DESIGN AND DEVELOPMENT OF A CUSTOMISED GIS FOR AIR QUALITY MANAGEMENT

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Commission VII, WG VII/3

KEY WORD: Spatial Information Science, Environment, GIS, Air pollution, Design, Development

ABSTRACT:

One of the major problems of Tehran, Capital city of Iran, is air pollution that seriously affects human's health. Spatial dispersion of air pollutants such as CO, NO_2, SO_2 and PM from stationary and mobile sources or natural disasters has important effect on the air quality.

Proper management of the problem is considered to be quite complex due to lack of accurate, up to date and organized geospatial data and analysis as well as lack of an integrated system for acquisition, storage, manipulation, retrieval, analysis, presentation and exchange of environmental data.

Nowadays, geospatial information systems (GIS) as management and supporting systems, enable us to integrate and analyze a number of environmental data from different sources to model the overall impact of air pollutants on environment.

This paper presents the process of design and development of a customized temporal GIS for environmental management. Based on hourly, daily and monthly data acquired from seven air quality monitoring stations distributed in Tehran, a number of spatial and statistical analyses have been performed.

Spatial analysis such as overlay, buffering and zoning have been performed and provide an environmental alarming system. Spatial correlation and distribution factors and their impact on environmental pollution have been considered in this research.

The initial results of the analysis showed that the developed customized system as an environmental decision support system (EDSS) can be effectively used in monitoring and managing different pollutants.

1. INTRODUCTION

Tehran is the capital of Iran with total area of about 700 Km2. Mountains surrounds North and East of the city. Tehran is one of the few capitals of the world, which is neither near a river nor close to a sea. The average of rainfall is 230 mm and there is no rain for about 6 months of a year. Also the growing population and urban as well as industrial development have created an air pollution problem for the city. [Asadollah-Fardi]

Regarding the special geographical situation of Tehran and expansion of spatial dispersion of the pollutants which belong to stationary and mobile sources or natural disasters, government and citizens in this metropolitan have to use the latest science and technology to develop air quality management.

The air pollution reaches to a level which can significantly influence human's health. For each city clean air is one of the most valuable sources. Air quality management system (AQMS) can be defined as a regulation of the amount, location and time of pollutant emissions to achieve some clearly defined set of ambient air quality standards or goals. For an efficient AQMS, there is a need to define a decision support system. [Hussain, 2003]

A geospatial information system (GIS) is a computer-based information system which enables us to capture, model, manipulate, retrieve, analyze and present the geographically referenced data. [Aronoff, 1991]

A number of new GIS-based systems are currently installed which play an important role in making decisions at various levels of management. Making decision is a complex process influenced by many factors. The basic advantage of this science and technology is its ability to manage and integrate with the present database. However, a better, efficient and cost effective approach to monitor the ambient air quality is to customize GIS to manage environmental data.

2. AIR POLLUTION MONITORING STATIONS IN TEHRAN

Air pollution is defined as any atmospheric condition in which certain substances present in such concentrations and duration that they may produce harmful effects on man and his environment [Mulaku, 2001]. Common air pollutants include carbon monoxide, nitrogen oxide, sulphur dioxide, total suspend particular mater (TSM) which includes dust, smoke, pollen and other solid particles.

The major sources of air pollutants are man's industrial manufacturing and motor vehicle operation activities, both of them have been concentrated in urban areas, where also the bulk of the World's population live.

Most developing countries have no air quality management capabilities despite having the fastest growing urban populations. Lack of expertise to formulate air pollution management policies; low budget priority given to air pollution when compared with other social and

environmental problems; inadequate political will and inappropriate legislative and administrative frameworks in which responsibility for air quality management is divided between a number of government ministries and the local administrations are some of the reasons.
Since 1995 the Department of the Environment (DOE) and the Air Quality Control Company (AQCC) of Iran have monitored some parameters of air pollution continually.
Figure 1 shows the locations of air pollution monitoring stations in Tehran.

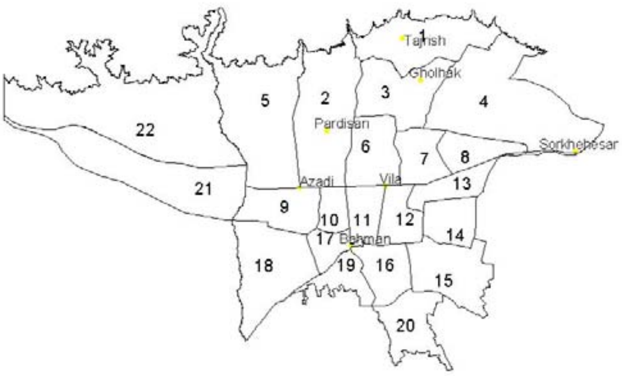


Figure 1.The Locations of air pollution stations in Tehran

Regarding various environmental standards defined in the world; in this paper PSI (Pollutant Standard Index) standard have been used.

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} \times (C_p - BP_{Lo}) + I_{Lo}$$

I_p = Pollution index
I_{Hi}= PSI related to high break point
I_{Lo}= PSI related to low break point
BP_{Hi}= High break point >= C_p
BP_{Lo}= Low break point <= C_p
C_p= Pollutant concentration

3. TEMPORAL GIS

We live in a dynamic world. Every thing around us changes at different rates. Most of the phenomena change over time so spatio-temporal GIS have been developed [Nadi, 2003.]. Traditional GIS applications deal with sets of static objects, many spatial referenced objects change with time and more and more applications referred to location and time are considered; therefore the necessity of using spatio-temporal GIS is inevitable. A spatio-temporal GIS aims to process, manage and analyze spatio-temporal data [Yuan, 1996.].
Storage of captured data from monitoring stations in temporal database helps us to optimally manage air quality. Air pollution depends on location and time. Capacity of each information system is extensively dependent on its data model [Yuan, 1996.]. A data model should define data type, relationship, operations and rules to maintain database integrity [Date, 1995.]. Considering large amount of monitored data, designing and normalizing database is seriously recommended. A rigorous data model must anticipate spatio-temporal queries and analytical method to be performed in the temporal GIS [Yuan, 1996.].

From temporality point of view, there are two types of information, static and dynamic, which must be modeled under a temporal GIS. In this research air pollution monitoring stations are mostly static and the value of pollutants over the time is dynamic.
Temporal modeling in GIS started with time stamping layers and then goes into process based modeling. This, trend is represented below [Nadi, 2003]:

- Time stamping
  - Snapshot model
  - Space time composite (STC)
  - Spatio-temporal objects
- Event or process-based
  - Event based spatio-temporal data model (ESTDM)
  - Domain oriented spatio-temporal data model

Air quality changes continually and we can monitor different values over the time for each pollutant .This changes should be stored in the database so snapshot model is chosen. In snapshot model, each layer is composed of temporally homogeneous units. In the other word, in the snapshot model, when an event occurs, new layer will be constructed and occurrence time will be stamped to the layer (all of the information, changed or not changed, will be stored in the layer) [Nadi, 2003].
An ideal spatio-temporal database is mentioned as a database that has the ability to keep the track of changed data besides having the normal function essential to every spatial database. In addition to the process of updating geographical objects, keeping the valid topological (either temporal or spatial) relationship are also operational [Roshannejad, 1996].

4. GIS IN AIR QUALITY MANAGMENT

By doing air quality modeling in a GIS environment, the output of the pollutant records can be obtained in the form of spatial records.
GIS science and technology is capable of supporting the development of geospatial air quality models. For modeling in GIS environment, AQMS may consider as be thought of comprising three phases namely, monitoring, development of DSS and execution. The milestone capabilities of GIS for AQMS are as fallow [Hussain, 2003.]:

a) To locate the monitoring station
b) To develop geospatial air quality models
c) To develop spatial decision support system (SDDS).

5. METHODOLOGY

In this research the monitored environmental data from seven stations in Tehran in 2002 were collected, and then the accuracy of the data was assessed by using statistical analysis. To detect and remove errorly recorded data, the specific domain of each pollutant should be determined. Accuracy of instrument in observation, record and transmit affect on data quality. Other parameter affecting data quality should be determined.
The data was structured and stored in the temporal database while Tehran's digital map at a scale of 1:2000 was being uploaded and topologically structured using ArcView and ArcInfo GIS software. The location of stations on the map was determined. Attribute data were assigned to spatial objects and the system became ready for spatio- temporal analysis and management.

6. CASE STUDY

The monitored raw environmental data include error. The data from Sorkhehesar, Tajrish, Gholhak, Bahman, Vila, Pardisan and Azadi air pollution monitoring stations in Tehran in 2002 was stored in Excel software. Then pollutant standard index (PSI) was calculated in daily, monthly and yearly interval by programming using Visual Basic as discuss in [Rahmatizadeh, 2003]. Database joined to digital map. Spatial Analysis module was used for interpolation in three dimensions. Inverse distance interpolation is used for modeling between the monitoring stations. This method of interpolation combines the idea of Thiessen polygon with the gradual change of trend surface. It considers weighted moving average. Weights are computed from a linear function of distance between sets of points and the points to be predicted. In this method the size of the starting radius is specified, which defines the starting search area for interpolation points around grid point. Figure 2 shows spatial dispersion of TSM in June 2002. Similarly such map was produce for the other pollutants.

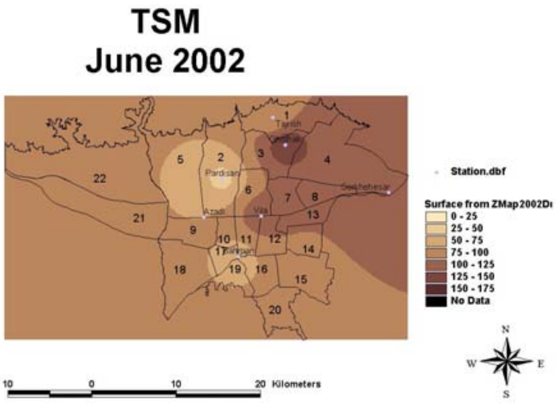


Figure 2.Spatial dispersion of TSM in June 2002

Considering the standards used, good, moderate, unhealthy, very unhealthy and dangers places were determined [Rahmatizadeh, 2004]. Figure 3 shows the spatial dispersion of CO in November 2002.

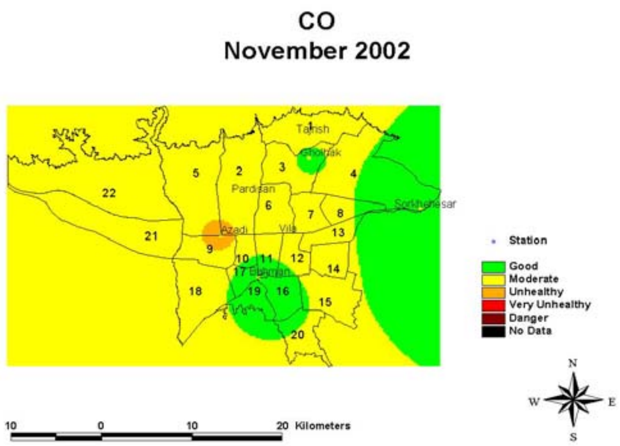


Figure 3.Spatial dispersion of co in November in 2002

Following statistical analysis draw chart foe each station. Figure 4 shows the trends of four important pollutants in Bahman air pollution station in 2002.

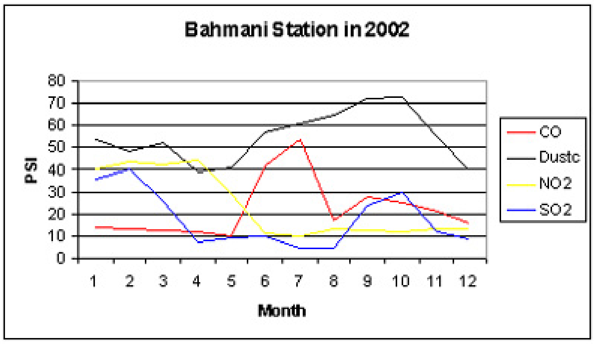
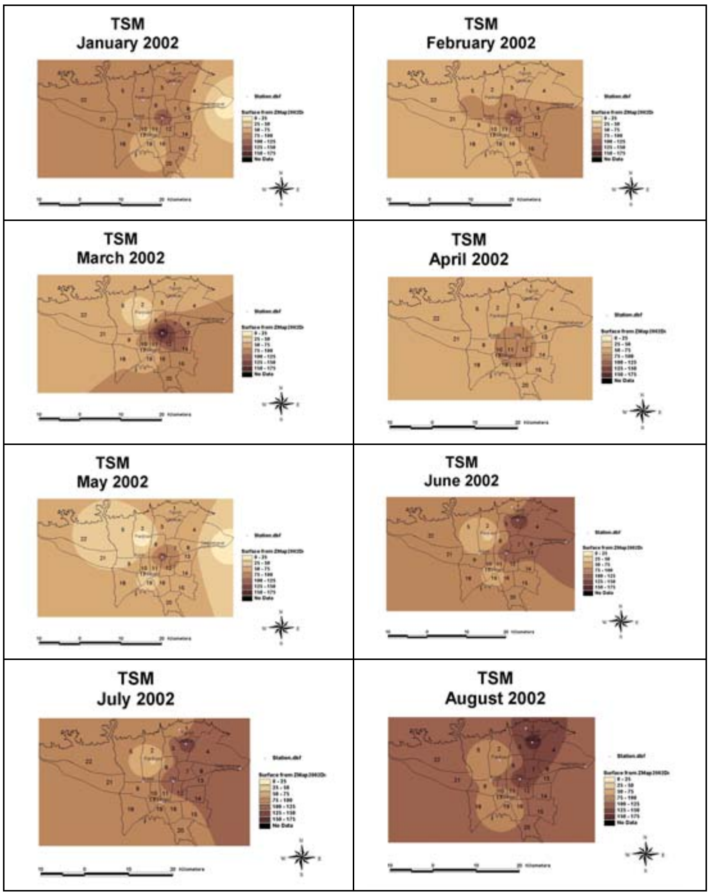


Figure 4.The trends of four pollutants in Bahman station in 2002

There is a strong wind blow in Tehran during last summer and beginning at autumn, due to specific topographic condition and arid or semiarid region of city. In addition, due to a number of large deserts including Central desert in Iran and finally because of creating heat islands, TSM penetration to the city increase.

Spring season, relative humidity and increased precipitation, TSM are deposited. This situation is illustrated in Figure 5.



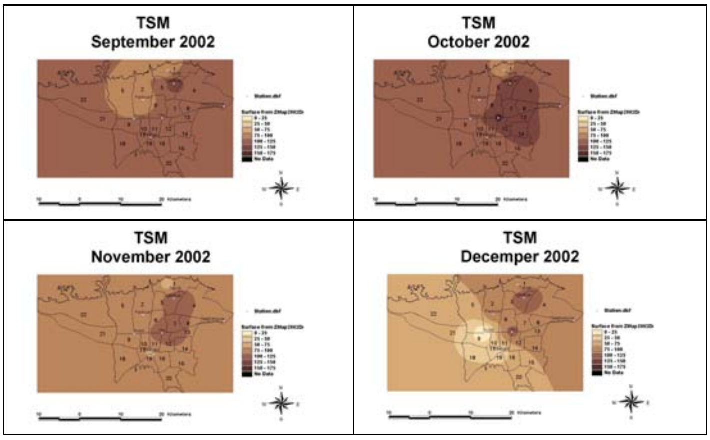


Figure 5.TSM in 2002

A voronoi diagram of the area air pollution monitoring stations in Tehran has been produced to is illustrate the spatial dispersion of the station and their influenced area (Figure 6).

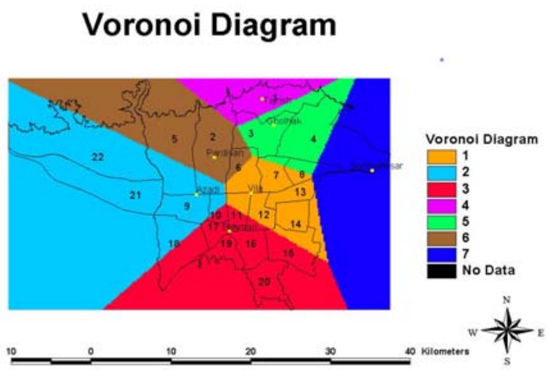


Figure 6.Voronoi Diagram of Tehran's air pollution monitoring stations

7. CONCLUSIONS AND FUTURE DIRECTIONS

The air pollution problem originating from the various sources can be controlled by the development of air quality management system.

The seasonal air pollution surfaces are useful for wide range of purposes: for health risk assessment of the population within the study area, to assist in establishing and monitoring air quality standards, and to evaluate transport policies. For high accuracy it is necessary to study meteorological parameters like wind direction, wind speed, temperature, altitude which affect pollutant dispersion. It is possible to improve the spatial predictions of air pollution levels by deriving an empirical regression model of the relation between pollutants and independent variables which is the aim of the next step of this research.

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