



## Surface water quality analysis of four perennial Tanks from Haliyal Taluk, Uttara Kannada District-India

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### Abstract

Surface water Quality analysis was analysed in the four perennial tanks of Haliyal Taluk. According to the Digital Elevation model, water chemistry in the four selected water bodies were dependent on precipitation events. Schoeller plot revealed anomalous salinity composition in the Mothikeri tank, indicating urban pollution. Nutrient analysis revealed bimodal fluctuations. Principal Component analysis classified the sample data matrix into four clusters, characterised by distinct nutrient dynamics. Water Quality index revealed poor water quality in the summer samples of Neelvani and Mothikeri Tank.

**Keywords:** haliyal, digital elevation model, schoeller plot, principal component analysis

### 1. Introduction

Water is the most common substance on the surface of the earth, with the oceans covering over 70 percent of the planet. Any physical, chemical, or biological property that influences the suitability of water for natural ecological systems or the use by humans is a water quality variable, and the term water quality refers to the suitability of water for a particular purpose. There are literally hundreds of water quality variables, but for a particular purpose only a few variables usually are of interest. (Boyd, 2015) [8]. Long term water quality analysis leads to complex data which deserves advance statistical analysis for better interpretations.

The application of multivariate statistical techniques Principal component analysis (PCA) helps in the interpretation of complex data matrices to better understand the water quality and ecological status of the studied systems, allows the identification of possible factors/ sources that influence water systems and offers a valuable tool for reliable management of water resources as well as rapid solution to pollution problems (Vega *et al.*, 1998; Lee *et al.*, 2001; Adams *et al.*, 2001; Wunderlin *et al.*, 2001) [1, 16, 36, 41].

In view of population growth and economic development, India is facing serious problem of water pollution. Agriculture and Urbanization are the primary anthropogenic factors, responsible for the degradation of surface water quality through erosion and chemical runoff. These factors have caused alarming levels of nutrient fixation, posing challenge for water management practices (Hellowell, 1986) [13]. India, as agricultural country, is mainly dependent on Minor irrigation tanks for domestic and industrial purposes. Water quality in these tanks are subjected to anthropogenic pressures and there is a dire need for examination and evaluation of pollution status of such vulnerable systems.

In realisation of the immense scope, the authors in the present work have investigated, surface water quality of four perennial tanks of Haliyal Taluk, the reason for selecting Haliyal Taluk

as the study area is due to the fact that it represents spectrum of catchment characteristics which includes urban, rural, agricultural and forested types. The data generated from this study area provide valuable insights in conservation and water quality management of the perennial tanks.

### 2. Materials and Methods

#### Study Area

Haliyal Taluk located in the Uttara Kannada district of Karnataka, 2.4% of its area is under minor irrigation. Soil is of mixed lateritic type and its geology is dominated by Quartz Chlorite Schist. Among thirty six water bodies, four perennial tanks (Ambadga, Belwatgi, Neelvani and Mothikeri) was chosen for water quality analysis during the period April 2014 to March 2016.

#### Mapping of water bodies

For understanding geo-morphological characteristics and elevation gradients, Digital elevation model (DEM) map were used for the representation of terrain's surface. DEM map of Haliyal Taluk was generated from the QGIS software version 2.8.6.

#### Sampling Methods

Composite surface water samples were collected from four perennial tanks for the period April 2014 to March 2016. Pre-sterilized 1L polyethylene bottles were used for sample collection.

#### Physico-chemical Analysis

Water Quality Analysis involved, estimation of cations ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Fe}^{2+}$ ), anions ( $\text{HCO}_3^-$ ,  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{NO}_3^-$ ,  $\text{PO}_4^{3-}$ ), besides general parameters (pH, Electrical conductivity, Alkalinity, Hardness, Dissolved Oxygen,  $\text{SiO}_2$  and Temperature), following the methods of APHA (1995) [3]. Field analysis involved pH, electrical conductivity,

temperature and fixation of DO samples. Spectrophotometric analysis were carried out by ELICO SL-159, UV-Visible Spectrophotometer.

### Statistical Analysis

Schoeller plot was represented, to illustrate major ionic dominance in the surface waters of selected perennial tanks. AQUA-CHEM software, version 2014, was used to generate Schoeller plot of the four perennial tanks.

Water Quality index (WQI) developed by Sahu and Sikdar

(2008) [27], was applied to Physico-chemical data. To calculate WQI, 14 parameters namely pH, electrical conductivity, total dissolved solids, total hardness, alkalinity, calcium, magnesium, sodium, potassium, chloride, sulphate, nitrate, fluorides and iron have been considered.

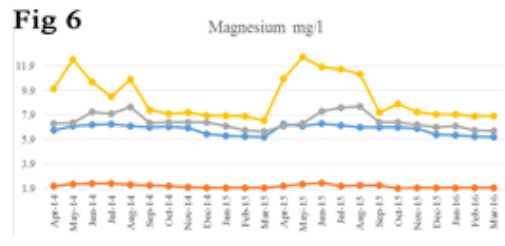
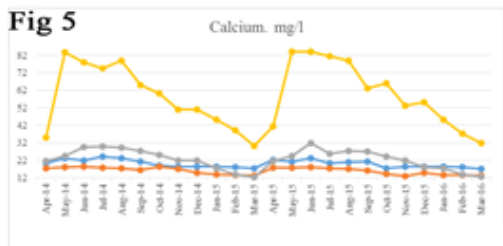
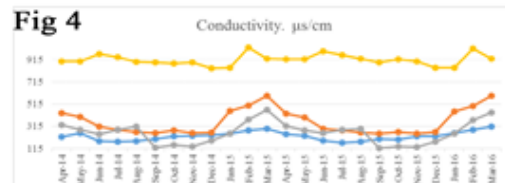
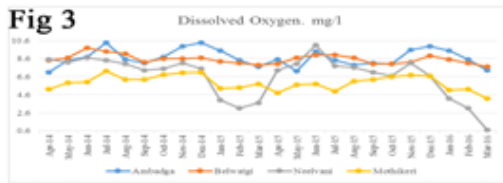
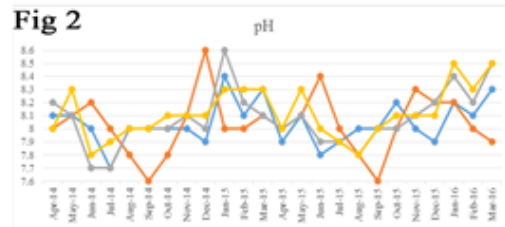
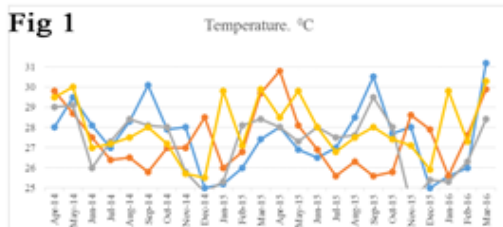
Principle Component Analysis (PCA) was applied in ordination of samples. Prior to PCA, the multivariate data was normalized from 1 to 40, following the methods of Leo and Leen (2013) [17]. XI-Stat software version 2014 was used to perform PCA.

### 3. Results and Discussion

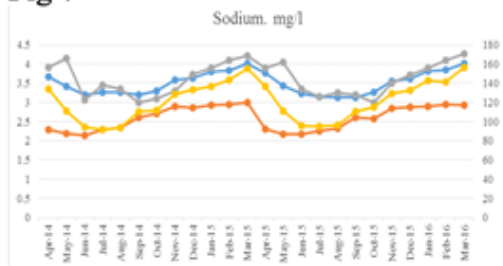
**Table 1:** Physico-chemical data of the four perennial tanks

Parameters	Units	WHO Limits	Basic Stat	Selected Perennial Tanks			
				Ambadga	Belwatgi	Neelavani	Mothikeri
pH		6.5-8.5	Range	7.8 – 8.3	7.6 – 8.4	7.8 – 8.5	7.9 – 8.4
			Mean	8.04	8.03	8.07	8.11
			Std.	0.14	0.20	0.19	0.18
			T-test (p)	<0.0001	<0.0001	<0.0001	<0.0001
EC	µS/cm	1250	Range	170 – 300	250 - 590	120 - 450	840 - 1020
			Mean	225.08	352.91	256.16	914
			Std.	39.46	115.81	100.9	51.4
			T-test (p)	<0.0001	<0.0001	<0.0001	<0.0001
Temp	°C	-	Range	25 – 30.3	25.4 – 30.3	25 – 28.8	25.7 – 30.0
			Mean	27.5	27.4	27.2	27.9
			Std.	2.3	2.3	1.8	2.0
			T-test (p)	0.0001	0.0002	0.0002	<0.0001
DO	mg/l	4	Range	7.5 – 10.2	7.8–9.4	2.2–9.4	5 – 6.9
			Mean	8.71	8.52	6.68	5.94
			Std.	0.73	0.23	5.12	0.48
			T-test (p)	<0.0001	<0.0001	0.0009	<0.0001
Ca <sup>2+</sup>	mg/l	75	Range	17.18-22.44	13.2-18.2	12.42-30.62	31-84
			Mean	19.9	15.91	22.4	58.83
			Std.	2.02	1.81	5.75	18.7
			T-test (p)	<0.0001	<0.0001	<0.0001	0.0061
Mg	mg/l	30	Range	6.09-7.02	1.96-2.34	6.56-8.56	7.6-12.5
			Mean	6.7	2.09	7.37	9.29
			Std.	0.39	0.13	0.62	1.70
			T-test (p)	<0.0001	<0.0001	<0.0001	<0.0001
Na	mg/l	-	Range	3.16-4.01	2.16-2.96	3.05-4.24	93.2-156.1
			Mean	3.5	2.58	3.61	120.98
			Std.	0.29	0.32	0.43	20.95
			T-test (p)	<0.0001	<0.0001	<0.0001	<0.0001
K	mg/l	-	Range	1.31-1.86	1.35-1.62	0.7-2.17	50-121
			Mean	1.57	1.49	1.48	78.3
			Std.	0.15	0.095	0.56	27.39
			T-test (p)	<0.0001	<0.0001	<0.0001	1.0000
HCO <sub>3</sub>	mg/l	-	Range	162.1-176.4	184.6-192.1	102.2-184	202.6-286.1
			Mean	169.22	188.4	148.1	247.04
			Std.	5.45	2.7	33.14	24.3
			T-test (p)	<0.0001	0.6162	0.0008	1.0000
TA	mg/l (as CaCO <sub>3</sub> )	200	Range	162.1-172.1	184.5-187.6	101.3-180.2	208.1-362
			Mean	167.28	186.09	144.26	290.44
			Std.	4.01	1.08	32.1	53.4
			T-test (p)	<0.0001	<0.0001	<0.0001	0.9999
TH	mg/l	300	Range	50.97-65.11	37.9-42.1	164.2-210.9	163.1-231
			Mean	59.1	40.01	184.01	192.82
			Std.	4.93	1.54	13.7	24.7
			T-test (p)	<0.0001	<0.0001	<0.0001	<0.0001
SO <sub>4</sub>	mg/l	150	Range	2.3-8.9	1.5-8.1	11.1-24.8	27.9-56.6
			Mean	6.34	5.54	19.86	42.12
			Std.	2.28	2.28	3.51	12.96
			T-test (p)	<0.0001	<0.0001	<0.0001	<0.0001

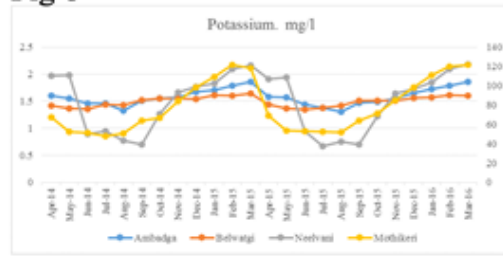
Cl	mg/l	250	Range	32.17-34.14	26.4-28.9	38.8-40.62	98.12-184.5
			Mean	32.93	28.01	39.46	134.19
			Std.	0.65	0.83	0.57	32.3
			T-test (p)	<0.0001	<0.0001	<0.0001	<0.0001
NO <sub>3</sub>	mg/l	45	Range	0.88-1.42	0.81-0.99	0.70-1.01	0.5-3.1
			Mean	1.03	0.90	0.79	1.65
			Std.	0.65	0.071	0.09	0.74
			T-test (p)	<0.0001	<0.0001	<0.0001	<0.0001
PO <sub>4</sub>	mg/l	10	Range	0.08-0.15	0.07-0.12	0.006-0.015	1.8-5.4
			Mean	0.103	0.089	0.010	4.11
			Std.	0.02	0.013	0.002	1.21
			T-test (p)	<0.0001	<0.0001	<0.0001	<0.0001
Fe	mg/l	0.3	Range	0.38-1.2	0.35-0.94	0.21-3.9	0.28-0.4
			Mean	0.70	0.577	0.94	0.339
			Std.	0.29	0.22	1.03	0.03
			T-test (p)	1.0000	1.0000	0.9919	1.0000
SiO <sub>2</sub>	mg/l	-	Range	11.82-12.84	9.94-13.98	4.05-9.88	5.81-10.61
			Mean	12.15	11.33	7.67	8.10
			Std.	0.34	1.43	1.81	1.70
			T-test (p)	1.0000	0.9982	0.0009	0.0026
Cu	mg/l	0.05	Range	0.03-1.57	0-0.018	0.34-2.18	0.88-1.209
			Mean	0.013	0.010	0.181	1.11
			Std.	0.010	0.004	0.066	0.113
			T-test (p)	<0.0001	<0.0001	1.0000	1.0000
Zn	mg/l	5	Range	0-0.026	0.007-0.031	0-0.083	0.14-1.152
			Mean	0.006	0.002	0.044	0.096
			Std.	0.008	0.002	0.033	0.039
			T-test (p)	<0.0001	<0.0001	<0.0001	<0.0001



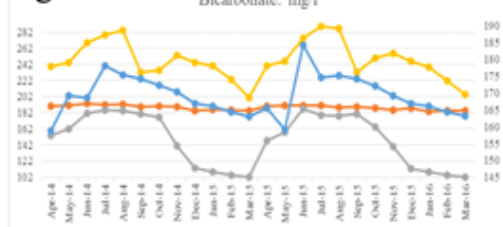
**Fig 7**



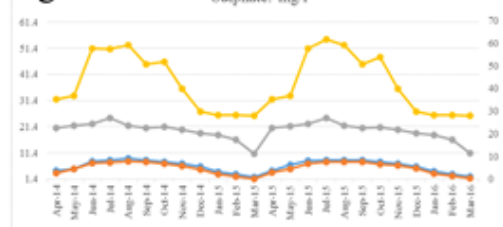
**Fig 8**



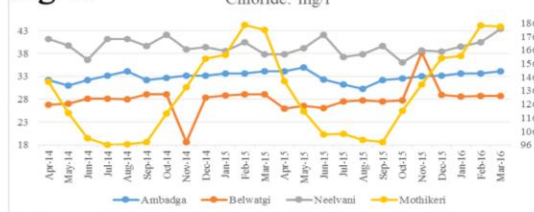
**Fig 9**



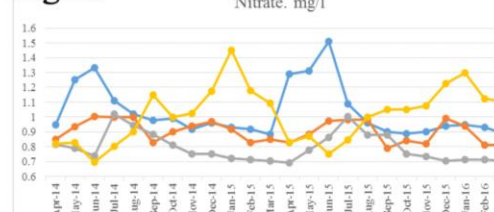
**Fig 10**



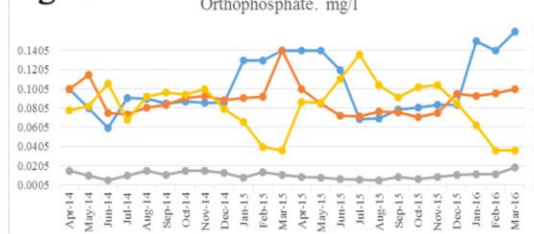
**Fig 11**



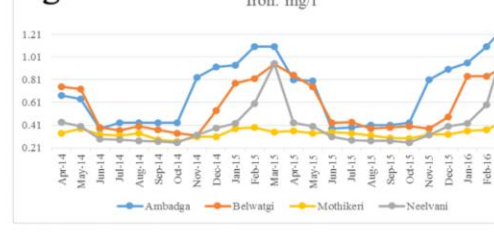
**Fig 12**



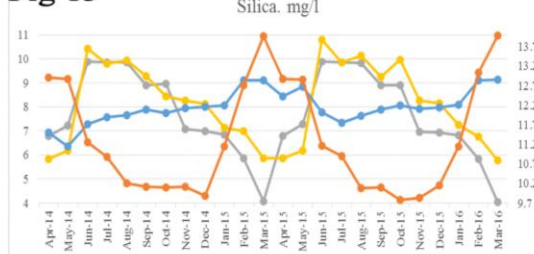
**Fig 13**



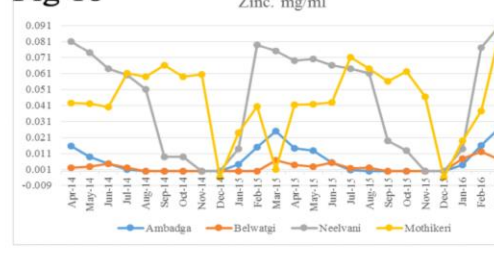
**Fig 14**



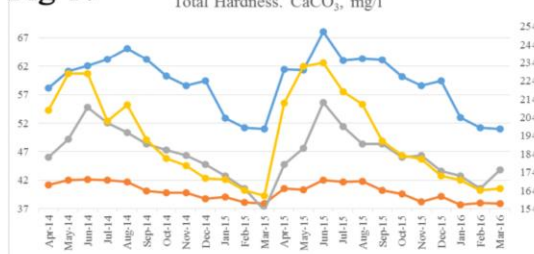
**Fig 15**



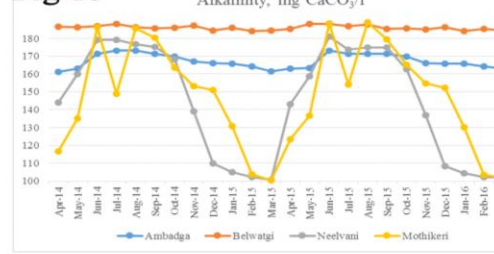
**Fig 16**



**Fig 17**



**Fig 18**



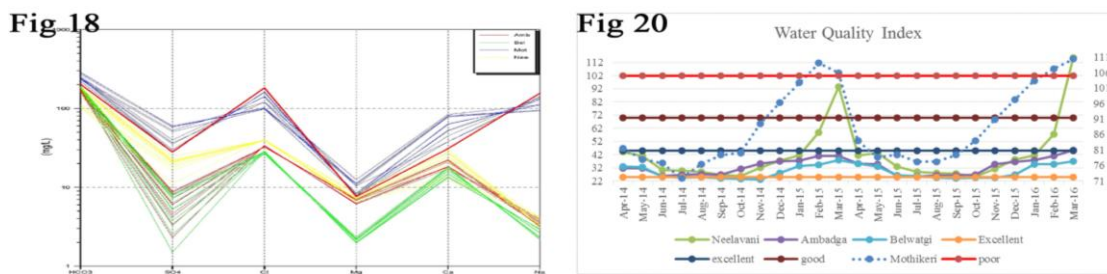


Fig 1-20: Physico-chemical Analysis

Mapping of Water Bodies

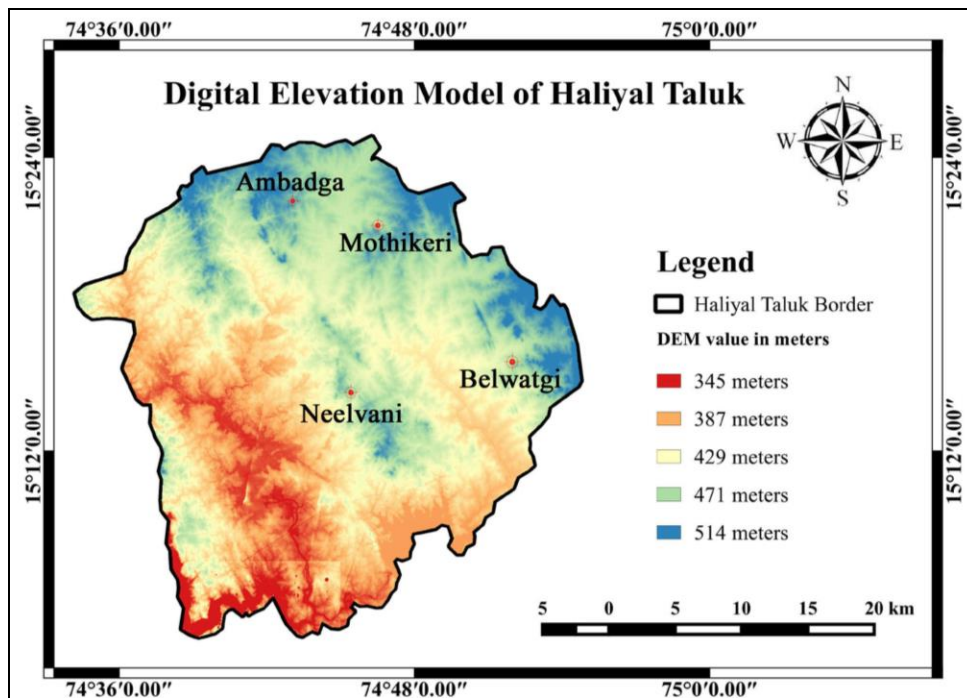


Fig 21: DEM map of Haliyal Taluk

Digital Elevation Model Map of Haliyal Taluk (Fig. 21), reveals that the four selected perennial tanks (Ambadga, Belwatgi, Neelvani and Mothikeri) are situated in the tertiary drainage basin (Saran *et al.* 2010) [30] of Kali river and are mainly rain dependent. According to Sugunan (1995) [33], rainfall play a crucial role in the nutrient fluctuation and water quality in these perennial water bodies

Rainfall

Rainfall patterns in the first year was comparatively high to the second year of study, revealing marginal increase of physico-chemical variables in the first year, which may be due to allochthonous origins (Waziri and Bomai, 2012) [37].

Salinity

Salinity compositions of the four perennial tanks was represented by Schoeller plot (Fig. 18), which revealed Bicarbonates and Calcium as the dominant anion and cation respectively, which is in accordance to Wetzel (2001) [38]. Ambadga, Belwatgi and Neelvani samples showed similar salinity composition and their ionic composition can be

represented as  $\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-}$  (Anionic) and  $\text{Ca}^{+2} > \text{Na} > \text{Mg}$  (cationic). Salinity in Mothikeri tank was anomalous, revealing dominance of sodium which is related to urban pollution and sewage loads (Ravikumar *et al.* 2013) [26], ionic composition represented as,  $\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-}$  and  $\text{Na} > \text{Ca}^{+2} > \text{Mg}$ .

Physico-chemical fluctuations (Table 1)

Physical variables

Common pattern of temperature fluctuations (Fig. 1) was observed in the four perennial tanks. During summers, values ranged from 27.2-28.5° C, in winters 25-25.3° C and during monsoons 26-27.8° C, which are in accordance to the results of Babu and Ramamirtham (1993) [4], and Mruthyunjaya *et al.* (2016) [21]. Seasonal fluctuations of electrical conductivity (EC) (Fig. 4), indicated higher values during summers which may be due to increased evaporation rate (Pathak and Shastree, 1993) [22]. And lower values during precipitation events may be attributed to dilution of surface waters (Bagde and Verma, 1985) [5].

Values of EC in Mothikeri tanks was significantly high which

may be due to urban pollution (Bilotta and Brazier, 2008) and absence of flushing activity (Scheffer, 2004) <sup>[31]</sup>. pH fluctuations (Fig. 2) was conservative and alkaline throughout the year and in accordance to the results of Saksena and Adoni, 1973 <sup>[28]</sup>, this alkaline nature may be due to dominance of bicarbonates (Wetzel, 1975) <sup>[38]</sup>. Marginal decline of pH during the monsoons was evident and comparatively increased pH during winter may be due to increased photosynthetic activity, which is in accordance to Scheffer (2004) <sup>[31]</sup>.

### Chemical variables

Temporal variation of total hardness (Fig. 17) was positively correlated to calcium concentrations (Huddar, 1995) <sup>[14]</sup>. Lowest values of alkalinity (Fig. 18) was observed in the summer which may be due increased temperature and consequent increase in photosynthetic activity (Kaul and Handoo, 1980) <sup>[15]</sup>.

Fluctuations of dissolved oxygen (Fig. 3) represented positive correlations with rainfall events, similar observations was made by Patil *et al.* (2012) <sup>[23]</sup> and Huddar (1995) <sup>[14]</sup>, maximum values during winter may be attributed to photosynthetic activity, which is in accordance to the results of Nanthakumar *et al.* (2015). Seasonal fluctuations of calcium (Fig. 5) revealed maximum values during rainfall, which may be due to allochthonous supply and lower values during summer may be attributed to decalcification process (Wetzel, 2001) <sup>[38]</sup>. Similar observations was made by Unni (2002) <sup>[34]</sup>. Significant higher values in Mothikeri tank may be due to pollution loads (Yogendra and Puttaiah (2008) <sup>[42]</sup>. Magnesium (Fig. 6) dynamics was conservative in the four perennial tanks. Marginal increase during precipitation events may be due allochthonous origins (Unni, 2002) <sup>[34]</sup>. Sodium concentrations (Fig. 7) was high during summer and low during monsoon, which may be attributed to increased evaporation and dilution rate respectively (Bheemappa *et al.* 2015) <sup>[7]</sup>. High values may also be contributed by phytoplankton decomposition and urban pollution (Huddar, 1995) <sup>[14]</sup> which is evident in the Mothikeri tank. Potassium fluctuations (Fig. 8) was similar to Sodium in all the perennial tanks which is in accordance to Huddar (1995) <sup>[14]</sup>.

Definite pattern of seasonal variation was observed in Bicarbonates (Fig. 9), minimum value during summer and maximum in winter, which may be attributed to increase rate of photosynthesis (Moss, 2010) <sup>[20]</sup>. Sulphate fluctuations (Fig. 10) revealed higher concentrations during rainfall and low during summer, which may be attributed to sulphate metabolism (Wetzel, 2001) <sup>[38]</sup>. Temporal variations in chloride (Fig. 11) indicate high values in summer which may be due to increased evaporation rate and decomposition of organic matter (Singh, 1987) <sup>[32]</sup>. Significant high values in

Mothikeri tank may be due to organic pollution (Singh, 1987) <sup>[32]</sup>.

### Major Nutrients

Nitrate fluctuations (Fig. 12) was seasonally significant in the four perennial tanks, higher values during rainfall due to allochthonous origins, moderate values during winter due to microbial decomposition of organic matter (Huddar, 1995) <sup>[14]</sup>. Due to urbanized catchment area, Mothikeri tank revealed highest concentrations of nitrates which is in accordance to Phillips *et al.* (2005) <sup>[24]</sup>.

Orthophosphate (Fig. 13) a major nutrient, revealed higher concentration during summer which may be due to sediment re-suspension (Scheffer, 2004) <sup>[31]</sup> and low concentrations during winters, which may be due to increased metabolic activity (Jain and Jain, 1988). Comparatively lower values in Ambadga and Belwatgi may be due to forest practices in the catchment area (Phillips *et al.*, 2005) <sup>[24]</sup>. Highest concentration was in Mothikeri tank, followed by Neelvani, which may be due to urban sewage loads (Huddar, 1995) <sup>[14]</sup> and sugarcane cultivation (Mattikali and Richards, 1996) <sup>[18]</sup> respectively.

### Minor Nutrients

Iron fluctuations (Fig. 14) was high during summer which may be due to autochthonous origins (Wetzel, 2001) <sup>[38]</sup> and silica concentrations (Fig. 15) was maximum during monsoon in Mothikeri and Neelvani tank which may be due to allochthonous origins (Urankar, 1994) <sup>[35]</sup>. In Ambadga and Belwatgi, maximum values was observed in summer due to diatom metabolism (Huddar, 1995) <sup>[14]</sup>.

Copper and Zinc (Fig. 16) concentrations was high during summer due to autochthonous origins which may be attributed to increased temperature (Forstner and Wittman, 1979) <sup>[12]</sup>, lower values during winter due to active metabolism (Wetzel, 2001) <sup>[38]</sup>. Similar trend was observed by Bhat *et al.* (2010) <sup>[6]</sup>.

### Ordination of Water Samples

Water quality information is a multidimensional environmental data. Treatment of such data is accomplished by multivariate statistics (Brown *et al.*, 1996) <sup>[9]</sup>. Principal component analysis (PCA) is one such multivariate statistics, which can explain correlation among large set of variables by reducing dimensionality without losing much variability in the complex water quality data (Meglen, 1992) <sup>[19]</sup>.

Since the water quality data have different magnitudes and variances, normalization by autoscaling is crucial, the present data was autoscaled following the methods of Leo and Leen (2013) <sup>[17]</sup>.

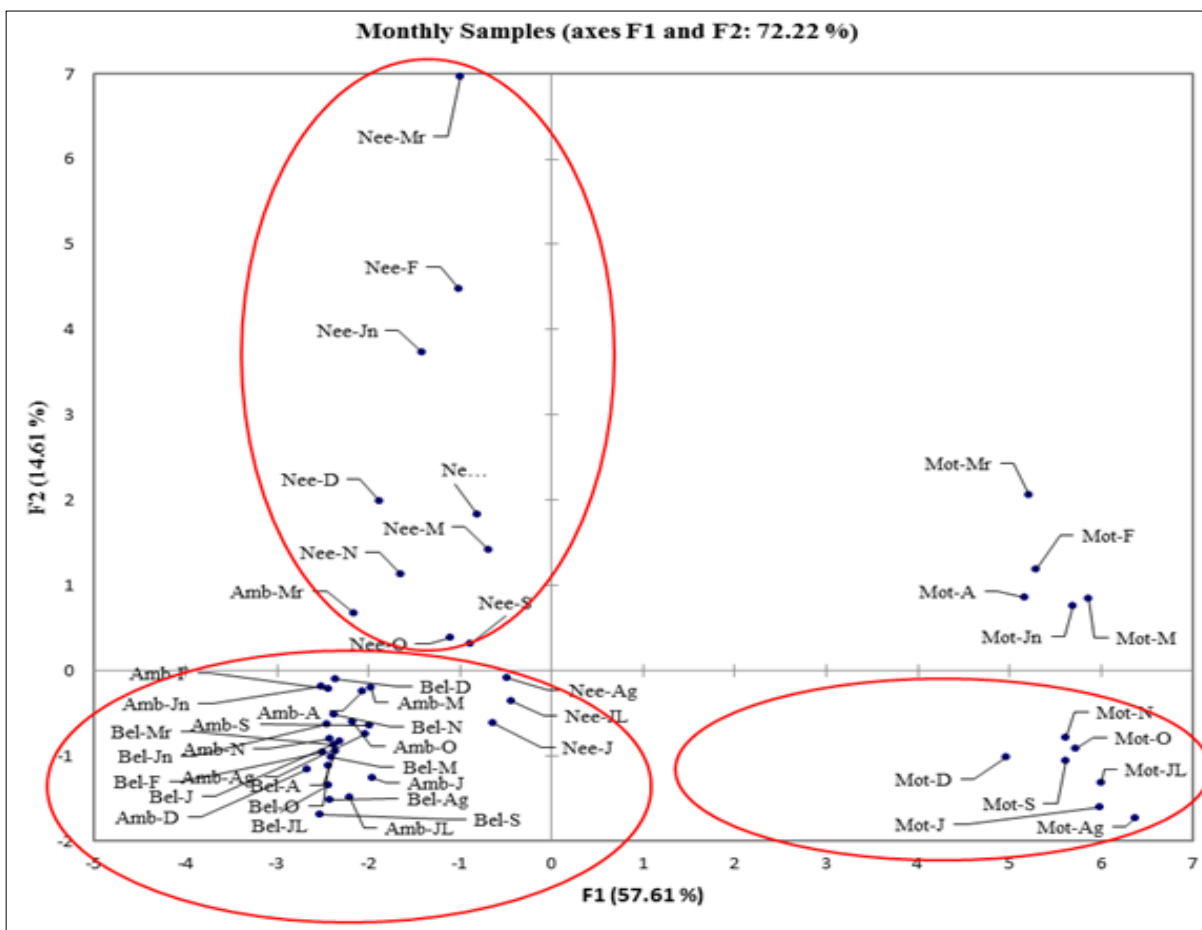


Fig 22: PCA Biplot

Nineteen factors (F1-F19) were resulted when the normalized data set was subjected for PCA. Among the factors, F1 and F2 indicating highest cumulative variability of 72.22% (Leo and Leen, 2013) [17] were chosen for generating PCA bi-plot.

F1 factor was characterised by positive correlation with Calcium, Sodium, Potassium, Bicarbonates, Sulphates, Orthophosphate, Copper, Zinc, Total Hardness and Total Alkalinity and negative correlation with dissolved oxygen, Iron and silica. F2 is characterised by negative correlation with former variables including pH, Iron, DO and silica. Hence the first selected factor is associated with salinity gradients (Darinka *et al.* 2002) [10] and the second factor is associated ion with pollution gradients (Sanchez *et al.* 2007) [29].

Based on the PCA biplot (Fig. 22), the monthly samples of the four perennial tanks were clustered into four groups. The 1<sup>st</sup> group consists of samples of Ambadga and Belwatgi and also the monsoon samples of Neelvani tank. This group is characterised by samples having low salinity and least organic pollution (Williams, 2001) [40].

The 2<sup>nd</sup> group consist of monsoon and winter samples of Mothikeri tank, this group is characterised by higher values Temperature, Chloride, Magnesium, Total hardness, Heavy metals (Na, K, Cu, Zn and Fe) and pH. And lower values of Dissolved Oxygen and Silica. Thus indicating high pollution and salinity (Radhakrishnan *et al.* 2007) [25].

The 3<sup>rd</sup> group consist of summer samples of Ambadga and all samples of Neelvani tank. This group is characterised by higher values of silica. The 4<sup>th</sup> group consist of post winter and summer samples of Mothikeri, characterised by higher values of nitrates, orthophosphates, sulphates, Calcium and Bicarbonates and low dissolved oxygen concentrations, indicating organic pollution (Amerasinghe *et al.* 2013) [2].

#### Water Quality Index (WQI)

The WQI provides a comprehensive picture of the quality of surface/ground water for most domestic uses. WQI is defined as a rating that reflects the composite influence of different water quality parameters (Sahu and Sikdar, 2008) [27]. WQI of the four perennial tanks were calculated following the methods of Ravikumar *et al.*, (2013) [26]. WQI (Fig. 20) revealed poor water quality in the summer samples of Neelvani and Mothikeri tanks, which is in accordance to the results of Farzadkia *et al.*, (2015) [11].

#### 4. Conclusion

The authors in the present work, revealed that in the four perennial tanks of Haliyal taluk, Mothikeri tank represents comparatively high nutrient composition which is due to urban pollution. It is concluded that application of Principal component analysis and Water Quality index may provide better insights in the water quality data.

## 5. References

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