



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

Razzagh Rahimpoor<sup>1</sup>, Fatemeh Sarvi<sup>2</sup>, Samira Rahimnejad<sup>3</sup>, and Seyed Mohammad Ebrahimi<sup>4</sup>

<sup>1</sup> Larestan University of Medical Sciences Faculty of Evaz Health, Department of Occupational Health Engineering, Research Center for Health Sciences, Larestan, Iran

<sup>2</sup> Larestan University of Medical Sciences, School of Health, Department of Public Health, Larestan, Iran

<sup>3</sup> Kurdistan University of Medical Sciences Faculty of Health, Department of Occupational Health Engineering, Sanandaj, Iran

<sup>4</sup> 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.

## 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).

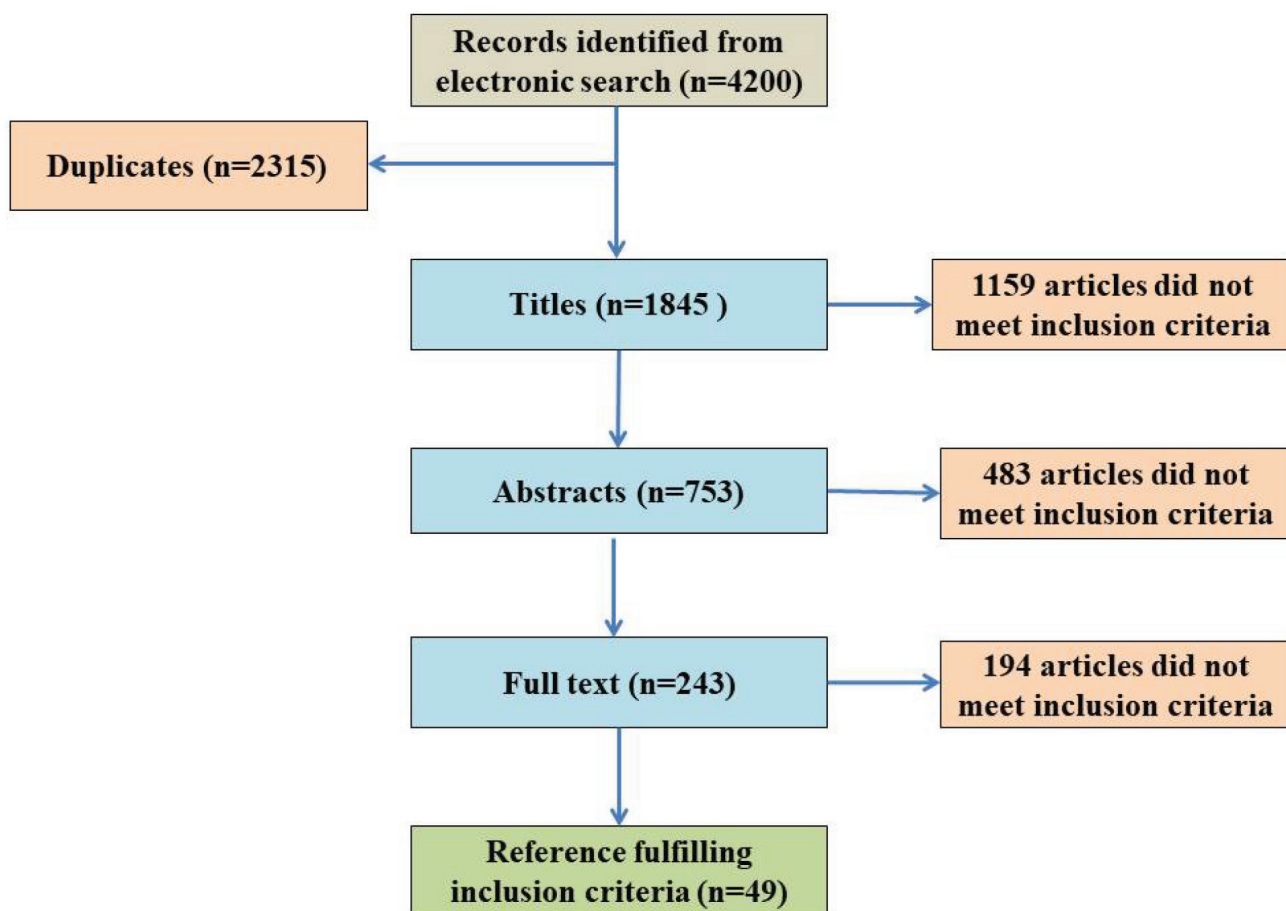


Figure 1 Search steps to identify full-text articles about occupational exposure in West Asian countries

**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	( <b>TS</b> =(Benzene OR Toluene OR Ethylbenzene OR Xylenes OR Styrene OR Volatile Organic compound) <b>AND</b> <b>TS</b> =(Occupational exposure OR Industrial exposure OR Workplace exposure OR Chemical exposure) <b>AND</b> <b>TS</b> =(Threshold limit value OR Occupational exposure limit OR Recommended exposure level OR Permissible exposure limit) <b>AND</b> <b>TS</b> = (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) <b>AND</b> LANGUAGE: (English) Indexes=SCI-EXPANDED, SSCI, <b>AND</b> Time span=1980-2021
Scopus	<b>TITLE-ABS-KEY</b> (Benzene OR Toluene OR Ethylbenzene OR Xylenes OR Styrene) <b>AND</b> <b>TITLE-ABS-KEY</b> (Occupational exposure OR Industrial exposure OR Workplace exposure OR Chemical exposure) <b>AND</b> <b>TITLE-ABS-KEY</b> (Threshold limit value OR Occupational exposure limit OR Recommended exposure level OR Permissible exposure limit) <b>AND</b> <b>TITLE-ABS-KEY</b> (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) <b>AND</b> 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]) <b>AND</b> (Occupational exposure [Title/Abstract] OR Industrial exposure [Title/Abstract] OR Workplace exposure [Title/Abstract] OR Chemical exposure [Title/Abstract]) <b>AND</b> (Threshold limit value [Title/Abstract] OR Occupational exposure limit [Title/Abstract] OR Recommended exposure level [Title/Abstract] OR Permissible exposure limit [Title/Abstract]) <b>AND</b> (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]) <b>AND</b> (Occupational exposure [Title Abstract Keywords] OR Industrial exposure [Title Abstract Keywords] OR Workplace exposure [Title Abstract Keywords] OR Chemical exposure [Title Abstract Keywords]) <b>AND</b> (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]) <b>AND</b> (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]) <b>AND</b> (Occupational exposure [Title/Abstract] OR Industrial exposure [Title/Abstract] OR Workplace exposure [Title/Abstract] OR Chemical exposure [Title/Abstract]) <b>AND</b> (Threshold limit value [Title/Abstract] OR Occupational exposure limit [Title/Abstract] OR Recommended exposure level [Title/Abstract] OR Permissible exposure limit [Title/Abstract]) <b>AND</b> (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	<b>TITLE-ABS-KEY</b> (Benzene OR Toluene OR Ethylbenzene OR Xylenes OR Styrene OR Volatile Organic compound) <b>AND</b> <b>TITLE-ABS-KEY</b> (Occupational exposure OR Industrial exposure OR Workplace exposure OR Chemical exposure) <b>AND</b> <b>TITLE-ABS-KEY</b> (Threshold limit value OR TLV OR Occupational exposure limit OR OEL OR Recommended exposure level OR REL OR Permissible exposure limit OR PEL) <b>AND</b> <b>TITLE-ABS-KEY</b> (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) <b>AND</b> PUB YEAR ≥ 1980
Science direct from inception	<b>TITLE-ABS-KEY</b> (Benzene OR Toluene OR Ethylbenzene OR Xylenes OR Styrene OR Volatile Organic compound) <b>AND</b> <b>TITLE-ABS-KEY</b> (Occupational exposure OR Industrial exposure OR Workplace exposure OR Chemical exposure) <b>AND</b> <b>TITLE-ABS-KEY</b> (Threshold limit value OR TLV OR Occupational exposure limit OR OEL OR Recommended exposure level OR REL OR Permissible exposure limit OR PEL) <b>AND</b> <b>TITLE-ABS-KEY</b> (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) <b>AND</b> 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:

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

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<sup>3</sup> (0.5 ppm) while the most recent recommendation of ECHA RAC is that of 0.16 mg/m<sup>3</sup> (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/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	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)				
						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)	<b>1.33±0.11*#</b>	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)	<b>1.41±0.80*#</b>	-	-	-	-
(Bakhtari 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	-
(Bakollu et al., 2004) (31)	Cross-sectional	Turkey	Static	Waste Incinerator	-	<b>1.33±0.08*#</b>	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)	<b>2.17±0.11*#</b>	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	-	<b>0.57±0.1*#</b>	1.23±1.1	1.18±1.2	0.58±0.6	-
(Golbabaie et al., 2018) (35)	Cross-sectional	Iran	Personal	Automobile Industry	40 (36:4)	<b>0.96±0.05*#</b>	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	-
(Hadeti 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)	<b>0.775±0.12*#</b>	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)	<b>2.12±0.95*#</b>	9.84±2.53	-	11.87±4.44	-
(Heibati et al., 2018) (4)	Cross-sectional	Iran	Personal	Petroleum transfer station	50 (50:0)	<b>2.7±2.91*#</b>	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)	-	<b>37.64±24.09*#</b>	-	<b>105±20.05*#</b>	-

References	Publication type	Country	Type of sampling	Industry or workplace	Number of workers (exposed vs unexposed)	Concentration (ppm)				
						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	-	-	-
(Jalil 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
(Mohamadyan and Baharf, 2015) (45)	Cross-sectional	Iran	Personal	Pesticide production factory	100 (100:0)	-	-	-	4.7±5.5	-
(Mohamadyan 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
(Rahimpour et al., 2014) (1)	Cross-sectional	Iran	Personal	Petrochemical industry	104 (104:0)	<b>1.19±0.63*#</b>	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)	<b>0.657±0.791*#</b>	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)	<b>1.28±2.10*#</b>	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)	<b>1.63±3.92*#</b>	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	-	<b>11.7±3.1*</b>	4.09±1.09	-	3.97±2.25	-
(Salehpour et al., 2019) (61)	Cross-sectional	Iran	Personal	Petrochemical industry	80 (40:40)	<b>1.03±1.40*#</b>	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)	<b>1.25±2.28*#</b>	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)	<b>1.28±0.447*#</b>	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; styrene 100 ppm; xylene 100 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  $\pm$  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 $\pm$ 0.038	0.03 $\pm$ 0.05	0.0063 $\pm$ 0.03	0.162 $\pm$ 0.09	-
Iran	Yes	Oil-related	<b>1.165<math>\pm</math>0.69<sup>*,#</sup></b>	5.87 $\pm$ 8.18	2.28 $\pm$ 8.93	12.104 $\pm$ 17.7	3.588 $\pm$ 4.52
		Solvent-related	<b>0.785<math>\pm</math>0.49<sup>*,#</sup></b>	4.53 $\pm$ 4.01	4.34 $\pm$ 5.11	10.56 $\pm$ 12.28	9.585 $\pm$ 3.70
Turkey	Yes (except for styrene)	Oil-related	<b>1.33<sup>*,#</sup></b>	0.051	0.015	0.041	0.0057
		Solvent-related	-	-	-	-	-
Saudi Arabia	No	Oil-related	<b>11.7<sup>*</sup></b>	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.

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## 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 povezanim 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