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Dynamics of Groundwater Quality along the Buffer Gradient in Mysuru City Local Planning Area

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Abstract: ***The study includes spatiotemporal changes in the groundwater quality in MysuruCity Local Planning Area (LPA) using Geographic Information System(GIS).The secondary groundwater data of 9 stations for 22 years (from 1994 to 2016) was used to analyse the variations. Inverse distance weighted method as well as kriging method of the interpolationare used to prepare the distribution map of physico-chemical parameters of groundwater while overlay method is used to assess temporal changes and prepare groundwater quality zones of Mysuru city LPA. The results of the study show that the quality of groundwater varies both spatially and temporally in Mysuru city. The groundwater quality showed a decreasing trend in all the directional zones due to rapid urban sprawl.***

Keywords: Physico-chemical parameters, groundwater, Geographic Information System (GIS), kriging, interpolation, Water Quality Index (WQI), transect profile

1. Introduction

Groundwater is a water resource which occurs underneath the Earth's surface where it possesses all or a part of the void spaces in geologic strata. Groundwater quality relies upon the quality of recharged water, atmospheric precipitation, inland surface water and sub-surface geochemical forms. Temporal changes in the source and constitution of the recharged water, hydrologic and human factors may cause periodic changes in groundwater quality yet in addition harms human wellbeing, economic development and social flourishing. The increase in urbanization results in reduction in infiltration, which affects the groundwater recharge and storage thereby causing depletion in the groundwater table (Sneha et.al., 2016). Access to clean freshwater will be one of the biggest global resource problem of the coming decades. Appropriate access to drinking water is considered as one of the essential aspects of water management, strategic populace management and future planning for urban advancement in macro level. This is while access to healthy water for human use is one of the present serious concerns. In fact, water is an incredible chemical media with high ability in exchanging a wide range of substances. Accordingly, it tends to be easily contaminated. Water resources are dynamically affected and contaminated by various factors such as, human, rural, and industrial activities and thus, presently we can watch the water quality in the undesirable condition brought about by those activities. Hence, to secure them, it is essential to explicitly determine the effect of land use changes on water quality patterns over time which in turn requires utilizing appropriate tools and techniques for analysing and foreseeing these effects.

2. Study Area

Mysuru is the second largest city in the state of Karnataka.It is located between 12°18'N and12°30'N latitudes and 76°39'E and 76°42'E longitudes and has an average altitudeof 770 meters (2,526 ft). Mysuru has a warm and cool climate throughout the year. It is salubrious, too. The climate of Mysuru is moderate. The weather in winter is cool and summers are bearable. The minimum temperature in winter is around 15^{o} Celsius and in summer the maximum temperature is around 35^{o} Celsius. Mysuru gets most of its rains during the monsoon between June and September. The annual average rainfall of Mysuru is around 860 mm. The summer season is from March to June, followed by the monsoon season from July to November and the winter season is from December to February. Mysuru lies however in the tropics, with summer temperatures ranging from 21^{o} to 35^{o} Celsius, while winter sees the temperatures dropping down from 30^{o} to 12^{o} C. (Mahalingam et.al.,2015)

3. Materials and Methodology

The Mysuru LPA boundary map was obtained from the Mysuru Urban Development Authority- MUDA. The ground water levels (in meters) and ground water quality (mg/L) data from the year 1994 to 2016 were collected from the Groundwater Directoriate, Saraswatipuram, Mysuru (Appendix). Landsat was the source for satellite images of the study area and they were downloaded from the website - www.earthexplorer.usgs.gov

Software used:
1) MS Excel – Data arrangements
2) ArcGIS -Interpolation, mapping, transect profiles, zonal statistics

Three kinds of analysis were carried out, that is:
a) Calculation of Water Quality Index (WQI)
b) Spatial variation of WQI
c) Temporal variation of WQI

The suitability of groundwater of the study area was examined based on percent compliance of the measured data with respect to Indian Standard for drinking water (**Bureau of Indian Standards – BIS, 1994).**

ArcGIS 10.5 has been used for spatial interpolation.MS excel has been used to encode, analyze and create graphical representation of the numerical data.**Fig 1**represents the data flow and different analysis and operations carried out.

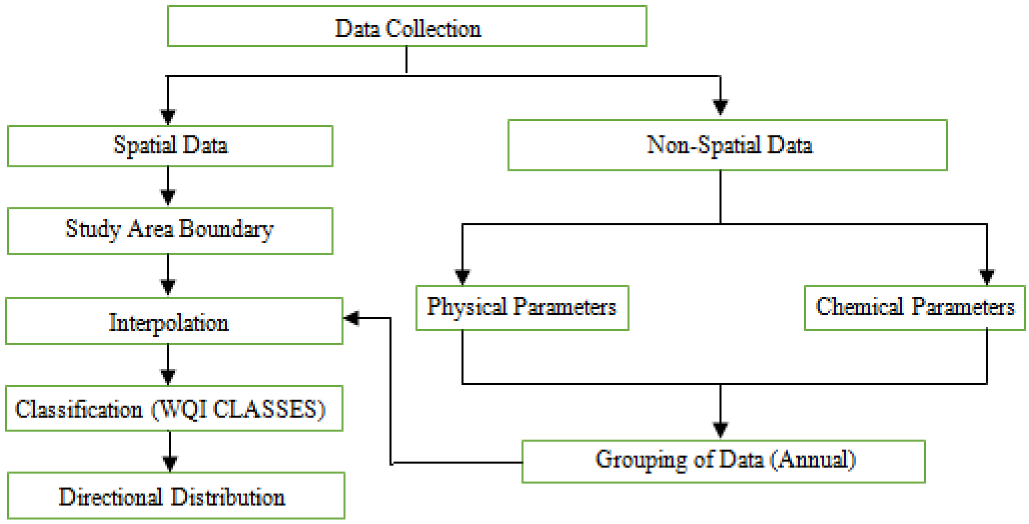


Figure 1: Flow chart showing the data flow and different analysis and operations carried out in the present study

4. Results and Discussion

a) Groundwater Chemical Standards: Changes within the water quality are more intense in shallow groundwater level aquifers than in deeper ones, the rationale being that shallow aquifers are easily stricken by human activities and differences due to the season. The various predominant parameters considered in the study area are – **Calcium (Ca), Magnesium (Mg), Chloride (Cl), Nitrate (NO_3),Total Dissolved Solids (TDS), Total Hardness (TH), pH, Bicarbonate (HCO_3), Sulphate (SO_4), Iron (Fe).** These values were obtained for all the stations in the study area from the year 1994 to 2016.

The suitability of groundwater of the study area was examined based on percent compliance of the measured data with respect to Indian Standard for drinking water (**Bureau of Indian Standards – BIS, 1994).Table 1** shows standards for the required parameters is given below:

Table 1: BIS (1991) Standards for Drinking Water

Chemical Parameters[a]	Standards[b]
Calcium	75 – 200
Magnesium	30 – 100
Chloride	250 – 1000
Nitrate	45 – 100
Total Dissolved Solids	500 – 2000
Total Hardness	300 – 600
pH	6.5 – 8.5
Bicarbonate	244 – 732
Sulphate	200 – 400
Iron	0.3 – 1.0

[a] Chemical parameters in mg/L
[b] Lower value indicates desirable limit, and higher value indicates permissible limit in the absence of alternate source (Bureau of Indian Standards, 1991)

b) Groundwater Quality in Mysuru City LPA:
The WQI was computed through three steps n this study. First, each of the ten parameters (pH, TDS, total hardness, HCO_3, Cl, SO_4, NO_3, Ca, Mg and Fe) was assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes.The maximum weight of 5 was assigned to nitrate because of its major importance in water quality assessment.Other parameters like pH,TDS, total hardness, HCO_3, Cl, SO_4, Ca, Mg and Fe were appointed weights between 1 and 5 based on their relative significance within the water quality analysis. (Ramakrishnaiah et.al., 2008)

Second, the relative weight (Wi) of the chemical parameter was computed using the following equation:

$$Wi = \frac{wi}{\sum_{i=1}^{n} wi}$$

Where,
Wi is the relative weight
wi is the weight of each parameter, and
n is the number of parameters.
The calculated relative weights for the respective chemical parameters are shown below in the **Table 2.**

Table 2: Relative weight of chemical parameters

Chemical Parameters	Weight (wi)	Relative weight (Wi)
Calcium	2	0.061
Magnesium	2	0.061
Chloride	3	0.091
Nitrate	5	0.151
Total Dissolved Solids	4	0.121
Total Hardness	2	0.061
pH	4	0.121
Bicarbonate	3	0.091
Sulphate	4	0.121
Iron	4	0.121
	$\sum wi = 33$	$\sum Wi = 1.0$

In the third step, a quality rating scale (qi) for each parameter is assigned by dividing its concentration in eachwater sample by its respective standard according to guidelines(BIS, 1991), and the result is multiplied by 100:

$$qi = \left(\frac{Ci}{Si}\right) * 100$$

Where,
qi is the quality rating,
Ci is the concentration of each chemical parameter in each watersample in mg/L,
Si is the Indian drinking water standard for each chemical parameter in mg/L.
For computing WQI, the sub index (SI) is first determined for each chemical parameter, as given below:

$$SIi = Wi * qi$$

$$WQI = \sum SIi \ \ of\ n\ parameters$$

Where,
SIi is the sub index of ith parameter;
Wi is relative weight of ith parameter;
qi is the rating based on concentration of ith parameter, and
n is the number of chemical parameters.
The computed Water Quality Index values are classified into 5 categories:

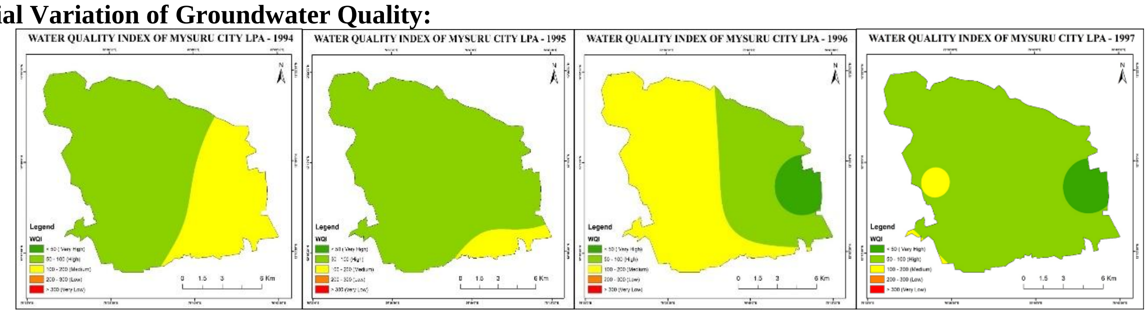
< 50	Very high quality
50 – 100	High quality
100 – 200	Medium quality
200 – 300	Low quality
> 300	Very low quality

The WQI values obtained for different stations are represented in the following **Table 3**,

Table 3: Calculated WQI values of different stations from 1994 to 2016

STATION	Alanahalli	Keelanapura	Jayapura	Kadakola	Bhogadi	Elwala	Devalapura
x_long	76.703	76.818	76.556	76.667	76.599	76.543	76.701
y_lat	12.298	12.253	12.204	12.192	12.304	12.358	12.223
WQI_1994	105.1984	-	-	-	75.0895	-	116.61409
WQI_1995	94.76623	-	94.828175	-	56.53635	-	130.65084
WQI_1996	39.29098	-	124.48472	-	123.1996	-	161.28694
WQI_1997	0	-	0	-	0	-	0
WQI_1998	48.77958	-	100.18451	-	77.33243	-	81.183729
WQI_1999	63.53234	-	111.69342	-	99.48627	-	119.55494
WQI_2000	55.70986	-	157.64664	145.6778	178.1992	140.12587	139.20676
WQI_2001	70.70132	-	188.65975	234.8488	81.13736	391.46892	311.89689
WQI_2002	111.0063	123.5811	174.15851	76.70215	164.1244	187.72808	94.398768
WQI_2003	86.49326	57.62231	77.369974	122.0207	129.9302	166.8272	109.9976
WQI_2004	86.65449	146.254	197.56081	257.2722	270.613	186.90601	133.38941
WQI_2005	116.2613	215.4045	266.11094	332.066	461.4829	268.80604	85.046331
WQI_2006	104.0064	134.3749	118.63153	210.264	161.5848	123.28532	171.1354
WQI_2007	103.9764	110.6368	207.75065	211.3658	171.4382	92.655471	222.83405
WQI_2008	91.10975	103.7373	251.13303	216.4805	294.9491	254.33913	154.80709
WQI_2009	45.84485	150.0393	260.46607	147.6431	134.6153	185.68756	170.32329
WQI_2010	78.4293	159.8274	272.69834	355.7912	208.06	186.64214	208.33435
WQI_2011	105.8667	63.20193	204.9408	107.191	167.9852	150.73216	143.62726
WQI_2012	36.02985	57.01431	73.873431	86.04547	89.7504	113.95054	122.35867
WQI_2013	86.24915	124.1246	179.75765	192.1045	106.049	123.05256	112.16993
WQI_2014	75.66877	117.7021	136.78657	201.7239	164.8431	156.68514	113.72296
WQI_2015	0	27.48267	61.621333	61.17115	0	12.605333	52.938667
WQI_2016	122.6257	237.5505	346.67533	88.34862	82.97272	239.20872	108.32746

c) Spatial Variation of Groundwater Quality:



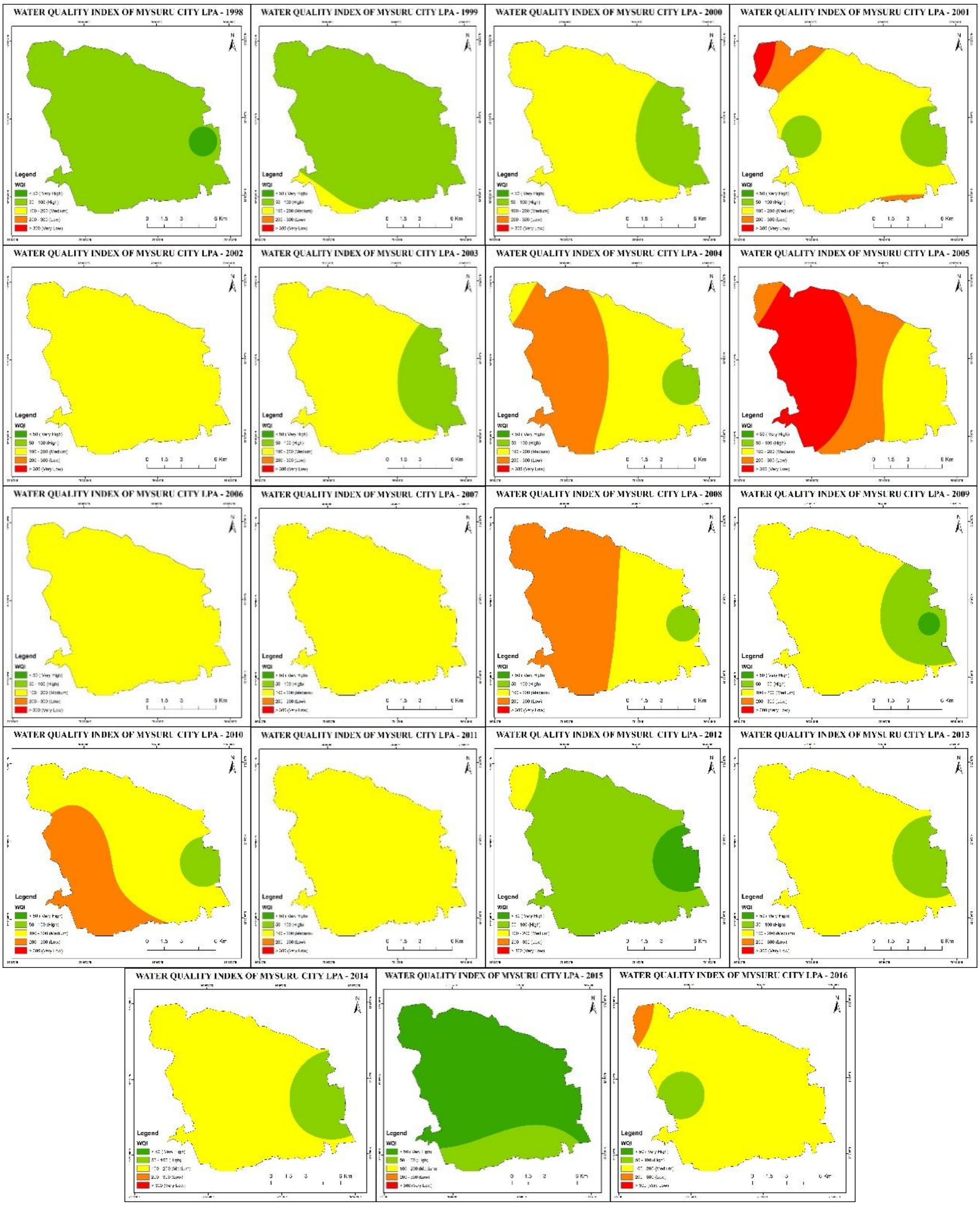


Fig Set 1: The Above Maps Represent Groundwater Quality Spatial Distribution in Mysuru City Local Planning Area (LPA) from 1994-2016.

Based on the Groundwater Quality Index of Mysore city LPA from the annual assessment year 1994 to 2016 shown in the **Fig Set**, it is evident that the groundwater quality is highly fluctuating annually due to various factors mainly climate change, urban growth, agricultural and domestic activities, run-off etc (Subramani et.al.,2012). During the year 2005, the quality was very low since the rainfall in 2005 and 2006 was least according to the meteorological data. Lower the rainfall directly affects the composition of the groundwater.

d) Temporal Variation of Groundwater Quality:

As per the directional temporal variations of WQI during the year 1994-2016 shown in the below figures, the groundwater quality was very high in the year 2015 in all the directions that is , north, north-east ,east, south-east, south, south-west, west and north-west due to replenishment of groundwater aquifer but low quality was observed in the year 2005, which is explained in the previous paragraph. Whereas the variations in mean WQI pattern was found to be irregular during the rest.

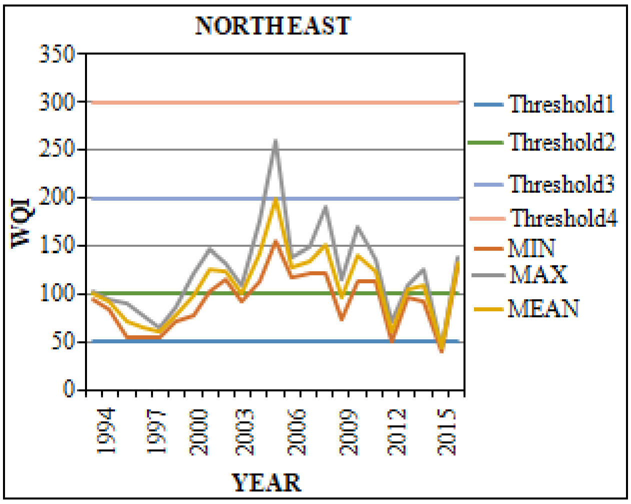


Figure 2: Temporal Variation of WQI towards North-East

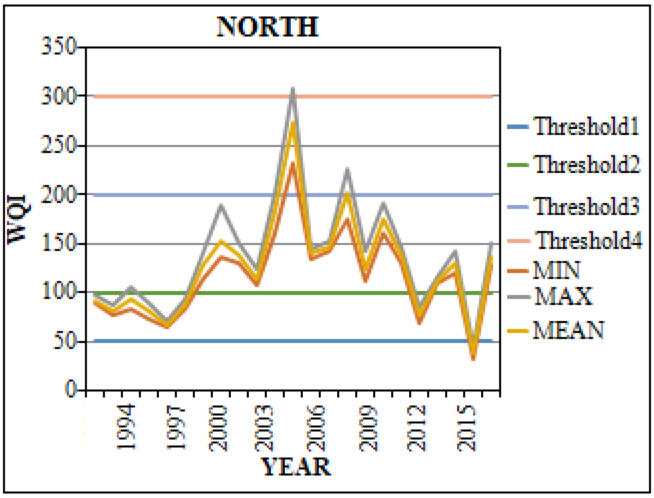


Figure 3: Temporal Variation of WQI towards North

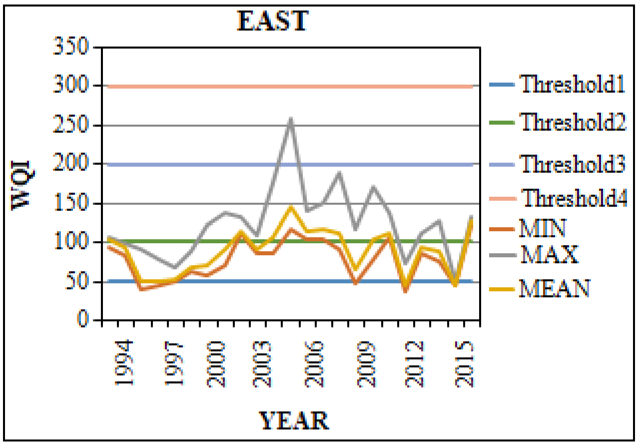


Figure 4: Temporal Variation of WQI towards East

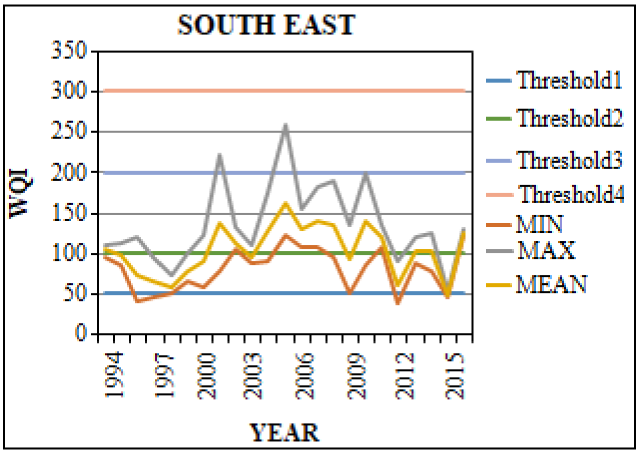


Figure 5: Temporal Variation of WQI towards South-East

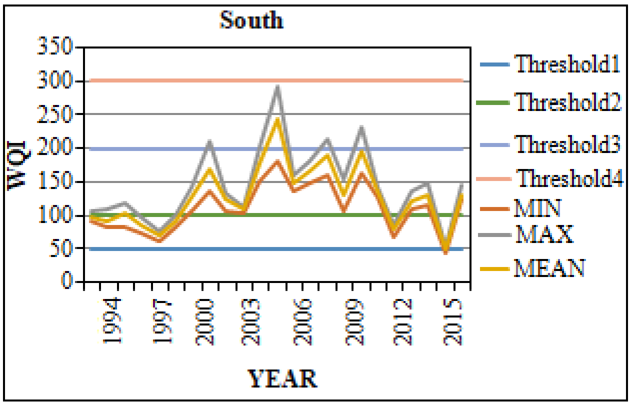


Figure 6: Temporal Variation of WQI towards North

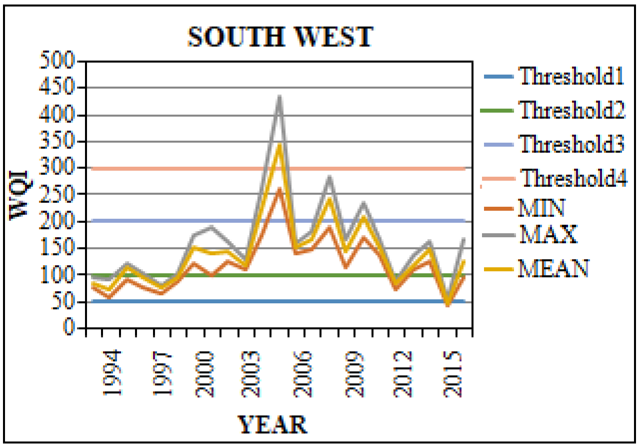


Figure 7: Temporal Variation of WQI towards South-West

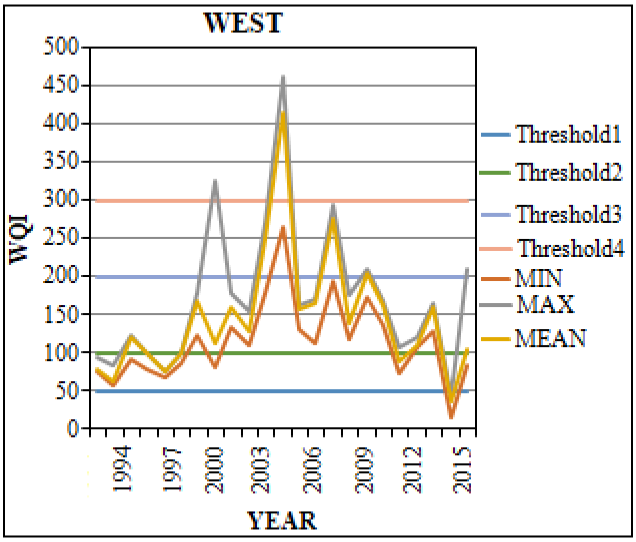


Figure 8: Temporal Variation of WQI towards North

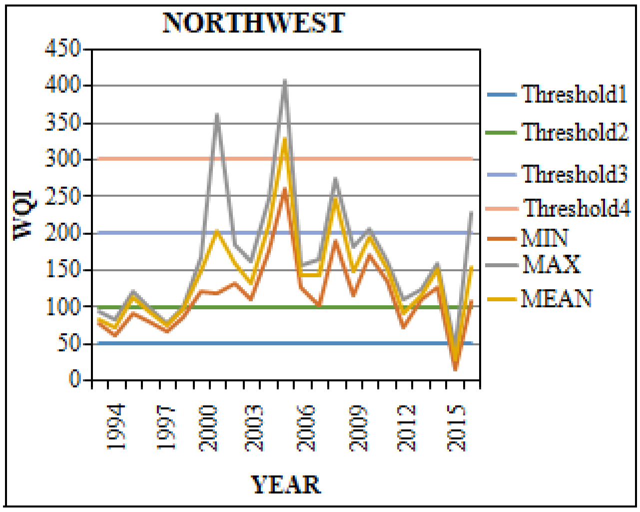


Figure 9: Temporal Variation of WQI towards North-West

5. Conclusions

As per the analysis there are variations in the quality of groundwater in Mysuru City LPA from the year 1994 to 2016. Urban and rural areas are significant sources of multipoint and heterogeneouspollution of groundwater. Improper handling, treatment and management ofhousehold wastes and wastewater, industrial effluents, uncontrolled wastedisposal sites, rain and melt water arethe main sources of multipoint pollution of municipal groundwater.Polluted runoff water from road surfaces (oil hydrocarbons, various salts), soiland groundwater acidification by transport emissions and particularly spills due toroad accidents, can have an immediate effect on groundwater quality in areaswhere roads are crossing vulnerable areas of aquifers.The intensification of agricultural production leads to Nitrate pollution of groundwater in rural areas in developing countries and it is mostly affected by point pollution sources. The quality of groundwater in public and domestic wells is affected by their poor construction, being located close to sources of pollution (septic tanks, latrines, animal slurry dumps) or by excrements surrounding some water supplies (Rizwan et.al.,). Even precipitation plays a key role as a natural regulating factor for the variations in groundwater quality.

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