

Assessment of water quality of Siliserh Lake in Alwar, Rajasthan

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Certificate

This is to certify that the research work embodied in this dissertation entitled “Assessment of water quality of Siliserh Lake in Alwar, Rajasthan” has been carried out in the Department of Environmental Engineering, Delhi Technological University, Delhi. This work is original and has not been submitted in part or full for any other degree or diploma to any university or institute.

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ABSTRACT

The present study was undertaken to assess water quality of Siliserh Lake in Alwar during the month of March 2018, and to assess its suitability for drinking, irrigation, and industrial usages using various indices. The suitability for drinking and irrigation were determined by comparing the obtained mean value with the BIS standards and prescribed indices. The water of the lake was found to be suitable for drinking for all the parameters, as all the parameters have their average value below the prescribed BIS standard. Slightly raised values were observed near Kishanpura and Ringaspura villages. Based on Piper classification, the water of Siliserh Lake was found to be CaHCO_3 type followed by Ca-Mg-Cl type. The relative dominance of cations represented $\text{Mg} > \text{Ca} > \text{Na} > \text{K} > \text{Fe} > \text{Li}$ trend, and anions represented $\text{HCO}_3^- > \text{Cl} > \text{NO}_3^- > \text{Dissolved SiO}_2 > \text{SO}_4^{2-} > \text{CO}_3^{2-} > \text{PO}_4^{3-}$ trend which validated the the major composition type of water. Based on the concentration of nutrients (nitrogen and phosphorus), the lake was classified as eutrophic and is in the zone of transition from oligotrophic to eutrophic. The partition coefficient with value less than unity for phosphate concentration in sediments to its concentration in water confirmed that the lake is gradually moving from oligotrophic to eutrophic status. Based on concentration of organic impurities, it was observed that most of the organic matter is received through flushing of catchment during monsoon; and autochthonous for rest of the period with BOD and dissolved ammonia levels within the permissible limits for sustaining aquatic life. Various indices used to calculate suitability of lake water for irrigation indicated that the water is good for use in irrigation with the only exception of magnesium hazard owing to high concentration of magnesium. Since the soil around the lake is sandy and permeable, the water is found to be suitable for long term use in irrigation. Since the concentration of dissolved ions in water is less, the water is undersaturated with respect to dissolved salts. Use of such water in industries is safe since it doesn't cause scaling. On the other hand, the water is found to be corrosive with respect to its chemical composition since the concentration of bicarbonate ions was almost three times higher than the concentration of magnesium ions. The FTIR study of sediments and geochemical classification of water revealed that silicate weathering is regulating the water chemistry and rock-water interaction (direct base exchange) is playing a major role in composition of dissolved ions in water.

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List of abbreviations and Symbols

WHO:	World Health Organization
BIS:	Bureau of Indian Standards
ppm:	Parts per million
USEPA:	United States Environmental Protection Agency
DALY:	Disability Adjusted Life Years
LNAPL:	Light non-aqueous phase liquid
DNAPL:	Dense non-aqueous phase liquids
ISCO:	In Situ Chemical Oxidation
TCE:	Trichloroethylene
DPVE:	Dual phase vacuum extraction
MCM:	million cubic meters
BCM:	billion cubic meters
PET:	Polyethylene terephthalate

Chapter 1

INTRODUCTION

INTRODUCTION

Water is an important and precious resource needed to support life. No life can exist without water. It exists in three forms solid, liquid and gaseous form and all the forms of water are extremely useful to human being for fulfilling his basic necessities of life as well as for his luxuries and comforts. Water is essential not only for survival of human being, but also for the survival of plants, animals and other living beings. If there was no water there would be no life on earth. Despite the earth having plentiful amount of water, scarcity of water does exist in large part of world (Igor et al., 1993). Almost three-fourth of the earth's surface is water still there is scarcity of water due the uneven distribution of water. Only 2% of water is fresh water remaining 98% resides in the ocean. Of this fresh water, 1.6% is locked up in polar ice caps and glaciers and 0.36% is found underground in aquifer and wells. Therefore, only about 0.036% of the planets total water supply is accessible in lakes and rivers (Harikishore et al., 2012).

Rivers and lakes are important sources of fresh water. Lakes are mostly fresh water bodies and provide generally purer water than the river system. The primary source of lake water is precipitation which is the purest form of water that may enter the lake directly, as runoff from surrounding higher ground or through small drains. Sometimes, lakes and ponds get formed naturally through some springs that enter natural depression and gets collected. Lakes can be natural or man-made. There are several type, kinds and categories of lakes in the world.

Lakes are classified on the basis of Origin, Trophic levels, mixing of water and nature of inflow-outflow. Trophic level classification is based on the productivity of the lakes. Trophic level states a Water body's Ability to Support Plants, Fish, and Wildlife. They are classified as oligotrophic, meosotrophic and eutrophic in nature. Healthy lakes not only supply their water for domestic uses, agricultural and industrial uses but also provide numbers of environmental benefits and also influence our quality of life which strengthens our economy. A healthy lake eco-system could conserve natural and social balance by contributing healthy environment of its location (Karmakar et. al., 2014). They replenish the groundwater, preserve the biodiversity and habitat of that area, and supports pisci-culture in it. If the lake is large enough it provides means of easy transportation and communication, supply of water for domestic, agricultural and for industrial uses, provides moderating effect on climate and for power generation. Salts and minerals can also be extracted from the lake. Example great Sambar Lake of India. They provide prime opportunities for recreation and tourism.

In present scenario urban lakes are under direct threat of qualitative and quantitative degradation by means of pollution due to Rapid urbanization, industrialization and indiscriminate use of chemical fertilizers and pesticides in agriculture and are causing heavy and varied pollution in aquatic environment leading to deterioration of water quality and depletion of aquatic biota.(Mishra et. al., 2015) There are numerous sources of pollutants that could deteriorate the quality of water resources (Tamiru, 2004). Factors that are directly or indirectly polluting the lake ecosystems includes population growth, unplanned growth of city area, urbanization, agricultural land expansion and lack of awareness among the local residents. All such activities and pollution causing factors are decreasing the utility of water day by day (Tank & Chippa, 2013). Accessible man made urban lakes and all other natural wetlands have gained the thrust of conservation in recent years due to their important functions in different hydrological processes. In relation to lakes across the country, many of them have disappeared due to illegal filling, dumping of waste and drying up of their catchment areas which have been reclaimed for uses like urbanization. Most of the lakes in India are under threat from nutrient overloading, which is responsible for their eutrophication and subsequent choking up from the weeds proliferating in the nutrient-rich water. The reason behind is the degrees of pollution and natural purification are measurable physically, biologically and chemically (Longe & Omole, 2008).

Since the fresh water sources are under threat and gradually becoming polluted, its time to time monitoring has become an important concern worldwide. Lake monitoring has become an essential part of lake management. It may provide early warning signs of ecosystem degradation resulting from contaminant inputs, nutrient addition, sediment runoff, and overuse of the resource. With the monitoring of physical, chemical, and biological status of a lake, changes of many aspects of the ecosystem can be detected quickly, and hopefully, harmful impacts can be eliminated before their consequence become unmanageable. Accurate and timely information on the quality of water is necessary to shape a sound public policy and to implement the water quality improvement programmes effectively and efficiently (Gayathri et. al., 2015).

Keeping in view the above said problems of water pollution in lakes and the need for its monitoring, the present study has been taken to study the Siliserh lake which is an important water body of Rajasthan state. Siliserh lake is a beautiful fresh water lake, spread in 7 sq kms area, and located 13 kms away from Alwar city. The water from the Siliserh lake is used for irrigation, aquaculture, and drinking. It is surrounded by agricultural land, crops and vegetables

from there are being supplied to the Alwar city and Delhi. It has an aquatic ecosystem with the presence of crocodiles, fish etc. The banks of Siliserh Lake are marshy which attracts some migratory birds. Siliserh Lake is also used for aquaculture of fish farming and chestnut within the lake. It is a hub of tourism and offers source of employment in terms of tourism, boating facilities etc. with the social, economic, biological significance it is same time being degraded. Till now, there have been limited studies on this lake, Hence the present study has been undertaken with the following objectives

- To characterize the surface water of Siliserh lake water.
- To determine suitability of water for drinking, irrigation and industrial uses.
- To identify the probable source regulating water chemistry.

Chapter 2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The distribution of water has been seen in previous chapter. From that it can be seen that even with so much water around us, all of that cannot be used to meet our needs. Due to the growing population, urbanization and industrialization various parts of the world are facing water scarcity because of the limited supply of water. If those limited water supply will get polluted that will add more stress on the limited supply of water. The problem of increasing population has become a matter of concern in today's world. And population directly affects the domestic demands of water. With the domestic water demand, water for agriculture and for industrialization and urbanization also increases as they are the key factors of our economy. The effluent from these industries, agricultural fields, mines, domestic waste goes on polluting the water bodies. All this leads to reduction of both quantity and quality of water. There have been number of studies have done in order to understand quality of water bodies and their monitoring.

Water Quality Index (WQI) was calculated for surface water of Sankey tank and Mallathahalli Lake, Bangalore urban district, Karnataka, India by [Ravikumar *et al.* \(2012\)](#). Their work aimed at assessing the water quality index (WQI) in the surface water by monitoring three sampling locations within Sankey tank (viz., A, B and C) and Mallathahalli lake (viz., Inlet, Centre and outlet) for a period of 3 months from March to May 2012. The surface water samples were subjected to comprehensive physico-chemical analysis involving major cations (Ca^{2+} , Mg^{2+} , Na^+ , K^+ , Fe^{2+}), anions (HCO_3^- , Cl^- , SO_4^{2-} , NO_3^- , F^- , PO_4^{3-}) besides general parameters (pH, EC, TDS, alkalinity, total hardness, DO, BOD, COD, CO_2 , SiO_2 , color, turbidity). For calculating the WQI, 14 parameters namely, pH, electrical conductivity, total dissolved solids, total hardness, alkalinity, calcium, magnesium, sodium, potassium, chloride, sulphate, nitrate, fluorides and iron were considered. SAR values indicated that both Sankey tank and Mallathahalli lake waters are excellent (S1) for irrigation, while electrical conductivity values classified this lake water, respectively under medium salinity (C2) and high (C3) salinity category. Correlation between SAR and electrical conductivity revealed that Sankey tank water is C2S1 (medium salinity-low sodium) type while Mallathahalli lake water is C3S1 (high salinity-low sodium) type. Sankey tank and Mallathahalli lake water were, respectively hard and very hard in nature. Further, it is apparent from WQI values that Sankey tank water belongs to good water class with WQI values ranging from 50.34 to 63.38. The

Mallathahalli lake water with WQI value ranging from 111.69 to 137.09, fall under poor water category.

Various physico-chemical characteristics of Katraj Lake which is situated in Pune in Western Maharashtra was also studied by [Khare and Jhadhav \(2008\)](#) in the year 2006-2007. Katraj Lake is a manmade lake situated at the bottom of hill ranges of Katraj Ghat in south west part of the city. It consists of an intricate system of two lakes, canals and dams. Lake acts as a sedimentation tank and the water from the first lake seeps into the second lake. Second lake has natural springs as its main source. The samples were collected by a boat and water analysis was performed on the samples taken. The study reveals that the temperature was found to be in the range between 24C to 28C in pre-monsoon and post- monsoon respectively. The pH was recorded 7.3-8.45. The high value of pH during rainy season may be due to dilution of alkaline substances or dissolution of atmospheric carbon dioxide. The dissolved oxygen varied from 4.8 to 5.7 mg/l. The BOD was recorded in the range 68-78 mg/l. These two parameters are temperature dependent. The chloride ranged from 76.01 to 82.03 mg/l. Chloride in urban areas are indicators of large amount of non- point source pollution by pesticides, grease, oil and other toxic materials. The total Hardness ranged from 160.02 – 298 mg/l. The total alkalinity ranged from 170 to 239 mg/l. The alkalinity might be due to high pH. The TDS ranged from 390 to 465 mg/l. The paper suggested restoration techniques for the lake.

Suitability assessment of groundwater for drinking, irrigation and industrial use in some North Indian villages was conducted by [Haritash et al. \(2008\)](#). A total of 34 groundwater samples were collected from Rewari town and its perimeter from the land chiefly used for agriculture. Rewari is located at 28° 12' North latitude and 76° 40' East longitude in the south–west direction of the national capital Delhi across the Delhi Jaipur National Highway No. 8 at a height of 241.95 m above mean sea level. The district is spread over 1,559 km² area with a total population of 7, 65,351 (2001 census) with sub-tropical continental monsoon climate. Rewari and the neighboring villages, primarily engaged in agriculture as a profession, were selected for the study. The villages identified in the perimeter of Rewari town were Gokalgarh (Sample nos. 1 and 2), GangaichaAhir (3–5), Dayaki (6 and 7), Tahana (8– 10), Mastapur (11–14), Harinagar (15–19), Thotwal (20–23), Hussainpur (24– 28), and some of the areas of Rewari town (29–34). All the samples were obtained in the month of May, 2001 from the hand pumps or tube-wells on agricultural land, the water being used for drinking and/or irrigation. Physico-chemical characterization of the samples revealed that groundwater from most of the

sources was not fit for drinking owing to a high concentration of calcium, magnesium, hardness and fluoride. Suitability for irrigation, too, was low since most of the sources had high value of sodium adsorption ratio (SAR), residual sodium carbonate (RSC), soluble sodium percentage (SSP) and magnesium hazard which can render salinity and alkali hazard to soils on long term use in irrigation. No source of water was found to be suitable for industrial application since it had high concentration of calcium carbonate which can precipitate very easily. It was observed that sodium, sulphate, and chloride were the chief ions present in water and based on the abundance of ions and their correlation type, most of the groundwater samples are of sodium sulphate and/or sodium chloride type. The high concentration of the chemical constituents is attributed to the lithological composition of the area. It was observed that the water of deep meteoric percolation type was of sodium sulphate type and the shallow of sodium chloride type.

Similarly, suitability of groundwater for irrigation uses in Alathur Block located in Perambalur District of the state of Tamil Nadu was studied by [Loganathan *et al.* \(2013\)](#). Perambalur is a centrally located inland district of the state of Tamil Nadu, India, spread over 3, 69,007 ha. The net area under irrigation is 71,624 ha. Alathur is one of the major blocks in this district. Ground Water samples from ten villages were analyzed in two seasons for major cations, anions and other parameters such as electrical conductivity, total dissolved solids, Kelly's ratio, sodium absorption ratio (SAR), magnesium ratio, percent sodium, chloro-alkaline indices, residual sodium carbonate and permeability index to know the suitability of groundwater for irrigation purpose. Piper trilinear diagram interpretations were made to know the suitability of chemical type of the groundwater. It reveals that the subsurface water is alkaline than the alkaline earth type. According to the SAR values plotted in the USSS Staff diagram, most of the groundwater samples belong to class high-salinity hazard and low-sodium hazard (C3-S1) and high-salinity hazard and medium-sodium hazard (C3-S2), which indicate that the groundwater of most stations require a special type of irrigation method.

[Al-Ahmadi *et al.* \(2013\)](#) performed and studied the Hydro chemical characterization of groundwater in wadiSayyah, Western Saudi Arabia. A total of 42 groundwater samples are collected from hand dug wells in this area and they were analyzed for various physical and chemical parameters. The sequence of the abundance of the major ion is in the following order: $\text{Ca}^{2+} > \text{Na}^+ > \text{Mg}^{2+} > \text{K}^+$ and $\text{Cl}^- > \text{SO}_4^{2-} > \text{HCO}_3^- > \text{NO}_3^-$. The dominated hydro chemical

faciases of groundwater are: CaCl, and mixed CaMgCl, and the alkaline earths (Ca^{2+} , Mg^{2+}) and strong acids (SO_4^{2-} Cl^-) are dominating over alkalis and weak acids. Statistical analysis indicates positive correlation among most of the chemical parameters. Based on the analytical results, groundwater in the study area is generally hard to very hard, fresh to brackish and alkaline in nature. The rock weathering and evaporation are among the most dominant processes in controlling water quality. The chloro-alkali indices illustrate that 80 % of the water samples have positive indicating exchange of Na^+ and K^+ from water with Mg^{2+} and Ca^{2+} from the rock. The suitability of water for drinking and irrigation is determined using WHO standards for drinking; some indices for irrigation purposes and it indicates that the groundwater in the study area can be used for drinking purposes in most of the locations (31 wells), while it is suitable for irrigation uses.

Suitability of groundwater quality for drinking and agricultural purposes in a predominantly farming and sprawling settlement in the Ga East Municipality (Ghana) was studied by Ackah *et.al.* Various water quality parameters were determined to assess groundwater quality of 16 wells in Teiman-Oyarifa community. The results revealed that groundwater in the study area were mostly acidic. Most of the water samples recorded TDS values less than WHO maximum allowable levels. Sodium ion concentration was generally high compared to other cations. The amounts of iron in the water samples were higher than recommended maximum allowable levels. Iron is a major component of all the wells and probably originated from the parent rocks. The measured concentrations of zinc in all the water samples were below WHO maximum permissible levels. Sodium Adsorption Ratio (SAR) values suggests suitability of groundwater from the study area for irrigation.

An assessment of the physio-chemical parameters of Oran Sebkhah basin was conducted by Nabila *et al.* (2014). In order to characterize the groundwater quality in the dry season, a sampling network was chosen to allow the acquisition of representative data on the spatial and temporal variability. This network covers the entire basin upstream to downstream and consists of a set of points of water wells, boreholes and springs. In all water samples, a critical look at the results revealed that the values of these physio-chemical parameters are higher in the basin based on geological position; discharges of industrial wastewater and contamination of the groundwater by seawater were excluded as the source of high concentrations. The quantity of waste in different phases of a natural aquatic system is reflected by the level of hardness, alkalinity and other physio-chemical parameters. The higher values of all these physio-

chemical parameters than those obtained could be a result of washing away of sulphate based fertilizers into the river. The results of this study show that analysis of hydro chemical data using statistical techniques such as inverse geochemical modelling of the statistical clusters can help to elucidate the geological factor controlling water chemistry. The groundwater in the studied area evolves from less saline Ca–Mg–HCO₃ water to blended Mg–Ca–HCO₃–Cl water to brackish Mg–Ca–Cl–HCO₃ water along the topographic flow path. The analysis indicates that the water of Oran sebkha basin is characterized with moderate alkalinity in the investigated period. Mineral saturation indices calculated from both major ions indicate that the groundwater is generally supersaturated with respect to most of the carbonate and silicate phases and is most probably responsible for the composition of the groundwater. Inverse geochemical modelling along groundwater flow paths indicates the dissolution of evaporate minerals, precipitation of carbonate minerals and weathering reactions of silicate minerals.

Similar work for determining water quality index (WQI) for the ground water of Indore City and its industrial area was studied by [Dohare et al.](#) The ground water samples of all the selected stations from the wards were collected for a physiochemical analysis. For calculating present water quality status by statistical evaluation and water quality index, following 27 parameters have been considered Viz. pH, color, total dissolved solids electrical conductivity, total alkalinity, total hardness, calcium, chromium, zinc, manganese, nickel. The results revealed that water quality is dependent on the type of the pollutant added and the nature of mineral found at particular zone of bore well. Estimation of water quality index through formulation of appropriate using method and evaluate the quality of tube well water by statistical analysis for post and pre monsoon seasons i.e. from Nov. to Feb. and March to may Result of water quality assessment showed that most of the water quality parameters slightly higher in the wet season than in the dry season.

Study of ground water quality for irrigation in Bandalamottu lead mining area, Guntur District, Andhra Pradesh, South India was done by [Nagarajuet et al. \(2014\)](#). The Bandalamottu base metal belt (Lat. 16°13': Long79°39'), is located in VinukondaTaluk of Guntur District in the northeastern part of the Cuddapah Basin and constitutes one of the prominent base metal deposits in India. About 30 copper–lead–zinc occurrences are localized within this belt, with Bandalamottu, Nallakonda and Dhukonda constituting the main deposits. The groundwater samples were analyzed for distribution of chemical elements Ca²⁺, Mg²⁺, Na⁺, K⁺, Fe²⁺, HCO₃⁻, Cl⁻, SO₄²⁻, NO₃⁻, F⁻, PO₄³⁻. It also includes pH, electrical conductivity, total hardness,

non-carbonate hardness and total alkalinity. The parameters, such as sodium absorption ratio (SAR), adjusted SAR, sodium percentage, potential salinity residual sodium carbonate, non-carbonate hardness, Kelly's ratio, magnesium ratio, permeability index, indices of base exchange (IBE) and Gibbs ratio was also calculated. The major hydro chemical facieses were Ca-HCO₃, Ca-Na-HCO₃ and Ca-Mg-Cl types. The result of saturation index calculated by Visual MINTEQ software combined with Gibbs diagram and IBE findings indicate that, dolomite and calcite dissolution and reverse ion exchange can be a major process controlling the water chemistry in the study area. The results also showed that the salinity (85 %, C3 class) and alkalinity due to high concentration of HCO₃⁻ and CO₃⁻ and low Ca: Mg molar ratio (97.5 %, \1), are the major problems with water for irrigation usage. As a result, the quality of the groundwater is not suitable for sustainable crop production and soil health without appropriate remediation.

Groundwater quality in the industrial zone of Visakhapatnam, a port city was studied by [Abbulu *et al.*](#) . Groundwater samples collected from 114 sampling locations covering uniformly the entire industrial zone of the city are analysed for various physico-chemical characteristics to assess the groundwater quality. The results revealed that pH, Conductivity, Alkalinity and Turbidity are found to be within the permissible limits, over the entire study area, Chlorides and Iron are also found to be in acceptable limits, Hardness, Calcium and Sulphates are found to be more than the permissible limits in the wards covering the entire port area, nitrates are found to be in permissible limits except in ward no. 45, fluoride is found to be exceeding the permissible limit of 1.5 mg/l in the region surrounding steel plant.

The study of correlation-regression model for physico-chemical quality of groundwater in the South Indian city of Gulbarga was done by [Saleem *et al.*](#) (2012). Gulbarga is a major city in the south Indian state of Karnataka. It covers an area of 54.13 km², with a population of 430,000. The study area is identified as a chronically drought prone district of the Karnataka state, due to less and variable occurrence of annual rainfall. The district is underlain by the Deccan traps of upper Cretaceous to Eocene age. Groundwater occurs in the deeper weathered and fractured zones. It occurs in water table condition in weathered zone and in semi confined conditions in the fractured and joined formations. Groundwater samples were collected in clean plastic containers of 2 L capacity during March 2009 from 150 bore wells, spread in all 55 municipal wards of the city. The selected bore wells are both municipal and private owned and

were fitted with either hand pump or electric motor and were being used to supply water for domestic demand. Water of the bore well was run for 2 to 3 min and the containers were rinsed with the sample water prior to collection of the sample. 150 bore well water samples were analysed for electrical conductivity (EC), pH, total dissolved solids (TDS), total hardness (TH), Ca^{2+} , Mg^{2+} , Na^+ , K^+ , HCO_3^- , CO_3^{2-} , Cl^- , SO_4^{2-} , NO_3^- , F^- and Fe^{2+} . All tests were performed as per standard methods and water quality was compared for both Indian and WHO drinking water standards. Significantly positive correlation at 1 and 5% was found between many parameters. EC prediction with multiple R^2 value of 0.999 indicated that 99.9% variability in observed EC could be ascribed to Cl^- (76%), HCO_3^- (12.5%), NO_3^- (10.3%) and SO_4^{2-} (1.1%). Multiple regression models can predict EC at 5% level of significance. Nitrate, chlorides, TDS and fluoride concentration exceed permissible level of drinking water in 75, 41, 95 and 3.33% of the samples respectively. It is recommended to treat groundwater prior to domestic use.

Groundwater quality of Greater Visakhapatnam Municipal Corporation (GVMC), Andhra Pradesh, India and analyzed for their physicochemical characteristics was done by [Satyanarayana et.al. \(2012\)](#). The results of this analysis were compared with the water quality standards of WHO, BIS and CPHEEO. The water samples have been collected from 21 bore wells in GVMC area in Visakhapatnam city. In this analysis the various physicochemical parameters such as pH, EC, Total Dissolved Solids, Total Hardness, Ca, Mg, Na, NO_3^- , K, Fe, Cl, SO_4 , Cr, Cu, HCO_3 and Manganese were determined using standard procedures. The results revealed that In this study, the most of the major ions of the water samples from industrial area have been found in excess of BIS, WHO and CPHEEO recommended guide line values due to impact of industrial effluents. The water quality of the various areas in GVMC clearly indicates that the water samples are highly polluted.

[Padmanabha and Belagali \(2005\)](#) monitored the water quality of four lakes in Mysore city during November 2004 to April 2005. Based on pH, total alkalinity, total hardness, chloride, calcium, magnesium, total dissolved solids, dissolved oxygen and BOD, it was found that the water of these lakes was severely polluted and unfit for human consumption. [Mahesha and Balasubramanian \(2010\)](#) found the Dalvoy Lake of Mysore city as having poor water quality. [Sisodia and Moundiotiya \(2006\)](#) found that the Kalakho Lake of Rajasthan has poor water quality due to lack of proper sanitation, flow of untreated municipal sewage and agricultural

runoffs. In both cases, the lake water was found unfit for drinking and propagation of wild life and fish culture. Further, [Moundiotiya & Sisodia \(2004\)](#) studied the physicochemical parameters of the Jamwa Ramgarh wetland and advocated habitat conservation and ecological restoration as the measures to prevent the wetland from becoming ecologically inactive. The water quality assessment done by [Khare and Jhadav \(2008\)](#) on the Katraj Lake, Pune, Maharashtra concluded that all the physicochemical parameters such as temperature, pH, dissolved oxygen (DO), Biochemical Oxygen Demand (BOD), chloride, hardness and alkalinity were within the permissible limits, only shooting high during the rainy season due to dilution of substances in water. [Mishra et al. \(2011\)](#) found higher values of electrical conductivity (422mg/l), turbidity (33.9 mg/l), total dissolved solids (673.25 mg/l), total hardness (177.58 mg/l), alkalinity (217.16 mg/l), chlorides (81.52 mg/l), biological oxygen demand (17.47 mg/l), chemical oxygen demand (54.74 mg/l), phosphate (2.35 mg/l) and nitrate (1.46 mg/l) than the prescribed standards. The study revealed low Dissolved Oxygen content than prescribed standards and the water was alkaline and hard. There was seasonal variation in water quality parameters. The results have clearly indicated that this lake is polluted and eutrophic in nature due to discharge of sewage and other anthropogenic activities. [Laishram and Dey \(\)](#), on assessment of Loktak Lake in Manipur found that the physicochemical properties of DO and BOD are above the WHO standard limit due to discharge of municipal sewage, domestic wastes, fertilizers and pesticides from agricultural practices disturbing the ecology of the Loktak Lake and potable nature of the water. Hence, we can conclude that the water of the Loktak Lake is polluted.

Surface Water Quality Assessment of Wular Lake, A Ramsar Site in Kashmir Himalaya, using Discriminant Analysis and WQI was done by [Bhat et al. \(2014\)](#). Surface water samples (0.5–1.0 m) were collected from five sites on monthly basis from February 2011 to January 2013. On each sampling date, three replicates were collected at each sampling site. The water samples were preserved in prerinsed 1-L polypropylene, acid-washed sampling bottles at 4°C in darkness and analyzed within 24 h. A saturated mercuric chloride solution was used at a final concentration of 0.2 mL⁻¹ to stop all microbiological activities in the water samples. The parameters including depth, transparency, temperature, pH, and conductivity were determined on spot while the rest of the parameters were determined in the laboratory. The parameters including orthophosphorus, total phosphorus, ammoniacal nitrogen, nitrite nitrogen, nitrate nitrogen, organic nitrogen (Kjeldahl nitrogen minus ammoniacal nitrogen), alkalinity, free

CO₂, conductivity, chloride, total hardness, calcium hardness, magnesium hardness, Na, K, silicate, sulphate, iron, and TDS were determined in the laboratory within 24 hours of sampling. Multivariate techniques, discriminant analysis, and WQI were applied to analyze a water quality data set including 27 parameters at 5 sites of the Lake Wular in Kashmir Himalaya from 2011 to 2013 to investigate spatiotemporal variations and identify potential pollution sources. Spatial and temporal variations in water quality parameters were evaluated through stepwise discriminant analysis (DA). The first spatial discriminant function (DF) accounted for 76.5% of the total spatial variance, and the second DF accounted for 19.1%. The mean values of water temperature, EC, total-N, K, and silicate showed a strong contribution to discriminate the five sampling sites. The mean concentration of total-N, and sulphate showed a strong contribution to discriminate the four sampling seasons and accounted for most of the expected seasonal variations. The results of water quality index, employing thirteen core parameters vital for drinking water purposes, showed values of 49.2, 46.5, 47.3, 40.6, and 37.1 for sites I, II, III, IV, and V, respectively. These index values reflect that the water of lake is in good condition for different purposes but increased values alarm us about future repercussions.

Physio-Chemical parameters for determining Water Quality of Shahpura Lake, Bhopal (M.P) with Special Reference to Pollution Effects on Ground Water of its Fringe Areas was done by [Trivedi et al. \(2012\)](#). The result revealed that the surface water of Shahpura Lake has shown lesser values of the parameters pH, total hardness, EC, TDS in comparison to the groundwater samples. However, the nitrates and microorganisms (Coliform bacteria) showed very high values in lake water. Studies carried out in present investigation revealed that one of the most important causes of water pollution is unplanned urban development without adequate attention to suitable management of sewage and waste material. It was summarized that propagation of pollution front in groundwater aquifer of the fringe area of Shahpura Lake is governed by the hydraulic gradient enhancing influent seepage from Shahpura Lake. The alarm bell therefore rings at the doorstep with the fear of polluting the ChunaBhatti groundwater sanctuary which supports tens of hundreds of water takers from the tube wells of the fringe area of Shahpura lake for water supply in different parts of Bhopal city. Also the entire population of ChunaBhatti Township depends on the water supply from Tube wells/ Bore wells. It is therefore, recommended that this groundwater supply from Tube wells should be used as drinking water only after pre-treatment.

A similar study was undertaken in lake Pichola In Udaipur by [Lal & Sharma \(2017\)](#). The study has been carried out to investigate the impact of organic loadings on water quality in relation to

fish and fisheries of Lake Pichhola. The physico-chemical parameters of water have been studied at two locations for a period of four months from February, 2010 to May, 2010. On the basis of physico-chemical characteristics, Lake Pichhola is nutrient rich, alkaline and hard water body. The water quality indicated the suitability of Lake Pichhola for fishery purpose. The orthophosphate is recorded in very high amount (0.05-1.25 mg/l) which already crossed the critical level. The lake Pichhola with high EC and TDS could be considered eutrophic. The water quality of Lake Pichhola is highly polluted. Attempt has been made to relate water quality with the observed waste water discharge in this lake. The overall results from the present investigation indicate that this water body is rapidly under going through process of eutrophication advancement. Therefore, suitable restoration programme should be initiated for the sustained use of this lake, as the lake attracts thousands of tourists from domestic and international level every year.

A similar study on relatively less studied Lake Siliserh was done by [Vashistha et al. \(2016\)](#) to study seasonal variation during a year. Water quality of Siliserh lake was studied for period of one year on the basis of monthly sampling. Correlation between various physiochemical parameters were also calculated according to Karl Pearson's formula. This study has provided the first data set for water quality of lake. The value of various physico-chemical parameter were temperature (90°C to 31°C), pH (7.1 to 8.3), electrical conductivity (127.0 µmhos/cm to 454.2 µmhos/cm), dissolved oxygen (4.5 mg/L to 12.5 mg/L), free CO₂ (3.08 mg/L to 12.32 mg/L), alkalinity (70 mg/L to 161.6 mg/L), acidity (2.4 mg/L to 68.0 mg/L), Hardness (56.8 mg/L to 148.6 mg/L), nitrate (1.0 mg/L to 5.78 mg/L), phosphate (0.004 mg/L to 0.022 mg/L), biological oxygen demand (2.04 mg/L to 8.98 mg/L) and sulphate (3.9 mg/L - 21.0 mg/L). Dissolved O₂ showed negative correlation with temperature, acidity, nitrate and sulphate. All the physico-chemical factors studied except BOD studied were found within the permissible limit for drinking water as recommended by Bureau of Indian Standard (BIS). The lake was found to be slightly eutrophic during monsoon months. Main reason was nutrients and other organic matter from the agriculture fields in the catchment area are brought to the lake due to influx of rain water.

Since there is only one study on water quality analysis of Siliserh lake, and it is fast growing popularity as a tourist destination; it is important to monitor its water quality on regular basis. The present study is devised to extend the work on Lake Siliserh to draw the present status of water quality *w.r.t.* its use and to classify it based on various indices.

Chapter 3

MATERIALS AND METHODS

MATERIALS AND METHODS

3.1 Study Area

Alwar is a city in northern Indian state of Rajasthan and it is located at 27°02'38"N, 74°21'79"E, 50 km south of Delhi. It is a hub of tourism with few forts and lakes, heritage havelis and nature reserves. Siliserh Lake is the largest lake of the city followed by Jaisamand Lake. Siliserh lake is beautiful tourist place in Alwar city surrounded by green Aravali mountain range of Rajasthan, India. It has a catchment area of 11.25 sq km with the maximum water level of 9.75m. About 4.814 MCM of water is discharged from the lake for irrigation and used in culturable command area of 7.2 km². The lake is also used for fish productivity and developed as tourist spot with boating facility.



Fig.3.1 Location of Siliserh Lake and sampling locations.

3.2 Collection of water samples

The water samples were collected from the Siliserh Lake in the month of April, 2018. Samples were collected directly from the lake in the pre rinsed fresh PET bottles and were filled up to the

brim and tightly closed to secure it from the leakage. Total number of water samples were sixteen, they were labeled from 1-16 as per the location and the coordinates were noted to mark them on the map (Table 3.1). A boat was used to collect the samples and to cover the entire lake. Four samples of sediments were also collected and labeled in the bottles. A grab sampler was used to collect the samples from bottom of the lake. Determination of pH, electrical conductivity (EC), total suspended solids (TDS), oxidation reduction potential (ORP) and dissolved oxygen (DO) were done onsite using Orion (USA) make star A320 model multi-parameter meter. Further the so collected samples were stored at the low temperature in an ice box and were analyzed within 24-48 hours in the lab for rest of the parameters.

Table 3.1: Metadata of Sampling Locations in Siliserh lake.

S.No.	Sample	Coordinates		Particulars
		Latitude (27°N)	Longitude (76°E)	
1	S1	32'06.92"	31'30.89"	Near to agricultural strip
2	S2	32'01.89"	31'47.59"	Channel through agricultural strip
3	S3	31'50.44"	31'32.94"	Nearby agricultural fields(marshy land)
4	S4	31'48.76"	31'48.69"	Channel through agricultural strip
5	S5	31'41.50"	32'15.15"	Across the hill, Ringaspura
6	S6	31'36.19"	31'30.42"	Paitpur village
7	S7	31'36.05"	31'49.01"	Near the centre platform
8	S8	31'34.79"	32'06.02"	Near the platform for bridge
9	S9	31'29.49"	32'14.52"	Agricultural fields of Ringaspura
10	S10	31'24.04"	31'37.19"	Near to lake palace
11	S11	31'21.24"	31'53.10"	Boating platform
12	S12	31'23.62"	32'03.03"	Near to centre platform (aquatic weeds)
13	S13	31'12.30"	32'06.65"	Eastern bank
14	S14	31'14.54"	31'56.72"	South of lake palace
15	S15	31'05.74"	31'58.93"	Near the dam
16	S16	31'07.00"	32'08.22"	Near the dam



Fig 3.2 Collection of water samples from Siliserh Lake, Alwar.

3.3 Analysis of samples

In order to find quality of water certain indicators or parameters are being used referred as water quality parameters. Determination of pH, electrical conductivity (EC), total suspended solids (TDS), oxidation reduction potential (ORP) and dissolved oxygen (DO) were done onsite using Orion (USA) make star A320 model multi-parameter meter. The characterization of the samples was performed in triplicate following standard prescribed methods (APHA, 2005) using analytical grade (AR) chemicals and ultrapure (type 1) water. The total alkalinity (TA), total hardness (TH), chloride (Cl^-), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) and silicate were analyzed by volumetric analysis; phosphate (PO_4^{3-}), sulphate (SO_4^{2-}), nitrate (NO_3^-), and iron (Fe) were determined spectrophotometrically on LabIndia make UV3092 model double beam UV-vis spectrophotometer. The cations, sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}) and lithium (Li^+), were analyzed on Systronics make 128 μC model flame photometer. Determination of chief minerals present in the sediments were found using FTIR spectroscopy (Perkin Elmer make Spectrum 2 model). Statistical analysis of the data obtained after analysis was performed over SPSS 25 and MS excel.

Procedures for Analysis

pH

pH measures the hydrogen ion concentration in water. It is measured on a log scale and equal to negative \log_{10} of hydrogen ion concentration. The pH can be measured by colorimetric method

by employing different indicators or by using hydrogen ion sensitive electrode. pH was measured by the pH meter at the site and the pH meter was first calibrated with buffer solutions of pH 4, 7, 9.2 and then pH of sample is determined.

Temperature

Temperature is the measure of hotness or coldness of any material. Temperature affects both chemical and biological reaction in the water. An average increase of 10° in the temperature of water almost doubles the biological activity. Temperature was also measured using HACH make HQ 40-D Multi-parameter meter at the site.

Total dissolved solids (TDS)

TDS are induced by any minerals, salts, metals, cations or anions and by organic matter dissolved in water. TDS doesn't contain any gas or colloids. This was also measured using HACH make HQ 40-D Multi-parameter meter.

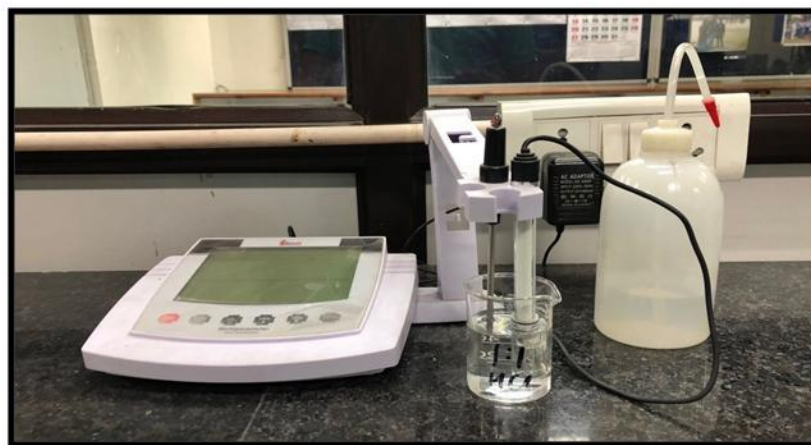


Figure 3.3. HACH make HQ 40-D Multi-parameter meter kit.

Total Dissolved Solids (TDS)

Electrical Conductivity

Conductivity denotes the capacity of substance or solution to conduct electric current. It was measured using HACH make HQ 40-D Multi-parameter meter. This method gives the concentration of major ions or common ions present in the water. The EC meter was calibrated with standard KCL solution (.10N). This solution was prepared by dissolving 0.7474g of KCL in

100ml of distilled water. EC of standard solution was set at 12.88 mhos/cm at 25°C. EC was calculated by the calibrated instrument.

Secchi Depth

Water clarity is measured in terms secchi depth. Water clarity often indicates a lake's overall water quality in terms of presence of algae, turbidity, colour etc. Secchi depth was taken using the 8 inch diameter weighted disc.



Fig 3.4 Measurement of secchi depth using secchi disc.

Dissolved Oxygen

(DO) were done onsite using Orion (USA) make star A320 model multi-parameter meter.

Dissolved oxygen is an important parameter since it is needed for the photosynthesis of aquatic plants as well as for the survival of the aquatic life.

Hardness

Concentration of all the multivalent cations in the water is referred as the hardness of the water. It is also defined as sum of calcium and magnesium concentrations, expressed as calcium carbonate in mg/l. When amount of hardness is numerically equal to total alkalinity, it is called carbonate hardness; the amount of hardness in excess of this is called non carbonate hardness.



Fig 3.5 On site analysis of DO using multi-parameter meter

When the hardness numerically is equal to or less than the sum of carbonates and bicarbonates, all hardness is carbonate hardness and non- carbonate hardness is absent..

Requirements

1. EDTA solution (0.01M): 3.732gm of EDTA disodium salt was dissolved in distilled water to make volume 1lit.
2. Ammonium acetate buffer solution: 1 ml
3. EBT indicator

Procedure

1. 25ml of water sample was taken in titration flask.
2. 1ml of ammonium acetate solution was added to it and then a pinch of EBT indicator.
3. It was titrated against standard EDTA solution till the colour changed from reddish pink to blue.

Calculations

$$\text{Total hardness} = (M_2 \times V_2 \times 100)/100$$

Where,

M₂ - Molarity of standard of EDTA solution

V₂ - Volume of EDTA solution used (ml)

V₁ - Volume of sample taken (ml)

Alkalinity

The concentration of all the ions present in the water which are capable of neutralizing the acids is referred as alkalinity of water or it may also be defined as ability of water to neutralize the acid. Major types of alkalinity are carbonate, bicarbonate and caustic alkalinity which is caused by inorganic mineral salts or by the biological decomposition of organic matter or by the dissolved gases in water.



Fig 3.6 Analysis of alkalinity in the laboratory.

Procedure:

Take 25ml sample of water and add 2-3 drops of phenolphthalein indicator. The colour will change colorless to pink. If no colour is produced, the phenolphthalein alkalinity is zero. If the sample turns pink, determine the alkalinity by titrating with standard acid until the pink color just disappears. In either case, continue the determination using the sample to which phenolphthalein has been added. Now add a few drops of methyl orange indicator and continue the titration further until the yellow colour changes to yellow colour at the end point. this is total alkalinity.

Calculations:

Phenolphthalein alkalinity as CaCO₃, $P = (100,000 \times A \times M)/V$

Total alkalinity as CaCO₃, $T = (100,000 \times B \times M)/V$

Where,

A= volume of H₂SO₄ (ml) used in phenolphthalein to reach end point Ph

B = volume of H₂SO₄ (ml) used in methyl orange to reach end point M=Molarity of H₂SO₄ (.01M)

V= Volume of sample (100 ml)

Cations (Na, K, Mg, Li)

Cations concentration in this study is calculated using Flame photometry, which is a branch of atomic spectroscopy in which the species examined in the spectrometer are in the form of atoms. The atoms under investigation are excited by light. Absorption techniques measure the absorbance of light due to the electrons going to a high energy level. Emission techniques measure the intensity of light of light that is emitted as electrons return to the lower energy levels.

Procedure:

1. Open the lid of filter chamber. Insert appropriate filter for the test opening and close the lids.
2. Insert the free end of the PVC take up capillary in distilled water or the reagent. Adjust set zero controls to obtain 00 display on read out.
3. Adjust the control of each channel to obtain a display exactly 100 on the read out of the channel.
4. Repeat operation of steps 3 and 6 to ensure 00 and 100 are display respectively when the blank and the working standard solution of highest concentration are aspirated into the flame.
5. Insert the free end of the PVC take up capillary in distilled water for a minute or two to wash the mixing chamber thoroughly before the actual test.
6. Insert the free end of the PVC take up capillary in the sample read out value of concentration as displayed in the read out.
7. Feed the working standard solution of known concentration from time to time in a series of tests to check calibration. Check the 00 with the blank solutions.

Sodium

It is one of the most important cations occurring naturally. Domestic sewage is one of the important sources of sodium to fresh water. Salts of sodium are highly soluble in water. Water with high sodium content is also not suitable for agriculture as it tends to deteriorate the soil for crops. Sodium associated for chlorides and sulphides make the water unpalatable. The concentration of sodium was determined using Systronics make Flame Photometer 128 μ C model.

Potassium

Potassium is also a naturally occurring element. However, the concentration remains quite lower than sodium, calcium and magnesium. It has got more or less chemistry like sodium and remains mostly in solution without undergoing precipitation. The concentration of potassium was determined using Systronics make Flame Photometer 128 μ C model.

Calcium

Calcium is an important element coming from crystal origin. It is an integral component of most of the rock minerals and ores. The weathering profile of the mineral rock determines its rate of solubilisation in water. Excessive dissolution of calcium salt results in an increase of total hardness in water. Presence of calcium ions in water/soil water interface regulates the cation exchange capacity of soil and uptake of nutrients from soil. It also affects the cationic concentration in water and an effect over quality of irrigation water. At high pH, much of its quantities may get precipitated as CaCO₃. The concentration of calcium was determined using Systronics make Flame Photometer 128 μ C model.

Lithium

It is a soft, silvery-white alkali metal. Like all alkali metals, lithium is highly reactive and flammable, and is stored in mineral oil. It never occurs freely in nature, but occurs as ionic compounds, such as pegmatitic minerals. Due to its solubility as an ion, it is present in ocean water and is commonly obtained from brines. The concentration of lithium was determined using Systronics make Flame Photometer 128^μC model.

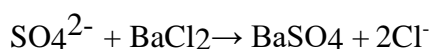
Magnesium

It occurs in all kinds of natural waters but its concentration remains generally lower than calcium. Like calcium, it is also one of the important ions imparting hardness to water. The concentration of magnesium is determined as the difference between (Ca²⁺ + Mg²⁺) titration and titration alone for Ca²⁺.

Anions

Sulphate

The turbidity method of measuring sulphate is based upon the fact that barium sulphate tends to precipitate in colloidal form of uniform size and that this tendency is enhanced in presence of sodium chloride, hydrochloric acid and glycerol



It was determined using spectrophotometer at 420nm. Requirements

- | | |
|------------|------------------------------------|
| 1. Gelatin | 3. BaCl ₂ |
| 2. HCl | 4. Na ₂ SO ₄ |

Preparation of reagents:

1. Conditioning reagent
 - Dissolve .3gm gelatin in 100ml distilled water, warm and dissolve.
 - Cool and keep in refrigerator for 12 hours. Allow it to come to room temperature and add 3gm of BaCl₂ and dissolve.
 - Allow to stand for 2 hours.
2. Stock solution
 - Dissolve .14gm anhydrous sodium sulphate in 1l of distilled water.
 - Take 1 volume of concentration HCl and add to 9 volume of distilled water.

Procedure:

1. To make standard solutions, prepare dilutions from stock solution from concentration varying to 5 to 100ml.
2. Take 20ml sample.
3. Add 1 ml of HCl.
4. Add 1ml of conditioning reagent and mix for 30 seconds.
5. Wait for 30 minutes and read absorbance.
6. By plotting a graph obtain the data (concentration vs percentage absorbance).
7. Trace the points for the sample against measured absorbance.

Total Phosphate

Total phosphate was extracted by Sulphuric acid-nitric acid digestion method. The acids, i.e. concentrated Sulphuric acid and concentrated nitric acid plays the role of converting bound phosphates in unbound form. Thus all phosphates present in acid digested sample is in unbound form which can later be read directly from spectrophotometer using ammonium molybdate – stannous chloride method.

Phosphate is a critical nutrient in growth of algae. The enrichment of phosphate contributes greatly to eutrophication. The most important source of phosphate is discharge of sewage, detergents and agricultural run-off.

1. Take 10 ml sample, .4ml of concentrated Sulphuric acid was added with 2 ml of concentrated nitric acid.
2. The solution was kept in digestion unit and microwave was set for 5-10 minutes at low (200Kw level).
3. After completion of digestion, sample was neutralized with NaOH. Neutralization as seen as pink color which appeared after adding 2 drops of phenolphthalein before adding NaOH to digested samples.
4. Take 10ml of sample, add .4ml of ammonium molybdate and mix well.
5. To this, 5 drops of stannous chloride was added and mixed well.
6. The solution was allowed to stand for 5 minutes; blue color appeared in the mix.
7. Absorbance was noted at 690 nm on spectrophotometer.
8. Multiplication of absorbance with graph factor gave the phosphate concentration.

Nitrate

It is one of the critical nutrient for the growth of algae and helps in accelerating the eutrophication. Important sources of nitrate are domestic sewage, natural runoff and agricultural waste. Presence of nitrate in water is not harmful as it indicates complete decomposition of organic matter but if present in excess it starts affecting the infants and results in disease called methemoglobinemia or blue baby disease.

Method: Nitrate was measured by using the nitrate electrode by multi-parameter meter. Firstly, the nitrate electrode was calibrated and then value of nitrate was measured by dipping it in each bottle of water sample.

Silica

Silicon ranks next to oxygen in abundance in the earth's crust. It appears as the oxide (silica) in quartz and sand and is combined with metals in the form of many complex silicate minerals, particularly igneous rocks. Degradation of silica-containing rocks results in the presence of silica in natural waters as suspended particles, in a colloidal or polymeric state, and as silicic acids or silicate ions. Volcanic and geothermally heated waters often contain an abundance of silica.

The silica content of natural water most commonly is in the 1 - to 30mg/l range, although concentrations as high as 100 mg/L are not unusual and concentrations exceeding 1000 mg/L are found in some brackish waters and brines.

Silica in water is undesirable for a number of industrial uses because it forms difficult-to-remove silica and silicate scales in equipment, particularly on high- pressure steam-turbine blades. Silica is removed most often by the use of strongly basic anion-exchange resins in the deionization process, by distillation, or by reverse osmosis. Some plants use precipitation with magnesium oxide in either the hot or cold lime softening process.

The concentration of calcium was determined using Molybdosilicate Method. Requirements:

- Sodium bicarbonate, NaHCO₃
- Sulfuric acid, H₂SO₄, 1N
- Hydrochloric acid, HCl, 1 + 1
- Ammonium molybdate reagent Procedure:
 1. Color development: To 50.0 mL sample add in rapid succession 1.0 mL 1 + 1

HCl and 2.0 mL ammonium molybdate reagent. Mix by inverting at least six times and let stand for 5 to 10 min. Add 2.0 mL oxalic acid solution and mix thoroughly. Read color after 2 min but before 15 min, measuring time from addition of oxalic acid. Because the yellow color obeys Beer's law, measure photometrically.

2. To detect the presence of molybdate unreactive silica, digest sample with NaHCO₃ before color development. This digestion is not necessarily sufficient to convert all molybdate unreactive silica to the molybdate reactive form. Complex silicates and higher silica polymers may require extended fusion with alkali at high temperatures or digestion under pressure for complete conversion. Omit digestion if all the silica is known to react with molybdate.

3. Preparation of standards: If NaHCO₃ pretreatment is used, add to the standards (approximately 45 mL total volume) 200 mg NaHCO₃ and 2.4 mL 1N H₂SO₄, to compensate both for the slight amount of silica introduced by the reagents and for the effect of the salt on color intensity. Dilute to 50.0 mL

4. Correction for color or turbidity: Prepare a special blank for every sample that needs such correction. Carry two identical portions of each such sample through the procedure, including NaHCO₃ treatment if this is used. To one portion add all reagents as directed. To the other portion add HCl and oxalic acid but no molybdate. Adjust photometer to zero absorbance with the blank containing no molybdate before reading absorbance of molybdate treated sample.

5. Prepare a calibration curve from a series of approximately six standards to cover the optimum ranges. Set photometer at zero absorbance with distilled water and read all standards, including a reagent blank, against distilled water. Plot micrograms silica in the final (55 mL) developed solution against photometer readings. Run a reagent blank and at least one standard with each group of samples to confirm that the calibration curve previously established has not shifted.

Calculations $\text{SiO}_2 \text{ (mg /L)} = \mu\text{g SiO}_2 \text{ (in 55 mL of final volume)} / \text{mL of sample}$

Chloride

Presence of chloride in water in high concentration indicates its pollution due to industrial waste or sewage. In natural fresh water its concentration is low.

Reagents

0.02 N silver nitrate solution

5% potassium chromate solution

Procedure:

25 ml sample was taken in a titration flask and 3-4 drops of K₂CrO₄ indicator were added. It was titrated against AgNO₃ solution till yellow colour changed to light brick red. The titration was repeated to get concordant readings.

Calculations: $Cl^{-} \text{ (mg/l)} = (N_2 \times V_2 \times 35.5 \times 1000) / V_1$

Where,

N₂ = Normality of standard AgNO₃ solution (0.0141 N)

V₂ = Volume of AgNO₃ solution used (in ml)

V₁ = Volume of sample taken (25 ml)

Analysis of Sediments

The sediment samples were digested with acids in the ratio of 3:1 HNO₃:H₂SO₄. It was digested on the hot plate till it turns grey in colour. 3-4 washing of conical flask were done repeatedly and collected samples were centrifuged to remove inorganic fraction. Supernatant of samples was analyzed for Ca, Mg, K, and Na using flame photometer after volume make up to 25 ml and TOC was measured by titration method.



Fig 3.7 Sediment samples of Siliserh Lake, Alwar.

Chapter 4

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The physico-chemical characterization revealed that the quality of water of the lake Siliserh was marginal to good. All the parameters were within the prescribed limit of BIS with minimum deviation except slightly higher level near the residential and agricultural areas of Doba and Kishanpura villages. The reason could be addition of domestic waste water and runoff from the nearby agricultural fields. The detailed description of different physico-chemical parameters is discussed below.

4.1 General Observations

The general parameters i.e. pH, Temperature, Electrical conductivity (EC), Total dissolved solids (TDS), Sechhi Depth (SD), Oxidation Reduction Potential (ORP), Total alkalinity (TA), Total hardness (TH) etc. of Siliserh Lake were analyzed on-site and represented relatively good quality of water. pH is the measure of the acidic or basic (alkaline) nature of the water. It is an important parameter for biotic communities because most of the plant and animal species can survive in a narrow range of pH from slightly alkaline to slightly acidic conditions. The average pH of the Siliserh Lake was 8.4 ranging from 7.3 to 9.5. The basic nature of pH shows dominance of alkaline species like Ca^{2+} and Mg^{2+} over the acidic species like Cl^- and SO_4^{2-} . The basic pH may also be due the high biological activity (Das *et al.*, 1997) including photosynthesis (Subramanian & Mahadevan, 1999) which adds CO_2 resulting in formation of bicarbonate and carbonate ions. The temperature also plays an important role in solubility of gases and affects both physico-chemical and biological reactions in the water. The dissolved oxygen (DO) was observed to vary from 7.1 mg/l to 9.1 mg/l with an average value of 7.6 mg/l. The values of DO indicated that the water quality is good to support the aquatic life; and for the oxidation of autochthonously generated organic matter. An average increase of 10°C in the temperature of water almost doubles the biological activity. In the present study, temperature of the water varied between 30.7°C and 36.9°C with an average value of 32°C . It also regulates solubility of minerals and salts, as a result of which average TDS was observed to be 112 mg/l, much lower than the prescribed BIS standard of 500mg/l. EC, which is the measurement of ionic strength of solution, varied between 152 to $248\mu\text{S}/\text{cm}$ with the average value of $224\mu\text{S}/\text{cm}$. Hence, EC and TDS were well within the prescribed limits in water of Siliserh Lake. Another important parameter to establish water quality for aquatic life is oxidizing/reducing environment present in the lake

ecosystem. Based on the values of ORP, the conditions were found to be oxidizing in nature. Although there were some sources of organic impurities in water, still average conditions were oxidizing with an average value of 82mV. The minimum ORP (50 mV) was observed near the Doba village and maximum (113 mV) at Ringaspura where the depth was shallow and rich growth of algae and other aquatic plants was observed. Since submerged aquatic vegetation and algae carries out photosynthesis; and oxygen is the byproduct of this process which eventually adds DO to surface water. This could be reason for elevated ORP level at this location. The relatively high levels of DO throughout the lake confirmed the prevalence of oxidizing conditions. The Secchi depth is an indirect measure of turbidity and eutrophication in water. It varied between 0.40 and 1.1m with an average value of 1.0m. Since algal growth was limited, suspended impurities have also contributed to turbid conditions. Spatial variations within the lake may be an outcome of variation in the growth of aquatic weeds, algae, and suspended solids. Total alkalinity (as CaCO_3) is the measure of capacity of water to neutralize the acids and it is represented by the sum of hydroxides, carbonates and bicarbonates. Total alkalinity of the samples of lake Siliserh varied between 64 and 96mg/l with an average value of 84mg/l. All the water samples of Siliserh lake were found below the BIS standard of 200mg/l. Based on the values of TA, the concentration of carbonates and bicarbonates was also deduced. Since the average pH of water was 8.5, most of the alkalinity existed in the form of bicarbonates. Bicarbonates had an average value of 40 mg/l with the range extending from 10 mg/l to 58 mg/l. Some of the locations with relatively higher pH values reported the presence of carbonate ions. The average concentration of carbonates in lake water was 5.5 mg/l. Spatial variations of carbonate may also be contributed to dissolution of carbonate minerals from the soil/rocks present in the region which has resulted in traceable amount of carbonates at some locations, particularly along the western bank of the lake. The other reason could be addition of domestic wastewater which has presence of carbonates since it is a component of detergents. These chemical species (HCO_3^- , CO_3^{2-} , Ca, Mg etc.) are also responsible for imparting hardness in water. Total hardness (as CaCO_3) was reported to vary between 64 mg/l to 96 mg/l with an average value of 84 mg/l. Based on TH, most of the samples were classified as soft to moderately hard (USGS, 2013).

Table 4.1 General properties of surface water in Siliserh Lake.

S. No.	Temp (°C)	pH	EC (µS/cm)	TDS (mg/l)	TSS (mg/l)	SD (m)	DO (mg/l)	TH (mg/l)	TA (mg/l)
1	32.8	8.9	209	104	44	0.5	7.2	124	80
2	32.8	7.3	248	124	70	0.55	7.3	228	96
3	32.9	9.5	154	77	48	0.40	7.3	104	64
4	33.2	8.6	245	123	32	0.65	7.5	172	96
5	33.1	8.1	245	122	20	0.55	7.5	148	80
6	33.2	8.9	185	92	34	1.10	7.4	152	64
7	30.7	9.0	200	100	16	0.66	7.2	76	80
8	30.7	8.5	242	122	20	0.65	7.2	112	96
9	36.9	8.4	239	120	20	0.56	7.6	124	80
10	31.1	8.0	224	112	34	1.10	7.2	136	88
11	31.4	8.6	228	114	12	0.81	7.1	220	72
12	33.7	7.8	226	113	12	0.61	7.5	132	88
13	31.8	8.1	236	118	8	0.58	8.0	136	80
14	31.7	8.8	236	118	16	0.71	9.1	116	96
15	31.7	8.8	234	117	16	0.99	8.6	116	88
16	31.8	8.5	236	118	20	0.96	8.3	104	96
Range	30.7-36.9	7.3 - 9.5	154-248	77-124	48-70	0.4-1.1	7.3-9.1	76-228	64-96
Mean	32	8.5	224	112	26	0.71	7.6	138	84
SD(±)	1.5	0.5	25.5	12.9	16.5	0.2	0.6	40.4	10.9

As per classification for hardness, none of the samples were found to be soft (0–60 mg/l); 38% moderately hard (61–120 mg/l); 50% hard (121–180 mg/l); and 12% were very hard (>181 mg/l). Further average sum of bicarbonates and carbonates exceeded the sum of chlorides and sulfates indicating that the hardness is primarily temporary in nature and the chemical species accounting for TH are natural in origin.

4.2 Cations in water (Ca, Mg, Na, K, Fe, Li)

The major cations in the water are Ca^{2+} , Mg^{2+} , Na^+ and K^+ which contribute around 9% of the TDS. Based on the observed values, Mg^{2+} was observed to be the most abundant species followed by calcium, sodium, potassium and lithium. The concentration of different cations is given in Table 4.2. It was observed that magnesium had an average value of 13mg/l ranging from the below detectable limit to 36mg/l. On comparing it with the standard value of magnesium (30mg/l) in drinking water as per BIS standard, it was found that 87% of the samples were below standard value. Only two samples exceeded the BIS standard.

Table 4.2 Concentration of different cations in water of Siliserh Lake.

S.No	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)	Li^{2+} (mg/l)	Fe (mg/l)
1	7.2	0	5.16	2.79	0.02	0.16
2	9.0	36	5.89	5.71	0.04	0.16
3	6.6	0	5.87	4.57	0.04	0.19
4	8.5	21	5.76	5.83	0.04	0.04
5	8.7	12	5.91	5.66	0.04	0.10
6	7.2	19	5.72	5.46	0.04	0.03
7	8.0	1	5.72	5.56	0.05	0.04
8	9.0	9	6.02	5.40	0.04	0.03
9	9.1	11	5.07	5.87	0.04	0.07
10	8.5	13	5.60	5.71	0.04	0.04
11	9.0	34	5.87	5.79	0.05	0.10
12	9.1	15	5.78	5.62	0.05	0.11
13	8.9	10	5.79	5.80	0.05	0.08
14	9.3	10	5.60	5.97	0.05	0.07
15	9.1	13	5.66	5.83	0.05	0.12
16	9.3	0	5.76	5.89	0.04	0.07
Range	7.2-9.3	0-36	5.07-6.02	2.79-5.97	0.02-0.05	0.03-0.19
Mean	8.5	12.75	5.70	5.47	0.04	0.09
SD(±)	0.8	10.8	0.3	0.8	0.01	0.05

Calcium is an important species with respect to dissolved minerals and hardness, and it has the

ability to affect the suitability of drinking water quality. Ca varies from 7.2 to 9.3 with an average value of 8.5, much lower than the standard value of 75mg/l. Hence, none of the sample exceeded the permissible limit of calcium in the study area. Similarly, concentration of sodium was also found to be low ranging from 5.07 to 6.02 mg/l with an average value of 5.70 mg/l. Based on relative concentration of cations, alkaline earth cations/metals (Ca^{2+} and Mg^{2+}) fairly exceeded the alkali metals (Na^+ and K^+). Dominance of earth metals is responsible for the basic pH of water throughout the region. On the other hand, lower levels of Na and K resulted in relatively lower concentration of salinity. This indicated that the water is alkaline but non-saline, which is an indication of good quality of water. Moreover, the levels of studied cations were well within the limits prescribed for drinking water pointing towards absence of a major source of pollution. Moreover, significant positive correlation of Ca with Li (which is purely crustal in origin) further validates the assumption that dominant fraction of cations comes from natural/crustal source. Similarly, traceable concentration of dissolved iron (Fe) in water with an average value of 0.09 mg/l confirmed the absence prominent anthropogenic addition of cations.

4.3 Anions in water (CO_3^{2-} , HCO_3^- , Cl^- , SO_4^{2-} , SiO_4^{2-})

Since pH of most of the samples was less than 9.0, the water had dominance of bicarbonate ions. The bicarbonates ions had an average value of 40 mg/l with the minimum value of 10 mg/l; and maximum concentration of 58 mg/l. Presence of carbonate ions was reported at some locations relatively which relatively higher values of pH (>8.5). The average concentration of carbonates in water was 5.5 mg/l. Spatial variations of carbonate may also be contributed to dissolution of carbonate minerals from the soil/rocks present in the region which have resulted in traceable amount of carbonates at some locations, particularly along the western bank of the lake. The other reason could be addition of domestic wastewater which has presence of carbonates since it is a component of detergents. High concentration of chloride in water bodies shows pollution due to industrial or sewage wastewater. In the present study, chloride ions were found to be in the range of 8 to 24mg/l with an average value of 17mg/l which is significantly lower than the prescribed standard for chloride *i.e.* 200mg/l (BIS, 2012). Similarly, low concentration of sulfate throughout the lake confirmed absence of addition of sewage or grey water. It varied from 3 mg/l to 13 mg/l with an average value of 5.8 mg/l; and it is well within the permissible limit specified for sulfate (200 mg/l) as per BIS, (2012). Significant positive correlation was observed for

concentration of sulfate with dissolved silica (which is purely crustal in origin) confirming that sulfate comes from crustal source. Based on relative abundance, average concentration of bicarbonate ions was maximum (40 mg/l), followed by chloride (17 mg/l), silicate (9.4 mg/l), sulfate (5.8 mg/l), and carbonate (5.5 mg/l). The sum of carbonates and bicarbonates ($\text{CO}_3^{2-} + \text{HCO}_3^-$) was almost double than the sum of chlorides and sulfate ($\text{Cl}^- + \text{SO}_4^{2-}$), which indicates that the basic anions dominate the acidic anions adding to basic nature of water. The concentration of different anions is given in [Table 4.3](#).

Table 4.3 Anions and nutrients in surface water of Siliserh Lake.

S. No.	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	SiO_4	TP	NO_3	BOD	NH_3
1	10	29	8	13	29	1.5	17	4	1
2	0	58	12	6	9.0	1.0	8.8	4	0.9
3	14	10	20	7	7.6	1.7	22	3	1.2
4	0	58	16	5	8.4	0.8	5	3	0.8
5	0	48	24	4	8.4	0.9	6	3	0.4
6	14	10	16	4	7.4	0.7	16	3	1.4
7	10	29	12	6	8.4	1.0	10	4	1.4
8	0	58	16	5	8.8	0.9	8	4	0.8
9	0	48	20	8	8.0	0.8	8	4	0.5
10	5	44	20	3	7.3	1.0	11	4	0.5
11	10	24	12	5	7.5	0.9	12	4	1.2
12	10	34	20	5	7.7	1.2	11	4	0.9
13	0	48	20	5	7.9	1.4	9	3	0.8
14	0	58	20	5	9.4	1.0	10	2	0.5
15	10	34	12	6	7.8	1.1	12	2	0.9
16	5	48	24	5	7.7	1.5	11	2	1.1
Range	0-14	10-58	8-24	3-13	7.3-29	0.7-1.5	5-17	2-4	0.4-1.2
Mean	5.48	39.88	17.00	5.75	9.40	1.09	11.08	3.0	1.0
SD(±)	5.53	16.20	4.73	2.27	5.29	0.29	4.23	0.79	0.32

**All the values are expressed in mg/l*

4.4 Nutrients in water (PO₄³⁻ and NO₃⁻)

Phosphate is a critical parameter with respect to the eutrophication in water body. Excess of nutrients is the reason for high biological activity of primary producers like phytoplankton and algae. Excessive growth of algae is referred as eutrophication and such lakes are designated as eutrophic lakes. In this study, the average value of phosphate was found to be 1.09 mg/l varying between 0.7 and 1.7mg/l. Maximum value was observed at location 3 and minimum at 6. With respect to the concentration of phosphate, lake Siliserh was found to be eutrophic in nature. Nitrate was observed to be in the range of 5.3 to 22mg/l. Minimum value (5.3 mg/l) was observed at sampling location 4; and maximum value (17 mg/l) at sampling location 1 near the village Ringaspura. Slightly raised level of nitrate at Ringaspura may be because of addition of domestic waste water from the adjoining villages and surface runoff from the agricultural fields since nitrate is the oxidized form of nitrogen, a major ingredient of fertilizer used for crops. The high concentration of nitrate is known to support the growth of algae. Based on the analysis of nitrogen and phosphorus, it was seen that the lake is eutrophic and had the N:P ratio of about 10:1 which may be categorized as transitional phase towards eutrophication. Limited growth of algae was observed in the lake which may be attributed to a functional food chain in which the nutrients are transferred from one level to another and finally being exported with the fish catch.

4.5 Pollutants in water (BOD and Dissolved Ammonia)

Biochemical oxygen demand (BOD) is the amount of dissolved oxygen required by microorganism to break down the organic matter present in the water body. BOD in Siliserh Lake was found to be in the range of 2-4 mg/l with an average value of 3 mg/l. The monsoonal rains are the major source of water to lakes Siliserh with an average annual rainfall of 675mm. The flushing of organic matter from the catchment area (about 11 sq kms) results in addition of organic load. For rest of the period, addition of organic matter takes place from within the lake due to death and decomposition of microbial and plant biomass. This could be the reason for relatively lower values of BOD. Lower levels of organic impurities result in sufficiently good level of dissolved oxygen which supports aquatic life and oxidizes impurities. Nitrogen is the other important parameter and it is estimated as dissolved ammonia and nitrate in water. Since the BOD values were low, the fraction of organic nitrogen in water is considered to be low. Had there been presence of organic nitrogen, relatively high values of BOD would have been obtained. The ammonical fraction (dissolved ammonia) varied from 0.4mg/l to 1.4mg/l with

average value of 1.0 mg/l. The values of dissolved ammonia were slightly higher than the prescribed limit of 0.5 mg/l of drinking water. The prevalent levels of dissolved ammonia are considered to be safe for aquatic life as compared against the limit of 1.4 mg/l as per CCME, 2007. The concentration of BOD and dissolved ammonia is given in [Table 4.3](#).

4.6 Suitability for Drinking

Lake Siliserh was the primary source for drinking water to Alwar city. The water from the lake was transmitted to Alwar through an open channel/conduit being constructed in historical times. Presently, the excess water spillage from the lake Siliserh is collected in lake Jaisamand located downstream of Siliserh. The water from both the lake is used for irrigation, aquaculture, and drinking (during lean period of summer). The suitability of surface water of Siliserh lake for drinking was determined by comparing the observed values against the recommended concentration (BIS standards) as shown in [Table 4.4](#). Weighted Arithmetic Water Quality Index (WQI) was also calculated to represent the quality of drinking based on the values of TDS, TH, TA, Ca^{2+} , Mg^{2+} , Fe, Cl^- , SO_4^{2-} , and NO_3^- .

The following equation was used to calculate WQI.

$$\text{WQI} = \frac{\sum W_i Q_i}{\sum W_i}$$

Where,

Q_i -quality rating for each parameter [$Q_i = 100 * (V_i - V_o)/(S_i - V_o)$];

V_i -observed value of i th parameter;

V_o -ideal value of the parameter in pure water (it is 0 for all parameters except pH—7.0);

S_i -is the recommended standard value of i th parameter;

W_i -unit weight of each parameter ($W_i = K/S_i$);

K -is proportionality constant ($K = 1/\sum(1/S_i)$).

4.7 Suitability for Irrigation

Siliserh Lake is surrounded by the agricultural fields; and its water is being used for irrigation. The criterion for suitability of groundwater for irrigation is entirely different from drinking purposes (Haritash et al. 2008). The development and maintenance of successful irrigation projects involves not only the supplying of irrigation water to the land but also the control of salt and alkali in the soil. The characteristics of water for irrigation which are important in

determining its quality are Percentage sodium (%Na), soluble sodium percentage (SSP), residual sodium carbonate (RSC), sodium absorption ratio (SAR), magnesium hazard (Mg Hz), Kelly's ratio (KR), and permeability index (PI). Different ratios or indices for the classification of Siliserh lake water for irrigation were calculated as follow:

Table 4.4 Suitability of water samples (%) of Siliserh Lake for drinking.

S. No.	Parameter	Mean Range (Min. – Max.)	Suitable Samples (%)	
			WHO	BIS
1	pH	8.49 (7.3-9.5)	37	37
2	EC	224 (154-248)	-NM-	-NM-
3	TDS	142 (77-124)	100	-NM-
4	Fe	0.09 (0.03-0.19)	-NM-	100
5	TH	138 (76-228)	100	93
6	TA	84 (64-96)	100	100
7	Ca	8.5 (6.6-9.3)	-NM-	100
8	Mg	13 (0-36)	-NM-	87
9	Na	5.7 (5.07-6.02)	-NM-	-NM-
10	K	5.4 (2.8-5.9)	-NM-	-NM-
11	Li	0.04 (0.02-0.05)	-NM-	-NM-
12	CO ₃	6 (0-14)	-NM-	-NM-
13	HCO ₃	40 (10-58)	-NM-	-NM-
14	Cl	17 (8-24)	100	100
15	SO ₄	6	100	100

		(3-13)		
16	NO ₃	11 (5.3-17)	100	100
17	PO ₄	1.1 (0.7-1.7)	100	-NM-
18	WQI*	21-78	---	75

Table 4.5 Indices to determine suitability for irrigation

Residual Sodium Carbonate (RSC) = $(\text{HCO}_3^- + \text{CO}_3^{2-}) - (\text{Ca}^{2+} + \text{Mg}^{2+})$	(Eaton, 1950)
Soluble Sodium Percentage (SSP) = $[\text{Na}^+ / (\text{Ca}^{2+} + \text{Mg}^{2+} + \text{Na}^+)] \times 100$	(Eaton, 1950)
Sodium Adsorption Ratio (SAR) = $\text{Na}^+ / (\text{Ca}^{2+} + \text{Mg}^{2+}/2)^{1/2}$	(Richards, 1954)
Percent Sodium (% Na) = $[(\text{Na}^+ + \text{K}^+) \times 100] / (\text{Ca}^{2+} + \text{Mg}^{2+} + \text{K}^+)$	(Wilcox, 1955)
Permeability Index (PI) = $[\text{Na}^+ + (\text{HCO}_3^-)^{1/2}] / (\text{Ca}^{2+} + \text{Mg}^{2+} + \text{Na}^+)] \times 100$	(Doneen, 1964)
Kelly's Ratio (KR) = $\text{Na}^+ / (\text{Ca}^{2+} + \text{Mg}^{2+})$	(Kelly, 1963)
Magnesium hazard (Mg Hazard) = $(\text{Mg}^{2+} \times 100) / (\text{Ca}^{2+} + \text{Mg}^{2+})$	(Paliwal, 1972)
Chlor-Alkali Index-1 (CAI-1) = $[\text{Cl} - (\text{Na} + \text{K})] / \text{Cl}$	(Schoeller, 1977)
Potential salinity (PS) = $\text{Cl} + 1/2(\text{SO}_4)$	(Doneen, 1961)
Base Exchange (BE) = $(\text{Na}^+ - \text{Cl}^-) / \text{SO}_4^{2-}$	(Matthess, 1982)

All ionic concentrations are in milli equivalent per litre (meq/l).

1. Percentage Sodium (%Na)

Sodium Percentage is one of the important factors to study sodium hazard. It is used for determining the quality of water for the use in agriculture. The high percentage of sodium in water for the irrigation restricts the plant growth. It reacts with the soil and reduces its permeability. Finer soil texture with high organic matter content has more impact of sodium. To tackle this, gypsum can be added to the soil to reduce the effect of high percentage of sodium in

irrigation water. As per the classification (Wilcox , 1995), Percentage sodium less than 20% is consider as very good for irrigation and its value above 80% is considered as harmful. The classification for different ratios is given in [Table 4.7](#). In the present study the average value of percentage sodium was found to be 26%, which shows that the water of Siliserh Lake is good for irrigation with respect to percentage sodium.

2 Soluble Sodium Percentage (SSP)

Soluble sodium percentage varied from 7% to 44% with an average value of 19%. Based on the ([Joshi, 1999](#)) classification, 75% of samples were classified as excellent for the irrigation ,19% of samples were classified as good and 6% samples were classified as fair for use in irrigation.

3 Residual Sodium Carbonate (RSC)

RSC is a measure of excess sodium carbonate present in surface water after all the calcium and magnesium have been precipitated with carbonate. Excess sodium carbonate reduces the permeability of soil particularly in clays as excess of RSC adsorb over the soil particles affecting the soil structure. The average value of RSC is -0.7. Negative value of RSC indicates that the water is suitable for irrigation. The water of Siliserh lake was classified as good to very good based on calculated values of RSC.

4 Sodium Absorption Ratio (SAR)

The SAR is the most useful parameter for determining the suitability of surface water for irrigation purposes because it measures the alkali/sodium hazard. Due to its effect on soil and plants, Na is considered one of the major factors governing the irrigation water. SAR in the present study indicated very good quality. Values of SAR were plotted against the EC for rating irrigation water in different classes using ([USSL, 1954](#)). This plot indicates the extent the water can affect the soil in terms of salinity hazard. All the samples were lie in C1S1 class, i.e. low salinity and low sodium hazard class, thus excellent for irrigation purpose ([Fig 4.1](#)).

5 Magnesium Hazard

Magnesium plays an important role in determining the suitability of water for irrigation and the parameter is designated as magnesium hazard (mg hazard). Value of magnesium hazard represents high concentration of magnesium and it is not suitable for irrigation as it may disturb

the cation exchange system of soil particles. Magnesium Ratio greater than 50% is considered to be harmful and unsuitable for irrigation. In the present study, average value of magnesium hazard was found to be 56%. Magnesium hazard was observed to be harmful for the irrigation at most of the locations.

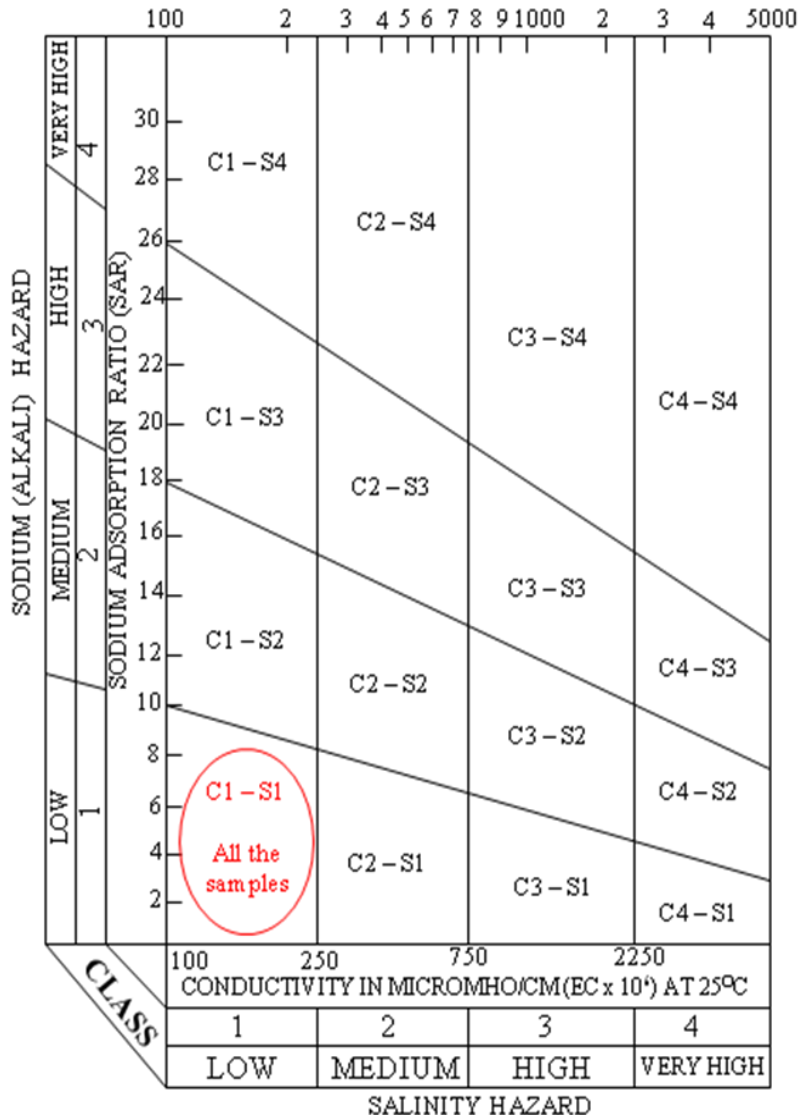


Fig 4.1 Plot of calculated values of SAR and EC of Siliserh lake for the classification of irrigation water.

6. Kelly's Ratio (KR)

The Kelly's ratio of Siliserh lake water ranged from 0.07 to 0.77 with an average value of 0.27,

which is well below unity indicating that the water is free from sodicity hazard and can be used for irrigation purpose.

7. Permeability Index (PI)

Long term irrigation influenced by Na^+ , Ca^{2+} , Mg^{2+} , and HCO_3^- contents of the soil affects soil permeability. Permeability index is another ratio to determine suitability of water for irrigation.

Table 4.6 Values of different parameters to assess suitability for irrigation.

S. No.	Na (%)	SSP (%)	RSC	SAR	Mg Hazard (%)	K.R.	P.I.
1	45	38	0.4	0.53	0	0.62	156.5
2	10	7	-2.5	0.19	87	0.07	33.2
3	53	44	0.3	0.63	0	0.77	112.6
4	16	10	-1.2	0.24	80	0.12	50.5
5	22	15	-0.6	0.30	70	0.18	67.6
6	17	11	-1.3	0.25	82	0.13	29.9
7	45	34	0.3	0.51	17	0.51	128.2
8	25	18	-0.3	0.34	62	0.22	84.5
9	21	14	-0.6	0.27	67	0.16	69.6
10	21	14	-0.6	0.28	72	0.16	62.3
11	11	7	-2.6	0.20	86	0.08	25.0
12	19	13	-0.8	0.27	73	0.15	51.0
13	24	16	-0.5	0.32	65	0.20	74.5
14	23	16	-0.3	0.30	64	0.19	78.9

15	20	14	-0.6	0.28	71	0.16	55.7
16	46	35	0.5	0.52	0	0.54	158.6
Mean	26	19	-0.7	0.34	56	0.27	77.4

Table 4.7 Suitability of water samples (%) of Siliserh Lake for irrigation.

S. No.	Parameter	Category	Inference	Suitable Samples (%)
1	EC	250	Very good	100
		250-750	Good	0
		750-2000	Marginal	0
		2000-3000	Very poor	0
		3000	Harmful	0
2	Na (%)	20	Very good	31
		20-40	Good	44
		40-60	Marginal	25
		60-80	Poor	0
		80	Harmful	0
3	RSC	<0	Very good	75
		0-2.5	Good	25
		2.5-5.0	Marginal	0
		5.0-7.5	Poor	0
		>7.5	Harmful	0
4	SAR	0-10	Very good	100
		10-18	Good	0

		18-26	Marginal-poor	0
		>26	Harmful	0
5	Mg Hazard	<50%	Good	25
		>50%	Harmful	75

4.8 Suitability for industrial application

Water for industrial use refers to applications such as boiler feedwater, cooling water, washing, and in manufacturing processes. In order to prevent corrosion and scaling in utilities, water quality must be monitored time to time. In this study, to determine the extent of corrosion in the pipes and in utilities due to dissolution of carbonates, saturation indices were calculated. The Langelier Saturation Index (LSI and RSI) is used to predict the calcium carbonate stability of water. It indicates whether the water will precipitate, dissolve, or be in equilibrium with calcium carbonate. Negative value of LSI indicates water has limited scaling potential and positive values of LSI indicate scaling tendency of water. With the increase in value of LSI, scaling potential also increases. LSI was calculated for all the samples and it was observed that about 6% samples had problem of scaling, 94% samples had $LSI < 0$. Hence, Siliserh lake water was found to be safe against the scaling problem.

Ryznar stability index (RSI) is used to determine aggressiveness and corrosion potential of the water. Ryznar (1942) gives an indication of aggressiveness whereas, Carrier (1965) gives and indication of corrosion potential of the water. As per the Carrier, RSI values indicated that 96% samples ($RSI > 9$) had intolerable corrosion potential while remaining 6% had heavy corrosion potential. As per Ryznar, all the samples were classified as aggressive water, thus unsuitable for transportation through pipes.

Water with the Corrosivity Ratio (CR) less than unity is considered to be safe for transport of water in any type of pipes and the corrosivity ratio more than unity indicates corrosive nature and hence not to be transported through metal pipes (Ryner, 1944; Raman, 1985). In the present study average value of corrosive ratio was found to be 0.82 varied from 0.49 to 1.12. Values for almost all the samples were below the unity except the sample 3 which was taken from agricultural fields adjoining Kishanpura village.

The Corrosion Coefficient (CC) is an indicator that reflects the intensity of corrosion. Positive values of corrosion coefficient indicate that water is corrosive while negative value

shows non corrosiveness of water. As per the data (Table 4.8), 63% water samples of the Siliserh lake were found to be corrosive in nature while remaining 37% of water were found to be non corrosive in nature.

Foaming is the continuous formation of the bubbles when water is boiled. Bubbles and froth build up on the surface of the boiler and elevate the water level in boilers resulting hindrance in its working. Values of foaming coefficient (FC) less than 60 lead to no foaming action whereas, values of fomaing above 200 lead to foaming action. Values in the range of 60-200, give marginal foaming. As per the obtained values of foaming coefficient for the Siliserh lake water, all the values were below 60. Hence, Siliserh lake water is safe against the action of foaming.

Table 4.8: Suitability of Siliserh lake water for industrial use

S. No.	Parameter	Classification		Samples (%)
		Value	Inference	
1	LSI	<0.0	No scaling	94%
		>0.0	Scaling	6%
2	RSI* (Carrier, 1965)	4-5	Heavy scale	-Nil-
		5-6	Light scale	- Nil-
		6-7	Little scale ot corrosion	-Nil-
		7-7.5	Corrosion significant	-Nil-
		7.5-9	Heavy corrosion	6%
		>9	Corrosion intolerable	94%
3	CR	<1	Safe	94%
		>1	Not safe	6%
4	CC (Wu <i>et al.</i> , 2015)	>0	Corrosive	63%
		<0	Not corrosive	37%
5	FC (Wu <i>et al.</i> , 2015)	<60	No foaming action	100%
		>200	Foaming action	- Nil-

4.9 Geochemical classification and weathering profile.

The major routes for addition of different anions and cations in water are atmospheric deposition, interaction with rocks and input from human activities (Subramanian, 1987). In this study, Gibbs

boomerang plots (Gibbs, 1970) were used to determine major routes for addition of cations and anions. Based on Gibb's boomerang plots (Fig. 4.2), it is observed that the prominent process controlling Siliserh lake water chemistry is rock-water interaction. To further classify the source and the type of weathering, relative ratios of cations and anions were calculated. Average Ca/Na value 1.5; Mg/Na value 2.23 (Fig 4.3); and HCO_3/Na value close to 6.99 suggest that silicate weathering is major weathering type which regulates the groundwater chemistry since water with silicate end member has Ca/Na ratio 0.35 ± 0.15 ; Mg/Na 0.24 ± 0.12 ; HCO_3/Na 2 ± 1 (Gaillardet *et al.*,1999). The observed values are significantly lower than the aquifers draining carbonate lithology (50 for Ca/Na; 10 for Mg/Na; and 120 for HCO_3/Na) (Meybeck, 1986). The sodium normalized calcium and magnesium relationship also suggests that silicate weathering plays the major role in regulating groundwater chemistry. The $(\text{Ca}+\text{Mg})/(\text{Na}+\text{K})$ value close to 1.0 also confirms that silicate weathering is the dominant process followed by carbonate weathering. Average value of 0.3 for $(\text{Na}+\text{K})/\text{TZ}^+$, too, confirms of silicate weathering. It was observed that most of the water samples belonged to NaCl or mixed CaMgCl type. Further, it was observed that alkaline earth (Ca+Mg) exceeded the alkaline metals (Na+K); and weak acids HCO_3^- and CO_3^{2-} exceed strong acids (Cl^- and SO_4^{2-}).

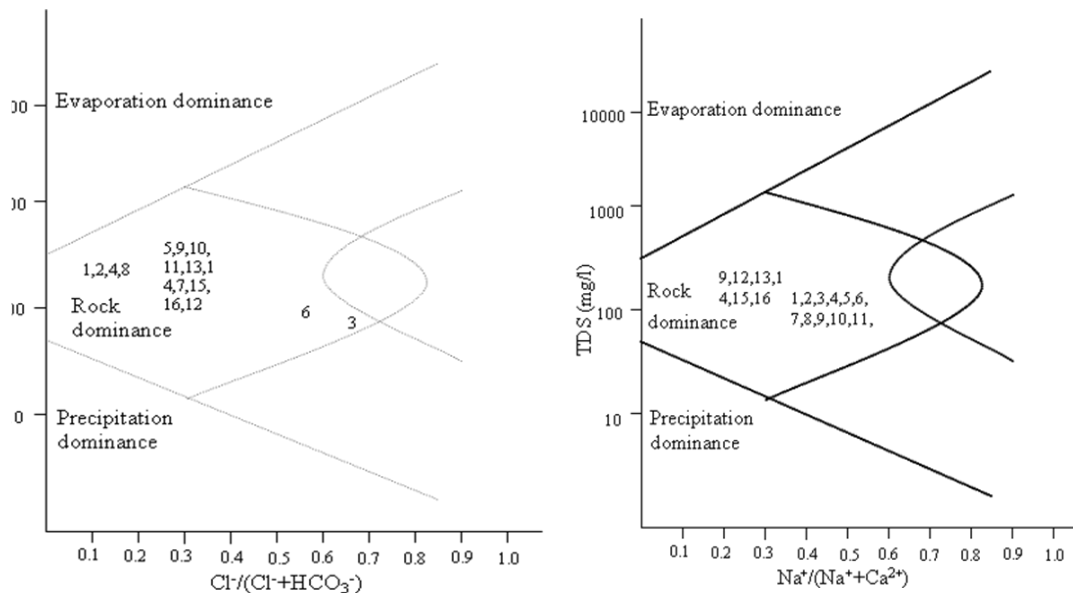


Fig 4.2. Gibbs boomerang plots for mechanism governing water chemistry.

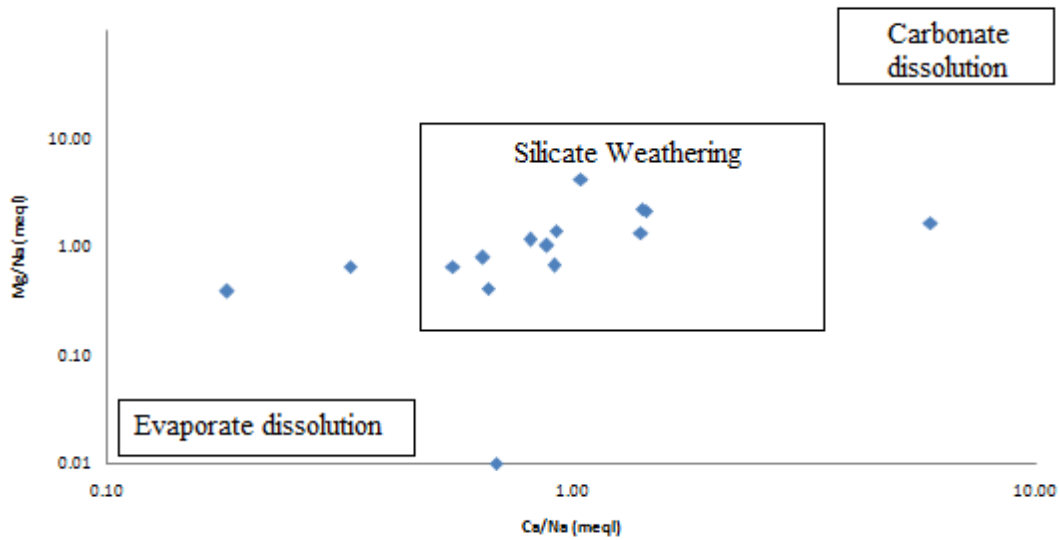


Fig 4.3 Weathering type based on Na-normalized Ca and Mg

Piper trilinear diagram was plotted (Piper, 1953) based on the standardized percentages of different anions and cations using GW chart software of USGS. The hydrochemical facies was interpreted using the plot for Siliserh lake water (Fig. 4.4). It was observed that most of the water samples of Siliserh Lake belonged to Ca-Mg type or mixed Ca-Mg-Cl type. Also, alkaline earth (Ca and Mg) exceeds alkaline (Na and K). Moreover, weak acids HCO_3^- and CO_3^{2-} exceed strong acids (Cl^- and SO_4^{2-}).

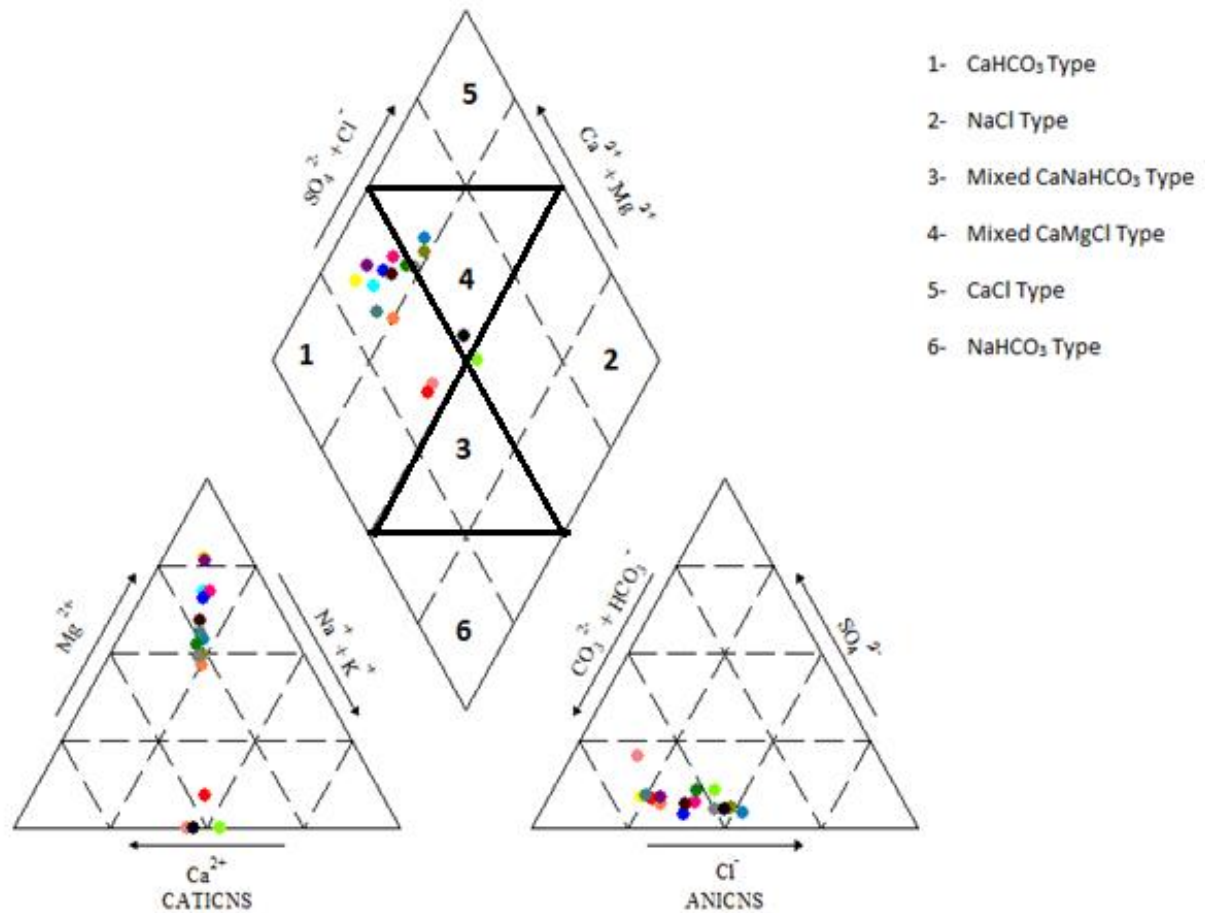


Fig4.4 Piper trilinear diagram for the classification of water of Siliserh lake.

The investigation of mechanism regulating the water chemistry to derive source specific outcomes based on relative ratios of cations and anions (Fig 4.5). The plot of Cl⁻ against Na⁺ represented excess of Cl⁻ ions as compared to sodium ions it indicated that chloride ions are also associated with other cations (Mg and K); and sodium ions of water might be replaced by calcium and magnesium of interacting rocks representing direct base exchange. Negative values of chlor alkaline index too confirmed direct Base Exchange. Similar observations were made for relative abundance of (Ca +Mg) against (Na +K). Excess of alkaline earth metals further strengthens that the assumptions that direct base exchange is being operated in rock-water interaction. Further, (Ca+Mg)/HCO₃ ratio close to 0.5 is an indication of addition of calcium and magnesium.

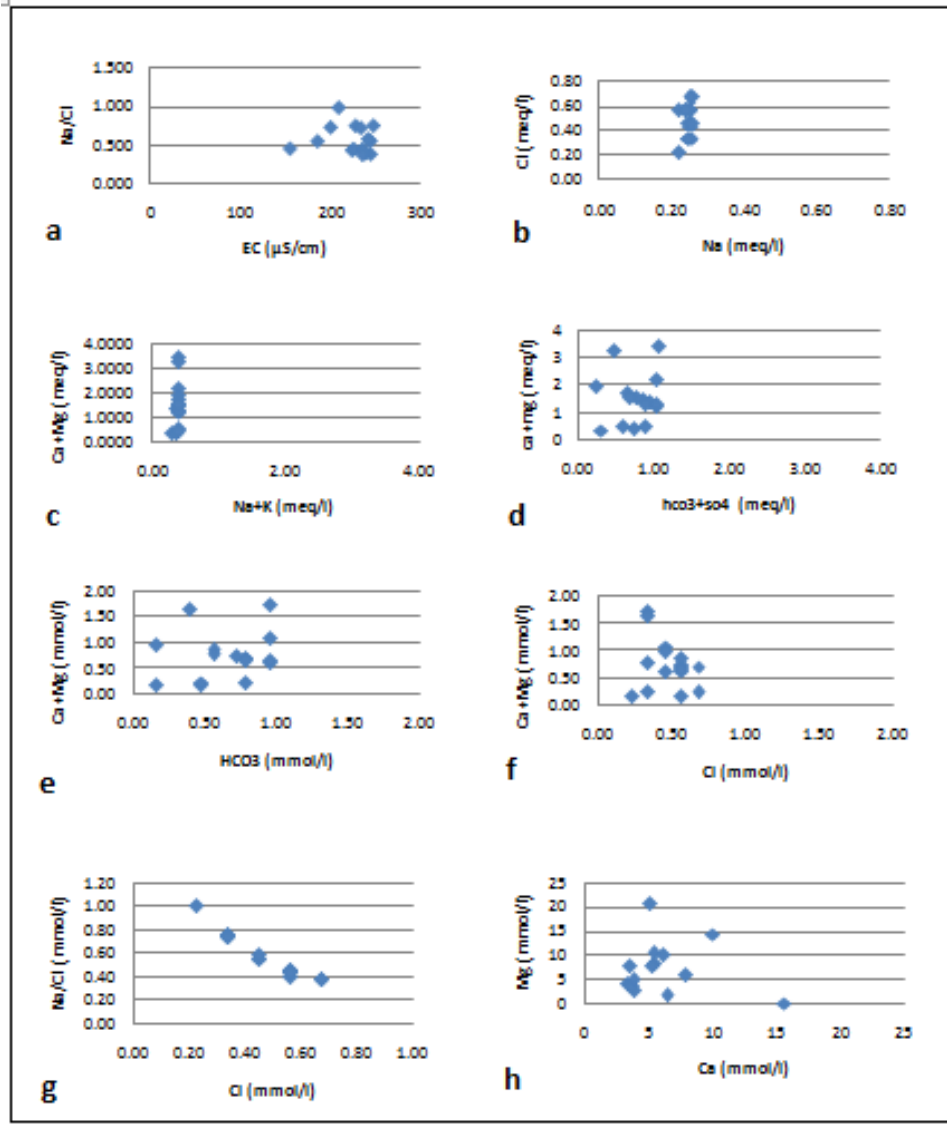


Fig 4.5 the plots of ionic ratios to represent rock water interactions

4.10 Analysis of sediments

Sediments in lake are operate as both carriers and storage sinks for contaminants, thus reflecting the history of long term geogenic or anthropogenic impacts (Bibi et. al.,2008; Maltby, 1992; Singh et. al., 2005). Sediments from the Siliserh Lake were analyzed for the Ca, Mg, Na, K, TOC and Available phosphate (AP) (Table 4.9).

Table 4.9 Analysis of Sediments of Siliserh Lake, Alwar.

S.No.	Na	K	Ca	Li	TOC (%)	AP (mg/g)
1	42.7	62.12	29.26	0.82	4.3	0.69
2	47.7	54.51	29.29	0.61	3.1	0.65
3	48.7	63.5	29.71	0.76	18.7	0.68
4	22.0	26.55	16.89	0.43	6.2	0.93
Mean	40.3	51.67	26.29	0.66	8.08	0.74
SD	12.43	17.21	6.27	0.17	7.20	0.13

It was observed that a significant function of the sediments was composed of potassium, calcium, sodium, and lithium which are a part of the rock material (crust) present in the region. The sediments had fairly good organic carbon (TOC) associated with it. Relatively high concentration of sediment-associated organic matter was observed near the dam since most of the suspended organic fraction settles to the bottom in this region. Similar to organic carbon, relatively high concentration of phosphate was observed near the dam. An almost equal average concentration of phosphate in sediments and water suggests of near equilibrium conditions w.r.t partitioning of phosphate, indicating that the sediments are almost at equilibrium with the mobile phase i.e water in respect of orthophosphate.

FTIR Analysis of sediments

Mineralogy is an important part of formation description but the analytical capabilities for accurate mineral analysis are still preliminary. There have been a number of studies on quantitative mineral analysis based on Fourier Transform Infrared (FTIR) spectroscopy measurements with specific sample preparation and signal processing procedures. It has been used as an alternative to X-ray diffraction (XRD) in the analysis of sedimentary minerals. Many common minerals exhibit similar absorbance spectra in the middle IR region, which extends from 400 cm^{-1} to 4000 cm^{-1} . In the present study, mineral analysis of sediments collected from Lake Siliserh was performed on FTIR (Perkin-Elmer make Spectrum Two model), and the major minerals were identified based on corresponding absorption bands (cm^{-1}) (Table 4.10; Fig. 4.6).

Table 4.10. Major minerals present in sediments of Lake Siliserh, Alwar, Rajasthan

S. No.	Major Mineral	Chemical Formula	Absorption Band (cm ⁻¹)
1	Kaolinite	Al ₂ Si ₂ O ₅ (OH) ₄	467, 694, 797, 1032, 3621, 3698
	Gypsum	CaSO ₄ .2H ₂ O	3406
2	Kaolinite	Al ₂ Si ₂ O ₅ (OH) ₄	535, 695, 913, 1032, 3622, 3698
	Gypsum	CaSO ₄ .2H ₂ O	3384
	Calcite	CaCO ₃	1419
3	Kaolinite	A4.11l ₂ Si ₂ O ₅ (OH) ₄	470, 535, 695, 798, 1032, 3622, 3698
4	Kaolinite	Al ₂ Si ₂ O ₅ (OH) ₄	470, 535, 695, 778, 797, 913, 1031, 3622
	Gypsum	CaSO ₄ .2H ₂ O	3385
	Hemihydrate of CaSO ₄	CaSO ₄ .0.5H ₂ O	647, 1638

Based on the FTIR analysis, it was observed that Kaolinite clay was the major mineral present in the sediments; and it was followed by presence of gypsum, hemihydrate of gypsum, and calcite. A correlation was observed between the chemical composition of dominant minerals and physico-chemical characteristics of water in Siliserh Lake.

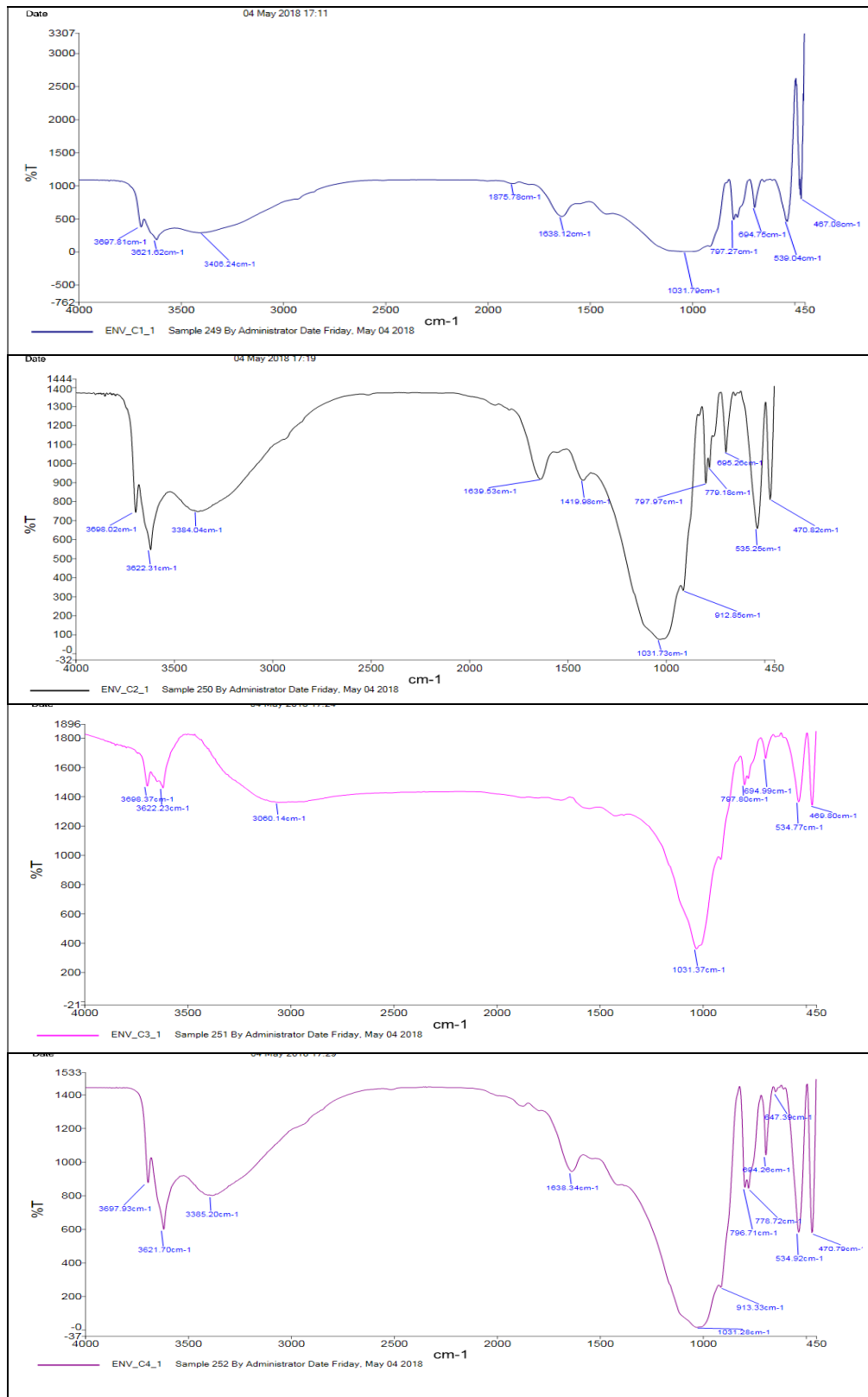


Fig 4.6 FTIR spectrum of Siliserh lake sediments

4.12 Statistical Analysis

Correlation Matrix

A detailed correlation study is carried out between physiochemical water parameters obtained from different sampling sites of the lake (Table 2). pH shows positive correlation with CO_3^{2-} , SO_4^{2-} , NO_3^- and NH_3 as these are inferred to come from a common source. EC shows positive correlation with ORP, TH, TA, K, Ca, Mg and HCO_3^- . DO shows positive correlation with K, Ca, Li and HCO_3^- . Oxidation Reduction Potential shows negative correlation with BOD, indicating increase in ORP results in decrease in BOD value. Total hardness shows positive correlation with Mg, as it is originated from crustal leaching and its presence defines hardness. The TA shows positive correlation with Ca, and HCO_3^- as their presence in water resembles alkalinity. Sodium is found to be positively correlated with K, Mg and Li. Potassium showed positive correlation with Ca, Mg, Li and HCO_3^- . Calcium showed positive correlation with Mg and Li, which inferred to be come from crustal origin. Iron showed positive correlation with CO_3^{2-} , SO_4^{2-} , NO_3^- , PO_4 and SiO_2 . Carbonates showed positive correlation with NO_3^- , PO_4 , and NH_3 . Sulphate showed positive correlation with NO_3^- , PO_4 , and SiO_2 , whereas NO_3^- showed positive correlation with PO_4 , SiO_2 and NH_3 as these are inferred to come from agricultural runoff containing chemical fertilizers.

Principal Component Analysis/Factor Analysis

Principal component analysis is carried out for all the physiochemical parameters of different sites of lake water in order to establish interrelationship between different parameters (Table 4.11). Five components were obtained during PCA i.e. Component-1 to Component-5 having eigen values ranging from 1.05 to 8.13 and a total cumulative variance of 85.89%. In Component-1 Parameters like EC, TA, Ca and HCO_3^- has got positive correlation as they are the components of crustal minerals, which is of natural origin. In the same component parameters like NO_3^- , NH_3 and CO_3^{2-} has got negative correlation and they comes from domestic wastewater and agricultural runoff. Moreover CO_3^{2-} is negatively correlated with HCO_3^- , which may be due to the carbonate cycle. As the pH rises to or more than 8.5, HCO_3^- is converted to CO_3^{2-} , which is precipitated to CaCO_3 at pH more than 9.2. Similarly, in Component-2 positive correlation is obtained between parameters like Na, K and Li and a negative correlation is obtained between SO_4^{2-} and SiO_4 respectively. All these parameters are of crustal origin.

Table 4.11 Rotated component matrix representing principal component Analysis (PCA) for Siliserh lake, Alwar.

Variables	Components				
	<i>PC 1</i>	<i>PC 2</i>	<i>PC 3</i>	<i>PC 4</i>	<i>PC 5</i>
pH	-0.662	-0.187	-0.464	-0.122	0.299
EC	0.903	0.055	0.277	-0.136	0.085
DO	0.291	0.106	-0.170	0.049	0.917
ORP	0.495	0.293	0.564	-0.362	-0.002
TH	0.105	0.051	0.944	0.062	-0.185
TA	0.863	0.078	-0.069	0.071	0.101
BOD	-0.014	-0.205	0.169	-0.098	-0.876
Na	-0.007	0.809	0.111	0.295	-0.195
K	0.350	0.760	0.205	-0.372	0.267
Ca	0.788	0.336	0.153	-0.087	0.243
Mg	0.114	0.239	0.927	-0.112	-0.123
Li	0.023	0.795	0.055	-0.117	0.309
Fe	-0.221	-0.328	0.270	0.798	0.086
CO₃²⁻	-0.903	-0.026	-0.071	0.152	-0.015
HCO₃	0.971	0.045	0.022	-0.072	0.047
SO₄	-0.143	-0.873	-0.122	0.284	-0.040
NO₃	-0.819	-0.243	-0.139	0.399	0.074
PO₄	-0.182	-0.159	-0.419	0.821	0.113
SiO₄	-0.033	-0.885	-0.112	0.251	-0.134
NH₃	-0.746	0.146	-0.042	0.146	-0.152
Eigen values	8.130	3.450	2.990	1.570	1.050
CV%	40.630	57.860	72.800	80.660	85.890

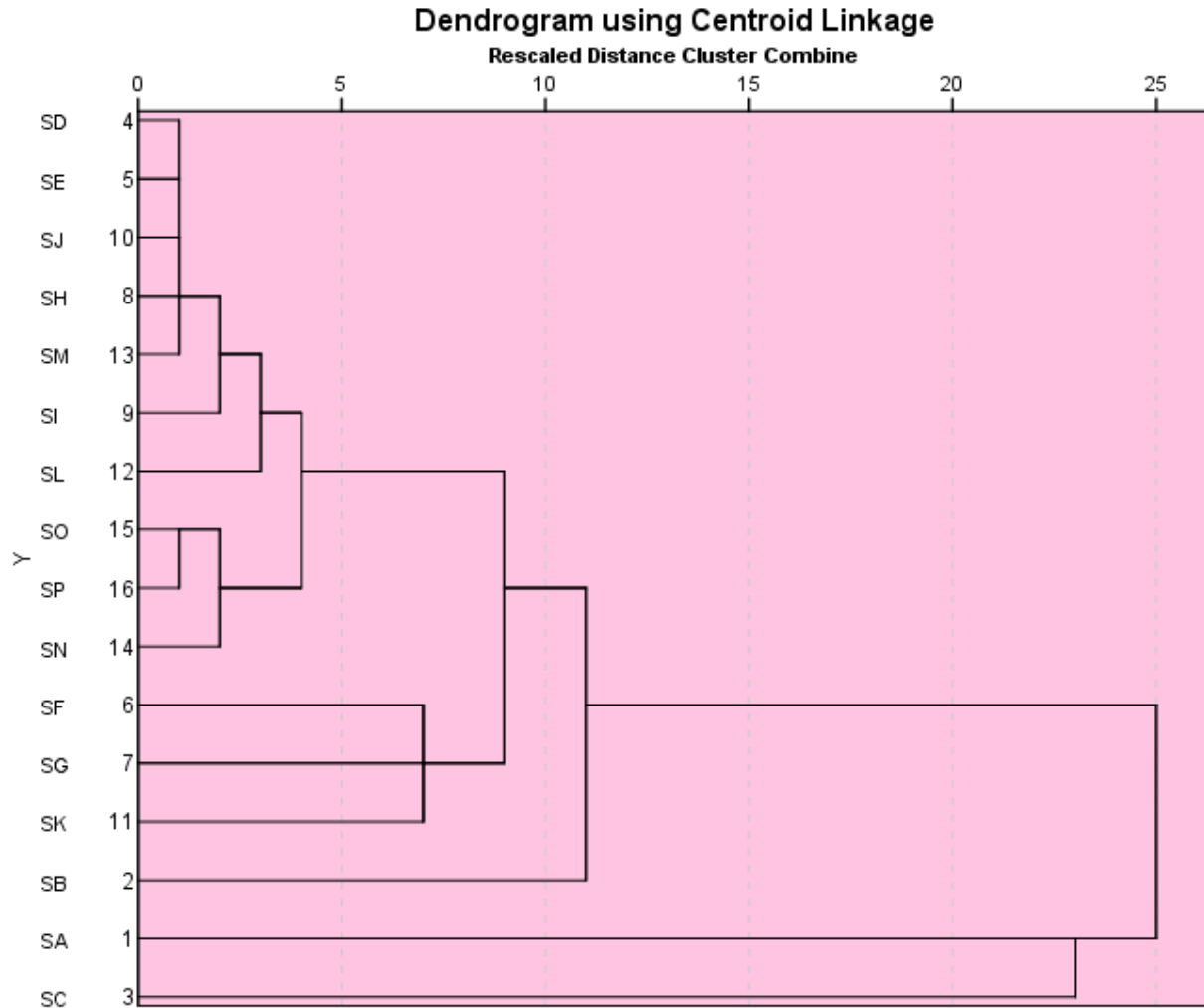


Fig 4.7 Dendrogram for cluster analysis of water samples of Siliserh lake

Cluster Analysis

A Hierarchical Cluster Analysis is carried out for various physicochemical characteristics of different sampling sites of the lake (Fig. 4.7). During the cluster analysis four clusters were obtained in the dendrogram for all the sixteen sampling sites i.e. cluster-1 (site 1), cluster-2 (site 2), cluster-3 (site 3) and cluster-4 (site 4 to site 16). The clusters formed resembles water quality of the lake, which means different clusters has got different water quality. Site-1, Site-2 and Site-3 formed different clusters as their water quality is different from each other and these are the locations situated near the agricultural fields.

Chapter 5

Conclusion

CONCLUSION

Based on the observations of physico-chemical characteristics of surface water of Siliserh lake, it was found that the water is dominantly CaHCO_3 type followed by CaMgCl type. The relative abundance of cations and anions followed $\text{Mg} > \text{Ca} > \text{Na} > \text{K}$, and $\text{HCO}_3 > \text{Cl} > \text{SO}_4 > \text{CO}_3$ trend. Upon study of Gibb's boomerang plots, it was observed that the prominent process controlling surface water quality is the rock water interaction. Further, it was found that the silicate weathering played a major role in genesis of water quality. The suitability analysis of water revealed that the lake Siliserh can be used as a source for drinking water supply since all the parameters were within the prescribed limits for drinking water. Similarly, the water quality for agricultural use was good with the only problem of excess magnesium (Mg Hazard) at most of the locations. The analysis of saturation index (LSI and RSI), corrosivity ratio (CR), coefficient of corrosivity (CC) and foaming coefficient (FC), most of the samples were found to be safe for industrial use. The geochemical classification of water indicates that direct base exchange results in addition of calcium and magnesium from the interacting rocks to water resulting in relatively higher concentration of calcium and magnesium resulting in naturally hardened water. The FTIR analysis of sediments identified the presence of Kaolinite, Gypsum and Calcite which are purely crustal in origin; and Kaolinite is the end member of process of silicate weathering. The chemical constitution of the identified minerals co-related with the chemical composition of water confirming to natural source for most of the dissolved ions. Similarly, natural flushing of organic impurities during the rainfall in the catchment is the major source for organic impurities in the lake. The analysis of sediments too confirmed the accumulation of organic matter and its autothonomous circulation subsequently. Since, the N:P is around 10:1 the lake is transforming from oligotrophic to eutrophic status which is a cause of concern, and requires immediate intervention for managing the water and sediment quality of Siliserh lake. The spatial variation in water quality was not very significant and slightly elevated levels of some of the pollutants were observed in regions which were close to the rural habitation or villages. The flushing of nutrients from nearby fields and discharge of waste water from adjoining villages need to be checked/ diverted for treatment since it may affect the water quality adversely in coming years.

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