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GIS Application for Spatial and Temporal Analysis of the Air Pollutants in Urban Area

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Abstract Air Pollution is a precarious issue for the City Dwellers. It is important to control and mitigate the Air Pollution in exceedingly Polluted Area of the City. Due to limited number of monitoring stations by the environmental agency in the city spatial interpolation tool in GIS predicts the pollutants concentrations at unmonitored stations we can get vital information about the distribution pattern of the air pollutions. In this paper evaluation of the Air Quality Data for the important pollutants like PM10, PM2.5, Ozone, and NOx is represented in GIS for whole city of Pune. A Temporal Analysis is also been done for the months of February, March and April year 2015. The most spatial interpolation techniques from inverse distance weighing, kriging, splining and nearest neighbor. The most suitable method for GIS mapping is professed as Inverse Distance Weighing according to the monitoring stations spatial distribution data available was selected for the interpolation.
Keywords *GIS Mapping; Air Pollution; Spatial Interpolation*

1. Introduction

Air Pollution is a highly intensifying issue which is engulfing almost each and every corner of the world mostly due to the human activities like huge industrialization, vehicular activity induced by enormous amount of fuel consumption and all other activities like urbanization, construction, power generation and rather all other anthropogenic activities.

The huge constructed towers affect the flow of the air quantity resulting in exchange of air and scattering or spreading of pollutants. The cities and metropolis encourages high human exposure to the harmful substances due to the escalated population and vehicular activity.

The temporal disparity of the concentration of the pollutant during 24 hours varies with the topographic and meteorological features such as altitude, which defines the local wind speed and direction at a given space and time.

There are already signs of distress and bother about this contamination of air quality mostly in cities and urban areas and is getting worldwide importance.

The proper quality sampling at each particular location can be an issue therefore it is very important to have a suitable process to calculate or predict the data for the area under study. Interpolation is a technique in which we can precisely calculate the values of unsampled areas actually calculated using sampled data. Interpolation mostly results in maps.

The quality of the air is very vital to our health and to all other living beings. The contamination in air can cause various health hazards and there is a major risk of chronic and respiratory diseases, but the monitoring of the air quality contamination is often termed as difficult. Geo spatial Technologies operate and manage spatial and statistical data and provide us with the results giving us the correlation between the air quality and human health. So, GIS and Geo spatial Technologies can be widely used for monitoring air quality.

Spatial Interpolation of the GIS Toolset is applied for environmental issue like air pollution, air pollution levels can be visualized the spatially distributed over the city, Pune from the 9 monitoring stations setup by the IITM agency. The properties of an interpolated surface can be managed by limiting the calculation of values of the output cell. When the maximum numbers of points are specified for the sampling, the closest output cell points position returns unless the maximum number is reached.

Table 1: *Techniques used to Measure the Pollutants*

Sr.No	Pollutant	Technique
1	NOx	Chemiluminescence
2	Ozone	UV radiation
3	Particulate Matter	Transmitter-Receiver

Zoning of the city is been possible and the suitable precautionary measure like dust control measures, such as vegetative covering, barrier methods, irrigation, and street sweepers. Are to be implemented to capture the spatial processes, linear regression analysis utilizes GIS capabilities and extracts the maximum amount of information from the different data sets (Briggs et al., 1997).

A GIS Map as far as air pollution is concerned will be able to represent spatially which pollutant are considered in which city or part of the city what period of time (Knowles and Hillier, 2008).

Pune is located in 18.5203° N, 73.8567° E; it is located 560 m (1,840 ft) above sea level on the western margin of the Deccan plateau. Pune City had been known as Pensioners Paradise, due to its salubrious climate and fresh clean air. But in the recent times, rapid industrial and commercial development with the name as 2-wheelers capital and increasingly high amount of motor vehicles registered in the city, Air pollution is a major issue in Pune.

Table 2: *Locations and Organisation of IITM's Installed Monitoring Stations*

Sr. No.	Location	Institute/Organization name
1	Pashan	Indian Institute of Tropical Meteorology
2	Shivajinagar	India Meteorological Department
3	Lohegaon	Pune Airport, Airforce base, Pune
4	Alandi	MAEER's Maharashtra Academy of Engineering
5	Katraj	Bharati Vidyapeeth
6	Hadapsar	Lohiya Udyan, PMC
7	Bhosari	PCMC
8	Nigdi	PCMC
9	Manjri	Vasantdada Sugar Institute

In this GIS Map we have considered 9 monitoring station by IITM are represented spatially as below Figure 1.

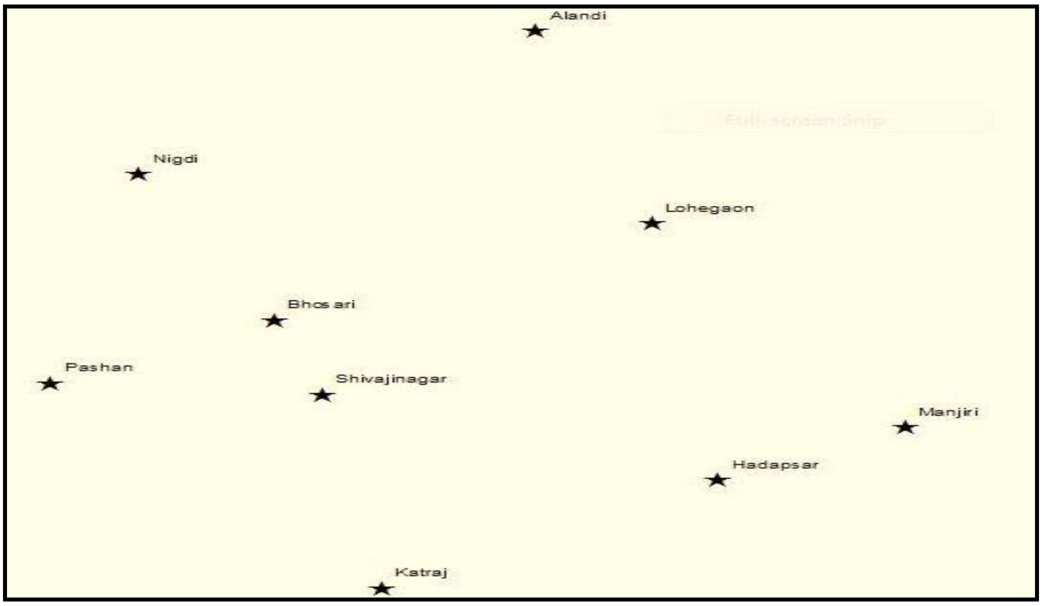


Figure 1: *Georeferencing the Monitoring Stations on GIS Platform*

2. Methods for Spatial Interpolation

So as per data availability and accuracy in the prediction of the concentration of the unknown points, most suitable method is selected accordingly out of the below mentioned methods.

2.1. Inverse Distance Weighing Method

For calculating the values of un-sampled positions precisely, Inverse Distance Weighing method allocates higher weight to the close by points than the far away ones. Thus this method (IDW) needs closely packed network of equally spaced observations. This method actually appraises weighted moving average.

A linear function of extent or distance between the sets of points and the sampled points is used to calculate the weights.

This method firstly specifies the extent of the area to be interpolated and which decides the starting point in the process. Weighted averages of sampled points in the surrounding cells are used to calculate the unknown cell values. Whenever there are less known sampled points, IDW is preferred over kriging. Thus for spatial modelling of air quality where we had less known samples, we decided to choose IDW instead of Kriging and other interpolation techniques.

2.2. Kriging

Kriging is another complex, efficient and widely used spatial interpolation technique for large number of spatially auto correlated sample points.

$$Z^*(u) = \sum_{\alpha=1}^{n} \lambda_\alpha \,(u) Z(u_\alpha)$$

Where, z (ua) represents random variable model at location ua

ua are the 'n' data locations
ya (u) represent the kriging weights
and z*u is the estimated value

While using kriging for pollutants it should be noted that the scale of the particles is correctly captured, else, it can lead to smoothing of the pattern by over simplification. Each pollutant was spatially interpolated for its concentration in each metropolitan. The kriging method of interpolation from the spatial analyst tools is preferred as it gives good accuracy.

Kriging uses the weighted average of known values (measured concentrations) to predict the value of each cell. The weights are statistically calculated based on the spatial correlation between the two points.

2.3. Nearest Neighbour

Each BG was assigned the air concentration level of the monitor nearest to its centroid regardless of how far away the monitor was located. This eliminated the search radius as a parameter in the interpolation (Detels et al., 1987; Schwartz and Zeger, 1990; Stern et al., 1994; Kunzli et al., 1997; Vedal et al., 1998).

This method involves the nearest coordinates to calculate the effect produced by a dispersed point on the resulting cells. Sometimes this kind of interpolation technique is known as point sampling or interpolation of proximity and is treated as a method of multivariate interpolation in one or more aspects or dimensions. As this interpolation technique is actually estimating the values precisely for an un-sampled point from its neighboring sampled points, what nearest neighbor does is that it takes only the closest point into consideration and leaves all the surrounding points.

2.4. Splining

The spline method works differently. It interpolates values so that the prediction raster makes up a smooth surface with minimized curvature. Thus splining results in a smooth surface that passes exactly through the input points. It can predict ridges and valleys in the data and is best method for representing smoothly varying surfaces of phenomenon.

There are 4 methods of Spatial Interpolation Available in the ArcGIS Toolset, in Spatial Interpolation Category. The following settings are to be done in the GIS projection co-ordinate system for the Pune city Maharashtra region; it is termed as WGS_1984_UTM_Zone_43N in which WGS Spatial reference number wherein the Indian topography is best represented and 43N is for Maharashtra region representation.

Table 3: *February - 2015 Air Quality Data*

Pollutant	Pashan	Shivajinagar	Lohegaon	Alandi	Katraj	Hadapsar	Bhosari	Nigdi	Manjri
PM10	112.55	150.82	113.71	132.66	132.66	152.87	164.97	88.06	149.07
PM2.5	51.16	63.03	70.34	55.34	72.97	92.29	64.30	39.53	85.09
Ozone	42	37	50	52	53	31	37	44	53
Nox	12.71	31.76	46.51	29.86	16.53	56.54	4.27	12.39	26.32

Table 4: *March - 2015 Air Quality Data*

Pollutant	Pashan	Shivajinagar	Lohegaon	Alandi	Katraj	Hadapsar	Bhosari	Nigdi	Manjri
PM10	93.20	127.21	96.44	107.32	107.32	110.54	125.45	72.02	100.55
PM2.5	45.86	56.71	63.29	40.33	68.28	67.02	43.66	25.59	44.68
Ozone	34	39	47	49	51	34	38	38	52
NOx	10.04	30.09	34.96	14.38	15.20	13.99	6.03	10.12	11.15

Table 5: *April - 2015 Air Quality Data*

Pollutant	Pashan	Shivajinagar	Lohegaon	Alandi	Katraj	Hadapsar	Bhosari	Nigdi	Manjri
PM10	93.20	127.21	96.44	107.32	107.32	110.54	125.45	72.02	100.55
PM2.5	45.86	56.71	63.29	40.33	68.28	67.02	43.66	25.59	44.68
Ozone	34	39	47	49	51	34	38	38	52
NOx	10.04	30.09	34.96	14.38	15.20	13.99	6.03	10.12	11.15

3. GIS Maps Representing the Air Quality Characteristics as Displayed Below

The representation of the air quality GIS Map in different colour schemes representing as per its Air Quality Index according to Table 6 given below.

Table 6: *Classification of Air Quality Index*

COLOUR CODING	AQI Range Index	O_3 (8h avg)	CO (8h avg)	NO2(ppm)	PM10(μg/m^3)	PM2.5(μg/m^3)
Good	0-100	0-50	0-1.7	0-42	0-100	0-60
Moderate	101-200	51-98	1.8-10.3	43-94	101-150	61-90
Poor	201-300	99-118	10.4-14.7	95-295	151-350	91-210
Very Poor	301-400	119-392	14.8-30.2	296-667	351-420	211-252
Very Unhealthy	401-Above	393-Above	30.3-Above	668-Above	421-Above	253-Above

4. Results and Discussion

Representation of Air Quality for Pune City on GIS Platform.

A small number of air quality monitors greatly reduces the availability of Kriging and Splining as a suitable Method for Interpolation. These Method require the greater number of monitoring stations for a particular map.

Spatial Interpolation is done using Inverse Distance Weighing Method.

The Pollutants for which the Interpolation is done are PM10, PM2.5, Ozone, NOx distribution over the city by which we can shortlist the causes.

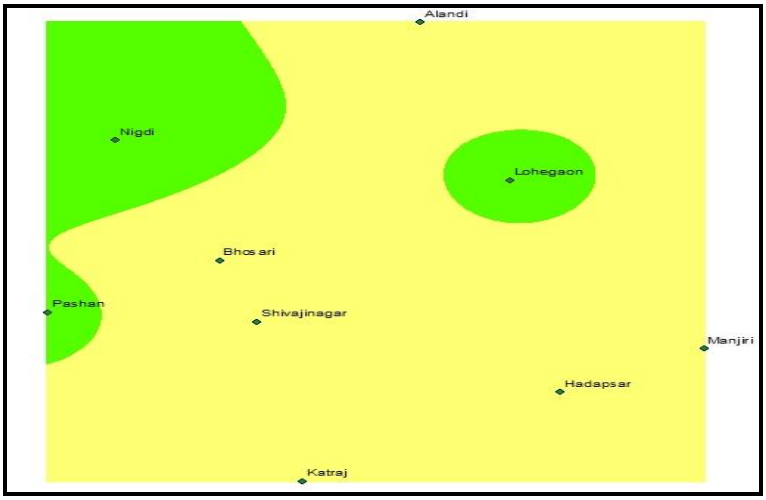


Figure 6: *Spatial Interpolation for PM_{10}*

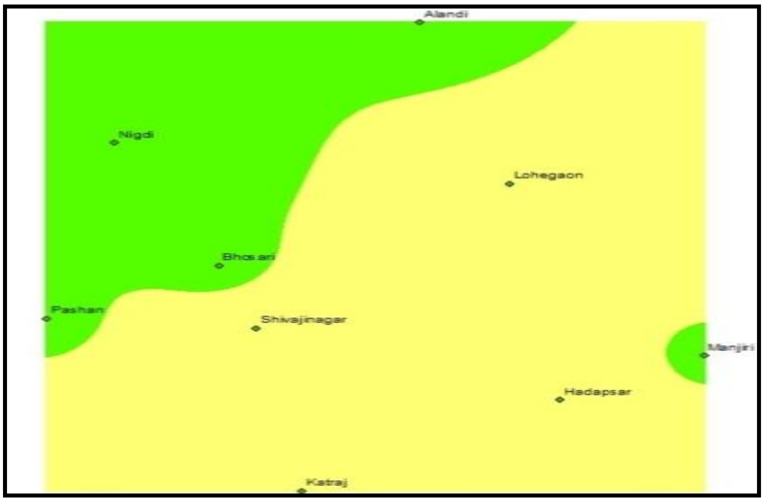


Figure 7: *Spatial Interpolation for $PM_{2.5}$*

The concentrations of the PM_{10} and $PM_{2.5}$ both are higher than the normal range so there are chances of people suffering from the diseases such as lung cancer, cardio vascular mortality. Particulate Matter can also cause Asthma and exacerbate Asthma.

PM_{10} particles deposit mainly in the upper respiratory tract while fine and ultra-fine particles are able to reach lung alveoli. So far, no single component has been identified that could explain most of the PM effects. Among the parameters that play an important role for eliciting health effects are the size and surface of particles, their number and their composition. The composition of PM varies, as they can absorb and transfer a multitude of pollutants. However, their major components are metals, organic compounds, material of biologic origin, ions, reactive gases, and the particle carbon core.

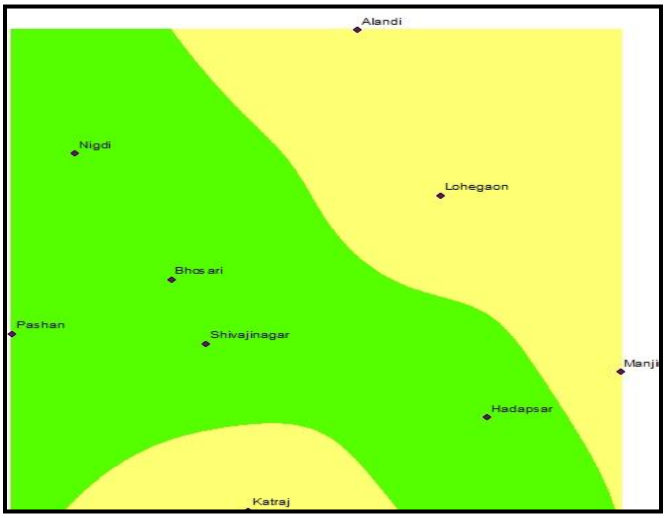


Figure 8: *Spatial Interpolation for Ozone*

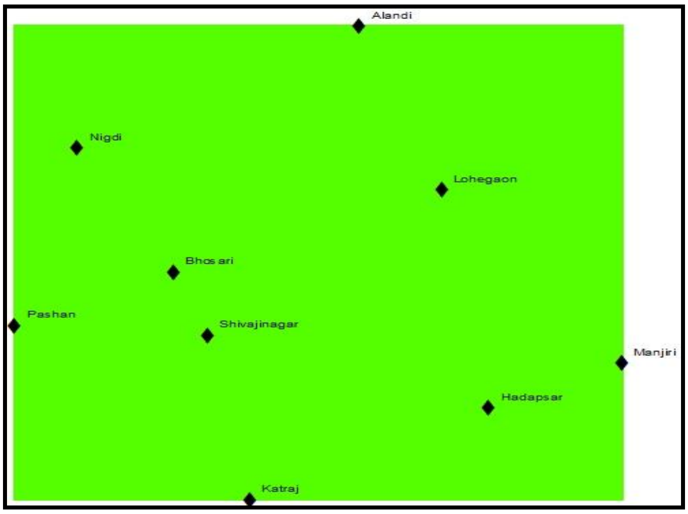


Figure 9: *Spatial Interpolation for NOx*

The two major precursors for ozone are volatile organic compound (VOCs) and NOx. The heavily industrialized area on the ship channel to the east of the city releases large quantities of VOCs and moderate quantities of NOx.

Air Quality Weekdays Typical Peak Hours (average of Monday to Friday)
Air Quality Weekends Typical Peak Hours (average of Saturday and Sunday)

Time-1- 6:00	Time-2-12:00	Time-3 20:00	Time-4 00:00

Change in the Air Quality as per different times of the day can be represented as

Intervals of the Pollutants is given on the Right Hand Index have considered the t Hazardous Pollutant PM2.5 for Spatial Interpolation in µg/m^3

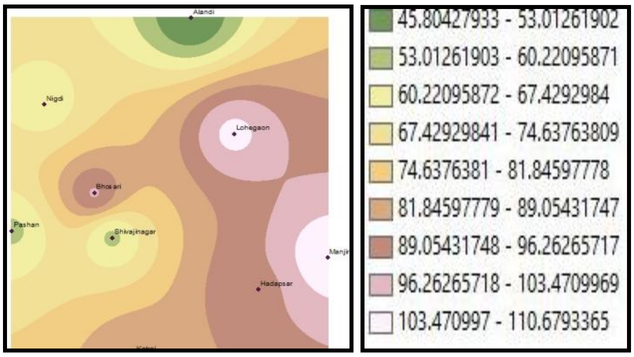


Figure 10: *Weekdays Spatial Interpolation of PM2.5 at 06*

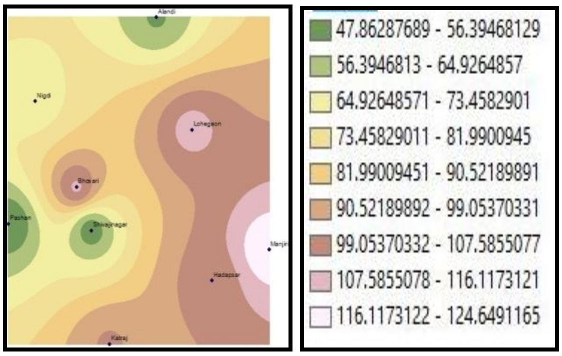


Figure 11: *Weekends Spatial Interpolation of PM2.5 at 6:00*

GIS Map is represented in such a way that classes been divided into 9 equal intervals as per their concentration.

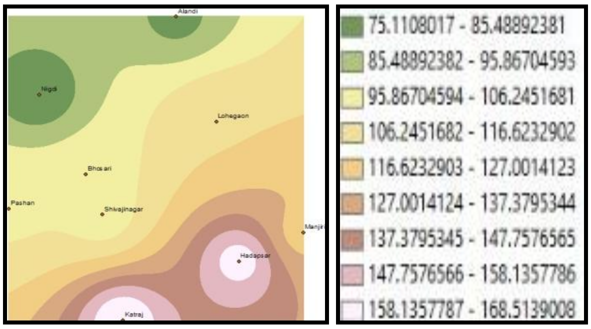


Figure 12: *Weekdays Spatial Interpolation of PM2.5 at 12*

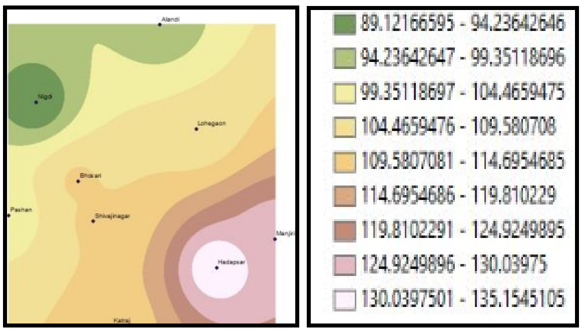
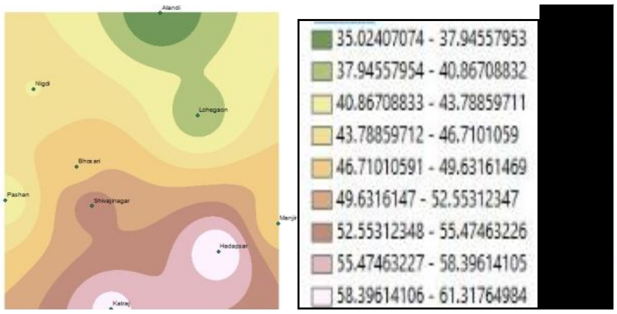


Figure 13: *Weekends Spatial Interpolation of PM2.5 at 12*



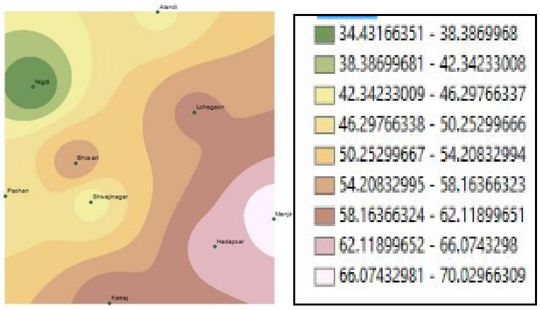
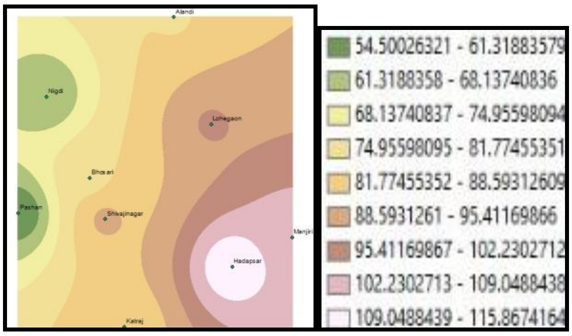


Figure 14: *Weekdays Spatial Interpolation of PM2.5 at 20*

Figure 15: *Weekends Spatial Interpolation of PM2.5 at 20*



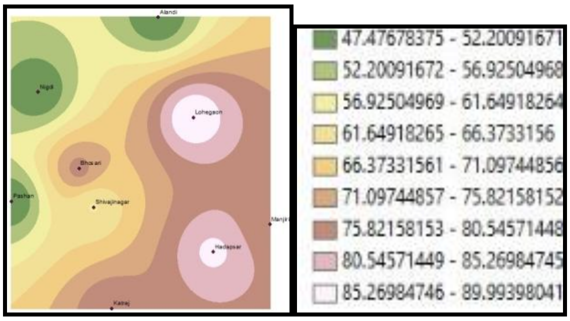


Figure 16: *Weekdays Spatial Interpolation of PM2.5 at 00*

Figure 17: *Weekends Spatial Interpolation of PM2.5 at 00:00*

It is found from the Air Quality Data that Weekdays have worse air quality than the weekends.

Gaur, 2015 concluded analysis on public holidays occurring per year. The pollution levels of parameters reduces by 3-4% for O3 and PM; 11-14 % for NO, CO and NO2on a holiday w.r.t. the pollution level of the same parameter during working days. This is due to lessened traffic during the public holidays. The concentrations near the data points are probably accurate, but it looks like there is a constant intermediate concentration over the vast areas that do not have monitors. It is unlikely that this is realistic. So, in order to get a better idea of spatial distributions in the Pune more monitors would need to be placed in the south eastern part and south western part of the city. We observe higher the vehicular traffic hours the air quality is worse from the Spatial Interpolation of pollutants on this GIS platform.

5. Conclusion

Spatial modelling of air quality in this paper is mainly focused on integration of a wide range of data in the frame of the GIS spatial database. GIS can be utilised by City Planners for the Pollution mitigation and Control programs. GIS maps can also be useful for Residents at to make an assessment as according to the air quality index for that particular area especially for the residents with the respiratory disorders can select a safer place to reside. As according to the prevalence of higher pollutant levels we can determine the potential pollutant source and can regulate it after studying the GIS Spatial Interpolation Maps. It is generally advised for us to have more number of monitoring station for further accuracy of the output data

6. Scope of Future Prospects of GIS in Environmental Engineering

GIS can be used for complete comparisons for different meteorological conditions such as wind speed, rainfall, seasons. Research in the field of integrated usage of Geostatistical methods, remote sensing and spatial analysis can introduce valuable information to identify, visualize and explore the relationship between transportation, land-use and air quality.

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