Original Article

Inhalation Exposure to Dust Pollution in the Workplace

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ABSTRACT

Exposure to dust in the air is one of the most common environmental hazards in workshops that can have devastating effects on health. In this study, workers' exposure to particles in inhaled air by conventional methods as well as GIS has been investigated. The research was performed cross-sectionally-analytically and the sample size was determined through homogeneous exposure groups. Environmental and individual exposure was performed based on standard methods and individual and environmental sampling methods. The obtained data were analyzed using GIS software to determine the distribution maps. In this paper, the mean concentration of exposure to dust for each individual in the matched exposure groups was 8.361 mg/m. The highest level of individual exposure was estimated in the powder operator with a value of 21313 mg/m3 and the lowest in the fine wire emperor with a value of 1.97 mg/m3. The minimum environmental concentration in the cutting hall was 0.305 mg/m and the maximum value was 22 mg/m3 in the powder hall. The results of the evaluation with AIHA criteria in all methods showed that weaving, material, and packaging halls had the highest concentration and cutting halls have the lowest dust concentration. Comparison with the GIS method showed that powdering, materializing, and packing halls had the highest concentration and cutting halls had the lowest dust concentration. Comparison with the GIS method showed that in this method, more people are classified in the risk area.

Introduction

Excessive exposure to dust in the air is one of the most common environmental hazards in workshops that can have devastating effects on workers' health. Excessive exposure to these contaminants can irritate and upset the respiratory system and, in some cases, cause debilitating diseases and malignancies such as lung cancer [1, 2]. Unfortunately, due to the lack of a systematic system of registration and reporting of diseases in most developing countries, an accurate estimate of the burden of occupational lung diseases in the world is not available. Published estimates of occupational disease burden consider occupational respiratory diseases to be among the most common occupational diseases with a share of 1.14% [3].

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Accordingly, timely identification of respiratory exposures in work environments and their proper management can play a very important role in reducing work-related illness and absenteeism, and worker mortality [4]. The use of computer-based systems in the field of assessment and exposure management has been considered in recent years. Mobile-based systems and geographic coordinates are among these systems that have been used to manage and evaluate encounters in articles [5]. So far, several studies have been used inside and outside the articles [6-19]. So far, several studies in the country and abroad have used GIS to manage and evaluate occupational exposures. GIS-based technologies using interpolation technology can play an important role in exposure screening. Mohammadpour *et al.*, aimed at the application of GIS in the study of noise pollution and hearing loss, using the output of GIS maps to analyze noise pollution and provide solutions to reduce noise [20]. Moussavi et al., also studied the role of GIS in occupational health and its application potentials in controlling air pollution and mapping occupational pollution exposure [21]. Major studies conducted in this field have been specifically related to occupational health related to noise pollution and in the environment related to traffic pollutants and urban pollution [22-24]. However, the application of this method and its possible capabilities in the assessment and management of occupational respiratory exposures using GIS has not been done yet.

Accordingly, the purpose of this article is to determine the concentration of particles in the inhaled air of workers and environmental concentration with the aim of mapping air pollution in different parts of one of the electrode industries and also to determine the best place to prioritize corrective actions using GIS. In this study, the potential capabilities and potentials of using GIS compared with conventional methods were investigated.

Survey Method

This cross-sectional article was conducted in four halls of the welding electrode production plant, including the cutting and stretching hall, press hall, packing hall, and powder making hall, which included 95 workers. The main purpose of this article was to evaluate the individual exposure of workers in their settlements and the capabilities of GIS in exposure management. The concentration of air pollutants was measured using a regular network method to prepare an air pollution map. In this method, initially, the workshop was divided into checkered areas with equal dimensions (5 by 5 meters) and the center of each area was a measuring station. A total of 236 stations were identified [25]. For more accuracy and precision in each station, three measurements were carried out and to equalize the concentration of pollutants in the air of the workplace, each measurement was performed with a time interval of 10 seconds. All measurements at this stage were performed using the Casella Microdust PRO 880nm Aerosol Monitoring System Kit made in the United Kingdom, with the ability to measure total suspended particles in the range of zero to 2500 mg/cubic meter.

The average concentration of three samples per station was reported as the concentration of dust pollution in each area. Individual workers' exposure was assessed based on the method of determining matched exposure groups. In fact, if in the same situation and working conditions, the manner and amount of exposure of workers in that situation are the same, they can be placed in the same exposure group and by evaluating the exposure of a worker in that group; the exposure of other people in that group predicted that it would save time and money. The number of sample sizes determined by the method of identical occupational groups in different occupational groups was determined to be 14 [26]. Individual exposure assessment in identical exposure groups was performed by the NIOSH0600 method to measure exposure to inhalable dust [27].

In summary, for a sampling of inhalable dust, SKC sampling pump (Universal model made in England) and cellulose ester filter with pour size of 0.5 microns and diameter 37 mm with cyclone with specified flow rate were used.

After sampling, the sampled dust on the filters was quantified by the gravimetric method. Finally, the values obtained in milligrams per cubic meter were compared with the permissible exposure limits provided by the American Institute of Industrial Health [28]. The data obtained from the measurement of networking were fed into the software Excel 2007. SPSS software version 16 was used for statistical analysis of data and the network layout of production halls was also fed into GIS software version 10. The data inserted in the Excel worksheet also served as a layer with coordinates.

A hypothesis was defined in GIS software and another layer called population, which represents the number of people exposed in each hall. Pollution map, air pollution level lines, and the best areas for air pollution control based on the hypotheses defined for the section Different production halls were drawn using GIS10 software. The classification in the map guide to determine the points in need of control was done based on AIHA classification [29-32].

Outputs from Simulation

According to the evaluation method of matched exposure groups in the production halls of welding electrode factory, a total of 14 occupational groups were identified as follows: 150 traction operator, cutting operator, weaving operator, 460 tray operator, bullet operator 450, sieve operator, silo operator, 450 wire operator, 450 press operator, packaging operator, material operator, material weighing operator, lathe operator and dosing operator. Table 1 shows the results of sampling in the respiratory area of workers in each group of matched exposure. The concentration of respirable dust was higher than the allowable limit in 12 identical exposure groups (85% of stations) and lower than the allowable TLV-TWA in 2 groups (TLV -TWA = 3mg/m3). Among the measured stations, the highest concentration of inhalable dust and the highest level of individual exposure were related to the powder salon station and powdering operator with the amount of 21.13 mg/cubic meter [33].

The lowest value was related to the press hall station and the micro-press wire operator with the amount of 1.97 mg/cubic meter.

Table 1 Results of evaluation of the concentration of inhalable dust in the air of the workers' respiratory area

Assessment	Inhalable dust concentration (mg/m^3)	Individual job
Above limit	3.89	Cut
Above limit	3.9	Dosage maker
Above limit	5.8	Traction 150
Above limit	21.13	Powder making
Above limit	17.29	Weighing materials
Above limit	3.94	Bullet 450
Above limit	3.91	Chinese tray 460
Above limit	9.66	Materials production
Less than allowed	1.97	Wiring 450
Above limit	3.92	Press 420
Above limit	15.45	Silo
Above limit	7.82	Packing
Above limit	19.32	Sieve
Less than allowed	2.52	Turning
Standard deviation = 75.6	Total average = 61.8	Number = 14

Distribution of Environmental Concentration of Particulate Pollutants

236 environmental samples were taken by direct reading at a height of 1.5 meters above the ground in all parts of the production process at a distance of 5 by 5 meters. Figure 1

shows the weighted inverse interpolation map for the production hall with dimensions of 138 by 111 meters and also the concentration of inhalable environmental dust in the production halls. The interpolated values were classified into four groups based on AIHA classification. The increase in color in Map 1 showed an increase in the intensity of the dust concentration. So, brown represented the high concentration of dust as a danger zone with a concentration higher than 3 mg/m^3 (TLV> 3mg/m3) and white was an indicator of a low concentration of dust in the workplace. The minimum and maximum concentrations in production halls were 322 mg/m and 0.305 mg/m. With the synergy of workers' location maps, the distribution of pollution concentrations was determined, with 40 workers in the danger zone and 55 workers in the warning zone [34-37].

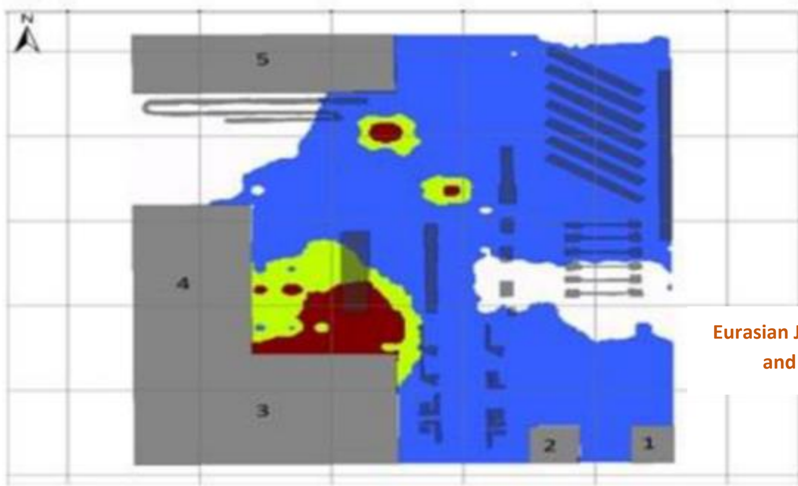

Figure 1 Interpolation map of ambient concentration of respirable dust

Scattering of Individual Concentrations of Particulate Pollutants

Figure 2 shows the interpolation map of the weighted inverse distance of individual inhalable dust in production halls, based on the results of individual sampling of the researcher and the history of evaluation. Individual items in the company are shown. In the map, 2 brown colors represented the high concentration of dust as a danger zone with a concentration higher than 3 mg/m3 TLV> 3mg/m3, and white was the indicator of low concentration of dust in different occupational groups. The minimum and maximum concentrations in different occupational groups were 12.31 mg/m for the powder milling operator and 1.397 mg/m for the wire rolling operator. As for the best area to control air pollution, Figure 3 is the best area to control the powder room, which was marked with a score of 13-9 and brown color. As far as pollution level lines and synergy of pollutants are concerned, to determine the simultaneous effect of activities and pollution of the existing grounds in the hall, dispersal maps were increased. Figure 3 also shows the line map of the level of concentration of inhalable environmental dust in production halls. The density of lines in the area of the powder room indicates a large difference in the amount of exposure in this area (Fig. 4). The results obtained from the measurement of dust concentration, and the dust concentration map obtained from GIS, especially the map of dust concentration level lines, showed that the highest dust concentration is related to the hall. Powder mills, materials from the new hall, and the packing hall are considered [38-41].

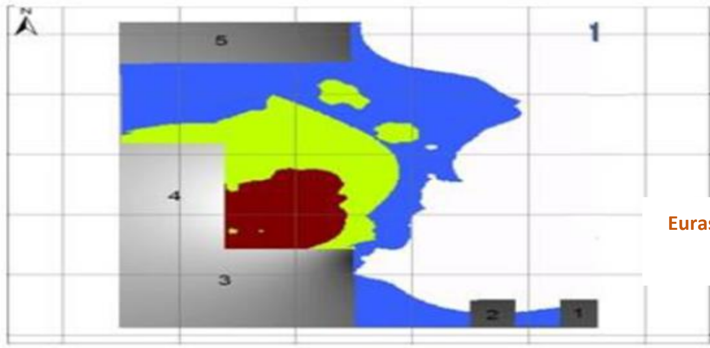

Figure 2 Scoring areas in terms of concentration increase

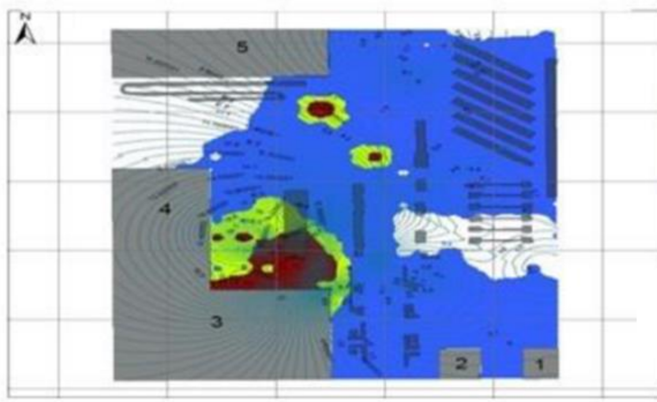

Figure 3 Map of lines equal to the concentration of inhalable environmental dust

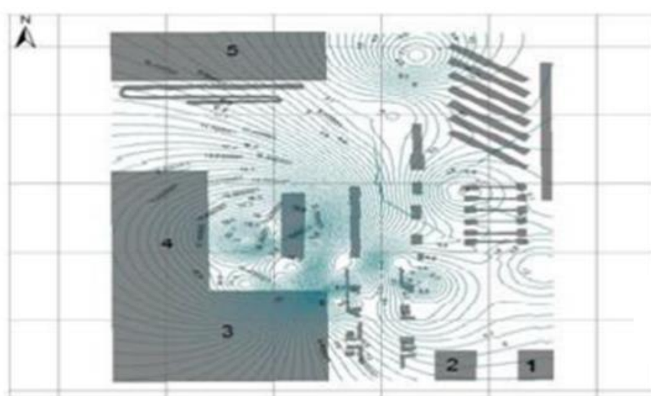

Figure 4 Density map of lines equal to the concentration of inhalable environmental dust

Issues Resulting from the Simulation of the Proposed Method

In the present study, after determining the concentration of particles in the inhaled air of workers and the environmental concentration, to draw a map of air pollution and contour lines in different parts of one of the electrode industries of the country and also determine the best place to prioritize corrective actions, the use of GIS was addressed. The average concentration of inhalable dust for individual samples in this study was estimated to be 8.61 mg/m3. Therefore, the mean dust concentration in this study was exceeded (TLV> 3mg/m3). To date, no similar study has been conducted in the industry to assess exposure to airborne pollutants. However, in different industries, the exposure to airborne pollutants was evaluated, and the results obtained in this study are consistent with industries with other relatively similar production processes [15-16]. In the study conducted by Golbabaie et al. (2020) in the cement industry, the range of workers' exposure to inhalable dust in different production units of the factory was in the range of 1.77-18.89 mg/m3, which is in line with the results of the current study in different units of the electrode industry. It was in the range of 1.98-21.13 mg/m3 [41-44]. Also, according to the Kvhpayy study (2019), which examined the concentration of dust on the workers of a tile factory, the average concentration of dust in the press hall number one of this industry was 52.2262 mg/m3 and in the press hall number two it was 158 mg/m3. It was found that this concentration is several times the standard limit concentration recommended by ACGIH [16]. Although no information is available on the concentration of dust in this industry, its comparison with other similar industries such as cement showed that the dust concentration of the electrode industry is similar to the cement industry and lower than the tile industry. It can be concluded that the electrode industry with moderate risk is at the level of the cement industry and employees in the electrode industry are inappropriately exposed to contaminants and therefore to maintain the health of employees, controlling contaminants should be measured.

In Table 1, the maximum and minimum mean concentrations of inhalable dust were related to the pulverizing operator and the wire-forming operator, respectively. The location of the workplace, the type of materials used in the workplace, the work process, and the type of control used in the workplace are among the reasons that can be used to justify the minimum and maximum dust concentrations in these occupational groups. Due to the high exposure in the powder milling occupational group, according to the overall result and the result of Figure 4, the control priority was determined for this occupational group, which can be used engineering and non-engineering controls. It is suggested that a set of ventilation and non-ventilation measures be performed in the field of engineering controls. Examining Maps 2 and 3, there was almost a correlation between the intensity of dust concentration in different areas in these two maps. To save time and money, one of these methods, environmental or individual sampling, can be used to prepare a workplace air pollution map.

Conclusion

Due to the fact that the average dust concentration in this study is higher than the allowable limit (TLV = 3mg/m3), it is necessary to implement appropriate engineering controls and respiratory protection programs. It also highlights the need for more comprehensive dust concentration screening studies using GIS in the industry. As other studies have shown the effective use of this method, it seems that its use in the field of assessment of respiratory exposure in occupational health can also improve and manage exposure. However, no similar study has been conducted in this area. The overall result of this study showed that this method can be used for situations where employees are working in different workplaces at different times and more accurate results can be obtained about their encounters, although in this study the steps taken to create GIS maps were short-lived, which can be considered as a limitation in the article. Using other methods of diffusion modeling may also produce comparable results. Due to the specificity of emission sources in this industry and the possibility of determining the emission rate, the use of other modeling methods to determine the distribution of pollution for future studies and comparison with these findings is recommended.

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