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INVENTORYING AND MONITORING OF WETLANDS IN GREATER BANGALORE

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ABSTRACT

Wetlands are the most productive and important freshwater resource on Earth, but are very fragile ecosystems that are susceptible to even a little change in the abiotic and biotic factors surrounding them. The reduction in water availability, massive generation of waste water, water pollution as well as reduction in the number of lakes in Greater Bangalore has to be addressed properly. These may be attributed to the increased population growth, industrialization, urbanization and modern agricultural practices that lead to nutrient enrichment of lakes, profuse algae and macrophyte growth. The main objective of the study was to understand the present condition of lakes in Greater Bangalore with reference to the various physico-chemical characteristics. The physico-chemical analysis was carried out for water samples collected from 68 Lakes of Greater Bangalore during the study period from December, 2012 to September, 2014. The inlet points of lakes had higher physico-chemical parameters than the middle and outlet portions of lakes because of untreated sewage entry. The cluster analysis had grouped the lakes based on pollution as non - polluted, slightly polluted, moderately and severely polluted lakes.

Keywords: wetlands, lakes, biodiversity

INTRODUCTION

Wetlands and lakes provide are an essential part of human civilisation as they provide us with many goods and services such as drinking water, protein production, water purification, energy, fodder, biodiversity, flood storage, transport, recreation, research-education, sinks and climate stabilizers (Ramachandra et al., 2007).The quality of water, determined by its physico- chemical and biological constituents has to be checked regularly to determine its suitability for certain purposes such as domestic usage, public water supply, irrigation, industrial application etc (Sedaghat and Hoseini, 2012). The increased rate of population growth, industrialization, urbanization as well as modern agricultural practices had made the surface water polluted and non–potable. These factors had also decreased the catchment yield, water storage capacity, area of wetland, number of migratory birds, flora and fauna diversity and ground water table.

The dumping of solid wastes, encroachment of catchment area, removal of riparian vegetation and letting off untreated or partially treated sewage into lakes are the major threats posed by lakes in Bangalore. Greater Bangalore had 207 water bodies in 1973, which later had declined to 93 in 2010 (Ramachandra et al., 2013). The surviving or remaining lakes have become cesspools due to direct discharge of industrial effluents and unregulated dumping of solid wastes. About 54% of lakes were unauthorised encroached for illegal buildings. According to the field survey done during July- August 2007, nearly 66 % of lakes are sewage fed, 14 % surrounded by slums and 72% showed loss of catchment area. The lake catchments were used as dumping yards for either municipal solid waste or building debris. Illegal constructions of buildings and even, slum dwellers seem to occupy the adjoining areas of most of the lakes. The local residents use the lake water for washing clothes, vehicles and other household activities and even fishing. The multi-storied buildings near to some lake beds have totally intervene with the natural catchment flow leading to sharp decline and deteriorating quality of waterbodies (Ramachandra, 2009; 2012). Water pollution is caused by pollutants entering from point sources (like nutrients from sewage, waste water, industrial effluents) as well as non-point sources (i.e. nutrients from fertilizers, pesticides through agricultural and urban run-off). This increases the nutrient levels of lakes, which in turn, allow the profuse growth of algae and macrophyte that deteriorates the quality of water, depletes the dissolved oxygen content and promotes malodour formation and thus, adversely affects the diversity of algae, fish, plant and other aquatic insects/animals (Mahapatra et al., 2011). Temperature, pH and dissolved oxygen control the exchange of nutrients between the sediment and water. pH, dissolved oxygen, alkalinity and nutrients are very important for the phytoplankton production in lakes (Shivakumar et al., 2008). Therefore, continuous and periodic monitoring of lakes should be carried out to take up some preventive and remedial measures to prevent it from further deterioration or extinction. The main objective of the study was to understand the prevailing condition of lakes and also to assess the water quality status of the lakes in Greater Bangalore and grouping them based on cluster analysis.

MATERIALS AND METHODS

Study Area: Greater Bangalore with an area of 741 square kilometers lies between the latitudes: 12°39'00'' to 131°3'00''N and longitude: 77°22'00'' to 77°52'00''E. The mean annual total rainfall is recorded as 880mm with about 60 rainy days a year. The summer temperature ranges from 18 °C – 38 °C, while the winter temperature ranges from 12 °C – 25 °C. Thus, Bangalore enjoys a pleasant climate all year round (Ramachandra et al., 2012). Bangalore is located at an altitude of 920 meters above mean sea level. The undulating topography had delineated Bangalore into three watersheds: Hebbal, Koramangala, Challaghatta and Vrishabhavathi watersheds. The Lakes of Bangalore occupies about 4.8% of city's geographical area that includes both urban as well as rural areas. Bangalore has no natural wetlands but have many man-made wetlands that were built for various hydrological purposes.

An exploratory field survey was conducted to understand the prevailing condition of Lakes in Bangalore (Figure 1) and assessed the physico – chemical characteristics of lakes. Altogether, 82 lakes were surveyed during the study period (December, 2012 – September, 2014). In this study, mainly three sampling sites are selected for monitoring lakes:

- Inlet is the point where the principal feeder opens into the lake.
- Center is the point that gives the general water quality of the lake.
- Outlet is the place where the overflow occurs.

Some lakes (14 in number) like Puttanahalli, Sarakki, Horamavu Agara, Herohalli, Byrasandra, Beninganahalli, Avalahalli, Puttenahalli, Horamavu, Amrutahalli, Hosakere, Gottigere and Doddabidrakallu, were found to be fully macrophyte covered. Lake such as Lakkasandra had completely turned to a barren land due to the dumping of building debris. The rest of the lakes (about 64 lakes) were categorized into two groups as restored/ well maintained lake and non – restored/ poorly maintained lake (as shown in Figure 1, Table 1).

Water sample collection : Water samples were collected by the grab sampling method from selected sites of 68 Lakes of Greater Bangalore (Table 1) during December, 2012 to September, 2014 for analysing the physico-chemical parameters.

Analysis of physico-chemical parameters: The water temperature, pH, electrical conductivity, TDS and DO were determined on spot at the time of sampling. Other parameters like nitrate, orthophosphate, total alkalinity, calcium and magnesium hardness, total hardness, chlorides, chemical oxygen demand (COD), sodium and potassium were analysed in the laboratory by using standard methods prescribed by Trivedi and Goel (1986) and APHA (1998) and compared with standards (Table 2).

Table 1: Lakes Monitored (Dec, 2012 – Sept, 2014).

No.	Restored/Maintained Lake	No.	Non Restored/ Destroyed Lake
1	Agara	35	Ambalipura
2	Allalasandra	36	Arekere
3	Anchepalya	37	Bagmane
4	Challakere	38	Ballahalli
5	Chinnapanahalli	39	Battarahalli
6	Chokkenahalli	40	Begur
7	Dasarahalli	41	Bellandur
8	Deepanjali Nagar kere	42	Bommasandra
9	Doraikere inlet	43	Chikkabanavara
10	Jakkur	44	Chikka begur
11	Kaikondrahalli	45	Chikka Togur
12	Kogilu	46	Chunchugatta
13	Kothnur	47	Doddanakundi
14	KR Puram	48	Dubasipalya
15	Lalbagh	49	Hebbagodi
16	Mahadevapura	50	Hebbal
17	Malathahalli	51	Heelalige
18	Munnekolalu	52	Hullimavu
19	Mylasandra Lake2	53	Kalkere
20	Nagavara	54	Kammasandra
21	Rachenahalli	55	Kelagene kere
22	RK1	56	Kengeri
23	RK2	57	Kodagisingasandra

24	RK3	58	Konanamkunte
25	RK4	59	Kundalahalli
26	Sankey	60	Madivala
27	Silavanthakere	61	Maragondanahalli
28	Tirumanehalli 1	62	Mylasandra Lake1
29	Tirumanehalli 2	63	Nallurahalli
30	Ulsoor	64	Rampura
31	Vittasandra	65	Rayasandra
32	Yediyur	66	Subbarayan Kere
33	Yekelghatta	67	Varthur
34	Yelahanka	68	YMC lake

Table 2: Standard methods followed for water quality analysis

Parameters	**Methods (with Reference)**
Onsite Measurements	
Water temperature (^{0}C)	Eutech: PCSTestr 35
pH	HANNA:
Total Dissolved Solids (TDS, mg/l)	HANNA:
Electrical conductivity (µS/cm)	Eutech: PCSTestr 35
Dissolved Oxygen (DO) (mg/l)	Winkler's Method (APHA, 1998: 4500-O)
Laboratory Measurements	
Hardness (mg/l)	EDTA titrimetric method (APHA, 1998: 2340-C)
Calcium hardness (mg/l)	EDTA titrimetric method (APHA, 1998: 3500-Ca B)
Magnesium hardness (mg/l)	Magnesium by calculation (APHA, 1998:3500-Mg)
Sodium (mg/l)	Flame emission photometric method (APHA, 1998:3500-Na B)
Potassium (mg/l)	Flame emission photometric method (APHA, 1998: 3500-K B)
Alkalinity (mg/l)	Titrimetric method (APHA, 1998: 2320 B)
Chloride (mg/l)	Argentometric method (APHA, 1998:4500-Cl^- B)
Chemical Oxygen Demand (COD) (mg/l)	Closed reflux, titrimetric method (APHA, 5220 C, Trivedi&Goel, 1986, pp.55-57)
Nitrates	Phenol disulphonic acid method (Trivedy and Goel, 1986: pp 61)
Orthophosphates (mg/l)	Stannous chloride method (APHA, 4500-P)

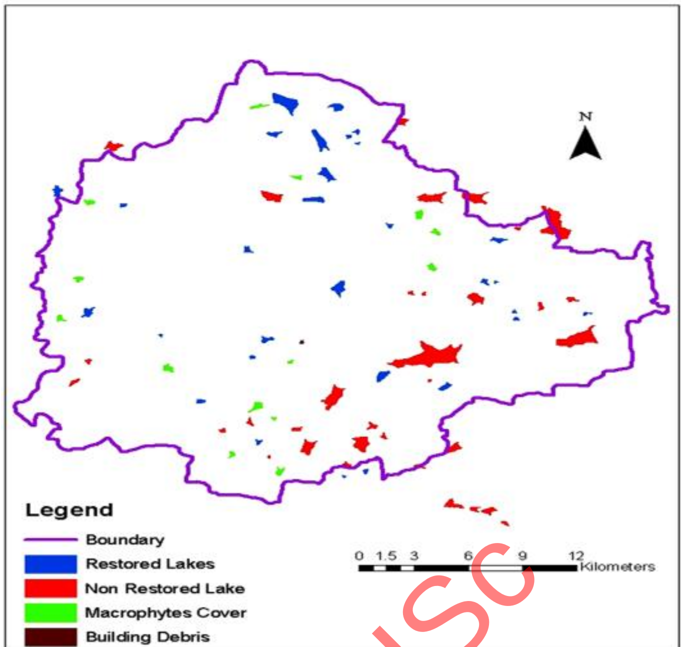

Figure 1: Lakes of Greater Bangalore, Karnataka, India.

RESULTS AND DISCUSSION

Temperature: Water temperature plays an important role in aquatic ecosystems as it brings about an increase in metabolic rate and physiological reactions of organisms, etc.in lakes. The variations in temperature occur due to changes in air temperature, humidity, wind and solar energy (Sincy et al., 2012). The average value of temperature was found to be 22°C - 31°C.

Electrical Conductivity and TDS: Electrical Conductivity denotes the ability of water to conduct an electric current. This mainly depends on the presence of ions, their total concentration, mobility, valency and temperature (Ramachandra et al., 2007). High electrical conductivity is due to increase in the concentration of salts as a result of high evaporation rates during summer whereas EC decreases due to dilution during precipitation or at increased water level in lakes. The average value of EC and TDS was found to be 138 – 2482µS and 59– 1471 mg/l respectively.

pH: pH gives the intensity of the acidic or basic character of water at a given temperature. It is largely governed by carbon dioxide, carbonates and bicarbonates equilibrium. Phytoplankton growth is promoted at slightly alkaline conditions but a low pH results due to macrophyte cover in lakes (Mahapatra et al., 2011). The average value of pH was found to be 7.2 – 10.6. All lakes were slightly alkaline.

Dissolved Oxygen (DO): Dissolved oxygen is very essential for aquatic life. The DO content varies with temperature, turbulence, salinity, atmospheric pressure, increased photosynthetic activity and respiration by microalgae as well as bacteria. A drop in DO level at inlet causes anoxic or hypoxic conditions and thereby, affects other aquatic biota (Trivedy et al., 1986). The average value of pH was found to be 0 - 18.92 mg/l. At the inlet of almost all the lakes,DO was found to be absent. DO is higher at outlet and middle portions due to high rate of photosynthesis and oxidative decomposition of dissolved organic matter and is similar to earlier studies, (Mahapatra et al., 2011).

Chemical Oxygen Demand (COD): Chemical oxygen demand determines the amount of oxygen required for the chemical oxidation of most organic matter and oxidizable inorganic substances with the help of strong chemical oxidant (Raut et al., 2011). Higher values of COD indicate pollution due to oxidisable organic matter. The average value of COD was found to be 6 – 229.14 mg/l. Begur had higher COD values as the region is more susceptible to anthropogenic activities and had reduced water level during the study period.

Total Alkalinity: The decomposition of aquatic plants, living organisms and organic wastes increases the carbonate and bicarbonate levels in lakes, thus, increasing alkaline nature of lakes. The average value of alkalinity was found to be 52 – 682.67 mg/l.

Chloride: The high chloride concentration in lakes may be due to high evaporation rates or due to sewage entry, industrial wastes as well as organic wastes of animal origin. The average value of chloride was found to be 19.41 – 791.57 mg/l.

Total Hardness, Calcium Hardness and Magnesium Hardness: Hardness is predominantly caused by divalent cations such as calcium, magnesium, alkaline earth metal such as iron, manganese, strontium, etc. The total hardness is defined as the sum of calcium and magnesium concentrations, both expressed as $CaCO_3$ in mg/L. Hardness (TH, CaH and MgH) of lake water increases due to sewage inflow mainly from nearby industrial and residential areas and also with the addition of detergents during bathing and washing of clothes. The depletion of magnesium reduces the phytoplankton population as it is essential for chlorophyll growth and thus, acts as a limiting factor (Ramchandra et al., 2014). The average value of Total hardness, Calcium and Magnesium hardness were found to be 30 – 981.33 mg/l, 6.95 – 261.32 mg/l and 5.6 – 174.96 mg/l respectively.

Potassium and Sodium: High concentration of sodium and potassium in lakes makes the water salty. The average value of Potassium and Sodium were found to be 2 – 119.6 mg/l and 9.6-675.6 mg/l.

Nitrate and Orthophosphate: The nitrate and phosphate are the two important nutrients that promote algae as well as plant (macrophyte) growth in lakes, which in turn, leads to shrinkage of wetland area, low light penetration, reduced oxygen concentrations, and clogging of water channels. These lower the biodiversity of wetlands/lakes; hinder recreational activities; sometimes, even leads to deterioration of the water quality or extinction of lakes due to excessive macrophyte cover (Parashar et al., 2006). Their concentration in lakes increases due to sewage inflow, surface run off, leaf litter and from sediments. The average value of Nitrate and Orthophosphate were found to be 0.075- 1.25 mg/l and 0.011- 2.785 mg/l.

Cluster Analysis: Cluster analysis (Figure 3) grouped all the lakes into two main clusters. Cluster 1 has all the severely polluted lakes like Begur, Bommasandra, Hebbagodi and Heelalige. These lakes receive direct sewage, industrial wastes and are susceptible to high anthropogenic activities. Cluster 2 is subdivided to many sub clusters, S1 has slightly polluted lakes such as Ulsoor, Yediyur, Kogilu, Deepanjalinagar kere, Doraikere and Bagmane.S2 possess lakes like RKmission lakes 1 – 4, Mylasandra Lake 1 – 2 and Vittasandra that are good lakes with rainwater runoff as the main water source. All the other lakes fall to S3 and are moderately polluted with similar physico-chemical characteristics.

CONCLUSION

The exploratory survey revealed about 14 lakes namely Puttanahalli, Sarakki, Horamavu Agara, Herohalli, Byrasandra, Beninganahalli, Avalahalli, Puttenahalli, Horamavu, Amrutahalli, Hosakere, Gottigere and Doddabidrakallu, were found to be fully covered with macrophytes. Lakes such as Lakkasandra had completely turned to a barren land due to the dumping of building debris. About 64 lakes in Greater Bangalore were monitored for physico-chemical characteristics in the present study. The inlet points of lakes had higher physico-chemical parameters than the middle and outlet portions of lakes because of untreated sewage entry. The cluster analysis had grouped the lakes based on pollution as non - polluted, slightly polluted, moderately and severely polluted lakes.

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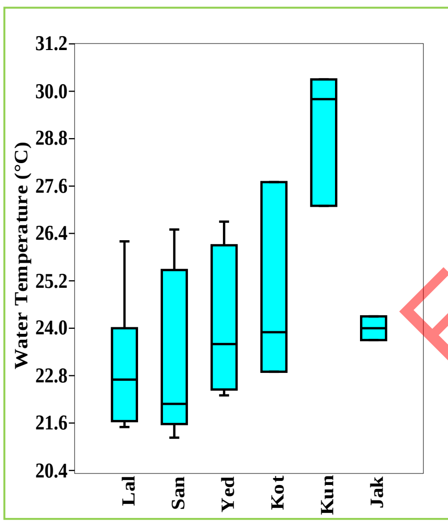
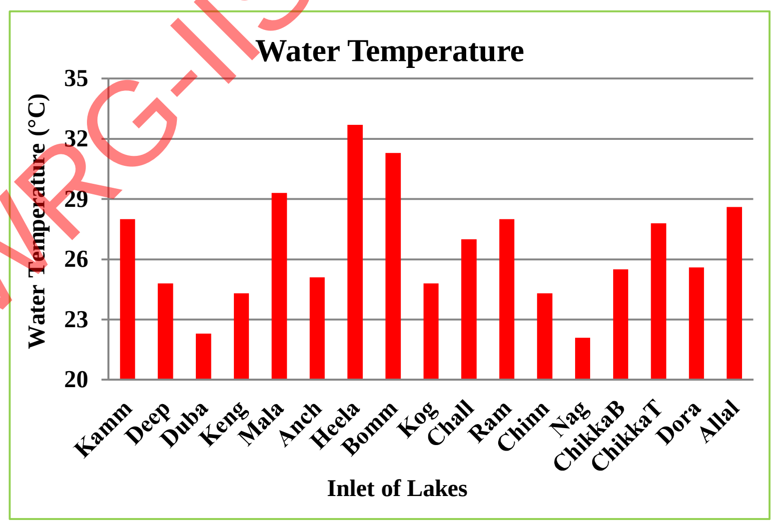
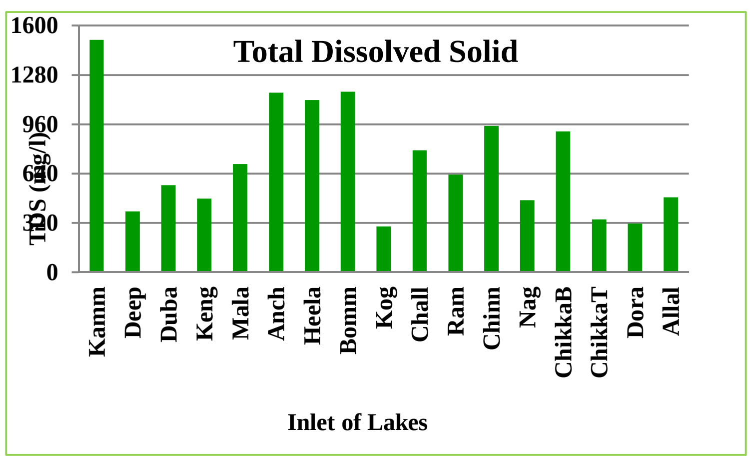
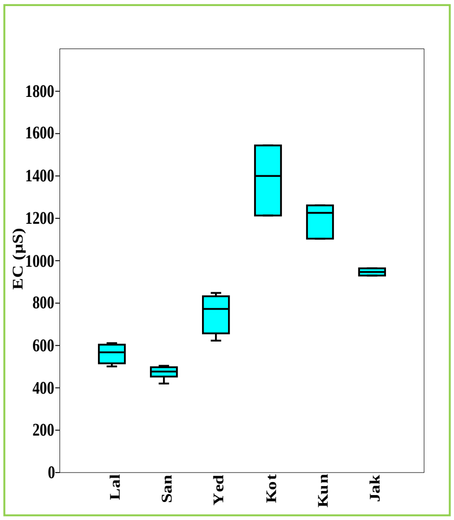
INLET OF LAKES





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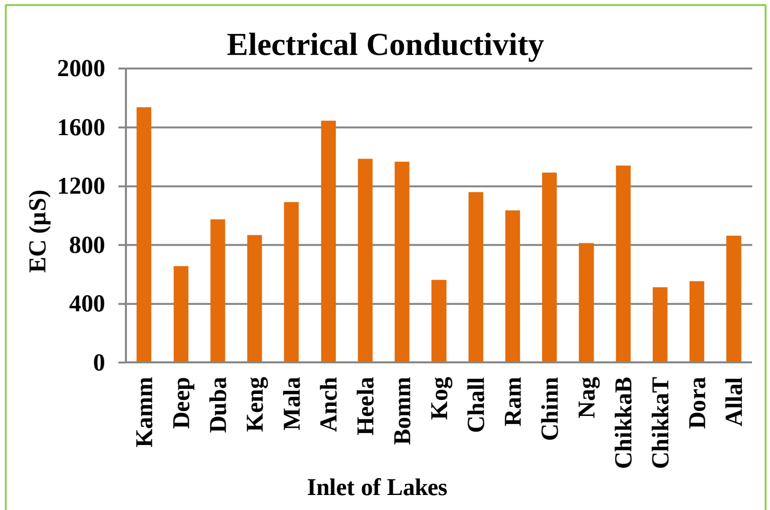
400
600
800
1000
1200
1400
1600
1800
Lal
San
Yed
Kot
Kun
Jak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EC (µS)
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2000
Kamm
Deep
Duba
Keng
Mala
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Bomm
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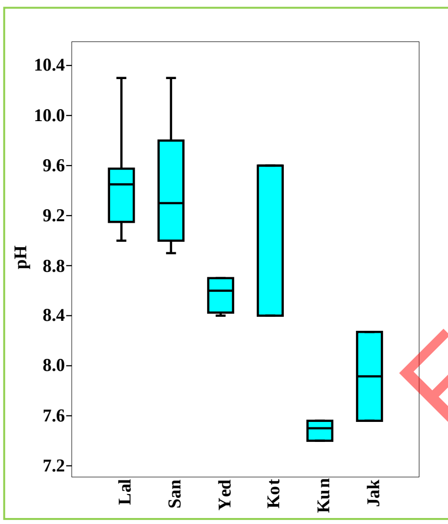
Ram
Chinn
Nag
ChikkaB
ChikkaT
Dora
Allal
Inlet of Lakes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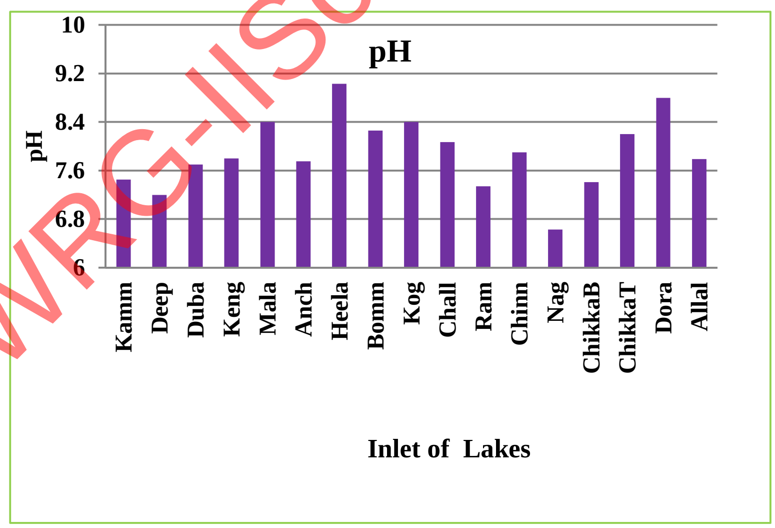
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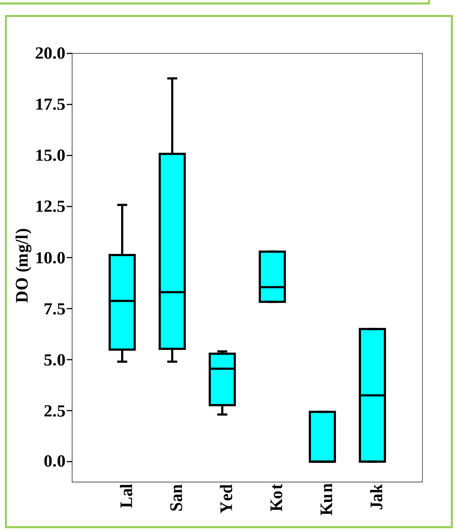
Allal
Inlet of Lakes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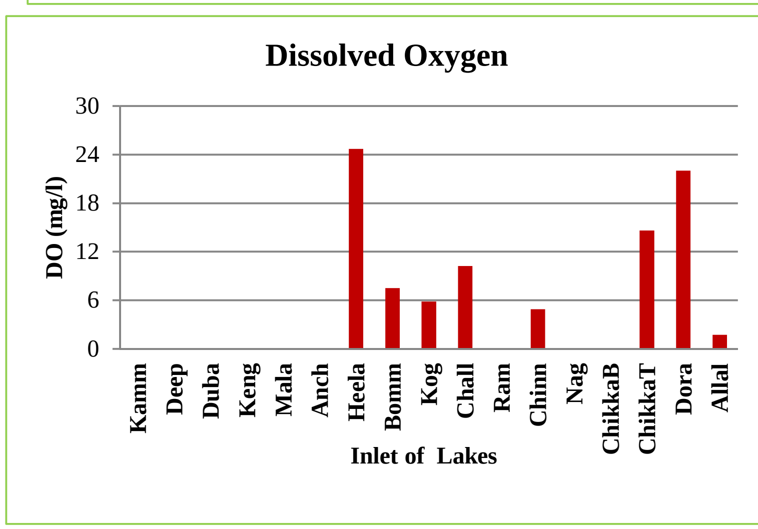
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Keng
Mala
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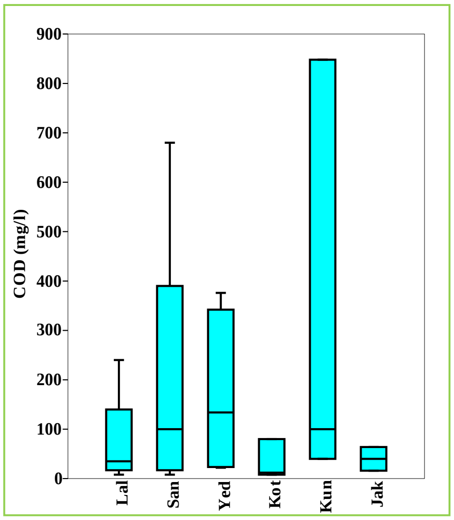
Dora
Allal
Inlet of Lakes


COD (mg/l)
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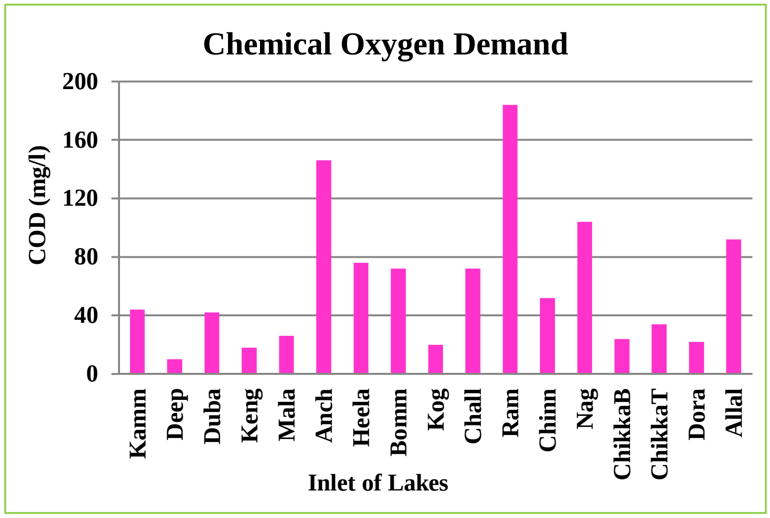
200
100
0
Lal
San
Yed
Kot
Kun
Jak


Chemical Oxygen Demand
COD (mg/l)
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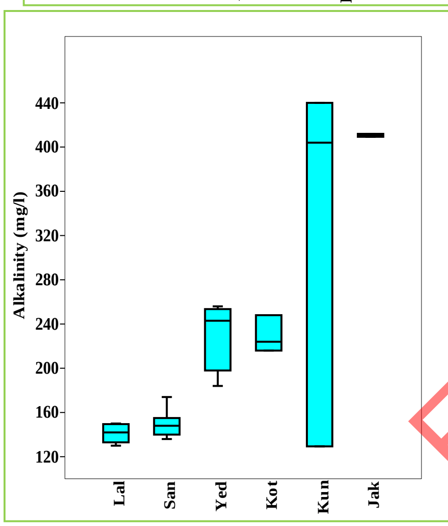
Allal
Inlet of Lakes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120
Lal
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Yed
Kot
Kun
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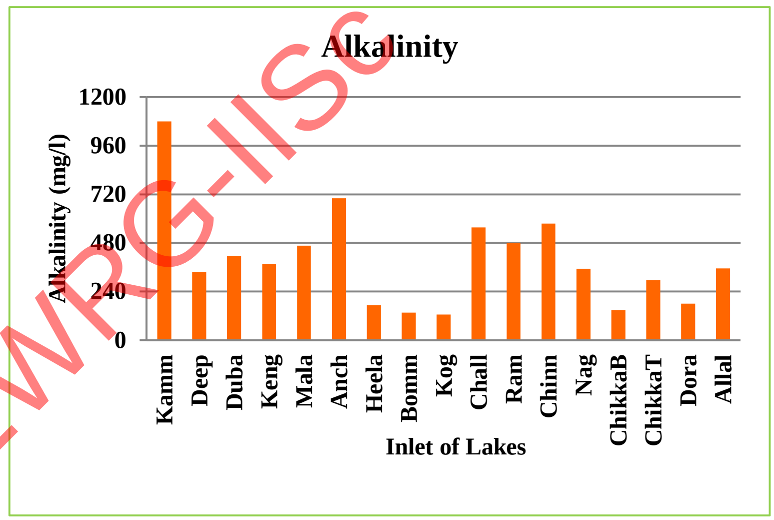
Alkalinity
Alkalinity (mg/l)
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Kamm
Deep
Duba
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ChikkaB
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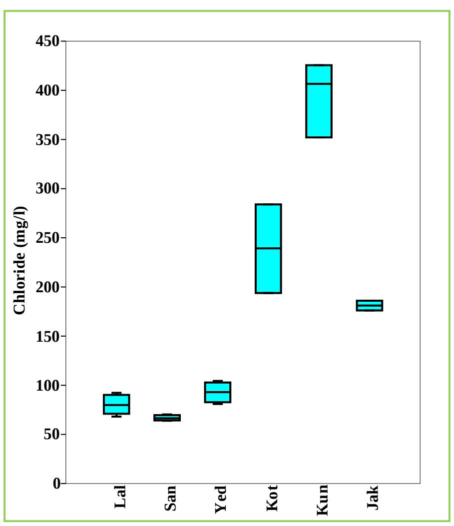
Dora
Allal
Inlet of Lakes


Chloride (mg/l)
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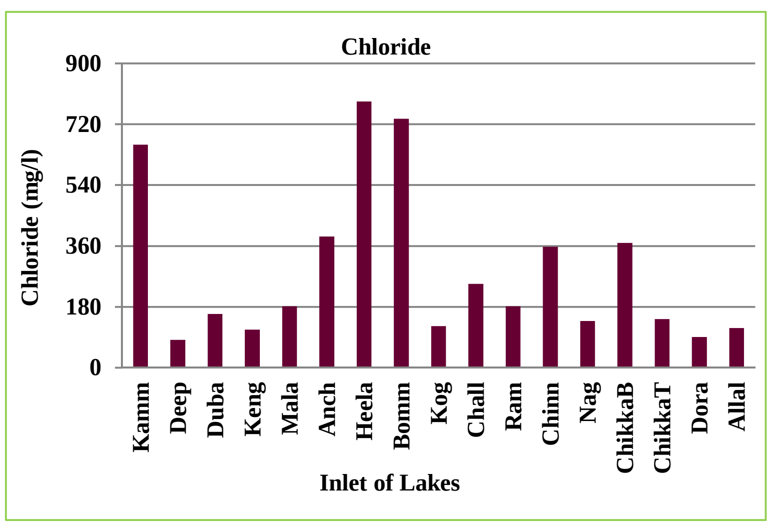
200
150
100
50
0
Lal
San
Yed
Kot
Kun
Jak


Chloride
Chloride (mg/l)
900
720
540
360
180
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Kamm
Deep
Duba
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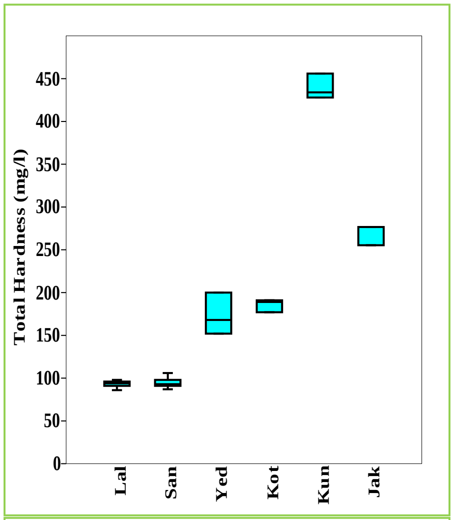
Allal
Inlet of Lakes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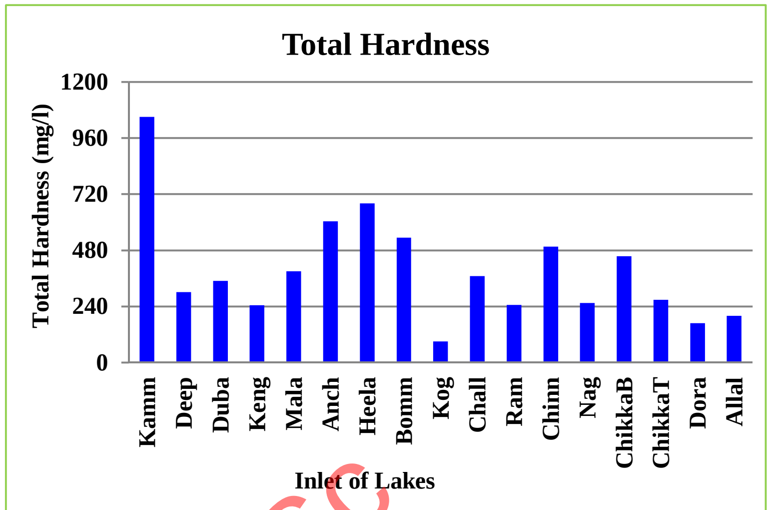
300
350
400
450
Lal
San
Yed
Kot
Kun
Jak


Total Hardness
Total Hardness (mg/l)
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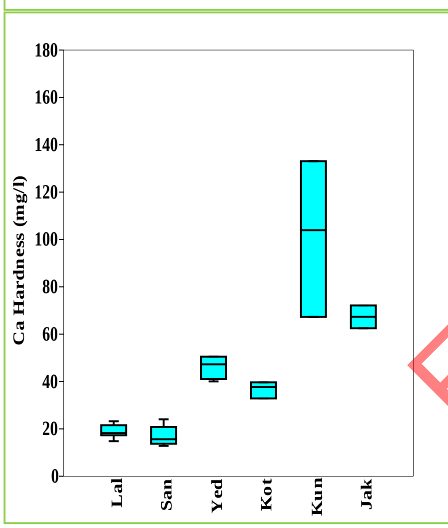
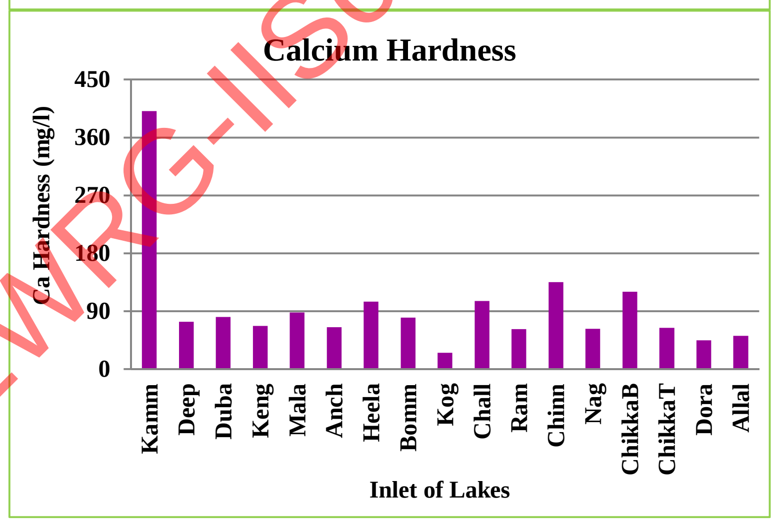
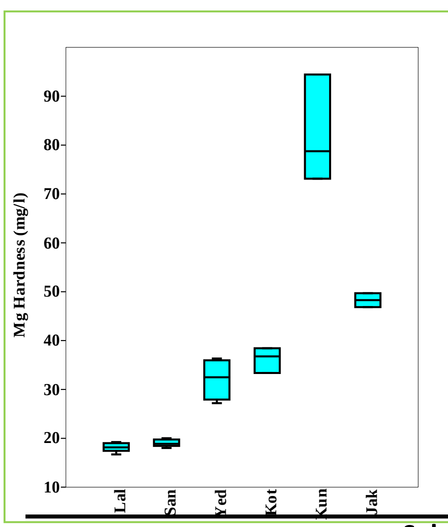
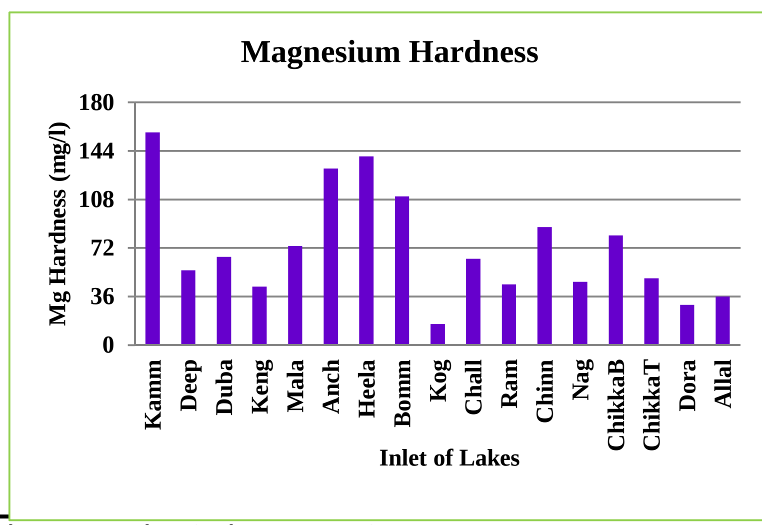
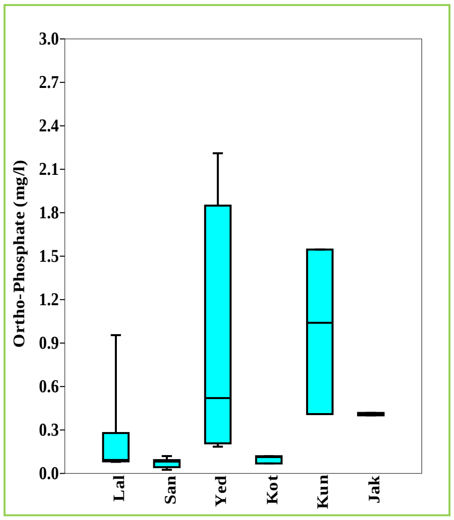
240
480
720
960
1200
Kamm
Deep
Duba
Keng
Mala
Anch
Heela
Bomm
Kog
Chall
Ram
Chinn
Nag
ChikkaB
ChikkaT
Dora
Allal
Inlet of Lakes

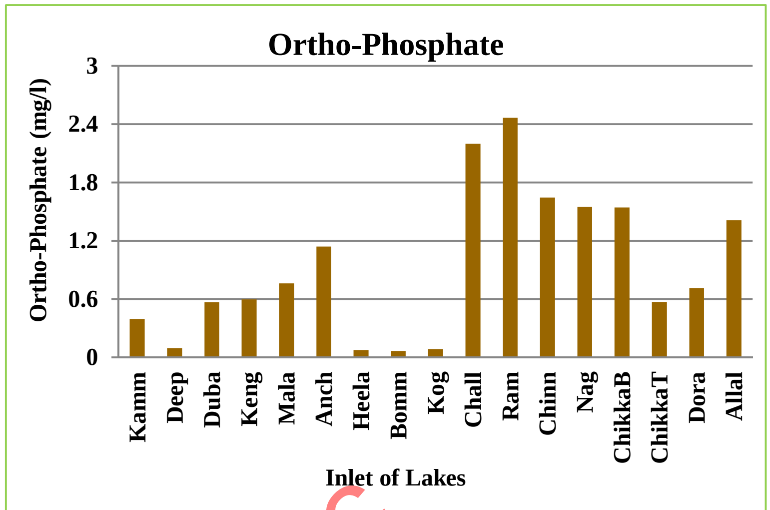

Ca Hardness (mg/l)
0
20
40
60
80
100
120
140
160
180
Lal
San
Yed
Kot
Kun
Jak

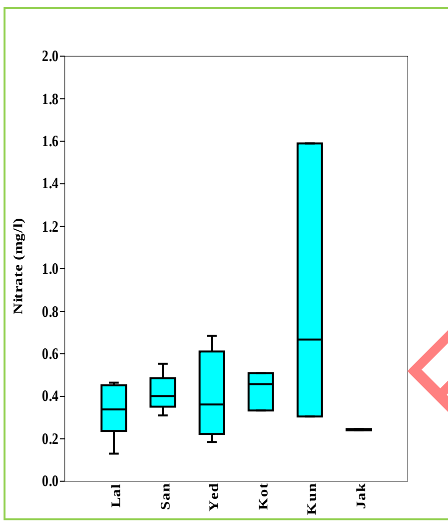

Calcium Hardness
Ca Hardness (mg/l)
0
90
180
270
360
450
Kamm
Deep
Duba
Keng
Mala
Anch
Heela
Bomm
Kog
Chall
Ram
Chinn
Nag
ChikkaB
ChikkaT
Dora
Allal
Inlet of Lakes

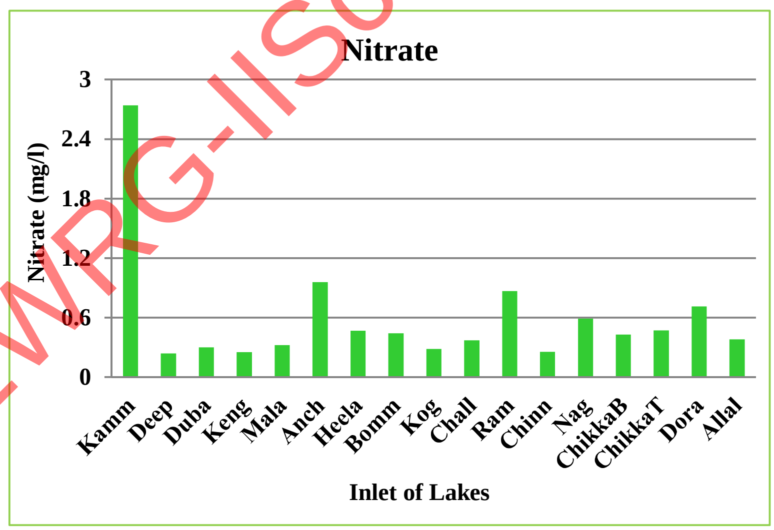

Mg Hardness (mg/l)
10
20
30
40
50
60
70
80
90
Lal
San
Yed
Kot
Kun
Jak

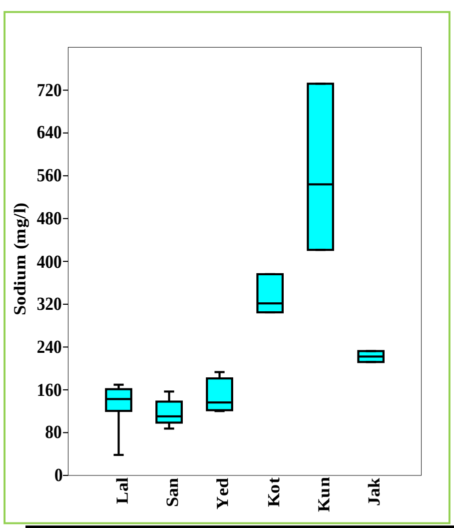

Magnesium Hardness
Mg Hardness (mg/l)
0
36
72
108
144
180
Kamm
Deep
Duba
Keng
Mala
Anch
Heela
Bomm
Kog
Chall
Ram
Chinn
Nag
ChikkaB
ChikkaT
Dora
Allal
Inlet of Lakes

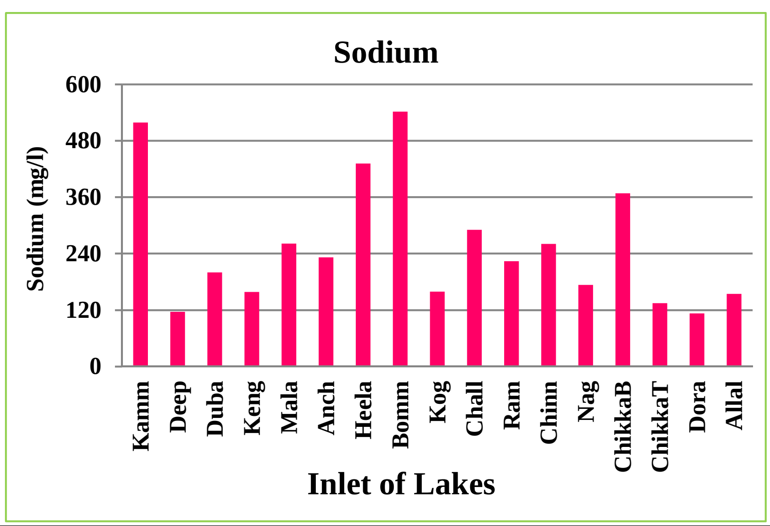

Ortho-Phosphate (mg/l)
3.0
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0.0
Lal
San
Yed
Kot
Kun
Jak

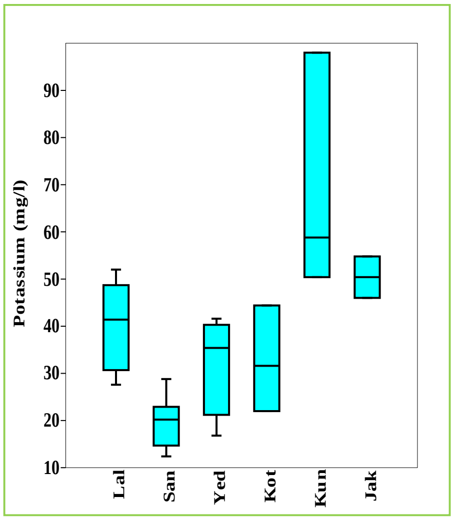

Ortho-Phosphate
Ortho-Phosphate (mg/l)
3
2.4
1.8
1.2
0.6
0
Kamm
Deep
Duba
Keng
Mala
Anch
Heela
Bomm
Kog
Chall
Ram
Chinn
Nag
ChikkaB
ChikkaT
Dora
Allal
Inlet of Lakes

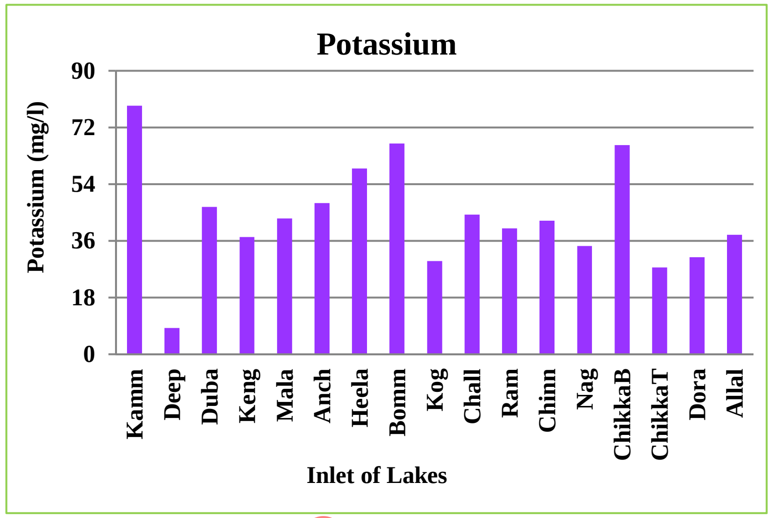

Nitrate (mg/l)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Lal
San
Yed
Kot
Kun
Jak


Nitrate
Nitrate (mg/l)
3
2.4
1.8
1.2
0.6
0
Kamm
Deep
Duba
Keng
Mala
Anch
Heela
Bomm
Kog
Chall
Ram
Chinn
Nag
ChikkaB
ChikkaT
Dora
Allal
Inlet of Lakes

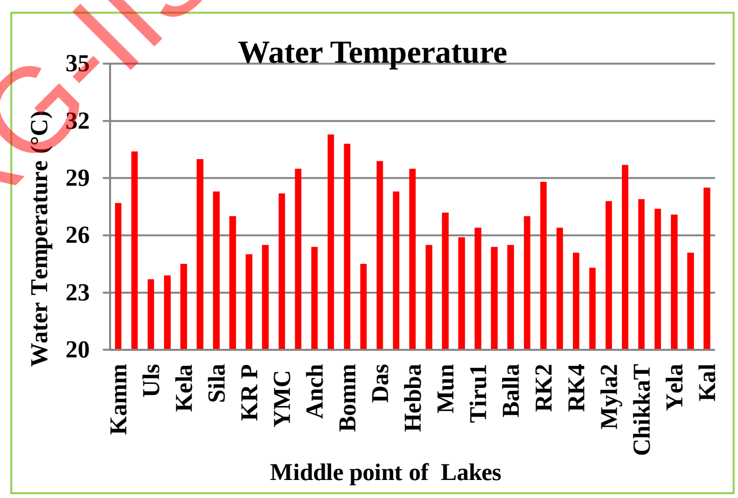

Sodium (mg/l)
720
640
560
480
400
320
240
160
80
0
Lal
San
Yed
Kot
Kun
Jak

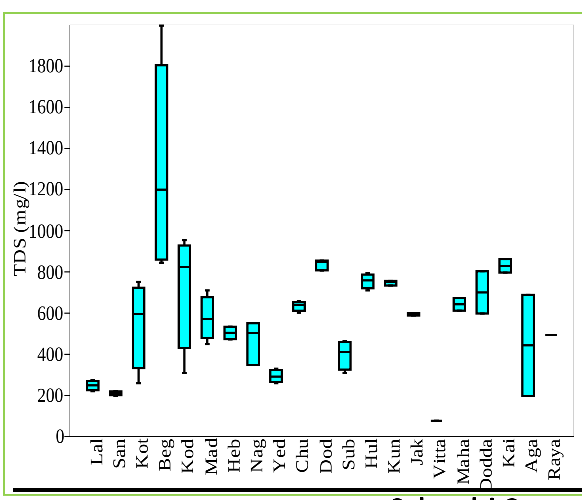

Sodium
Sodium (mg/l)
600
480
360
240
120
0
Kamm
Deep
Duba
Keng
Mala
Anch
Heela
Bomm
Kog
Chall
Ram
Chinn
Nag
ChikkaB
ChikkaT
Dora
Allal
Inlet of Lakes

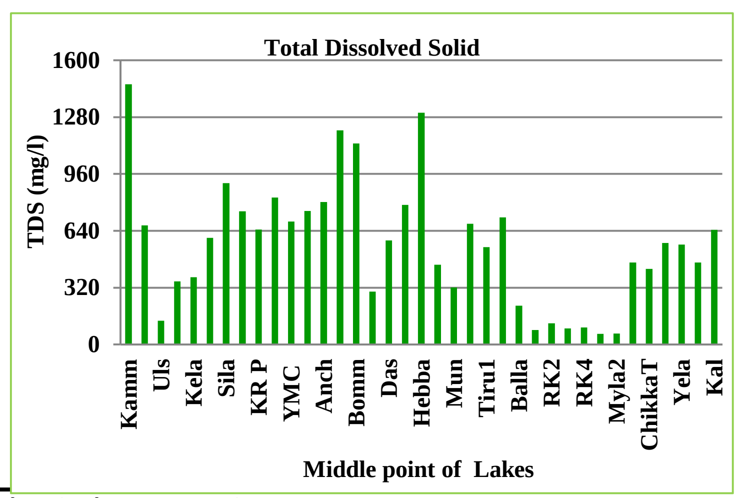


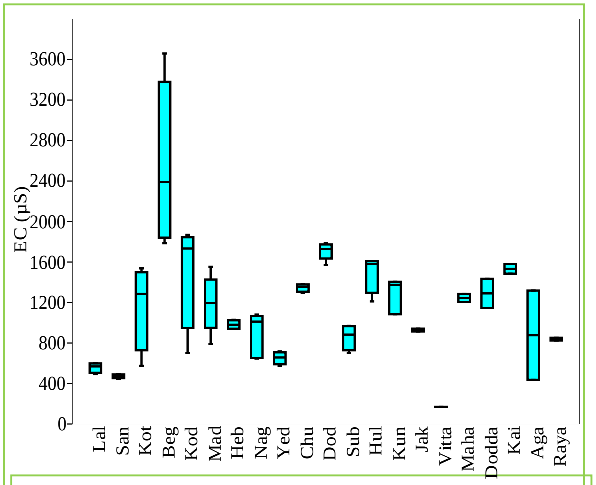


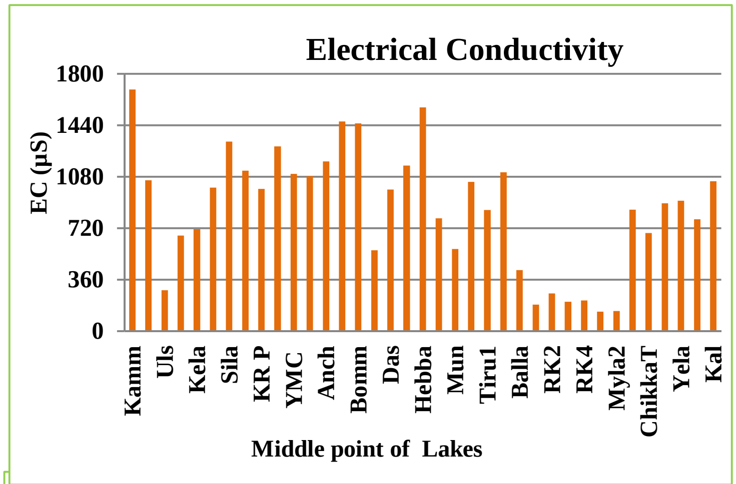
Middle point of Lakes

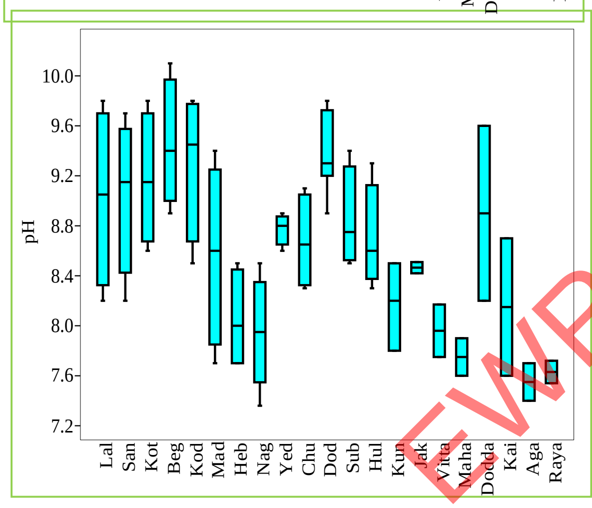


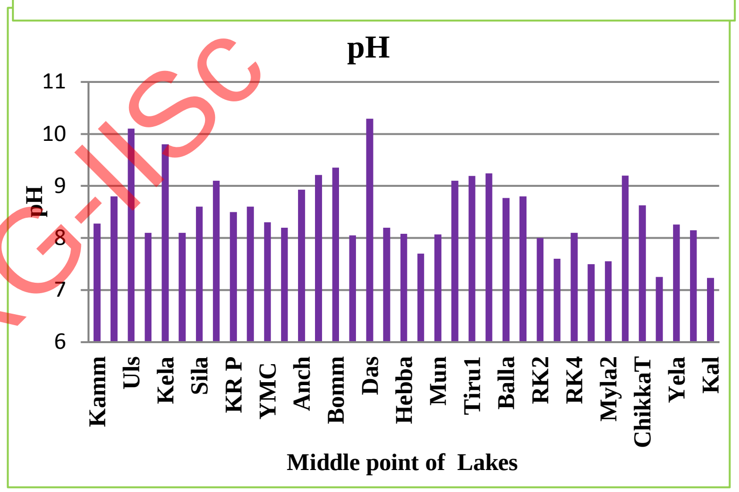


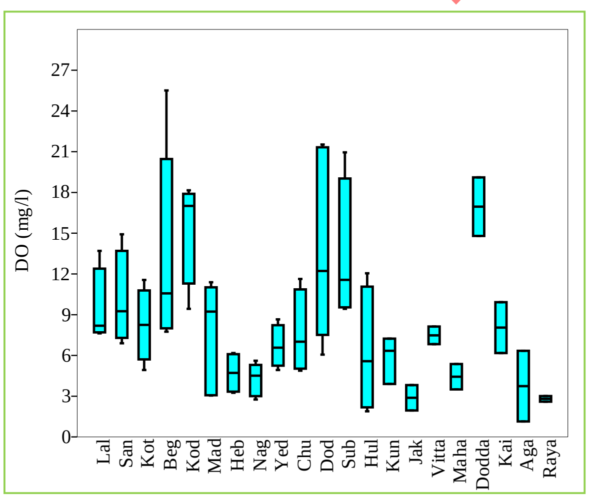


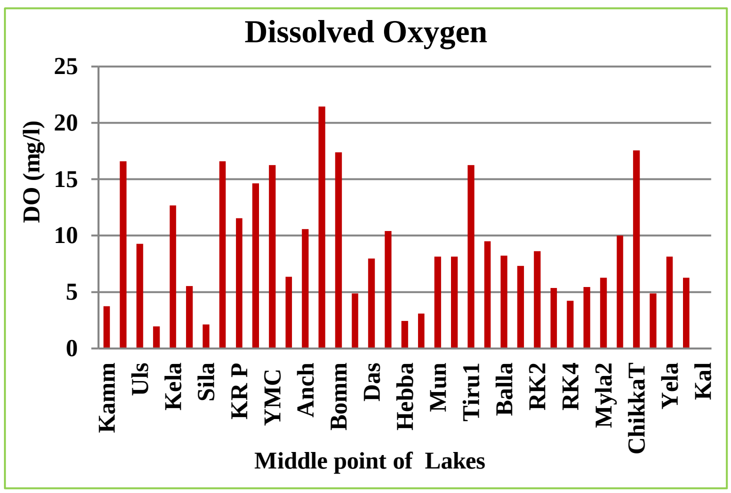

EC (µS)
Lal San Kot Beg Kod Mad Heb Nag Yed Chu Dod Sub Hul Kun Jak Vitta Maha Dodda Kai Aga Raya

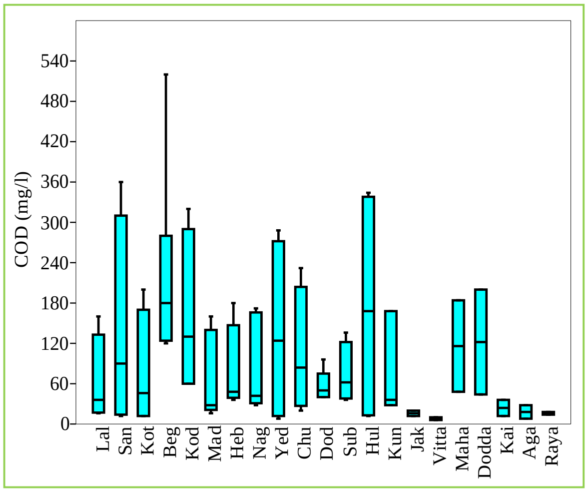

Electrical Conductivity
EC (µS)
Middle point of Lakes

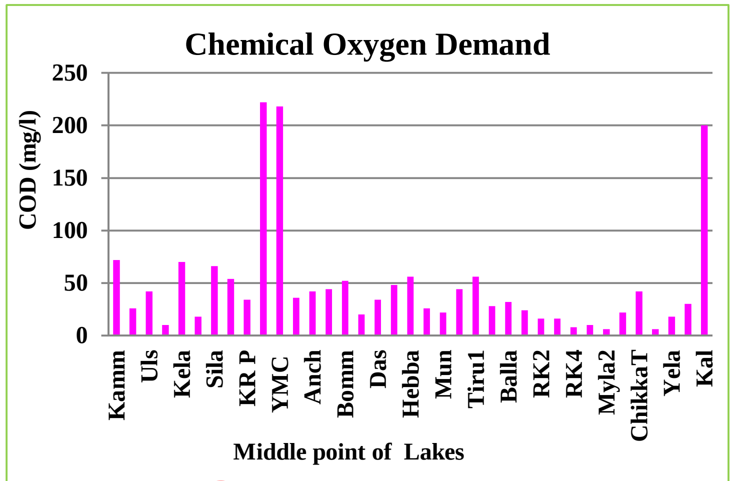

pH
Lal San Kot Beg Kod Mad Heb Nag Yed Chu Dod Sub Hul Kun Jak Vitta Maha Dodda Kai Aga Raya

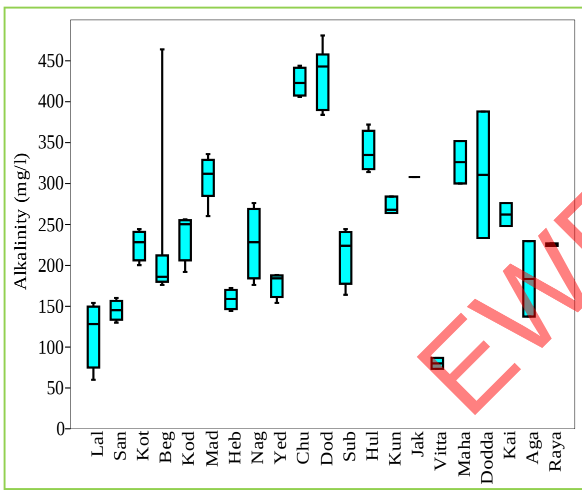

pH
Middle point of Lakes

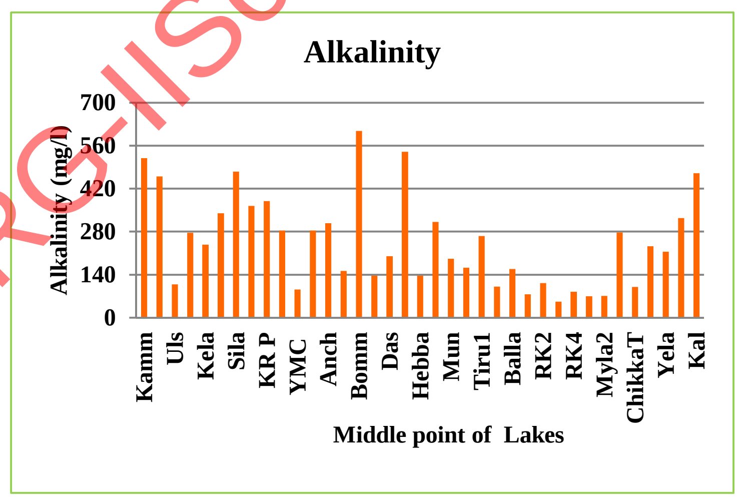

DO (mg/l)
Lal San Kot Beg Kod Mad Heb Nag Yed Chu Dod Sub Hul Kun Jak Vitta Maha Dodda Kai Aga Raya

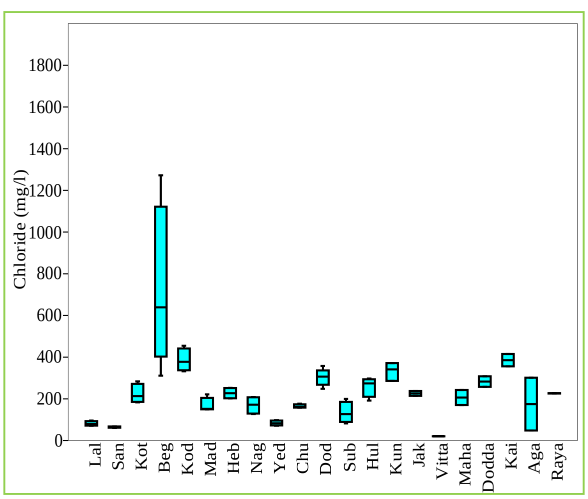

Dissolved Oxygen
DO (mg/l)
Middle point of Lakes

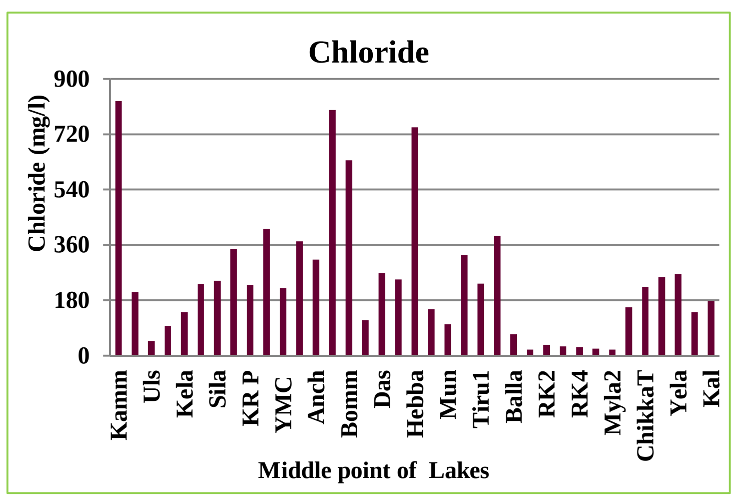

COD (mg/l)
540
480
420
360
300
240
180
120
60
0
Lal San Kot Beg Kod Mad Heb Nag Yed Chu Dod Sub Hul Kun Jak Vitta Maha Dodda Kai Aga Raya

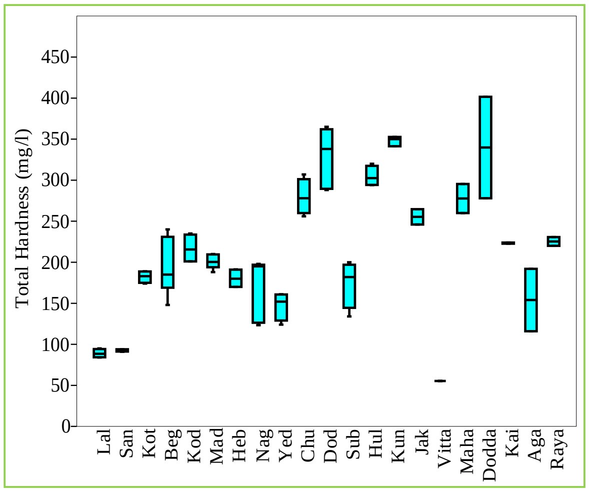

Chemical Oxygen Demand
COD (mg/l)
250
200
150
100
50
0
Kamm Uls Kela Sila KR P YMC Anch Bomm Das Hebba Mun Tiru1 Balla RK2 RK4 Myla2 ChikkaT Yela Kal
Middle point of Lakes

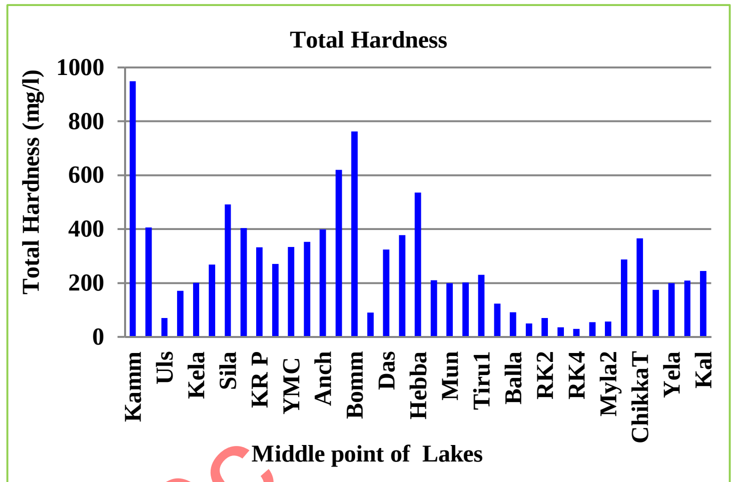

Alkalinity (mg/l)
450
400
350
300
250
200
150
100
50
0
Lal San Kot Beg Kod Mad Heb Nag Yed Chu Dod Sub Hul Kun Jak Vitta Maha Dodda Kai Aga Raya

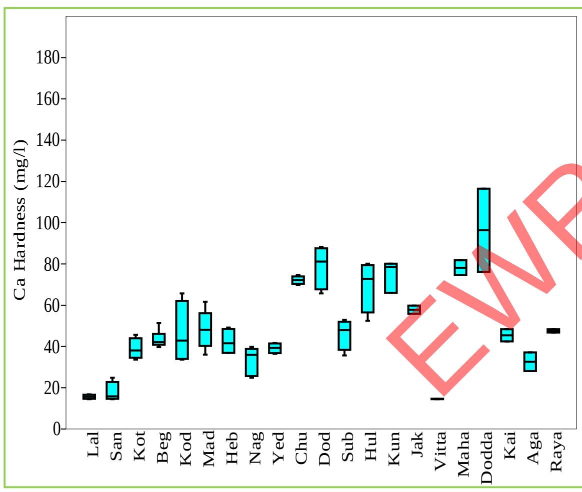

Alkalinity
Alkalinity (mg/l)
700
560
420
280
140
0
Kamm Uls Kela Sila KR P YMC Anch Bomm Das Hebba Mun Tiru1 Balla RK2 RK4 Myla2 ChikkaT Yela Kal
Middle point of Lakes

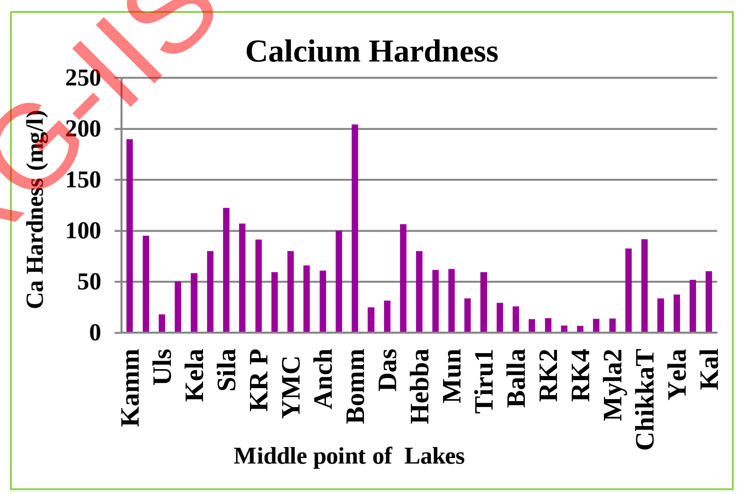

Chloride (mg/l)
1800
1600
1400
1200
1000
800
600
400
200
0
Lal San Kot Beg Kod Mad Heb Nag Yed Chu Dod Sub Hul Kun Jak Vitta Maha Dodda Kai Aga Raya

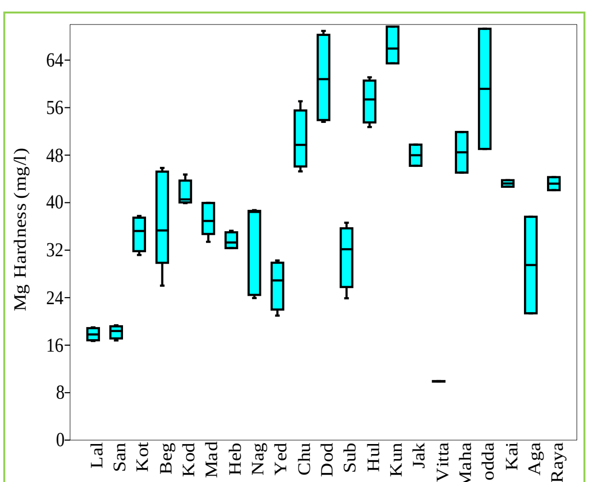

Chloride
Chloride (mg/l)
900
720
540
360
180
0
Kamm Uls Kela Sila KR P YMC Anch Bomm Das Hebba Mun Tiru1 Balla RK2 RK4 Myla2 ChikkaT Yela Kal
Middle point of Lakes

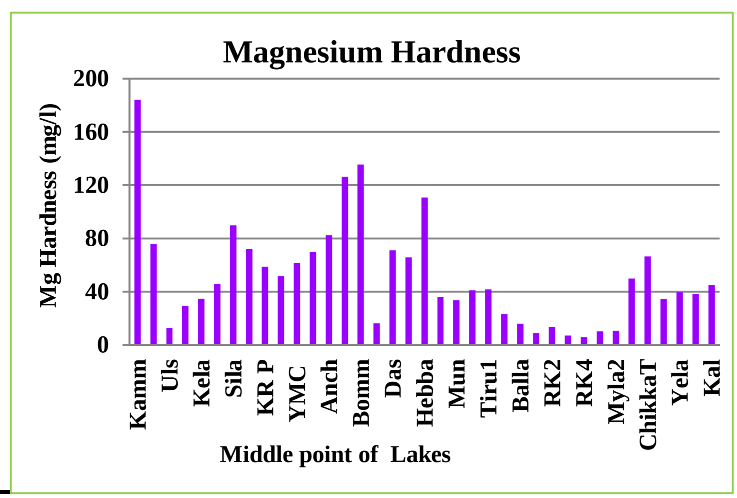

Total Hardness (mg/l)
0
50
100
150
200
250
300
350
400
450
Lal
San
Kot
Beg
Kod
Mad
Heb
Nag
Yed
Chu
Dod
Sub
Hul
Kun
Jak
Vitta
Maha
Dodda
Kai
Aga
Raya

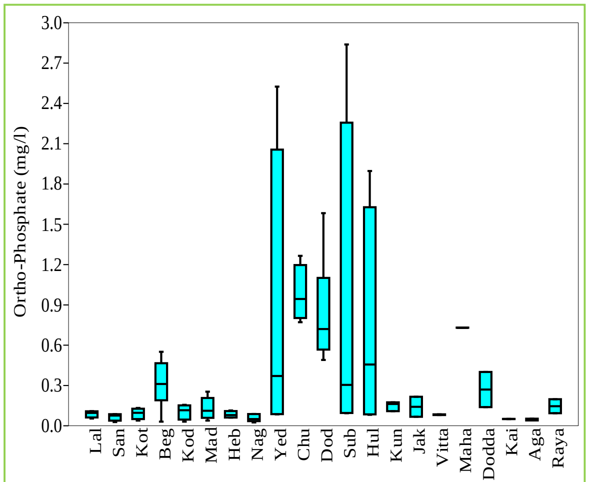

Total Hardness
Total Hardness (mg/l)
0
200
400
600
800
1000
Kamm
Uls
Kela
Sila
KR P
YMC
Anch
Bomm
Das
Hebba
Mun
Tiru1
Balla
RK2
RK4
Myla2
ChikkaT
Yela
Kal
Middle point of Lakes

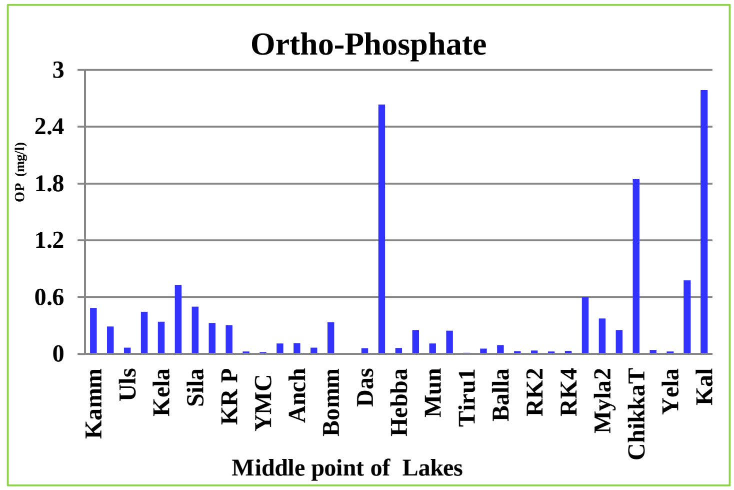

Ca Hardness (mg/l)
0
20
40
60
80
100
120
140
160
180
Lal
San
Kot
Beg
Kod
Mad
Heb
Nag
Yed
Chu
Dod
Sub
Hul
Kun
Jak
Vitta
Maha
Dodda
Kai
Aga
Raya

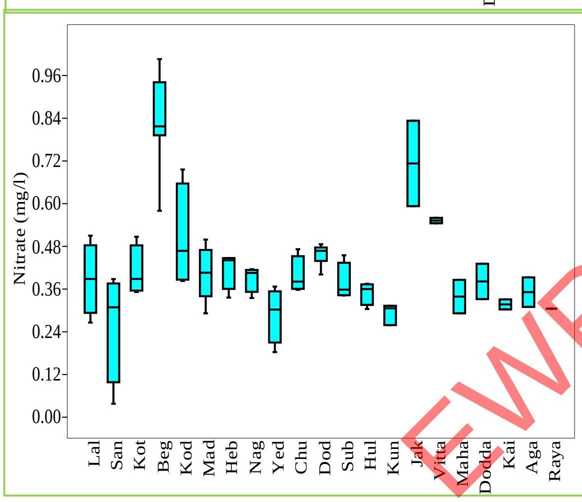

Calcium Hardness
Ca Hardness (mg/l)
0
50
100
150
200
250
Kamm
Uls
Kela
Sila
KR P
YMC
Anch
Bomm
Das
Hebba
Mun
Tiru1
Balla
RK2
RK4
Myla2
ChikkaT
Yela
Kal
Middle point of Lakes

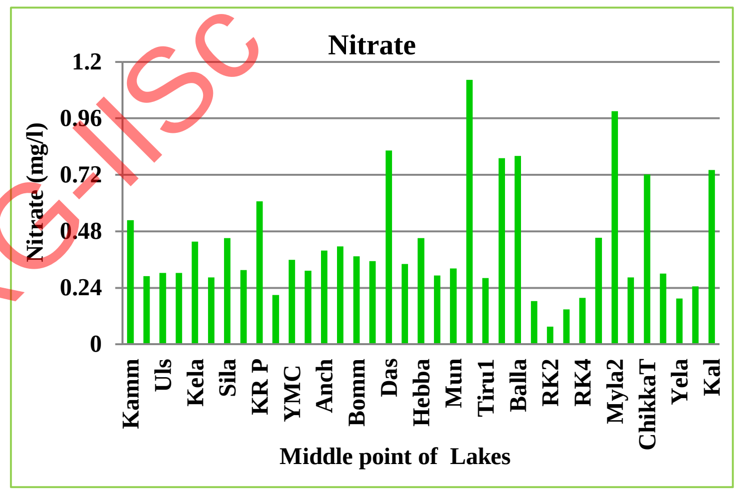

Mg Hardness (mg/l)
0
8
16
24
32
40
48
56
64
Lal
San
Kot
Beg
Kod
Mad
Heb
Nag
Yed
Chu
Dod
Sub
Hul
Kun
Jak
Vitta
Maha
Dodda
Kai
Aga
Raya

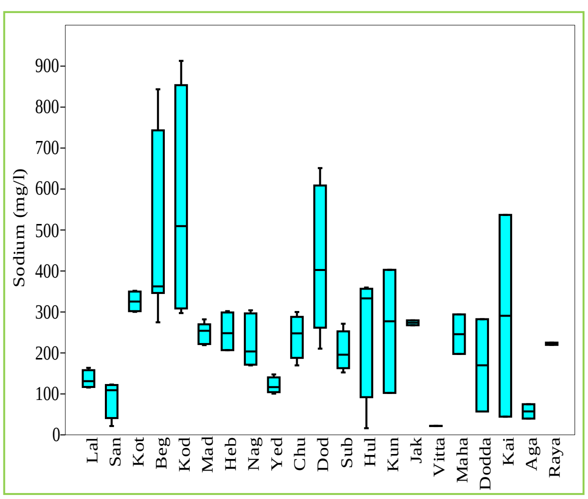

Magnesium Hardness
Mg Hardness (mg/l)
0
40
80
120
160
200
Kamm
Uls
Kela
Sila
KR P
YMC
Anch
Bomm
Das
Hebba
Mun
Tiru1
Balla
RK2
RK4
Myla2
ChikkaT
Yela
Kal
Middle point of Lakes

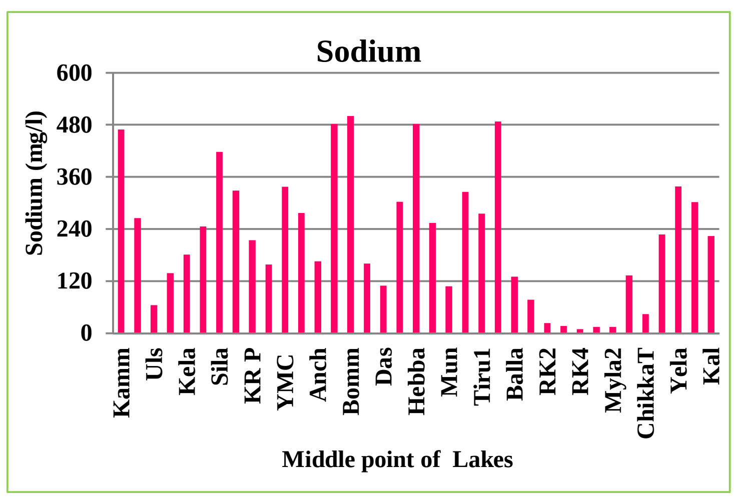

Ortho-Phosphate (mg/l)
3.0
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0.0
Lal San Kot Beg Kod Mad Heb Nag Yed Chu Dod Sub Hul Kun Jak Vitta Maha Dodda Kai Aga Raya

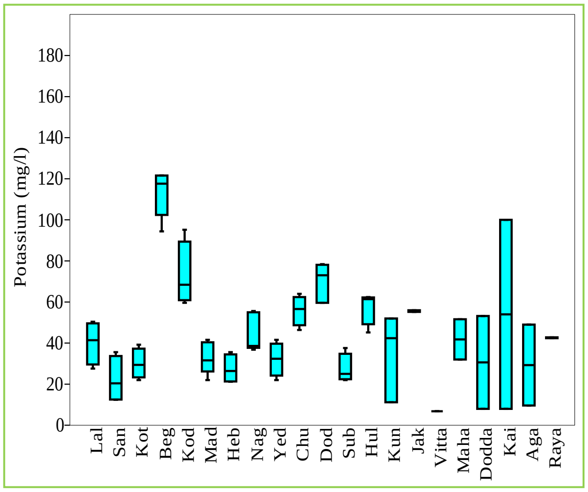

Ortho-Phosphate
OP (mg/l)
3
2.4
1.8
1.2
0.6
0
Kamm Uls Kela Sila KR P YMC Anch Bomm Das Hebba Mun Tiru1 Balla RK2 RK4 Myla2 ChikkaT Yela Kal
Middle point of Lakes

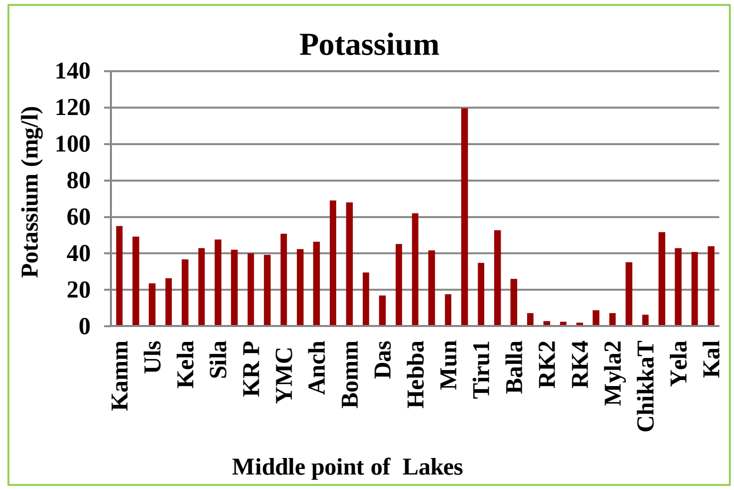

Nitrate (mg/l)
0.96
0.84
0.72
0.60
0.48
0.36
0.24
0.12
0.00
Lal San Kot Beg Kod Mad Heb Nag Yed Chu Dod Sub Hul Kun Jak Vitta Maha Dodda Kai Aga Raya


Nitrate
Nitrate (mg/l)
1.2
0.96
0.72
0.48
0.24
0
Kamm Uls Kela Sila KR P YMC Anch Bomm Das Hebba Mun Tiru1 Balla RK2 RK4 Myla2 ChikkaT Yela Kal
Middle point of Lakes

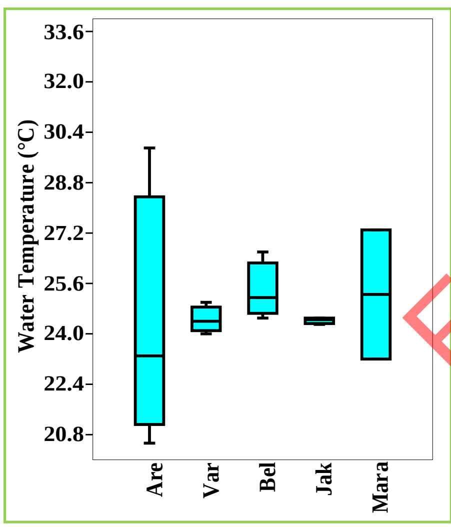

Sodium (mg/l)
900
800
700
600
500
400
300
200
100
0
Lal San Kot Beg Kod Mad Heb Nag Yed Chu Dod Sub Hul Kun Jak Vitta Maha Dodda Kai Aga Raya

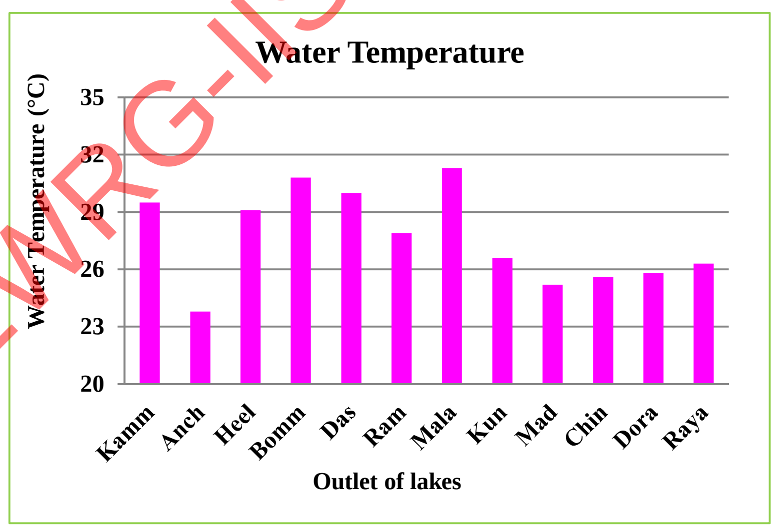

Sodium
Sodium (mg/l)
600
480
360
240
120
0
Kamm Uls Kela Sila KR P YMC Anch Bomm Das Hebba Mun Tiru1 Balla RK2 RK4 Myla2 ChikkaT Yela Kal
Middle point of Lakes

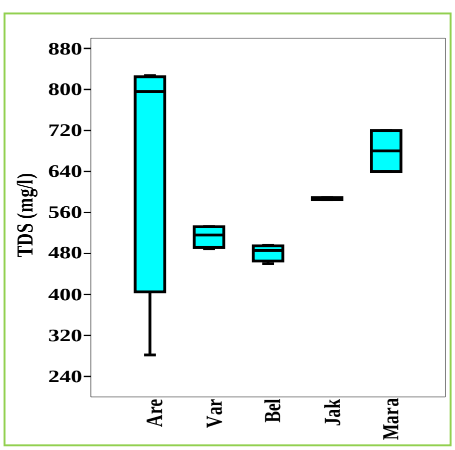


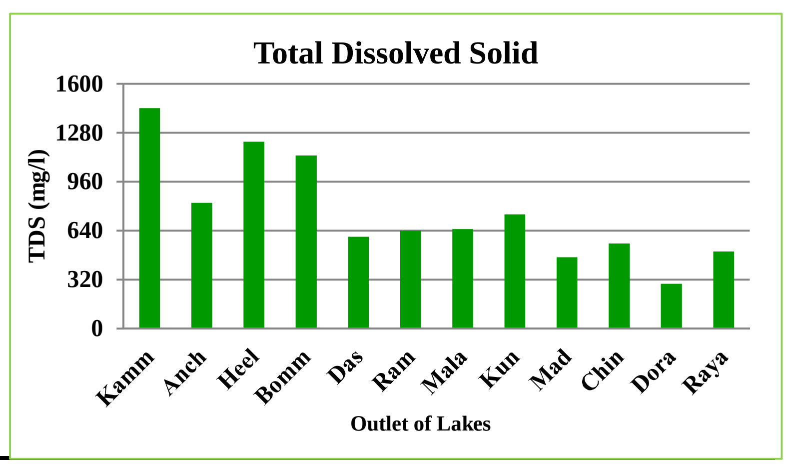


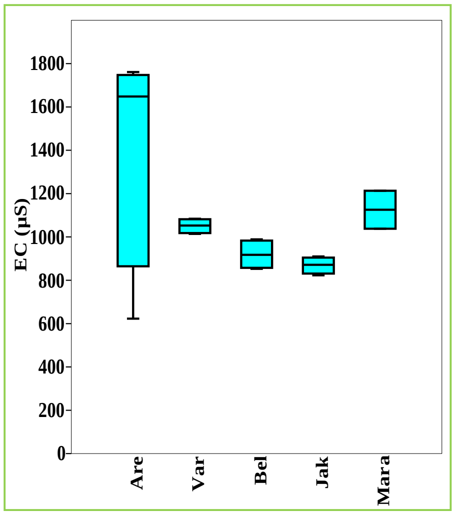
Outlet of lakes values

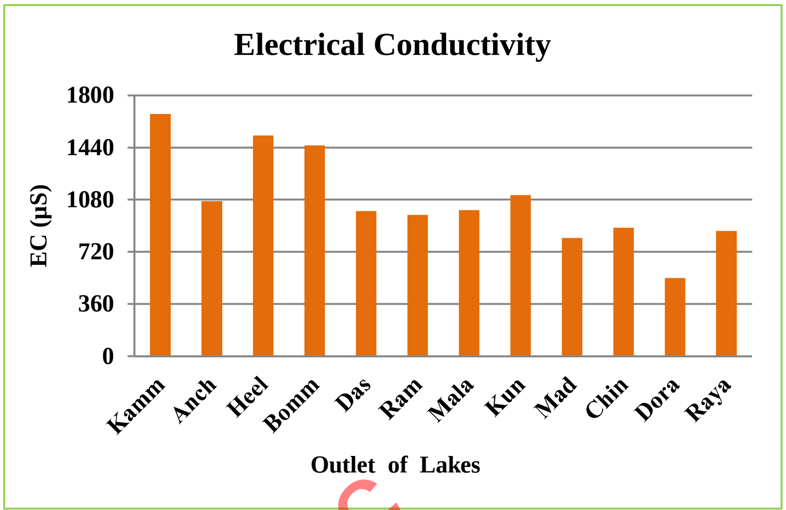


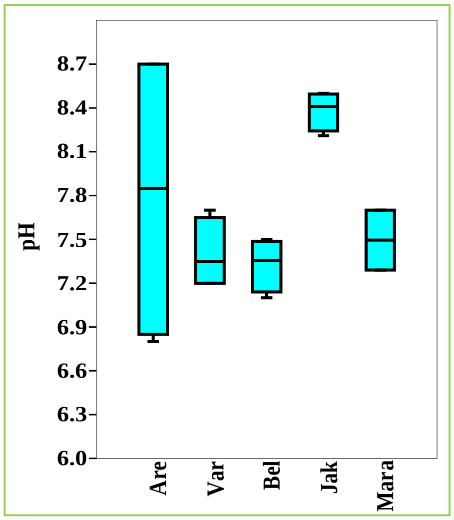


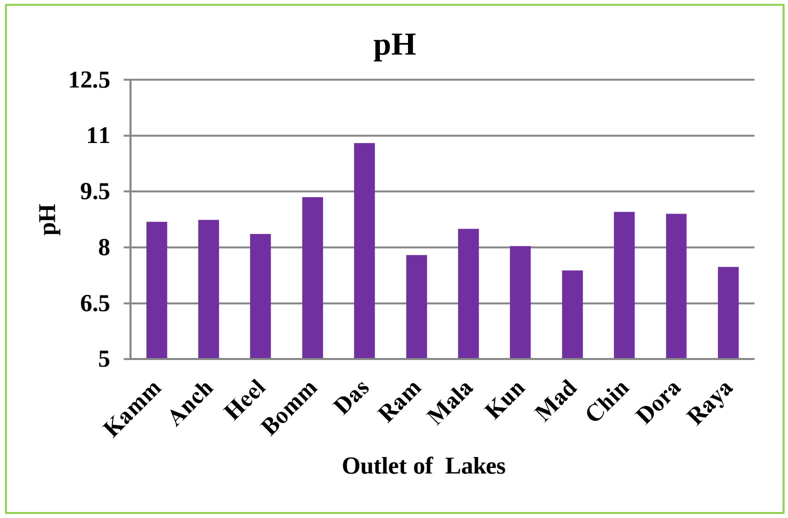


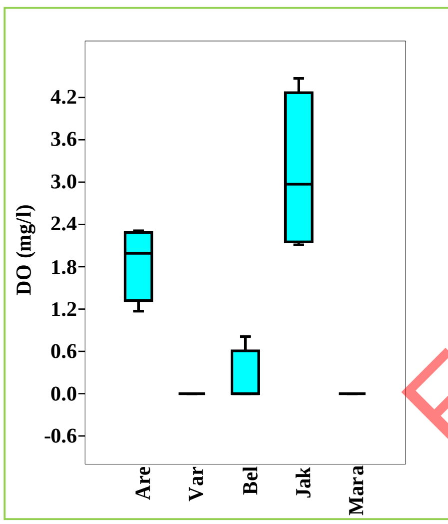


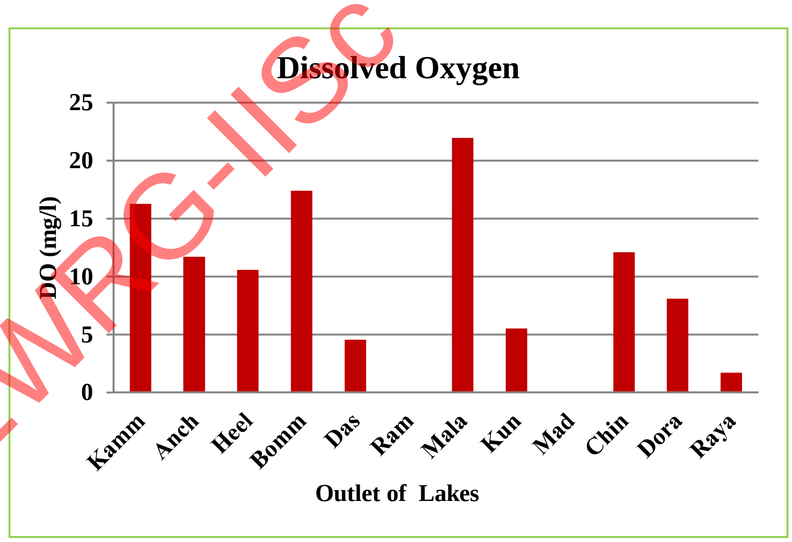

EC (µS)
1800
1600
1400
1200
1000
800
600
400
200
0
Are
Var
Bel
Jak
Mara

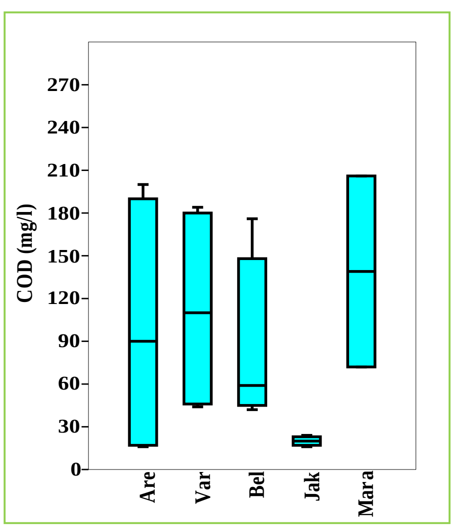

Electrical Conductivity
EC (µS)
1800
1440
1080
720
360
0
Kamm
Anch
Heel
Bomm
Das
Ram
Mala
Kun
Mad
Chin
Dora
Raya
Outlet of Lakes

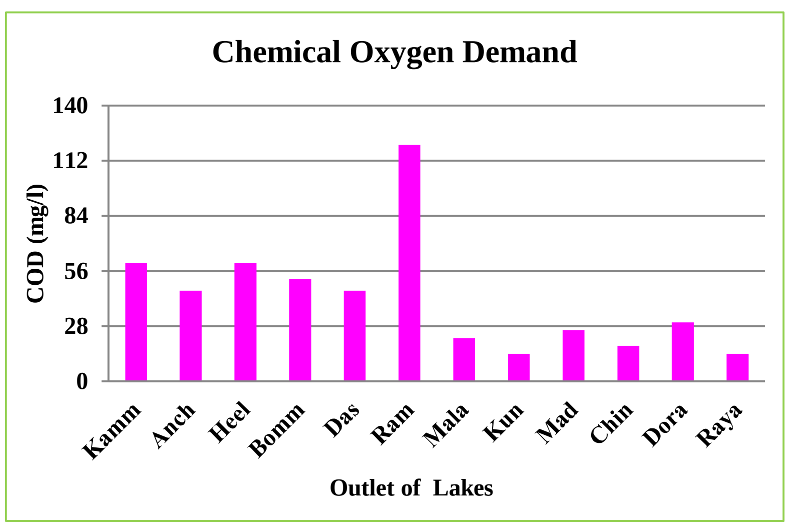

pH
8.7
8.4
8.1
7.8
7.5
7.2
6.9
6.6
6.3
6.0
Are
Var
Bel
Jak
Mara

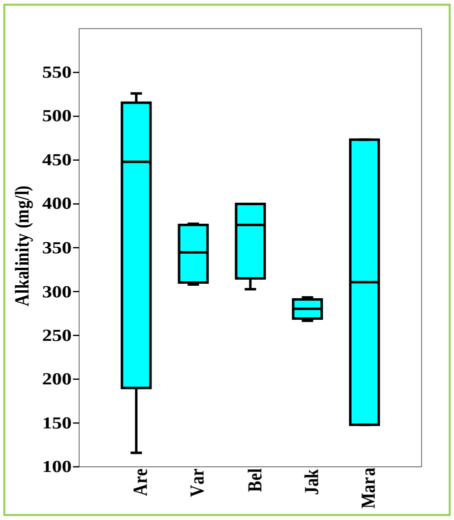

pH
12.5
11
9.5
8
6.5
5
Kamm
Anch
Heel
Bomm
Das
Ram
Mala
Kun
Mad
Chin
Dora
Raya
Outlet of Lakes

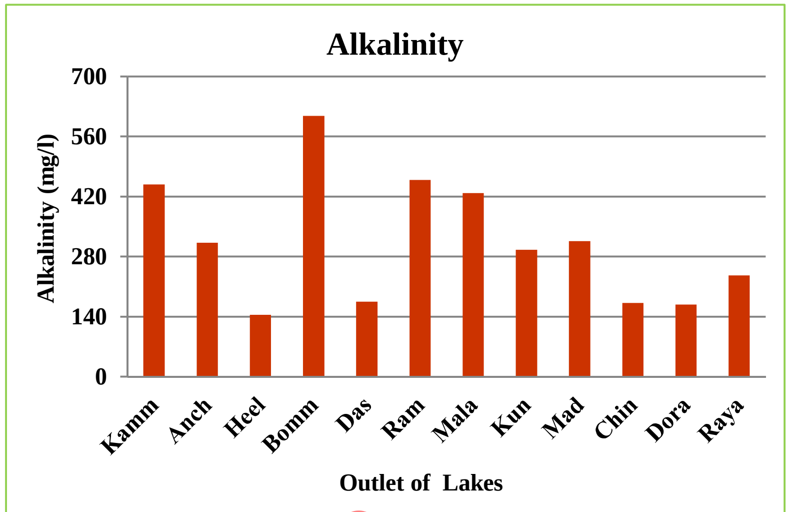

DO (mg/l)
4.2
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6
Are
Var
Bel
Jak
Mara

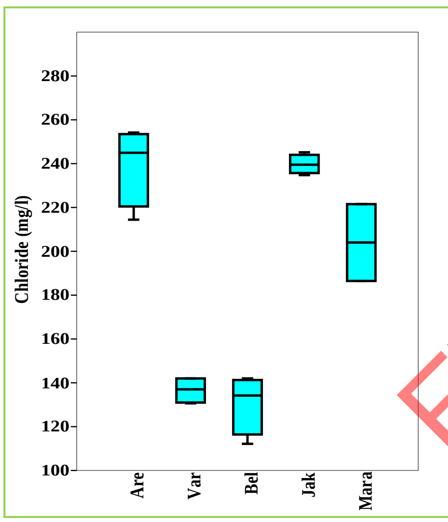

Dissolved Oxygen
DO (mg/l)
25
20
15
10
5
0
Kamm
Anch
Heel
Bomm
Das
Ram
Mala
Kun
Mad
Chin
Dora
Raya
Outlet of Lakes

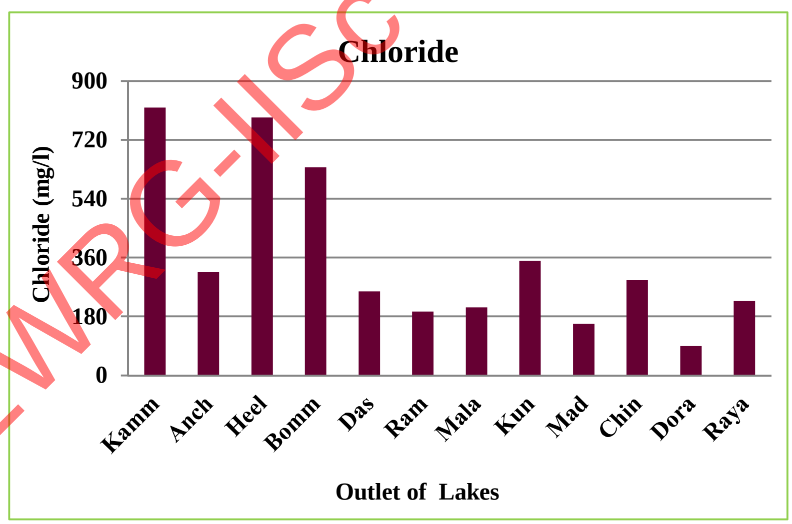

COD (mg/l)
270
240
210
180
150
120
90
60
30
0
Are
Var
Bel
Jak
Mara

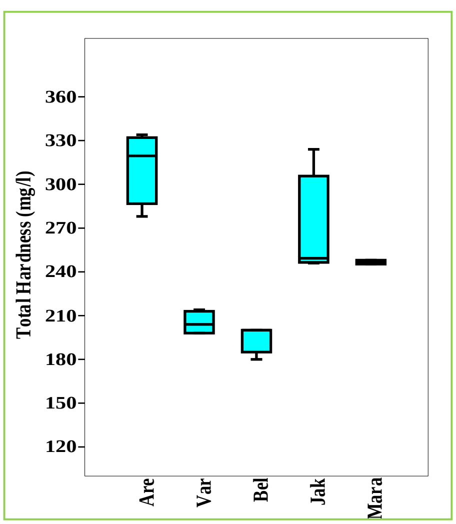

Chemical Oxygen Demand
COD (mg/l)
140
112
84
56
28
0
Kamm
Anch
Heel
Bomm
Das
Ram
Mala
Kun
Mad
Chin
Dora
Raya
Outlet of Lakes

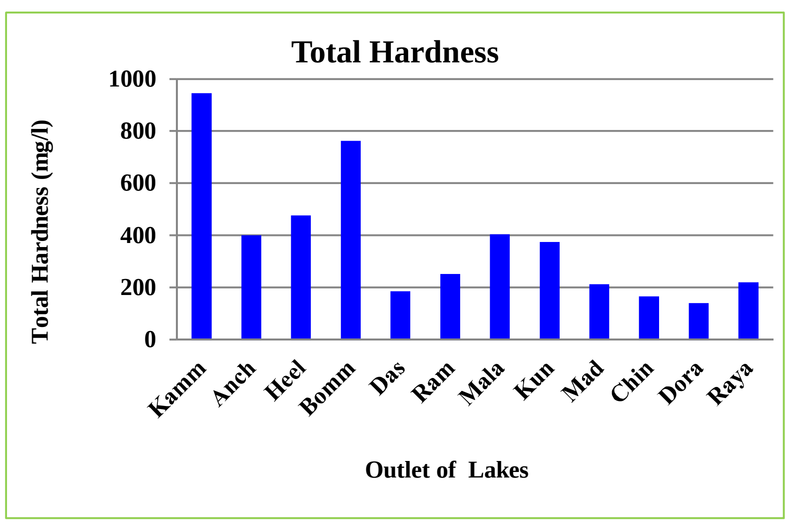

Alkalinity (mg/l)
550
500
450
400
350
300
250
200
150
100
Are
Var
Bel
Jak
Mara

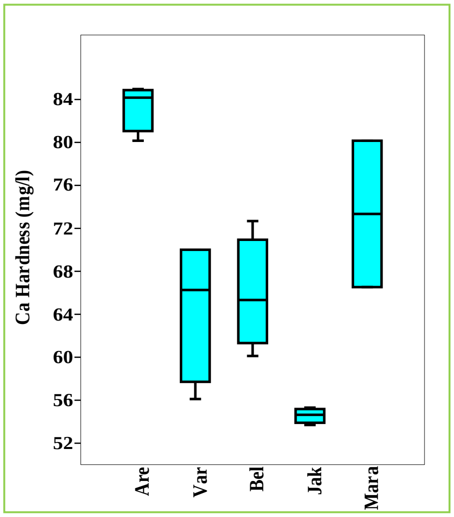

Alkalinity
Alkalinity (mg/l)
700
560
420
280
140
0
Kamm
Anch
Heel
Bomm
Das
Ram
Mala
Kun
Mad
Chin
Dora
Raya
Outlet of Lakes

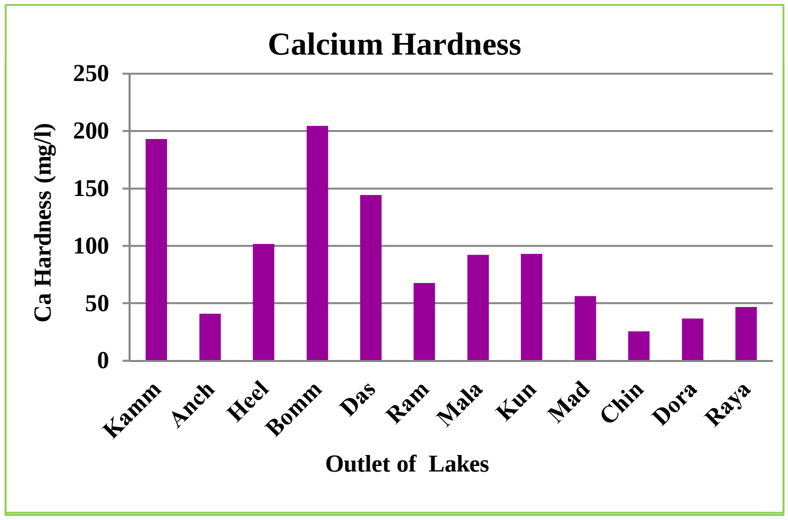

Chloride (mg/l)
280
260
240
220
200
180
160
140
120
100
Are
Var
Bel
Jak
Mara

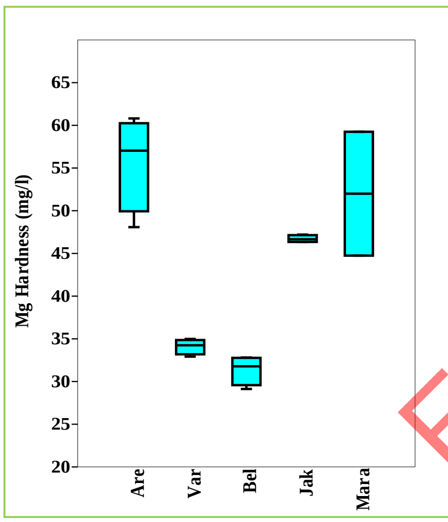

Chloride
Chloride (mg/l)
900
720
540
360
180
0
Kamm
Anch
Heel
Bomm
Das
Ram
Mala
Kun
Mad
Chin
Dora
Raya
Outlet of Lakes

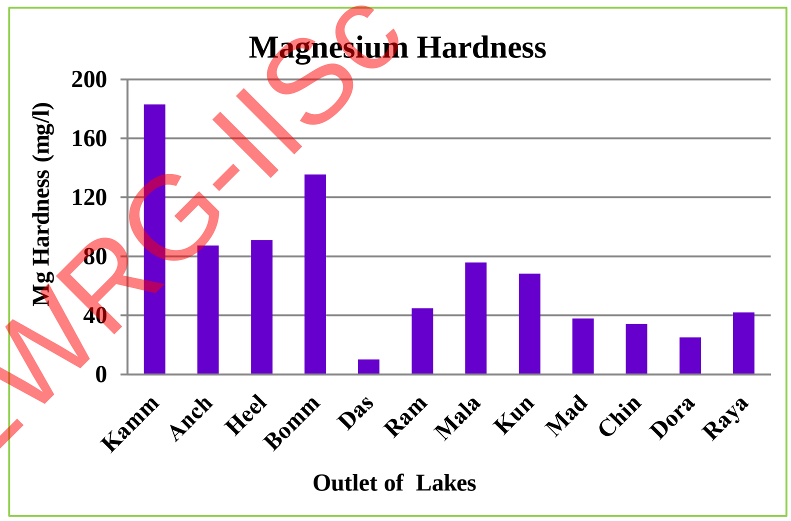

Total Hardness (mg/l)
360
330
300
270
240
210
180
150
120
Are
Var
Bel
Jak
Mara

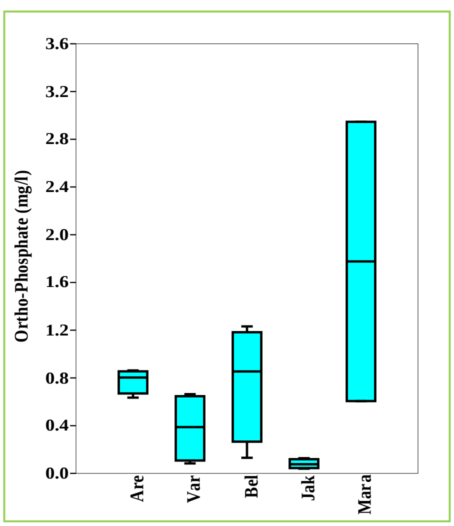

Total Hardness
Total Hardness (mg/l)
1000
800
600
400
200
0
Kamm
Anch
Heel
Bomm
Das
Ram
Mala
Kun
Mad
Chin
Dora
Raya
Outlet of Lakes

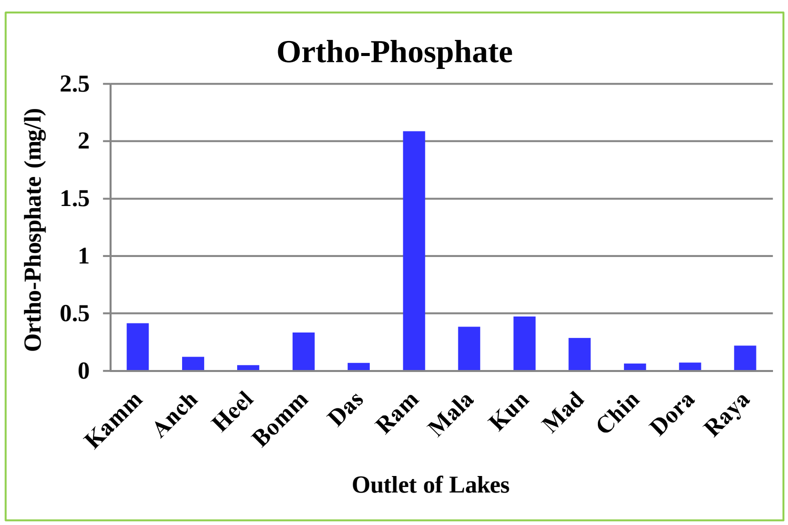

Ca Hardness (mg/l)
84
80
76
72
68
64
60
56
52
Are
Var
Bel
Jak
Mara

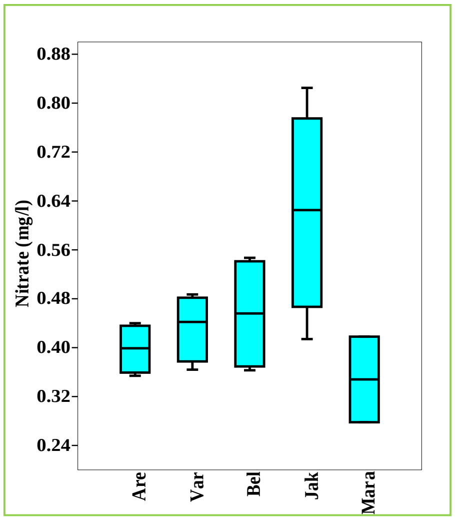

Calcium Hardness
Ca Hardness (mg/l)
250
200
150
100
50
0
Kamm
Anch
Heel
Bomm
Das
Ram
Mala
Kun
Mad
Chin
Dora
Raya
Outlet of Lakes

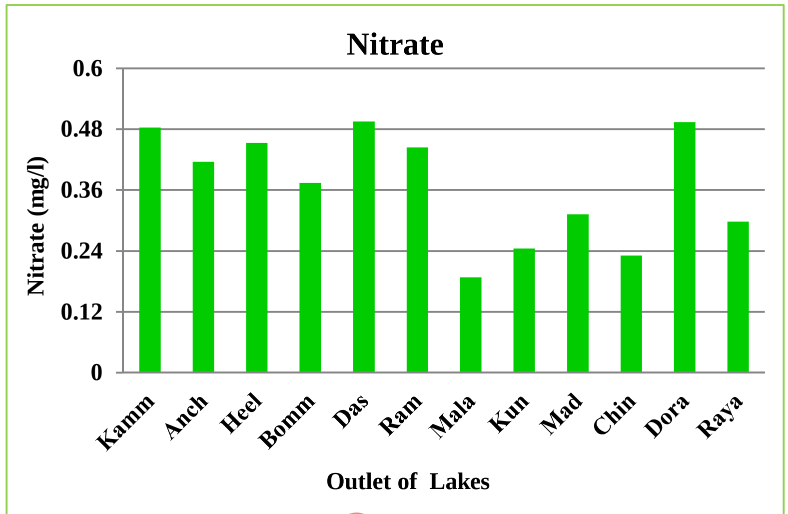

Mg Hardness (mg/l)
65
60
55
50
45
40
35
30
25
20
Are
Var
Bel
Jak
Mara

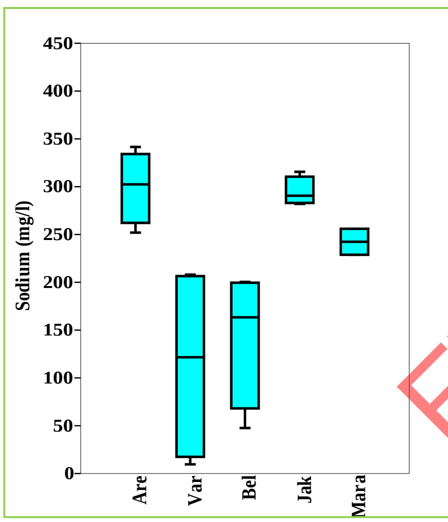

Magnesium Hardness
Mg Hardness (mg/l)
200
160
120
80
40
0
Kamm
Anch
Heel
Bomm
Das
Ram
Mala
Kun
Mad
Chin
Dora
Raya
Outlet of Lakes

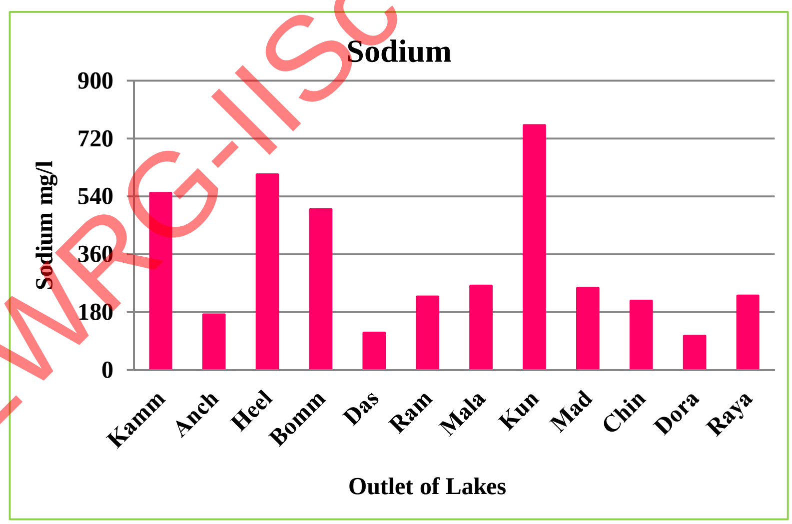

Ortho-Phosphate (mg/l)
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
Are
Var
Bel
Jak
Mara


Ortho-Phosphate
Ortho-Phosphate (mg/l)
2.5
2
1.5
1
0.5
0
Kamm
Anch
Heel
Bomm
Das
Ram
Mala
Kun
Mad
Chin
Dora
Raya
Outlet of Lakes


Nitrate (mg/l)
0.88
0.80
0.72
0.64
0.56
0.48
0.40
0.32
0.24
Are
Var
Bel
Jak
Mara


Nitrate
Nitrate (mg/l)
0.6
0.48
0.36
0.24
0.12
0
Kamm
Anch
Heel
Bomm
Das
Ram
Mala
Kun
Mad
Chin
Dora
Raya
Outlet of Lakes


Sodium (mg/l)
450
400
350
300
250
200
150
100
50
0
Are
Var
Bel
Jak
Mara


Sodium
Sodium mg/l
900
720
540
360
180
0
Kamm
Anch
Heel
Bomm
Das
Ram
Mala
Kun
Mad
Chin
Dora
Raya
Outlet of Lakes

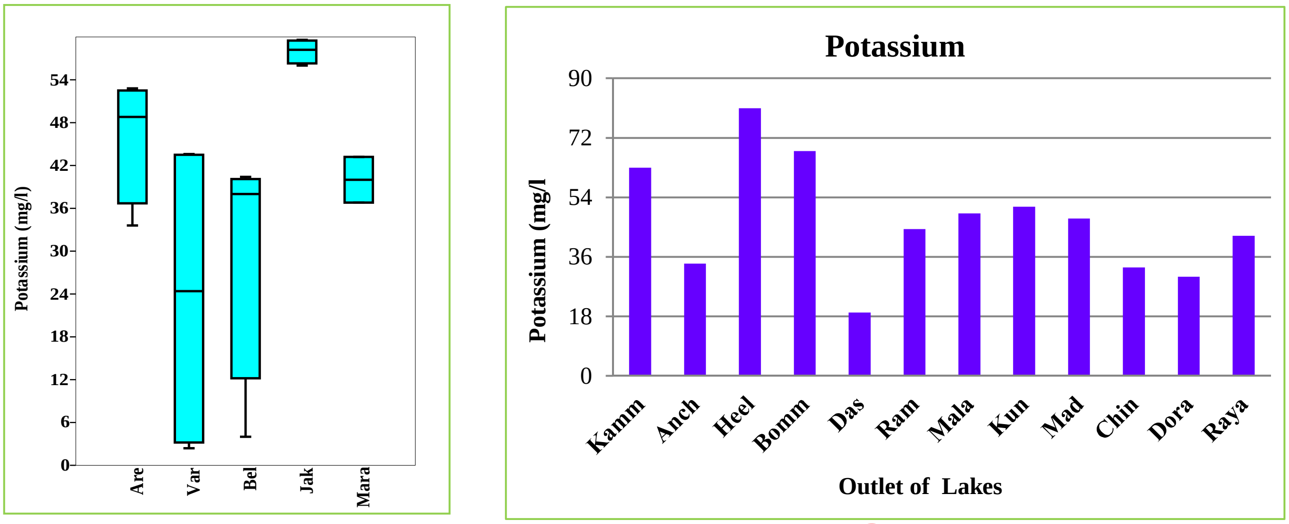


Figure 2: Shows the variations in the physic-chemical characteristics of lakes

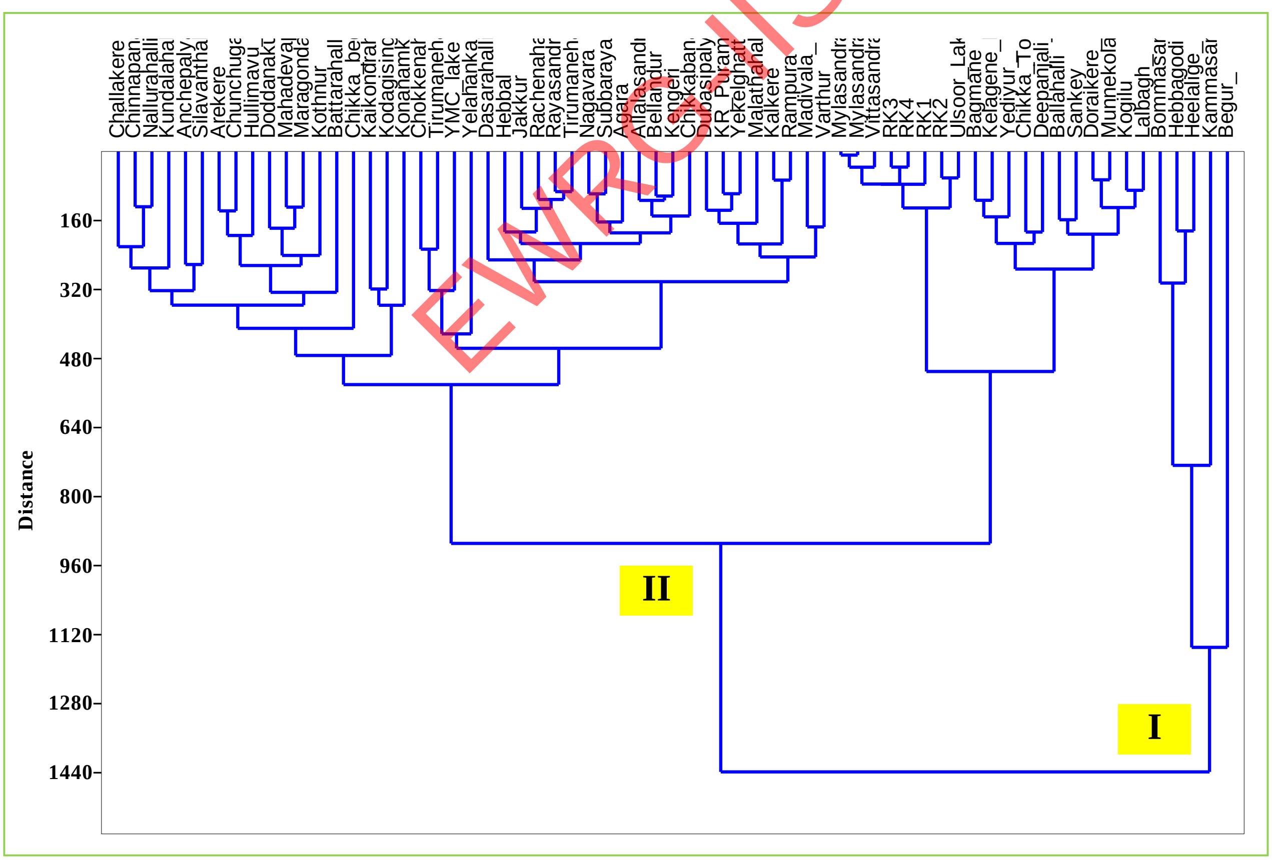


Figure 3: Cluster analysis of lakes based on pollution