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Review

Ambient air quality and exposure assessment study of the Gulf Cooperation Council countries: A critical review

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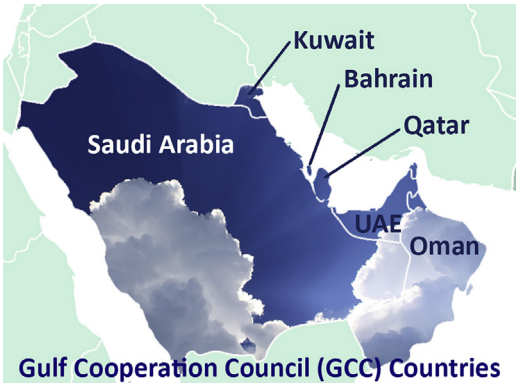
HIGHLIGHTS

- This review paper identifies the major sources of air pollutants in the GCC region.
- CO_2, CO, PM, metal elements, NO_x, O_3, SO_2, VOCs, PAHs, and POP were considered here.
- The exposure assessment of major air pollutants was reviewed.
- Sand, industrial chemicals and vehicles were the main contributors to air pollution.
- Oil and natural gas activities have also the most important impact in the region.

GRAPHICAL ABSTRACT



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ABSTRACT

With rapid urbanization and economic growth, many developing countries have faced a greater share of air pollutants in recent years. An increasing number of exposure studies on air pollutants have been reported lately. However, due to lack of strict regulations and monitoring stations among developing countries, such as Gulf Cooperation Council (GCC) countries, limited air pollution and exposure assessment studies have been conducted in this region. Thus, the objective of this critical review was to identify the major sources of air pollutants in the region with hot and arid/semiarid climate for the main categories contributing to specific pollutants. Finally, a summary of the limitations and knowledge gaps were discussed. Additionally, the current available regulations, emission inventories and source apportionment studies in this region were discussed. In this study, the concentration levels of carbon dioxide (CO_2), carbon monoxide (CO), particulate matter (PM), metal elements, nitrogen oxides (NO_x), ozone (O_3), sulfur dioxide (SO_2), volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), and persistent organic pollutants (POPs) were reviewed. Due to lack of scientific studies, various databases and indexed journals from early 2000 (sometimes prior that time) were considered. The review findings clearly indicated that the sand, dust (natural and anthropogenic, such as cement, metal, stone cutting industries), chemical industries (refinery, petrochemical, etc.) and transportation activities were the major contributors to the overall air pollution in the GCC countries. Besides, the study recommended that the difference between anthropogenic pollution and natural events in dust formation should be explored extensively. Furthermore, possible suggestions for future researches in the region were proposed.

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1. Introduction

The environmental pollution is becoming more and more serious subject and a hot topic of debate in recent years. Currently, air pollution is named as one of the major issues affecting both the environment and human beings (Al-Salem and Bouhamrah, 2006; Al-Wahaibi and Zeka, 2015). Exposure to air pollutants leads to a variety of health effects, which is subjected to type, concentration level, duration, frequency, and associated toxicity of them (Cooke et al., 2007; Al-Wahaibi and Zeka, 2015). Age, cultural practices, living places, and lifestyle may influence the exposure to air pollutants as well. Therefore, the impacts of air pollutants and the severity of health outcomes in a given population depend on the population sensitivities and cannot be directly generalized from the results of other backgrounds.

According to the World Health Organization (WHO) report in 2014, one in eight of total global deaths (around 7 million people) died as a result of air pollution exposure. The number of death is more than double compared to previous estimates and confirms that air pollution is now the world's largest environmental health risk (WHO, 2014). Therefore, reducing air pollutants could save millions of lives every year. Unfortunately, due to lack of both awareness and proper regulations, air quality has been deteriorating progressively in developing countries (Abdul-Wahab, 2008). For example, air pollution was ranked as the major contributor to premature mortality in terms of risk priority in the United Arab Emirates (UAE) (Gibson and Farah, 2012).

Rapidly expanding economy, especially in developing countries, has a direct relationship with the environmental quality. As reported by Ebinger et al. (2011), the Gulf Cooperation Council (GCC) countries are likely to experience one of the most rapid growth rates in economic and energy consumption in the world over the next twenty years. During this period, oil and gas reserves are the primary causes of air pollution, which result in steadily deteriorating of air quality in this region (Al-Ghamdi et al., 2015). Furthermore, distribution of the air pollutants in this region is strongly affected by the major seasonal sandstorms (Brown et al., 2008; Meo et al., 2013). To address air pollution and other environmental challenges in the GCC countries, a major initiative of the countries was organized in the 18th UN climate change conference in Doha, Qatar in 2012 (Klemes et al., 2012). From the different studies conducted in this regard, rapid urbanization and population growth, lack of a well-developed urban transit system, high number of personal vehicles, low fuel prices, and traffic congestion were found as the main parameters that should be taken into account more seriously (SAADI, 2011; Elmi and Al-Rifai, 2012). Additionally, it was found that indoor air quality was considered much less than that of ambient air quality in the GCC countries (Al-Rashidi et al., 2012; Cohen et al., 2013; Gevao et al., 2007; Yeatts et al., 2012). Worth noting that, Oman, Kuwait, Bahrain, Qatar, Saudi Arabia, and the UAE formed GCC in March 1981 to promote stability and cooperation in the region. Some basic information about the GCC countries is summarized as shown in Table 1.

1.1. Types of air pollutants

Air pollutants, which may cause environmental health risk (Willis et al., 2010; Al-Wahaibi and Zeka, 2015), are categorized in a number of different ways. The composition of air pollutants and their associated toxicity vary in different settings (Baawain and Al-Serihi, 2014). Millions of people suffer from preventable chronic respiratory diseases worldwide because of air pollution. Such respiratory diseases could result in a major public health challenge in both developing and developed countries due to their frequency and economic impact, through increased health care expenses and lost disability adjusted life years (Aït-Khaled et al., 2001). Deaths due to the economic burden of air pollution cost the global economy about US$ 225 billion in lost labor income in 2013 (World Bank, 2016). According to the World Bank and the Institute for Health Metrics and Evaluation predict, an estimated 125,000 lives were lost in the Middle East and North Africa countries because of diseases associated with outdoor and indoor air pollution in 2013, which result in human suffering and reducing economic development. When looking at fatalities across all age groups through the

Table 1
Some basic information about the GCC countries obtained from GCC Statistical Center (2016).

GCC country	Area[a]	Population	GDP	GDP	GNI[a]	CO_2 emissions[a]
	km^2 in 2017	#	Million USD	Per capita USD	Per capita in USD in 2016	Metric tons per capita in 2014
UAE	83,600	9,121,167	348,744	38,234.54	40,480	23.302
Bahrain	771	1,423,726	32,179	22,602.20	NA	23.450
KSA	2,149,690	31,742,580	644,936	20,317.68	21,720	19.529
Oman	309,500	4,414,051	66,824	15,139.03	NA	15.443
Qatar	11,610	2,617,634	152,452	58,240.46	NA	45.423
Kuwait	17,820	4,132,415	109,674	26,540.02	34,890	25.224

[a] Data from World Bank website.