Iran J Public Health, Vol. 52, No. 10, Oct 2023, pp.2157-2168

Original Article

Workplace Risk Factors Assessment in North-Azadegan Oil Field Based on Harmful Agents Risk Priority Index (HARPI)

Ali Askari [1], Mohsen Poursadeghiyan [2], Alimardan Alinia [3], Arash Sephvand [4], Emad Jafarzadeh [5], Gebraeil Nasl-Saraji [1], *Ali Salehi Sahlabadi [6]

1. *Department of Occupational Health, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran*
2. *Department of Occupational Health, School of Health, Ardabil University of Medical Sciences, Ardabil, Iran*
3. *Department of HSE, MAPNA-Group, Tehran, Iran*
4. *Department of Occupational Health and Safety, Atlantic International University, Hawaii, USA*
5. *Department of Toxicology and Pharmacology, Faculty of Pharmacy, Tehran University of Medical Sciences, Tehran, Iran*
6. *Workplace Health Promotion Research Center, Department of Occupational Health and Safety at Work, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran*

***Corresponding Author:** Email: asalehi529@sbmu.ac.ir

(Received 04 Jul 2022; accepted 21 Sep 2022)

Abstract

Background: Considering the necessity of health risk management, the present study conducted to provide a comprehensive model for identifying, evaluating, and prioritizing occupational health risks in an oilfield.

Methods: We conducted this descriptive-analytical cross-sectional study in 2022 at the North-Azadegan oil field in Iran. The occupational health risk was assessed using the "Harmful Agents Risk Priority Index" (HARPI) method.

Results: Among the employees for the office section in all job groups, ergonomic risks due to people's posture while working has the highest risk score and is the most critical risk for implementing corrective actions. In the operational section, for the HSE group, benzene, the production group, Electromagnetic Fields (EMFs), and other groups, undesirable lighting has the highest risk score, and exposure to Toluene, Ethylbenzene, Xylenes (TEX) has the lowest risk score. In this oil field, controlling exposure to benzene, correcting ergonomic conditions, and controlling noise exposure, with scores of 81.3,74.85 and 71.36, have the highest priority, respectively. Sequentially, Toluene, Xylene, and ethylbenzene, with scores of 10.25,11.61, and 11.61, have the lowest control priority.

Conclusion: The proposed model can prioritize the workplaces' harmful agents based on the HARPI score due to exposure to chemicals, physical factors, and analysis posture.

Keywords: Environmental exposure; Occupational health; Oil and gas industry; Risk priority number

Introduction

Todays, energy demands are key in determining the progress of nations' industrial sectors. Particularly, the oil industry makes a significant impact on a country's economic growth. Nonetheless, the growing concern regarding safety, health, and the environment is inseparable from the development of these industries (1).Millions of accidents and occupational diseases occur worldwide (2). According to the WHO statistics, 55 million people die annually due to Non-Communicable Diseases (NCD) (3). In addition, based on the statistics published by the Iranian Center for Environmental and Occupational Health in 2009, one million and two hundred thousand people were covered by occupational medical examinations (4).

The International Labor Organization (ILO) report indicates that 60% of the world's workforce is in developing countries. From 5% to 15% have access to occupational health engineering services (5). Occupational accidents and illnesses generate economic and human burdens. They have led to serious concerns for the ILO and related organizations (6). One of the most important factors influencing the improvement of health and safety management is developing and implementing risk assessment methods to ensure the achievement of health and safety programs 7).Risk management is legally required in some countries, such as the United Kingdom and Singapore (8). To minimize the potential conflict between work and family, implementing effective safety and health management systems, focusing on improving workplace occupational health, can be beneficial (9) .

Risk assessment focuses on workplace safety (10). However, workers exposed to health hazards include physical, chemical, biological, ergonomic, and psychological harmful agents. 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 (11). 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 select remedial actions with the desired impact, the assumed benefits at an acceptable cost, and resource savings (12). In studies, many investigations have been done on health risk assessment in both processing and non-processing industries. As a result, only some health risks have been assessed independently due to exposure to harmful factors in the workplace in most studies (13).

Thus, we aimed to provide a comprehensive model for identifying, evaluating, and prioritizing occupational health hazards in the North-Azadegan (13) oil field in 2022. Another purpose of this study was to simplify decision-making for the organization's senior management in determining the location of the budget allocated for remedial measures using clarifying and prioritizing health risks.

Methods

Ethical approval was obtained from Shahid Beheshti University of Medical Sciences: IR.SBMU.PHNS.REC.1401.051.

The NAZ oil field located 120 km southwest of Ahvaz. The number of employed workers is 915, with an average age of 34.05±7.8 years. By observing the ethical principles, this study was conducted according to the conceptual model (Fig.1). First, a team including managers and supervisors of the units, including the Health, Safety and Environment manager, maintenance, operation, and occupational health expert, implemented checklists and instructions presented by the Iranian Environment and Occupational Health Center (IEOHC) to identify harmful health agents in the workplace (14). In the next step, to measure the harmful occupational health agents for the different company job groups, the instructions approved by the Ministry of Health and Medical Education (MHME) were used in Table 1. In the next step, we combined Noise control priority index (NCPI) (15, 16) and Comprehensive Occupational Health Risk Assessment (COHRA) (7) with two purposes and provided the Harmful Agent Risk Priority Index (HARPI). 1) Using COHRA to determine each harmful agent's weight factor and eliminate their unit (dimension) to compare all agents' priorities (Table 2) 2) Using NCPI to consider the parameters of exposure time and the number of workers exposed to pollutants (Table 3).

Figure 1 shows the location of HARPI in the occupational health management process. Some potentially harmful factors, like vibration, were excluded due to the lack of identification at the initial stages or investigation because of limited exposure time or repetition. Nonetheless, researchers can now investigate all possible harmful work-related factors based on the proposed model.

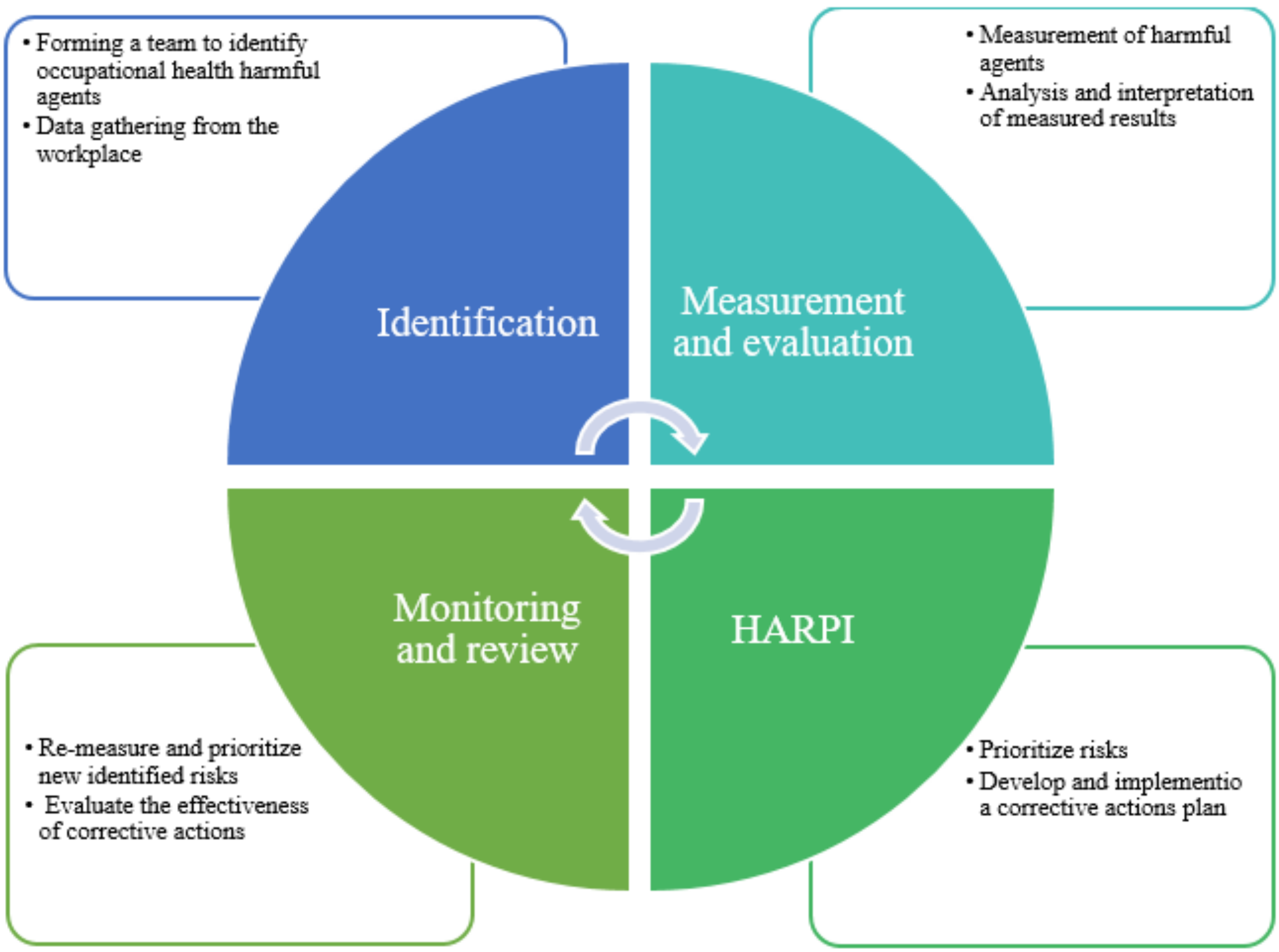

Fig.1: Conceptual risk Process management model

Eq.1: $WFi = \sqrt{ER \times HR}$
WFi: Weight factor
ER: Exposure rate
HR: Hazard rate
Eq.2: $HARPI = 100 \times \frac{\sum_{i=1}^{n} WFi\ pi\ ti}{\sum PT}$
pi: Number of people exposed to pollutants
ti: Job group exposure time average (hr.)
P: People total number
T: Total exposure times

Table 1: Identified harmful agents, measurement methods and devices used

Agents	*Methods*	*Devices*
Noise	OEL – NV–9505	CEL-450
Lighting	OEL–L – 9507	TES-1339
EMFs	OEL – R – 9506	Extech-480846
Ultraviolet ray		Lutron UV-340 A
Infrared ray		Hagner ECI 1-IR
Heat stress	OEL-HC-9508	Casella-Microtherm
Analysis Posture	OEL – E – 9509	Worksheet and related software's
Volatile organic compounds	NIOSH[1] 2549 1501	SKC Air lite pump - activated carbon 50/100 mg
Dust	NIOSH[1] 0600	SKC Air Check pump – PVC[2] filter
Acid	NIOSH[1] 7909 OSHA[4] ID 113	SKC Air Check pump - quartz fiber filter, MCEF[3]

[1] National Institute of Occupational Safety and Health, [2] Polyvinyl Chloride, [3]Mixed Cellulose Membrane Filter, [4]Occupational Safety and Health Administration

Table 2: ER and HR table for harmful agent's weight factor calculation

Agents	*Analysis Posture (3)*			*Physical*				
ER	ROSA score	RULA & REBA	QEC score	Heat stress (WBGT)	Lighting	Vibration	Ultraviolet, Infrared, and electromagnetic fields	Noise
5	-	Level 4	S>75%	E>100% OEL	E < OEL	E >100% OEL	E>100% OEL	E > OEL
4	-	Level 3	51%≤S≤75 %	AL<E≤100% OEL	-	-	75%OEL<E≤100%OEL	AL<E≤OEL
3	S ≥5	Level 2	41%≤S≤50 %	E≤ AL	-	AL<E≤100% OEL	50%OEL<E≤75%OEL	E ≤AL
2	S<5	Level 1	S≤40%	-	-	E≤ AL	25%OEL<E≤50%OEL	-
1	-	-	-	-	E ≥ OEL	-	E≤25%OEL	-

ER	**Chemicals**	
	Exposure rate to a single contaminant	Mixed exposure rate with synergic effects
5	E>1	E>100% OEL
4	-	75%OEL<E≤100%OEL
3	-	50%OEL<E≤75%OEL
2	-	25%OEL<E≤50%OEL
1	E≤1	E≤25%OEL

HR	**Physical and Ergonomics**
5	Catastrophic: More than one death due to significant irreversible health or physiological effects, toxins affecting re-

	production, life-threatening consequences, lack of light and loudness that pose a risk of an accident
4	Severe: death of one person, irreversible or debilitating health effects in one or more people, chronic progressive complications such as hearing loss, pneumoconiosis, and obstructive pulmonary disease
3	Moderate: Reversible health effects with missed workdays such as musculoskeletal disorders, effects of vibration, manual load carrying, physical effects of sunburn, heat stress, effects of the nervous system other than narcosis, non-fatal airborne diseases, complications Ultraviolet, infrared, and electromagnetic fields
2	Minor: Reversible health effects, requires treatment without missed workday, bacterial food poisoning, sunburn, and narcosis
1	Negligible: No effect on performance, reversible effects, requires first aid, minor muscle discomfort, and headache
HR	Chemicals
5	The carcinogenic, mutagenic, and teratogenic effects of the substance are known. Elements that ACGIH and IARC classify in category A1 and group 1
4	Substances in ACCIH class A2. Group A2 in IRAC class, highly corrosive substances (0 <PH< 2 or 11.5 <PH< 14).
3	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.
2	Substances with reversible effects on the skin, eyes, and mucous membranes, but their effects are not severe enough to cause serious harm to humans. Substances that ACGIH has placed in the A4 class of carcinogens. Substances with skin sensitivity and irritation effect.
1	Substances that have no known health effects and are not classified as toxic or harmful substances. Substances that ACGIH has placed in class A5 carcinogens.

Table 3: Job groups identified based on human resource database analysis

Job groups	*Staff total number*	*Offices*	*Exposure time (hr)*	*Operational*	*Exposure time (hr)*
HSE	99	19	14	80	10
Laboratory	12	2	8	10	5
Quality	6	2	12	4	5
Planning	2	2	12	0	0
Production	102	12	14	90	5
Logistic	171	11	14	160	5
Commercial	39	39	14	0	0
Security	275	25	8	250	5
Legal affairs	3	3	6	0	0
Management	4	4	6	0	0
Technology	15	15	8	0	0
Human Resource	7	7	10	0	0
Process	4	2	14	2	5
Maintenance	175	45	12	130	5
SUM	914	188		726	

Physical agents

Noise

We measured the Sound Pressure Level (SPL) based on ISO 9612-2009 (E) and then calculated the average SPL based on Eq.3 to determine the noise-related ER (17).

Eq.3: $\overline{SPL}(dB) = 10\log[\frac{1}{n}\sum_{i=1}^{n} 10^{Lpi/10}]$

n: Stations number

Lp_i: Each stations SPL (dB)

Lighting

To measure the average general light intensity in the operational areas, we selected certain stations and measured the light intensity on the horizon and at workers' eye level. We used IES patterns to calculate the average light intensity in office areas, warehouses, and roofed locations. We measured light intensity in industrial and roofed areas after sunset, and then used Equation 4 to determine exposure to average light intensity (18).

Eq.4: $E\ (Avg) = \frac{1}{T}\sum_{i=1}^{n} Ei \times Ti$

Heat stress

We used the Wet Bulb Globe Temperature (WBGT) index to calculate the ER to heat stress in the workplace (Eq.5and 6) (19).

Eq.5: $WBGTi = \frac{WBGT\ head + (2 \times WBGT\ abdomen) + WBGT\ foot}{4}$

Eq.6: $WBGT(Avg) = \frac{1}{T}\sum_{i=1}^{n} WBGTi \times Ti$

Rays and EMF

To determine the level of exposure to ultraviolet and infrared rays, considering the region's climate and the large number of outdoor workers, we measured their intensity at midday (11am to 1pm). Furthermore, we measured EMFs from the sources we identified. The measurements were achieved using direct-reading devices, and the results were applied to calculate the rate of exposure for workers, based on the Eq.7. (20).

Eq.7: $R(Avg) = \frac{1}{T}\sum_{i=1}^{n} Ri \times Ti$

Analysis posture

We used Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA), Quick Exposure Check (QEC), and Rapid Office Strain Assessment (ROSA) to analyze posture assessment (7).

Chemical agents

Volatile Organic Compounds (VOCs)

By NIOSH 2549, we made sure of VOCs. We calculated the concentration of pollutants in the workers breathing zone and the pollutant's synergistic effects by Eq.8,9 and 10, respectively(21) .

Eq.8: $C = \frac{(Wf + Wb - Bf - Bb)}{V}$

$W_{f,b}$: Analyte found in the sample front and back (Coconut shell charcoal)

$B_{f,b}$: Average media in the blank front and back

V: Air volume sample (1)

C: Pollutant concentration (mg/m3)

Eq.9: $TLV - TWA = \frac{(C1T1 + C2T2 + \cdots + CnTn)}{8\ hr.}$

Eq.10: $TLV - Mixture = \frac{C1}{T1} + \frac{C2}{T2} + \frac{Cn}{Tn} \leq 1$

Dust

The NIOSH 0600, was used, to measure the number of respirable particles, and to calculate the concentration of respirable particulate (mg/m³) in the air volume sampled (1), utilizing Eq.11 (22).

Eq.11: $C = \frac{(W2 - W1) - (B2 - B1)}{V} \times 10^3$

W1,2: Tare weight of filter before and post-sampling (mg)

B1,2: Mean tare weight of blank filters and post-sampling (mg)

V: Volume as sampled at the nominal flow rate (1.7 L/min - 2.2 L/min)

Acids

During the initial investigation, it was discovered that acid was present only in the oil quality lab. The concentration of the substances in the technician's breathing zone was measured using NIOSH 7909 and OSHA ID 113. Equations 12 and 13 were used from related literature to calculate the pollutant levels, which enabled us to determine the concentration of each substance (mg/m³) (22).

Eq.12: $C = \frac{(C1 \times V1 \times Fd) - (C0 \times V0)}{V} \times Fc$

$C_{0,1}$: Mean concentration, in mg/L, of anion in the field blank test solutions and post-sampling

V: Air sample volume (1)

$V_{0,1}$: Field blank and sample test solutions volume (mL)

F_d: Dilution factor for each sample test solution

F_c: Conversion factor to convert from anion to acid concentration

F_c: 1.0284 for chloride

Eq.13: $$mg/m3 = \frac{(mg\ calculated)\times(mg\ sample\ vol)\times(1.03)\times(\text{dilution factor})}{(liter\ of\ air)\times(ml\ aliqut)}$$

Due to the large volume of collected data, we have shown in Table 4 the calculations as an example for the HSE group.

Results

Upon reviewing the organization's database, we recognized 14 job groups, which were subsequently differentiated into operational and office categories, according to their respective job characteristic (Table 3).

Due to the large volume of results, we have shown the HARPI calculation for the HSE (Health, Safety, and Environment) job group as an example in Table 4.

Table 5 shows the maximum and minimum HARPI values calculated for the harmful agents identified in the offices and operational sectors.

Table 6 and Fig. 2, show the average of HARPI score for the all scope of the study to clarify the factors with the highest risk and the budget priority allocation for corrective actions.

Table 4: HARPI calculation for the HSE group

Harmful agents	*Operational*				*Offices*			
	ER	HR	Wfi	HARPI	ER	HR	Wfi	HARPI
Noise	4	5	4.47	41.05	2	2	2	23.58
Lighting	5	5	5.00	45.91	1	2	1.41	16.62
EMFs	2	2	2.00	18.37	1	1	1	11.79
	5	3	3.87	35.08	NI[1]	NI	NI	NI
IR	2	3	2.45	22.50	NI	NI	NI	NI
Heat stress	5	3	3.87	35.54	3	1	1.73	20.39
Analysis posture (3)	4	3	4.47	31.77	2	3	4.11	48.46
Benzene	4	5	4.47	451.52	NI	NI	NI	NI
Toluene	1	3	1.73	15.89	NI	NI	NI	NI
Ethyl benzene	1	3	1.73	15.89	NI	NI	NI	NI
Xylene	1	3	1.73	15.89	NI	NI	NI	NI
Synergic effect (BTEX)[2]	1	5	2.24	20.57	NI	NI	NI	NI
Sulfuric acid	1	4	2.00	18.37	NI	NI	NI	NI
Hydrochloric acid	2	4	2.83	25.99	NI	NI	NI	NI
Dust	2	1	2	18.37	NI	NI	NI	NI

[1]No Identify, [2] Benzene, Toluene, Ethylbenzene, Xylenes

Table 5: Min and max HARPI calculated and related harmful agents for job groups

Job groups	*Operational*				*Offices*			
	HARPI min		HARPI max		HARPI min		HARPI max	
	Agents	Amount	Agents	Amount	Agents	Amount	Agents	Amount
HSE	TEX[1]	15.89	Benzene	451.52	EMFs	11.79	AP	48.46
Laboratory	TEX	1.19	Lighting	3.44	EMFs	0.71	AP	2.92
Quality	TEX	0.48	Lighting	1.38	EMFs	1.06	AP	4.37
Planning	-	-	-	-	EMFs	1.06	AP	4.37
Production	TEX	10.72	EMFs	284.59	EMFs	7.47	AP	30.61
Logistic	TEX	19.06	Lighting	55.10	EMFs	6.83	AP	28.06
Commercial	-	-	-	-	EMFs	13.83	AP	56.84
Security	TEX	29.79	Lighting	86.09	EMFs	6.65	AP	27.33
Legal affairs	-	-	-	-	EMFs	0.80	AP	3.28
Management	-	-	-	-	EMFs	1.42	AP	5.83
Technology	-	-	-	-	EMFs	6.65	AP	27.33
Human Resource	-	-	-	-	EMFs	4.34	AP	17.85
Process	Toluene	0.07	Lighting	0.69	EMFs	0.71	AP	2.91
Maintenance	Toluene	4.77	Lighting	44.77	EMFs	27.93	AP	114.77

1. Toluene, Ethylbenzene, Xylenes

Table 6: Average of calculated HARPI in all scope of study

Harmful agents	*ER*	*HR*	*Wfi*	*HARPI*
Noise	4	5	3.235	71.36
Lighting	5	5	3.205	70.66
EMFs	2	2	1.5	53.96
UV	5	3	1.91	36.90
IR	2	3	1.225	41.72
Heat stress	5	3	2.8	51.67
Analysis posture	4	3	3.785	74.85
Benzene	4	5	2.235	81.30
Toluene	1	3	0.865	10.25
Ethyl benzene	1	3	0.865	11.61
Xylene	1	3	0.865	11.61
Synergic effect (BTEX)	1	5	1.12	15.03
Sulfuric acid	1	4	1	13.42
Hydrochloric acid	2	4	1.415	18.99
Dust	4	1	1	13.42

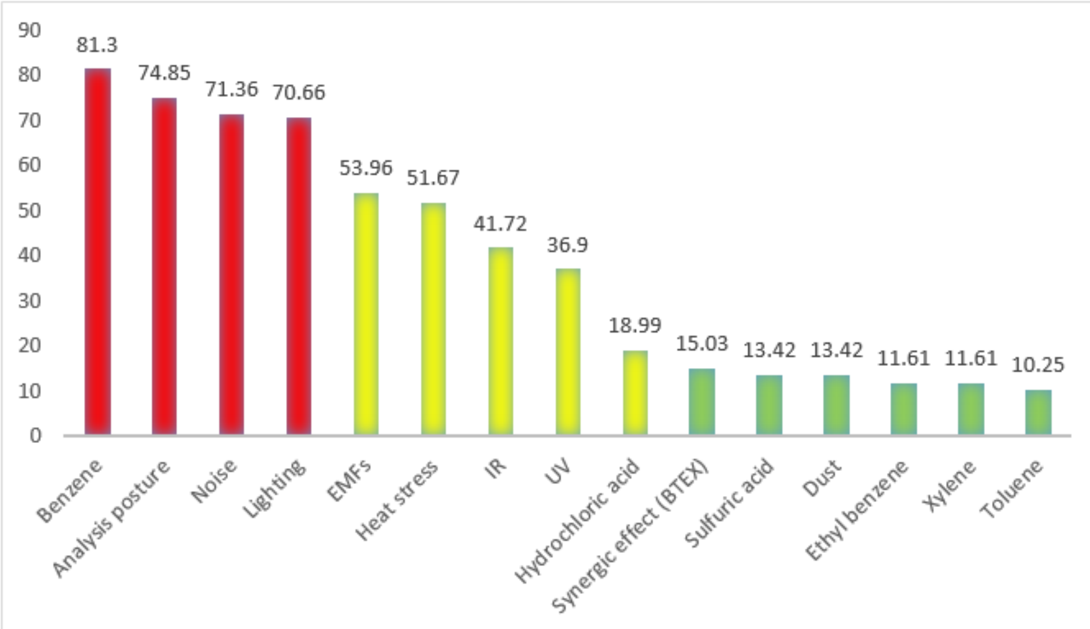

Fig. 2: Calculated HARPI in all scope of study

Discussion

According to Anthony Giddens, we live in a civilization preoccupied with safety, thus emphasizing the concept of "risk." As a result, the risk appears as a pervasive and inescapable reality in modernity. Risks to HSE abound, and the notion of risk and risk-taking are increasingly preoccupying people, governments, organizations, and scientists (23) . This study aimed to provide a comprehensive model that would detect, assess, and prioritize occupational health risks and thereby assist senior management in using the budget to execute the necessary corrective measures in the NAZ oil field. The results revealed that among all administrative department employees of various positions, the highest risk score was for ergonomic risks due to workers' positions while working. This finding was in agreement with another study (7). Moreover, among the harmful factors identified for office workers in each job group, exposure to electromagnetic fields was determined as the factor with the lowest risk (Table 5).

The priorities in the administrative and operational job groups are different. For the HSE group, benzene, the production group, EMFs, and other groups, undesirable lighting has the highest risk score, and exposure to TEX has the lowest risk score (Table 5). In Jahangiri et al.'s study (7), the risk of exposure to benzene was moderate, and the risk of other chemical agents was low. In the present study, the risk of different chemical agents was medium and low, but benzene was identified as the most dangerous factor in the workplace. Based on other implemented research, benzene can cause cancer at low concentrations and a high-risk level (23). This difference in the results is due to the data analysis methods; in the study (7), risk prioritization was calculated based on risk levels frequency. Still, in the proposed model, other influential factors such as exposure time, number of workers exposed, and exposure dose are considered. Table 6 and Fig. 2 reported that workers' ergonomic conditions were identified as a second priority.

According to the WHO statistics, Safarian et al. said musculoskeletal disorders are the second most common work-related disease (24). According to Anagha, one of the most important causes of musculoskeletal disorders among workers is awkward posture (25). Recent statements can confirm the results provided by our proposed model. As mentioned, our proposed model ranked noise as the third priority among the 14 harmful factors studied and as the first factor among the physical agents. This result is consistent with previous statements (Table 6 and Fig. 2).

From a managerial point of view, risk acceptability is significant and of great importance (26).Risk and risk assessments have a long history in making decisions, and human beings have always sought to reduce the rate of exposure to dangers (27). As a result, various risk assessment approaches have many methods for each industry. Therefore, what is essential in adopting a risk assessment method is to simplify the decision-making in the risk management process and focus on a selection of the appropriate corrective actions with the desired effect, assumed benefits at an acceptable cost, and resource savings (12). For example, Multi-Criteria Decision Making (MCDM) approaches provide risk assessment knowledge with their capability to solve real-world problems with multiple, inconsistent, and discrepant criteria (28).

In our proposed model, in addition to the frequency of exposure, we used the most important factors affecting workers' health, including exposure dose and duration of exposure, to determine the priority of risks. The significance and strength of the risk management approach reside in the fact that it consolidates diverse evaluation and discussion techniques, integrates them into a whole, and supplies structure to the decision-making process (29). In Buckingham's theory, dimensionless parameters can be substituted for the main variables (30). In the present study, we used a model (7), to eliminate the unit of parameters and another model (15) to influence the factors affecting health (duration and dose of exposure).

Limitations

The workplace harmful factors are not limited to those mentioned in the present study. Based on the provided model, any known substance with occupational exposure limits (OEL) can be evaluated using Table 2. Among the five main categories of harmful factors in the workplace, psychological and biological factors require specialized methods and have a high cost for sampling and Paraclinical tests. The present study examined the most common elements in the study scope as samples to present the current model.

Conclusion

Among the employees of the administrative department of all job groups, ergonomic risks due to people's posture while working has the highest risk score and is the most critical risk for implementing corrective actions. For the HSE group, benzene, the production group, EMFs, and other groups, undesirable lighting has the highest risk score, and exposure to TEX has the lowest risk score. In our proposed model, in addition to the frequency of exposure, we used the most important factors affecting workers' health, including exposure dose and duration of exposure, to determine the priority of risks. The significance and strength of the risk management approach reside in the fact that it consolidates diverse evaluation and discussion techniques, integrates them into a whole, and supplies structure to the decision-making process. The proposed model can prioritize measuring and evaluating the harmful agents of the workplaces based on the health risk score (HARPI score) due to exposure to chemicals, physical factors, and analysis posture. By developing the ER and HR table, this model can assess semi-quantitative risk in other fields, such as the environment.

Journalism Ethics considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Acknowledgements

This work supported by the Health School, and Neuroscience Research Center, Shahid Beheshti University of Medical Sciences (No:32732).

Conflicts of interest

There is no conflicts of interest

References

1. Kulkarni SJ (2017). Safety and hazards in petroleum industries: research, studies and surveys. *Int J Emerg* Trends *Eng Res,* 3 (1):31-4.
2. Kim EA, Kang SK (2013). Historical review of the List of Occupational Diseases recommended by the International Labour organization (ILO). *Ann Occup Environ Med*, 25 (1):14.
3. Chaiklieng S, Suggaravetsiri P, Autrup H (2019). Risk assessment on benzene exposure among gasoline station workers. *Int J Environ Res Public Health*,16(14):2545.
4. Tak S, Davis RR, Calvert GM (2009). Exposure to hazardous workplace noise and use of hearing protection devices among US workers—NHANES, 1999–2004. *Am J Ind Med*, 52 (5):358-71.
5. Halvani G, Fallah H, Barkhordari A, et al (2010). A Survey of causes of occupational accidents at working place under protection of Yazd Social Security Organization in 2005. *Iran Occupational Health*, 7(3):22-9.
6. Leuenberger A, Farnham A, Azevedo S, et al (2019). Health impact assessment and health equity in sub-Saharan Africa: A scoping review. *Environ Impact Assess Rev*, 79 (2019):106288.
7. Jahangiri M, Abaspour S, Derakhshan Jazari M, et al (2018). Development of comprehensive occupational health risk assessment (COHRA) method: Case study in a petrochemical industry. *Journal of Occupational Hygiene Engineering,* 5 (3):53-62.
8. Gan SL (2019). Importance of hazard identification in risk management. *Ind Health*,57 (3):281-2.
9. Malakoutikhah M, Karimi A, Hoseini M,et al (2017). Survey of the relationship between musculoskeletal disorders and work-family conflict in one of the country's steel industry. *Journal of Occupational Hygiene Engineering,* 4 (1):10-7.
10. Gul M (2018). A review of occupational health and safety risk assessment approaches based on multi-criteria decision-making methods and their fuzzy versions. *Hum Ecol Risk Assess,* 24 (7):1723-60.
11. Białas A (2016). Cost-benefits aspects in risk management. *Polish Journal of Management Studies,* 14 (1):28-39.
12. Yarmohammadi H, Poursadeghiyan M, Shorabi Y, et al (2016). Risk Assessment in a Wheat Winnowing Factory Based on ET and BA Method. *Journal of Engineering and Applied Sciences,* 11: 334-338.
13. Jahangiri M, Mostafavi A, Choobineh A, et al (2020). Development and validation of hoshra index for occupational safety and health risk assessment in hospitals. *Shiraz E-Medical Journal*, 21 (6):e95357.
14. Heyns S, Dekker K, Ker-Fox J, et al (2021). COE 180701–Review The Current Sami Noise Exposure Limit And Conduct A Study On Vibration Oel In Relation To The Sami. Enterprises at the University of Pretoria, South African. Available from: https://mhsc.org.za/wp-content/uploads/2021/07/Agenda-Item-8.2.1.-Draft-Final-Report-for-project-CoE-180701.pdf
15. Askari A, Golmohammadi R, Alinia A, et al (2021). Study the Impact of Acoustic Barrier on Noise Reduction of Generator Building, Case Study: North.Azadegan Oil Field. *Journal of Occupational Hygiene Engineering*, 8 (3):50-8.
16. Askari A, Abadi ASS, Alinia A, et al (2021). Prioritizing and Providing Sound Pollution Control Strategies at the CPF of North Azadegan Oilfield Project.*Sound & Vibration*,55 (4):329-341.
17. Monazzam MR, Golmohammadi R, Nourollahi M, et al (2011). Assessment and control design for steam vent noise in an oil refinery. *J Res Health Sci*,11(1):14-9.

18. Abdullah KG, Bishop FS, Lubelski D, et al (2012). Radiation exposure to the spine surgeon in lumbar and thoracolumbar fusions with the use of an intraoperative computed tomographic 3-dimensional imaging system. *Spine (Phila Pa 1976)* , 37 (17):E1074-E8.
19. Young MS (2002). Guide to Methodology in Ergonomics: *Designing for Human Use.* 1st ed. CRC Press. Florida, USA.
20. Qutubuddin S, Hebbal S, Kumar A (2013). Ergonomic risk assessment using postural analysis tools in a bus body building unit. *Rev Ind Eng Lett*, 3 (8):10-20.
21. Schenk L, Hansson SO, Rudén C, et al (2008). Occupational exposure limits: A comparative study.*Regul Toxicol Pharmacol*,50(2):261-70.
22. Ashley K, O'Connor PF (2017). NIOSH manual of analytical methods (NMAM), NIOSH, USA. Available from: *https://stacks.cdc.gov/view/cdc/50253/cdc_50253_DS1.pdf*
23. Lin YC, Lai CY, Chu CP (2021). Air pollution diffusion simulation and seasonal spatial risk analysis for industrial areas. *Environ Res*, 194:110693.
24. Safarian MH, Rahmati-Najarkolaei F, Mortezapour A (2019). A comparison of the effects of ergonomic, organization, and education interventions on reducing musculoskeletal disorders in office workers. *Health Scope*, 8(1):e68422.
25. Majdabadi HA, khadri B, Pirposhteh EA, et al (2022). Relationship between the status of occupational health management and job satisfaction among farmers: A health promotion approach. *J Educ Health Promot*,11:390.
26. Dargahi A, Vosoughi Niri M, Zandian H, et al (2023). Determinants of Noncompliance with Health Guidelines Related to COVID-19 in Ardebil, Iran Based on Network Analysis Process. *Health in Emergencies and Disasters Quarterly*, 8 (2):133-144
27. Khandan M, Vosoughi S, Azrah K, et al (2017). Decision making models and human factors: TOPSIS and Ergonomic Behaviors (TOPSISEB). *Management Science Letters*, 7 (2):111–8.
28. Wu HY, Tzeng GH, Chen YH (2009). A fuzzy MCDM approach for evaluating banking performance based on Balanced Scorecard. *Expert Syst Appl,* 36 (6):10135-47.
29. Mahoney JF, Yeralan S (2019). Dimensional analysis. *Procedia Manuf*, 38 (2019):694-701.
30. Cherniak O, Trishch R, Kim N, et al (2020). Quantitative assessment of working conditions in the workplace. *Engineering Management in Production and Services*,12 (2):99-106.