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OD POTCENJENOG RIZIKA DO PROFESIONALNOG OBOLJENJA: POVEĆANJE SVESTI ZAPOSLENIH U GRAĐEVINSKOJ INDUSTRIJI O ZDRAVSTVENIM POSLEDICAMA IZLOŽENOSTI RESPIRABILNOJ SILIKATNOJ PRAŠINI

FROM UNDERESTIMATED RISK TO OCCUPATIONAL DISEASE: RAISING EMPLOYEE AWARENESS IN THE CONSTRUCTION SECTOR OF THE HEALTH EFFECTS OF RESPIRABLE CRYSTALLINE SILICA EXPOSURE

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KRATAK SADRŽAJ

Zagađenje vazduha je svakodnevni problem na gradilištima, a najveći problem je prašina, koja se javlja tokom bušenja, kopanja, rušenja, površinske obrade betona, sečenja drveta, testerisanja raznih greda, sečenja pločica i sličnih operacija. Zajedničko za sve pomenute radne operacije je supstanca - silicijum dioksid, koja se nalazi u hemijskom sastavu materijala koji se obrađuje, i to je trenutak kada se formira silikatna prašina. Silikatna prašina je hemijska opasnost koja, kao takva, ima sistemске efekte po zdravlje. Sistemski efekat po zdravlje je efekat po zdravlje koji se javlja na mestu udaljenom od početne tačke kontakta sa telom i takođe utiče na bubrege, jetru ili druge organe. Supstance sa sistemskim efektima često se akumuliraju u ciljnim organima, gde ispoljavaju štetne efekte. Silikoza je bolest pluća uzrokovana udisanjem prašine koja sadrži čestice silicijum dioksida. Čestice silicijuma su definisane kao „respirabilne“ i obično su manje od 5 mm u prečniku. Ovaj oblik silicijuma se naziva „respirabilni kristalni silicijum“ (RCS). Često se zanemaruje na radnom mestu jer je bezbojan, bez mirisa, ne iritira i ne izaziva neposredne efekte po zdravlje. Silikoza je fibrozna bolest pluća koja se razvija kada čestice silicijumske prašine ostanu u plućima, izazivajući ožiljke tkiva. U zavisnosti od koncentracije silicijumske prašine u vazduhu, silikoza može biti hronična (najčešći oblik), akutna ili akumulirana. Velike količine prašine koje se talože u plućima radnika slabe njihov imunitet i time postaju podložniji različitim simptomima (kratkoća daha tokom fizičkog napora, bol u grudima, jak kašalj, umor), ali i bolestima kao što su tuberkuloza, određene kardiovaskularne bolesti, sarkoidoza, plućna tuberkuloza, infekcije pluća, hronična opstruktivna bolest, određene vrste tumora, rak pluća, autoimune bolesti i poremećaji bubrega, koje mogu biti pogoršane HIV-om ili pušenjem. Često, gore pomenuti efekti i bolesti nisu vidljivi dok se ne dostigne kritično opterećenje organizma. Najveći rizik je silikoza, bolest za koju ne postoji lek i za koju je prevencija neophodna. Na osnovu navedenog, napominje se da tokom obuke zaposlenih o bezbednom i zdravom radu u građevinskom sektoru, značajnu pažnju treba posvetiti podizanju svesti radnika o zdravstvenim efektima silikatne prašine. Cilj ovog istraživanja je podizanje svesti zaposlenih u građevinskom sektoru o zdravstvenim efektima izloženosti respirabilnoj silikatnoj prašini i isticanje važnosti edukacije radnika kao ključne preventivne mere.

Povećanjem svesti o zdravstvenim posledicama i pružanjem realnih primera progresije bolesti, menja se mentalni model rizika i percepcija radnika o njihovom ponašanju, čime se smanjuje izloženost. Iz tog razloga je neophodno da, pored obuke zaposlenih, poslodavac obezbedi adekvatnu podršku, neophodnu ličnu zaštitnu opremu i pojačan nadzor. Edukacijom zaposlenih o zdravstvenim efektima silikatne prašine, preventivne mere se transformišu od obaveznih zadataka u svesne lične odluke.

Ključne reči: silikatna prašina, zdravstveni efekti, edukacija radnika

ABSTRACT

Air pollution is a daily problem on construction sites, and the biggest problem is dust, which occurs during drilling operations, digging, demolition, surface treatment of concrete, cutting wood, sawing various beams, cutting tiles, and similar operations. Common to all the mentioned work operations is the substance - silicon dioxide, which is found in the chemical composition of the material being processed, and that is the moment when silicate dust is formed. Silicate dust is a chemical hazard that, as such, has systemic health effects. A systemic health effect is a health effect that occurs at a site distant from the initial point of contact with the body and also affects the kidneys, liver, or other organs. Substances with systemic effects often accumulate in target organs, where they exert adverse effects. Silicosis is a lung disease caused by inhaling dust containing silicon dioxide particles. Silica particles are defined as "respirable" and are typically less than 5 μm in diameter. This form of silicon is called "respirable crystalline silicon" (RCS). It is often overlooked in the workplace because it is colorless, odorless, non-irritating, and does not cause immediate health effects. Silicosis is a fibrotic lung disease that develops when silica dust particles remain in the lungs, inducing tissue scarring. Depending on the concentration of silica in the air, silicosis can be chronic (the most common form), acute, or accumulated. Large amounts of dust that settle in the lungs of workers weaken their immunity and thus become more susceptible to various symptoms (shortness of breath during physical exertion, chest pain, severe cough, fatigue), but also to diseases such as tuberculosis, certain cardiovascular diseases, sarcoidosis, pulmonary tuberculosis, lung infections, chronic obstructive disease, certain types of tumors, lung cancer, autoimmune diseases and kidney disorders, which can be aggravated by HIV or smoking. Often, the aforementioned effects and diseases are not visible until the organism's critical burden is reached. The greatest risk is silicosis, a disease for which there is no cure and for which prevention is essential. Based on the above, it is noted that during employee training on safe and healthy work in the construction sector, considerable attention should be paid to raising workers' awareness of the health effects of silicate dust. The aim of this research is to raise employees' awareness in the construction sector of the health effects of exposure to respirable silicate dust, and to emphasize the importance of worker education as a key preventive measure.

By increasing awareness of health consequences and providing realistic examples of disease progression, the mental model of risk and workers' perceptions of their behavior are altered, thereby reducing exposure. For this reason, it is necessary that, in addition to employee training, the employer provide adequate support, the necessary personal protective equipment, and enhanced supervision. By educating employees about the health effects of silicate dust, preventive measures are transformed from merely obligatory tasks into conscious personal decisions.

Key words: silica dust, health effects, worker education

INTRODUCTION

Human health can be affected by various chemical substances in the air, ranging from mild irritation to serious illness. One of the main characteristics of the working environment on construction sites is polluted air, with dust as the most common pollutant (1). Silica dust (also known as Respirable Crystalline Silica, RCS) is among the most hazardous dusts on construction sites, posing a serious risk of illness, such as silicosis (2,3,4). In 1987, the International Agency for Research on Cancer (IARC) recognised the carcinogenicity of silica dust, and this classification was re-evaluated and confirmed in 1997 and 2012. Meanwhile, in 1995, the World Health Organisation launched a campaign to eliminate silicosis worldwide by 2030. However, the mortality risk associated with silicosis continues to increase worldwide (5), thereby maintaining silicosis as a significant global health problem (6,7). Reviewing global exposure among construction workers to silica dust, it is evident that exposure levels vary widely, ranging from 3.2 million workers in the European Union and 2.3 million in the United States to 11.5 million in India and 23 million in China (8). Since there is no cure for silicosis, prevention should be prioritised as the primary strategy. To achieve a campaign to eliminate silicosis worldwide by 2030, there is a need to develop silica-exposure control that encompasses not only technology and regulation but also education and organisational culture (9). An example of effective prevention practice is evident in the USA, where ongoing HSE training and regular inspections have generally led to high awareness of dust-control methods (10), underscoring the significant impact of HSE training in eliminating silicosis.

Silica dust consists of particles that vary in size, shape and composition, and it is in such a form that has no colour, no smell, no taste (11,12). To assess silica dust contamination in the workplace, specialised tests are conducted (12). According to Occupational Safety and Health Administration OSHA (13), there are four main potential hazards of silica dust: flammability, irritation, toxicity, and carcinogenicity. The amounts of silica dust that can cause damage are not large, and the allowed concentration is usually compared to the British penny (2), because it is smaller than the penny itself. The amount of silica dust to which construction workers are exposed on construction sites largely depends on the type of work, the duration and frequency of tasks, the materials used, the location, and the preventive measures implemented to reduce exposure (14). Sources of silica dust are numerous, as silica is present in many building materials, including concrete, sand, ceramic tiles, and bricks (15). Among all materials, concrete represents the greatest source of dust (16). Activities such as cutting, drilling, shredding, sanding, and grinding materials (eg. sand, concrete, brick, block, stone, mortar, clay, gravel, fluxes, constructive aggregate, abrasives, porcelain) pose a risk of high exposure to silica dust (17,18). The most severe forms of exposure to silica dust generally occur during pneumatic drilling, rock/well drilling, concrete mixing, concrete drilling, brick and concrete block cutting and sawing, tuck pointing, and tunnelling operations (19,20). Other activities, such as sandblasting, demolition of structures, and sweeping of dirty areas, also generate RCS. The exposure of construction workers to silica dust is highest among bricklayers, tilers, carpenters, painters, and road construction and demolition workers (19). Practical examples (4, 21, 22, 23) confirm that the described activities and materials contribute to high levels of silica dust exposure

HEALTH CONSEQUENCES OF EXPOSURE TO RESPIRABLE SILICATE DUST

A healthy immune system is crucial for humans to combat diseases and infections (24). Therefore, because construction workers' immune systems are continually exposed to various air pollutants, they face a higher risk of developing a range of diseases. Since inhaling the RCS represents the main cause for a dozen deaths of construction workers caused by silicosis and other related illnesses (25,26), it is necessary to inform construction workers about the health effects of RCS exposure.

Silicosis represents a fibrotic lung disease caused by inhaling dust particles containing silicon dioxide. Once RCS is inhaled, particles (typically less than 5 μm in diameter) reach the lower respiratory tract and areas of gas exchange where they interact with lung tissue and eventually develop fibrous nodules and scars around the entrapped silica particles. To determine whether a person has silicosis, a medical examination should include not only a review of the complete work history but also a chest X-ray and a lung function test (13). Figure 1 shows three types of silicosis and their main features defined by Keramydas et al. (27), Hoy and Chambers (28) and OSHA (13).

However, it is well known that silicosis isn't the only disease caused by RCS, and that additional illnesses are associated with RCS inhalation. The most common diseases are chronic obstructive pulmonary disease (COPD) and lung cancer. COPD represents a group of lung diseases (e.g., bronchitis) that cause shortness of breath, a prolonged cough, and chronic disability. On the other side, lung cancer occurs due to long exposure to RCS, and the increased risk occurs if the patient is already diagnosed with silicosis (26). Other diseases, such as tuberculosis (29), Sjogren's syndrome (30), scleroderma (31), rheumatoid arthritis, systemic lupus erythematosus, and sarcoidosis (29), represent a risk factor to construction workers' health if RCS is inhaled. If all of these listed diseases are additionally exposed to the dangers posed by tobacco, the risk of mortality will increase (32, 33).

It can be concluded that the health consequences of exposure to silica dust are well documented and well established, as they have been the subject of research in recent years (34). Therefore, since there is no cure for silicosis and other diseases require long-term treatment, the most accessible way to reduce silicosis and its related diseases is through the adequate implementation of preventive measures, with HSE training as a key component.

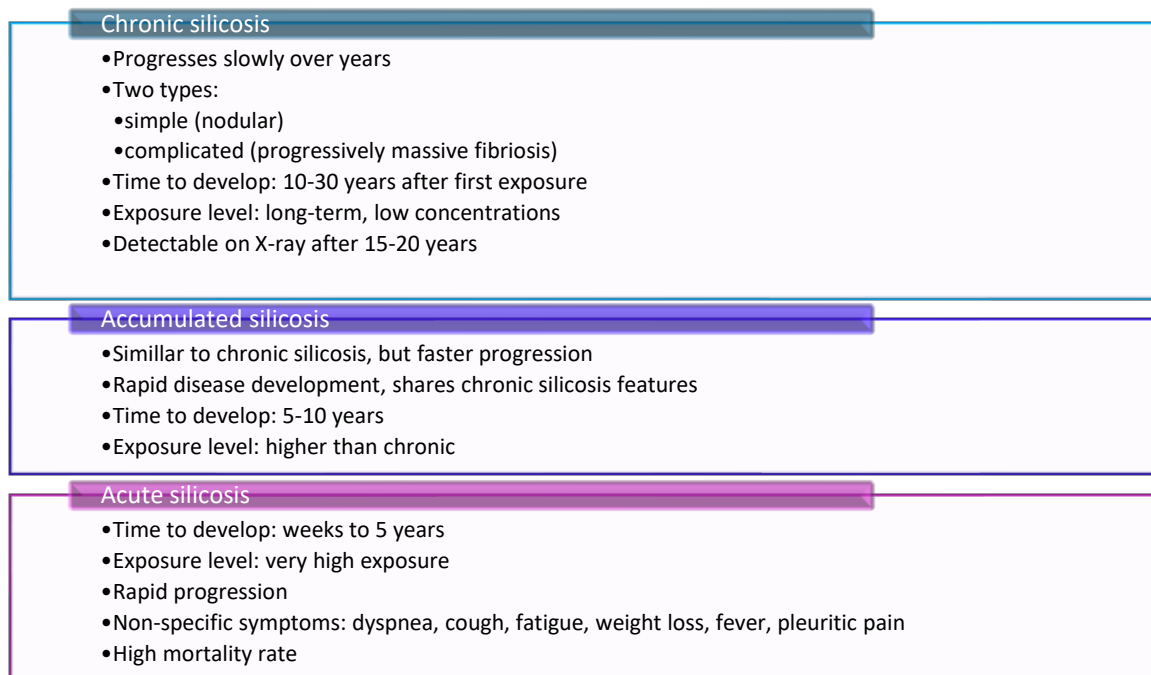


FIGURE 1 - TYPES OF SILICOSIS AND THEIR MAIN FEATURES

WORKER EDUCATION ON SILICA DUST

Importance of Health and Safety (HSE) Training

To help people learn how to do something and what they should/not do, training sessions were conducted. By providing qualified HSE personnel and adequate information during HSE training, it is easier to teach employees to work safely in compliance with all HSE requirements, thereby ensuring a work environment free of work-related injuries and occupational diseases. Compelling HSE training also has ancillary benefits for the business and employer, as it reduces the financial costs associated with accidents and occupational ill health. Competent HSE training is composed of employees' capabilities, training, knowledge, and experience, with increased awareness given to young employees and job changers, as they are most commonly associated with a high risk (35)

The Law on Occupational Safety and Health in the Republic of Serbia (36) prescribes the employer's duty to provide HSE training to ensure health and safe working conditions. HSE training under the aforementioned law requires understanding workplace risks and the corresponding preventive measures. According to the Law, HSE training is conducted both practically and theoretically. The theoretical part consists of a general part and a special part. The general section is designed to introduce employees to their rights, obligations, and responsibilities in the field of HSE and to the employer's general HSE acts. The special part comprises employee familiarization with all potential workplace risks and associated preventive measures. HSE training must align with workplace procedures and be conducted during working hours in a language the employee understands. Periodic HSE training of an employee working in a workplace with increased risk is carried out within one year from the date of the previous training, and in other workplaces within three years from the date of the previous training at the latest.

Since silicate dust represent chemical hazard in the workplace, Rules on preventive measures for safe and healthy work when exposed to chemical substances (37) which among other provisions stipulates that employees should be introduced with the risk of injuries at work or damage to health caused by chemical hazards. This statement confirms that the goal of this work is justified, as educating workers about the health consequences of silica dust increases their awareness of these risks. Ways to educate workers about the health risks posed by silica dust are presented in the following chapter.

Education of construction workers about the health effects of silica dust

The effective management of RCS exposure in construction is, among other factors (e.g., risk perception, regulatory enforcement), also achieved through HSE training (38). Fontaine (39) emphasises that HSE training needs to transform from compliance-focused instruction to competency-based, risk-informed, and systems-integrating learning models. Also, Robson et al. (40) identify common limitations of traditional HSE training, such as passive training, generic content, a focus on compliance rather than prevention, and a lack of feedback. Adequate education of construction workers on RCS must be grounded in adult learning principles (41), human factors science (42), and risk-based training models (43). HSE training based on this approach would enhance hazard recognition, support safe behaviour and strengthen preventive capacity. In everyday life in the digital age, digital learning platforms have increased HSE training availability. Potential benefits of implementing technology in HSE training include consistent E-learning, realistic hazard simulation via virtual reality (VR), just-in-time learning via mobile tools, and targeted training insights. On the other hand, this development has key limitations, including passive engagement, cost, accessibility, distraction, and overreliance. Nevertheless, digital learning platforms, when integrated with coaching, supervision, and adequate organisation, would be effective (39). To appraise how theoretical principles are reflected in practice, selected online RCS courses were critically reviewed from the perspective of how effectively they increase awareness of the health consequences that RCS can cause among construction workers.

The UK branch of the Workplace Health Without Borders – WHWB (44) is a non-profit international organisation that produced a course on respirable crystalline silica, comprising a brief PowerPoint presentation, a summary of the section's key points, and a few self-assessment questions to assess understanding of the material. The course comprises several aims and learning outcomes and, notably, includes a module on the health effects of crystalline silica exposure. After reviewing all parts of the module on the health effects of crystalline silica (RCS) exposure, it is possible to critically evaluate the course management to raise awareness of the health consequences of RCS exposure. The module is effective in raising basic awareness of the seriousness of the risk. For a worker without medical knowledge, it is sufficient to understand that the danger is associated with a long-term, potentially fatal disease and that effects may persist even after exposure has stopped. It is based on a visual support, with a clear cause-and-effect relationship between RCS and death. Additionally, the progressiveness and mortality are emphasised, and the module includes multiple diseases associated with RCS exposure. While there are noted advantages, the module is also subject to critical review. The disadvantages lie in the lack of quantitative context and in test questions at a basic level. The lack of quantitative context means there are no frequency statistics, relative risks, information on the dose-dependent relationship, or information on the time frame of disease development, which affects workers' understanding of the risk. Also, test questions are designed to measure memorisation rather than the depth of understanding. It can be concluded that the module on the health effects of crystalline silica effectively conveys the seriousness of the problem, but does not provide sufficient depth to develop a comprehensive understanding of the clinical picture of RCS exposure. It is helpful to compare this module with more structured, commercially produced e-learning programs to more rigorously evaluate this finding.

For example, the OSHA Educational Center (45) provides a balanced, structured educational model of RCS and its health consequences, relating medical effects to work situations in the construction sector. Also, the course explains disease mechanisms and integrates practical exposure-control measures. An advantage of this course is its use of multimedia elements and a knowledge check, which contribute to more effective content acquisition. On the other hand, OSHA Outreach Courses (46) offer a course on Crystalline Silica Awareness that provides a basic understanding of the health risks associated with RCS. The course identifies the main diseases caused by exposure, using simple language understandable to construction workers without professional knowledge, and includes a final test to confirm understanding of the key information. Therefore, the course is effective in raising basic awareness among construction workers.

While the presented courses are offered in an introductory format, courses such as Human Focus – Silica Dust Awareness Training (47) provide a comprehensive and organised overview of health risks and their management. This course is designed to provide a detailed explanation of the health consequences of exposure to silica dust, integrating health information with the broader context of risk assessment and management. Also, it is educationally informative and systematic, but less visually engaging.

Similar to this structured online course, written guidance materials, such as instructions for safe and healthy work, aim to raise awareness of the health consequences of RCS exposure. A guide for employees on controlling exposure to silica dust, published by HSE UK (26), introduces employees to the harmful effects of inhaling RCS, details the most important lung diseases, and highlights that the health risks are preventable when exposure is adequately controlled. A guide provides concise, accurate, and relevant data on the most common diseases caused by RCS, and is intended for an elementary level of understanding. The advantage is overlooked in the definition of every disease, in highlighting its severity, and in noting that symptoms may be absent in silicosis. On the other side, an explanation of disease progression, consequences for the daily life of workers and a message about the irreversibility of lung damage are missing. It can be concluded that a guide for employees published by HSE UK (26) is informative but insufficiently detailed for an in-depth understanding of the health risks posed by silica.

Based on theoretical foundations and a critical analysis of the presented RCS courses, a conceptual model of HSE training focused on the health effects of exposure to RCS was developed and presented in Figure 2. It is necessary to note that the model also suggests the inclusion of real stories from workers who lost close family members and friends to diseases caused by RCS, as well as video sources and 3D animations of disease progression, to better implement this suggested model.

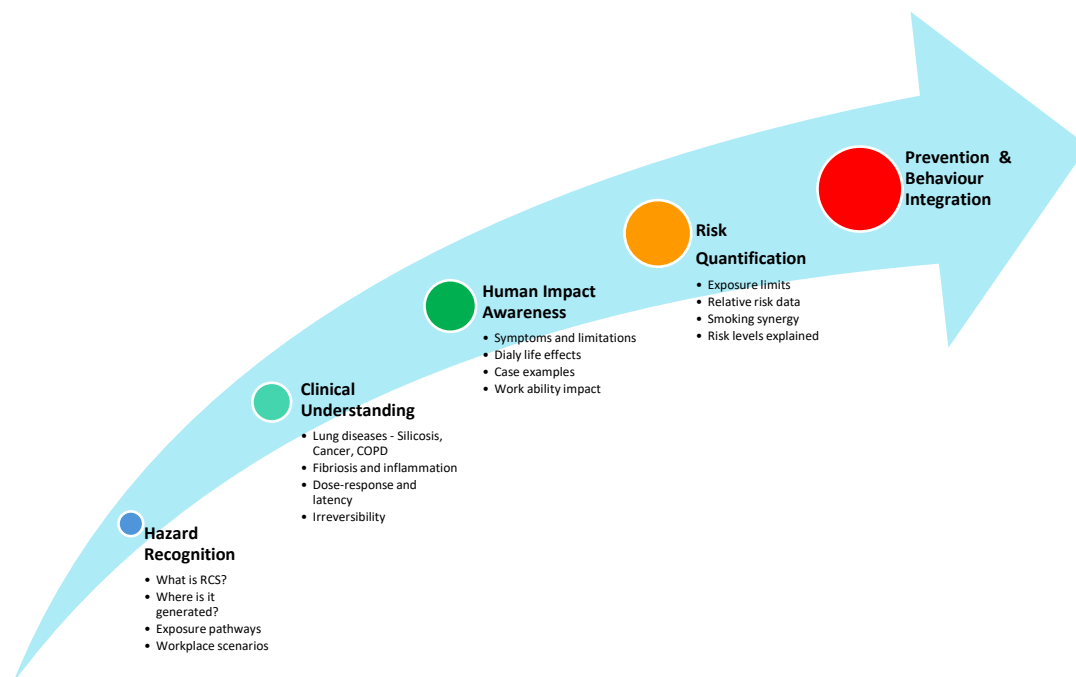


FIGURE 2 - A CONCEPTUAL MODEL OF HSE TRAINING FOCUSED ON THE HEALTH EFFECTS OF EXPOSURE TO RCS

CONCLUSION

Exposure to silicate dust is a serious problem in the construction sector, causing complex, long-term health effects that are often progressive and fatal for construction workers. Although the scientific literature clearly documents the health consequences of RCS exposure, existing educational programs only provide employees with information about the impact of RCS on their health. In most cases, educational programs are designed to raise basic awareness, without providing a deeper understanding of risk quantification, the clinical picture, or the long-term consequences for workers' health and life.

The results of the work show that the effectiveness of HSE training must extend beyond traditional approaches and be grounded in the principles of adult education, risk management, and human factors. By applying the aforementioned principles, a conceptual model was developed that integrates medical understanding, risk quantification, and preventive measures, with the aim of training that goes beyond a formal character and becomes a tool for the development of conscious and responsible employee behaviour. Precisely by applying the proposed conceptual framework, employees' awareness in the construction sector of the health effects of exposure to respirable silicate dust will increase.

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