Effect of Air Quality Index on Health

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Abstract

Air quality index (AQI) or pollution index (API) is usually wont to report the extent of severity of pollution to public. variety of methods were developed within the past by various researchers/environmental agencies for determination of AQI or API but there's no universally accepted method exists, which is acceptable for all situations. Different method uses different aggregation function in calculating AQI or API and also considers differing types and numbers of pollutants. The intended uses of AQI or API are to spot the poor air quality zones and public reporting for severity of exposure of poor air quality. Most of the AQI or API indices are often broadly classify as single pollutant index or multi-pollutant index with different aggregation method. Every indexing method has its own characteristic strengths and weaknesses that affect its suitability for particular applications. This paper plan to present a review of all the main air quality indices developed worldwide.

Key words: Air pollution, Air quality index, Health, Environmental factors

1. Introduction

Current research indicates that guidelines of recommended pollution values can't be considered threshold values below which a zero adverse response could also be expected. Therefore, the simplistic comparison of observed values against guidelines may mislead unless suitably quantified. In recent years, air quality information are provided by governments to the general public comes during a number of forms like annual reports, environment reviews, and site or subject specific analyses/ report. These are generally having available or access to limited audiences and also require time, interest and necessary background to digest its contents. Presently, governments throughout the planet have also began to use real-time access to stylish management programs to supply their citizens with access to site-specific air quality index/air pollution index and its probable health consequences. Thus, a more sophisticated tool has been developed to speak the health risk of ambient concentrations using pollution index (API) or air quality index (AQI)

Air Quality Index (AQI)

The AQI is an "index" by calculating the degree of pollution in the city (as an average) or at the monitoring point and includes five main pollutants – PM, O3, SO2, NOx, and CO. Every pollutants has an air quality standard which is used to calculate the overall AQI. Simultaneously, one can also establish the limiting pollutant (the most damaging of the pollutants measured) and estimate the AQI. In numbers (see Fig. 2), AQI is represented between 0 to 500 with 0 representing good air and 500 representing hazardous air.

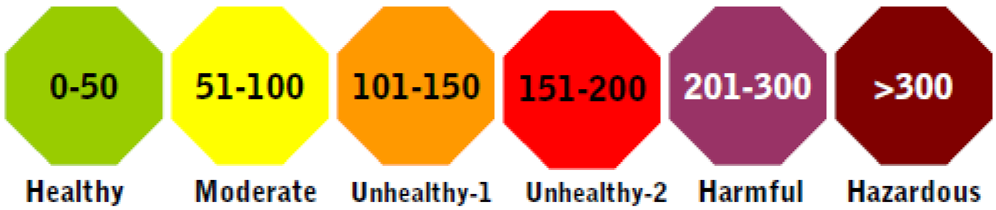

fig. 2 **The AQI color ranges**

For better understanding and presentation, the AQI is broken down into six categories, each color coded with the number scale

Air Pollution Index Criteria (Gary C. et al., 1976)

Easily understood by the people
Not inconsistent with perceived air pollution levels
Spatially meaningful
Includes major air pollutants and able to of including future pollutants
Calculated in a easy manner using reasonable assumptions
Corrosponds to ambient air quality standards and goals
Exhibits day to day changes
If possible forecast a day in advance

3. Formulas used to calculate AQI

3.1. U.S. EPA

U.S. EPA's AQI explained with respect to the five main common pollutants: carbon monoxide (CO), nitrogen dioxide (NO2), ozone (O3), particulate matter i.e. PM10 and PM2.5 and sulphur dioxide (SO2). Each pollutant index as in the eqn. (1) is calculated first by using the following linear interpolation equation, pollutant concentration data and reference concentration. The breakpoint concentrations have been described by the EPA on the basis of National Ambient Air Quality Standards (NAAQS) as shown in Table 1, and on the results of epidemiological studies stands the effect of single pollutants on human health.

$$I_p = \frac{(I_{HI} - I_{LO})}{BP_{HI} - BP_{LO}} (C_P - BP_{LO}) + I_{LO}$$

where
IP=Index for pollutant P
CP=Rounded concentration of pollutant P
BPHI=Break point that is greater than or equal to CP

BPLO=Breakpoint that is less than or equal to CP
IHI=AQI value corresponding to BPHI
ILO=AQI value corresponding to BPLO

The highest individual pollutant index, IP, represents the Air Quality Index (AQI) of the particular location. The above method unable to the flexibility to incorporate any number of air pollutants. The method also not considers the pollutant aggregation and spatial aggregation. It can be used for determining the short term and long term air quality indices.

Table 1: Breakpoint concentration of air pollutant defined by U.S. EPA

Breakpoints							AQI	Category
O_3 (ppm) 8-hour	O_3 (ppm) 8-hour[1]	PM_{10} (μg/m^3)	$PM_{2.5}$ (μg/m^3)	CO (ppm)	SO_2 (ppm)	NO_2 (ppm)		
0-0.064	–	0-54	0-15.4	0-4.4	0-0.034	([2])	0-50	Good
0.065-0.084	–	55-154	15.5-40.4	4.5-9.4	0.035-0.144	([2])	51-100	Moderate
0.085-0.104	0.125-0.164	155-254	40.5-65.4	9.5-12.4	0.145-0.224	([2])	101-150	Unhealthy for sensitive groups
0.105-0.124	0.165-204	255-354	65.5-150.4	12.5-15.4	0.225-0.304	([2])	151-200	Unhealthy
0.125-0.374 (0.155-0.404)[4]	0.205-0.404	355-424	150.5-250.4	15.5-30.4	0.305-0.604	0.65-1.24	201-300	Very unhealthy
([3])	0.405-504	425-504	250.5-350.4	30.5-40.4	0.605-0.804	1.25-1.64	301-400	Hazardous
([3])	0.505-0.604	505-604	350.5-500.4	40.5-50.4	0.805-1.004	1.65-2.04	401-500	Hazardous

[1]Areas are required to report the AQI based on 8 hour ozone values. However, there are areas where an AQI based on 1-hour ozone values would be more protective. In these cases the index for both the 8-hour and the 1-hour ozone values may be calculated and the maximum AQI reported.
[2]NO_2 has no short term NAAQS and can generate an AQI only above a value of 200.
[3]8-hour O_3 values do not define higher AQI values (≥301). AQI values of 301 or higher are calculated with 1-hour O_3 concentration.
[4]The numbers in parentheses are associated 1 hour values to be used in this overlapping category only.

3.2. Oak Ridge Air Quality Index (ORAQI).

(Priyanka Agarwal et al., 2018) In this study done by (Sengupta *et al.* 2000) examined the Oak Ridge Air Quality Index supported on additive function of sub-indexes for Delhi and analyse that this index affected from eclipsing effect,

AQI for every year in the study area was estimated with the help of a mathematical equation developed by the Oak Ridge National Laboratory , USA (Panwar, 2014) as given below:

$$AQI = [5.7 \Sigma C_i / C_s]^{1.37}$$

where,

C_i = value of air quality parameters PM_{10}, $PM_{2.5}$, NO_2, SO_2 and NH_3
C_s = standard or prescribed limit for air quality parameters
5.7 and 1.37 are constant

The rating scale is range from 0 to 100 and it has further classified into 5 sub grades of air quality categories as shown in table 2

Table 2: Oak Ridge National Air Quality Index (Ravikumar *et al.* 2014)

Index value	**Descriptive category**
$(0 \geq AQI \leq 25)$	clean air
$(26 \geq AQI \leq 50)$	light air pollution
$(51 \geq AQI \leq 75)$	moderate air pollution
$(76 \geq AQI \leq 100)$	heavy air pollution
$(AQI > 100)$.	severe air pollution

In the present study, an annual monitored air quality value was compared with recent Indian national ambient air quality standards Table 3 for PM10, PM2.5, NO2, SO2 and NH3 respectively

Table 3: Indian national ambient air quality standards (NAAQS) (CPCB, 2009)

Pollutants	Time weighted average	Concentration in ambient air	
		Industrial, residential, rural and other area	Ecologically sensitive area
Sulphur dioxide SO_2 (μg/m³)	Annual average*	50	20
	24 hours**	80	80
Nitrogen dioxide NO_2 (μg/m³)	Annual average*	40	30
	24 hours**	80	80
Particulate Matter PM_{10} (μg/m³)	Annual average*	60	60
	24 hours**	100	100
Particulate Matter $PM_{2.5}$ (μg/m³)	Annual average*	40	40
	24 hours**	60	60
AmmoniaNH_3 (μg/m³)	Annual average*	100	100
	24 hours**	400	400

*Note: *annual average values are the annual arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform interval and **24 hourly/ 8 hourly or 1 hourly monitored values should be met 98% of the time in a year. 2% of the time, it may exceed but not on two consecutive days.*

Oak Ridge Air Quality Index , where different types of activities viz. industrial, commercial and residential is presented. It is calculated by equation:

$$AQI = [39.02 \sum^{3}_{i=1} (Xi/Xs)]^{0.967}$$

Where
Xi = Concentration of individual pollutant (SO2, NOx, SPM)
Xs = CPCB standard for 24 hrs annual average for the individual pollutant

The descriptor categories for AQI are :

AQI : <20 Excellent, AQI : 20-39 Good, AQI : 40-59 Fair,
AQI : 60-79 Poor, AQI : 80-99 Bad, AQI : <100 Dangerous

Table 4: CPCB standard of air pollution

	Ambient air Quality Standards 24Hr average		
	Ind.	Com.	Res.
SO_2	120	80	30
Nox	120	80	30
SPM	500	200	100

3.3. common air quality index (CAQI)

(Sef van den et al., 2008) The CAQI is calculated by the grid in Table 5, by linear interpolation between the class borders. The final index is the highest value of the sub-indices for each pollutant. It is seen that there are two CAQIs: one for traffic monitoring sites and one for urban background sites. The traffic index related to NO2 and PM10, with CO as an auxiliary component. The background index obligatory related to NO2, PM10 and O3, with CO and SO2 as auxiliary components. In many cities the auxiliary components will rarely calculate the index (that is why they are auxiliary) but in a city with industrial pollution or a seaport SO2 might occasionally play a role. The CAQI index will be considered both for roadside and city background locations The calculation grid for the hourly and daily values is the same for most pollutant.

Table 5: Proposed pollutants and calculation grid for the CAQI

Index class	Grid	Traffic				City background					
		Mandatory pollutant			Auxiliary pollutant	Mandatory pollutant				Auxiliary pollutant	
		NO_2	PM_{10}		CO	NO_2	PM_{10}		O_3	CO	SO_2
			1-hour	24-hours			1-hour	24-hours			
Very low	0	0	0	0	0	0	0	0	0	0	0
	25	50	25	12	5000	50	25	12	60	5000	50
Low	26	51	26	13	5001	51	26	13	61	5001	51
	50	100	50	25	7500	100	50	25	120	7500	100
Medium	51	101	51	26	7501	101	51	26	121	7501	101
	75	200	90	50	10,000	200	90	50	180	10,000	300
High	76	201	91	51	10,001	201	91	51	181	10,001	301
	100	400	180	100	20,000	400	180	100	240	20,000	500
Very high [a]	>100	>400	>180	>100	>20,000	>400	>180	>100	>240	>20,000	>500

NO_2, O_3, SO_2: hourly value / maximum hourly value in $\mu g/m^3$
CO: 8 h moving average / maximum 8 h moving average in $\mu g/m^3$
PM_{10}: hourly value / daily value in $\mu g/m^3$

[a] An index value above 100 is not calculated but reported as ">100".

Advantage: i) The usefulness of a separate background and traffic index.
Disadvantage: Not clear with health effects, fairly arbitrarily quality interpretation for short-term exposure
Limitation: The CAQI is a work in progress

3.4. Green Index

(Marvin h. Green et al.,1966) Only by Inhalation , most sulfur dioxide is exerted by the mouth, nose and throat, thereby resisting all but a small fraction from getting entrance into the lower respiratory tract. But when substantial particulate matter like PM10, PM2.5 is present in ambient air along with the sulfur dioxide, the sulfur dioxide may be adsorbed onto the particles and may then be transfered into the respiratory tract where any irritation it produces would be of much greater significance. The alignment charts in Fig. present the air pollution index range from zero to 100 with the related pollutant levels for rapid selection of values. For sulfur dioxide the index value doubles for a fivefold increase in concentration; for smoke shade it doubles for every increase of three and one-third times. A power function associate with pollutant level to the index number. The following equations are used:

For sulfur dioxide: I = 84.0S0-431
For smoke shade: I = 26.6C0-576

where ,
I = the air pollution index,
S = the sulfur dioxide concentration in ppm, and
C =is the smoke shade level in COH's/1000 ft.

Sulfur dioxide and particulate matters are at raising high levels during cold weather when burning of fuels is the greatest source of these pollutants. The photochemical, eye-irritating smog that occures during warm weather should receive major attention when considering health effects during these seasons. In this respect, an index associated with health effects to air pollution during warm weather should incorporate those pollutants that produce and comprise photochemical smog, including nitrogen oxides, hydrocarbons, and ozone. Therefore, the index related to sulfur dioxide and particulates is pertinent only to the colder seasons.
The Green Index is calculated as the arithmetic mean of the two sub-indices:

GI = 0.5 * (ISO2 + ICOH)

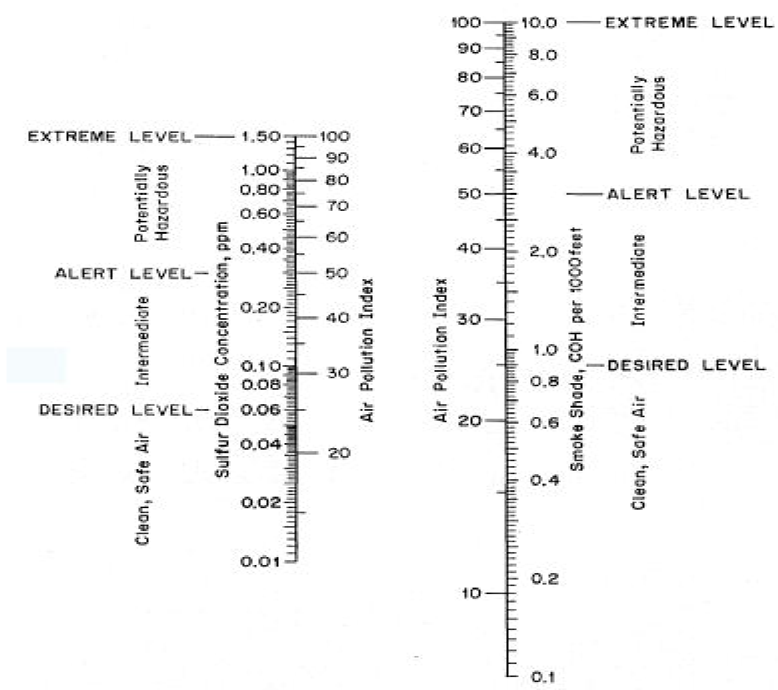

Fig.1. Proposed air pollution index

3.5. Air Quality Health Index

(Xihao Dua et al., 2020)A new Air Quality Health Index (AQHI) was invented in Canada or several single cities as a health risk communication tool. AQHI is available for about ten cities in Canada, including Vancouver and Victoria.

The AQHI is calculated as the sum of excess mortality risk related with NO2, ground-level O3, and PM2.5 at respective concentrations. It is calculated hourly based on 3-hour rolling average of every pollutant concentrations, and is then adjusted to a range of 1 to 10. The value of 10 corresponds to the highest observed weighted average in an initial data set covering a reference period from 1998 to 2000 (Stieb *et al.*, 2008; Taylor, 2008).

The distribution of daily excess mortality risk related with a given pollutant during the study period, with the assumption of a non-threshold log-linear association between air pollutant concentrations and daily mortality (Stieb et al., 2008). It is calculated by Eq.

$$ER_{it} = 100 \ * \ [\exp(\beta_i * X_{it}) - 1]$$

Where,

ER$_{it}$ = excess mortality risk (%) associated with the ith air pollutant on a particular day;

t = “particular day”;

βi = the coefficient of concentration–response relationship between the ith pollutant and mortality obtained from the single-pollutant time series model (Chen et al., 2013; Stieb et al., 2008);

and Xit =the concentration of the ith pollutant each day.

The highest value of daily excess mortality risk for each city. Then, daily mortality risks in percentage were averaged aross the cities and weighted by the average daily death counts in each city during the period. We calculated the average of highest daily mortality risks in every city that were weighted in proportion to the frequency of deaths. Weighted average excess risks were implement to avoid undue weighting to small cities with high air pollution levels and to achieve comparable assessment of impacts on mortality in absolute terms across cities. The formuled as Eq.

$$c = \sum j = 1. ..n [max_{t=1...n}(ERit)] / \sum_{j=1...n} [Meant = 1. ..n (ER_{it})]$$

Where

c = scaling factor that represents the maximum weighted average excess deaths per 100 people in the 272 cities.

$maxt$=1...n is the maximum daily excess mortality risk for each city.

$Mean$t = 1. ..n is the average daily excess mortality risk for each city.

The formula for the national AQHI as Eq.

$$AQHI = (10/c) \sum_{i=1...p} 100 * [exp(\beta_i * X_{it}) - 1]$$

3.6. Pollution Index

(G. Cannistraro et al., 2009) to calculate air pollution and its effects on human health, a method for calculating a pollution index was implemented and applied in the urban centre of the city. This index is considered the weighted mean of the most detrimental air pollutants concentrations respect of their limit values for protecting human health. The pollution index method here studied is based on a simple indicator of the air quality in an urban context that is helpful for informing to citizens about the status of air quality of a waste urban area. This index calculates the air quality by means of a series of pollutants critical in the Italian urban contexts. The calculation of the Pollution Index is related to the weighted mean value of the sub-indexes of the most critical pollutants. It is represented by a numerical index ranging from 1 to 7; an highest value of the index expresses an highest value of environmental pollution, and, of course an highest health risk. The seven levels of the index indicates the satisfaction degree of the people as well as the protection degree of human health

The Pollution Air Quality Index is estimated by :

$$I_{IQA} = \frac{I_1 + I_2}{2}$$

The two sub-indexes I_1 and I_2 are calculated for the two most critical pollutants, presenting the maximum value. The sub indexes of NO2, PM10, C6H6 are calculated by :

$$I_X = \frac{\overline{V_{\max hX}}}{V_{rifX}} * 100$$

Where

I_X is air quality index of the X pollutant;

$V_{\max hX}$ = highest value of the mean values of the x pollutant during an hour, monitored from 01:00 to 24:00 by all the monitoring stations of the area;

V_{rifX} = limit value of the x pollutant during an hour for protection of human health

While for calculating the sub-indexes of O3 and CO by :

$$I_X = \frac{\overline{V_{\max 8hX}}}{V_{rifX}} * 100$$

where:

I_X is air quality index of the X pollutant;

$V_{\max 8hX}$ = highest value of the mean values of the X pollutant during an hour, monitored from 01:00 to 24:00 by all the monitoring stations of the area;

V_{rifX} = limit value of the X pollutant during an hour for protection of human health

Table 6: Values, Indexes and Health Risk for AQI

NUMERIC VALUE	QUALITY INDICATOR	NUMERIC INDEX	HEALTH RISKS
0 ÷50	OPTIMUM	1	No risks for people
51 ÷75	GOOD	2	No risks for people
76 ÷00	MODERATE	3	No risks for people
101 ÷ 125	MEDIOCRE	4	Generally there aren't risks for people. People with ashtma, chronic bronchitis croniche o cardiopathy may feel light respiratory symptoms only during an intense physical activity
126 ÷ 150	NOT MUCH HEALTHY	5	There risks for people with heart-diseases, olds and children
151 ÷ 175	UNHEALTHY	6	Many people may feel light adverse symptoms, however reversile. Weak people may feel gravest symptoms.
> 175	VERY UNHEALTHY	7	People may feel light adverse effects for health. There are more risks for olds, children and people with respiratory diseases.

3.7. Air Quality Depreciation Index

(GURDEEP SINGH et al., 2006) The air quality depreciation index, attempts to measure declining in air quality on an arbitrary scale that ranges between 0 and −10. An index value of '0'represents most desirable air quality having no collapse from the best possible air quality with respect to the pollutants under consideration while an index value of −10 represents maximum collapse or worst air quality. Index values differing from 0 towards −10 represent successive devaluation in air quality from the most desirable.
The air quality depreciation index is calculated by:

$$AQ_{dep} = \sum_{i=1}^{n} (AQ_i * CW_I) - \sum_{i=1}^{n} CW_i$$

Where,
AQi is Air quality index value for ith parameter;
CWi = Composite weight for ith parameter and
n = Total no. of pollutants considered.
The values of the AQi are getting from the value function curves. In the value function curves the value of 0 indicates worst air quality and value of 1 indicates the best air quality for corresponding pollutant concentration. Typical value function curves for SPM, SO2, NOx and (TSP×SO2) are given in Figures a–d, respectively.
Value of CWi in Equation is calculated by using the following equation:

$$CW_i = \frac{TW_i}{\sum_{i=1}^{n} TW_i} \times 10$$

where
TWi = Total weight of ith parameter
$= Ai + BPIWi + HWi$
Where,
AWi means Aesthetic weight for ith parameter;

BPIWi = Bio-Physical Impact Weight for ith parameter and
Hwi = Health Weight for ith parameter.

For TWi, an importance weight between 1 to 5 is represents to AWi , BPIWi and HWi (i.e. for the ith pollutant) by a team of leader. Least important value is 1 and most important value is 5. The weights are then calculated in accordance with Equations

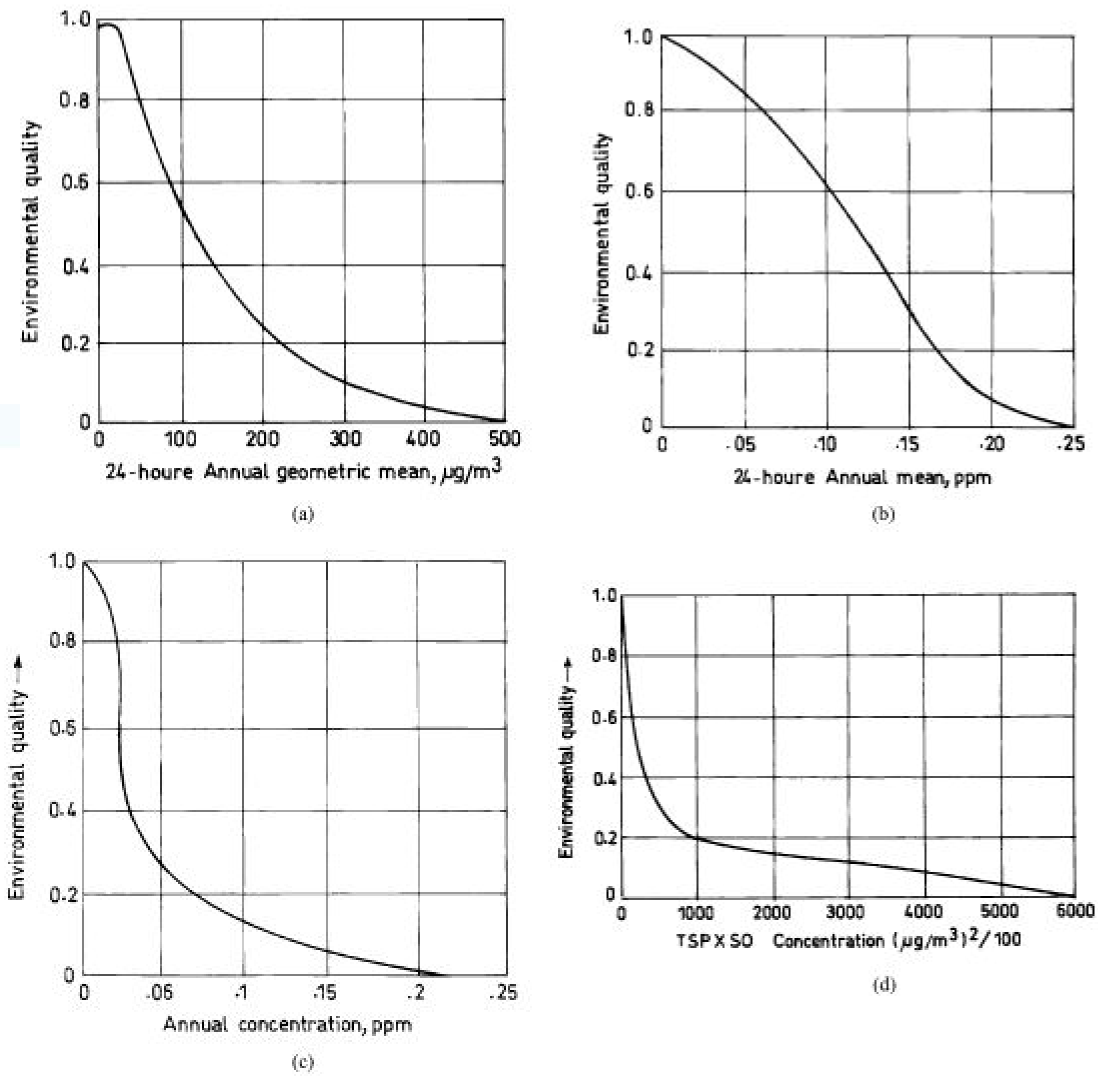

Fig2. Value function curve for (a) suspended particulate matter (Jain *et al.*, 1977), (b) sulphur dioxide (Jain *et al.*, 1977), (c) nitrogen oxides (Jain *et al.*, 1977) and (d) TSP × SO2 (Luhar and Khanna, 1988).

3.8. Aggregate Air Quality Index

(George Kyrkilis et al., 2007)There are many models that reflect the effect of various pollutants to the air quality have already been developed. According to almost all of these models, the concentration of each pollutant is converted to a sub-index. Sub-indices are represented as functions of the ratio of pollutant concentration q to a standard concentration qs, that is:

$$\mathrm{AQI} = \mathrm{AQI}_s \left(\frac{q}{q_s}\right)$$

Where,

AQI = sub-index and AQIs = a scaling coefficient equal to 500 (Swamee and Tyagi, 1999).

Sub-indices give the common metric in terms of which the ambient concentrations of different pollutants may be combined into an overall Air Quality Index. A uniform Air Quality Index is very important if we want to compare air quality over space and time and to forecast its health effects. An aggregate function that include the combined effects of all pollutants has been proposed as the most appropriate among others in the study of Swamee and Tyagi (1999) following Equation used to calculate an overall Air Quality Index for area.

$$I = \left(\sum_{i=1}^{n} (\mathrm{AQI}_i)^{\rho}\right)^{\frac{1}{\rho}}$$

where,

I = the overall Air Quality Index,

AQIi= the AQI for a single pollutant i

ρ = a constant.

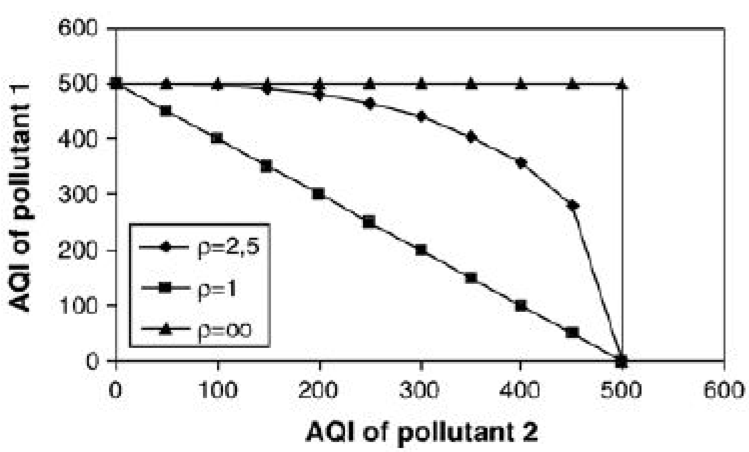

Fig.3 Various values of ρ that give combined AQI=500.

Fig.3 shows different isopollution lines for various values of ρ. According to Eq. when ρ=∞ the index I is equal to the max AQI of a single pollutant, regardless of the rest of the pollutants' AQI value. This kind of calculation resembles to the way that EPA calculates the overall AQI, however, it underestimates the air pollution levels.

When ρ = 1, (at the other extreme, the overall index I = the sum of all AQI indices. This calculation overestimates the air pollution levels, since it supposes that all the effects of the different pollutants can be added in a linear way.)
When ρ =2.5, (an intermediate case between the two extremes, then the isopollution line takes the expedient concave shape. The calculated I errs on the safe side for peoples protection.)
The value ρ=2 corresponds to the expected value of I, for the AQIi (i=1, n) assumed as independent (SRSS, square root of sum of squares). Values of ρ between 2 and 3 we account empirically for some dependence.

3.9. Aggregate Risk Index
(Pierre Sicard et al., 2012)The Aggregate Risk Index (ARI) is calculated from the Relative Risk (RR) values, for a given health endpoint, related with a 10 mg m^{-3} increase of individual pollutant concentration. These RR values are gained from the published exposure-response relative risk functions. For further information, the ARI methodology has been implemented and produced by Sicard et al. (2011). The ARI enables an assessment of extra effects of short-term exposure to the main air pollutants. To account for the simultaneous short-term exposure to air pollutants, the final index is the sum of the normalized values of the individual RRi values (Eq.). It thus supplies a ready method of comparing the relative contribution of each pollutant to total risk.

$$\mathrm{ARI} = \sum_i (\mathrm{RR_i} - 1) = \sum_i \mathrm{Index}_i = \sum_i a_i{*}C_i$$

Ci is the corresponding time-averaged concentrations (in mgm^{-3}) and
the risk index coefficient "ai" is proportional to the incremental risk values (RRi _ 1).
For every pollutant and pathology the risk index coefficients, calculated from the RRi values, allows formulating an arbitrary numerical scale specific for the study area (Eq.).

$$a_i = \frac{4{*}(\mathrm{RR_i} - 1)}{10{*}(1.120 - 1)}$$

The Table 6 presents the RRi values, produced by the WHO, and the risk index coefficients allowing derive an arbitrary numerical scale for information and communication means of the short-term effects of pollution on health

Table 6. The average Relative Risk (RR) per 10 mgm_3 increase (lag 0e1 days), in the European regions, the 95% confidence interval and the risk index coefficients ai for calculating pollutant index values for various

pollutants and its health effects (WHO, 2001, updated in 2004*, 2008*). þ Chronic Obstructive Pulmonary Disease (COPD), nd: non determined

HEALTH ENDPOINTS	$PM_{2.5}$ (24 h average)		PM_{10} (24 h average)		SO_2 (24 h average)		O_3 (1 h maximum)		O_3 (8 h maximum)		NO_2 (1 h maximum)	
	RR	$a_{PM_{2.5}}$	RR	$a_{PM_{10}}$	RR	a_{SO_2}	RR	a_{O_3}	RR	a_{O_3}	RR	a_{NO_2}
Mortality												
All causes	1.015 [1.001, 1.019]	0.050	1.006* [1.004, 1.008]	0.020	1.004 [1.003, 1.0048]	0.013	1.0046 [1.0028, 1.0066]	0.015	1.003* [1.002, 1.004]	0.010	1.003* [1.0018, 1.0034]	0.010
Cardiovascular	1.005* [0.998, 1.022]	0.017	1.009* [1.005, 1.013]	0.030	1.008 [1.002, 1.012]	0.027	1.004 [1.002, 1.006]	0.013	1.004* [1.003, 1.005]	0.013	1.002 [1, 1.002]	0.007
Respiratory	1.011* [1.002, 1.020]	0.037	1.013* [1.005, 1.021]	0.043	1.010 [1.006, 1.014]	0.033	1.008 [1.004, 1.012]	0.027	1.000* [0.996, 1.005]	0	1.006 [1.003, 1.010]	0.020
Daily hospital admissions												
Respiratory 15–64 years	1.0028 [1.008; 1.044]	0.009	1.0062 [0.994, 1.019]	0.021	1.0018 [1, 1.005]	0.006	1.0038 [1.001, 1.0066]	0.013	1.001* [0.991, 1.012]	0.003	1.0008 [1, 1.0022]	0.003
Respiratory > 65 years	1.0028 [1.008; 1.044]	0.009	1.006* [1.000, 1.011]	0.020	1.004 [1.001, 1.009]	0.013	1.0062 [1.003, 1.0094]	0.021	1.005* [0.998, 1.012]	0.017	1.001 [1. 1.0066]	0.003
Asthma exacerbation 15 years	nd	–	1.051 [1.047, 1.055]	0.170	1.015 [1.0052, 1.025]	0.050	1.0012 [1, 1.0074]	0.004	1.000 [1, 1.0076]	0	1.0024 [1, 1.005]	0.008
Asthma exacerbation > 15 years	nd	–	1.004 [1.000, 1.008]	0.013	1.000 [1, 1.0068]	0	1.003 [1, 1.0156]	0.010	1.007 [1, 1.0288]	0.023	1.0058 [1.0006, 1.011]	0.019
Hospital Admissions COPD+	1.004 [0.999, 1.008]	0.013	1.005 [1.002, 1.008]	0.017	1.0044 [1, 1.011]	0.015	1.0068 [1.0022, 1.0094]	0.023	1.0086 [1.0044, 1.0130]	0.029	1.0026 [1.0006, 1.0044]	0.009

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The averaging times, for each pollutant, are based on the recommendations published by the WHO (2006). For O3, a running 8-h average most closely represents the exposures likely to be harmful to human health. For PM10 and PM2.5, evidence indicates that acute health effects occur after pollution episodes lasting at least 24 h, therefore the averaging period should be 24 h. For the nitrogen dioxide, an hourly and daily averaging period are appropriate and the effects

of sulphur dioxide may occur very rapidly, a short averaging period should be desirable, but a daily averaging period is used. This approach is regular with the reporting and forecasting of air pollution levels, which are usually on a day-by-day basis. Research has represents that variations in day-to-day concentrations of air pollutants can have delayed effects. Taking these delayed effects is very difficult. A high concentration on a pericular day could produce effects on that day as well as in the following few days but also for a month or more afterwards (Zanobetti et al., 2003; COMEAP, 2011).

The ARI is based on health evidence. For each ARI, and index range, a daily risk increase can be calculated and associated. To take into account the multiple exposures impacts of various pollutants, the final daily risk increase is the sum of the daily risk increase for each individual pollutant. The new index will be associated with the corresponding daily risk increase, easy to

understand and intuitive for the general public.

3.10. Ontario API

(Shenfeld 1970) proposed Ontario Air Pollution Index in Canada. This index was develpoed to provide the public with daily information about air quality levels and to control actions during air pollution episodes. It has two pollutants variables:

$$API = 0.2\ (30.5\ COH + 126\ SO2)^{1.35}$$

Both COH and SO2 (in ppm) are 24 hour averages

3.11. AQI Based on PCA-Neural Network Model

(Kumar and Goyal et al.,2013) developed forecasting system for daily AQI using a coupled artificial neural network (ANN) - Principal component analysis (PCA) model. The architecture of the system is shown in Fig.. It was outlined for forecasting AQI in one day advance using the previous day's AQI and meteorological variables. It has two steps involved in determining the AQI. Step 1 is the formation of sub-indices for each pollutant and step 2 is the aggregation of sub indices. The sub-indices were estimated using formula of U.S. EPA but the breakpoint concentration of each pollutant is related with the Indian NAAQS and epidemiological studies, which are representing the risk of adverse health effects of specific pollutants. The AQI value was calculated for each individual pollutant (SO2, NO2, RSPM, and SPM) and highest among them was considered as the AQI of the day. The previous day's AQI value was considered as one of the input parameters in the PCA-ANN model for forecasting the AQI value of next day

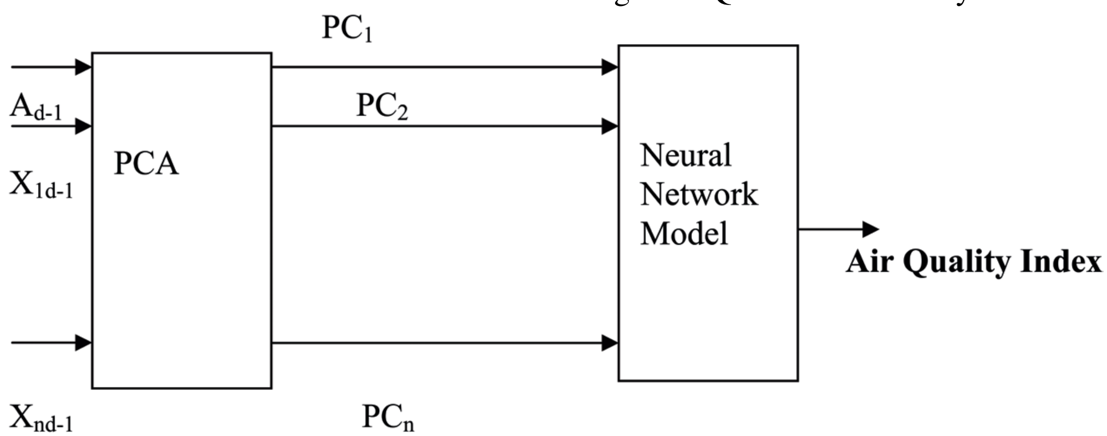

Fig. 1. Outlineof PCA-neural network model for the forecasting of AQI.

Summary:

Name	Formula	Health based	Application
U.S. EPA	$I_p = \frac{(I_{HI} - I_{LO})}{BP_{HI} - BP_{LO}}(C_P - BP_{LO}) + I_{LO}$	Yes	Use for continuous reporting of air quality status to public
Oak Ridge Air Quality Index (ORAQI)	$AQI = [5.7 \Sigma Ci / Cs]^{1.37}$ $AQI = [39.02 \Sigma^{3}_{i=1} (Xi/Xs)]^{0.967}$	Yes	To assess air quality status in metropolitan cities
common air quality index (CAQI)	Based on U.S. EPA method but with different criteria	No	Comparing urban air quality in real time.
Green Index	GI = 0.5 * (ISO2 + ICOH)	Yes	An index established to relate health effects to air pollution
Air Quality Health Index	$AQHI = (10/c) \sum_{i=1...p} 100 * [exp(\beta_i * X_{il}) - 1]$	Yes	Described the application of concentration of -
Pollution Index	$I_{IQA} = \frac{I_1 + I_2}{2}$	Yes	response functions from epidemiological studies of air pollution to an AQI. The index aims at measuring the status of air pollution with respect to its effect on human health.
AIR QUALITY DEPRECIATION INDEX	$AQ_{dep} = \sum_{i=1}^{n}(AQ_i * CW_I) - \sum_{i=1}^{n} CW_i$	No	To define the depreciation in air quality with respect to standard
Aggregate Air Quality Index	$AQI = AQI_s \left(\frac{q}{q_s}\right)$	No	Based on the combined effects of five criteria pollutants (CO, SO2, NO2, O3 and PM10) taking into account European standards. Useful towards the informing of the citizens and protection of human health in an urban agglomeration
Aggregate Risk Index	$ARI = \sum_i (RR_i - 1) = \sum_i Index_i = \sum_i a_i * C_i$	Yes	The index measure of the mortality/morbidity risk associated with simultaneous exposure to the common air pollutants and provides a ready method of comparing the relative contribution of each pollutant to total risk. An arbitrary index scale facilitates risk communication. The index values may extend beyond 0 for highly polluted areas.
ONTARIO API	$API = 0.2 (30.5 COH + 126 SO2)^{1.35}$	No	This index was intended to provide the public with daily information about air quality levels and to trigger control actions during air pollution episodes
AQI Based on PCA-Neural Network Model	Based on U.S. EPA formula	Yes	The AQI of each pollutant has been calculated individually and highest among them is declared as the AQI of the day.

Conclusions

There are many air quality indices have been developed and they continue to evolve. However lot work is still to be made, specially when more pollutans are combined for calculation, low level exposure and with more timely transfer of useable information to the general public. Thus further work is required on the statistical structure and multi pollutant problem.This brief review on air quality indices shows the wide interest or concern for poor air quality problem. Also helpful for observing health status of particular city.

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