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OCCUPATIONAL RISK ASSESSMENT TO EXPOSURE OF RESPIRABLE CRYSTALLINE SiO_2 AT CEMENT MANUFACTURING

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ABSTRACT

According to the European Agency for Safety and Health at Work (EU - OSHA) and the Roadmap on Carcinogens about 120,000 work - related cancer cases occur each year as a result exposure to carcinogens at the workplace in the EU, leading to approximately 80,000 fatalities annually. Occupational risk assessment is used as a criterion for occupational safety.

At the cement manufacturing sector, it was revealed that the main hazard is exposure to carcinogen substances such as respirable crystalline SiO_2. In the present work, two methods were used for risk assessment in a cement production enterprise: the classical Fine - Kinney method and Flexible risk assessment method developed by Reinhold and Tint. The results of the joint application of these two methods show the advantages and disadvantages of each of them and point to the need to combine more than one method to effectively cover aspects of risk assessment.

It was made the evaluation of applied existing control measures, as well as new measures for better protection have been proposed.

Keywords: occupational risk assessment, workplace, carcinogen, respirable crystalline silica dust.

INTRODUCTION

By ensuring safe and healthy working conditions reduces the risk of occupational diseases and accidents. Occupational risk assessment is one of the key criteria used to ensure occupational safety. During the preparation of the risk assessment at the workplace various stages are applied, the most important of which are: identification of the work positions/places exposed to the hazards, measurement of the specific agent of the work environment, determination of the risk elements and risk calculation [1, 2]. One of the most recent changes made in Ordinance No 10 on the protection of workers from risks related to exposure to carcinogens and mutagens at work [3]. It is reported that, about 120,000 work -related cancer cases occur each year as a result of exposure to carcinogens at work in the EU, leading to approximately 80,000 fatalities annually [4]. Improving the prevention of work - related cancer is one of the priorities of the EU Strategic Framework for Health and Safety at Work 2021 - 2027 [5].

According to Ordinance (EC) No 1272/2008 there are two categories of carcinogenic hazard, category 1 (1A and 1B) and cat. 2 [6]. The International Agency for Research on Cancer (IARC) uses another classification, taking into account the evidence on their danger to humans, with carcinogens classified into 4 groups [7, 8].

An example of production with the generation of carcinogens at work is the production of cement. The main sources of carcinogens (respirable crystalline SiO_2 dust) in the process of its preparation are the raw materials used to obtain the target product. The manufacturing of Portland cement includes the following stages [9]. The first stage is the quarrying of the raw materials (limestone, clay and sand for lime, silica, alumina, and iron), crushing, pre - homogenization and raw meal grinding. The next step is clinker burning were preheating, pre - calcining, clinker production in the rotary kiln and cooling and storing was included. The final steps include cement preparation were blending, cement grinding, storing in the cement silo are applied, sent for packing in bags or shipped in cement trucks for bulk cement [9]. Contents of Portland cement includes mixtures of calcium oxide – 62 % - 66 %, silica – 19 % - 22 %, aluminum oxide – 4 % - 8%, ferric oxide - 2 % - 5 %, magnesium oxide – 1 % - 2 % and also contains low concentration of hexavalent chromium and other impurities [10].

Dust can be comprised of particles of different materials, which can vary mainly in shape, size, and density. Based on the aerodynamic diameter, they can reach various sections of the respiratory tract and are assigned to the inhalable, thoracic, or respirable dust fraction. The largest particles (an aerodynamic diameter of up to 100 μm) can be inhaled and are deposited in the air passages of the extrathoracic region between the mouth, the nose, and the larynx. Smaller particles are able to reach the gas - exchange region of the lungs and form the respirable dust fraction [11 - 13].

It has been reported that the crystalline silica dust was one of the most serious occupational hazards in the workplace [14]. The most abundant form of silica is α - quartz, and the term quartz is often used in place of the general term crystalline silica together with cristobalite and tridymite [8]. Limit value for occupational exposure for 8 hours working day, according to the Directive 2004/37/EC on the protection of workers from risks related to exposure to carcinogens or mutagens at work and national standards, is 0.1 mg m^{-3} [3, 15]. Due to the proven danger in 2013, the US Occupational Safety and Health Administration (OSHA) lowered the occupational exposure limit for crystalline silica from 0.1 to 0.05 mg m^{-3} [16]. Exposure to this type of dust has been shown to cause silicosis, lung cancer, and other respiratory diseases [8, 14, 16, 17 - 21]. It is assumed that other types of cancer may develop upon exposure to respirable silica [8]. The IARC classifies respirable crystalline silica as a group 1 carcinogen (Carcinogenic to humans) [20]. Risks to human health after exposure to respirable crystalline silica in workplace is associated with the development of silicosis, an irreversible scarring disease of the lung and lung cancer [21]. When crystalline silica is inhaled, the lung tissue reacts by developing fibrotic nodules and scarring around the SiO_2 particles. The mechanism by which silica causes lung cancer is still unclear, but the most likely cause is that its toxicity makes it difficult for the body's natural defense cells to remove it, so the particles stay there, causing persistent inflammation. This chronic inflammation can damage DNA in lung cells and lead to lung cancer. The latency period between exposure and silica - related lung cancer can be up to 10 - 20 years [22]. In a review published in 2018, by Sato et al. it has proposed a mechanism of silica - induced pulmonary toxicity [16].

In the present work, the object of the study is the risk assessment of exposure to respirable crystalline SiO_2 in a cement production plant.

EXPERIMENTAL

The respirable crystalline silica dust fraction has been determined using the gravimetric method in accordance with BDS 2200:1985 and BDS EN 13205 - 2:2014 standards [23, 24]. The measurements were performed by Casella Apex 2 Personal Air Sampling Pump with filters FPP15, IOM Respirable Dust Cyclone heads (and filter cassettes), analytical balance (Scaltec SBC 32), digital barometer (Testo 511), Thermohygrometer (Testo 605 – H1). The parameters are as follows: air flow (ω) - 20 dm^3 min^{-1}; time of measurement (τ) - 50 min; barometric pressure - 709 mm Hg; air temperature (t) - 27°C - 29°C; relative humidity - 40 % - 62 %.

A standard BDS EN IEC 31010:2019 [25] was used in the risk assessment, and the semi - quantitative risk assessment was performed using the classical Fine - Kinney method [26 - 29]. A flexible risk assessment method developed by Reinhold and Tint was applied too [30 - 32].

RESULTS AND DISCUSSION

The present research is a case study, and was done in a cement production factory, located in the North - West region of Bulgaria.

The risk assessment was carried out according to BDS EN IEC 31010:2019 [25]. The present analysis, assessment, and program of actions to prevent or reduce the risk is prepared based on Ordinance No 10 on the protection of workers from risks related to exposure to carcinogens and considers the potential risk effects of exposure to crystalline silica in cement factory depending on the time of exposure and the severity [3].

The analysis and evaluation include all workplaces and processes, as well as the specific additional activities performed. The following sources of information were used during the assessment:

- Employee surveys and consultations;
- Visit on place, getting to know the manufacturing;
- Exposure map;
- Dust measurement;
- Analysis of general morbidity. Follow - up of the respiratory diseases in a target groups.

The monitoring of the manufacturing process at cement production shows that the dust exposure is highest during the quarrying of raw materials, where the main hazard was the generation of a respirable crystalline SiO_2 dust. The results of the measurements and the survey of the workers about the general morbidity and the manifestation of respiratory diseases in the target groups are presented in Table 1. Workers report that they often feel irritation in the throat and nose, cough, or watery eyes. During the year, no single case of bronchial diseases was registered. Allergic skin reactions and respiratory allergies have been registered. No chronic respiratory diseases or development of silicosis or lung cancer were reported. Increased control is exercised for workplaces - driller quarry and vacuum cleaner worker due to increased exposure to respirable crystalline silica dust.

The results of the risk assessment using the Fine - Kinney model are presented in Table 3. This model derives the overall risk score (RS) as an outcome of three risk parameters, namely, probability (P), consequence (C), and exposure (E). Based on the calculated risk score, the degree of risk and its class are determined according to Table 2, [29].

The calculated RS shows that the risk is high (class B) at the stage quarrying of raw materials for driller quarry and front - end loader operator workplaces. As can be seen at this stage of cement manufacturing, the predominant is substantial risk (C) and only for the position of mechanic risk form class D, i.e. possible risk was determined. It has been observed that for the rest of the technological processes, class C risk prevails, but a class D risk has also been identified for several workplaces.

Based on the five - level risk assessment model, developed by Reinhold and Tint, a link between the levels of risk and the health status of the workers was made [30, 31]. According to this method, the risk rating is determined depending on the probability of harm and the severity of the harm, using the national occupational exposure limit (OEL). The impact of the specific hazard on human health is also noted, with the degrees of risk being: Tolerable, Justified, Unjustified, Inadmissible, and Intolerable. A visualization of the five - step model for determining the degree of risk for exposure to respirable crystalline SiO_2 is presented in Fig. 1. Consequences on the health for the cement factory workers is prepared based on the epidemiological study made by Dahmann et al. [33].

In our case, Tolerable risk was determined according to the measured values of respirable crystalline SiO_2 dust (Table 1): at quarrying of raw materials for positions: driver raw materials, mechanic, and waste processing operator. All position at crushing, pre - homogenization and raw meal grinding pre - homogenization and raw meal grinding; at cement grinding, packaging, and expedition, excepting cleaner; at electrical repair and power distribution; at process automation and maintenance planning and at preventive diagnostics.

Risk of the second level, i.e. Justified risk includes the three positions at quarrying of raw materials – front - end loader operator, bulldozer operator, and waste processing operator one position at stage cement grinding, packaging – cleaner. As would be expected with the highest level of risk, Unjustified risk, fall worker with vacuum cleaner and driller quarry from the quarrying of raw materials stage at quarry.

The proposed model can be used as an alternative method to support the preparation of risk assessment for the health and safety of workers and to increase the efficiency of management in enterprises.

The next stage of the analysis is to undertake risk mitigation measures. The "STOP principle" has been applied, where "STOP" stands for the order of priorities [34]. In our case, existing control measures and new measures for better protection are as follows. The Substitution of hazardous materials as a measure is practically impossible. The Technical safety measures that are applied, are two "common" engineering control options available, namely the local Exhaust Ventilation (LEV) and Wet Dust Suppression (WDS) systems. Cleaning of Personal protective equipment (PPE) and

Table 1. Respirable crystalline silica dust measurements, general morbidity and respiratory diseases by target groups.

Location/Who affected	Respirable crystalline silica dust, mg m^{-3}	Registered diseases /complaints/ silicosis danger	Exposition/Process
1. Quarry			
1.1. Driller quarry	0.110	No chronic respiratory diseases were registered or triggering of lung carcinoma or silicosis. The workers report that they often feel irritation in the throat and nose, cough, or watery eyes. Throughout the year, no single case of bronchial diseases was registered. Skin allergic reactions and respiratory allergies have been registered.	During all the time from working hours. Drilling and cargo – unloading activity. Quarrying raw materials.
1.2. Front - end loader operator	0.064		
1.3. Bulldozer operator	0.076		
1.4. Driver raw materials	0.039		
1.5. Mechanic	0.034		
1.6. Worker - vacuum cleaner	0.118		
1.7. Waste processing operator	0.052		
2. Crushing, prehomogenization and raw meal grinding			
2.1. Mechanical support: Schlosser	0.021	No chronic respiratory diseases were registered or triggering of lung or pancreatic carcinoma.	Exposure time up to 2/3 of the working time. Inspection, bypass and servicing of technological processes.
2.2 Mechanical maintenance: Organizer, repair and maintenance	0.011		
2.3. Driver raw materials	0.015		
3. Cement grinding, packaging, and expedition			
3.1. Motorized palletizer	0.021	No chronic respiratory diseases were registered or triggering of lung or pancreatic carcinoma.	Exposure time up to 1/2 of the working time. Inspection, bypass, and servicing of technological processes. Mechanical maintenance.
3.2. Cleaner	0.065		
3.3. Mechanical support: Schlosser	0.034		
3.4. Mechanical maintenance: Organizer, repair and maintenance	0.027		
3.4.Mechanical support: Schlosser on duty	0.025		
4. Electrical repair and power distribution			
4.1. Organizer, repair and maintenance	0.030	No chronic respiratory diseases were registered or triggering of lung or pancreatic carcinoma. The workers report that they often feel irritation in the throat and nose, cough, or watery eyes. During the year, no single case of bronchial diseases or pneumonia was registered.	Exposure time up to 1/2 of the working time. During all the time from working hours–in specific cases. Inspection, bypass, and repair of equipment.
4.2. Electrician	0.027		

Table 1. Respirable crystalline silica dust measurements, general morbidity and respiratory diseases by target groups. - *continued.*

Location/Who affected	Respirable crystalline silica dust, mg m^{-3}	Registered diseases /complaints/ silicosis danger	Exposition/Process
5. Process automation			
5.1. Electrician	0.029	No chronic respiratory diseases were registered or triggering of lung or pancreatic carcinoma. The workers report that they often feel irritation in the throat and nose, cough, or watery eyes. During the year, no single case of bronchial diseases or pneumonia was registered.	Exposure time up to 2/3 of the working time. Inspection, bypass, and repair of equipment.
5.2. Senior electrician	0.015		
5.3. Maintenance planning and preventive diagnostics	0.014		
6. Maintenance planning and preventive diagnostics			
6.1. Schlosser - inspector	0.014	No chronic respiratory diseases were registered or triggering of lung or pancreatic carcinoma. The workers report that they often feel irritation in the throat and nose, cough, or watery eyes. During the year, no single case of bronchial diseases or pneumonia was registered.	Exposure time up to 1/2 of the working time. During all the time from working hours– in specific cases. Inspection, bypass, and repair of equipment.
7. Furnaces, Coal Mill and Ancillary Activities			
7.1. Driver - truck crane	0.015	No chronic respiratory diseases were registered or triggering of lung or pancreatic carcinoma. The workers report that they often feel irritation in the throat and nose, cough, or watery eyes. During the year, no single case of bronchial diseases or pneumonia was registered.	Exposure time up to 1/2 of the working time. During all the time from working hours– in specific cases. Loading and unloading operations.
7.2. Organizer, repair and maintenance	0.016		
7.3. Organizer, repair and maintenance - on duty	0.0156		
7.4. Schlosser on duty	0.014		

Table 2. Risk scores, degrees, and classes [29].

Risk score	Risk class	Risk situation
< 20	E	Risk; perhaps acceptable
20 - 70	D	Possible risk; attention indicated
70 - 200	C	Substantial risk; correction needed
200 - 400	B	High risk; immediate correction required
more than 400	A	Very high risk; consider discontinuing operation

Table 3. Risk assessment for exposure to respirable crystalline SiO_2 in cement production.

Location/ Who Effected	Risk parameters			Risk score	Risk class
	P	E	C		
1. Quarry					
1.1. Driller quarry	6	10	6	397	B
1.2. Front - end loader operator	6	8	7	336	B
1.3. Bulldozer operator	6	8	3	144	C
1.4. Driver row materials	3	8	7	168	C
1.5. Mechanic	3	6	3	54	D
1.6. Worker - vacuum cleaner	6	8	3	144	C
1.7. Waste processing operator	6	8	3	144	C
2. Crushing, prehomogenization, and raw meal grinding					
2.1. Mechanical support: Schlosser	3	6	7	126	C
2.2. Mechanical maintenance: Organizer, repair, and maintenance	3	6	7	126	C
2.3. Driver raw materials	3	8	7	168	C
3. Cement grinding, packaging, and expedition					
3.1. Motorized palletizer	3	6	7	126	C
3.2. Cleaner	3	3	7	126	C
3.3. Mechanical support: Schlosser	1	6	7	42	D
3.4. Mechanical maintenance: Organizer, repair, and maintenance	1	6	7	42	D
3.5. Mechanical support: Schlosser on duty	1	6	7	42	D
4. Electrical repair and power distribution					
4.1. Organizer, repair, and maintenance	3	6	7	126	C
4.2. Electrician	3	6	7	126	C
5. Process automation					
5.1. Electrician	3	8	7	168	C
5.2. Senior Electrician	3	8	7	168	C
6. Maintenance planning and preventive diagnostics					
6.1. Schlosser - inspector	3	8	7	168	C
7. Furnaces, Coal Mill and Ancillary Activities					
7.1. Driver - truck crane	3	6	7	126	C
7.2. Organizer, repair and maintenance	3	6	7	126	C
7.3. Organizer, repair, and maintenance - on duty	1	6	7	42	D
7.4. Schlosser on duty	1	8	7	56	D

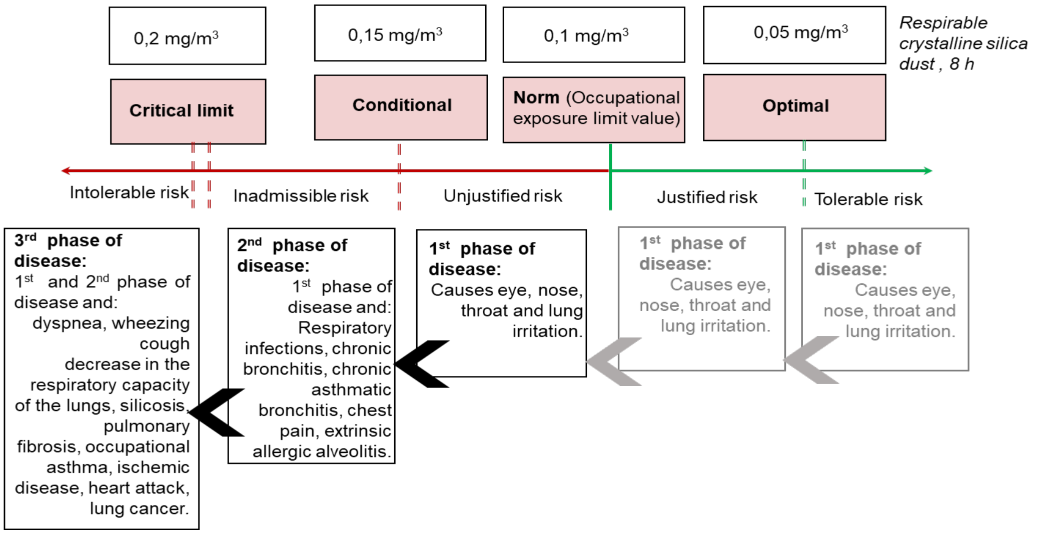

Fig. 1. Five - step flexible risk assessment method.

the removal of floor dust with cleaners are applied. The dusty clothes were not taken at home to wash. It is recommended that industrial vacuum cleaners be replaced with an industrial vacuum HEPA (high - efficiency particulate air) filter. Organizational safety measures include the use of warning signs for silica dust exposition, and staff rotation to limit the exposure time. Silica dust work activities are located outdoors, away from other workers who are not required for that task. Personal protective equipment shall include full body protection. Particular attention should be paid to the protection of the respiratory tract, and it is recommended to replace the used FFP3 disposable masks with ones providing a higher degree of protection, for example, a full - face respirator (cartridge) or a reusable half - face respirator.

CONCLUSIONS

A risk assessment was performed regarding exposure to respirable crystalline SiO_2 in a cement manufacturing plant. Combining several risk assessment methods allows more aspects to be covered in hazard assessment and shows the gaps in applying only one risk assessment method. The comparability of the results of the applied methods guarantees the effectiveness of the recommended safety measures and defines new potential hazards that were not considered when using any of the selected methods. Although no occupational diseases have been recorded, worker - reported throat and nose irritation, coughing, or watery eyes are an indication of the need for stricter control when implementing risk reduction measures and a recommendation to lower the respirable exposure limit value SiO_2.

REFERENCES

1. B. Savova, E. Evgeniev, Occupational risk assessment, ISBN 9789549217926, Publishing house “Shans” Joint - stock company, 2008, Sofia, (in Bulgarian).
2. E. Evgeniev, B. Savova, V. Kutsarova, Occupational risk assessment part 2, ISBN 9789549217964, Publishing house “Shans” Joint - stock company, 2011, Sofia, (in Bulgarian).
3. Ordinance № 10 from 2003 on the protection of workers from the risks related to exposure to carcinogens or mutagens at work (published in state newspaper number 94/2003, amendment state newspaper number 8/2004, amendment and addition newspaper number 5/2020, amendment newspaper number 47/2021).
4. https://osha.europa.eu/bg/themes/work-related-diseases/work-related-cancer
5. The European Commission’s Strategic Framework on Health and Safety at Work 2021 - 2027 available at https://osha.europa.eu/en/safety-and-health-legislation/eu-strategic-framework-health-and-safety-work-2021-2027
6. Ordinance (EC) № 1272/2008 of the European parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, Official Journal of the European Union L 353/1.
7. J.M. Samet, W.A. Chiu, V. Cogliano, J. Jinot, D. Kriebel, R.M. Lunn, F.A. Beland, L. Bero, P. Browne, L. Fritschi, J. Kanno, D.W. Lachenmeier, Q. Lan, G. Lasfargues, F. Le Curieux, S. Peters, P. Shubat, H. Sone, M.C. White, J. Williamson, M. Yakubovskaya, J. Siemiatycki, P.A. White, K.Z. Guytonet et al., The IARC Monographs: Updated Procedures for Modern and Transparent Evidence Synthesis in Cancer Hazard Identification, J. Natl. Cancer. Inst., 112, 1, 2020, 30-37.
8. IARC monographs on the evaluation of carcinogenic risks to humans; volume 100 C A review of human carcinogens, WHO, 2012.
9. The International Energy Agency 2009, ‘Cement Technology Roadmap 2009
10. R. Manjula, R. Praveena, R.R. Clevin, C.H. Ghattargi, A.S. Dorle, D.H. Lalitha. Effects of occupational dust exposure on the health status of portland cement factory workers. Int. J. Med. Public Health, 3, 3, 2013, 192-196.
11. C. Wippich, J. Rissler, D. Koppisch, D. Breuer, Estimating Respirable Dust Exposure from Inhalable Dust Exposure, Ann. Work Expo. Health, 64, 4, 2020, 430–444.
12. World Health Organization. Occupational and Environmental Health Team. Hazard prevention and control in the work environment: airborne dust. World Health Organization, 1999.
13. BDS EN 481:2000 Workplace atmospheres - Size fraction definitions for measurement of airborne particles

14. D. Wang, M. Yang, J. Ma, M. Zhou, B. Wang, T. Shi, W. Chen, Association of silica dust exposure with mortality among never smokers: A 44-year cohort study, Int. J. Hyg. Environ. Health., 236, 2021, 113793.
15. Directive (EU) 2022/431 of the European parliament and of the council of 9 March 2022 amending Directive 2004/37/EC on the protection of workers from the risks related to exposure to carcinogens or mutagens at work Official Journal of the European Union L 88/1.
16. T. Sato, T. Shimosato, D.M. Klinman, Silicosis and lung cancer: current perspectives, Lung Cancer: Targets Ther., 9, 2018, 91–101.
17. F.L. Rice, R. Park, L. Stayner, R. Smith, S. Gilbert, H. Checkoway, Crystalline silica exposure and lung cancer mortality in diatomaceous earth industry workers: a quantitative risk assessment, Occup. Environ. Med., 58, 2001, 38–45.;
18. M. Sogl, D. Taeger, D. Pallapies, T. Brüning, F. Dufey, M. Schnelzer, K. Straif, L. Walsh, M. Kreuzer, Quantitative relationship between silica exposure and lung cancer mortality in German uranium miners, 1946–2003, Br. J. Can., 107, 7, 2012, 1188-1194.
19. T. Brown, Silica exposure, smoking, silicosis and lung cancer-complex interactions, Occup. Med., 59, 2009, 89-95.
20. IARC, Silica, Some Silicates, Coal Dust and Para-aramid Fibrils. Lyon, France: International Agency for Research on Cancer, 1, 1997.
21. J.W. Charrie, M. Gorman Ng., A. Sreal, A. Shafrir, M. van Tongeren, M. Sobey, C. Corden, L Rushton, S. Hutchings. Health socio-economic and environmental aspects of possible, amendments to the EU Directive on the protection of workers from the risks related to exposure to carcinogens and mutagens at work. Respirable crystalline silica. IOM Research Project: P 937/8, 2011, https://ec.europa.eu/social/BlobServlet?docId=10161&langId=en
22. www.roadmaponcarcinogens.eu/silicadust.
23. BDS 2200:1985 Harmful substances in the workplace air. Methods for determining the concentration of dust.
24. BDS EN 13205-2:2014 Workplace exposure - Assessment of sampler performance for measurement of airborne particle concentrations - Part 2: Laboratory performance test based on determination of sampling efficiency.
25. BDS EN IEC 31010:2019 Risk management - Risk assessment techniques, IEC 31010:2019.
26. W.T. Fine, Mathematical evaluations for controlling hazards, J. Saf. Res., 3, 4, 1971, 157–166.
27. G.F. Kinney, A.D. Wiruth, Practical risk analysis for safety management. Naval Weapons Center, 1976, 1–20.
28. M. Gul, S. Mete, F. Serin, E. Celik, Fine–Kinney Occupational Risk Assessment Method and Its Extensions by Fuzzy Sets: A State-of-the-Art Review Chapter 1, 2021, 1-11 in Fine–Kinney-Based Fuzzy Multi-criteria Occupational Risk Assessment, Approaches, Case Studies and Python Applications; Publisher Springer Cham; Springer Nature Switzerland AG 2021, eBook ISBN978-3-030-52148-6.
29. S.H. Gokler, D. Yılmaz, Z.F. Ürük, S. Boran, A new hybrid risk assessment method based on Fine-Kinney and ANFIS methods for evaluation spatial risks in nursing homes, Heliyon, 8, 10, 2022, e11028.
30. K. Reinhold, P. Tint, Chemicals in the air of the work environment and health risks, Med. Health Sci. J., 2, 2010, 1-9.
31. K. Reinhold, Workplace Assessment: Determination of Hazards Profile Using a Flexible Risk Assessment Method, Tallinn University of technology, PhD thesis, 2009.
32. K. Reinhold, P. Tint, Hazard profile in manufacturing: Determination of risk levels towards enhancing the workplace safety, J. Environ. Eng. Landsc. Manag., 17, 2, 2009, 69-80.
33. D. Dahmann, D. Taeger, M. Kappler, S. Büchte, P. Morfeld, T. Brüning, B. Pesch. Assessment of exposure in epidemiological studies: the example of silica dust. J. Expo. Sci. Environ. Epidemiol., 18, 2008, 452–461.
34. R.N. Carey, T.R. Driscoll, S. Peters, D.C. Glass, A. Reid, G. Benke, L. Fritschi, Estimated prevalence of exposure to occupational carcinogens in Australia (2011–2012), Occup. Environ. Med., 71, 2014, 55–62.