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Air Pollution Risk Assessment using Air Quality Index (AQI)

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Introduction

Air is the major resource and need for sustenance of life. The advancement in technology a huge quantity of data on ambient air quality is produced and used to begin the quality of air in various areas. As per World Health Organization (WHO), air pollution refers to the presence of unwanted material in the ambient air which are harmful to mankind and their environment. The air pollution level of mega cities and industrial areas increases year after year due to rapid industrial development and growth of automobile usages [1-4]. Previous studies reported a strong relationship between weather conditions and the concentrations of particulates [5-7]. Suspended particulate matter, NO_2 and SO_2 are major air pollutants found in many of the polluted areas including India [8]. These are present in the air due to burning of fossil fuels and adversely affect the living beings [9]. Emissions from automotive vehicles are the main cause of air pollution in the highly populated area and accounts for 60-70 % of the pollution in the urban environment [10]. The most important issues related to environment and health is air pollution and public health. Urbanization, economic development, transportation/motorization, energy consumption and rapid population growth are powerful forces of air pollution in large cities and industrial area. Recent WHO air quality model shows that 92% of the world's population live in those areas where the air pollution exceeding the limits [11]. Children, the elderly, peoples with pulmonary and cardiovascular diseases, and frontline workers of industries may be at a very high risk.

Three or more major pollutant levels have exceeded WHO health protection guidelines in seven megacities of the world and those are Beijing, Mexico, Jakarta, Cairo, Sao Paulo, Los Angeles, and Moscow. Suspended particulate matter (SPM) is a major pollutant affects the entire city environment and is a serious problem in cities of Asian continent. The high level of SPM causes high mortality rate so having its own importance during consideration of pollutants. The different sources for SPM include the natural (Dust by the action of wind from desert) as well as manmade sources (Diesel motor vehicles, power plants, mining etc.). Although leaded petrol has been phased out or greatly reduced in many countries, serious lead problems are still experienced in Cairo and Karachi. Lead has serious health implications particularly for infants and young children. Ozone is a secondary pollutant and requires a high degree of sunshine and vehicle pollution for its formation. These conditions are experienced in many cities and megacities [12]. So many adverse effects are associated with the exposure of air pollution and those are physiological changes in pulmonary functions and the cardiovascular system and ultimately pre-mature deaths. Every year almost six lakh Indians die due to side effects of air pollution which has become fifth leading cause of death across the country after other causes like water pollution, nuclear pollution etc. Out of these, almost 35,000 deaths occur in national capital i.e. Delhi, rest 15,000 deaths are recorded in each industrial areas [1]. Other cities that are suffering due to extensive threat of pollution are Ghaziabad, Punjab, Patna, Raipur, Agra and many more. Almost all the cities are suffering due to increase in concentration of Particulate Matter (PM) in air along with gaseous pollutants like oxides of nitrogen, sulphur along with other toxic materials that are already causing serious damage to environment [13].

Air Quality Index

The approaches for evaluating environmental quality are based on the comparison of monitored values with the respective standards. The citizens and general peoples should be aware about the daily level of air pollution. Special alertness is also required for sensitive group of peoples. The idea of an air quality index (AQI) is the

transformation of the individual air pollution related parameter to a single number for the betterment in the understanding, communication and decision making in many countries. Eight parameters (PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3, NH_3, and Pb) having short-term standards have been considered for near real-time dissemination of AQI. One way to describe air quality is to report the concentrations of all pollutants with acceptable levels [14,15]. Air Quality Index is used to assess the overall environmental condition and its trends with a specific standard. It is based on the lines of health index and measured by the degree [16].

The revised National Ambient Air Quality Standards (CPCB, 2009) in India, are notified for 12 parameters – PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3, NH_3, Pb, Ni, As, Benzo (a) pyrene, and Benzene. Although AQI is usually based on criteria pollutants (i.e. PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO and O_3). However, the selection of parameters primarily depends on AQI objective(s), data availability, averaging period, monitoring frequency, and measurement methods. While PM_{10}, $PM_{2.5}$, NO_2 , SO_2 , NH_3 , and Pb have 24-hourly as well annual average standards, Ni, As, benzo(a)pyrene, and benzene have only annual standards and CO and O_3 have short-term standards (01 and 08 hourly average). There are different indices developed by different periods of time by different scientists and researchers to describe the air quality which are having different measuring scales. Some of the AQI are the Green Index (GI), Fenstock Air Quality Index (AQI), Ontario API, Oak Ridge Air Quality Index (ORAQI), Greater Vancouver Air Quality Index (GVAQI), and Most Undesirable Respirable Contaminants Index (MURC) etc.

Primarily two steps are involved in formulating an AQI: (i) formation of sub-indices (for each pollutant) and (ii) aggregation of sub-indices to get an overall AQI.
Formation of sub-indices (I_1 , I_2 ,...., I_n) for n pollutant variables (X_1 , X_2 ...., X_n) is carried out using sub-index functions that are based on air quality standards and health effects. Mathematically;

$$I_i = f(Xi), \text{ Where, } i=1, 2,...,n \quad \text{.....(1)}$$

Each sub-index represents a relationship between pollutant concentrations and health effect. The functional relationship between sub-index value (I_i) and pollutant concentrations (X_i) is explained later in the text.

Aggregation of sub-indices, Ii is carried out with some mathematical function (described below) to obtain the overall index (I), referred to as AQI.

$$I = F(I_1, I_2 ... I_n) \quad \text{..... (2)}$$

The aggregation function usually is a summation or multiplication operation or simply a maximum operator. The break point of AQI scale is shown in Table 1 and the AQI with associated health effects is shown in Table 2. Furthermore different countries uses different types of air quality indexing system with different consideration of pollutants, levels of health concern, colour codes and point value ranges shown in (Tables 1- 3).

AQI Category (Range)	PM_{10} 24-hr	$PM_{2.5}$ 24hr	NO_2 24-hr	O_3 8-hr	CO 8-hr (mg/m^3)	SO_2 24-hr	NH_3 24-hr	Pb 24-hr
Good (0-50)	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5
Satisfactory (51-100)	51-100	31-60	41-80	51-100	1.1-2.0	41-80	201-400	0.5-1.0
Moderately Polluted (101-200)	101-250	61-90	81-180	101-168	2.1-10	81-380	401-800	1.1-2.0
Poor (201-300)	251-350	91-120	181-280	169-208	10-17	381-800	801-1200	2.1-3.0
Very poor (301-400)	351-430	121-250	281-400	209-748*	17-34	801-1600	1200-1800	3.1-3.5
Severe (401-500)	430+	250+	400+	748+*	34+	1600+	1800+	3.5+

Table1: Breakpoints for AQI Scale (units: µg/m^3 unless mentioned otherwise) [17].

AQI	Associated Health Impacts
Good (0-50)	Least Impacts.
Satisfactory (51-100)	Sensitive people may suffer minor breathing discomfort
Moderately polluted (101–200)	Peoples with lung diseases (asthma), heart diseases may suffer discomfort in breathing.
Poor (201–300)	Prolonged exposure of peoples with heart diseases may feel breathing discomfort.
Very poor (301–400)	Prolonged exposure may cause respiratory. More effect to peoples with lung and heart diseases.
Severe (401-500)	Healthy peoples also may suffer respiratory problems and diseases. Peoples with serious lung/ heart diseases will suffer severe impacts.

Table 2: AQI and Associated Health Impacts [17].

Sl. No.	Location	Parameters considered	Level of health concern/ Colours used/ Value ranges
1	USA- Common Air Quality Index (or CAQI) [18]	PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, CO	6/6/0-500
2	Canada- Air Quality Health Index or (AQHI) [19]	PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, CO	4/11/1-10+
3	Hong Kong- Air Quality Health Index or (AQHI [20]	PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3	5/5/1-10+
4	Mainland China- Air Pollution Index (API) [21]	PM10, PM2.5, SO2, NO2, O3, CO	6/6/0-300+
5	India- IND-AQI [22]	PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, CO, NH_3, Pb	6/6/0-500
6	Mexico- AQI [23]	PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, CO	6/6/0-200+
7	Singapore- Air Quality Health Index or (AQHI) [24]	PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3	6/6/0-400
8	South Korea- Comprehensive Air-quality Index (CAI) [25]	PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, CO	5/4/0-500
9	United Kingdom- AQI [26]	PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3	4/4/0-10
10	Europe-AQI [27]	PM_{10}, NO_2, O_3 –Major CO, PM2.5,SO2- Additional	5/5/0-100

Table 3: Pollutants consideration for different countries for AQI calculation [18-27].

Conclusion

Taking the seriousness of the effects of air pollution, tools like AQI plays a very important role for the better understanding of the associated health effect towards the general public and sensitive groups. Ott has listed the objectives that are served by an AQI [28-30], these are: resource allocation, ranking of locations, enforcement of standards, trend analysis, public information and scientific research. Further the application of AQI have so many usefulness and those are simple way of understanding of air quality for, a politician to appeal quick actions, a decision maker to know the status of air quality and to take corrective measures, study of the impact of control actions by a government officials and for a scientist help in research using air quality data. So proper understanding of AQI is very much essential for every responsible citizen for the betterment in the control of air pollution.

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