Action for printing industry, Department of Environment and Conservation NSW 2006 Available at: http://www.epa.nsw.gov.au/resources/clm/2006357PrintIndustry.pdf Assessed 16.10.2016.

[6] Caselli, M., Gennaro, G., Saracino, M., Tutino, M.: Indoor contaminants from newspapers: VOCs emissions in newspaper stands, *Environ. Res.*, 109, 149–157, 2009

[7] Xu, J., Szyszkowicz, M., Jovic, B., Cakmak, S., Austin, C., Zhu, J.: Estimation of indoor and outdoor ratios of selected volatile organic compounds in Canada, *Atmos. Environ*., 141, 523–531, 2016

[8] Su, Y., Chen, S., Tong, Y., Fan, C., Chen, W., Wang, J., Chang, J.: Assessment of regional influence from a petrochemical complex by modeling and fingerprint analysis of volatile organic compounds (VOCs), *Atmos. Environ*., 141, 394–407, 2016

[9] Gil, R., Ruiz, B., Lozano, M., Martín, M., Fuente, E.: VOCs removal by adsorption onto activated carbons from biocollagenic wastes of vegetable tanning, *Chem. Eng. J.*, 245, 80-88, 2014

[10] Guo, H., Lee, S., Chan, L., Li, W.: Risk assessment of exposure to volatile organic compounds in different indoor environments, *Environ. Res*., 94, 57–66, 2004

[11] Ji, C., D'Souz, J., Batterman, S. Distributions of personal VOC exposures: A population-based analysis, *Environmental International*, 34, 922-931, 2008

[12] Wenjing. W., Bin, Zh., Shuxiao, W., Jiming, H.: Ozone and secondary organic aerosol formation potential from anthropogenic volatile organic compounds emissions in China, *J. Environ. Sci*., 2016, In Press

[13] Al-Khulaifi, N., Al-Mudhaf, H., Alenezi, R., Abu-Shady, R., Selim, M.: Seasonal and Temporal Variations in Volatile Organic Compounds in Indoor and Outdoor Air in Al-Jahra City, Kuwait, *J. Environ. Protect*., 5, 310-326, 2014

[14] US Environmental Protection Agency (US-EPA) (1999) Compendium Method TO-15: Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using Specially Prepared Canisters with Subsequent Analysis by Gas Chromatography. In: Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, 2nd Edition, Washington DC.

[15] Occupational Safety and Health Administration (OSHA), 2014, Available at: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992, Accessed 11.10.2016.

[16] National Institute for Occupational Safety and Health (NIOSH), 1996, Availabe at: http://www.cdc.gov/niosh/idlh/intridl4.html, Accessed 11.10.2016.

[17] Elango, N., Kasi, V., Vembhu, B., Govindasamy Poornima, J.: Chronic exposure to emissions from photocopiers in copy shops causes oxidative stress and systematic inflammation among photocopier operators in India, *Environ. Health*., 12, 78, 2013

[18] Lee, C., Dai, Y., Chien, C., Hsu, D.: Characteristics and health impacts of volatile organic compounds in photocopy centers, *Environ. Res*., 100, 139-149, 2005

[19] Singh, B., Kumar, A., Singh, D., Punia, M., Kumar, K., Kumar, V.: An assessment of ozone levels, UV radiation and their occupational health hazard estimation during photocopying operation, *J. Hazar. Mater*., 275, 55–62, 2014

[20] He, C., Morawska, L., Taplin, L.: Particle Emission Characteristics of Office Printers, *Environ. Sci. Technol*., 41(17), 6039-6045, 2007

[21] International Finance Corporation (IFC) (2007) Environmental, Health, and Safety Guidelines for Printing. pp. 1-18, http://www.ifc.org/wps/wcm/connect/Topics_Ext_Content/IFC_External_Corporate_Site/IFC+Sustainability/Sustainability+Framework/Environmental,+Health,+and+Safety+Guidelines/. Accessed 10.10.2016.

[22] Hegazi, H.: Removal of heavy metals from wastewater using agricultural and industrial wastes as adsorbents, *HBRC Journal*, 9, 276–282, 2013

[23] Prica, M., Adamović, S., Dalamcija, B., Rajić, Lj., Tričković, J., Rapajić, S., Bečelić-Tomin, M.: The Electrocoagulation/Flotation Study: The Removal of Heavy Metals from waste fountain solution, *Process Safety and Environmental Protection*, 94, 262-273, 2015

[24] Adamović, S., Prica, M., Dalmacija, B., Rapajić, S., Novaković, D., Pavlović, Ž., Maletić, S.: Feasibility of electrocoagulation/flotation treatment of waste offset printing developer based on the response surface area, *Arabian Journal of Chemistry*, 9, 152-162, 2016