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Semi-quantitative risk assessment for workers exposed to occupational harmful agents in an oilfield in Iran

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Abstract.
BACKGROUND: Workers are exposed to occupational health hazards from physical, chemical, biological, ergonomic, and psychological agents. Assessing occupational health risks is vital for executing control measures to protect employees‘ health against harmful occupational agents.
OBJECTIVE: The present study aimed to identify, evaluate, and prioritize occupational health risks to assist senior management in determining where to allocate the budget to carry out the required corrective actions in the oilfields project.
METHODS: This descriptive-analytical cross-sectional study was performed in 2021 among Iran's Sarvak Azar oil field job groups. The occupational health risk was assessed using the Harmful Agents Risk Priority Index (HARPI) as a semi-quantitative method. Then, to simplify decision-making and budget allocation, we reported HARPI final score in the Pareto principle format.
RESULTS: The results show that in this oil field, controlling exposure to adverse lighting, improving the thermal conditions and ergonomics, and preventing noise exposure has the highest priority, with scores of 6342, 5269, 5629, and 5050, respectively. Production, HSE, laboratory, and commissioning need the most health care measures with scores of 8683, 5815, 5394, and 4060, respectively.
CONCLUSION: HARPI could be used to prioritize occupational health hazards, and this method can simplify managers' decisions to allocate resources to implement control measures.

Keywords: Workplace, health priorities, decision making, health planning

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1. Introduction

Workplace injuries and conditions were the direct cause of about 2.5 million deaths worldwide in 2014 [1]. Approximately 85 % of these were due to work-related diseases, and 15% resulted from accidents [2]. On the other hand, studies show that risk assessment is focused on workplace safety [3–5]. In addition, studies show that the lack of an integrated risk management plan covering all aspects of occupational health and safety (OHS) can increase work-related accidents and diseases [6]. Regardless, in addition to workplace safety conditions, workers are exposed to occupational health hazards from physical, chemical, biological, ergonomic, and psychological agents [7–10]. Risk management is the main subject of the preventive strategy for occupational safety and health (OSH), and it has become a lawful commitment for employers in many countries [11]. According to the European Agency for Safety and Health statement, risk assessment is the basis of OHS risk management [12]. One of the significant factors influencing health and safety management is the improvement of risk assessment techniques to assure the achievement of health and safety programs [11]. In occupational environments, each identified harmful agent is assessed individually by comparing exposure levels to occupational exposure limits (OELs) or other health-based guidelines. It is not common to evaluate the combined risk from simultaneous exposure to multiple stressors in occupational (and non-occupational) environments [10]. According to the history of attention to safety issues and the spread of harmful health factors in work environments, many industrialized countries and international organizations responsible for maintaining safety and health have recently sought to develop different risk assessment methods [13]. But choosing a suitable method depends on the conditions and experience of those who use them, and each method has its strengths and weaknesses [14]. Therefore, to evaluate the conditions more accurately, the researchers suggest that quantitative and qualitative methods be used in a consolidated manner [13, 14].The oil industry and its derivatives have a specific place in oil-producing countries. This industry's high number of workers necessitates further studies in occupational health engineering services [15, 16]. On the other hand, we should note that one of the main tasks of risk assessment as a management tool is simplifying the perception of subjects and decisions. Therefore, the risk management process should focus on selecting remedial actions with the desired impact, the assumed benefits at an acceptable cost, and resource savings [17]. In general, assessing occupational health risks to protect employees' health against harmful occupational factors is a necessity that requires more attention than before in terms of the development of risk management methods. Therefore, we conducted this study intending to: manage occupational health risks; identify, evaluate, and prioritize employees' exposure to harmful factors in the workplace; and in order to help the senior management in determining where to spend the allocated budget, to carry out the necessary corrective measures in the Sarvak Azar oil field in 2021. This field is active in western Iran, with an operational capacity of producing 65000 barrels per day. The reservoir of this field is shared with the Badra oil field in Iraq and is located along the Chengoleh oil field. The number of employees in this industry is 840, with an average age of 32.02 ± 6.07 years.

2. Material and methods

The risk management process in this study includes four steps as follows;

2.1. Workplace harmful agent's identification

At this step, we formed a team of experts familiar with Health, Safety, And Environment (HSE) and the workplace. Based on the checklists and guidelines provided by the Iranian Environment and Occupational Health Centre (IEOHC), we classified a list of the most common harmful factors in the workplace. In addition, the human resource information related to each job group, such as the number of people, was specified [18, 19].

2.2. Harmful agent's measurement

In the second step, we used the Ministry of Health and Medical Education (MHME)-approved instructions (OELs) to measure the harmful occupational health agents for the different job groups.

2.2.1. Harmful Physical Agents (HPA) and analysis posture (AP)

We analyze the intensity of noise, types of rays, lighting, heat stress intensity, and ergonomics condition (analysis posture) according to the MHME standard methods, including OEL – NV – 9505, OEL – R – 9506, OEL – L – 9507, OEL-HC-9508, and OEL – E – 9509 respectively. In addition, we applied following devices to measuring agents. TES 1350 C (Noise), EXTECH radiometer 480846 (magnetic fields), Hagner EC1X (Ultraviolet), Hagner EC1 (Infrared), EXTEC HT30 (Heat stress), RULA, REBA, ROSA, and QEC Worksheets and software.

2.2.2. Harmful Chemical Agents (HCA)

The National Institute of Occupational Safety and Health (NIOSH) and Occupational Safety and Health Administration (OSHA) standard methods also use the following devices to measure the pollutants in a worker's breathing zone.

- Volatile organic compounds (VOCs): NIOSH 2549 – 1501, [SKC AirLite pump, Flow rate: 0.2 (lit/min) - Adsorbent: activated carbon 50/100 mg].
- Dust: NIOSH 0500-NIOSH 0600, [SKC model Air Check touch pump, Flow rate: 1.75 - 2.5 (lit/min) and PVC filter].
- Acid: NIOSH 7909, OSHA ID113, [SKC Air Check touch pump, Flow: 2 (lit/min), Quartz fiber filter, Mixed Cellulose Membrane Filter (MCEF)].

2.3. Risks prioritization

We used Tables 1 and 2 to prioritize the risk caused by exposure to the measured pollutants; the intensity and effects of the measured factors were equated with Exposure Rate (ER) and Hazard Rate (HR) values. Using these tables helps to eliminate mathematical dimensions such as lux, decibels, etc. Then, we applied equation 1 to calculate the weight factor (WF_i) of each agent [20].

Table 1
Standard limits of occupational exposure to HPA, AP and HCA (ER)

Harmful agents	Exposure rate				
	1	2	3	4	5
Noise	–	–	E ≤ AL	AL<E ≤ OEL	E>OEL
Lighting	E ≥ OEL	–	–	–	E<OEL
Rays	E ≤ 25%OEL	25%OEL<E ≤ 50%OEL	50%OEL<E ≤ 75%OEL	75%OEL<E ≤ 100%OEL	E>100% OEL
Heat stress	–	–	E ≤ AL	AL<E ≤ 100%OEL	E>100% OEL
QEC Score	–	S ≤ 40%	41%≤S ≤ 50%	51%≤S ≤ 75%	S>75%
RULA and REBA	–	Level 1	Level 2	Level 3	Level 4
ROSA Score	–	S<5	S ≥ 5	–	–
Single chemical contaminant	E ≤ 25%OEL	25%OEL<E ≤ 50%OEL	50%OEL<E ≤ 75%OEL	75%OEL<E ≤ 100%OEL	E>100% OEL
Chemical synergic effects	E ≤ 1	–	–	–	E>1

Table 2
Consequences of exposure to HPA, AP and HCA (HR)

Hazard Rate Catastrophic (5)	Serious irreversible health or physiological effects, reproductive toxins, life-threatening consequences, lack of light, and multiple deaths due to accident-prone sound levels. The carcinogenic, mutagenic and teratogenic effects of this substance are well known. Elements classified by ACGIH and IARC as Category A1 and Group 1.
Severe (4)	One death, irreversible or debilitating injury to 1 or more persons, chronic progressive complications such as hearing loss, pneumococcal, obstructive pulmonary disease. Chronic progressive complications such as hearing loss, pneumococcosis, and obstructive pulmonary disease. ACCIH Class A2 substance. IRAC class group A2, highly corrosive substances (0<PH<2 or 11.5<PH<14).
Moderate (3)	Reversible health effects of downtime (musculoskeletal disorders, vibration effects, manual load carrying, physical effects of sunburn, heat stress, neurological effects other than anaesthesia, non-fatal No airborne infections, ultraviolet, infrared, electromagnetic field complications). Substances that ACGIH has placed in class A3. Group B2 materials in IRAC classification. Corrosive substances (5 PH< 3 or 12 PH< 9) and respiratory sensitizers.
Minor (2)	Reversible health effects, treatment with no downtime, bacterial food poisoning, sunburn, anaesthesia required. A substance that has reversible effects on the skin, eyes, and mucous membranes, but the effects are not strong enough to cause serious harm to humans. A substance classified as a class A4 carcinogen by the ACGIH. Substances with skin irritants and irritants.
Negligible (1)	No effect on performance, reversible effects, first aid required mild muscle discomfort and headache. A substance classified as a class A5 carcinogen by ACGIH.

$$WF_i = \sqrt{ER \times HR} \quad (1)$$

Then we used equation 2 to calculate Harmful Agents Risk Priority Index (HARPI) (16).

$$HARPI = \frac{\sum_{i=1}^{n} WFi\ pi\ ti}{\sum PT} \times 100 \quad (2)$$

pi: Number of people exposed to pollutants
ti: Average exposure time (hours)
P: Total number of people
T: Total exposure times

2.4. Evolution and decision-making

In the last step, we analyze and compare the HARPI Scores in the Pareto principle format to better understand and simplify the decision-making and budget allocation of the results obtained through the present study. The Pareto principle is a simple technique with the logic of cumulative frequency for data analysis. Pareto's 80/20 principle says that approximately 80% of the consequences come from 20% of the cause (80 : 20 Rule) [21]. Therefore, according to the Pareto principle, after obtaining the maximum and minimum HARPI values, the range of discounts obtained is divided into three parts. Harmful agents in the range of 20% of the upper boundary of the domain have the highest management priority, and harmful agents in the range of 20% of the lower limit of the spectrum have the lowest priority, whereas the rest were cases between 20 to 80% of the domain evaluated with moderate priority (Table 3). Finally, according to the results, the budget is allocated based on the organization's acceptable risk level.

3. Results

We identified 14 job groups in the studied industry in the first stage by exploring the human resources database. Then according to the nature of the tasks, the employees were divided into operational and administrative groups. Table 4 and Figs. 1 and 2 show the results related to investigating the HARPI for administrative employees and the harmful factors identified. For operational employees, the results are given in Table 5 and Figs. 3 and 4. In the tables and figures, the number zero indicates that the harmful factor has not been identified for the investigated occupational groups. Also, in some job groups, all employees are in the administrative department, so results in corresponding figures and tables of the operational section, the related values reported equal to zero.

In the next step, by summing the HARPI values calculated for the administrative and operational divisions, the general conditions of prioritizing harmful agents has been scrutinized, and the priority of job groups in terms of corrective and management measures has been shown within the scope of the study. The results are shown in Figs. 5 and 6, respectively. According to Table 3, the results obtained from the present study are calculated and shown in Table 6 based on Pareto's principle.

4. Discussion

Risks and the concept of risk and risk-taking are increasingly preoccupying people, nations, communities, and scientists. Many fields nowadays are fixated on assessing, handling, or foreseeing a broad kind of risks from industry and manufacturing to health and society care and education [22, 23]. In 2018, Tian et al. conducted a study investigating the methodology of different occupational health risk assessment (OHRA) models to understand the qualitative and quantitative differences between the standard OHRA models in industries. This study uses common health risk assessment models, including; the Environmental Protection Agency (EPA), Australia, Romania, Singapore, International Council on Mines and Metals, and Control of Substances Hazardous to Health (COSHH) models were compared quantitatively and qualitatively. Qualitative comparisons showed that each OHRA model has strengths and limitations and offers a diverse distribution at different levels for each evaluation index. The Singapore, COSHH, and EPA models had a much higher comprehensive advantage than the others for all indicators. Quantitative comparisons showed that the three models also have a more vital ability to detect

Table 3
HARPI results classification analyzing in Pareto principle

Risk rate	High priority	Medium priority	Low priority
HARPI score in Pareto principle format	The most leading 20% of the HARPI	Middle range of the HARPI	The lowest leading 20% of the HARPI

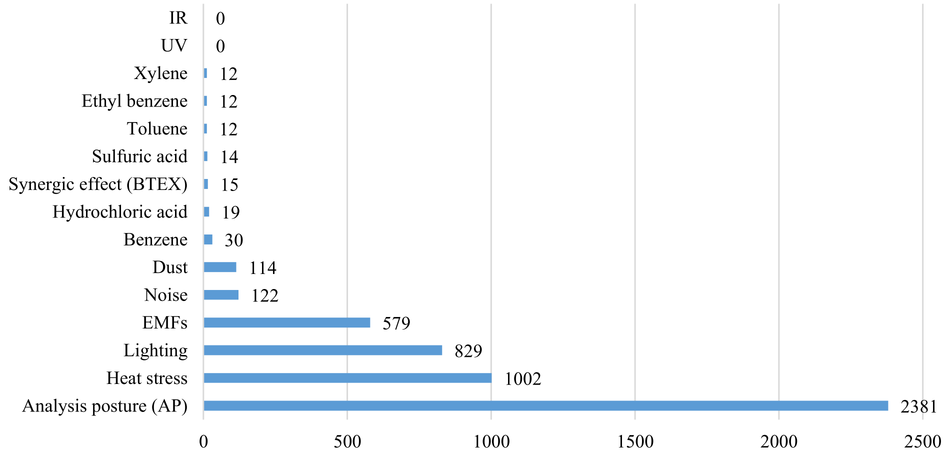

Fig. 1. Calculated HARPI score for harmful agents in administrative section.

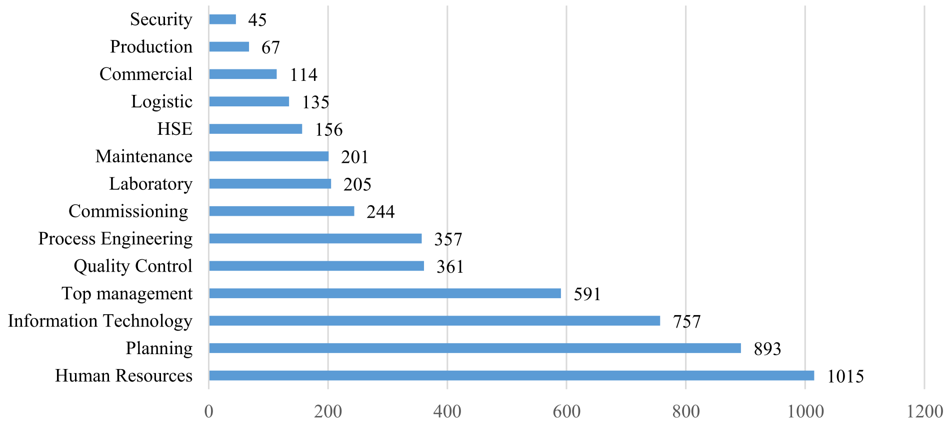

Fig. 2. Calculated HARPI score for job groups in administrative section.

differences in risk ratios between different industries. The Singapore models had the strongest correlation with other models. In general, the results of this study showed that each model had its strengths and limitations depending on its unique methodological principles. A combination of the EPA, Singapore, and COSHH models may be helpful in the development of the OHRA strategy [14]. In addition, Niemeier et al. explored practical cumulative risk assessment methodologies and tools to meet the demands of complex and changing work environments. It has been found to be essential [24]. Therefore, we aimed in this study to identify, evaluate, and prioritize occupational health risks and ultimately assist senior management in deciding to use the budget to implement the remedial measures required at the Sarvak Azar oil field by using NCPI and COHRA Models [16, 20]. The results of the present study, according to Table 4 and Fig. 1, show that, among the harmful factors identified for office workers, improper posture has the highest exposure (HARPI Score:2381), and chemical compounds (TEX) have the lowest amount (HARPI Score:12). According to Table 4 and Fig. 2, we calculated the highest and lowest HARPI values for human resources employees (HARPI Score: 1015) and security (HARPI Score: 45) units. That shows among the administrative job groups, these units have the highest and lowest possible vulnerability in exposure to harmful factors. Table 5 and Fig. 3 show that improper lighting is the harmful factor with the highest (HARPI Score: 5513) priority, and TEX has the lowest (HARPI Score: 982) risk for operational staff. Figure 4 also shows that among the investigated job groups, production and process engineering groups have the highest (HARPI Score: 8616) and lowest (HARPI Score: 1965) risk of exposure to harmful factors in the workplace. Figures 5 and 6 show the total HARPI values for the harmful agents and job

Table 4
Job groups, identified harmful agents, and calculated HARPI for administrative job groups and agents

Job groups / Agents	HSE	Laboratory	Quality control	Planning	Production	Logistic	Commercial	Security	Commissioning	Management	Information technology	Human resources	Process engineering	Maintenance	Agents total HARPI
Noise	30.09	7.78	17.50	8.75	2.22	4.43	0.00	1.19	25.00	8.75	0.00	0.00	7.00	8.85	121.56
Lighting	21.21	21.93	49.35	148.05	10.93	21.86	17.40	6.73	35.25	98.70	123.38	172.73	59.22	42.49	829.22
EMFs	15.04	15.56	35.00	105.00	7.75	15.51	12.34	4.77	25.00	70.00	87.50	122.50	42.00	21.24	579.21
UV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat stress	26.03	26.91	60.55	181.65	13.41	26.83	21.34	8.26	43.25	121.10	151.38	211.93	72.66	36.75	1002.04
Analysis posture (AP)	61.83	63.93	143.85	431.55	31.87	63.73	50.71	19.62	102.75	287.70	359.63	503.48	172.62	87.31	**2380.56**
Benzene	0.00	17.38	13.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30.42
Toluene	0.00	6.73	5.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.77
Ethyl benzene	0.00	6.73	5.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.77
Xylene	0.00	6.73	5.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.77
Synergic effect (BTEX)	0.00	8.71	6.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.24
Sulfuric acid	0.00	7.78	5.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.61
Hydrochloric acid	0.00	11.01	8.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.26
Dust	2.15	3.89	5.83	17.50	1.11	2.22	12.34	4.77	12.50	4.38	35.00	4.38	3.50	4.43	113.98
Job groups total HARPI	156.35	205.06	360.88	892.50	67.29	134.57	114.12	45.34	243.75	590.63	756.88	**1015.00**	357.00	201.06	

Table 5
Job groups, identified harmful, and calculated HARPI for operational job groups and agents

Job groups Agents	HSE	Laboratory	Quality control	Planning	Production	Logistic	Commercial	Security	Commissioning	Management	Information technology	Human resources	Process engineering	Maintenance	Agents total HARPI
Noise	914.91	405.61	347.67	0.00	879.29	462.09	0.00	583.13	670.50	0.00	0.00	0.00	312.90	352.69	4928.79
Lighting	1023.39	453.70	388.89	0.00	983.54	516.88	0.00	652.27	750.00	0.00	0.00	0.00	350.00	394.51	**5513.19**
EMFs	409.36	181.48	155.56	0.00	393.42	206.75	0.00	260.91	300.00	0.00	0.00	0.00	140.00	157.80	2205.28
UV	781.87	346.63	297.11	0.00	751.43	394.89	0.00	498.34	573.00	0.00	0.00	0.00	267.40	301.40	4212.08
IR	501.46	222.31	190.56	0.00	481.94	253.27	0.00	319.61	367.50	0.00	0.00	0.00	171.50	193.31	2701.46
Heat stress	792.11	351.17	301.00	0.00	761.26	400.06	0.00	504.86	580.50	0.00	0.00	0.00	270.90	305.35	4267.21
Analysis posture (AP)	141.64	313.96	269.11	0.00	680.61	357.68	0.00	451.37	519.00	0.00	0.00	0.00	242.20	273.00	3248.58
Benzene	182.98	730.10	347.67	0.00	879.29	8.32	0.00	4.86	13.41	0.00	0.00	0.00	18.77	352.69	2538.09
Toluene	70.82	282.57	134.56	0.00	340.31	3.22	0.00	1.88	5.19	0.00	0.00	0.00	7.27	136.50	982.30
Ethyl benzene	70.82	282.57	134.56	0.00	340.31	3.22	0.00	1.88	5.19	0.00	0.00	0.00	7.27	136.50	982.30
Xylene	70.82	282.57	134.56	0.00	340.31	3.22	0.00	1.88	5.19	0.00	0.00	0.00	7.27	136.50	982.30
Synergic effect (BTEX)	91.70	365.87	174.22	0.00	440.63	4.17	0.00	2.44	6.72	0.00	0.00	0.00	9.41	176.74	1271.88
Sulfuric acid	81.87	326.67	155.56	0.00	393.42	3.72	0.00	2.17	6.00	0.00	0.00	0.00	8.40	157.80	1135.61
Hydrochloric acid	115.85	462.23	220.11	0.00	556.69	5.27	0.00	3.08	8.49	0.00	0.00	0.00	11.89	223.29	1606.89
Dust	409.36	181.48	155.56	0.00	393.42	206.75	0.00	260.91	6.00	0.00	0.00	0.00	140.00	157.80	1911.28
Job groups total HARPI	5658.95	5188.92	3406.67	0.00	**8615.85**	2829.51	0.00	3549.59	3816.69	0.00	0.00	0.00	1965.17	3455.90	

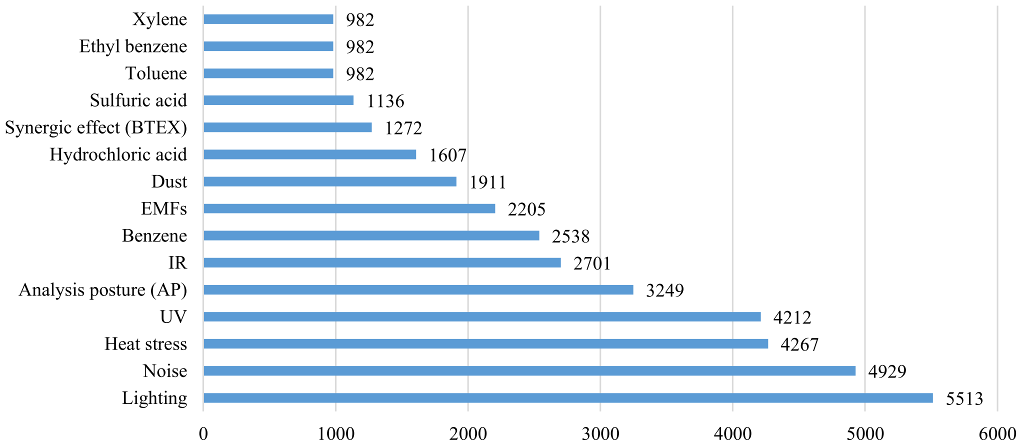

Fig. 3. Calculated HARPI score for harmful agents in operational section.

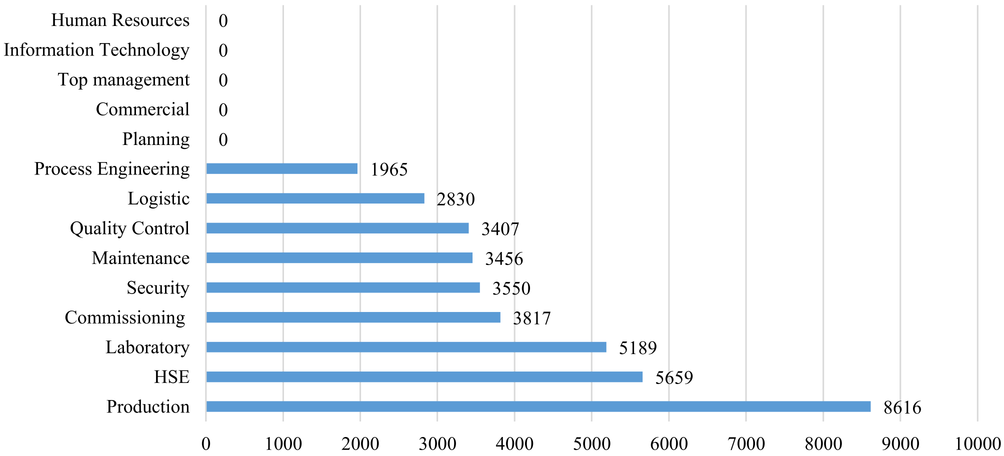

Fig. 4. Calculated HARPI score for job groups in operational section.

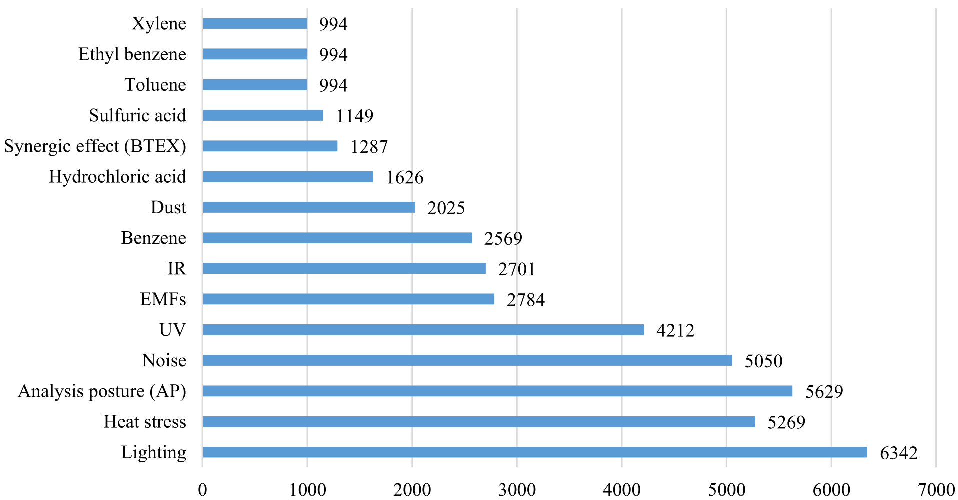

Fig. 5. Total HARPI score for investigated harmful agents.

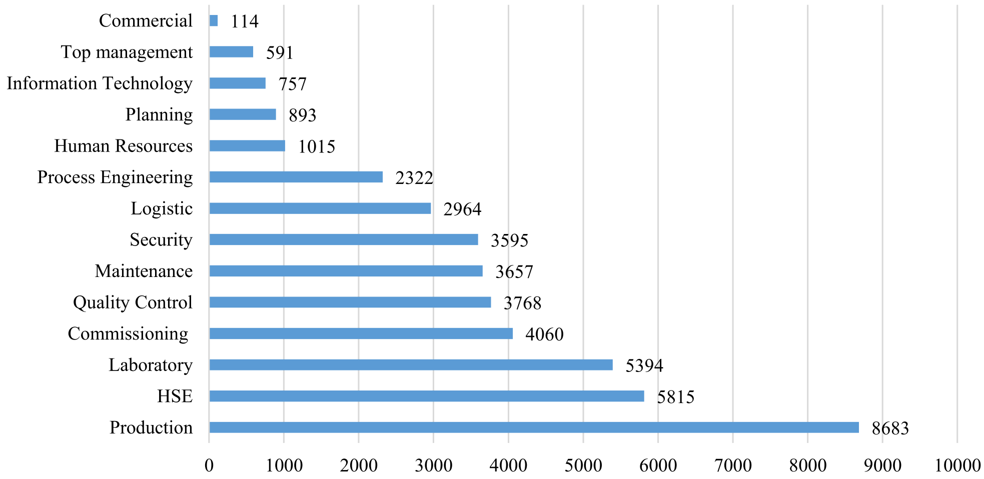

Fig. 6. Total HARPI score for investigated job groups.

Table 6
HARPI scores classification in pareto principle

Risk rate	High priority	Medium priority	Low priority
Calculations	[$HARPI_{Max}$-($HARPI_{Max} \times 20\%$)]	[$HARPI_{Max}$-($HARPI_{Max} \times 20\%$)] < Medium priority ≤ [$HARPI_{Max} \times 20\%$]	[$HARPI_{Max} \times 20\%$]
HARPI score in Pareto principle	High ≥ 5074	5074 < Medium ≤ 1268	Low<1268
Harmful agents priority at workplace	1- Lighting 2- Heat stress 3- Analysis posture 4- Noise	1. UV 2. EMFs 3. IR 4. Benzene 5. Dust 6. Hydrochloric acid 7. Synergic effect (BTEX)	1- Sulfuric acid 2- Toluene 3- Ethyl benzene 4- Xylene
HARPI score in Pareto principle	High ≥ 6947	6947 < Medium ≤ 1737	Low<1737
Job groups priority at workplace	1- Production	1- HSE 2- Laboratory 3- Commissioning 4- Maintenance 5- Security 6- Logistic 7- Process engineering	1- Human resource 2- Planning 3- Information technology 4- Management 5- Commercial

groups investigated in the study scope. Examining the results from this point of view determines the overall risk of the studied industry regarding occupational health. The results show that unfavorable lighting with a score of 6342 and TEX with a score of 994 have the highest and lowest risks for employees in the studied industry (Fig. 5). Among the occupational groups studied, the production, HSE, and laboratory groups have the highest risk of exposure to harmful factors in the work environment, and the commercial unit has the least risk (Fig. 6). In addition, to adjust the organization's risk tolerance level based on the Pareto principle, Table 6 shows that the production group is exposed to the highest health risk due to occupational exposures. Lighting, heat stress, and ergonomic disorders caused by improper posture and noise in the workplace are the most critical risks that require control measures. Various studies show a significant relationship between ergonomic disorders caused by awkward posture and undesirable lighting [25]. Musculoskeletal disorders [26] and unfavorable lighting are the most common harmful factors in the workplace [27]. Noise is known as the most common harmful factor in the workplace [16]. The results of this study are consistent with the statements mentioned in specialized studies conducted in the field of harmful elements. In addition, the high priority of thermal stress in the studied area can be attributed to the region's climatic conditions [28]. Compared with the results of studies based on health risk assessment in the workplace [13, 14], in addition to the number of exposed people and the duration of exposure, we removed the mathematical dimensions related to the measured values. Pure scores are one of the essential advantages of the method used in this study, which provides the ability to compare different parameters.

5. Conclusion

The HARPI can prioritize the results of measuring and evaluating the harmful agents of the workplaces. In addition, this method can simplify managers' decisions to allocate resources to implement control measures and finally reduce risk levels to an acceptable level. This method can assess semi-quantitative risk in other field of HSE, such as the environment by developing the ER and HR tables.

5.1. Study limitations

Among the categories of harmful factors in the workplace, we investigated the most common elements of physical, chemical agents, and ergonomics. At the same time, the other cases require specialized methods and have a high cost for sampling and para-clinical tests.

5.2. Recommendations

For future studies, we recommended that other researchers in the HSE field expand the ER and HR tables based on the epidemiology of occupational diseases and their complications. In addition, the main parameters measured in environmental issues such as noise pollution, water, soil, and air pollutants are numerically reported and compared with the standard limits. Therefore, the development of the above ER and HR tables can make this method more efficient by a risk assessment of environmental aspects.

Ethical approval

The study was approved by the Research Ethics Committee of the Faculty of Health and Neuroscience Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran (IR.SBMU.PHNS.REC.1401.051).

Informed consent

Informed consent was obtained from all participants. Each participant received a code to remain anonymous.

Conflict of interest

There are no conflicts of interest.

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