HEALTH AND THE ENVIRONMENT IN ARAB COUNTRIES
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Health Impact of Air Pollution
In Arab Countries

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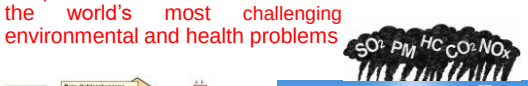
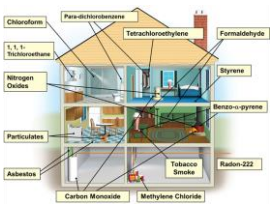
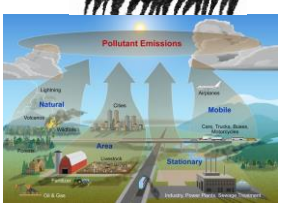
Sources of Indoor & Outdoor Air Pollution

Air pollution is considered one of the world's most challenging environmental and health problems







Adopted from the US National Parks Services on Air Quality (https://www.nps.gov/)

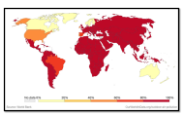
Matyssek, R., Clarke, R., Cudlin, P., Mikkelsen, T. N., Tuovinen, J. P., Wieser, G., & Paoletti, E. (2013). Climate Change, Air Pollution and Global Challenges, 1st Edition: Elsevier Science.

Alarming Reports From the Arab World

- Ambient air quality data shows a trend of increasing **Criteria Air Pollutants (CAPs)** emission levels over the Arabian Peninsula.
- Rapid **urbanization** and **economic growth** led air pollution in the Arab world has climbed to alarming levels in recent years *(Farahat, 2016)*.
- Emissions increased over the past three decades in the MENA by up to 5-fold due to growth in the **energy**, and **transportation** sectors *(Abbas et al. 2018)*
- According to the WHO, air quality indicators in the Arab countries often exceed the WHO guideline values *(Saade, 2019)*

Annual Particulate Matter Levels in the Last 10 years

Country	$PM_{2.5}$ Concentration (μg/m³) - 2015	$PM_{2.5}$ Concentration (μg/m³) - 2016	$PM_{2.5}$ Concentration (μg/m³) - 2017	PM_{10} Concentration (μg/m³)	PM_{10} City	PM_{10} Year
UAE	42	41	41	150	Abu Dhabi	2015
Bahrain	73	70	71	250	Ras Hayan	2012
Comoros	21	20	21	-	-	-
Djibouti	46	46	46	-	-	-
Algeria	36	40	39	-	-	-
Egypt	88	88	87	284	Cairo	2015
Iraq	66	64	62	178	Baghdad	2016
Jordan	54	53	53	58	Amman	2017
Kuwait	65	61	61	130	Al-Jahra	2015
Lebanon	31	30	31	41	Beirut	2014
Libya	52	52	54	-	-	-
Morocco	31	33	33	43	Casablanca	2016
Mauritania	49	47	47	-	-	-
Oman	43	42	41	82	Muscat	2009
Qatar	94	88	91	-	-	-
Saudi Arabia	97	84	88	161	Dammam	2016
Sudan	59	54	55	-	-	-
Syria	44	44	44	-	-	-
Tunisia	36	38	38	90	Tunis	2010
Yemen	54	50	50	-	-	-



(WHO, 2020)
(World Bank, 2020)

	Outdoor Sources	Indoor Sources	USEPA Ambient Primary AQS	USEPA Ambient AQS	EU Ambient AQ Guidelines	EU Indoor AQ Guidelines	WHO Ambient AQ Guidelines	WHO Indoor AQ Guidelines
$PM_{2.5}$	• Combustion processes	• Stoves, heaters, fireplaces • Tobacco smoking	• 35 μg/m³ - 24 hours • 12 μg/m³ - 1 year	• 25 μg/m³ - 1 year	• 25 μg/m³ - 24 hours • 10 μg/m³ - 1 year	No limit available		
PM_{10}	• Construction activities • Road dust re-suspension	• Stoves, heaters, fireplaces • Tobacco smoking	• 150 μg/m³ - 24 hours	• 50 μg/m³ - 24 hours • 40 μg/m³ - 1 year	• 50 μg/m³ - 24 hours • 20 μg/m³ - 1 year	No limit available		

SOx and NOx Trends Over Arab Urban Centers

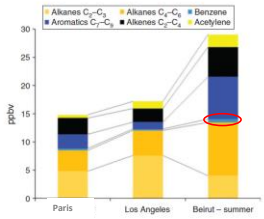
- Increase over Arab urban centers 2005-2014 *(Barkley et al., 2017).*

SOx: **+ 60-120%**

NOx: **+ 3-12%**

- High levels over oil ports and refineries, and urban settlements in **GCC countries**.
- CAP emissions in the Arab World attributed to fossil-fuel addicted societies, high population density, and absence of ecofriendly public transportation systems.

Hazardous Air Pollutants Levels: Non-Methane Hydrocarbons (NMHCs)



- Non-Methane Hydrocarbons (**NMHCs**) +2-7% increase over Arab urban centers 2005-2014 *(Barkley et al., 2017)*
- NMHCs levels are higher in **Beirut** compared to **Paris, and LA** *(T. Salameh et al. 2015)*

Pollutant	Outdoor Sources	Indoor Sources	EU Ambient AQ Standards	WHO Ambient AQ Guidelines	WHO Indoor AQ Guidelines
Benzene	• Vehicular exhaustion • Evaporation from gasoline products • Burning of coal and oil	• Tobacco smoking • Paint, glue, wax, detergents • Building material	• 5 μg/m³ - 1 year	• No safe level of exposure can be recommended.	• No safe level of exposure can be recommended.

Reports on Indoor Air Pollution levels

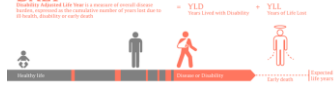
Pollutant	WHO Indoor AQGV
Carbon Monoxide (CO)	• 100 mg/m³ - 15 min • 35 mg/m³ - 1 hour • 10 mg/m³ - 8 hours • 7 mg/m³ - 24 hours
Lead (Pb)	No limit available
Nitrogen Dioxide (NO_2)	• 200 μg/m³ - 1 hour • 40 μg/m³ - 1 year
Ozone (O_3)	No limit available
$PM_{2.5}$	No limit available
PM_{10}	No limit available
Sulfur Dioxide (SO_2)	No limit available

Countries	Study Environment	Average Concentration of Pollutants	Latest Reference
Bahrain	Homes	NO_2 29.8 μg/m³	(Madany & Danish, 1992)
Egypt	Indoor smoking area	$PM_{2.5}$ 478 μg/m³	(Loffredo *et al.*, 2016)
KSA	Restaurants	PM_{10} 78.2 μg/m³ $PM_{2.5}$ 38.1 μg/m³ CO 5.4 mg/m³ CO2 2360 mg/m3 VOCs 0.4 ppm NO_2 608 μg/m³ SO_2 0.2 mg/m³	(El-Sharkawy & Javed, 2018)
	Mosques Carpet Dust	PAHs 4.09 μg/g	
Kuwait	Elementary Schools	SO_2 7.7 μg/m³ NO_2 29.8 μg/m³ H_2S 6.3 μg/m³	(Al-Hemoud *et al.*, 2017)
Oman	Residential Homes	O_3 159 μg/m³ NO_2 20.3 μg/m³ CO_2 1170 mg/m³ CO 321 μg/m³ VOCs 689 ppb	(Abdul-Wahab, 2017)
Palestine	Schools	CO 0.8 ppm	(Elbayoumi *et al.*, 2014)
Qatar	University	CO_2 1938 mg/m³ CO 1.2 mg/m³ O_3 424 μg/m³	(Benammar *et al.*, 2018)
UAE	Homes	$PM_{2.5}$ 206 μg/m³ CO 5.5 mg/m³	(Weitzman *et al.*, 2017)

The Air Pollution Burden of Disease In Arab Countries

Country	Risk factors (DALYs/ 1000 capita, per year) Indoor Air Pollution	Ambient Air Pollution
Algeria	-	-
Bahrain	-	0.4
Comoros	-	-
Djibouti	3	3
Egypt	0.2	2
Iraq	0.8	5
Jordan	-	0.8
Kuwait	-	1.1
Lebanon	-	1.4
Libya	0.2	3
Mauritania	-	-
Monocco	-	0.2
Oman	-	1.1
Palestine	-	-
Qatar	-	0.6
Saudi Arabia	-	1.1
Somalia	-	0.4
Sudan	2.4	1
Syria	0.6	0.9
Tunisia	0.3	0.6
U.A.E	-	1.8
Yemen	13	0.7

Ambient PM are the 5th leading DALYs risk in EMR countries *(Cohen et al., 2017).*



Elevated Attributable Premature Mortality

- Ambient air pollution is the leading environmental contributor to mortality in **UAE**, with **651** attributable premature deaths (AD), making **7% of all deaths** *(MacDonald Gibson et al., 2013)*
- The average AD associated with $PM_{2.5}$ in Beirut were found to between **257-327 deaths,** making between 7.8-10% of all death ***(Dhaini et al., 2017)***

Country	Premature Mortality Indicators	Attributable Pollutant(s)
Egypt	114 deaths/100,000	PM NO_2
Kuwait	YLL Projections (2015-2025): 252.18 to 8487.28	$PM_{2.5}$
Lebanon	AD: 257-327 YLL: 3,086-3,923	$PM_{2.5}$
UAE	Premature excess deaths: 545 (7% of all deaths) 62 (1% of all deaths)	PM O_3

AP is Associated with Various Cardiopulmonary Diseases

- With increasing urbanization in recent years, the prevalence of asthma is generally increasing in the Arab world *(El Margoushy et al., 2013)*

+42 % in respiratory diseases in EMR (1990-2015)

Country	Type and/or Source of Air Pollutant(s)	Associated Outcomes
Algeria	CO	Asthma & Chronic obstructive pulmonary disease (COPD)
Bahrain	SO_2, CO	Respiratory hospital admissions
Egypt	NO_2, SO_2, H_2S, Dust storms	Asthma-related symptoms
Kuwait	$PM_{2.5}$ NO_2, SO_2, H_2S, Dust storms	Ischemic heart disease and stroke Asthma-related symptoms
Lebanon	PM_{10} $PM_{2.5}$, busy road, local diesel generators, local power plant	Total respiratory admissions Hypertension, Cardiovascular diseases, Chronic bronchitis
Morocco	NO_2, SO_2, H_2S, Dust storms	Asthma-related symptoms
Oman	NO_2, SO_2, H_2S, Dust storms Industrial park	Asthma-related symptoms Adverse respiratory conditions ER visits
Qatar	NO_2, SO_2, H_2S, CO, NO, O_3, SO_2, PM10, Dust storms	Ischemic heart disease & Asthma-related symptoms
Saudi Arabia	PAHs, PM_{10}, $PM_{2.}5$, Oil refiner	Prehypertension
Syria	Dust storms	Asthma-related symptoms
Tunis	Biomass	Cardiopulmonary diseases
UAE	Industrial plant, gas station, dumpsite, or construction	Asthma, wheezing, and dry cough

Reports on Attributable Cancer Risk In Certain Arab Nations

- Eastern Mediterranean Region (EMR) show a large disease burden, including cancer *(Cohen et al., 2017)*.
- A recent study in Beirut, showed that the average cumulative cancer risk attributable to NMHCs exceeds the USEPA acceptable risk by **30-40 fold** *(Dhaini et al., 2017).*
- Another Lebanese study showed that exposure to $PM_{2.5}$ and PM_{10} contributed to **13%** of total *lung cancer* cases in 2018 *(Charafeddine et al., 2017)*

Country	Pollutant(s)	Excess Cancer Risk (x 10^{-6})
KSA	**Heavy metals of PM_{10}**	108
	PAHs	8.3 (children); 7.4 (adults)
Lebanon	**NMHCs**	30-40
Egypt	PAHs	6.64

Conclusions

- AP levels in the Arab world are showing increasing patterns especially in urban areas.
- Observed trends are mainly due to **fossil fuel burning**, **road transport**, **industrial activities** the oil and gas sector, all topped by sand storms and seaspray.
- Challenges facing Arab countries towards improved air quality include **outdated regulations**, **lack of law enforcement**, and **absence of sustainable AQM** networks.
- Data from the past 25-30 years, report an **increase in cardiopulmonary diseases and cancer incidence**.
- However, **large data gaps** in Arab countries still exist that precludes an accurate assessment of the health impact

Recommendations

1. Update the **regulatory framework** in order to reflect the best available technology (BAT).
2. Enforce **the Law** in an efficient manner and penalize non-compliance.
3. Sustain and maintain **AQMS networks**
4. Establish and update nationwide **emission inventories**, and employ high resolution air quality modeling systems.
5. Derive **concentration-Response (C-R) functions** for every country to relate accurately exposure to health risks.
6. Develop priority lists for **health risk assessment** as the basis for future interventions and risk management.