

A Review of Traffic-Related Air Pollution

Mohsin Khan

Department of Mechanical Engineering, University of Engineering & Technology, Peshawar, Pakistan

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Abstract— Traffic-related air pollution in urban areas is of growing concern as it worsens air quality which ultimately causes health problems. The exponential growth in urban traffic vehicles seriously deteriorate air quality as a result of higher fuel combustion products which disperse in the air. This review investigate and compile prominent researches conducted about traffic-related air pollution. The review found that traffic related air pollution is measured usually with Air Quality Index (AQI), which determines how much the concentration of a traffic air pollutant surpasses the satisfactory AQI category. The higher the value of AQI or the pollutant concentration, the worse the air quality. Each AQI category have its own implication to health and wealth of the people.

Keywords— Traffic-related air pollution, AQI, Particulate Matter, NO₂, SO₂

I. INTRODUCTION

The review paper summarizes some of the most significant researches conducted about traffic-related air pollution impact on public health, economy, air quality and climate change. Some of the major urban challenges includes congestion, lack of funds for basic services, a shortage of adequate housing, declining infrastructure and rising traffic air pollution. United Nations estimates that 3.5 billion people lives in cities currently and 5 billion projected to live in cities by 2030 and with only 3% of the Earth's land occupied by cities, but account for 60-80% of energy consumption and 75% of carbon emissions. Rapid growth in population, industrialization and urbanization have led to increases in the overall number of motor vehicles. Many local vehicles are aged and poorly maintained and contribute excessively to air emissions and pose adverse health risk to the residents in the city. One of the most prominent cause of urban air pollution in Pakistan is vehicular traffic emissions, as motor vehicles increased from 2 million to 10.6 million during period of 20 years from 1991 to 2012 [1]. Traffic emissions which includes but not limited to; PM₁, PM_{2.5}, PM₁₀, CO₂, SO₂, NO₂, O₃, which contribute to overall air pollution largely. Traffic Related Air Pollution (TRAP) is increasing day by day in Pakistan while policy makers have no KPIs.

Similarly, air pollution is the 6th leading risk factor for mortality in Pakistan, responsible for more than 9% of deaths

(128,000) in 2017 alone as shown in Fig 1. Air pollution exposures, including exposure to outdoor particulate matter (PM_{2.5}) and household air pollution have been linked to increased hospitalizations, disability, and early death from respiratory diseases, heart disease, stroke, lung cancer, and diabetes. Exposure to ambient ozone is linked to Chronic Obstructive Pulmonary Diseases (COPD). Also, air pollution is associated with climatic changes, global warming, deteriorating telecommunication networks, economic and ecological losses. Pakistan currently has 5th largest numbers of deaths because of PM_{2.5} exposure and is ranked 6th in the world for the greatest number of deaths from chronic destructive pulmonary diseases (COPD) SOGA 2019 [14]. A scientific research has found that long term exposure to ambient air pollution increases mortality and morbidity from cardiovascular Han [20], respiratory diseases Kim et. al. [7], effects Pulmonary function and inflammation Li [19] lung cancer and reducing life expectancy.

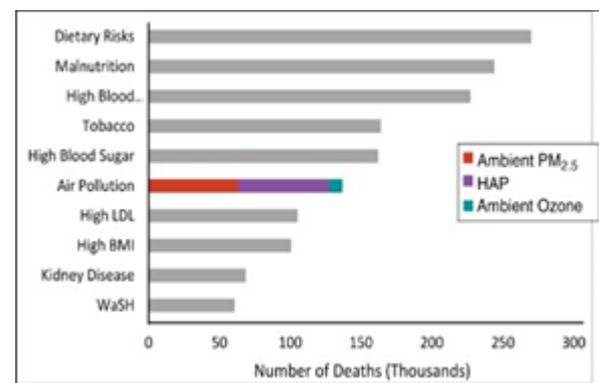
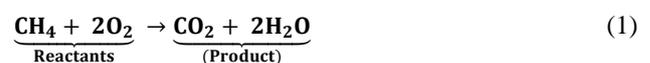


Fig. 1 Leading risk factors for death and disability in Pakistan in 2017 (SOGA, 2019)

A. Measuring methods for TRAP

Fig 2. shows the three distinct stages of TRAP measurements, each require different type of apparatus. Usually, measuring stage III emissions are useful and easy. Combustion of fossil fuel such as hydrogen (H_2), methane (CH_4), and octane (C_8H_{18}) produces product of combustion such as (1) shows its chemical process.



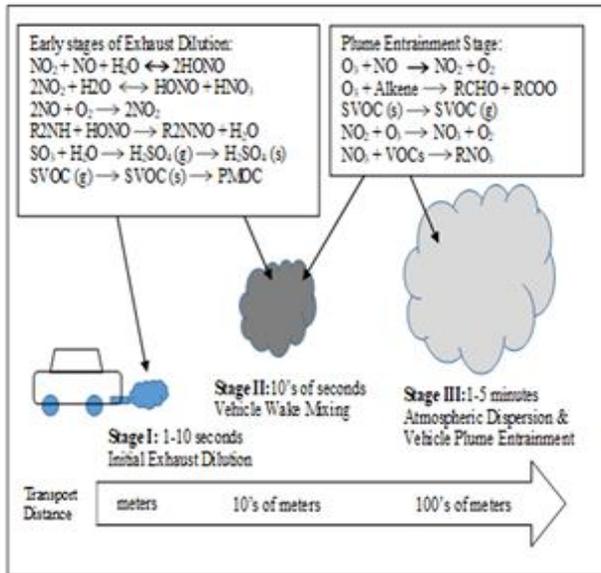


Fig. 1 Layout of possible chemical transformation of motor vehicle emissions [HEI, 2010]

The reactions described here is carried out in air, which can be approximated as 21% O_2 and 79% N_2 . This composition is referred to as 'theoretical air.' With this definition, for each mole of O_2 , 3.76 (or 79/21) moles of N_2 are involved Eastop [17]:



Even if the nitrogen is not part of the combustion process, but due to high temperature in the combustion chamber, Nitrogen heats up, Oxides of Nitrogen forms because of the excess air and temperature. Other pollutants form light duty vehicles (LDVs) which uses gasoline and ethanol as fuel, are the cause of CO and volatile organic compounds (VOC) Pérez-Martínez [11]. Also, heavy duty vehicle (HDVs) generate Nox and Particle Matter (PM). The concentration of traffic-air pollutant once measured, converted to Air Quality Index (AQI) using US EPA breakeven point technique, using (3) [2] along with breakpoints Table I. AQI categorical representation by colour scale is in II, which helps in knowing the level of hazard or toxicity of a pollutants through color.

Daily average AQI was calculated from pollutant concentration based on US EPA procedures

$$I_p = \left(\frac{I_{high} - I_{low}}{BP_{high} - BP_{low}} (C_p - BP_{low}) + I_{low} \right) \quad (3)$$

I_p = the (Air Quality) index,

C_p = the pollutant concentration,

BP_{low} = the concentration breakpoint that is $\leq C_p$

BP_{high} = the concentration breakpoint that is $\geq C_p$

I_{low} = the index breakpoint corresponding to, BP_{low}

I_{high} = the index breakpoint corresponding to BP_{high}

TABLE I. BREAKPOINTS FOR CALCULATING AQI (SOURCE: US EPA, AIRNOW [2])

These Breakpoints...							...equal this AQI	...and this category
O_3 (ppm) 8-hour	O_3 (ppm) 1-hour	$PM_{2.5}$ ($\mu g/m^3$) 24-hour	PM_{10} ($\mu g/m^3$) 24-hour	CO (ppm) 8-hour	SO_2 (ppb) 1-hour	NO_2 (ppb) 1-hour	AQI	
0.000 - 0.054	-	0.0 - 12.0	0 - 54	0.0 - 4.4	0 - 35	0 - 53	0 - 50	Good
0.055 - 0.070	-	12.1 - 35.4	55 - 154	4.5 - 9.4	36 - 75	54 - 100	51 - 100	Moderate
0.071 - 0.085	0.125 - 0.164	35.5 - 55.4	155 - 254	9.5 - 12.4	76 - 185	101 - 360	101 - 150	Unhealthy for Sensitive Groups
0.086 - 0.105	0.165 - 0.204	(55.5 - 150.4)	255 - 354	12.5 - 15.4	(186 - 304)	361 - 649	151 - 200	Unhealthy
0.106 - 0.200	0.205 - 0.404	(150.5 - 250.4)	355 - 424	15.5 - 30.4	(305 - 604)	650 - 1249	201 - 300	Very unhealthy
	0.405 - 0.504	(250.5 - 350.4)	425 - 504	30.5 - 40.4	(605 - 804)	1250 - 1649	301 - 400	Hazardous
	0.505 - 0.604	(350.5 - 500.4)	505 - 604	40.5 - 50.4	(805 - 1004)	1650 - 2049	401 - 500	Hazardous

TABLE II. AQI SCALE OF CATEGORIZATION (US EPA)

AQI Class	AQI Category	Colour Representation
0-50	Good	Green
51-100	Moderate	Yellow
101-150	Unhealthy for Sensitive Groups	Orange
151-200	Unhealthy	Red
200-300	Very Unhealthy	Purple
>300	Hazardous	Maroon

B. Research review

To the best of our knowledge, there is hardly any mechanism locally available to measure the concentration of these air traffic pollution systematically using IoT and implement appropriate strategies. Reviewing the extensive literature available can help to develop a compressive design of a measuring and monitoring system for traffic related air pollution. Based on the investigation, design for TRAP containment through research process can help government to implement strategies for its citizens. Data collected though measurement by IoT sensors, may be exploited to increase the transparency and promote the actions of the local government towards the citizens, enhance the awareness, of people about the status of city. By controlling those parameters originated from traffic related air pollution, it is possible to improve the level of comfort and health of residents in the city. Also, by publishing the findings of the compilation of extensive review investigation, thereby contributing meaningful and relevant data to the peer-reviewed literature. Various investigations conducted throughout are summarized the Table II explaining TRAP, its measurement and its impact.

II. REVIEW OF STUDIES

Various studies investigate traffic-related air pollution. Some prominent work done in this regard is summarized in below Table III. Real-time traffic air measurement is not an unachievable task but certainly a complicated business. Numerous methods have been implemented to know air pollution. Berkowicz, et al. [3] used Danish Operational Street Pollution Model (OSPM) of estimation for traffic emission (NOx and CO) at the Copenhagen University building based on the COPERT model. Other studies adopted an indirect approach such as Zanella, et al. [4] have conducted a pilot study at Padova, Italy, about new IoT technology, for the street lighting system and measurement of environmental parameters. Mobile Crowd Sensing (MCS) was another IoT technique coined by Montori, et al. [5], which collected corporate, state, and end-user data for analysis. Another research by Ahmad, et

al. [6] on determining the concentration of particulate matter PM10 and Pb at Upper Dir and Charsadda by using Reference Ambient Air Sampler and graphite furnace atomic spectroscopy. Similarly, an investigation discovered the level of temperature, humidity, and Carbon Dioxide using IoT, where data from the transmitter node has been sent to the receiver node and stored in a customized excel sheet [7]. For measurement of the concentration of CO2, NOx, and PM10, Non-Dispersive Infrared Photometry, Chemiluminescence, and an automatic sampling of Beta Radiation methods were employed respectively by Pérez-Martínez, et al. [8]. The correlation of exposure to TRAP and hospital readmission was analyzed by Newman, et al. [9] for a period of 12 months by means of logistic regression and the COX Proportional Hazard model and found that hospital TRAP has positive effect on readmission to hospital. Another method was applied by Pascal, et al. [10] where the concentration of ozone (O3) and Particle Matter (PM2.5) was collected with the UV Absorption method and Tapered Element Oscillating Microbalance (TEOM) respectively.

Not many studies assess TRAP as most of them worked on the interconnection of health with air pollution [10] and excessively focused on impact of TRAP on Asthma [9] and other health issues [1, 11-15]. There is hardly any research in the city for monitoring TRAP based on contemporary IoT system. However, this research tried to provide a long-term systematized approach for the understanding of this issue, by measuring and monitoring TRAP. Traffic air is being the primary concern in this research, and is being analyzed by measuring the concentration of parameters that are responsible for the degradation of air quality. Depending on the climate, including humidity, temperature, and rainfall, the concentration of traffic air pollutants changes region to region [16]. So, it was necessary to measure TRAP in Peshawar as well.

TABLE III. TRAFFIC-RELATED AIR POLLUTION STUDIES

Study	Location	Data acquisition	Parameter
Zanella, et al. [4]	Padova Italy	IoT for smart cities	Benzene, light, Temperature and Humidity
Montori, et al. [5]	Multiple locations	Mobile crowd sensing	Environmental parameters i.e. Temperature, Humidity
Wong, et al. [17]	Hong Kong	Outdoor and indoor infiltration data	PM2.5, CO, O3, BC etc
Wu, et al. [18]	Macao, China	DustTrack monitoring system	PM1, PM2.5, PM10
Fontes, et al. [19]	Beijing, China	4 hours a day	PM2.5
Kesavachandran, et al. [13]	India	Spirometer	Particulate matter
Kim, et al. [14]	Francisco	Logistic regression	BC, NOx, SOx, Particle matter
Berkowicz, et al. [3]	Denmark	OSPM and COPERT models	NOx and CO
Shah and Mishra [7]	Gujrat, India	IoT based system	Temperature, Humidity and CO ₂
Nigam, et al. [20]	Nagpur, India	AQI based comparison	PM2.5, PM10, SO2 and NO2
Ahmad, et al. [6]	Khyber Pakhtunkhwa, Pakistan	Reference Ambient Air Sampler (RAAS)	PM10 and Lead concentration
Ahmad, et al. [1], [11]	Rome, Italy	Comparative assessment	PM10, NO2
Linares and Díaz [15]	Madrid, Spain	Data analysis from hospital	NO2, NOx, PM2.5, PM10, SO2
Pascal, et al. [10]	Europe	Aphekom Project	PM2.5
Pérez-Martínez, et al. [8]	São Paulo, Brazil	nondispersive infrared photometry	CO, NOx, O3, PM10
Abdullah S. Modaihsh [21]	Riyadh City, Saudi Arabia	aerosol spectrometer	PM2.5, PM10

CONCLUSION

After extensive review of the literature available on traffic-related air pollution, it can be concluded that traffic air pollutant has declined the air quality in large. Further, various methods for estimation of pollutant concentration have been applied. Real time concentration of traffic air pollution is monotonous job, however recommendation of sensor deployment for continues monitoring of traffic related air pollution can be found from the exploration of various investigations.

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