Mini-review DOI: 10.2478/aiht-2022-73-3634

Occupational exposure to BTEX and styrene in West Asian countries: a brief review of current state and limits

Razzagh Rahimpoor[1], Fatemeh Sarvi[2], Samira Rahimnejad[3], and Seyed Mohammad Ebrahimi[4]

[1] Larestan University of Medical Sciences Faculty of Evaz Health, Department of Occupational Health Engineering, Research Center for Health Sciences, Larestan, Iran
[2] Larestan University of Medical Sciences, School of Health, Department of Public Health, Larestan, Iran
[3] Kurdistan University of Medical Sciences Faculty of Health, Department of Occupational Health Engineering, Sanandaj, Iran
[4] Ahvaz Jundishapur University of Medical Sciences, Pharmacy School, Department of Toxicology, Ahvaz, Iran

[Received in February 2022; Similarity Check in February 2022; Accepted in June 2022]

The aim of introducing occupational exposure limits (OELs) is to use them as a risk management tool in order to protect workers' health and well-being against harmful agents at the workplace. In this review we identify OELs for benzene, toluene, ethylbenzene, xylene (BTEX), and styrene concentrations in air and assess occupational exposure to these compounds through a systematic literature search of publications published in West Asian countries from 1980 to 2021. OELs for BTEX and styrene have been set in Iran and Turkey to levels similar to those in European countries and the US. The search yielded 49 full-text articles that cover studies of exposure assessment in six countries, but most (n=40) regard Iran. Average occupational exposure to benzene of workers in oil-related industries is higher than recommended OEL, while average occupational exposure to other compounds is lower than local OELs (where they exist). Currently, information about levels of occupational exposure to BTEX and styrene is insufficient in West Asian countries, which should be remedied through OEL regulation and application. Furthermore, coherent research is also needed to determine actual levels of occupational exposure, dose-responses, and the economic and technical capacity of local industries to address current issues.

KEY WORDS: benzene; ethylbenzene; OEL, oil industry; risk management; toluene; xylene

As far as national income is concerned, West Asian countries vary largely, spanning from low- to high-income. Over the last hundred years, some of them have made great strides in development thanks to oil resources. Oil and gas-related industries are the leading sources of uncontrolled hydrocarbon emissions, including volatile organic compounds (VOCs), aldehydes, alkenes, and phenols and present increased health risks for workers in oil-related industries (1, 2). Chronic occupational exposure to these compounds can lead to various adverse health effects and place considerable pressure on already high global burden of diseases (3).

This in particular concerns highly volatile, non-methane, and aromatic hydrocarbons benzene, toluene, ethylbenzene, xylene (BTEX), and styrene, which are extracted from petroleum and used in petroleum and chemical industries (4, 5). These compounds are released during various industrial processes and are quickly absorbed by workers through inhalation and skin (6–11), which can, in turn, lead to neurological, psychological, developmental, liver, and respiratory adverse effects, lung cancer and leukaemia (11–14).

Increased awareness of health hazards of exposure has led to the introduction of occupational exposure limits (OELs), first in Germany in 1877 and then in the USA in 1910 (15). In the 1940s, the American Conference of Governmental Industrial Hygienists (ACGIH) proposed the threshold limit values (TLVs) (16, 17) and other countries or organizations gradually followed suit with their own OELs to protect the health and well-being of workers and ensure effective risk management strategies (18).

This, however, resulted in uneven standards between countries, so that we now distinguish those "health-based" from those that are adjusted to technical and economic considerations (18, 19).

West Asian countries have used various methodologies to regulate their own OELs. In Iran, the legal authority for OELs is the Centre for Environmental and Occupational Hygiene at the Ministry of Health and it has relied on the ACGIH TLVs in setting the OELs.

The objectives of this review were threefold: 1) to identify available data about exposure to airborne BTEX and styrene at workplaces in West Asian countries, 2) to relate these data to applicable OELs, and 3) to identify research needs for the development of new regulations concerning OELs for chemical pollutants in West Asian countries.

Corresponding author: Seyed Mohammad Ebrahimi, Ahvaz Jundishapur University of Medical Sciences, Pharmacy School, Department of Toxicology, Ahvaz, Iran, E-mail: *smebrahimi67@gmail.com*, ORCID: 0000-0002-2656-7860

METHODS

Compiling OELs for West Asian countries

To get as complete coverage of current OELs across the countries in West Asia, we compiled available information from the GESTIS database and online searches for OEL lists from West Asian countries. The European Chemicals Agency (ECHA) webpage was searched for recent EU level recommendations and derived no-effect levels (DNELs) based on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation (20). Scientific documentation about OELs from the US ACGIH, German maximum workplace concentrations (MAK), Scientific Committee on Occupational Exposure Limits (SCOEL) and ECHA Committee for Risk Assessment (RAC) were compiled and reviewed for information on critical effects, skin notation, carcinogen classifications, and biological monitoring guidance values.

Systematic literature searches for occupational exposure data

We systematically searched international datasets including PubMed, Scopus, Cochrane Library, CINAHL, ISI Web of Science, ScienceDirect, PROSPERO, and EMBASE to identify articles in English related to occupational exposure to BTEX and styrene in West Asian countries and published between 1980 and 2021. For this purpose, we used several combinations of the key words (benzene, toluene, ethylbenzene, xylene, styrene, occupational exposure, industrial exposure, threshold limit value, occupational exposure limit, recommended exposure level, permissible exposure limit, West Asia, and Middle East) and search criteria, including language and publication year (Table 1).

Study selection

First we identified 4199 references that matched our search key terms. Figure 1 shows how we proceeded until we got the final number of 49 full-text articles that met the inclusion criteria: they all had to be original articles in English reporting airborne workplace concentrations of the studied chemicals from 1980 to 2021. We excluded articles not containing original data, such as review articles, case series, and case reports. Each included article was individually assessed for completeness of reporting by two independent reviewers according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist (21).

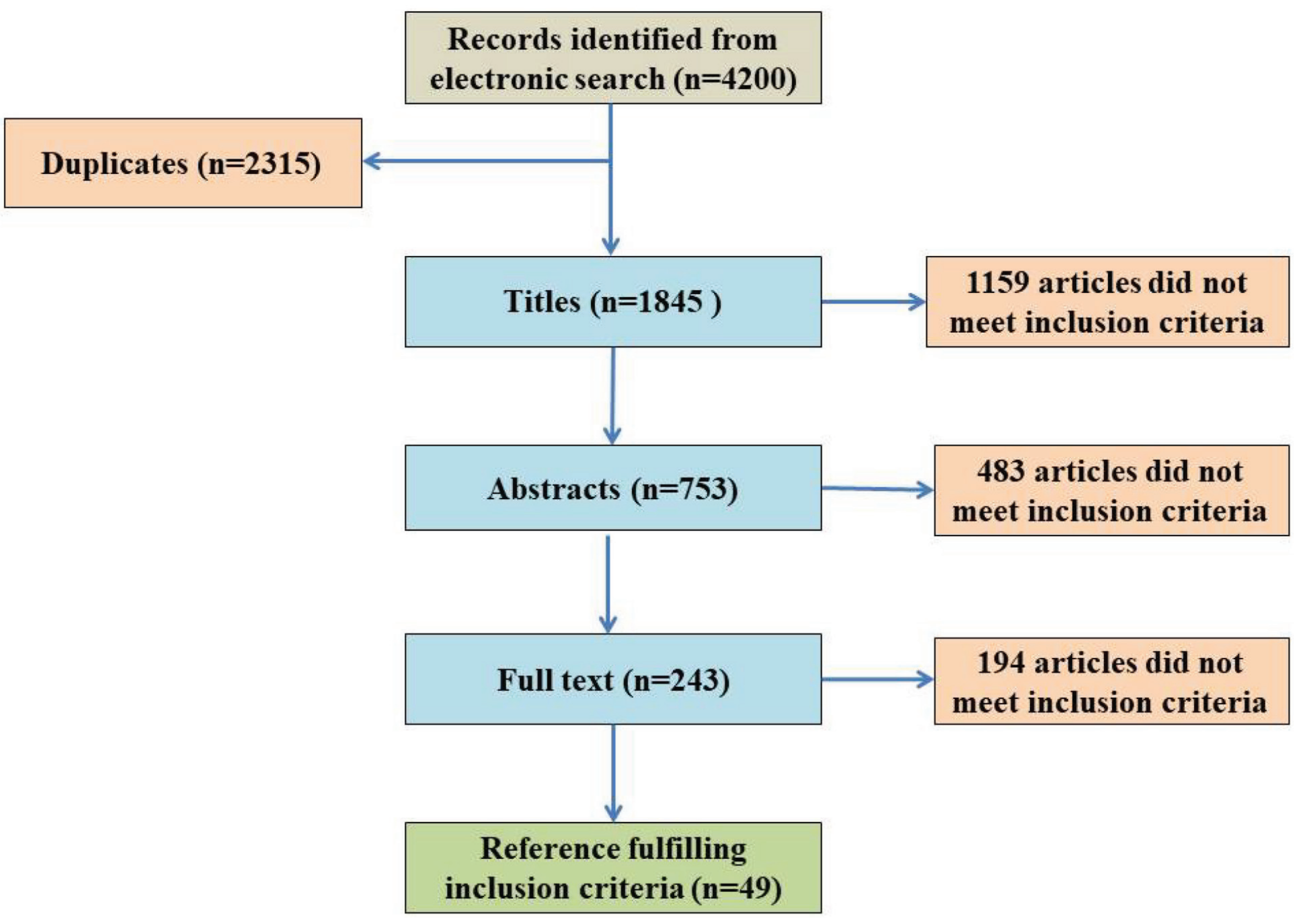

Figure 1 Search steps to identify full-text articles about occupational exposure in West Asian countries

Table 1 Search strategy for articles on occupational exposure to BTEX and styrene across major literature databases (slight differences in search strings are owed to different functionality of these systems)

Web of Science	(**TS**=(Benzene OR Toluene OR Ethylbenzene OR Xylenes OR Styrene OR Volatile Organic compound) **AND** TS=(Occupational exposure OR Industrial exposure OR Workplace exposure OR Chemical exposure) **AND** TS=(Threshold limit value OR Occupational exposure limit OR Recommended exposure level OR Permissible exposure limit) **AND** TS= (West Asia OR Middle east OR Iran OR Iraq OR Kuwait OR Syria OR Jordan OR Bahrain OR Lebanon OR Oman OR Qatar OR Saudi Arabia OR Afghanistan, Armenia OR Azerbaijan OR Yemen OR Israel OR Turkey OR Palestine) **AND** LANGUAGE: (English) Indexes=SCI-EXPANDED, SSCI, **AND** Time span=1980-2021
Scopus	**TITLE-ABS-KEY** (Benzene OR Toluene OR Ethylbenzene OR Xylenes OR Styrene) **AND TITLE-ABS-KEY** (Occupational exposure OR Industrial exposure OR Workplace exposure OR Chemical exposure) **AND TITLE-ABS-KEY** (Threshold limit value OR Occupational exposure limit OR Recommended exposure level OR Permissible exposure limit) **AND TITLE-ABS-KEY** (West Asia OR Middle East OR Iran OR Afghanistan, Armenia OR Azerbaijan OR Yemen OR Israel OR Turkey OR Arab countries, Gulf Cooperation Council countries) **AND** PUBYEAR ≥ 1980
PubMed	(Benzene [Title/Abstract] OR Toluene [Title/Abstract] OR Ethylbenzene [Title/Abstract] OR Xylenes [Title/Abstract] OR Styrene [Title/Abstract] OR Volatile Organic compound [Title/Abstract]) **AND** (Occupational exposure [Title/Abstract] OR Industrial exposure [Title/Abstract] OR Workplace exposure [Title/Abstract] OR Chemical exposure [Title/Abstract]) **AND** (Threshold limit value [Title/Abstract] OR Occupational exposure limit [Title/Abstract] OR Recommended exposure level [Title/Abstract] OR Permissible exposure limit [Title/Abstract]) **AND** (West Asia [All Fields] OR Middle East [All Fields] OR Iran [All Fields] OR Iraq [All Fields] OR Kuwait [All Fields] OR Syria [All Fields] OR Jordan [All Fields] OR Bahrain [All Fields] OR Lebanon [All Fields] OR Oman [All Fields] OR Qatar [All Fields] OR Saudi Arabia [All Fields] OR [All Fields] Afghanistan [All Fields], Armenia [All Fields] OR Azerbaijan [All Fields] OR Yemen [All Fields] OR Israel [All Fields] OR Turkey [All Fields] OR Palestine [All Fields]) Filters: from 1980/1/1 - 2020/6/30
Cochrane Library	(Benzene [Title Abstract Keywords] OR Toluene [Title Abstract Keywords] OR Ethylbenzene [Title Abstract Keywords] OR Xylenes [Title Abstract Keywords] OR Styrene [Title Abstract Keywords] OR Volatile Organic compound [Title/Abstract]) **AND** (Occupational exposure [Title Abstract Keywords] OR Industrial exposure [Title Abstract Keywords] OR Workplace exposure [Title Abstract Keywords] OR Chemical exposure [Title Abstract Keywords]) **AND** (Threshold limit value [Title Abstract Keywords] OR Occupational exposure limit [Title Abstract Keywords] OR Recommended exposure level [Title Abstract Keywords] OR Permissible exposure limit [Title Abstract Keywords]) **AND** (West Asia [Title Abstract Keywords] OR Middle East [Title Abstract Keywords] OR Iran [Title Abstract Keywords] OR Afghanistan [Title Abstract Keywords], Armenia [Title Abstract Keywords] OR Azerbaijan [Title Abstract Keywords] OR Yemen [Title Abstract Keywords] OR Israel [Title Abstract Keywords] OR Turkey [Title Abstract Keywords] OR Arab countries [Title Abstract Keywords], Gulf Cooperation Council countries [Title Abstract Keywords]) Filters: from 1980/1/1 - 2020/6/30
CINAHL (EBSCO)	(Benzene [Title/Abstract] OR Toluene [Title/Abstract] OR Ethylbenzene [Title/Abstract] OR Xylenes [Title/Abstract] OR Styrene [Title/Abstract] OR Volatile Organic compound [Title/Abstract]) **AND** (Occupational exposure [Title/Abstract] OR Industrial exposure [Title/Abstract] OR Workplace exposure [Title/Abstract] OR Chemical exposure [Title/Abstract]) **AND** (Threshold limit value [Title/Abstract] OR Occupational exposure limit [Title/Abstract] OR Recommended exposure level [Title/Abstract] OR Permissible exposure limit [Title/Abstract]) **AND** (West Asia [All Fields] OR Middle East [All Fields] OR Iran [All Fields] OR Iraq [All Fields] OR Kuwait [All Fields] OR Syria [All Fields] OR Jordan [All Fields] OR Bahrain [All Fields] OR Lebanon [All Fields] OR Oman [All Fields] OR Qatar [All Fields] OR Saudi Arabia [All Fields] OR [All Fields] Afghanistan [All Fields], Armenia [All Fields] OR Azerbaijan [All Fields] OR Yemen [All Fields] OR Israel [All Fields] OR Turkey [All Fields] OR Palestine [All Fields]) Filters: from 1980/1/1 - 2020/6/30
EMBASE	**TITLE-ABS-KEY** (Benzene OR Toluene OR Ethylbenzene OR Xylenes OR Styrene OR Volatile Organic compound) **AND TITLE-ABS-KEY** (Occupational exposure OR Industrial exposure OR Workplace exposure OR Chemical exposure) **AND TITLE-ABS-KEY** (Threshold limit value OR TLV OR Occupational exposure limit OR OEL OR Recommended exposure level OR REL OR Permissible exposure limit OR PEL) **AND TITLE-ABS-KEY** (West Asia OR Middle East OR Iran OR Iraq OR Kuwait OR Syria OR Jordan OR Bahrain OR Lebanon OR Oman OR Qatar OR Saudi Arabia OR Afghanistan, Armenia OR Azerbaijan OR Yemen OR Israel OR Turkey OR Palestine) **AND** PUB YEAR ≥ 1980
Science direct from inception	**TITLE-ABS-KEY** (Benzene OR Toluene OR Ethylbenzene OR Xylenes OR Styrene OR Volatile Organic compound) **AND TITLE-ABS-KEY** (Occupational exposure OR Industrial exposure OR Workplace exposure OR Chemical exposure) **AND TITLE-ABS-KEY** (Threshold limit value OR TLV OR Occupational exposure limit OR OEL OR Recommended exposure level OR REL OR Permissible exposure limit OR PEL) **AND TITLE-ABS-KEY** (West Asia OR Middle East OR Iran OR Iraq OR Kuwait OR Syria OR Jordan OR Bahrain OR Lebanon OR Oman OR Qatar OR Saudi Arabia OR Afghanistan, Armenia OR Azerbaijan OR Yemen OR Israel OR Turkey OR Palestine) **AND** PUB YEAR ≥ 1980

MESH terms in PubMed and Cochrane including: benzene, toluene, ethylbenzene, VOCs, occupational exposure, occupations, occupational groups, Asia western, oil and gas industry, threshold limit values

Both static and personal monitoring studies were included. Quality of sampling was considered sufficient if sampling pump flow rate was between 0.1 and 0.3 L/min, and in case of static monitoring if samplers were placed at the height of 1.5 to 2 m.

Data extraction

After the screening, the data were extracted and cross-checked. Any inconsistencies were resolved by consultation with a third reviewer. The following information was extracted and tabulated: bibliographic information (reference ID, authors, year published, publication type), country where study was performed, industry sector, type of sampling (static or personal monitoring), type of sampler (active/pump or passive sampling), number of exposed workers and non-exposed workers (not applicable to static monitoring), number of area samples (not applicable to personal monitoring), number of individual samples (may be more than one per worker or area), duration of sampling, gender distribution (male/female; not applicable to static monitoring), mean and standard deviation of age (of exposed and unexposed groups, not applicable to static monitoring), means and standard deviations of BTEX and styrene concentrations across all sections of investigated workplace, and, if applicable, range of means for subsections of investigated workplace and whether the reported concentrations were recalculated to represent the eight-hour (workday) exposure scenario (where the workday was shorter than 8 h).

All reported airborne concentrations were converted to ppm, using the following equation:

$$ppm = \frac{mg/m^3 \times 24.45}{molecular\ weight} \qquad [Equation\ 1]$$

This assumes 25 °C and air pressure of 101.325 kPa (760 Torr).

Data analysis

Descriptive results of variables are given as means and standard deviations. For all analyses we used the Statistical Package for Social Sciences (SPSS), version 22 (IBM, Armonk, NY, USA).

Evaluating compliance with an OEL requires assessment of exposure variability for an exposed group. There is also a normative aspect, that is, how certain we wish to be that exposure is unlikely to be exceeded for a small part of the exposed group and how small that group should be. Industrial hygiene guidance documents refer to 70 % certainty that no more than 5 % of similarly exposed workers would experience exposures exceeding the OEL (22, 23). We, however, approached OEL compliance in a simpler fashion, by comparing reported average exposure to the applicable OEL, as the reviewed papers do not report their results in sufficient detail. As airborne exposures are generally log-normally distributed, the arithmetic mean will be a slightly more conservative than the true central estimates of the median or geometric mean. Where reported, we also compared the full range (min–max) of reported exposure to applicable OELs.

RESULTS

Overview of OELs

Benzene is a well-known carcinogen, although conclusions as to whether its mechanism of action supports a threshold or not differs between OEL expert groups. However, more recent assessments tend to conclude that benzene can be viewed as a threshold carcinogen, and consequently that sufficiently low exposures would protect against cancer risk. Most eight-hour time-weighted averages (TWA) for OELs are 1.6 mg/m^3 (0.5 ppm) while the most recent recommendation of ECHA RAC is that of 0.16 mg/m^3 (0.05 ppm) (Table 2).

Carcinogenicity is generally not considered critical for the other substances. However, the International Agency for Research on Cancer (IARC) has classified ethylbenzene as possibly carcinogenic to humans (group 2B) and styrene as probably carcinogenic to humans (group 2A). All of the reviewed substances are potentially neurotoxic, and most of the OELs for toluene, xylene, and styrene take into account some form of neurotoxicity and irritation as critical effects. Assignment of skin notation varies: ACGIH has a skin notation only for benzene, whereas the German MAK commission and SCOEL have assigned skin notations to all BTEX substances but not to styrene. All the substances have several biological guidance values, mostly in urine.

Overview of occupational exposure to BTEX and styrene in West Asian countries

Our review of the 49 full-text articles shows that occupational exposure levels to BTEX and styrene in West Asian countries have not been measured and reported in a structured or uniform manner, and that most reports refer to Iran. Furthermore, studies investigating occupational exposure to styrene are few and far between. The summary of the extracted data is available in Table 3 (24–65). Most studies address exposure in oil-related industries (such as petrochemical, oil refineries, petrol and compressed natural gas stations, and petroleum depots), while the rest looks into exposure in the shoe factories, plastic industries, pesticides production factories, printing, electronics, or steel industries or among beauty salon workers, drivers, and traffic policemen. Average occupational exposure to benzene in oil-related industries is higher than the OELs recommended in Table 2. As shown in Table 4, the mean air concentrations of toluene, ethylbenzene, xylene isomers, and styrene reported by most studies are lower than the recommended OELs for the same country (if any, see Table 2).

Table 4 shows the analysis of reported occupational exposure to BTEX and styrene narrowed down to oil-related and solvent-related industries (such as shoe factories, printing, electronics, automobile industry, pesticide production factory, tyre factories, steel industries, chemical industry, plastic industry, and beauty salons).

Table 2 Comparison of existing OELs and DNELs of BTEX and styrene by institutions and countries

Institution or country	Benzene		Toluene		Ethylbenzene		Xylene (isomers)		Styrene	
	mg/m³	ppm	mg/m³	ppm	mg/m³	ppm	mg/m³	ppm	mg/m³	ppm
ACGIH, USA	1.6	0.5	75.37	20	86.84	20	434.19	100	85.19	20
OSHA, USA	3.19	1	376.85	100	434.22	100	434.19	100	212.99	50
NIOSH, USA	0.32	0.1	753.7	200	434.22	100	434.19	100	425.97	100
Australia	3.19	1	188.43	50	434.22	100	347.35	80	212.99 (monomer)	50 (monomer)
Brazil	-	-	293.94	78	338.69	78	338.67	78	-	-
Canada	1.6	0.5	75.37	20	86.84	20	434.19	100	149.09 (monomer)	35 (monomer)
Japan	3.19	1	188.43	50	86.84	20	217.1	50	85.19	20
South Korea	3.19	1								
MAK, Germany	-	-	188.43	50	86.84	20	217.1	50	85.19	20
AGS, Germany	1.92 (0.19*)	0.6 (0.06*)	-	-	-	-	-	-	-	-
Netherlands	0.7	0.22	150.74	40	214.07	49.3	217.1	50		
Poland	1.6	0.5	99.87	26.5	198.87	45.8	99.86	23	49.84	11.7
United Kingdom	3.19	1	188.43	50	434.22	100	217.1	50	425.97	100
European Union	0.32	0.1	188.43	50	434.22	100	217.1	50	-	-
REACH RAC	0.16	0.05	-	-	-	-	-	-	-	-
REACH DNELs**	0.8	0.25	192	50	77	100	221	50	85	23.5
Iran	1.6	0.5	75.37	20	86.84	20	434.19	100	85.19	20
Turkey	0.32	0.1	188.43	50	434.22	100	217.1	50	-	-

***** Value corresponding to the proposed tolerable cancer risk, 4:1000 (value corresponding to the proposed preliminary acceptable cancer risk, 4:10000). ****** DNELs – derived no-effect levels for workers with long-term inhalation exposure submitted by registrants (available at: https://echa.europa.eu/information-on-chemicals/registered-substances); values calculated to ppm by authors. ACGIH – American Conference of Governmental Industrial Hygienists; AGS – German Committee on Hazardous Substances (Ausschuss für Gefahrstoffe); MAK – German maximum workplace concentrations; NIOSH – National Institute for Occupational Safety and Health; OSHA – Occupational Safety and Health Administration; RAC – Committee for Risk Assessment; REACH – Registration, Evaluation, Authorisation and Restriction of Chemicals

DISCUSSION

Our research shows that occupational exposure limits have been set only in Iran and Turkey, while other countries, even the oil-rich ones of the Persian Gulf, have not set or formally proposed any (Table 4).

Oil and gas industry is run by some of the largest companies in the world, many of which are based in West Asian countries (66) whose gross domestic product (GDP) and economic development significantly surpass that of other countries in the region. Highly developed industry has attracted migrant workers to the point that they make as much as 48.1 % of the total population of the Gulf Cooperation Council countries (67–70). Yet, despite reports of occupational diseases among migrant workers in West Asian countries (70–72), levels of occupational exposure to BTEX and styrene are poorly reported.

OELs recommended by different organisations and countries are mostly the product of current scientific knowledge and reflect scientific judgment of those researchers who develop them and they should be reviewed periodically as this scientific knowledge grows (18, 73–75). Furthermore, it is necessary to assess and record new hypotheses, data, and methods used, as this guarantees the validity of the proposed OELs. Current scientific data and hypotheses used in regulating OELs of chemical compounds are ambiguous or completely unavailable in some countries (76, 77).

However, OEL regulations are not only evidence-based in terms of determining threshold exposure dose without adverse health effects. They also take into account economic and technical capability of the country that is to apply them (78), even though feasibility issues of achieving exposure lower than OELs should not drive decision making. Instead, industrial managers and health experts should be encouraged to lower occupational exposure below science-based limits through effective engineering control, replacement of production sore spots, administrative management control, separation, elimination, or personal protective equipment (PPE) as needed (18, 79).

Currently, however, data needed to accurately assess the risk of occupational exposure to BTEX and styrene are scarce. This

Table 3 Summary of occupational exposure to BTEX and styrene in West Asian countries from data gathered from 49 published articles between 1999 and 2021 (mean ± SD)

References	Publication type	Country	Type of sampling	Industry or workplace	Number of workers (exposed vs unexposed)	Concentration (ppm) Mean ± SD				
						Benzene	Toluene	Ethylbenzene	Xylene	Styrene
(Alabdulhadi et al., 2019) (24)	Cross-sectional	Kuwait	Static	Printing industry	-	0.0028±0.076	0.062±0.101	0.118±0.071	0.311±0.174	-
(Alfoldy et al., 2019) (25)	Cross-sectional	Qatar	Static	Traffic police, Petrochemical	-	0.038±0.025	0.07±0.05	0.007±0.009	0.009±0.007	-
(Al-Harbi et al., 2020) (7)	Cross-sectional	Kuwait	Static	Gasoline station	-	0.23±0.062	0.144±0.07	0.085±0.07	0.16±0.12	-
(Azari et al., 2012) (26)	Cross-sectional	Iran	Personal	Shoe factory	12 (12:0)	**1.33±0.11**[*,#]	14.24±1.77	-	-	-
(Baghani et al., 2018) (27)	Cross-sectional	Iran	Static	Beauty salon	-	0.01±0.009	0.0045±0.0041	0.0143±0.007	0.0031±0.002	-
(Baghani et al., 2019) (28)	Cross-sectional	Iran	Static	Gas & CNG station	-	0.145±0.045	0.231±0.053	0.113±0.031	0.209±0.016	-
(Bahrami et al., 2007) (29)	Cross-sectional	Iran	Personal	Petrol station	145 (80:65)	**1.41±0.80**[*,#]	-	-	-	-
(Bakhtiari et al., 2018) (30)	Cross-sectional	Iran	Static	Taxi driver	-	0.088±0.008	0.088±0.011	0.073±0.009	0.126±0.015	-
(BakoIlu et al., 2004) (31)	Cross-sectional	Turkey	Static	Waste Incinerator	-	**1.33±0.08**[*,#]	0.051±0.003	0.015±0.03	0.041±0.08	0.0057
(Dehghani et al., 2020) (32)	Cohort	Iran	Personal	Steel factory	372 (372:0)	**2.17±0.11**[*,#]	4.08±3.25	0.32±1.39	1.38±1.35	-
(El-Hashemy and Ali, 2018) (33)	Cross-sectional	Saudi Arabia	Static	Printing and copy centre	-	0.0067±0.002	0.253±0.032	0.022±0.005	0.73±0.005	-
(Farshad et al., 2014) (34)	Cross-sectional	Iran	Static	Waste disposal in hospital	-	**0.57±0.1**[*,#]	1.23±1.1	1.18±1.2	0.58±0.6	-
(Golbabaei et al., 2018) (35)	Cross-sectional	Iran	Personal	Automobile Industry	40 (36:4)	**0.96±0.05**[*,#]	0.28±0.08	2±0.2	3.02±0.08	-
(Golkhorshidi et al., 2019) (36)	Cross-sectional	Iran	Static	Bus driver: terminal	-	0.108±0.001	0.235±0.002	0.188±0.001	0.304±0.06	-
(Hadei et al., 2018) (37)	Case-control	Iran	Static	Beauty salon	-	0.0034±0.002	0.0026±0.0018	0.0054±0.004	0.0043±0.006	-
(Harati et al., 2018) (38)	Case-control	Iran	Personal	Automobile Industry	80 (40:40)	**0.775±0.12**[*,#]	1.2±2.08	45.8±8.5	42.5±23.9	-
(Harati et al., 2020) (39)	Cross-sectional	Iran	Personal	Petrochemical industry	50 (50:0)	**2.12±0.95**[*,#]	9.84±2.53	-	11.87±4.44	-
(Heibati et al., 2018) (4)	Cross-sectional	Iran	Personal	Petroleum transfer station	50 (50:0)	**2.7±2.91**[*,#]	4.07±3.65	0.535±0.412	0.752±0.812	-
(Hormozi et al., 2019) (9)	Case-control	Iran	Personal	Printing industry	84 (44:40)	-	**37.64±24.09**[*,#]	-	**105±20.05**[*,#]	-

References	Publication type	Country	Type of sampling	Industry or workplace	Number of workers (exposed vs unexposed)	Concentration (ppm) Mean ± SD				
						Benzene	Toluene	Ethylbenzene	Xylene	Styrene
(Hosseini et al., 2015) (40)	Cross-sectional	Iran	Personal	Tyre Factory	100 (100:0)	**1.88±1.37**$^{*,\#}$	3.2±2.79	-	-	-
(Jalai et al., 2017) (10)	Cross-sectional	Iran	Personal	Chemical industry & police officer	260 (185:75)	**1.56±0.34**$^{*,\#}$	-	-.	-	-
(Javadi et al., 2017) (41)	Cross-sectional	Iran	Personal	Petrol station	24 (24:0)	**0.56±0.102**$^{*,\#}$	0.242±0.033	0.223±0.041	0.109±0.025	-
(Karbasi et al., 2020) (42)	Cross-sectional	Iran	Personal	Oil pit worker	40 (40:0)	**0.82±0.38**$^{*,\#}$	-	-	-	-
(Maghsodi Moghadam et al., 2013) (43)	Cross-sectional	Iran	Personal	Petrochemical industry	204 (204:0)	**2.0±8.3**$^{*,\#}$	0.27±0.50	0.16±0.59	0.8±2.7	-
(Mohamadyan et al., 2019) (44)	Cross-sectional	Iran	Personal	Plastic industry	53 (53:0)	-	-	-	-	19.56±9.03
(Mohammadyan and Baharfar, 2015) (45)	Cross-sectional	Iran	Personal	Pesticide production factory	100 (100:0)	-	-.	-.	4.7±5.5	-
(Mohammadyan et al., 2019) (46)	Cross-sectional	Iran	Personal	Electronic industry	59 (59:0)	-	-	-	-	18.68±5.68
(Moradi et al., 2019) (47)	Case-control	Iran	Personal	Beauty salon	72 (36:36)	0.015±0.019	0.31±0.36	0.017±0.021	0.055±0.051	-
(Moradpour et al., 2017) (48)	Cross-sectional	Iran	Personal	Petrochemical industry	358 (358:0)	**1.08±1.46**$^{*,\#}$	9.19±1.68	11.56±2.94	8.88±2.46	8.45±8.29
(Moshiran et al., 2021) (49)	Cross-sectional	Iran	Personal	Petrochemical industry	50 (50:0)	-	-	-	-	0.455±0.392
(Moslem et al., 2020) (50)	Cross-sectional	Iran	Static	Surgery room	-	0.003±0.0005	0.002±0.0004	0.004±0.0006	0.001±0.0003	-
(Nabizadeh et al., 2020) (51)	Cross-sectional	Iran	Static	Paper recycling	-	0.27±0.01	0.28±0.01	0.151±0.02	1.7±0.007	-
(Nassiri and Golbabai, 1999) (52)	Cross-sectional	Iran	Personal	Paint industry	54 (54:0)	-	11.2±7.3	-.	20.2±4.1	-
(Nazarparvar-Noshadi et al., 2021) (11)	Cross-sectional	Iran	Personal	Tyre factory	38 (38:0)	**2.306±2.63**$^{*,\#}$	8.65±7.7	0.07±0.09	0.10±0.14	0.07±0.08
(Neghab et al., 2015) (12)	Cross-sectional	Iran	Personal	Petrol station	60 (60:0)	0.25±0.083	0.39±0.071	-	0.69±0.36	-
(Omidi et al., 2019) (53)	Cross-sectional	Iran	Personal	Poultry slaughterhouse	20 (20:0)	**1.34±0.75**$^{*,\#}$	3.65±1.12	15.4±0.68	-	-
(Partovi et al., 2018) (54)	Cross-sectional	Israel	Personal	Petrol station	258 (258:0)	**0.41±0.18**$^{*,\#}$	-	-	-	-

References	Publication type	Country	Type of sampling	Industry or workplace	Number of workers (exposed vs unexposed)	Concentration (ppm) Mean ± SD				
						Benzene	Toluene	Ethylbenzene	Xylene	Styrene
(Rahimpoor et al., 2014) (1)	Cross-sectional	Iran	Personal	Petrochemical industry	104 (104:0)	**1.19±0.63**$^{*,\#}$	1.3±4.74	-	3.2±7.94	-
(Rahimpour et al., 2018) (55)	Cross-sectional	Iran	Personal	Petrochemical and petroleum depot industry	84 (84:0)	**0.657±0.791**$^{*,\#}$	12.42±5.95	-	32.24±22.1	-
(Ramadan, 2010) (56)	Cross-sectional	Kuwait	Static	Police officer	-	0.004±0.001	0.01±0.008	0.0026±0.003	0.0138±0.008	-
(Rashnuodi et al., 2021) (57)	Cross-sectional	Iran	Personal	Petrochemical industry	30 (30:0)	**1.28±2.10**$^{*,\#}$	2.62±4.50	4.45±7.35	2.41±1.07	-
(Rezazadeh Azari et al., 2012) (58)	Case-control	Iran	Personal	Petroleum depot industry	78 (46:32)	**1.63±3.92**$^{*,\#}$	2.72±19.33	0.46±1.61	3.53±10.84	-
(Rostami et al., 2021) (59)	Cross-sectional	Iran	Personal	Printing and copy centre	136 (136:0)	0.029±0.019	0.039±0.026	0.007±0.0038	0.006±0.003	-
(Salama et al., 2020) (60)	Cross-sectional	Saudi Arabia	Static	Petrol station	-	**11.7±3.1***	4.09±1.09	-	3.97±2.25	-
(Salehpour et al., 2019) (61)	Cross-sectional	Iran	Personal	Petrochemical industry	80 (40:40)	**1.03±1.40**$^{*,\#}$	5.6±13.66	-	8.19±22.20	3.48±10.75
(Sarkhosh et al., 2012) (62)	Cross-sectional	Iran	Static	Printing and copy centre	-	0.0257±0.029	0.0713±0.0328	0.0083±0.056	0.0063±0.024	0.0316±0.0352
(Shanh et al., 2017) (63)	Cross-sectional	Iran	Personal	Petrochemical industry	169 (169:0)	**1.25±2.28**$^{*,\#}$	1.21±4.17	2.975±6.125	3.6±4.32	1.97±3.01
(Yaghmaien et al., 2019) (64)	Cross-sectional	Iran	Personal	Landfill plant	-	0.009±0.005	0.011±0.006	0.014±0.009	0.024±0.014	-
(Zoleikha et al., 2017) (65)	Cross-sectional	Iran	Personal	Petrol station	15 (15:0)	**1.28±0.447**$^{*,\#}$	0.337±0.71	0.124±0.13	0.092±0.012	-

* above ACGIH OELs (benzene 0.5 ppm; toluene 20 ppm; ethylbenzene 20 ppm; xylene 100 ppm; styrene 20 ppm). $^{\#}$above national OELs. SD – standard deviation

Table 4 Occupational exposure to BTEX and styrene reported for oil-related and solvent-related professions in West Asian countries (mean ± SD, where available)

Country	National OELs	Industry	Benzene (ppm)	Toluene (ppm)	Ethylbenzene (ppm)	Xylenes (ppm)	Styrene (ppm)
Qatar	No	Oil-related	0.39	7.02	0.75	0.32	-
		Solvent-related	0.004	0.012	0.0046	0.016	-
Kuwait	No	Oil-related	0.23	0.144	0.085	0.16	-
		Solvent-related	0.003±0.038	0.03±0.05	0.0063±0.03	0.162±0.09	-
Iran	Yes	Oil-related	**1.165±0.69*,#**	5.87±8.18	2.28±8.93	12.104±17.7	3.588±4.52
		Solvent-related	**0.785±0.49*,#**	4.53±4.01	4.34±5.11	10.56±12.28	9.585±3.70
Turkey	Yes (except for styrene)	Oil-related	**1.33*,#**	0.051	0.015	0.041	0.0057
		Solvent-related	-	-	-	-	-
Saudi Arabia	No	Oil-related	**11.7***	4.09	-	3.97	-
		Solvent-related	0.0067	0.253	0.022	0.73	-
Israel	No	Oil-related	0.41	-	-	-	-
		Solvent-related	-	-	-	-	-

* above ACGIH OELs; # above national OELs; SD – standard deviation

information may be available to authorities and organisations in West Asian countries, which we could not access. To the best of our knowledge, in Iran, biological indicators that could help to accurately evaluate occupational exposure to BTEX and styrene during annual worker examinations are not available. Occupational exposure to chemical pollutants in any industry is not regularly monitored.

Our findings, we believe, point to a large problem with (or rather, lack of) occupational exposure and health monitoring in West Asian countries. What each country urgently needs is to identify its own weaknesses in collecting and reporting data from occupational medical surveillance, in economic and technical capabilities of their industries, and in exposure monitoring and control. In addition to respiratory exposure to BTEX and styrene, future studies should also include skin. There is also a need to study dose-response relationships and combined exposure, including alcohol and smoking. Namely, before OELs are adopted or adjusted, it is important to establish actual exposure and health effects in local workers.

CONCLUSION

For the time being, our results suggest that occupational exposure to benzene may present increased health risk in West Asian countries, whereas exposure to the other compounds is generally lower than the OELs given above. However, these data are random and do not provide a reliable picture of actual exposure in these countries. Given the industrial burden in each of these countries, but most particularly in those with developed oil industry, understanding the current state of exposure and adopting local OELs is crucial to protect the health of a vast number of workers.

Conflict of interests

None to declare.

Acknowledgements

This study was supported by Larestan University of Medical Sciences, Larestan, Iran (grant No. 1400-93). We thank Dr Linda Schenk of the Institute of Environmental Medicine, Karolinska Institutet, Sweden for her expertise and assistance throughout all aspects of our study and for her wonderful collaboration.

REFERENCES

1. Rahimpoor R, Bahrami AR, Ghorbani F, Assari MJ, Negahban AR, Rahimnejad S, Mehdizadegan B. Evaluation of urinary metabolites of volatile organic compounds and some related factors in petrochemical industry workers. J Mazandaran Univ Med Sci 2014;24:119–31.
2. Negahban SAR, Ghorbani Shahna F, Rahimpoor R, Jalali M, Rahiminejad S, Soltanian A, Bahrami A. Evaluating occupational exposure to carcinogenic volatile organic compounds in an oil-dependent chemical industry: a case study on benzen and epichlorohydrin. J Occup Hyg Engin 2014;1(1):36–46.
3. Prüss-Ustün A, Vickers C, Haefliger P, Bertollini R. Knowns and unknowns on burden of disease due to chemicals: a systematic review. Environ Health 2011;10:9. doi: 10.1186/1476-069X-10-9
4. Heibati B, Godri Pollitt KJ, Charati JY, Ducatman A, Shokrzadeh M, Karimi A, Mohammadyan M. Biomonitoring-based exposure assessment of benzene, toluene, ethylbenzene and xylene among workers at petroleum distribution facilities. Ecotoxicol Environ Saf 2018;149:19–25. doi: 10.1016/j.ecoenv.2017.10.070
5. Kuranchie FA, Angnunavuri PN, Attiogbe F, Nerquaye-Tetteh EN. Occupational exposure of benzene, toluene, ethylbenzene and xylene (BTEX) to pump attendants in Ghana: Implications for policy

guidance. Cogent Environ Sci 2019;5(1):1603418. doi: 10.1080/23311843.2019.1603418

6. Tunsaringkarn T, Siriwong W, Rungsiyothin A, Nopparatbundit S. Occupational exposure of gasoline station workers to BTEX compounds in Bangkok, Thailand. Int J Occup Environ Med 2012;3:117–25. PMID: 23022861
7. Al-Harbi M, Alhajri I, AlAwadhi A, Whalen JK. Health symptoms associated with occupational exposure of gasoline station workers to BTEX compounds. Atmosph Environ 2020;241:117847. doi: 10.1016/j.atmosenv.2020.117847
8. Ghanbarian M, Nazmara S, Masinaei M, Ghanbarian M, Mahvi AH. Evaluating the exposure of general population of Tehran with volatile organic compounds (BTEX). Int J Environ Anal Chem 2020:1–11. doi: 10.1080/03067319.2020.1781839
9. Hormozi M, Mirzaei R, Nakhaee A, Payandeh A, Izadi S, Haghighi JD, Rahimpoor R. Quantification of urinary metabolites of toluene and xylene isomers as biological indices of occupational exposure in printing industry workers. Health Scope 2019;8(1):e82962. doi: 10.5812/jhealthscope.82962
10. Jalai A, Ramezani Z, Ebrahim K. Urinary trans, trans-muconic acid is not a reliable biomarker for low-level environmental and occupational benzene exposures. Saf Health Work 2017;8:220–5. doi: 10.1016/j.shaw.2016.09.004
11. Nazarparvar-Noshadi M, Yadegari M, Mohammadian Y, Fakhri Y. The exposure to BTEX/styrene and their health risk in the tire manufacturing. Toxin Rev 2022;41:437–45. doi: 10.1080/15569543.2021.1891937
12. Neghab M, Hosseinzadeh K, Hassanzadeh J. Early liver and kidney dysfunction associated with occupational exposure to sub-threshold limit value levels of benzene, toluene, and xylenes in unleaded petrol. Saf Health Work 2015;6:312–6. doi: 10.1016/j.shaw.2015.07.008
13. Chambers D, Reese C, Thornburg L, Sanchez E, Rafson J, Blount B, Ruhl JRE, de Jesús VR. Distinguishing petroleum (crude oil and fuel) from smoke exposure within populations based on the relative blood levels of benzene, toluene, ethylbenzene, and xylenes (BTEX), styrene and 2,5-dimethylfuran by pattern recognition using artificial neural networks. Environ Sci Technol 2018;52:308–16. doi: 10.1021/acs.est.7b05128
14. Werder EJ, Beier JI, Sandler DP, Falkner KC, Gripshover T, Wahlang B, Engel LS, Cave MC. Blood BTEXS and heavy metal levels are associated with liver injury and systemic inflammation in Gulf states residents. Food Chem Toxicol 2020;139:111242. doi: 10.1016/j.fct.2020.111242
15. Galer D, Leung H, Sussman R, Trzos R. Scientific and practical considerations for the development of occupational exposure limits (OELs) for chemical substances. Regul Toxicol Pharmacol 1992;15:291–306. doi: 10.1016/0273-2300(92)90040-g
16. Rappaport SM. Threshold limit values, permissible exposure limits, and feasibility: the bases for exposure limits in the United States. Am J Ind Med 1993;23:683–94. doi: 10.1002/ajim.4700230502
17. Hansson SO. Setting the Limit: Occupational Health Standards and the Limits of Science. New York (NY): Oxford University Press; 1998.
18. Deveau M, Chen C, Johanson G, Krewski D, Maier A, Niven K, Ripple S, Schulte PA, Silk J, Urbanus JH, Zalk DM, Niemeier RW. The global landscape of occupational exposure limits-Implementation of harmonization principles to guide limit selection. J Occup Environ Hyg 2015;12(Suppl 1):S127–44. doi: 10.1080/15459624.2015.1060327
19. Schenk L, Hansson SO, Rudén C, Gilek M. Occupational exposure limits: A comparative study. Regul Toxicol Pharmacol 2008;50:261–70. doi: 10.1016/j.yrtph.2007.12.004
20. REGULATION (EC) No 1907/2006 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 18 December 2006 [displayed 3 June 2022]. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32006R1907&from=EN
21. STROBE Statement - checklist of items that should be included in reports of observational studies [displayed 3 June 2022]. Available at https://www.equator-network.org/wp-content/uploads/2015/10/STROBE_checklist_v4_combined.pdf
22. CEN - EN 689:2018+AC:2019. Workplace exposure-measurement of exposure by inhalation to chemical agents-strategy for testing compliance with occupational exposure limit values [displayed 3 June 2022]. Available at https://standards.iteh.ai/catalog/standards/cen/4e4b7b42-9785-4c48-a8c5-16cad508ff9a/en-689-2018ac-2019
23. British Occupational Hygiene Society (BOSH). Testing Compliance with Occupational Exposure Limits for Airborne Substances. Derby: BOSH; 2011.
24. Alabdulhadi A, Ramadan A, Devey P, Boggess M, Guest M. Inhalation exposure to volatile organic compounds in the printing industry. J Air Waste Manage Assoc 2019;69:1142–69. doi: 10.1080/10962247.2019.1629355
25. Alfoldy B, Mahfouz MMK, Yigiterhan O, Safi MA, Elnaiem AE, Giamberini S. BTEX, nitrogen oxides, ammonia and ozone concentrations at traffic influenced and background urban sites in an arid environment. Atmos Pollut Res 2019;10:445–54. doi: 10.1016/j.apr.2018.08.009
26. Azari MR, Hosseini V, Jafari MJ, Soori H, Asadi P, Mousavion SMA. Evaluation of occupational exposure of shoe makers to benzene and toluene compounds in shoe manufacturing workshops in East Tehran. Tanaffos 2012;11:43–9. PMCID: PMC4153221
27. Baghani AN, Rostami R, Arfaeinia H, Hazrati S, Fazlzadeh M, Delikhoon M. BTEX in indoor air of beauty salons: Risk assessment, levels and factors influencing their concentrations. Ecotoxicol Environ Saf 2018;159:102–8. doi: 10.1016/j.ecoenv.2018.04.044
28. Baghani AN, Sorooshian A, Heydari M, Sheikhi R, Golbaz S, Ashournejad Q, Kermani M, Golkhorshidi F, Barkhordari A, Jafari AJ, Delikhoon M, Shahsavani A. A case study of BTEX characteristics and health effects by major point sources of pollution during winter in Iran. Environ Pollut 2019;247:607–17. doi: 10.1016/j.envpol.2019.01.070
29. Bahrami AR, Jafari AJ, Ahmadi H, Mahjub H. Comparison of benzene exposure in drivers and petrol stations workers by urinary trans, trans-muconic acid in west of Iran. Ind Health 2007;45:396–401. doi: 10.2486/indhealth.45.396
30. Bakhtiari R, Hadei M, Hopke PK, Shahsavani A, Rastkari N, Kermani M, Yarahmadi M, Ghaderpoori A. Investigation of in-cabin volatile organic compounds (VOCs) in taxis; influence of vehicle's age, model, fuel, and refueling. Environ Pollut 2018;237:348–55. doi: 10.1016/j.envpol.2018.02.063
31. Bakollu M, Karademir A, Ayberk S. An Evaluation of the occupational health risks to workers in a hazardous waste incinerator. J Occup Health 2004;46:156–64. doi: 10.1539/joh.46.156
32. Dehghani F, Omidi F, Heravizadeh O, Barati Chamgordani S, Gharibi V, Sotoudeh Manesh A. Occupational health risk assessment of volatile organic compounds emitted from the coke production unit of a steel

plant. Int J Occup Saf Ergon 2020;26:227–32. doi: 10.1080/10803548.2018.1443593
33. El-Hashemy MA, Ali HM. Characterization of BTEX group of VOCs and inhalation risks in indoor microenvironments at small enterprises. Sci Total Environ 2018;645:974–83. doi: 10.1016/j.scitotenv.2018.07.157
34. Farshad A, Gholami H, Farzadkia M, Mirkazemi R, Kermani M. The safety of non-incineration waste disposal devices in four hospitals of Tehran. Int J Occup Environ Health 2014;20:258–63. doi: 10.1179/2049396714Y.0000000072
35. Golbabaei F, Dehghani F, Saatchi M, Zakerian SA. Evaluation of occupational exposure to different levels of mixed organic solvents and cognitive function in the painting unit of an automotive industry. Health Promot Perspect 2018;8:296–302. doi: 10.15171/hpp.2018.42
36. Golkhorshidi F, Sorooshian A, Jafari AJ, Baghani AN, Kermani M, Kalantary RR, Ashournej Q, Delikhoon M. On the nature and health impacts of BTEX in a populated middle eastern city: Tehran, Iran. Atmos Pollut Res 2019;10:921–30. doi: 10.1016/j.apr.2018.12.020
37. Hadei M, Hopke PK, Shahsavani A, Moradi M, Yarahmadi M, Emam B, Rastkari N. Indoor concentrations of VOCs in beauty salons; association with cosmetic practices and health risk assessment. J Occup Med Toxicol 2018;13(1):30. doi: 10.1186/s12995-018-0213-x
38. Harati B, Shahtaheri SJ, Karimi A, Azam K, Ahmadi A, Afzali Rad M, Harati A. Evaluation of respiratory symptoms among workers in an automobile manufacturing factory, Iran. Iran J Public Health 2018;47:237–45. PMCID: PMC5810387
39. Harati B, Shahtaheri SJ, Yousefi HA, Harati A, Askari A, Abdolmohamadi N. Cancer risk assessment for workers exposed to pollution source, a petrochemical company, Iran. Iran J Public Health 2020;49:1330–8. doi: 10.18502/ijph.v49i7.3587
40. Hosseini SY, Azari MR, Zendehdel R, Souri H, Rahimian RT. Feasibility the biological monitoring of workers exposed to benzene and toluene via measuring the parent compounds in the exhaled breath. Health Scope 2015;4(3):e25774. doi: 10.17795/jhealthscope-25774
41. Javadi I, Mohammadian Y, Elyasi S. Occupational exposure of shahindej county refueling stations workers to BTEX compounds, in 2016. J Res Environ Health 2017;3:74–83.
42. Karbasi A, Khoramnezhadian S, Asemi Zavareh SR, Pejman Sani G. Urinary and air biomonitoring of occupational exposure to benzene in oil pit workers. Human Ecol Risk Assess 2020;26:430–42. doi: 10.1080/10807039.2018.1513318
43. Maghsodi Moghadam R, Bahrami A, Ghorbani F, Mahjob H, Malaki D. Investigation of qualitative and quantitative of volatile organic compounds of ambient air in the Mahshahr petrochemical complex in 2009. J Res Health Sci 2013;13:69–74. PMID: 23772018
44. Mohamadyan M, Moosazadeh M, Borji A, Khanjani N, Moghadam SR. Occupational exposure to styrene and its relation with urine mandelic acid, in plastic injection workers. Environ Monit Assess 2019;191(2):62. doi: 10.1007/s10661-019-7191-z
45. Mohammadyan M, Baharfar Y. Control of workers' exposure to xylene in a pesticide production factory. Int J Occup Environ Health 2015;21:121–6. doi: 10.1179/2049396714Y.0000000098
46. Mohammadyan M, Moosazadeh M, Borji A, Khanjani N, Rahimi Moghadam S, Behjati Moghadam AM. Health risk assessment of occupational exposure to styrene in Neyshabur electronic industries. Environ Sci Pollut Res Int 2019;26:11920–7. doi: 10.1007/s11356-019-04582-8
47. Moradi M, Hopke P, Hadei M, Eslami A, Rastkari N, Naghdali Z, Kermani M, Emam B, Farhadi M, Shahsavani A. Exposure to BTEX in beauty salons: biomonitoring, urinary excretion, clinical symptoms, and health risk assessments. Environ Monit Assess 2019;191(5):286. doi: 10.1007/s10661-019-7455-7
48. Moradpour Z, Ghorbani Shahna F, Bahrami A, Soltanian A, Hesam G. Evaluation of volatile organic compounds at petrochemical complexes in Iran. Health Scope 2017;6(4):e62595. doi: 10.5812/jhealthscope.62595
49. Moshiran VA, Karimi A, Golbabaei F, Yarandi MS, Sajedian AA, Koozekonan AG. Quantitative and semiquantitative health risk assessment of occupational exposure to styrene in a petrochemical industry. Saf Health Work 2021;12:396–402. doi: 10.1016/j.shaw.2021.01.009
50. Moslem AR, Rezaei H, Yektay S, Miri M. Comparing BTEX concentration related to surgical smoke in different operating rooms. Ecotoxicol Environ Saf 2020;203:111027. doi: 10.1016/j.ecoenv.2020.111027
51. Nabizadeh R, Sorooshian A, Delikhoon M, Baghani AN, Golbaz S, Aghaei M, Barkhordari A. Characteristics and health effects of volatile organic compound emissions during paper and cardboard recycling. Sustain Cities Soc 2020;56:102005. doi: 10.1016/j.scs.2019.102005
52. Nassiri P, Golbabai F. Assessment of workers' exposure to aromatic hydrocarbons in a paint industry. Ind Health 1999;37:469–73. doi: 10.2486/indhealth.37.469
53. Omidi F, Dehghani F, Fallahzadeh RA, Miri M, Taghavi M, Eynipour A. Probabilistic risk assessment of occupational exposure to volatile organic compounds in the rendering plant of a poultry slaughterhouse. Ecotoxicol Environ Saf 2019;176:132–6. doi: 10.1016/j.ecoenv.2019.03.079
54. Partovi E, Fathi M, Assari MJ, Esmaeili R, Pourmohamadi A, Rahimpour R. Risk assessment of occupational exposure to BTEX in the National Oil Distribution Company in Iran. Chronic Dis J 2018;4:48–55. doi: 10.22122/cdj.v4i2.223
55. Rahimpour R, Farhadi S, Jalali M. Lifetime cancer risk and hazard quotient of BTXs compounds in Iranian petrochemical and petroleum depot workers. Iranian J Health Saf Environ 2018;5:982–90.
56. Ramadan A. Air quality assessment in Southern Kuwait using diffusive passive samplers. Environ Monit Assess 2010;160:413–23. doi: 10.1007/s10661-008-0705-8
57. Rashnuodi P, Dehaghi BF, Rangkooy HA, Amiri A, Poor SM. Evaluation of airborne exposure to volatile organic compounds of benzene, toluene, xylene, and ethylbenzene and its relationship to biological contact index in the workers of a petrochemical plant in the west of Iran. Environ Monit Assess 2021;193(2):94. doi: 10.1007/s10661-021-08878-6
58. Rezazadeh Azari M, Naghavi Konjin Z, Zayeri F, Salehpour S, Seyedi MD. Occupational exposure of petroleum depot workers to BTEX compounds. Int J Occup Environ Med 2012;3:39–44. PMID: 23022850
59. Rostami R, Fazlzadeh M, Babaei-Pouya A, Abazari M, Rastgho L, Ghasemi R, Saranjam B. Exposure to BTEX concentration and the related health risk assessment in printing and copying centers. Environ Sci Pollut Res 2021;28:31195–206. doi: 10.1007/s11356-021-12873-2
60. Salama KF, Omar EOM, Zafar M. Assessment of BTX concentration around fuel station in Eastern Province Kingdom of Saudi Arabia. Indian J Occup Environ Med 2020;24:163–7. doi: 10.4103/ijoem.IJOEM_157_19
61. Salehpour S, Amani R, Nili-Ahmadabadi A. Volatile organic compounds as a preventive health challenge in the petrochemical

industries. Int J Prevent Med 2019;10:194. doi: 10.4103/ijpvm.IJPVM_495_18

62. Sarkhosh M, Mahvi AH, Zare MR, Fakhri Y, Shamsolahi HR. Indoor contaminants from Hardcopy Devices: Characteristics of VOCs in photocopy centers. Atmos Environ 2012;63:307–12. doi: 10.1016/j.atmosenv.2012.09.058
63. Shanh FG, Rahimnejad S, Bahrami A, Farhadian M. Risk assessment of workers' exposure to volatile organic compounds in the air of a petrochemical complex in Iran. Indian J Occup Environ Med 2017;21:121–7. doi: 10.4103/ijoem.IJOEM_86_17
64. Yaghmaien K, Hadei M, Hopke P, Gharibzadeh S, Kermani M, Yarahmadi M, Emam B, Shahsavani A. Comparative health risk assessment of BTEX exposures from landfills, composting units, and leachate treatment plants. Air Quality Atmos Health 2019;12:443–51. doi: 10.1007/s11869-019-00669-w
65. Zoleikha S, Mirzaei R, Roksana M. Exposure to chemical hazards in petrol pumps stations in Ahvaz City, Iran. Arch Environ Occup Health 2017;72:3–9. doi: 10.1080/19338244.2015.1058233
66. Lahn G, Stevens P, Preston F. Saving oil and gas in the gulf: A Chatham House Report, 2013 [displayed 6 June 2022]. Available at https://www.chathamhouse.org/sites/default/files/public/Research/Energy%2C%20Environment%20and%20Development/0813r_gulfoilandgas.pdf
67. Charfeddine L, Barkat K. Short- and long-run asymmetric effect of oil prices and oil and gas revenues on the real GDP and economic diversification in oil-dependent economy. Energy Econ 2020;86:104680. doi: 10.1016/j.eneco.2020.104680
68. International Labour Organization (ILO). Promoting Cooperation for Safe Migration and Decent Work. Dhaka: ILO Country Office for Bangladesh; 2014.
69. Buqammaz M, Gasana J, Alahmad B, Shebl M, Albloushi D. Occupational noise-induced hearing loss among migrant workers in Kuwait. Int J Environ Res Public Health 2021;18(10):5295. doi: 10.3390/ijerph18105295
70. Low WY, Tong WT, Binns C. Migrant workers in Asia Pacific and their rights to health. Asia Pac J Public Health 2015;27:584–7. doi: 10.1177/1010539515600007
71. Moyce SC, Schenker M. Migrant workers and their occupational health and safety. Annu Rev Public Health 2018;39:351–65. doi: 10.1146/annurev-publhealth-040617-013714
72. Khaled SM, Gray R. Depression in migrant workers and nationals of Qatar: An exploratory cross-cultural study. Int J Soc Psychiatry 2019;65:354–67. doi: 10.1177/0020764019850589
73. Capleton AC, Levy LS. An overview of occupational benzene exposures and occupational exposure limits in Europe and North America. Chem Biol Interact 2005;153:43–53. doi: 10.1016/j.cbi.2005.03.007
74. Neumeier G. Occupational Exposure Limits: Criteria Document for Benzene. Berlin: Federal Environmental Agency; 1993.
75. Paustenbach DJ, Cowan DM, Sahmel J. The history and biological basis of occupational exposure limits for chemical agents. In: Patty's industrial hygiene. New York: Wiley; 2000. p. 1903–2000.
76. Skowroń J, Czerczak S. Rules and recent trends for setting health-based occupational exposure limits for chemicals. Int J Occup Med Environ Health 2015;28:243–52. doi: 10.13075/ijomeh.1896.00243
77. Topping M. Occupational exposure limits for chemicals. Occup Environ Med 2001;58:138–44. doi: 10.1136/oem.58.2.138
78. Schenk L, Rudén C, Gilek M, Hansson SO. Occupational exposure limits: A comparative study of the levels today and development during the past 10 years. Toxicol Lett 2007;172(Supplement):S123-S4.
79. Schenk L. Comparison of data used for setting occupational exposure limits. Int J Occup Environ Health 2010;16:249–62. doi: 10.1179/107735210799160255

Profesionalna izloženost BTEX-u i stirenu u zemljama (jugo)zapadne Azije – kratak pregled trenutačnog stanja i graničnih vrijednosti

Svrha je uvođenja graničnih vrijednosti profesionalne izloženosti (engl. *occupational exposure limits*, krat. OELs) upravljanje rizikom ne bi li se zaštitilo zdravlje i dobrobit radnika od štetnih agensa kojima su izloženi na radnome mjestu. U ovom smo pregledu izdvojili granične koncentracije benzena, toluena, etilbenzena, ksilena (BTEX) i stirena u zraku i, analizirajući 49 članaka objavljenih u zemljama (jugo)zapadne Azije od 1980. do 2021., pronađenih sustavnom pretragom literature, ocijenili profesionalnu izloženost tim spojevima. Granične vrijednosti za BTEX i stiren uvedene su samo u Iranu i Turskoj, i na sličnim su razinama kao one koje vrijede u europskim zemljama i SAD-u. Analiziranih 49 članaka obuhvaćaju istraživanja izloženosti u šest zemalja, ali se većina (njih 40) odnosi na Iran. Prosječna profesionalna izloženost benzenu u radnika u industrijama povezanima s naftom viša je od preporučene granične vrijednosti, a profesionalna izloženost ostalim spojevima niža je od lokalnih graničnih vrijednosti (tamo gdje su uvedene). Trenutačno nema dovoljno podataka o razinama profesionalne izloženosti BTEX-u i stirenu u zemljama (jugo)zapadne Azije, stoga je u njima potrebno regulirati granične vrijednosti i primjenjivati ih. Osim toga, potrebno je provoditi sustavna istraživanja ne bi li se utvrdile stvarne razine profesionalne izloženosti, odgovori na koncentracije onečišćivala i gospodarske i tehničke mogućnosti industrija tih zemalja da riješe trenutačne probleme.

KLJUČNE RIJEČI: benzen; etilbenzen; ksilen; naftna industrija; OEL; toluen; upravljanje rizikom