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Review of Outdoor Air Pollution in Sri Lanka Compared to the South Asian Region

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ABSTRACT

Air pollution is a significant issue that affects almost all the countries in the world while predominating in South Asian Regional countries due to poverty, less attention, and less awareness towards the implementation and obeying of air quality guidelines in public. As a developing country, Sri Lanka stands at an optimum state of national air quality compared to other SARC because it is an island with a minor population compared to India, Pakistan, Bangladesh, etc. Maldives and Bhutan lie straightforwardly in owing mild air quality in SARC. However, SARC is far behind the world in maintaining optimistic air quality nationwide. Ambient air pollution-attributable deaths have become interim in past decades, a severe burden to the sustainable existence of SARC. A well-established systematic epidemiological, empirical studies and revisions regarding air pollution, strategic planning for mitigating air pollution, and frequent Spatio-temporal pollution monitoring nodes are necessary for Sri Lanka to achieve the sustainable goal. Other South Asian countries: India, Bangladesh, Pakistan, Afghanistan, Nepal, Bhutan, and Maldives, also should pay attention to minimizing outdoor air pollution nationwide for the betterment of future existence.

INTRODUCTION

Substances in the atmosphere that are harmful to living creatures and cause damage to climate are generally considered "Air Pollutants," which release into the air through anthropogenic activities and natural phenomena (Saxena & Sonwani 2019). Following this definition, particulate matter (PMs), ground-level ozone (O_3), carbon monoxide (CO), sulfur oxides (SOx), nitrogen oxides (NOx), and lead (Pb) (Table 1a & 1b) are identified as the primary air pollutants (EPA 2020). Air Pollution imbalances the whole environment making it a more perilous risk; it kills millions of human beings and meanwhile affects trees, animals, and inanimate objects (Senarath 2005). Air pollution affects public health, the economy, and aesthetics in a country, and it resulted in much concern raised among policymakers, clinicians, public health experts, and the general public in recent years (Ileperuma 2020, Nandasena et al. 2012)

Air pollution is not manageable like other pollution, such as water, soil, and solid pollution, also predominantly associated with environmental health problems (Jacqumin et al. 2012, Karunasekara 2012). It is confirmed that nine out of ten people breathe air containing a high level of pollutants, and 91% of the world's population lives in polluted atmospheres that predominantly exceed the WHO air quality permissible levels (WHO 2021). Asian Environment has considerably become polluted and a significant threat to both the life quality of people and the economic prospects in Asia, indicating that 13 mostly polluted cities lie in out of the world's most polluted 15 cities (Ileperuma & Oliver 2010). Rapid urbanization, industrialization, and no proper attention to air pollutants aggravated air pollution worldwide, especially in SAR (Kumar et al. 2018). South Asia undergoes the worst air pollution in the world, which is maximal in India (Hasnat et al. 2018). In recent years, a phenomenon called "Brown Cloud" caused by air pollution due to Carbon aerosols (atmospheric haze) over the SAR was captured by satellite images (Begum 2017).

This review describes Air Quality Guidelines (AAQS) of SAR, AQI parameters, health outcomes due to OAP, and mitigation policies of OAP, respectively.

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AQI Value	Color	Description
0-50	Green	Good
51-100	Yellow	Moderate
101-150	Orange	Unhealthy for Sensitive Group
151-200	Red	Unhealthy
201-300	Violet	Very Unhealthy
301-Higher	Maroon	Hazardous

Fig. 1: Color-coded AQI values (USEPA, 2021).

AMBIENT AIR QUALITY STANDARDS (AAQS)

A comparison of WHO guidelines with local and SAR national AAQS is shown in Tables 2a & 2b. The guideline values recommended by WHO acknowledge the heterogeneity and, in particular, should be recognized when formulating policy targets. Governments (each country) should consider their local circumstances carefully before adopting the guidelines directly as legally based standards (WHO 2005).

Generally, AAQS vary from a 1-hour maximum to 8 hours or 24-hour mean annual averages. Short-term averaging values protect from peak concentrations that can cause adverse health risks, while long-term averaging values protect from chronic health effects (WHO 2005). AAQS plays a crucial role in maintaining the air quality of a country, supporting its legislation, and regulating criteria for its self-sustainability.

AIR QUALITY INDEX (AQI)

AQI is an index (ranging from 0-500, no units) introduced by the US EPA, regulated by the "Clean-Air Act" (Ileperuma

Table 1a: Major Air Pollutants, Origination, Risk Effects, and Health Effects.

Air Pollutant	Origination/Formation	Risk Effect	Health effects
PMs	• Emits directly from motor vehicles, and power plants (HEI 2004) • Forms by reactions with gaseous emissions in the atmosphere (e.g.: [NOx, SOx] react to form nitrates and sulfates) (HEI 2004)	• PM_{10} get deep into the lungs (EPA 2020) • $PM_{2.5}$ get into the bloodstream pose, reduce visibility (haze) (EPA 2020) • Particles can be conveyed long distances by wind and settle on ground or water, resulting in lakes and streams being acidic, changing the nutrient, depleting the nutrients in the soil, damaging sensitive forests, and farm crops, affecting the diversity of ecosystems, and contributing to acid rain (EPA 2020)	• Aggravates heart and lung conditions (Senarath 2005, WHO 2014b) • Smaller particles ($<PM_{2.5}$) can pass through the lungs, causing inflammation and scarring to lung tissue (Senarath 2005, WHO 2014b) • Irritates nose and throat (Senarath, 2005) (WHO 2014b)
Ground Level O_3	• Created by chemical reactions between NOx and volatile organic compounds (Pollutants emitted by cars, power plants, industrial boilers, refineries, chemical plants, and other sources chemically react in sunlight). (EPA 2020).	• Ground Level O_3 affects human health, echo systems (forests, parks, wildlife refuges, wilderness areas), and water bodies. (EPA 2020) • Threatens and harms sensitive vegetation during the growing season (EPA 2020)	• Asthma attacks (Senarath 2005) • Loss of lung function (Senarath 2005) • Breathing and respiratory problems (Senarath 2005)
CO	• Emissions of vehicles (cars, trucks, etc.). (EPA 2020) • Machinery that burns fossil fuels. (EPA 2020). • Household appliances: unvented kerosene, gas-space heaters, leaking chimneys and furnaces, and gas stoves (WHO 2014a).	• Harmful when inhaled in large amounts (EPA 2020) • Long-term exposure to low concentrations affects health (HEI 2004). • Affects indoor air quality (HEI 2004).	• CO poisoning: Dizziness, Headache, General fatigue (Senarath 2005, WHO 2014b) • Blocks the uptake of oxygen by blood by forming carboxyhemoglobin. Respiration, Brain, and heart functioning are affected (Senarath 2005)

Table 1b: Major Air Pollutants, Origination, Risk Effects, and Health Effects.

Air Pollutant	Origination/Formation	Risk Effect	Health effects
SO_2	• Burning fossil fuels (coal, oil) (HEI 2004) • Smelting of mineral ores containing Sulphur (HEI 2004)	• Poisonous substance (EPA 2020) • Forms harmful acids (EPA 2020). • Affects both human health and the environment (EPA 2020). • Forms fine particles that reduce visibility (haze). (EPA 2020).	• Irritation of the mucous membrane (Senarath 2005) • Aggravate existing conditions- bronchitis (Senarath 2005) • Cause wheezing, shortness of breath, and coughing (Senarath 2005)
NO_2	• Power generation, industrial and traffic sources (HEI 2004).	• Severe threat to human health (HEI 2004) • Form acid rains (HEI 2004). • Harms sensitive echo systems (HEI 2004).	• Irritates mucous lining of nose and throat, coughing, choking, headache, and lung inflammation such as bronchitis or pneumonia (Senarath 2005)
Pb	• Ore and metals processing. (EPA 2020) • Piston-engine aircraft operate on leaded aviation fuel. (EPA 2020) • Waste incinerators, utilities. (EPA 2020) • Lead-acid battery manufacturing process. (EPA 2020)	• Decreases growth and reproductive rates of plants (EPA 2020). • Neurological effects in vertebrates (EPA 2020).	• Anemia (Senarath 2005) • Weakness (Senarath 2005, WHO 2014b) • Kidney and brain damage (Senarath 2005) • High exposure can cause death (Senarath 2005)

Table 2a: WHO and SAR countries' AAQS.

Pollutant	Averaging-Time	Maximum Concentration (Ambient air)												
		WHO	Sri Lanka		Nepal	Bangladesh		India		Pakistan	Bhutan			Afghanistan
		[µg.m^{-3}]	[µg.m^{-3}]	ppm	[µg.m^{-3}]	[µg.m^{-3}]	ppm	Industrial Area, Residential, Rural & Other Areas [µg.m^{-3}]	Ecologically Sensitive Area (Notified by Central Govt) [µg.m^{-3}]	[µg.m^{-3}]	Industrial Area [µg.m^{-3}]	Mixed Area[1] [µg.m^{-3}]	Sensitive Area[2] [µg.m^{-3}]	[µg.m^{-3}]
NO_2	Annual	40	-	-	40	100	0.053	40.0	30.0	40	-	-	-	40
	24hrs	-	100	0.05	80	-	-	80.0	80.0	80	-	-	-	80
	8hrs	-	150	0.08	-	-	-	-	-	-	-	-	-	-
	1hr	200	250	0.13	-	-	-	-	-	-	-	-	-	-
SO_2	Annual	-	-	-	50	80	0.33	50.0	20.0	80	80	60	15	50
	24hrs	20	80	0.03	70	365	0.14	80.0	80.0	120	120	80	30	-
	1hr	-	200	0.08	-	-	-	-	-	-	-	-	-	-
	10 min	500	-	-	-	-	-	-	-	-	-	-	-	-
O_3	24hrs	-	-	-	-	-	-	60.0	60.0	-	-	-	-	-
	8hrs	100	-	-	-	-	-	100.0	100.0	-	-	-	-	100
	1hr	-	200	0.10	-	-	-	180.0	180.0	130	-	-	-	-
CO	8hrs	-	10,000	9.00	10,000	157	0.08	-	-	5000	5000	2000	1000	30
	1hr	-	30,000	26.00	-	235	0.12	4000.0	4000.0	10,000	10,000	4000	2000	10
	30 min	-	-	-	-	-	-	-	-	-	-	-	-	60
	15 min	-	-	-	100,000	-	-	-	-	-	-	-	-	-
	Any Time	-	58,000	50.00	-	-	-	-	-	-	-	-	-	-

[1] Residential, Commercial areas
[2] Areas such as hospitals, schools, sensitive ecosystems

Table 2b: WHO and SAR countries' AAQS.

Pollutant	Averaging Time	Maximum Concentration in Ambient air												
		WHO	Sri Lanka		Nepal	Bangladesh		India		Pakistan	Bhutan			Afghanistan
		[µg.m^{-3}])	[µg.m^{-3}])	ppm	[µg.m^{-3}]	[µg.m^{-3}]	ppm	Industrial Area, Residential, Rural & Other Areas [µg.m^{-3}]	Ecologically Sensitive Area (Notified by Central Govt) [µg.m^{-3}]	[µg.m^{-3}]	Industrial Area [µg.m^{-3}]	Mixed Area [µg.m^{-3}]	Sensitive Area [µg.m^{-3}]	[µg.m^{-3}]
NOx	Annual	-	-	-	-	-	-	-	-	40	80	60	15	-
	24hrs	-	-	-	-	-	-	-	-	40	120	80	30	-
PM_{10}	Annual	20	50	-	-	50	-	60.0	60.0	120	120	60	50	70
	24hr	50	100	-	120	150	-	100.0	100.0	150	200	100	75	150
$PM_{2.5}$	Annual	10	25	-	-	15	-	40.0	40.0	15	-	-	-	35
	24hr	25	50	-	-	65	-	60.0	60.0	35	-	-	-	75
TSP[3]	Annual	-	-	-	-	-	-	-	-	360	360	140	70	300
	24hr	-	-	-	230	-	-	-	-	500	500	200	100	-
Lead	Annual	-	-	-	0.5	0.5	-	0.50	0.50	1	-	-	-	0.5
	24hrs	-	-	-	-	-	-	1.0	1.0	1.5	-	-	-	-
Benzene	Annual	-	-	-	20	-	-	-	-	-	-	-	-	-
	24hrs	-	-	-	-	-	-	-	-	-	-	-	-	-

[3] Total Suspended Particulates

Sources Table 2a, 2b: (CPCB 2009, Government of Pakistan 2010, Government of the People's Republic of Bangladesh 2013, Ministry of Environment 2003, National Environment Commission 2010, SriLanka Government 2008, Torabi & Nogami 2016, WHO 2005)

2020), to indicate the air quality status and its relation to health effects due to air pollutants. All national governments use a color-coded AQI (Fig. 1) to effectively circulate air quality measurements to the general public (CEA 2021a, USEPA 2021). AQI values are generally based on $PM_{2.5}$ (Ileperuma 2020).

OAP in SAR

WHO 2021 reported that about 4.2 million premature deaths would cause worldwide (2016) due to OAP by inhaling PM_{10} and $PM_{2.5}$ particles. $PM_{2.5}$ is the 5th ranking global mortality risk factor and reported 7.6% of global mortality in 2015 (Saud & Paudel 2018). Most low and middle-income countries experience the burden of ambient air pollution, specifically South-Asia and Western Pacific Regions (WHO 2021). The sources of the significant ambient air pollutants are a massive range of stationery (industries, household sources, open burning of domestic and agricultural waste and mobile (road vehicles, trains, ships) (Nandasena et al. 2012, Thishan et al. 2008).

In Sri Lanka, 40- 50% of power is generated by burning fossil fuels (NCSD 2009). Seneviratne et al. (2017) concluded that aged sea salt, soil, traffic, biomass burning, and industrial sources distinguished as the general air pollution sources in the city, Kandy while reporting the familiar sources of particulate pollution in metropolitan Colombo is motor vehicles, road dust, and biomass. Gunathilaka et al. (2011) investigated that the atmospheric Pb and Zn amounts are more highly perceived in Colombo than that in Kurunegala, a rural city, highlighting the increased traffic in Colombo would be the reason for the OAP. The industrial sector accounts for nearly half of the total emission of SO_2 in Sri Lanka; the primary reason is the improper release of air pollutants into the atmosphere (Senarath 2005).

The reported PM_{10} concentration variation at Colombo-Fort Air Quality Monitoring Station (AQMS) during 1998-2016 had remained relatively stable between 72-82 $\mu g.m^{-3}$ while it ranged from 55-100 $\mu g.m^{-3}$ with an increasing proving the exceedance in the annual air quality standard of 50 $\mu g.m^{-3}$ in Sri Lanka (Ileperuma 2020). In 2007, the Colombo-Fort AQMS data analysis in a day indicated a peak in CO, NO_2, and SO_2 during traffic congestion (office and school traffic) at around 8.00 am, while the O_3 showcases a steady rise with increasing the solar-intensity at noon and an increase of NO_2, SO_2 levels were reported. Dharshana et al. (2008) reported that PM_{10} is the prominent air pollutant in the Colombo atmosphere using the data monitored from the Colombo-Fort AQMS.

In 2016 (January - May), National Building Research Organization (NBRO) monitored exposure levels due to vehicular emissions in the country, focusing on several major cities (Colombo, Gampaha, Kalutara, Horana, Kurunegala, Ratnapura, Galle, Kurunegala, Kandy, Anuradhapura) using passive-sampling technology, according to wet-analysis methods and showcased an exceedance in average SO_2 levels in 24-hours. Recent annual air-quality (2019, 2020) measurements-reports of AQMS in Battaramulla and Kandy, Sri Lanka (Table 3), show PM levels exceed WHO acceptable limits. Further, analysis for $PM_{2.5}$ and PM_{10} at the same AQMS indicates a frequent exceedance in the relevant Sri Lanka standards in 2018-2019 (Ileperuma O. A. 2020), while the yearly summary in 2020 reveals a specific control in $PM_{2.5}$ and PM_{10} at the same AQMS (Fig. 2, 3) because of the enacted curfew and travel restrictions due to the corona pandemic situation in the country. Yet, there was a sudden unexpected increase of $PM_{2.5}$ levels at the end of October 2020 in most of the urban cities of Sri Lanka (Jaffna, Vavuniya, Puttalam, Kegalle, Kurunegala, Anuradhapura, Kandy, Colombo, Rathnepura, Nuwara-Eliya) according to the NBRO (2020) air-quality measuring data, indicated US-AQI values in between 100-150, alerting the sensitive groups about their health while confessing the reason of this higher increase would be the prevailed wind pattern around the island and the high amount of air pollutants found at in Indian peninsular which was reported in Air Visual website within the due time period. Coarse particulates (windblown dust from deforested and eroded areas), soot, and vapor from combustion vehicles and open burnings such as agricultural and domestic waste are highly contributable to PMs (Thishan et al. 2008).

AQI values measured at Battaramulla AQMS (December 2020 - May 2021) show a satisfactory trend in lying in good (0-50) and (51-100) moderate AQI categories (Fig. 4). But more significant than that in March-June, 2020 as being regular the human life after the 2nd wave of Covid-19 outbreak in Sri Lanka. Recently (2021), the prominent pollutants were $PM_{2.5}$ and O3 in Battaramulla and Kandy, Sri Lanka (CEA 2021a).

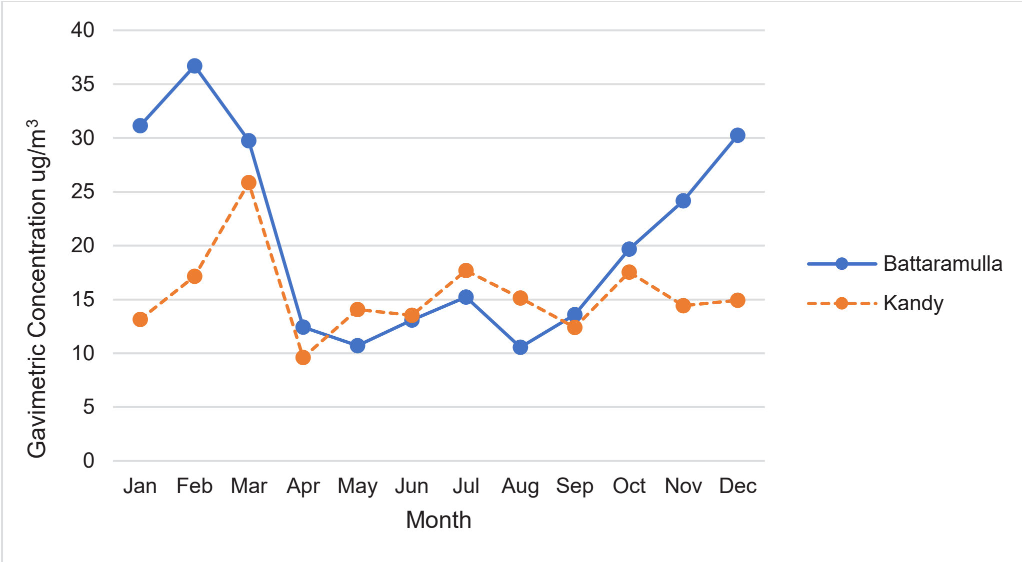
Though the OAP in Sri Lanka causes primarily due by commercial energy combustion (soot and condensed vapor highly contributed to $PM_{2.5}$ (Thishan et al. 2008), the most significant contributor is the increased vehicle population (Senarath 2005) and traffic congestion (Ileperuma 2020). As per the updated statistics on vehicle population in Sri Lanka, the newly registered total vehicle population (Fig. 5) in 2015 is the maximum throughout the past 5 years (2015-2019) (MoT 2021a). Further, the total new registration of vehicles dramatically reduced in 2019 to 367,303 (in 2018, it was 479,340) due to government taxes and some measures taken to limit vehicle importation to Sri Lanka (MoT 2021b, NTC 2017). Overall vehicle registration from 1997 to 2019 devoted 50% in Western Province, Sri Lanka (Ileperuma 2020). Meanwhile, private vehicles have a higher rate of registering than that public vehicles and tend to increase outdoor air pollution due to the formation of higher traffic congestion (dust stirring), uncomfortable road conditions as well as low priority for vehicle maintenance and fuel efficiency, mainly in Colombo city (Senarath 2005). However, the total vehicle population has been increasing each year respectively, making considerable weight into ambient air pollution in the country.

Further, improper economic and planning policies have become the parent cause of the problems relating to ambient air pollution in Colombo by today; the use of low-quality fuels, incoherent traffic management policies, poor land-use planning, and use of reconditioned vehicles and engines are some of the examples that contribute to the OAP problem (Thishan et al. 2008, Torabi & Nogami 2016).

Table 3: Annual Air Pollutant Averages in Sri Lanka 2019, 2020 (Central Environment Authority AQMS) (CEA 2021b).

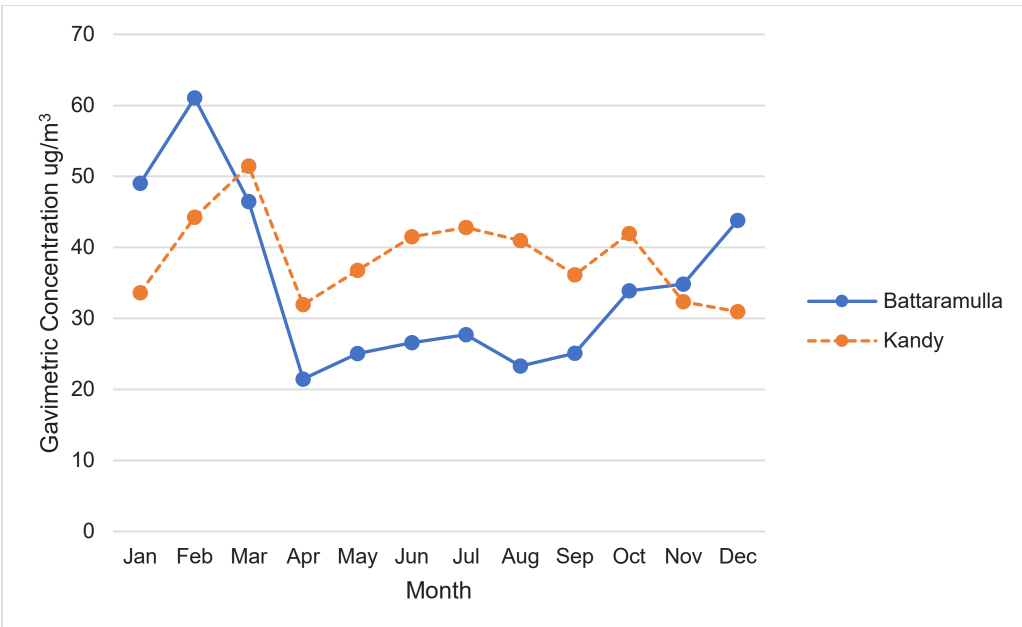
Pollutant	Mean Concentration[4,5]			
	2019		2020	
	Battaramulla AQMS	Kandy AQMS	Battaramulla AQMS	Kandy AQMS
O_3	13.68	11.74	15.72	15.71
CO	629	673	237	912
NO_2	11.41	13.36	11.18	8.72
SO_2	5.77	1.65	6.87	1.17
$PM_{2.5}$	21.36	16.49	21.18	15.10
PM_{10}	40.35	42.68	35.66	38.66

[4] Gas concentrations in 'ppb' and Particulates in 'μg.m^{-3}'
[5] Averaging Method: Averages of 1hr (Hourly) Concentrations



[Source: Central Environmental Authority, Sri Lanka]

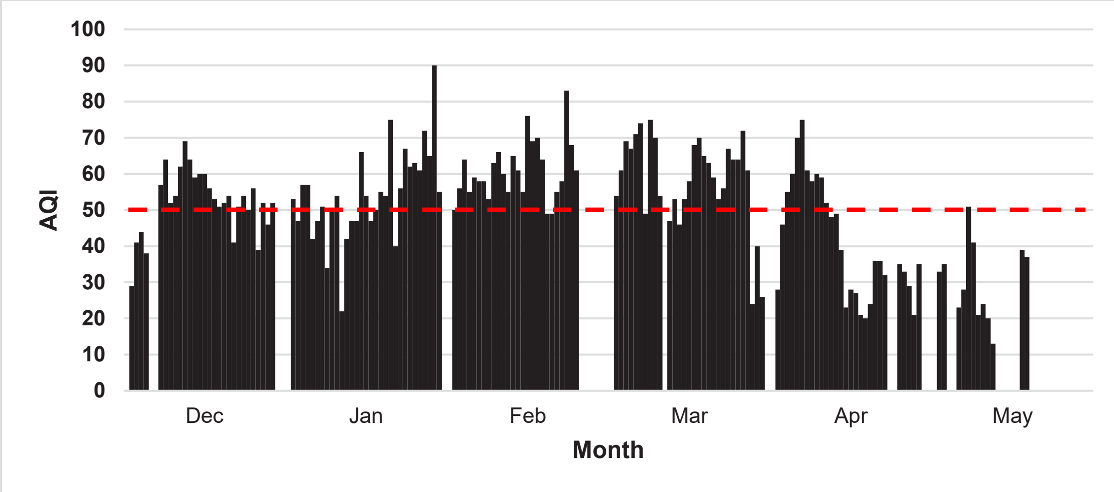
Fig. 2: $PM_{2.5}$ by Month (Diurnal) Battaramula and Kandy in 2020 (From 01-01-2020 to 01-01-2021) $PM_{2.5}$ Concentration 1-month Average ($ug.m^{-3}$).



[Source: Central Environmental Authority, Sri Lanka]

Fig. 3: PM_{10} by Month (Diurnal) Battaramula and Kandy in 2020 (From 01-01-2020 to 31-12-2020) $PM1_0$ Concentration 1-month Average ($ug.m^{-3}$).

Liu et al. (2013) reported that the primary reasons for outdoor air pollution in Kanpur, India are industries and vehicle emissions. The dense population and the higher usage of motor vehicles significantly contribute to OAP in Pakistan and Bangladesh (Hopke et al. 2008). Pakistan Environmental Protection Agency (PEPA) reports that air pollution levels in major cities of Pakistan delineated seven times higher than the WHO permissible levels (Purohit et al. 2013). Kathmandu (Nepal) possessed 4.78% population growth in 2011 amidst the country's rapid urbanization. The registered number of vehicles has been more than 32 times within the last 1.5 decades (~ 2000-2016), susceptible to in-



[Source: Central Environmental Authority, Sri Lanka; Some AQI values are missing due to the power failure of AQMS, Battaramulla]

Fig. 4: Ambient AQI at Battaramulla AQMS (From Dec 2020 to May 2021).

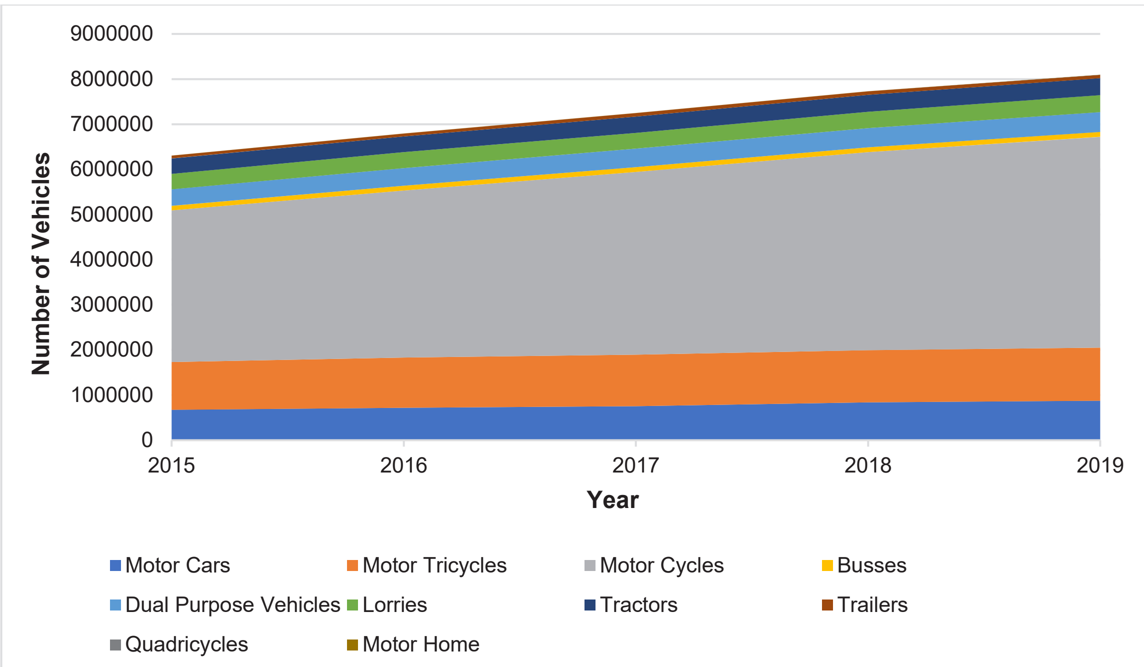


Fig. 5: Total vehicle population in Sri Lanka 2015-2019 (MoT, 2021b; NTC, 2017).

crease air pollution in Nepal (Saud & Paudel 2018). The key factors are the ongoing industrial activities without proper air pollution control, inefficient energy usage, higher numbers of motor vehicle usage, and open burning of solid waste and plastics (Purohit et al. 2013, Saud & Paudel 2018). In Afghanistan, massive traffic congestion due to limited road capacity, poorly maintained timeworn vehicle usage, using electric generators, combustion processes, using poor fuel quality, and population growth are the significant reasons for OAP (Mehrad 2020, Torabi & Nogami 2016). Thereby it accounts for about 75% of OAP in Afghanistan by 2020, and been reported that old and smoky cars are the primary source of O_3 concentration in Kabul and in 2019, NO_2 (305 μg/m^3 – 1-hour average) and SO_2 (63.7 μg/m^3 – 1hours average) expose a significant exceedance in that of WHO permissible concentration level in Kabul ensuring the failure

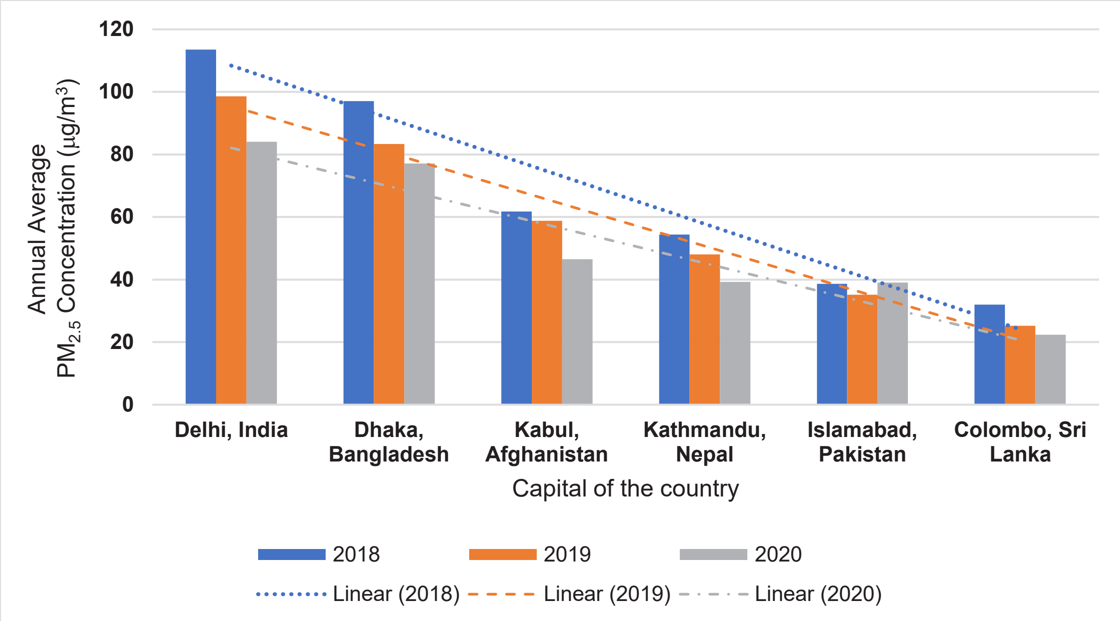


Fig.6: Annual average $PM_{2.5}$ concentration of the SAR (Visual, 2018, 2019, 2020).

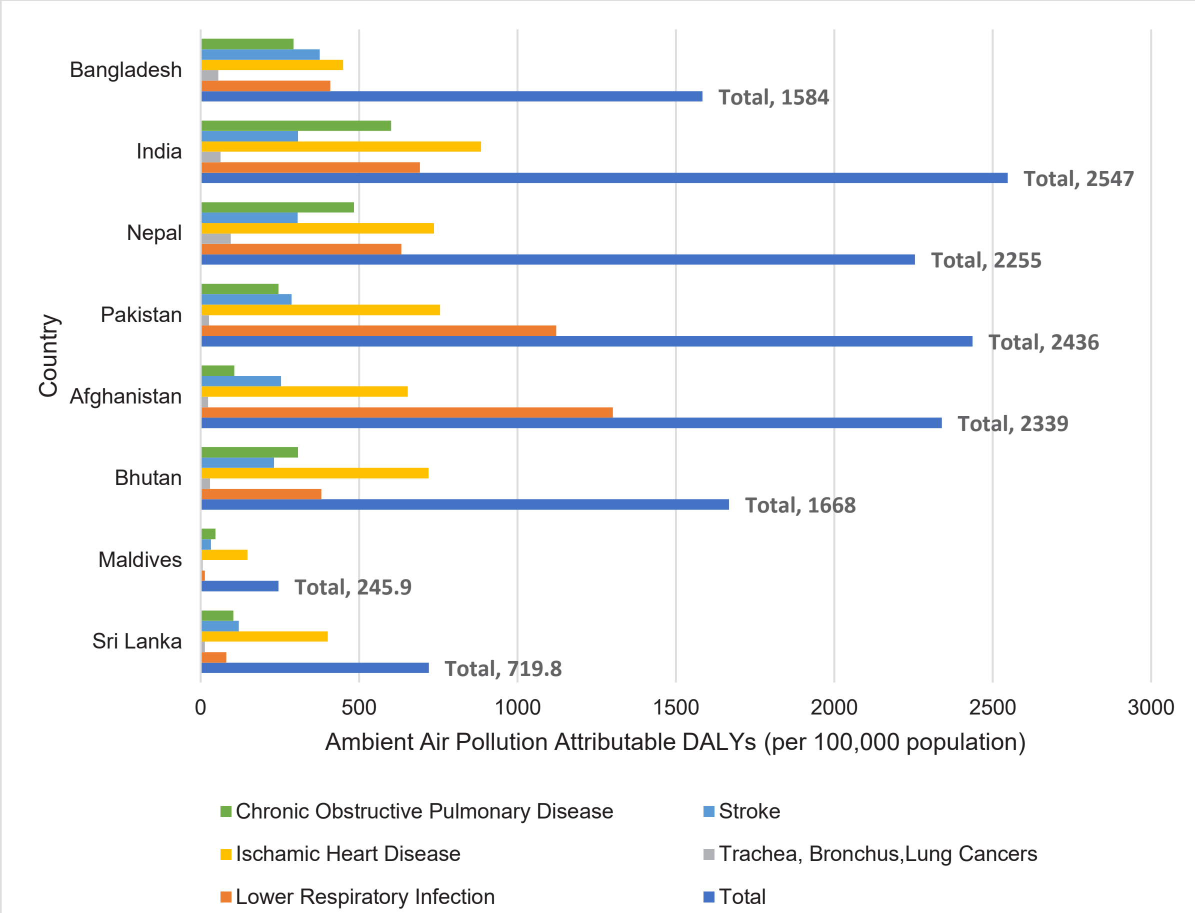
of adapting to an efficient air quality plan in the country (Mehrad 2020). Also, the higher NO_2 concentration is why the frequently occurring smog in Kabul (Mehrad 2020). Begum 2017 reveals that cars, trucks, and industrial activities are the primary reason for the highest emissions of black carbon in SAR. Pollutant exposures have increased considerably due to improper management of waste, construction, and energy derived from dirty fuels in developing countries in SAR (Brauer et al. 2016).

PM levels in SAR report alarming levels owing to more air pollution in most cities (Fig. 6). The overall impact of $PM_{2.5}$ in SAR has been reduced linearly from 2018 to 2019. Limiting traveling and transportation due to the Covid-19 pandemic would be the reason, along with the weather (rain and tropical cyclones occurred during the period). In 2019, about 32% of the days were reported as unhealthy, with AQI values between 101-300 in Kabul, Afghanistan (Mehrad 2020). In 2018 and 2019, Delhi (India), Dhaka (Bangladesh), and Kabul (Afghanistan) were reported as the most polluted cities in the world (Mehrad 2020). Generally, the PM disperses readily in India, Nepal, Bangladesh, and Pakistan due to lower humidity-level and increased wind speeds in the summer. Yet, it traps PMs on the ground surface in winter, increasing PM air pollution, and PM concentration tends to decrease as it settles down with rainfall in the monsoon season (Junaid et al. 2018). In 2019, $PM_{2.5}$ and PM_{10} concentrations indicated an alarming level in Kabul, Afghanistan exceeding the WHO permissible levels (Mehrad 2020). Qiu et al. (2021), studied the air pollution levels in major cities in Bangladesh using multi-sensor readings and investigated a significant reduction of PM_{10}, $PM_{2.5}$, and gaseous pollutants except for O_3 during the strict and partial lockdown in 2020 when compared to that in 2019 and reported that the reason for reducing of O_3 concentration might be the prevailed sunny weather during the strict lockdown period (2020) in Bangladesh.

Economic aspects indicate that the possible economic loss is estimated to be about USD 7.0 million due to OAP (due to $PM_{2.5}$) in Colombo. An undertaken case study in Kanpur, India, estimated that the annual economic benefit of approximately 3.96 million US dollars could be achieved by uplifting air quality to safe levels per 2.7 million population (Nandasena et al. 2012). Pakistan's government undergoes about US$ 250 to US$ 350 million in economic losses alone due to deaths attributable to vehicular emission air pollution (Purohit et al. 2013). Thus, there is a burden on economic status in SAR due to prevailing health outcomes that are directly attributable to IAP and OAP.

OAP AND HEALTH IN SAR

Ghaffar et al. (2004) stated that the primary reason for chronic respiratory diseases in SAR is the effect of chronic obstructive airway diseases (emphysema and chronic bronchitis) and asthma due to OAP and IAP exposures. Cohen et al. (2017) concluded that exposure to $PM_{2.5}$ is directly attributable to mortality from cardiovascular disease (IHD and cerebrovascular disease) and DALYs globally with



[Source: WHO Country Health Statistics-2016 (WHO 2016).

Fig. 7: Ambient Air Pollution attributable DALYs values (per 100,000 population) in SAR.

respect to OAP.

$PM_{2.5}$ is more perilous compared to PM10 because of its properties, such as deep penetration into the alveolar sacs, high adsorption capacity, and large surface area (Xing et al. 2016). Dharshana et al. (2018) revealed that PM_{10} is significantly related to three types of respiratory diseases (bronchitis, emphysema, and chronic obstructive pulmonary diseases) among children (Tables 1a, 1b). A high prevalence of obstructive airway disease is directly associated with industrial pollution in Sri Lanka (Premaratna et al. 2002). Researchers observed that there would be a high tendency of increased asthma with exposure to dust at home for children of 11 years of age (Karunasekera et al. 2009). Cardiovascular mortality is convincing solid evidence for the OAP, and pre-existing cardiovascular diseases and smoking predisposes cause adverse exposure to air pollution (Nandasena et al. 2012).

Senanayake et al. (2004) reported that Lead exists for 50 days in soft tissue while having a half-life of 25 days in the bloodstream, causing terrible health problems to almost all humans with no age limits. In Sri Lanka, studies have proved that the most people living in and adjacent to traffic-congested areas, traffic police officers approach the interim toxic levels of blood lead concentrations (Senanayake et al. 2004). Higher abdominal discomfort, tremor, and hypertension levels were more common among traffic police officers than non-traffic police officers, although the differences were insignificant. The exposure misclassification would be led to non-traffic police officers being duty-bound to control traffic during busy hours. Nandasena et al. (2012) suggested through their study that the respiratory health status of school children living in urban areas is much poorer than that of children from semi-urban areas due to poor outdoor air quality. Senanayake et al. (2009) reported that the highest recorded SO_2 and oxides of Nitrogen levels in Colombo correlate with hospital attendance rate that was primarily correlated with the air pollution in Colombo and investigated that there exists an association between air pollution and drastic wheezy occurrence in children in Colombo by analyzing the correlation between daily rates of nebulization and ambient air pollutant levels.

About 2500 people die due to air pollution combined with vehicular emissions every year in Pakistan (Purohit et al. 2013). Lahore, the most polluted city in Pakistan (2018), afflicted with heavy smog due to industrialization and urbanization, lacks a proper air quality action plan and results in more perilous health issues that cause premature deaths by cardiac pathologies and exacerbation of asthma allergies, respiratory tract infections, and eye infections. Liu et al. (2013) reported a higher correlation between OAP and cardiopulmonary diseases in Kanpur, India, indicating an alarming situation in 2006. Non- communicable diseases such as lung cancer, chronic obstructive pulmonary disease (COPD), heart diseases, strokes, allergies, eye infections, respiratory illness, etc., have become more alarming in Nepal today (Saud & Paudel 2018).

The Sri Lankan Disability Adjusted Life Years (DALYs) value for OAP is somewhat less, unlike other SAR countries. At the same time, the Maldives is the neap (Fig. 7). India indicates the highest rate of DALYs value attributable to OAP, proving the country's poor outdoor air quality among other countries in the SAR. Generally, SAR is far behind the world in outdoor air quality. The primary reason would be less consideration and advocacy towards air quality management (WHO 2005).

Maldives' ambient air quality is generally said to be in a pristine state because the sea breezes flush the air masses over the islands by keeping air over the islands fresh to some extent through transboundary air pollution (generally, 90% of $PM_{2.5}$ results from transboundary sources in Male, Maldives) (Hameed et al. 2019, SACEP 2001). IAMAT 2020 states that Maldives is considered to possess safe air quality in accordance with WHO guidelines the recent data indicate that the annual mean concentration of $PM_{2.5}$ (8.0 $\mu g.m^{-3}$) is prevailing below the WHO permissible maximum value and frequently has low levels of SO_2 ($\mu g.m^{-3}$) compared to other SAR countries throughout the year (Hameed. et al. 2019).

Better immunization coverage, better nutrition indicators, widely accessible and well-established public health system would help mitigate adverse health problems in the presence of OAP exposures (Nandasena et al. 2012). Unlike India, Pakistan, Bangladesh, etc., Sri Lanka possesses an excellent public health profile that OAP causes, albeit far from the world.

MINIMIZE OAP EFFECTS

WHO (2018) published a set of successful policies assisting policymakers in mitigating air pollution to secure public health in the world by considering several categories (Table 4).

The air quality of a country can be enhanced through favorable policies in the long run by minimizing polluting sources and exposed population, also encouraging a city structure that would minimize pollution emissions (World Bank 2016). Unfortunately, urban regulations in SAR have historically contributed to the misallocation of land use and the growth of urban shapes that are not necessarily conducive to air quality improvement and economic development (World Bank Group 2002). Existing political platforms, such as the South Asian Association for Regional Cooperation,

Table 4: Successful Policies Proposed by WHO to Mitigate Air Pollution (WHO 2018).

Category	Description
Industry	• Use clean technologies that demote flue (E.g., biogas) • Optimistic waste management
Energy	• Use clean, affordable fuel for household cooking, heating, lighting
Transport	• Develop walking, and cycling networks • Develop public transportation • Shifting to clean fuel (including less sulfur content), low-emissions vehicles • Maintain the quality of vehicles
Urban Planning	• Improve the energy-efficient means/ ways of building • Make greenish cities
Power Generation	• Augment the use of renewable combustion–accessible power sources (hydropower, wind, solar energy) • Limit the usage of high-emissions fuels • Co-generation of heat and power • Implement distributed energy generation (Rooftop solar grids, mini-grids)
Municipal and Agricultural Waste Management	• Implement strategic plans for waste reduction, waste separation, recycling, waste reprocessing (E.g., Feasible, Low-cost, Environmental friendly biological waste management (Produce biogas; anaerobic waste digestion))

should be authorized and leveraged to perform action plans to improve air quality (Begum 2017).

Sri Lanka has taken many actions such as the Clean-Air 2000 Action Plan, standards revisions in 2007 and 2015 for fuel quality (reducing Sulphur in fuel from 0.5% to 0.25%) and vehicle importation, banning of leaded-petrol, controlling of importing two-stroke vehicles and introducing Vehicle Emission-maintenance Testing (VET) programs since 1992. Still, most of these have been limited to papers due to political and socio-economic issues (Ileperuma 2020, Thishan et al. 2008). In Sri Lanka (2002), tetraethyl lead was removed from the petrol initiative to the "Clean-Air Action Plan-2000." Drastically it realizes a significant reduction in lead in blood being positive in reducing the risk of environmental lead exposure and also reported a reduction in atmospheric lead in Colombo one year after introducing the free lead petrol in Sri Lanka (Ileperuma & Oliver 2010, Senanayake et al. 2004).

India has standardized a National AAQS of annual 40 µg/m^3 $PM_{2.5}$ concentrations to improve the country's air quality and enhance both economic and social development by introducing the "2018 legislation" emission scenario accessing the effective additional policy interventions, including all emission control measures, standards, regulations (Purohit et al. 2019). In 2017, "Harith Diwali" and "Swasth Diwali" campaigns were launched involving about 2000 schools in Delhi and over two lakh schools in the country by the Indian government as an advocacy for mitigating air pollution (MoEFCC 2020).

In Bhutan, the National Environment Protection Act -2007 regulates the legal framework for environmental protection and management and aims to broaden green space and reduce dust through the act. National Human Settlements Strategy-2017 and finer public transport system promoting electric vehicles are some strategies that aim to uplift the ambient air quality in the country Bhutan (NEC 2020).

Municipal solid waste, non-ferrous metal smelting, and galvanizing activities result in emitting Zinc and contribute to a fine fraction as well as two-stroke emissions consequentially contribute to the urban dust; coarse fraction and literature explained that regulating such activities in Bangladesh could be able to witness a substantial decrease in PM levels together with reported a decreased value of one third from the previous airborne particulate matter concentration as a result of the introduction of unleaded gasoline in 1999 (Hopke et al. 2008).

Air quality monitoring is a confident manner of an effective air quality management system. Almost all the SAR countries maintain ambient air-quality monitoring systems nationally. In 1997, automated air quality monitoring stations, Peak and Background stations, were authorized at Colombo Fort and Baudhdhaloka Mawatha (Ileperuma O. A. 2020). NBRO is maintaining a mobile AQMS at Colombo Municipal Council, Sri Lanka. The Indian government is executing a national program: The "National Air Quality Monitoring Program" (NAMP), for ambient air-quality monitoring (MoEFCC 2020). "CLEAN" laboratory; Pakistan regularly monitors the air in Islamabad, Pakistan (PEPA 2021). In Bhutan, automatic stations to monitor air quality are being installed to track whether the industries comply with the national environmental standards (NEC 2020).

Thus, Bhutan, Maldives, and Sri Lanka own optimistic air quality nationwide, unlike other countries in SAR, and should be empowered with public awareness programs through social interventions. Optimum policies in consuming clean fuels, managing pollutant exposures and emissions, and establishing efficient infrastructures would help to mitigate OAP.

CONCLUSION

Sri Lanka prevails in an optimum stage in air pollution compared to other countries in SAR. The available data sources indicate that the air quality of Maldives is outstanding among other countries in SAR. Higher population and less public awareness of air quality guidelines and health effects have uplifted countries like India, Bangladesh, and Nepal toward polluted air, specifically among other SAR Countries. Consuming efficient energy means clean fuels, obey to air quality guidelines, often air quality monitoring and a colossal public awareness of air pollution and its mitigating techniques make a country with magnificent national air quality. Most of the countries in SAR suffer a huge loss of GDP due to the health effects of air pollution. Quantitative and qualitative research studies should be performed to mitigate air pollution. The rules and regulations should be updated regularly while continuing regular monitoring of air pollution in a country to achieve good air quality.

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