

## Particulate Matter Caused Health Risk in an Urban Area of the Middle East and the Challenges in Reducing its Anthropogenic Emissions

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### Introduction

Particulate matter (PM) has been identified as an important contributor of numerous adverse health effects, such as exacerbation of chronic respiratory and cardiovascular disease, decreased lung function, which are subject to the size of the PM, the encompassed chemical components and a variety of local conditions, including geology, meteorology, road surface, and traffic. Mostly, anthropogenic PM emissions in a country predominate over the PM resulted from natural activities, such as desert storm events, except Middle Eastern countries, in which extreme weather conditions are often observed. Their anthropogenic emissions act as a higher enrichment factor for the total PM concentrations, especially for the PM-bound heavy metals, resulting from low utilization of public transport, aging vehicle fleet and the increasing number of personal vehicles [1]. Further, the high density urban development and rapid urbanization in the Middle East enhance the PM exposure for the public. This commentary is intended to remark the PM-caused health effects in an urban area in the Middle Eastern countries, and the challenges in the anthropogenic PM control measures, in terms of Air Quality Guideline (AQG) controls, public awareness improvement, and PM control strategies and abatement measures.

### PM Related Air Quality Guidelines

So far, a safe level of PM exposure has not been identified yet. Any AQG may not completely protect every individual from undergoing any possible PM-caused adverse health effects. The AQG recommended by World Health Organization (WHO) direct to achieve the lowest concentrations possible in the context of local constraints, capabilities, and public health priorities. The PM background concentrations in the Middle Eastern region are initially higher than in other countries for its natural weather conditions. However, their anthropogenic PM emissions are not really inferior to the emissions from the natural activities, especially traffic-related emissions. In Egypt, almost 36% of the ambient PM<sub>2.5</sub> (76 µg/m<sup>3</sup>) is emitted by the one million vehicles in Cairo, which mostly are older ones with poor technical specifications [2]. More than one million vehicles are registered in Jordan, but 80% of them are running on the roadways in Amman. Another study found that in Jordan the PM<sub>10</sub> and total suspended particulates are higher in the areas with heavy traffic [3].

Lack of a complete public transport system and high population density facilitate the PM-caused adverse health effects taking place in the public. Even so, only two countries (Iran and Israel) in the Middle East, have established some legislations, law, policies or acts specifically for ambient air quality. However, none of the Middle East countries have quantitative PM<sub>2.5</sub> standards [4]. Some countries have published their specific national PM AQGs, whereas they are usually higher than the WHO's AQGs. For instance, the AQG of 150 µg/m<sup>3</sup> for 24 h exposure is recommended in Qatar, which is three times higher than 50 µg/m<sup>3</sup> by WHO [5]. In spite of the less stringent AQG, the ambient PM concentrations are still far to meet their standards.

Qatar is deemed as one of the most polluted cities in the world for its higher PM<sub>2.5</sub> concentrations. The WHO estimated that 75 µg/m<sup>3</sup> of PM<sub>2.5</sub> concentrations will increase the risk of short-term mortality about 5% over the AQG level [6].

### Public Awareness of Exposure to PM Emissions

More importantly, most of the people in Middle Eastern countries are not aware of the health consequences from their daily exposure to anthropogenic PM emissions. Road traffic is the common source of the PM emissions among the countries, and ranks on the top of the sources in an urban area of the Middle East [2]. More than 800,000 people die from the PM<sub>2.5</sub> exposures in cities around the world [7]. In Qatar, 31 out of every 100,000 people will die as a direct result of air pollution, which is higher than nearby United Arab Emirates, and much higher than most other countries, such as UK and USA [8]. Meanwhile, personal motor vehicle traffic has been kept expanding in the most Middle East countries, such as Lebanon, Qatar, Syria and United Arab Emirates, many of which just started to invest the public transport only around a decade ago and their public networks are still limited [9]. Due to the rapid growth of vehicle traffic, frequent traffic congestion is inevitable. A significant amount of PM emissions is attributed to the traffic congestion and a large number of old vehicle combined with poor vehicle maintenance. During the congestion, commuters are exposing to the exhaust and non-exhaust PM emissions from the vehicle being stuck on roads. Personal PM exposure level could be varied with commuting modes and cities with different traffic situations. In most cities located in Europe and Oceania, the PM exposure is higher in buses and cars than bicycles and walking [10,11]. Besides, Shaaban and Muley [12] found that pedestrians in Qatar walk more during the weekdays in the winter, and the weekend in the summer and spring. However, PM exhaust emissions from light-duty vehicles doubled for every 20°F drop in ambient temperature [13].

The lack of awareness of personal exposure could be ascribed to a gap in the information regarding air quality monitoring, educational programs on health burden of ambient air pollution exposure to urban populations or under-appreciation of the potential solutions and measures addressed air pollution. Additionally, the impact of vehicle traffic on air quality and adverse health effects in the Middle Eastern

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countries are rarely investigated. Qatar is one of the few countries that have its own ground monitoring stations in the Middle East. However, only PM<sub>10</sub> data have been collected [5] and plenty of construction projects have been active nationwide for the FIFA World Cup 2011. The construction activities raise another source of PM emissions, little quantitative data of which are available for the air quality deterioration and its associated health risk. Comparatively, the PM related air quality study in the Middle East countries fall far behind other developed countries.

## PM Control Strategies and Abatement Measures

A review study concluded that insufficient effort is made to implement convenient and practical alternative solutions for the ambient anthropogenic air pollution in the Middle East [2]. Considerable attention is suggested to pay to the future urban expansion, the absolute increase in motor vehicles and their poor technical specification, the extensive use of poor quality fuel and inappropriate combustion activities. In fact, more extensive PM control strategies and abatement measures have been carried out outside of the Middle Eastern. In many European countries, governments enforced stricter standards and regulations for motor vehicles, such as substituting old vehicles by newer ones with more efficient engines and using cleaner fuels. They also financially promoted the use of public transport to reduce exhaust emissions from congestion. In the USA and China, financial subsidies have been implemented to encourage people to buy electrical vehicles. A voluntary national low emission vehicle program has been fulfilled to mitigate the growth rate of vehicle mileage traveled in the USA. Over the recent decades, direct anthropogenic PM emissions decreased by 14% in the European Union [14]. Between 1990 and 2011, the reduction of anthropogenic PM emissions ranges from 40% to 53% [15]. These successful control strategies could be valuable references to the Middle Eastern countries.

In the last few decades, most research and policy actions have extensively emphasized on exhaust emission reductions, whereas the PM<sub>2.5</sub> emissions are predominately contributed by non-exhaust emissions. The PM emissions from wearing and tearing vehicle parts, such as brake, tire and clutch and resuspension of dust, are classified as non-exhaust emissions. Evidence demonstrates that the non-exhaust emissions are consisted of coarse (PM<sub>2.5-10</sub>) and fine particle (PM<sub>2.5</sub>) [16]. Compared to exhaust emissions, the knowledge of non-exhaust emission characteristics and patterns is relatively scarce [17]. Several studies found that even with zero exhaust emissions (e.g. electrical vehicles), traffic will continue to emit fine and ultrafine particles, performing non-exhaust emissions [18,19]. By the end of the decade, almost 90% of the total emissions from road traffic will be derived from the non-exhaust sources [20]. Further, there is no specific regulation and effective estimate method to control and quantify the non-exhaust emissions, even in a developed country like the USA, which raise tremendous concern on the uncertainties of the PM-caused health effects [21]. Recent studies demonstrated that the non-exhaust emissions could be minimized by improving drivers' driving behaviors, reducing congestion, and material improvement. Driving behaviors could be improved with the aid of an intelligent transportation system (ITS), such as V2V and V2I, to control traffic flow speed for minimal vehicle turbulence, and allow them to prevent hard brake events from occurring [22]. During congestion, drivers are more likely to conduct a stop-and-go action during congestion, leading to higher abrasion PM emissions [23].

Besides, higher exhaust emissions are observed at the pavement with lower and higher roughness [24]. In this case, pavement material

as well as type material could improve to mitigate material abrasion while braking or accelerating. However, it is worth noting that most of research in the PM controls and abatement measures are carried out in North America and Europe. The characteristics of the PM emissions in the Middle Eastern countries could be varied for their extreme meteorological conditions. The measures of ITS and material improvement ought to adapt to the regional conditions for effective PM abatement. In the USA, watering is commonly used to control PM emissions from scraper travel surfaces and other temporary travel routes at construction sites, which reduce an average of above 75% of PM<sub>10</sub> emissions for 2 h [25]. There are more efficient methods, such as chemical dust suppressants, and building graveled and paved aprons, but more expensive. However, beside of these, few alternatives have been proposed to address the PM emissions from construction activities in the last decade.

## Conclusion

Airborne PM emissions pose a threat of adverse health effects to the public, particularly in an urban area of the Middle East. In comparison to developed countries, the PM control strategies and abatement measures in the Middle Eastern countries fall far behind. It is suggested to pay attention to future urban expansion, the number motor vehicles and their technical specification, poor quality fuel and inappropriate combustion activities, for better air quality. In terms of PM abatement measures, researchers are confronting the uncertainties in monitoring and qualifying the non-exhaust from road traffic. The knowledge of non-exhaust PM emission characteristics and patterns is relatively scarce. Besides, a breakthrough is required for alternatives to effectively and economically reduce PM from construction activities.

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