MODELING OF AIR QUALITY INDEX

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Abstract: *Air quality models have been used in the pollution control field for more than 60 years. Only in the last decade' however has much attention been paid to assessing the performance of such models. The recent upsurge of interest is largely due to the fact that model simulations may now be the basis for control strategies. Which include raw material change, process change, end of the pipe treatment, dilution by pollutant release through elevated stack etc. costing millions of rupees? For example, height of stack in coal based thermal power plant in India depends on the minimum stack formula (a function of SO_2 emission rate) criteria of central pollution control board, derived using meteorology of three metropolitan cities.*

Key Words: *Decade, stack, models, control formula*

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PROBLEM OF AIR POLLUTION

Degradation of air quality due to presence of unwanted material is terms as air pollution. Ambient air composition over earth has undergone various changes throughout the history. In particular evidence, that “the primeval gaseous environment probably contains almost no free oxygen “and that” oxygen in recent years has accumulated as a result of photosynthetic process utilized by early non-oxygen –dependent species”. Those early living species have either disappeared, as a consequence of these changes or adapted the emergence of petroleum product in this century has characterized a new industrial revolution in 1945’ it was recognized that petroleum products are responsible for new type of “smog” a photochemical summer time smog quit different from traditional winter type smog also known as LONDON SMOG.

AQHI

The Air Quality Health Index provides a number from 1 to 10+ to indicate the level of health risk associated with local air quality. On occasion, when the amount of air pollution is abnormally high, the number may exceed 10. The AQHI provides a local air quality current value as well as a local air quality maximums forecast for today, tonight, and tomorrow, and provides associated health advice.[13]

1	2	3	4	5	6	7	8	9	10	+

Risk: Low (1–3) Moderate (4–6) High (7–10) Very high (above 10)

Table 1: Air Quality Health Index

Health Risk	Air Quality Health Index	Health Messages	
		At Risk population	*General Population
Low	1–3	Enjoy your usual outdoor activities.	Ideal air quality for outdoor activities
Moderate	4–6	Consider reducing or rescheduling strenuous activities outdoors if you are experiencing symptoms.	No need to modify your usual outdoor activities unless you experience symptoms such as coughing and throat irritation.
High	7–10	Reduce or reschedule strenuous activities outdoors. Children and the elderly	Consider reducing or rescheduling strenuous activities outdoors if you experience symptoms such as

		should also take it easy.	coughing and throat irritation.
Very high	Above 10	Avoid strenuous activities outdoors. Children and the elderly should also avoid outdoor physical exertion.	Reduce or reschedule strenuous activities outdoors, especially if you experience symptoms such as coughing and throat irritation.

Health Breakpoints

AQI Category, Pollutants and Health Breakpoints								
AQI Category (Range)	PM_{10} (24hr)	$PM_{2.5}$ (24hr)	NO_2 (24hr)	O_3 (8hr)	CO (8hr)	SO_2 (24hr)	NH_3 (24hr)	Pb (24hr)
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+

Health Impacts

AQI	Associated Health Impacts
Good (0-50)	Minimal impact
Satisfactory (51-100)	May cause minor breathing discomfort to sensitive people.
Moderately polluted (101–200)	May cause breathing discomfort to people with lung disease such as asthma, and discomfort to people with heart disease, children and older adults.
Poor (201-300)	May cause breathing discomfort to people on prolonged exposure, and discomfort to people with heart disease.
Very poor (301-400)	May cause respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart diseases.
Severe (401-500)	May cause respiratory impact even on healthy people, and serious health impacts on people with lung/heart disease. The health impacts may be experienced even during light physical activity.

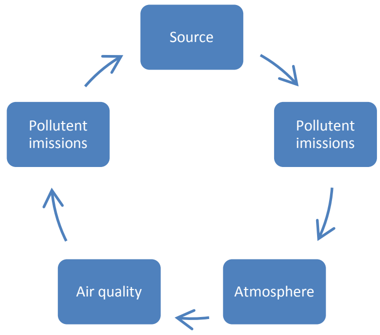
Environmental Effects

Index	Ozone, Running 8 hourly mean ($\mu g/m^3$)	Nitrogen Dioxide, Hourly mean ($\mu g/m^3$)	Sulphur Dioxide, 15 minute mean ($\mu g/m^3$)	PM2.5 Particles, 24 hour mean ($\mu g/m^3$)	PM10 Particles, 24 hour mean ($\mu g/m^3$)
1	0-33	0-67	0-88	0-11	0-16
2	34-66	68-134	89-177	12-23	17-33
3	67-100	135-200	178-266	24-35	34-50
4	101-120	201-267	267-354	36-41	51-58
5	121-140	268-334	355-443	42-47	59-66
6	141-160	335-400	444-532	48-53	67-75
7	161-187	401-467	533-710	54-58	76-83
8	188-213	468-534	711-887	59-64	84-91
9	214-240	535-600	888-1064	65-70	92-100
10	≥ 241	≥ 601	≥ 1065	≥ 71	≥ 101

Need of Air Quality Model

The step in environment impact assessment which requires a greatest degree of scientific application is the predication of impacts. This step involves projecting the future environmental quality and then calculations for predicting impacts investigated from a proposed development. The use of prediction models usually comprises of a four-step approach

i. Identification of Model
ii. Collection of information
iii. Calibration and
iv. Verification of Model



Urban Air quality Management

The need to effectively manage urban air quality locally and nationally was emphasized in the recent National Air Quality Stratergy. Although national initiatives are important it was recognized that local athorities could play a key role in improving air quality of their region. At all levels the air quality involves detailed monitoring of the main pollutents coupled with the capability of models allowing predction and forecasting of pollutant levels at appropriate spatial and temporal scales. Within India networks of air pollutant monitors exist, that are regulated nationally and locally and provide comprehensive coverage. These monitoring stations are employed to identfy –

- Air Pollution episodes
- Exceedness of standards
- Long-Term Trends

There are numerous models available for local, regional and national scales for predicting air quality and for forecasting air pollutant levels. These models consist of the roadside monitoring models such as CAR international, Aeolius, GRAM and CALINE4 some are urban scale models as ADMS, BOXURB and PEARL. In India we generally use Industrial Source complex Model for determining concentration in industrial area and is regulated by CPCB.

Pridction models for other environmental components are once established and a software is been developed commercially so they can be applied with necessary understanding in each different case of impact predction. Air environment is used for simulation of transport and diffusion of the pollutant being released into the atmosphere.they are widely applied as regulatory tools for Impact assessment of either an existing or a proposed source, forecasting of pollution episodes, evaluation of control stratergies and designof air quality surveillance program. Several mathematical models have been developed to determine ambiant air concentration.

Computing the AQI

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 $I = \frac{I_{high} - I_{low}}{C_{high} - C_{low}}(C - C_{low}) + I_{low}$ AQI this equation is used:

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}.

EPA's table of breakpoints is:

O_3 (ppb)	O_3 (ppb)	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)	CO (ppm)	SO_2 (ppb)	NO_2 (ppb)	AQI	AQI Category
C_{low} - C_{high} (avg)	C_{low} - C_{high} (avg)	C_{low}- C_{high} (avg)	C_{low} - C_{high} (avg)	C_{low} - C_{high} (avg)	C_{low} - C_{high} (avg)	C_{low} - C_{high} (avg)	I_{low} - I_{high}	
0-59 (8-hr)	-	0.0-12.0 (24-hr)	0-54 (24-hr)	0.0-4.4 (8-hr)	0-35 (1-hr)	0-53 (1-hr)	0-50	Good
60-75 (8-hr)	-	12.1-35.4 (24-hr)	55-154 (24-hr)	4.5-9.4 (8-hr)	36-75 (1-hr)	54-100 (1-hr)	51-100	Moderate
76-95 (8-hr)	125-164 (1-hr)	35.5-55.4 (24-hr)	155-254 (24-hr)	9.5-12.4 (8-hr)	76-185 (1-hr)	101-360 (1-hr)	101-150	Unhealthy for Sensitive Groups
96-115 (8-hr)	165-204 (1-hr)	55.5-150.4 (24-hr)	255-354 (24-hr)	12.5-15.4 (8-hr)	186-304 (1-hr)	361-649 (1-hr)	151-200	Unhealthy
116-374 (8-hr)	205-404 (1-hr)	150.5-250.4 (24-hr)	355-424 (24-hr)	15.5-30.4 (8-hr)	305-604 (24-hr)	650-1249 (1-hr)	201-300	Very Unhealthy
-	405-504 (1-hr)	250.5-350.4 (24-hr)	425-504 (24-hr)	30.5-40.4 (8-hr)	605-804 (24-hr)	1250-1649 (1-hr)	301-400	Hazardous
-	505-604 (1-hr)	350.5-500.4 (24-hr)	505-604 (24-hr)	40.5-50.4 (8-hr)	805-1004 (24-hr)	1650-2049 (1-hr)	401-500	Hazardous

Suppose a monitor records a 24-hour average fine particle ($PM_{2.5}$) concentration of 12.0 micrograms per cubic meter. The equation above results in an AQI of: $\frac{50-0}{12.0-0}(12.0-0)+0=50$

corresponding to air quality in the "Good" range. To convert an air pollutant concentration to an AQI, EPA has developed a calculator. If multiple pollutants are measured at a monitoring site, then the largest or "dominant" AQI value is reported for the location. The ozone AQI between 100 and 300 is computed by selecting the larger of the AQI calculated with a 1-hour ozone value and the AQI computed with the 8-hour ozone value.

8-hour ozone averages do not define AQI values greater than 300; AQI values of 301 or greater are calculated with 1-hour ozone concentrations. 1-hour SO_2 values do not define higher AQI values greater than 200. AQI values of 201 or greater are calculated with 24-hour SO_2 concentrations.

Real time monitoring data from continuous monitors are typically available as 1-hour averages. However, computation of the AQI for some pollutants requires averaging over multiple hours of data. (For example, calculation of the ozone AQI requires computation of an 8-hour average and computation of the $PM_{2.5}$ requires a 24-hour average.) To accurately reflect the current air quality, the multi-hour average used for the AQI computation should be centered on the current time, but as concentrations of future hours are unknown and are difficult to estimate accurately, EPA uses surrogate concentrations to estimate these multi-hour averages. For reporting the $PM_{2.5}$ AQI, this surrogate concentration is called the NowCast. The Nowcast is a particular type of weighted average constructed from the most recent 12-hours of $PM_{2.5}$ data. EPA estimates eight-hour average ozone values in real time using the most recent 1-hour ozone average and the historical relationship between 1-hour maximum and 8-hour maximum values developed for each ozone monitoring site.

What is in this paper?

Air quality models are used for simulation of transport and diffusion of air pollutants. They are widely applied as regulatory tools for impact assessment of either existing or proposed sources, forecasting of pollution episodes etc. Several mathematical models have been developed to determine ambient air concentration by several assumptions. Most of these models were initially developed by United States Environmental Protection Agency (USEPA) and used for regulatory compliance. Some of these off the shelf models are approved by

Indian regulatory agency for decision making. Industrial Source Complex (ISC) model is one such widely used model. ISC is a Gaussian model and is limited by its assumptions. One of the limitations is use of stability class developed by Pasquill, Gifford and Turner (PGT). A single stability class includes wide range of meteorological changes thereby ioosing the sensitivity of meteorological variables. The ISC model can be used to predict pollutant concentrations from continuous point, area, and volume and open pit sources. ISC model uses hourly meteorological data records to define the conditions for plume rise, transport, diffusion, and deposition. The model estimates the concentration or deposition value for each source and receptor combination for each hour of input meteorology, and calculates the averages for the required short-term periods. To eliminate this flaw. USEPA has developed a new algorithm for meteorological parameters that estimates dispersion parameters (σ_y. σ_z) from field monitored parameters thereby excluding stability class from the main program This new model was jointly developed by American Meteorological - Society and Environmental Protection Agency to be used for Regulatory MODeling purpose and is named AERMOD. AERMOD is an advanced plume model that incorporates updated treatments of the planetary boundary layer, understanding of turbulence and dispersion EPA formally proposed the model in April 2000 as a replacement for the ISC model. Several model enhancements were made as a result of public comment, including the installation of the PRIME Downwash algorithm. In India ISC is the approved model for air quality prediction in regulatory requirements. This work gives a detailed account of additional data collection effort required for using AERMOD in place of ISC.

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