Advances in Environmental Research, *Vol. 9, No. 3 (2020) 151-160*
DOI: https://doi.org/10.12989/aer.2020.9.3.151

Comparative assessment of surface and ground water quality using geoinformatics

Giridhar M.V.S.S.[a], Shyama Mohan[*] and D. Ajay Kumar[b]

Centre for Water Resources, Institute of Science and Technology, Jawaharlal Nehru Technological University Hyderabad (JNTUH), Kukatpally, Hyderabad, Telangana (500085), India

(Received April 1, 2020, Revised July 13, 2020, Accepted July 14, 2020)

Abstract. Water quality demonstrates physical, chemical and biological characteristics of water. The quality of surface and groundwater is currently an important concern with population growth and industrialization. Over exploitation of water resources due to demand is causing the deterioration of surface water and ground water. Periodic water quality testing must be carried out to protect our water resources. The present research analyses the spatial variation of surface water and groundwater in and around the lakes of Hyderabad. Twenty-Seven lakes and their neighboring bore water samples are obtained for water quality monitoring. Samples are evaluated for specific physico-chemical parameters such as pH, Total Dissolved Solids (TDS), Cl, SO_4, Na, K, Ca, Mg, and Total Hardness (TH). The spatial variation of water quality parameters for the 27 lakes and groundwater were analysed. Correlation and multiple regression analysis were carried out to determine comparative study of lake and ground water. The study found that most of the lakes were polluted and this had an impact on surrounding ground water.

Keywords: water quality; physico-chemical parameters; surface water; ground water; urbanization

1. Introduction

Water is significant element and most important source for our life. Earth surface contains 70% of water. In maintaining human health water plays a major role, because our body contains two third of water. Among all natural resources water is most important one. On earth water occurs in three physical states of matter i.e., liquid, solid and gas. Water presents mostly in liquid state, next comes gases and at last solids. From total earth's water 0.3% is usable by humans and 99.7% by oceans, soils and icecaps. From 0.3% usable water lake contains 87%, swamps contain 11% and 2% in rivers. To maintain a significant role in natural heritage, lake and river water plays a major role. Human beings depend on water for variety of purposes like agriculture use, industrial use and for domestic purposes. In the past few decades ground water and lakes have been polluted owing to disposal of waste without treatment and overexploitation. The problems of groundwater quality

∗Corresponding author, Ph.D., E-mail: shyama7789@gmail.com
[a]Professor, E-mail: mvssgiridhar@gmail.com
[b]Ph.D. Student, E-mail: ajaydheeti@gmail.com

http://www.techno-press.org/?journal=aer&subpage=7 ISSN: 2234-1722 (Print), 2234-1730 (Online)

are much more acute in the areas which are densely populated, thickly industrialized, excess use of pesticides and fertilizers in rural area and shallow ground water tablets (Magroliya and Monika 2018). The use of pesticides is increasing which contaminates the groundwater, and these should also be analyzed continuously. It is only by multidisciplinary approach that environmental problems can be assessed. Required tools and techniques should be developed for an effective environmental decision (Manuel *et al*. 2008). Research on water quality on groundwater and surface water has been widely recognized method.

Obi (2017) carried out a comparative analysis on surface and groundwater quality research in Nigeria. This study was very significant because disease vector was prevalent and thrive well in water. So, analysis has been performed for quality status of Otamiri River and water boreholes located in Owerri west, Nigeria. Bacteriological, physical and chemical analyses were carried out. The results showed the surface water was heavily polluted and unsafe for drinking. Spatial and statistical studies have been more effective in understanding the assessment of groundwater and lake water analysis. Application of correlation coefficients and regression analysis were implemented for better understanding of relationship between parameters (Rehman *et al*. 2018). Statistical analysis such as discriminant analysis (DA) and principal component analysis (PCA) are widely used in the qualitative and statistical analysis and evaluation of environmental data sets, especially where flux data are absent (Shamsuddin *et al*. 2015). The groundwater impact on surface water quality can be explored through spatial variability and statistical analysis (Liang Yu *et al*. 2018). Nnadi and Fulkerson (2002) have carried out the assessment of groundwater under direct influence of surface water. The study explored the risk of groundwater contamination due to the geology and land use. Through Microscopic Particulate Analysis, the risk of groundwater contamination to surface water is assessed. The results showed majority of high risk index of wells near the geologic formations. Andrew *et al*. (2014) performed a multivariate study of the hydrochemical properties of groundwater, in particular nitrate pollution. The study has shown that statistical analysis can be used to interpret the complex physicochemical characteristics of groundwater.

Brindha *et al*. (2014) identified the surface water and groundwater interactions in Chennai, India. Research was conducted in the densely populated city to establish the suitability of groundwater for drinking and irrigation purposes. High concentrations of EC, Na–Cl and Ca–Mg–Cl were observed in both groundwater and surface water. The results concluded that The groundwater quality of this region is affected by the contaminated surface water. Samuel *et al* (2019) has analysed the surface water and groundwater sources using the water quality index. Different sources of peri-urban town in the Southwest region of Nigeria were analysed. A Flame Atomic Absorption spectrophotometer was used to determine the concentrations of Ca, Mg, Cu, Cr, and Pb in the water samples. Most of the water resources were found to be contaminated with faecal coliform. The study recommended Microbial water quality parameters to be included in all Water Quality Index (WQI) analyses in order to give the true status of the quality of a water resource. Effective ground water and surface water management can be carried out by investigation the surface and groundwater assessment. Omoleomo *et al*. (2008) investigated the chemistry of surface and groundwater. A total of 137 surface and groundwater samples were collected between 2003 and 2007 during the rainy and dry seasons, from 15 sites and analysed for their physico-chemical constituents. Principal Component Analysis (PCA)/Factor Analysis (FA) and Hierarchic Cluster Analysis (HCA) were carried out for chemical data sets. The statistical method was used to analyse spatial similarity among the sampling sites. The results indicated five dominant processes for surface water that explained 77.11% of the variance in the data set whereas in groundwater, the factors account for 80.55% of the total variance. The study concluded the oil producing region have an effect on surface water and groundwater resource management.

The primary objective of the research was to identify the adverse effect of surface water on groundwater quality in the selected surface water bodies of Hyderabad city, Telangana. The majority of potable water is extracted from the groundwater through borewells. 27 lakes and surrounding borewells in Hyderabad have been identified and analyzed for specific physico-chemical parameters. The statistical and spatial variation analysis has provided an insight on groundwater and surface water characteristics.

2. Study area

Hyderabad, a city in Telangana state, is situated at an elevation of 536 meters and lies in the Deccan Plateau. Hyderabad city is situated between 17°22' N latitude and 78°27' E longitude. The semi-arid tropical climate conditions are observed in Hyderabad. The average annual rainfall of the city is 810 mm. 74% of annual precipitation is received by Southwest mountain and 14% by North Eastern mountain. During the summer season the temperatures touch 45ºC and with the onset of monsoons in June the temperature decreases.

Hyderabad is equipped with a multitude of natural and artificial lakes. Ground water occurs under phreatic conditions in weathered zone and under semi-confined to confined conditions in the fractured zones (CGWB). Ground water is presently being exploited through shallow and deep bore wells with depth of around 100-300 m. Urbanization and industrialization in Hyderabad has contributed to groundwater pollution. Direct release of effluents into streams and channels resulted in contamination of ground water. The cause being poor sewerage systems and inadequate treatment systems.

The lakes selected in Hyderabad city for the surface and groundwater quality study is shown in Table 1. Location of surface water bodies in Hyderabad is shown in Fig. 1.

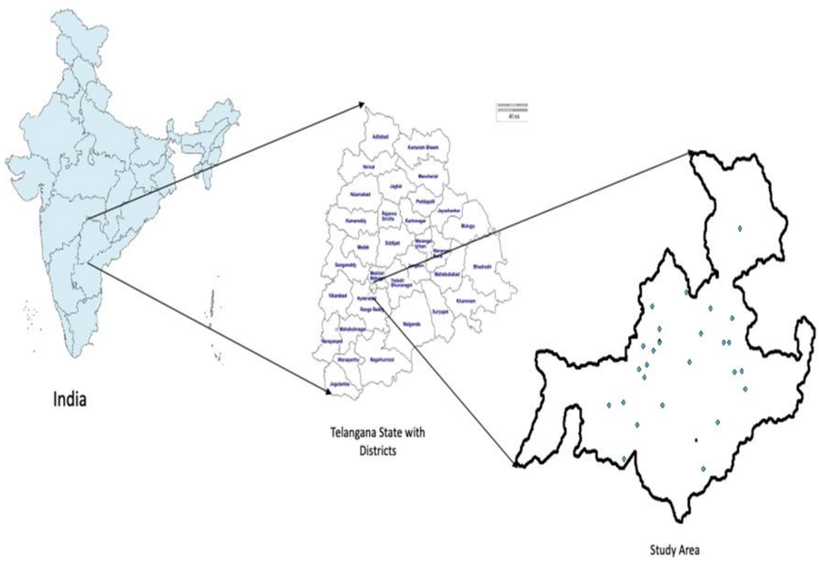


Fig. 1 Location map of study area

Table 1 The selected 30 lakes located in Hyderabad, Telangana

S. No	Lakes	Latitude	Longitude
1	Durgam cheruvu	17.4327	78.3889
2	Khajaguda lake	17.4268	78.3735
3	Timmidkunta lake	17.4573	78.3819
4	Ambir cheruvu	17.5081	78.3993
5	IDL lake	17.4783	78.4134
6	Sunnam cheruvu	17.4517	78.4018
7	Chinna maisamma cheruvu	17.4629	78.4134
8	Kamuni cheruvu	17.4610	78.4134
9	Jeedimetla cheruvu	17.5263	78.4650
10	Bon cheruvu	17.4731	78.4925
11	Alwal lake	17.5057	78.5113
12	Banda cheruvu	17.4615	78.5469
13	Safilguda lake	17.4617	78.5359
14	Kapra cheruvu	17.4928	78.5529
15	Osman sagar	17.3806	78.3163
16	Himayat sagar	17.3121	78.3456
17	Peeran cheruvu	17.3555	78.3702
18	Ibrahim cheruvu	17.3843	78.3440
19	Malaka cheruvu	17.4162	78.3844
20	Langarhouz cheruvu	17.3809	78.4191
21	Hussain sagar	17.436	78.471
22	Pedda cheruvu uppal	17.4230	78.5572
23	Nalla cheruvu	17.4018	78.5781
24	Rama cheruvu	17.4248	78.5705
25	Pedda Cheruvu	17.2996	78.4973
26	Saroornagar Lake	17.3588	78.5249
27	Shamirpet Lake	17.6076	78.5671

3. Methodology

The surface water samples were obtained from the 27 lakes and groundwater samples are collected from the borewells located nearby the lakes. The sample from the lakes are collected from 1-2 m depth without any external contamination. Sterile plastic bottles were used to collect the water. Precaution were taken and the bottles were immediately tested for 13 chemical parameters. The parameters are pH, total dissolved solids, electrical conductivity, alkalinity, sodium, calcium, potassium, magnesium, sulphates, fluorides, chlorides, nitrates and hardness. Appropriate procedures are used for finding out the parameters based on resources and study area.

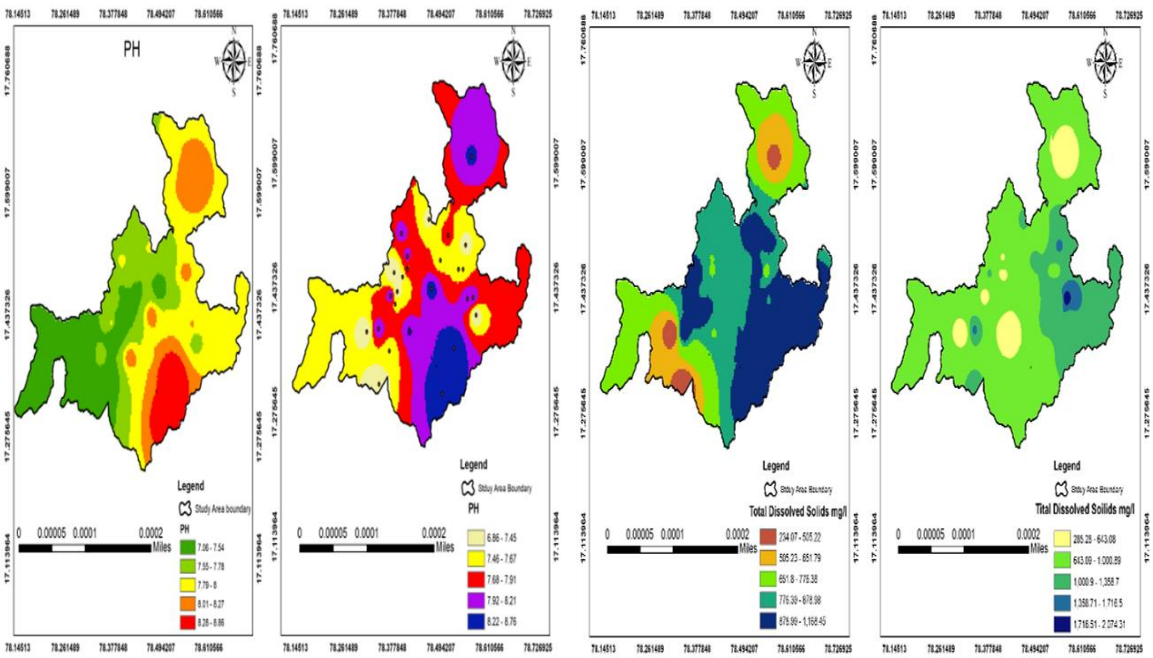
The spatial variability of resultant parameters for surface and ground water were conducted in

GIS. The sampling locations were integrated with data obtained from water quality testing and spatial maps were generated using inverse weighted distance. Each parameter was analysed for the spatial variation across the study area for both surface and groundwater. The impact of surface water on ground water quality is done through statistical analysis. Correlation coefficient and multiple regression analysis were carried out to obtain the influence of lakes on groundwater quality. The parameters of surface water were correlated with groundwater quality and correlation matrix was obtained to find the significant relation between the two. A linear regression equation is obtained for each parameter.

4. Results and discussions

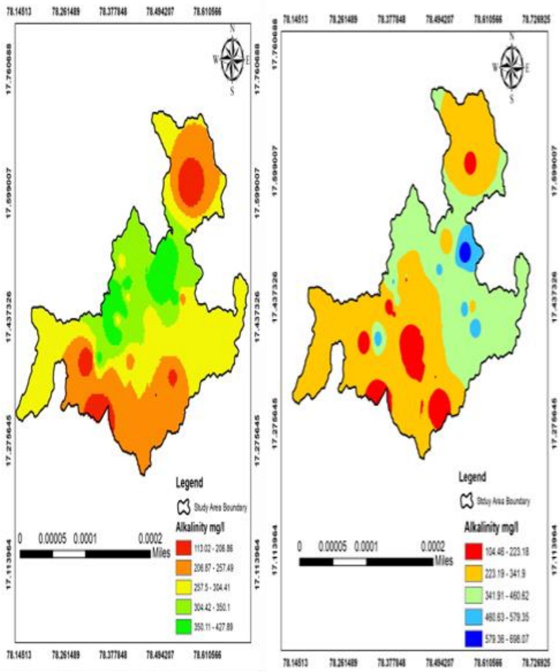
Specific parameters were analyzed spatially and statistically for lake and ground water. The various parameters determined were pH, TDS, electrical conductivity, chlorides, calcium, sodium, potassium, magnesium, alkalinity, nitrates, sulphates, fluorides, and total hardness shown in Figs. 2(a)-2(j).

A common spatial pattern has been observed for both surface and ground water. Spatial distribution shows the most groundwater parameter concentrations were higher than surface water. The pH, electric conductivity, total dissolved solids, sodium, alkalinity, calcium, magnesium, fluoride, sulphates and chlorides have been found to be higher in groundwater than in lakes.

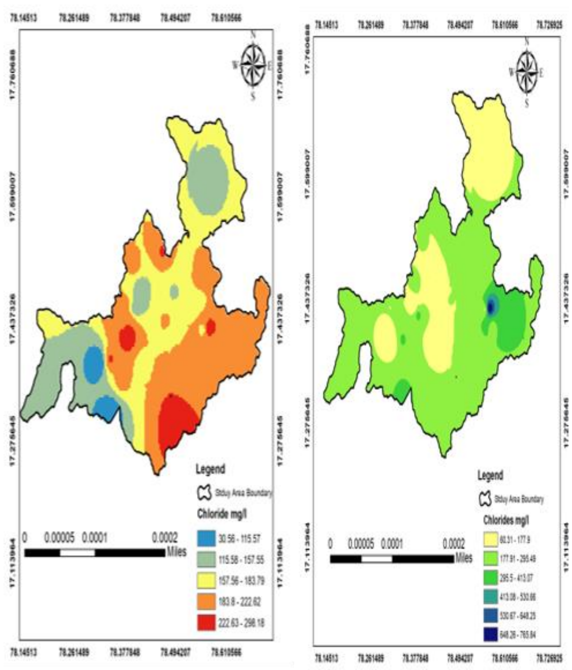


(a) pH of lake and ground water (b) TDS of lake and ground water

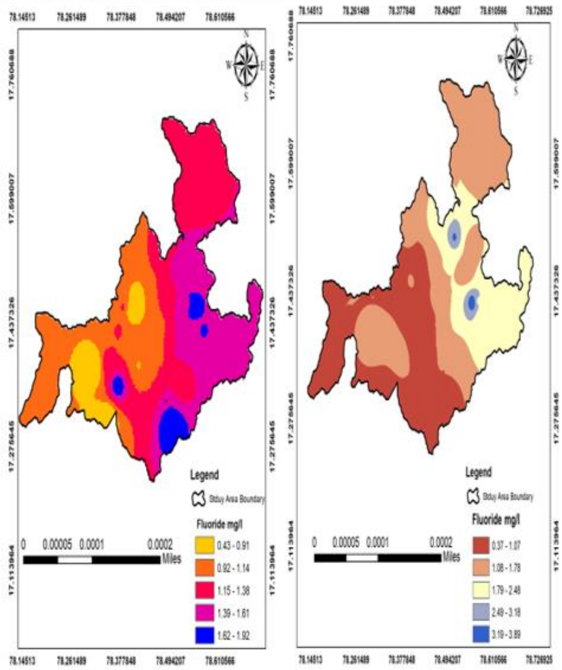
Fig. 2 Spatial representation of the physico-chemical parameters for lakes and groundwater respectively (a) PH, (b) TDS, (c) alkalinity, (d) chloride, (e) EC, (f) fluoride, (g) magnesium, (h) potassium, (i) sodium and (j) sulphates



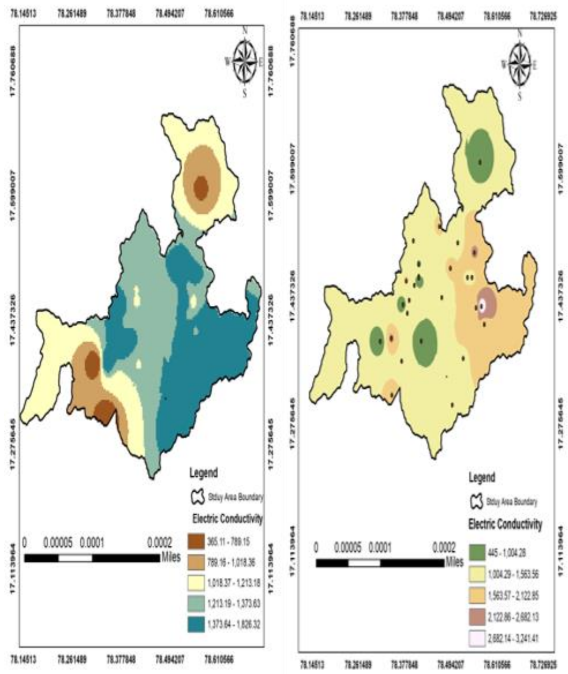
(c) Alkalinity of lake and ground water



(d) Chloride of lake and ground water

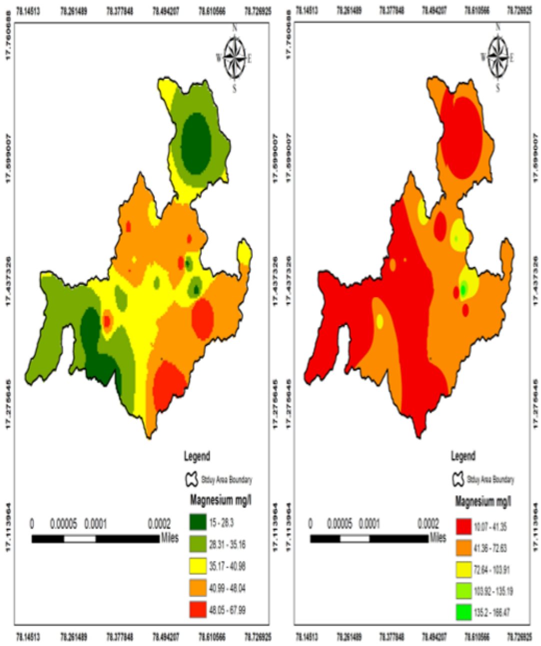


(e) Fluoride of lake and ground water

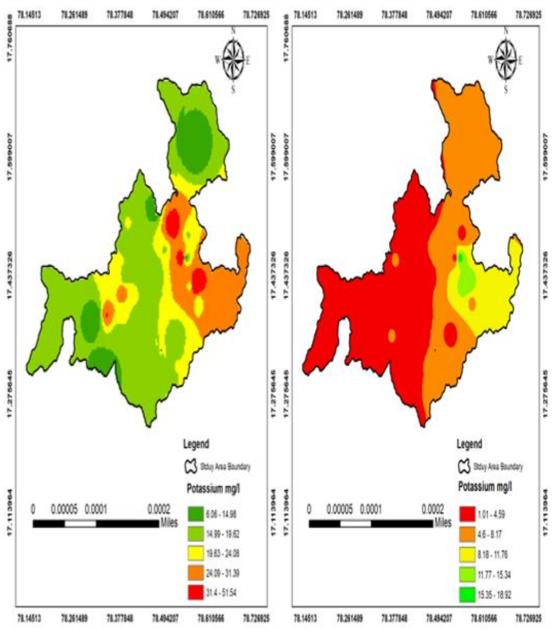


(f) EC of lake and ground water

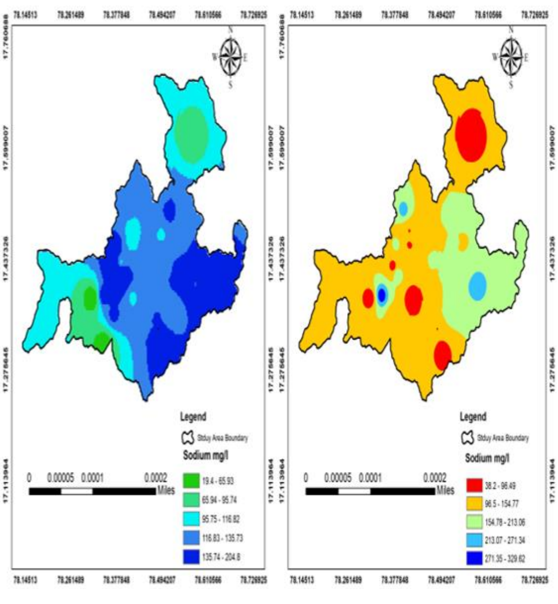
Fig. 2 Continued



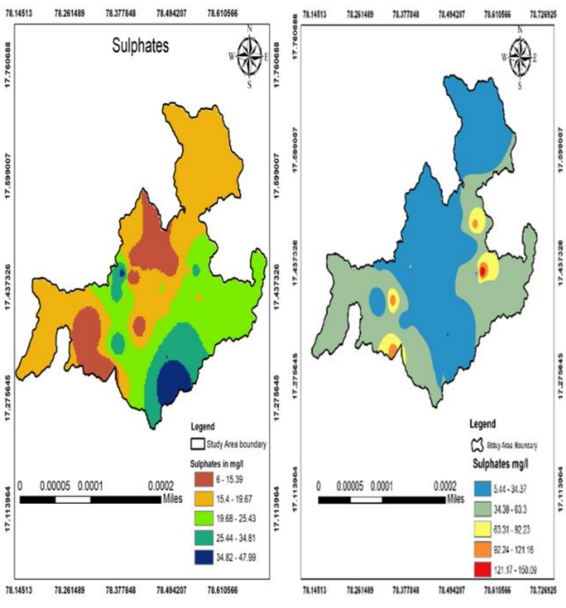
(g) Magnesium of lake and ground water



(h) Potassium of lake and ground water



(i) Sodium of lake and ground water



(j) Sulphates of lake and ground water

Fig. 2 Continued

Whereas potassium and nitrates were found to surpass the desirable limit of BIS standards in lakes. Groundwater near Ramancheruvu lake exhibited most of the high concentrations of chemical parameters. In some lakes and groundwaters, physical chemical parameters such as nitrates, phosphates, sulfates, EC, alkalinity, TDS and calcium, exceeded the allowable BIS requirements.

4.1 pH

pH of 8.77, slightly higher on alkaline side, was found in groundwater when compared to the BIS standard. Malaka Cheruvu lake recorded the lowest pH 7.05 within the permissible limit of standards.

4.2 Electric conductivity (EC) and total dissolved solids (TDS)

Electric conductivity and TDS was found to be higher in groundwater near Ramancheruvu lake, 3280 and 2099 mg/l respectively and is beyond the desirable limit of BIS standards. The lowest EC and TDS were found in Himayat Sagar lake which is 365 and 234 mg/l respectively.

4.3 Sodium

Groundwater near Ibrahim Cheruvu has high sodium concentration of 332 mg/l and lowest in groundwater of Kamunicheruvu of 9 mg/l. Sodium concentrations in lakes showed within the permissible limit of BIS standards.

4.4 Alkalinity

High alkalinity was found in groundwater situated near Ramancheruvu lake of 192 mg/l and lowest near Kamuni chruvu of 55 mg/l. Lake water had alkalinity below the permissible limit in the range of 24 to 48 mg/l.

4.5 Calcium, magnesium and sulphates

Groundwater near Ramancheruvu showed high amount of calcium, magnesium and sulphates of 192, 170, 153 mg/l respectively and Himayat sagar lake showed the lowest concentrations.

4.6 Fluoride

Fluorides were high in groundwater near Pedda cheruvu of 3.9 mg/l which is beyond the permissible limit of 1.5 mg/l and lowest was analysed in Osman Sagar lake of 0.43 mg/l.

4.7 Nitrates and potassium

Nitrates and Phosphates were found to be high in lakes. Ramancheruvu lake showed of 52 and 246 mg/l of nitrates and phosphates respectively. Lowest concentrations were seen in ground water.

4.8 Statistical analysis

Correlation and multiple regression analysis were used to explore the relation between surface water and groundwater. The trendline was similar for groundwater and surface water. The correlation coefficient indicated a significant relationship between surface water and ground water. In most lakes and groundwaters, R^2 was found mainly between 0.94 and 0.99 as shown in Table 2. Multiple regression analysis revealed that the significant value was less than 0.05, which suggested that there is an influence of surface water on ground water. The parameters of surface water were considered as independent variable and dependent variable was ground water. Regression showed for every unit rise in the surface water there is considerable change in the ground water. The relation showed a higher positive degree of freedom. No substantial connection between lakes and ground water has been found for nitrates and phosphates. The concentrations of nitrates and phosphates were higher in lakes than those in groundwater.

Table 2 Regression and correlation coefficient of surface water and groundwater at various location

S. No	Location	Regression coefficient	R^2 value	t value	*P* value
1	Osman sagar	1.44	0.99	32.69	< 0.05
2	Himayat sagar	4.68	0.94	12.64	< 0.05
3	Peeran cheruvu	1.29	0.98	23.97	< 0.05
4	Ibrahim cheruvu	1.32	0.97	20.8	< 0.05
5	Malaka cheruvu	0.81	0.98	24.8	< 0.05
6	Langarhouz cheruvu	0.37	0.98	26.1	< 0.05
7	Hussain sagar	0.83	0.97	20.3	< 0.05
8	Pedda cheruvu	1.22	0.97	20.2	< 0.05
9	Nalla cheruvu	1.35	0.98	25.1	< 0.05
10	Rama cheruvu	1.8	0.95	13.9	< 0.05
11	Saroornagar lake	1.04	0.97	20.15	< 0.05
12	Shamirpet lake	0.9	0.98	24.6	< 0.05
13	Amber cheruvu	1.12	0.96	17.2	< 0.05
14	IDL Kukatpally	0.80	1.00	79.18	< 0.05
15	Sunnam cheruvu	0.78	0.99	36.29	< 0.05
16	Chinna maisamma	1.37	0.99	29.45	< 0.05
17	Kamuni cheruvu	0.28	0.97	18.63	< 0.05
18	Jeedimetla cheruvu	1.20	0.99	42.40	< 0. 05
19	Bon cheruvu	1.25	0.99	141.30	< 0 05
20	Alwal lake	0.86	0.98	24.40	< 0. 05
21	Banda cheruvu	1.35	0.99	32.69	< 0.05
22	Safilguda lake	1.02	0.99	43.26	< 0.05
23	Kapra cheruvu	1.62	0.99	29.68	< 0.05
24	Durgam cheruvu	1.15	0.99	30.64	< 0.05
25	Kajaguda lake	0.38	1.00	56.41	< 0. 05
26	Thimmidikunta lake	1.11	1.00	188.24	< 0.05

5. Conclusions

A clear surface water impact was identified on groundwater. Multiple correlation indicated a significant value of less than 0.005, rejecting null hypothesis and concluding a significant relationship between lake and groundwater. The approach presented contributes to efficient water quality monitoring and is useful in regulation of water management in surface and ground water. The correlation between groundwater and surface water is mainly considered for urban area but other anthropogenic activities like leaking and overflowing of sewers also affect the quality of both lake and ground water.

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