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Computational Methods Of Air Quality Indices: A Literature Review

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Abstract: *Air quality indices attempt to standardize and synthesize air pollution information and permit comparisons to be readily undertaken and to satisfy public demands for accurate and easy to interpret data. It is infeasible and perhaps impossible to formulate a universal technique for determining air quality index one that considers all pollutants and that is appropriate for all situations. Every index has its own characteristic strengths and weaknesses. This paper attempts to present a review of computational methods of air quality indices.*

Keywords: *Air quality index, literature review.*

I. Introduction

The World Health Organization (WHO) estimates that 25% of all deaths in developing country can be directly attributed to environmental factors (WHO 2006)[1]. The problem of air pollution and its corresponding adverse ecological impacts have been aggravated due to increasing industrial and other developmental activities. This has made the constant need to identify critically polluted areas and identify their problematic dimensions . An air quality index is a number used by Govt. agencies to communicate to public how polluted the air currently is or how polluted it is forecast to become.

The concept of an Air Quality Index (AQI) has been developed and used effectively in many developed countries for over last three decades (USEPA 1976, 2014; Ontario, 2013;Shenfeld, 1970). An AQI is defined as an overall scheme that transforms weighted values of individual air pollution related parameters (SO2, CO, visibility, etc.) into a single number or set of numbers[2]. The challenge of communicating with the people in a comprehensible manner has two dimensions:

(i) translate the complex scientific and medical information into simple and precise knowledge and
(ii) communicate with the citizens in the historical, current and futuristic sense.

Addressing these challenges and thus developing an efficient and comprehensible AQI scale is required for citizens and policy makers to make decisions to prevent and minimize air pollution exposure and ailments induced from the exposure.

II. Approaches to determine the Air Quality Indices (AQI)

AQI which is also known as air pollution index (API) [Shenfeld, 1970[3]; Ott and Thom,1976[2]; Thom and Ott, 1976[4];Murena,2004[5]] or pollution standard index (PSI) (Ott and Hunt,1976[6];USEPA,1994[7]) has been developed by many agencies in USA, Canada, Europe, Australia, China, Indonesia, Taiwan etc.(Cairncross et al,2007[8];Cheng et al,2007[9]). Various methodologies developed for determining AQI are explained below.

III. Green Index

One of the earliest air pollution indices to appear in literature was proposed by Green (1966)[10]. It included just two-pollutant variables - SO2 and COH (Coefficient of Haze). The equations to calculate the sub indices were:

$I_{SO2} = 84 * X^{0.431}$
$I_{COH} = 26.6 * X^{0.576}$

Where,
I_{SO2} = Sulphur dioxide sub-index
I_{COH}= Coefficient of Haze Sub-index
X = Observed pollutant concentration

The Green Index is computed as the arithmetic mean of the two sub-indices:

$GI = 0.5 * (I_{SO2} + I_{COH})$

IV. ONTARIO API

Shenfeld (1970)[3] developed Ontario Air Pollution Index in Canada. This index was intended to provide the public with daily information about air quality levels and to trigger control actions during air pollution episodes. It includes two pollutants variables:

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

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

V. OAK RIDGE AIR QUALITY INDEX

Oak Ridge National Laboratory published the ORAQI in 1971 (Thom and Ott)[11] . It was based on the 24-hour average concentrations of the following five pollutants:
1. SO2
2. NO2
3. PM
4. CO
5. Photochemical Oxidants

The sub-index is calculated as the ratio of the observed pollutant concentration to its respective standard. As reported by Babcock and Nagda (1972), the ORAQI aggregation function was a non-linear function:
ORAQI = $\{5.7\ \Sigma\ I_i\}^{1.37}$
where, $I_i = (X/X_s)_i$
X = Observed pollutant concentration
X_s = Pollutant Standard
I = Pollutant

VI. USEPA

In 1976 the USEPA established a pollutant standard index (PSI) which rated air quality from 0-500, with 100 equal to national ambient air quality standards (NAAQS). The PSI was revised , renamed to air quality index (AQI) and subsequently implemented in 1999 by the USEPA[12]. The air quality index is a piecewise linear function of the pollutant concentration. At the boundary between AQI categories, there is a discontinuous jump of one AQI unit. To convert from concentration to AQI this equation is used:

$$I = \frac{I_{high} - I_{low}}{C_{high} - C_{low}}(C - C_{low}) + I_{low}$$

where:

I = the (Air Quality) index,
C = the pollutant concentration,
C_{low}= the concentration breakpoint that is ≤ C,
C_{high}= the concentration breakpoint that is ≥ C,
I_{low}= the index breakpoint corresponding to C_{low},
I_{high}= the index breakpoint corresponding to C_{high}.

VII. Air Quality Depreciation Index

The air quality depreciation index (Sharma et al[13]) attempts to measure deterioration 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 depreciation from the best possible air quality with respect to the pollutants under consideration while an index value of –10 represents maximum depreciation or worst air quality. The reduction in index values ranging from 0 to –10 represents the successive depreciation in air quality from the most desirable. The air quality depreciation index is calculated as follows:

$$AQ_{dep} = \sum_{i=1}^{n}(AQi * CWi) - \sum_{i=1}^{n} CWi$$
(1)

Where,
AQ_{dep} = Air quality depreciation index
AQ_i = Air quality index value for i^{th} parameter
CW_i = Composite weight for i^{th} parameter

n = Total no. of pollutants considered
The values of the AQi were obtained from the value function curves. In the value function curves the value of 0 signifies worst air quality and value of 1 represents the best air quality for corresponding pollutant concentration.
The value of CW_i in equation (1) is computed using the following expression:

$$CW_i = \frac{TWi}{\sum_{i=1}^{n} TWi} * 10$$
(2)

Where,
TW_i = Total weight of i^{th} parameter
$TW_i = A_i + BPIW_i + HW_i$ (3)

Where,
AW_i = Aesthetic weight for it parameter
$BPIW_i$ = Bio- Physical Impact Weight for i^{th} parameter

VIII. New Air Quality Index

New air quality index is based on factor analysis of the major pollutants and is given by Bishoi et. al[14] in 2009. The new air quality index (NAQI) is given by the equation

$$NAQI = \{\sum_{i=1}^{n}(PiEi) / \sum_{i=1}^{n} Ei\}$$

Where n=3, P_1 ,P_2 ,P_3 are the three principal components for which the cumulative variance is more than 60%. E_1, E_2 and E_3 are the initial eigen values ($\geq$ 1) with respect to the percentage variance
The principal components were given by Lohani (1984)

$$Pi = \sum_{j=1}^{n} \frac{aji\ Xi}{\lambda i}$$

Where e_i is the eigen value associated with P_i
If the X_j is used for pollutant concentration then

$$Xj = \sum_{1}^{n} aji\ Pi$$

IX. Conclusion

A variety of air quality indices have been developed and they continue to evolve. However much progress is still to be made , mainly through more careful considerations of combined impact of multiple pollutants, low level exposure and with more timely transfer of useable information to the public. Thus further work is required on the statistical structure and multi pollutant problem.

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