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Review article

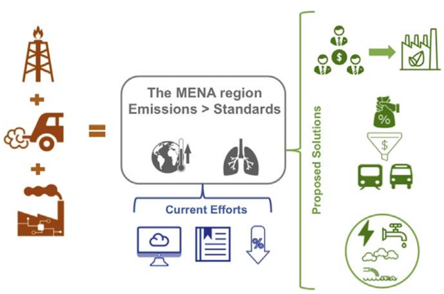
An overview of monitoring and reduction strategies for health and climate change related emissions in the Middle East and North Africa region

Rana Alaa Abbass[a], Prashant Kumar[a,*], Ahmed El-Gendy[b]

[a] Global Centre for Clean Air Research (GCARE), Department of Civil and Environmental Engineering, Faculty of Engineering and Physical Sciences, University of Surrey, Guildford GU2 7XH, United Kingdom

[b] Department of Environmental Engineering, School of Sciences and Engineering, The American University in Cairo, New Cairo 11835, Egypt

GRAPHICAL ABSTRACT



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ABSTRACT

This review assesses the current state of air pollution in the Middle East and North Africa (MENA) region. Emission types and sources in the region are identified and quantified to understand the monitoring, legislative and reduction needs through a systematic review of available literature. It is found that both health (e.g., particulate matter, PM; and heavy metals) and climate change (e.g., carbon dioxide and methane) emissions are increasing with the time. Regarding health emissions, over 99% of the MENA population is exposed to PM levels that exceed the standards set by the World Health Organization (WHO). The dominant source of climate change emissions is the energy sector contributing ~38% of CO_2 emissions, followed by the transport sector at ~25%. Numerous studies have been carried out on air pollution in the region, however, there is a lack of comprehensive regional studies that would provide a holistic assessment. Most countries have air quality monitoring systems in place, however, the data is not effectively evaluated to devise pollution reduction strategies. Moreover, comprehensive emission inventories for the individual countries in the region are also lacking. The legislative and regulatory systems in MENA region follow the standards set by international environmental entities such as the WHO and the U.S. Environmental Protection Agency but their effective reinforcement remains a concern. It is concluded that the opportunities for emission reduction and control could be best implemented in the road transportation sector using innovative technologies. One of the potential ways forward is to channel finance flows from fossil fuel subsidies to upgrade road transport with public transportation systems such as buses and trains, as suggested by a 'high shift' scenario for MENA region. Furthermore, emission control programs and technologies are more effective when sponsored and implemented by the private sector; the success of Saudi Aramco in supporting national emission monitoring is one such example. Finally, an energy-pollution-water nexus is assessed for the region as an integrated approach to address its urban issues. The assessment of topic

* Corresponding author.
E-mail addresses: P.Kumar@surrey.ac.uk, Prashant.Kumar@cantab.net (P. Kumar).

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areas covered clearly suggests a need to control the main sources of air pollution to limit its relatively high impact on the human health in the MENA region.

1. Introduction

Air pollution has an adverse effect on human health (Heal et al., 2012) and contributes to climate change (Waked and Afif, 2012). On a global scale, developing countries are major contributors to air pollution due to their growing economies that result in the emergence of emissions-generating sectors including energy, transport and industrial (Galeotti and Lanza, 1999; Kumar et al., 2015, 2016). The Middle East and North Africa (MENA) region is one of the major contributors worldwide to global health and climate change emissions (El Fadel et al., 2013). Countries within the region include Algeria, Bahrain, Egypt, Jordan, Iran, Iraq, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Kingdom of Saudi Arabia (KSA), Syria, Tunisia, Turkey, United Arab Emirates (UAE) and Yemen (El Fadel et al., 2013). The region hosts about 355 million people living in overpopulated cities that suffer from air pollution (El Fadel et al., 2013). Air pollution attributed to about 125,000 lives lost in MENA region in 2013, constituting 7% of total premature deaths (Saade, 2016). Such deaths also resulted in a loss of more than US$ 9 billion from annual labor income in 2013 and welfare losses amounting to 2.2% of regional GDP (Saade, 2016).

The ambient environment of the MENA region is injected with a large amount of dust caused by desert storms (Parajuli et al., 2016). Furthermore, high on-road emissions in the region are attributed to older on-road vehicles, inefficient fuel usage and unregulated control of exhaust emissions (Waked and Afif, 2012; Chapman, 2007). For example, particulate matter having 10 μm or smaller (PM_{10}) and sulphur dioxide (SO_2) concentrations continuously exceed the World Health Organization (WHO) standards in Egypt, Iran and UAE (Waked and Afif, 2012). The region is also amongst the highest global contributors of carbon monoxide (CO) and nitrogen oxides (NO_x) emissions in countries such as Iran, KSA, Iraq, Turkey and Egypt (Waked and Afif, 2012). Consequently, the highest numbers of deaths and economic costs are attributed to air pollution in Egypt and Iran (Saade, 2016).

The MENA region possesses 60% of the world's proven oil reserves and 45% of natural gas resources (El Fadel et al., 2013). Hence, fossil fuels are the main source of energy resulting in considerable climate change emissions. Oil producing countries such as Qatar, UAE and Kuwait rank among the top per capita emissions relative to per capita income (Baehr, 2009). Iran and KSA resulted in 65% of the region's fossil-fuel-related carbon dioxide (CO_2) in 2010 (Farzaneh et al., 2016).

The MENA region has the fastest growth rate in emissions globally and is responsible for 4.5% of global greenhouse gas (GHG) emissions contributing to climate change (El Fadel et al., 2013). The region is already vulnerable to climate change and suffers from fresh water scarcity and rapid population growth (Evans, 2009). Climate change models predict an overall temperature increase of ~1.4 K by mid-century and ~4 K by late-century (Evans, 2009). Such a change in conditions will result in a considerable decrease in precipitation in Turkey, Syria, Iraq and Iran (Evans, 2009). There will be an inevitable loss of viable rain-fed agricultural land and increases in the length of the dry season (Evans, 2009). In contrast, precipitation is expected to increase in the southernmost region by 25% in contrast to current precipitation rates by late century (Evans, 2009).

Governments in MENA region have started to commit to international agreements to mitigate and adapt to climate change by setting targets for renewable energy penetration (El Fadel et al., 2013). Other efforts to reduce emissions such as the use of natural gas for electricity production are being encouraged (Farzaneh et al., 2016).

A considerable number of studies have focused on the air pollution crisis in MENA, as summarised in Table 1. The majority of past studies have focused on identifying quantities and sources of major polluting sources with limited emphasis on addressing the issue. Generally, their focus has been on a particular city or a country to characterise the nature of its air pollutants and their adverse impacts. Table 1 also indicates that studies were mostly carried out in Lebanon and Egypt as opposed to other countries. Existing studies create a good basis for identifying the problem on a national level, however, regional studies that explore efforts to address the issue are limited. Furthermore, governments have put systems and standards in place. However, the extent to which these measures are effective has not been investigated thoroughly.

For the first time, this review article attempts to capture a comprehensive overview of the studies conducted on the main types and sources of air pollution in the MENA region, the monitoring systems put in place to quantify the issue, the national and regional legislations

Table 1
Overview of emission studies in the MENA region.

Location	Study Focus	Major Findings	Author (year)
Kuwait	Source apportionment of airborne nanoparticles	Six sources identified were fresh traffic emissions (46%), aged traffic (27%), industrial (9%), regional background (9%), sources (6%) and dust (3%).	Al-Dabbous and Kumar (2015)
Cairo, Egypt	Integration of GPS and GIS to Study Traffic Congestion	A positive correlation was found between travel time and emissions quantity for gasoline vehicles and no correlation for diesel vehicles.	El-Mansy (2013)
Lebanon	Emissions inventory from road transport	Highest contributors to CO and NO_x are countries that exceed 20 million inhabitants.	Waked and Afif (2012)
Beirut, Lebanon	Origin and variability of PM_{10} and $PM_{2.5}$	Higher percentages of sulfates and nitrates were in fine PMs from vehicle emissions and construction debris.	Saliba et al. (2010)
Ankara, Turkey	Air pollution forecasting using air pollution index	Air quality in Ankara was more affected by meteorology rather than emissions.	Genc et al. (2010)
Cairo, Egypt	PAHs in road dust	The carcinogenic content of PAHs is 0.8–46.6%; PAHs are greater near traffic routes and industries.	Hassanien and Abdel-Latif (2008)
Beiruit, Lebanon	Effect of transport emissions on $PM_{10-2.5}$ and $PM_{2.5}$ composition	Cu and Zn were generated from worn brakes and tires in high traffic areas	Saliba et al. (2007)
Lebanon	Field study of CO, SO_2, PM_{10} and O_3	Vehicle-induced emissions contribute to CO levels while winter heaters cause SO_2; High levels of PM_{10} and O_3 result from transport.	Saliba et al. (2006)
Beirut, Lebanon	Seasonal behaviors of lower carbonyl compounds	Vehicle emissions are the dominant source of carbonyls	Moussa et al. (2006)
Beirut, Lebanon	Measurements and composition of $PM_{10\text{-}2.5}$	Inorganic ions and organic species found in higher concentrations of $PM_{2.5}$; In $PM_{10\text{-}2.5}$, higher water concentrations were observed.	Shaka and Saliba (2004)