Analysis & Application of GIS Based Air Quality Monitoring- State of Art

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Abstract

The degradation of air quality is a major environmental problem that affects many surrounding regions of industrial sites. Exposure to gaseous pollutants like SOx, NOx, Gaseous Hg, Gaseous F and particulate matter like RSPM, SPM, particulate Hg etc. cause severe health effect like respiratory, cardiovascular diseases and cardio pulmonary mortality. This paper carry out of comparative review of GIS based systems and mathematical models for air quality monitoring. Further it presents a schematic framework for the GIS based evaluation of air pollution situation in surrounding regions of industrial sites and the factors that should be taken in consideration for developing the GIS based system based on the proposed framework.

Keywords: *Air quality, Air quality indices, GIS, Geostatistical Analysis, Health risk*

1. Introduction

Air pollution today's major problem in our modern society and several factors concur to create unfavourable conditions for air pollutant dispersion. The effect of air pollution on public health depends on several factors like chemical composition of a particular pollutant, the level of concentration; health status of individuals and time of exposure. Assessment of the impact of air quality effects on plants, animals, natural ecosystems, ecosystem and human health is important. Air quality management include monitoring and analysis of pollutant concentration, spatial distribution of pollutant concentration, assessment of no. of environmental factors affected by air pollutants, health risk map. Application and analysis of GIS for assessment of air quality is very useful for mapping and examine the Air pollutant data. The application of GIS for air quality analysis and health risk map helps in finding out the relationship between the distribution of air quality, density of population and health risk of the population. By using geostatistical analysis functionalities of GIS relationship between long term exposure to air pollution and the development of specific chronic diseases including bronchitis, asthma and cancer can be established.

2. Literature review

Researchers have carried out research about spatial models that examine concentration and spatial distribution of air pollutants. Majorly they have provide feasible method using GIS and decision support system that examine spatial point pattern of air pollutants and identifies the relationship between air quality and health risk and gives better visualization and analysis possibilities. Table 1 review the research work carried out by different authors. Comparative analysis of works carried out by different authors suggested the importance of geostatistical analysis for air quality monitoring.

Table 1. Comparative Analysis of Research Work for Air Quality Monitoring

Author Name	Technology used	Type of the Application	Information Provided	Remark
Chattopadhyay S. et al, (2010)	GIS Technology, Digital elevation model (DEM), Inverse Distance Interpolation (IDINT) Technique.	Digital elevation model (DEM) & Inverse Distance Interpolation (IDINT) technique generated on the basis of Air quality Index (AQI) GIS based air pollution surface models.	To evaluate the pre monsoon and post monsoon distribution of selected gaseous pollutants i.e. SO_2, NO_2 and RSPM and investigate the seasonal variation of ambient air quality status of Burdwan town using GIS approach.	This shows the significant seasonal variation due to gaseous pollutants.
Maantay et.al., (2009)	GIS, Air dispersion model, Proximity analysis, Loose coupling.	Developed new procedures to loosely integrate an air dispersion model, AREMOD, and a GIS package ArcGIS to simulate air dispersion from stationary sources for five pollutants: PM_{10}, $PM_{2.5}$, NO_X, CO and $SO_{2.}$	Provides a relatively simple and feasible method for health scientists to take advantage of both air dispersion modelling and GIS by avoiding the need for intensive programming and substantial GIS expertise.	The air dispersion modelling exhibited advantages over proximity analysis and geostatistical method for environmental health research.
Fischer et.al., (2006)	GIS and Spatial analysis method "Ripley's K", ISCST3 air dispersion model.	Ripley's K method examines the spatial point pattern of industrial toxic substances.ISCST3 air dispersion model identify the number of people potentially affected by air toxic.	Using Ripley's K with GIS that identify statistically significant areas of clusters and also the scales at which those clusters exist.	Examine the spatial point pattern of industrial toxic substances and problem of non-point sources with an analysis of the street network.
Matejicek L.,(2005)	GIS, ERDAS Imagine, LIDAR.	The spatial models and their extensions are developed in the framework of the ESRI's ArcGIS and ArcView programming tools The measurement of NO_X and O_3 by an automatic monitoring system and data from the differential absorption LIDAR are used for investigation of air pollution.	Wide range of data collected by monitoring systems and by mathematical and physical modeling can be managed in the frame of spatial models developed in GIS.	Manage all the data together with GIS model outputs to carry out risk assessment analysis and map composition, spatial database , spatial modeling for air quality. .

Lim et.al., (2005)	Integrated decision support system, GIS.	Through the development of prototype software IMPAQT (Integrated Modular Program for Air Quality Tools) with using a countywide transportation model, an advanced atmospheric dispersion model and a desktop GIS to carry out urban air quality assessments and to test traffic scenarios.	Identify high concentrations of pollutants in places such as residential/commercial areas. Predict travel impacts on present or future transportation systems. Evaluation of existing travel demands on the current transport network, and the prediction of future traffic flows for transportation planning. Dispersion model assess future air quality based on emission scenarios derived from transportation models.	Identification of high concentration of pollutants in residential/commercial areas.
Marquez et.al., (1999)	GIS, Airshed model.	Develop a framework for integrating land use, transport and airshed models for evaluating the effect of city form on air quality.	The framework identifies the relationship between various components such as the GIS database, the land use- transport- environment module and the airshed model.	This paper evaluate the effect on city due to air quality that identify the relationship between various components components such as the GIS database, the land use-transport-environment module and the airshed model
Sengupta et.al., (1997)	GIS, GRAM Software, Air quality index (AQI).	Integrated existing emission calculation software with a graphical user interface, which includes a GIS component.	Gives a summary of the basic road traffic emission model and then focuses on the design and implementation of the computer application with the emphasis on the used component and GIS technology.	This integrated emission evaluation system offers entirely new ways of using the emission model and gives additional visualization and analysis possibilities.
Briggs et.al., (1997)	GIS, Regression based approach.	With GIS regression based approach is used for mapping traffic related air pollutant NO_2.	By using GIS that containing data on monitored air pollution levels, road network, traffic volume, land cover, altitude assessed predicted pollution levels.	This provide pollution map by estimation of NO2 concentrations.

3. Mathematical modelling

In the previous section we have discussed many issues regarding air quality analysis, air quality index and health risk map and use of many technology that provide appropriate information but there are need of mathematical modelling that are applicable for mapping traffic related air pollution, estimation of air pollutant concentrations, analysis of association between air pollution and mortality, focused on the contributions of air pollutant emissions from stationary sources to the ambient air and their local impact on public health etc.

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They have discussed some mathematical models that applicable for solving traffic related air pollution, air pollutant concentrations, association between air pollution and human health effect, contributions of air pollutant emissions from stationary sources to the ambient air and their local impact on public health etc are given below in tabular form:-

Author name	Equation	Applicability
Briggs et.al., (1997)	Mean NO_2 = 11.83 + (0.00398 $Tvol_{300}$) + (0.268$Land_{300}$) - (0.0355RSAlt) + (6.777Sampht) Stepwise multiple regression analysis was return using the two compound factors ($Tvol_{300}$ and $Land_{300}$), together with altitude (variously transformed), topex, sitex and sampler height, against the modeled mean nitrogen dioxide concentrations.	This equation is applicable for mapping traffic related air pollution for NO_2 that compute the predicted pollution level at all unmeasured sites.
Wong et al., (1994)	$Z(Xo) = \sum_{i=1}^{n} \lambda i \ Z(Xi)0$ and $\sum_{i=1}^{n} \lambda i = 1$ where λi represent the weights assigned to each of the neighbouring values, and the sum of the weights is one. Compute the air pollution concentration, z at an unsampled point, x0, given a set of neighboring sampled values zi, sampled at locations denoted by xi. The interpolating relationship is given above.	Estimate air pollutant concentrations like O_3, PM_{10} by using four different interpolation methods (1) spatial averaging, (2) nearest neighbor, (3) inverse distance weighting, and (4) Kriging.
Jerrett et al., (2005)	Develop model that can be expressed mathematically in the form- hij s (t) = h0 s (t) ηj exp (β'xij s) Where h_{ij} is the hazard function or instantaneous hazard probability of death for the i^{th} subject in the j^{th} ZCA, whereas s indicates the stratum (defined by sex,race and age). Here $h_{0\,s}(t)$ is the baseline hazard function. The η_j are positive random effects representing the unexplained variation in the response among neighbourhoods, in this case zip code areas. Only the moments of the random effects need to be specified within our modeling framework: E (η_j) = 1 and Var(η_j)= τ^2 ·The vector x_{ij} represents the known risk factors for the response such as air pollution, smoking habits, and diet. The regression parameter vector is denoted by β.	Developed and used Cox proportional hazards regression for analysis of association between air pollution and mortality.
Maantay et.al., (2009)	Calculated and compared the sub-indices for the five air pollutants at each receptor (point), and the highest sub-index is used as the SII for that point. The equation followed that of the US EPA AQI, expressed below: $I_p = \frac{I_{HI} - I_{LO}}{BP_{Hi} - BP_{Lo}}(C_p - BP_{Lo}) + I_{Lo}$ Where Ip is the sub-index for pollutant p, Cp is the concentration of pollutant p, BP_{Hi} is the top breakpoint that is greater than or equal to Cp , BP_{Lo} is the bottom breakpoint that is less than or equal to Cp, I_{Hi} is the sub-index corresponding to BP_{Hi} , I_{Lo} is the sub-index corresponding to $BP_{Lo.}$	They have focused on the contributions of air pollutant emissions from stationary sources to the ambient air and their local impact on public health.

Crabbe et al.,(2000)	$E_p = \sum_x \bar{e}\,(x,t)$ $\bar{e}_{(x,t)} = \frac{\int_{t0}^{t1} C_{(x,t)}\ dt}{t_1 - t_0}$ And x= home, work, and other locations identified in the GIS, t= time spent at each location identified from the environmental factor questionnaire, e = the exposure to air quality at that location, either measured or modeled, c = concentration of air quality at that point, Ep = total personal exposure.	Modeled personal exposure of air pollutants for purpose of characterization of human exposure and dose assessment techniques.
Chelani et.al., (2010)	The Oak Ridge air quality index is given by, $\text{ORAQI} = 5.7 \times \left(\sum_{i=1}^{s} Ii\right)1.37$ Where, $I_{i=}$ Concentration of pollutants ÷ Standard level of pollutant.	The use of an index called Oak Ridge Air Quality Index (ORAQI) based on 24 hourly average concentrations of air pollutants. This index is formulated based on the premise that the effect on environmental quality varies inversely in relation to the pollutant concentration.
Chattopadhyay et.al, (2010)	(1) q = 100 × V / Vs ; where q = quality rating ; V = observed value of parameter ; Vs = value recommended for that parameter. If total 'n' no of parameters were considered for air monitoring, then geometric mean of these 'n' number of quality ratings can calculated in the following way : (2) $g = \text{antilog}\,\{(\log a + \log b + ...\log x)/n\}$ where g = geometric mean ; a, b,c,d,x = different values of air quality rating; and n= number of values of air quality rating, log = logarithm.	Air quality rating of each parameter used for monitoring is calculated in each zone.
Joshi et al., (2010)	used following computation to drive the air quality index of the sites under consideration: AQ I= ¼ $\left[\frac{RSPM}{sRSPM} + \frac{SPM}{sSPM} + \frac{SO2}{sSO2} + \frac{NO2}{sNO2}\right] \times 100$ Where sRSPM, sSPM, sSO2, and sNO2 represent the ambient air quality standards as prescribed by the Central Pollution Control Board of India and RSPM, SPM, SO2 and NO2 represent the actual values of pollutants obtained on sampling. After compiling the results, the concentration of each pollutant was converted into an AQI.	The ambient air quality survey was carried out at four different locations with respect to SO2, NO2, SPM and RSPM, and monthly air sampling was carried out for a period 24 hrs at each of the site.

4. Implementation Factor

The major implementation issues associated with air quality index and environmental health research data acquiring and integrate with the geographic data that should be selected in a way that geographic data (both spatial and associated non-spatial attribute data). Concentration and emission data of major air pollutants like RSPM, PM10, PM2.5 , NOX, CO and SO2 should be collected and can be analyze the statistical parameters of air pollutants such as average concentration of the air pollutants, mean monthly value of air pollutants and emission rate of air pollutants and meteorological data should be collected and then we can assess statistical parameters of meteorological condition like wind speed, wind direction, atmospheric stability, mixing height, humidity, rainfall and can be assessed the seasonal variation and with this context we can assess the human health risk assessment with the help of collection of human health data like type of disease caused by air pollution like risk of developing cancer, respiratory and allergy diseases and aggravates the condition of people suffering from respiratory or heart diseases and no of peoples that can be affected by these diseases and no of mortality. The air pollutants that raise health concerns and with the help of this we can be analyze data related to environmental and socio-economic factors.

The above mention problem can be solve with using ArcGIS Geostatistical Analyst. With the help of this ArcGIS Geostatistical Analyst we can be describe the behaviour of the concentrations emitted by a group of polluting sources and analyze the behaviour and distribution of pollutants and particulate matter. This statistical technique used for the estimation, prediction and simulation of information correlated spatially. Geostatistical methods provide a tool like semivariograms that allows to explore and estimate the available information, allowing to take better decisions. The other tools are Kriging application that is possible to minimize the variance of the error prediction and it estimate the characteristics of variability and spatial correlation of the studied area.

Geostatistical methods can be apply for health risk map. Health risk map representing the spatial distribution of respiratory symptoms and diseases that can be produced through spatial interpolation techniques. Exploratory Spatial Data Analysis can be used for understanding the properties of the spatial dataset.

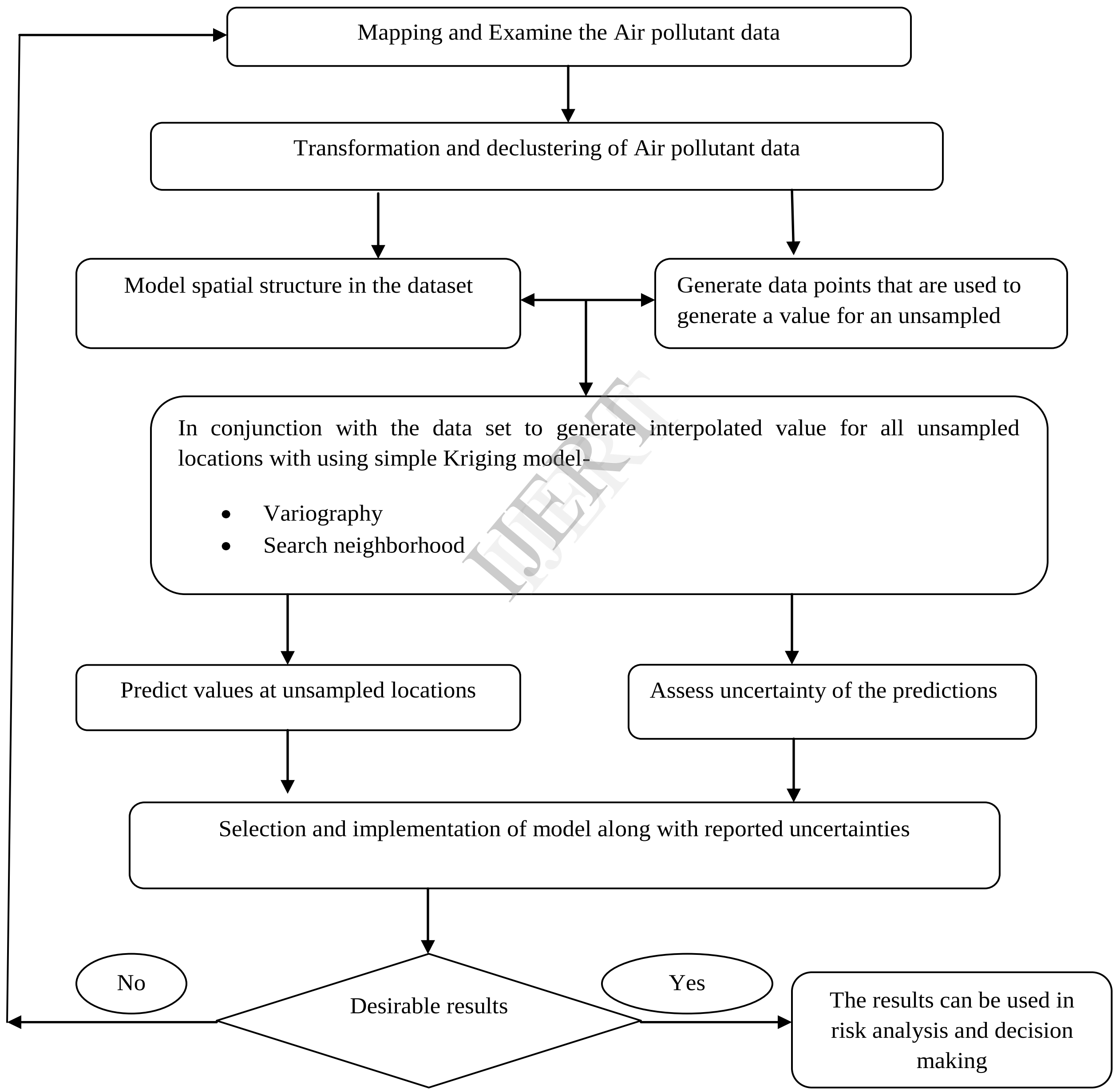
The implementation factors are given below in tabular form:-

Author name	Statistical Parameters	Software	Data	Outcomes
Jensen et.al, (2001)	Danish operational street pollution model (OSPM), hourly inputs of traffic, meteorological parameters, urban background concentration, street configuration parameters.	GIS Software (Arc View), Danish operational street pollution model (OSPM).	Technical and cadastral digital maps, Danish national administrative databases on buildings, cadastres and populations.	OSPM model calculates ambient hourly concentration levels of CO, NO_2, NO_x ($NO + NO_2$), O_3 and benzene.
Chattopadhyay et al, (2010)	Average concentration of the RSPM, SO2 and NO2 for both Premonsoon and Post monsoon season, Meteorological parameters such as humidity, temperature, wind speed, wind direction and rainfall for both premonsoon and post monsoon seasons.	Resourcesat-1 satellite image and Geomatica V.10.2 software.	Concentration of Air pollutant such as RSPM, SO2 and NO2. Meteorological data.	Seasonal variation of ambient air quality status using GIS approach.

Briggs et al., (1997)	All roads (stored as 10m grid), Mean 18 hour traffic flow (vehicle/hour) for each road segment, Land cover class (20 classes, stored as 10 m grid), Mean NO2 concentration (by survey period, and modeled annual mean).	ARC/INFO version 7.1 software.	Concentration of air pollutant NO2. Traffic volume and composition, traffic speed, emission factors for all main classes of vehicle, street characteristics (e.g. road width, building height or type) and meteorological conditions (e.g. wind speed, wind direction, atmospheric stability, mixing height).	Mapping traffic-related air pollution within a GIS environment.
Wong et al.,(2004)	Mean value of air pollutants.	Spatial interpolation technique.	Concentration of CO, NO2, O3, lead, PM10, and SO2.	Assess the role of exposure to ambient air pollutants as risk factors only for respiratory effects in children.
Maantay et al., (2009)	Emission rate of PM10, PM2.5, NOX, CO and SO2.	ArcGIS 9.2, ArcV2CAD, ISC-AERMOD, SPSS software.	Emission data of PM10, PM2.5, NOX, CO and SO2, Asthma hospitalization data with the location of each patient's home address, Population data.	Analysis of relationship between the asthma hospitalization rate and the combined impact of all selected criteria air pollutants contributed by each stationary source.
Sengupta et al.,(1996)	Mean monthly level of TSP, SO2 and NOx.	GIS package GRAM software.	Concentration of three pollutants (NO2, SO2 and Total suspended particulate matter), Density of the population.	Assess the exposure and health risk of the population from atmospheric pollutants.

5. Proposed Framework for Analysis and application of GIS based Air Quality monitoring

Geostatistical analysis is used to analyze and predict the values associated with spatial or spatiotemporal phenomena. Geostatistics can be used to estimate pollutant levels and health risk foe prediction of environmental contaminant levels and their relation to the incidence rates of disease. Exhaustive studies are expensive and time consuming so Geostatistics is used to produce predictions for the unsampled locations.



6. Conclusion

This study concludes that Air pollution and its adverse effects on public health have require air quality management and assessment on public health. The air pollution problem originating from the various sources can be analyzed by Geostatistical analysis. The DSS based GIS analysis provide information on how much pollution exposed how many population affected and estimate environmental impacts from present and future developments so establish strategies that reduce pollution. GIS enable to integrate and analyze number of environmental data from different sources that model the overall impact of air pollutants on environment. The geostatistical analysis are used for air pollution modelling that allow the spatial variability of the elements and estimating pollution level and tools that are used for geostatistical analysis like variogram, Kriging that measure the spatial variance regarding the distance between two points and determine the spatial characteristics of the variables. By applying geostatistical methods that obtain population health risk status from information regarding cancer, respiratory and allergy diseases.

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