☩ IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY
HYDROCHEMISTRY AND POLLUTION ASSESSMENT OF FRESH WATER LAKES

Parvaiz A. Bhat, Arshid J. Bhat* & B U Khan
Department of Chemistry, University of Kashmir, Srinagar, J&K, India.
*Department of Environmental Science , University of Kashmir, Srinagar, J&K, India

ABSTRACT
This study investigates spatial and temporal change in lake water quality, relationships between quality parameters, and sources of contamination. For this purpose, samples were collected from 12 different sampling sites chosen according to their hydrogeological properties and location relative to anthropogenic interface between March 2007 and Feb. 2008. Various physical (temperature, depth, water transparency) and water chemistry parameters (pH, EC, DO, TDS, calcium, Iron, magnesium, potassium, sodium, chloride, total alkalinity, nitrate, ammonia, sulphate, Orthophosphate and Total Phosphorous) were monitored. It was observed that the lake water has bicarbonate alkalinity. Agricultural contamination was determined in the region, especially during the summer. Organic matter contamination was also investigated in the study area during monitoring period. The long-term hydrochemical data of the studied water bodies have been also evaluated; general trend of increase of the analyzed ion was observed. The positive correlation values between various parameters indicate that most of ions come from same lithological sources & the studied lakes face similar anthropogenic stress

KEYWORDS: Water chemistry; anthropogenic stress, dal and Nigeen lakes, environmental pollution; correlation analysis.

INTRODUCTION
Contamination of lake water ecosystems is a worldwide environmental problem. The pollution of fresh water urban lakes has become one of the major quality issues in fast growing cities, because maintenance of water quality and sanitation infrastructure could not increase alongside the population and urbanization growth especially in developing countries due to rapid urbanization and industrial development during last two decades (Sundary *et al.,*2006; Karbassi *et al.,*2007; Akoto *et al.,* 2008; Ahmad *et al.,* 2010).

The chemical composition of natural waters is the result of a variety of chemical reactions and physico-chemical processes acting in concert. These interactions include acid-base reactions, gas solution processes, precipitation and dissolution of solid phases, complexation reactions of metal ions and ligands, redox reactions and absorption processes at interface (Stumm and Morgan,1970). An aquatic ecosystem normally responds to variations in temperature, pressure, pH, oxygen concentration, levels of nitrogen, carbon, phosphorous, and other common cations and anions. The biological activity of a natural water body can be too high (eutrophication) or too low (oligotrophication). Eutrophication results from an excess availability of nutrients or energy source in the water body, as is faced by the prominent lakes in Kashmir. A suggested method of controlling the very high rate of eutrophication is lowering the levels of nitrogen and phosphorous in the lake waters (Stumm and Morgan, 1970).

In unaffected environments these water chemistry parameters / chemical species are always present in fresh waters lakes, derived mostly from the mineralogy and weathering (Anderson, 2003; Samarghandi *et al.,*2007; Al-Juboury, 2009; Karbassi *et al.,*2008). Main anthropogenic sources of lake water contaminants include mining, long term disposal of untreated and partially treated effluents containing metals as well as metal chelates, indiscriminate use of various chemical fertilizers and pesticides in agriculture fields, wet and dry fallout of atmospheric particulate matter, urban runoff and direct solid waste dumping (Hatie *et al.,* 1998; Amman *et al.,* 2002; Nouri *et al.,* 2006; Kraft *et al.,*2006; Nouri *et al.,*2008; Singh *et al.,* 2008; Venugopal *et al.,*2009; Sarika *et al.,*2008). With many of them being non-biodegradable, these chemical species can get accumulated

along the food chain and show their toxic effects at points often far away from the sources of pollution (Fernandez et al.; Berzins and Bundy; Kishe and Machiva).

The behaviour of various chemical species in natural waters is a function of the substrate sediment composition , the suspended sediment composition and the water chemistry(Osmond *et al.*,1995;Shrestha *et al.,* 2007; Harikumar *et al .,* 2009). Upon their entry in the lake water column they undergo numerous changes in their speciation due to dissolution, precipitation, sorption and complexation phenomena (Akcay *etal.,* 2003; Abdel-Ghani *et al.,*2007; Abdel-Ghani and Elchaghaby*,* 2007) which affect their behaviour and bioavailability.

The list of natural water bodies / fresh water lakes getting polluted grows every year, presenting a serious problem for human health and a fearful danger to the environment (Marin *et al.,*2001; Kar *et al.,*2008). Therefore monitoring these natural water bodies becomes important for safety assessment of the environment and human health in particular. Dal and Nigeen lakes, the world famous twin urban fresh water lakes in Srinagar, Kashmir, India, are the major recipients of urban runoff and surrogate end points for pollutants of domestic and commercial effluents (*Sabah-u- soluem and Ashwani.,2007*) and are increasingly being polluted with direct discharge of raw effluents, untreated and partially treated sewage and waste water from commercial and domestic establishments besides other nonpoint sources. The Dal and Nigeen lakes being in the heart of City are very important because they are at the core of tourism industry in Kashmir, dubbed as paradise on earth. Contamination of these lakes is of grave concern to all for the reason that not only the dwellers around them but also the hundreds and thousands of visitors from around the world are likely to be affected by the problems from contamination of these lakes.

Water chemistry analysis of natural water bodies provides useful data if multiple sampling is carried out at regular intervals to determine the degree of fluctuation of various natural constituents and the pollutants in the water bodies.

The objects of the study were to; 1) investigate the water chemistry of the two lakes exclusively based on inorganic parameters 2) study the relationship among selected parameters and physico-chemical characteristics and 3) examine the natural and anthropogenic influences on the water chemistry and of the two lakes to determine the common origin of the contaminants using statistical (correlation, cluster and principal component)analysis. This study was carried out during March 2007 to February 2008.

MATERIALS AND METHODS
Study area
Srinagar (study area,fig.1), the main city of Kashmir valley and summer capital of J&K state is situated on the banks of river Jhelum at an altitude of 1585 meters above sea level, which dissects the city diagonally from the southeast to the northwest and located in the geographic coordinates of $30° \ 44' \ N \ 76°48' \ E$. It is home to the population of more than 1.2 million people and spread over an area of 294 sq. kms[1a,1c]. The climate of Srinagar is by and large temperate to Mediterranean type of climate[1]. The average rainfall was 558 mm during the study period and the minimum and maximum average monthly temperature ranged from -1.9^0C to 20.3 ºC. In fact the genesis of the weather in Kashmir valley is intrinsically linked with the mechanism of weather in the Indian sub-continent in general.

In carrying out the present study both the natural fresh water lake ecosystems (Dal and Nigeen) which are located in the heart of Srinagar city were selected for sampling. Dal lake, the cradle of Kashmir civilization is considered one of the most beautiful lakes of the world and included in the heritage sites of India, lies in the foot hill formation of the catchment of Zabarwan hills which surround it on three sides. It is situated in the northeast of Srinagar city and is integral to it. Located at an elevation of 1581 meters above sea level, the Dal lake rests in the coordinates 34º.09ʾ - 34º15ʾ N latitude and 74º84ʾ - 74º88ʾ E longitude. Dal is a shallow, post glacial lake of warm monomictic type with an average depth of about 2.50 meters. This multi-basin lake with an area of about 18 sq. Kms, out of which open water area is not more than 11 sq. One of the striking features of Dal lake is its vast and diverse catchment that spreads over an area of about 337 sq. kms which is about twenty times more than the lake area, consisting of mountain ranges on its north and north east side and on the other side's it is enclosed by flat arable land. Nigeen lake, also called as "Emerald Set in Jewels" is a charming lake situated at a distance of about 9 kms. to the east of Srinagar city centre and is integral to it. Located at an elevation of 1581 meters above sea level and covering an area of about 4.5 sq. kms, rests in the coordinates 34º.11ʾ - 34º13ʾ N latitude and 74º82ʾ - 74º83ʾ E longitude is deeper of the two fresh water lakes with maximum depth of 6 metres[4] (*Sabah-u- soluem and*

Ashwani.,2007). Nigeen too is a shallow, post glacial lake of warm monomictic type with an average depth of about 3 meters.
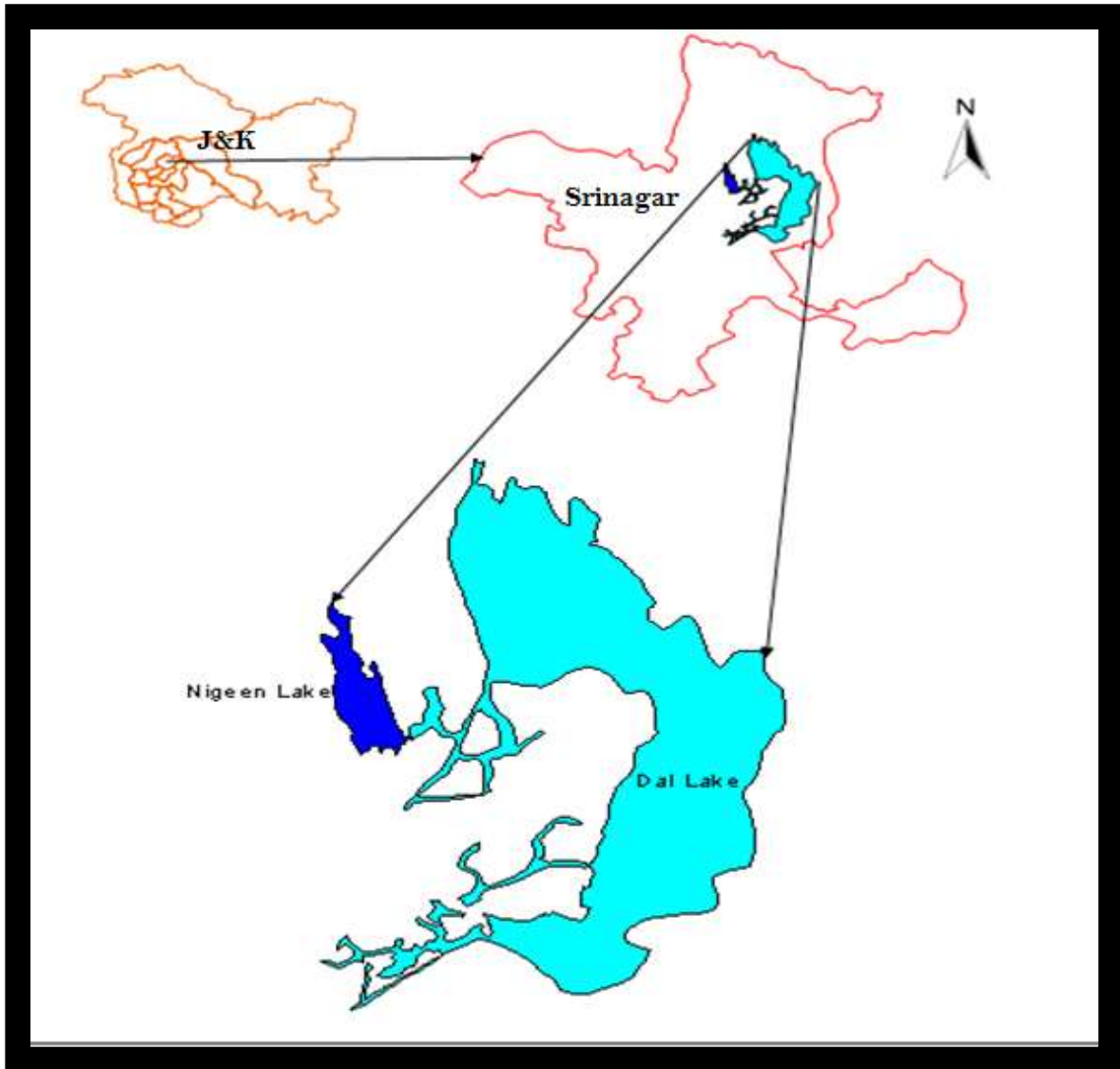

Fig. 1 Geographical representation of the study area as in P-5

Sampling sites and field sampling
Twelve sampling sites were selected (Table 1) and) from different locations of two lakes for collection of samples in the present study. The sampling programme was spread over one calendar years from March 2007 to February 2008 and sampling was carried out every month. Criteria for selection of sampling stations were based on the locations of various point and nonpoint sources and land use pattern to quantify the contamination levels. Nine sampling sites were chosen from Dal lake and three from Nigeen lake (fig. 2). Care was taken to ensure the collection of first and subsequent samples from exact locations. All chemicals and reagents used were of analytical grade reagent quality (Sigma-Aldrich, E-Merck and some from Hi Media labs India). Before use, all glass and plastic ware were soaked in 14% HNO_3 for 24 h followed by washing with Millipore water rinse.

Table. 1 Location and description of sampling sites.

| Site	Code	Activity/ Establishment
This site was situated close to Dalgate in the vicinity of the outflow channel.	D1	There are human settlements close to this site on eastern and western sides.
Located near Nehru Park in the Gagribal basin.	D2	This area has highest tourist activity going around throughout the year and has dense settlements both on the bank as well in shore.
This site was fixed in the Boddal basin of the lake towards Char Chinari lying between Nehru Park and SKICC & falls in Boddal Basin.	D3	This area too has highest tourist activity going around throughout the year and has dense settlements on the western side.
This site was located in the middle of the Nishat area of the lake almost in front of the famous Nishat Garden.	D4	This area too has highest tourist activity going around throughout the year and has dense settlements on the eastern side.
This site was located within the lake catchment area of the Telbal Nallah which lies between Nishat and Hazratbal basins.	D5	This site falls in Hazratbal Basin at the Telbal Nallah inlet & receives inflow contents of Telbal Nallah .
This site was located in front of the famous Hazratbal Shrine.	D6	In addition to large number of human settlements, this area is used for washing by thousands of people who congregate here.
This site was fixed in the open water area towards the centre of the lake between Charchinari and Sonalank.	D7	This site represents the centre of the open water lake area.
This site was fixed in the Rupalank catchment area of the lake.	D8	It is an interior part of the lake on the western side having numerous settlements around, which discharges their wastes directly into the lake waters.
This site was Located in the Nowpora catchment of the lake .	D9	It has numerous densely populated human settlements in its vicinity falling in the south-western side of the lake.
This site was located in the middle of Nigeen lake.	N1	It is the deepest zone of the lake having a depth of about $5 - 6$ metres.
This site was fixed near the Ashai Bagh bridge.	N2	The area houses a good number of house boats, having an average depth of about 4-meters.
This site was fixed in the shallow zone of the lake with an average depth of 2-metres in the vicinity of Zaildar Mohalla.	N3	It links to the outflow Nallah Amir Khan that connects the lake with Khushalsar lake & densely populated human settlements in its vicinity.
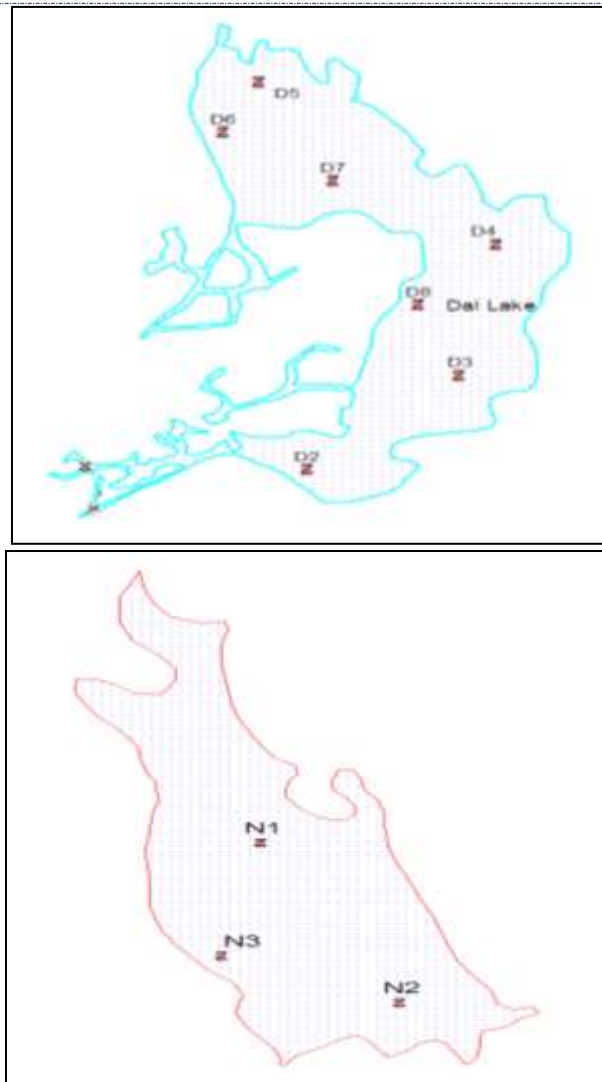
Fig. 2. Location map of the selected sampling sites of Dal and Nigeen lakes

Sampling and chemical analysis

The samples were taken from 10 to 15 cm below the water surface film with the help of a Ruttner sampler (Bately and Gardner)[35]. Sampling bottles were washed with dilute nitric acid, rinsed with deionised and triple distilled water and again washed three times with the lake water before they were filled. Water samples were collected from all the sampling sites in water tight one litre polyethylene bottles for laboratory investigation. Parameters like water column depth, water temperature, pH, transparency, electrical conductivity, and total dissolved solids, were determined on site using portable meters, while other parameters were determined in the laboratory within 24 hours of sampling. The analysis was done as per the standard methods given by Davis [2], Mackreth[3], Golterman and Clymo[4], CSIR[5] and APHA[6]. For heavy metal analysis, a 500 mL bottle of linear polyethylene was used to collect water samples and added five drops of ultra pure nitric acid for sample preservation (APHA; Golterman and Clymo). All these technicalities were ensured to avoid unpredictable changes in characteristics as per standard procedures (APHA, 1998). The analyses were carried out as per the standard methods given by Davis , Mackreth, Golterman and Clymo, CSIR and APHA. The elements were then analyzed by direct aspiration of the sample solution into a Perkin Elmer Model, A Analyst 800 atomic absorption spectrophotometer (AAS) after calibration with suitable elemental standards at close intervals. It is a single element analyzer having multi in one system with burner system for flame atomization and graphite furnace for electro thermal atomization with automatic atomizer change. The heavy metal analyses of the samples were carried out in USIC (University Science and Instrumentation Centre), University of Kashmir, by an:; Make, Ltd During AAS operations specific

instrumental conditions were maintained for each element as recommended (Whiteside and APHA) and the detection limit was set to 10 PPB. Average values of three replicates were taken for each determination.

Assessment of lake hydrochemistry
Total dissolved solids (TDS) Waste Wastewater TDS classification consists of three classes (0-220 mg/L) ranging from weak to strong (< 100 mg/L) weak (100 – 220 mg/L) medium and strong wastewater (> 220 mg/L),Akan *et al* (2008).

Statistical Analysis
Correlation analysis: Pearson correlation's correlation analysis was adopted to analyse and establish inter-parameter relationship and physico-chemical characteristics of the lake water. The data were standardized to give a normal distribution with a mean of 0 and a variance of 1. Sample means were standardized by subtracting the mean of their distribution and dividing by standard error (SE) or square root of the variance.

Cluster analysis (CA) : CA was performed using Minitab Release 14 or 15 to classify elements of different sources on the basis of their similarities using dendrogram and to identify relatively homogeneous groups of variables with similar properties. The data was standardized to give a normal distribution with a mean of 0 and a variance of 1. Sample means were standardized by subtracting the mean of their distribution and dividing by standard error (SE) or square root of the variance.

RESULTS AND DISCUSSION

Mean values of water chemistry parameters are given in Table 2. Temperature is an important factor which governs vital processes in a fresh water ecosystem. Various chemical processes taking place in the system are directly or indirectly influenced by thermal cycles. Water temperature influences the uptake of heavy metals by submerged plants in water bodies and increasing temperature increases the heavy metal uptake by them (Fritioff et al.). The lake waters remain well mixed throughout the year without depicting either summer or winter stratification. According to Crumrine and Beeton (1975), for developing summer stratification, the depth of lakes should usually exceed 8 meters. In the present investigation the depth of lakes does not exceed 4.5 metres. The water temperature in general ranged from 3.3 to 33.4°C during the entire course of study. The depth of water bodies is another important parameter which could be viewed in terms of total water volume and the extent of dilution factor viz-a-viz the concentration of lake water constituents. The maximum depth (6.5 m) and mean depth (3.7 m) in case of Nigeen Lake in higher as compared of that of Dal Lake (Max. = 4.5 m and mean depth = 2.39 m). As a result of this Nigeen lake should be at lower levels of eutrophication in comparison to Dal Lake and the same situation surfaced in the present studies.Water transparency is an important factor that controls the energy relationship at different trophic levels and shows seasonal and annual variations depending upon fluctuations in seston (Riley), evaporation and disturbance of bottom silt by winds (Banerjee and Choudhary), density of plankton population (Zutshi et al.) and the entry of storm water runoff. Transparency was much higher in open water areas [Mean 1.9 m (D_7), 1.4m (D_3, D_8, N_1, N_3)] in comparison to in shore waters [Mean (0.3 m.), 0.4 m, 0.5 m, 0.8 m (D_4, D_1, N_2)]. The average transparency value for all the sites of Dal Lake was 1.04 m compared to 1.14 m of Nigeen lake.

The pH of the lake waters ranged from 7.2 to 9.4 during the course of present investigation indicating that the waters are alkaline and well buffered as no sudden shifts in the pH were observed. The variations in pH values from one season to another is generally related to dilution, due to influence of various kinds of water in the water bodies and to photosynthetic activity which being higher during summer results in a greater utility of carbon sources and an associated decrease in hydrogen ion concentration (Kaul; Kaul and Handoo; Zutshi and Vass; Zutshi et al.; Anon). It is interesting to note that the average pH values were generally higher at sites which could be designated more stagnant water sites were a number of processes operate for the same water column for longer periods. The pH values of 7.5-8.0 usually indicate the presence of calcium and magnesium carbonates and pH of 8.5 and above

Table 2. Mean values of hydrochemistry parameters of lake water at different sites in Dal lake & Nigeen lake.

Site	WT	Depth	TRPCY	pH	CON	DO	TA	Ca	Mg	Na	K	Cl	Fe	SO4	NO3	NH3	OrthoP	TP	TDS
D1	18.7	2.3	0.9	8.1	279.1	6.1	118.4	39.3	8.3	6.8	2.8	8.9	250.8	9.9	831.2	430.3	119.3	391.5	155.7
D2	18.9	2.3	1.0	8.6	229.8	6.9	151.8	31.8	4.6	3.8	1.5	10.4	191.9	5.9	513.3	315.8	92.7	281.2	129.4
D3	18.8	2.4	1.4	8.4	199.6	6.8	147.1	30.6	3.7	3.5	1.3	10.0	179.8	5.0	631.4	259.6	101.8	293.3	122.7
D4	17.5	3.3	1.0	7.9	259.9	6.0	114.1	36.7	7.3	5.4	2.2	7.5	225.1	10.2	816.0	339.9	101.8	348.3	138.3
D5	17.8	1.4	0.1	8.0	305.2	5.4	141.8	47.1	10.9	4.6	2.2	10.1	319.6	15.7	840.2	698.3	186.4	583.4	186.7
D6	18.6	1.4	1.2	8.5	290.2	4.9	197.5	40.3	8.8	4.9	1.8	10.9	285.3	11.0	583.3	644.9	157.7	605.4	167.0
D7	18.8	2.7	2.0	8.8	229.4	7.4	141.7	29.3	4.3	3.3	1.3	10.0	165.7	5.4	575.1	229.2	95.3	285.7	127.0
D8	18.5	2.8	1.7	8.2	280.6	7.6	125.9	39.0	8.0	3.4	1.4	8.2	206.5	11.1	703.7	361.2	115.3	405.0	165.6
D9	18.2	2.6	1.2	8.1	267.4	6.1	125.5	45.2	7.2	4.3	1.8	12.8	268.8	10.6	649.0	339.5	121.3	356.2	138.1
N1	18.8	6.0	2.1	8.0	256.7	7.2	145.7	51.8	3.8	3.7	1.4	15.7	255.0	9.3	412.1	221.8	104.5	279.1	142.9
N2	18.8	2.7	1.1	7.9	295.9	5.8	164.6	51.5	4.5	4.4	1.8	16.3	270.3	10.2	459.0	276.4	114.3	312.3	163.8
N3	18.4	1.8	1.4	7.3	358.5	3.3	170.6	63.1	5.3	3.9	1.9	19.5	287.6	14.1	471.3	311.5	137.6	372.1	203.6

WT = Water Temp. (ºC) , TRPCY= Transparency, CON= Conductivity ((μScm^{-1})), TA= Total alkalinity .
Depth (Meters), Rest parameter units= (mgL^{-1}).

shows appreciable exchangeable sodium. The conductivity of lake waters exhibited variations within the range of 101-592 μScm^{-1}. Conductivity is an important parameter that has been used as an indicator of the scale of trophy in lakes (Berg et al.), being low in oligotrophic and high in eutrophic ones (Pandit). Two of the investigated sites D_5 and D_6 of Dal lake and one (N_3) of Nigeen Lake depicted high conductivity values throughout the study in comparison to other sites. These sites are the Dal lake catchment of Telbal Nallah and Hazratbal shrine and the Zaildar Mohalla catchment of Nigeen lake which receive good quantities of sewage, kitchen refuge, toilet waste and runoff waters directly on daily basis. Data obtained on dissolved oxygen concentrations depicted considerable variations from 1 mgL^{-1} to 9mgL^{-1}during two years study. Variations in the content of the dissolved oxygen in lake waters is regulated by a number of factors which include the rate of aeration, intensity of photosynthesis, microbial activity and temperature (Reid and wood). The low oxygen concentration in waters may reflect the extent of microbial respiration which indirectly points to the rate of enrichment. During some months the oxygen concentration was as low as 1.2mgL^{-1} which is indicative of anoxic conditions. Total alkalinity which is a measure of temporary hardness expressed as $CaCo_3$ displayed variations ranging from 28 - 422 mgL^{-1} during the entire course of study. When total alkalinity is high the bicarbonate system prevails and pH is usually on the alkaline side (Freiser and Fernando) and this is true for the lakes under investigation. The maximum alkalinity was observed during summer and autumn and minimum during winter and spring with a few exceptions in all the study sites.

Calcium and magnesium accounted for most of the hardness of lake waters. The ions depicted a variation range of 19.2 - 88 mgL^{-1} for calcium and 1.9 - 32 mgL^{-1} for magnesium. In general, the cationic composition of the lake waters revealed the predominance of calcium over other ions and the cation progression surfaced as $Ca^{2+} > Mg^{2+} > Na^+ > K^+$ which brings it close to the well known sequence for global fresh waters (Rhode)[29]. Calcium is generally the dominant cation in Kashmir lakes because of predominance of lime rich rocks in their catchment areas (Zutshi et al.)[21]. The maximum values for calcium and magnesium were generally observed during mid autumn, winter and early spring. Site variations with regard to calcium concentrations were quite significant and it was observed that D_5 and D_6 sites of Dal Lake and N_1, N_2 and N_3 sites of Nigeen lake (Tables 4.2.8a to 8b) had higher calcium concentration than other sites. The magnesium content of the two lake waters remained low throughout the present investigation (maximum Mean = 10.8 mgL^{-1}) which may be due to uptake of this ion by plants in the formation of chlorophyll and also in enzymatic transformations as has been reported by Wetzel[30]. Potassium was observed to be present in low concentrations with the highest annual mean of 2.8mgL^{-1} at D_1 and lowest value of 1.3mgL^{-1} at D_7 of Dal Lake. While sodium concentration appears to fluctuate in an irregular manner, Potassium was found to record higher values during early spring and autumn and least during summer, probably due to its utilization by the primary producers (which are mainly, macrophytes).The annual mean concentration of sodium was lower than calcium and magnesium and was highest in site D_1 (6.8 mgL^{-1}) and lowest in site D_7 (3.3 mgL^{-1}) of Dal Lake. Relatively higher concentrations of sodium have been attributed to domestic sewage (Sharma et al.[31]; Panno et al.[32]) which fits well for the sodium concentration of studies sites.

The chloride ion concentrations in general were found maximum in spring and summer seasons and minimum in autumn and winter seasons for most of the sites studied. Considerable spatial variations in chloride concentration between different sites suggest a difference in the input levels of impurities that contaminate the sites of the water bodies. The higher values during summer may be attributed to higher rainfall which dissolves more salts from soils (Ramesam; Ballukraya and Ravi). Further the high chloride content in springs may be related to presence of large amounts of organic matter of both allochthonous and autochthonous origin and contamination by sewage waste carrying detergents and sewerage from human settlements (Blum; Paramsivan and Srinavasan; Bhat et al.; Bhat and Pandit). Thresh et al related it to organic pollution of animal origin.Iron being an essential element in the metabolism of animals and plants when present in fresh water bodies in excessive amounts becomes undesirable and forms red hydroxide precipitates that cause problems for laundry and plumbing processes hence becomes an objectionable impurity in fresh water bodies. Upon observing the Iron concentration in the two water bodies studied, it fluctuated from a minimum of 48 μgL^{-1} to 806 μgL^{-1}during the study year.. There were wide fluctuations in both the monthly as well as seasonal concentration values of Iron at different sites. The higher Iron concentrations at times during the

present study may be attributed to the dissolution of iron bearing minerals which might be abundant in these water bodies (Rao)[43] besides the Iron rich effluents / wastes going into these water bodies.

Concentrations of sulphate proved highly variable from $0.7 mgL^{-1}$ at D_6 to $34 mgL^{-1}$ at D_8. Sulphate in carbon rocks may be derived from dissolution of sulphate minerals primarily gypsum and anhydrates or oxidation of pyrite (Drever) and the concentration of sulphate in the lake waters may be controlled by study state dissolution process that gets perhaps influenced by biological sulphate reduction (McCready and Krouse).The maximum allowable sulphate concentration for fresh water bodies is 250 mgL^{-1}. Sulphate gives water a bitter taste and at higher concentrations > 500 mgL^{-1} a laxative effect. The reason for low sulphate values in the studied water bodies may be attributed to rock formation being impregnated with low concentrations of $CaSo_4$ (Cole) besides other factors. The nitrate-nitrogen (NO_3-N) concentration varied between 172-1825 μgL^{-1} throughout the study period. The NO_3N is an important drinking water standard and its higher concentration is fatal for infants (steel and Mc Ghee)[44]. The WHO standards prescribe 10 ppm as maximum permissible nitrate concentration for portable water (Fresinius et al.)[45]. The higher concentration of Nitrogen compounds may be due to domestic sewage (Voznaye[46]; Chhathawal[47]; Suzukie[48]) which enters into these water bodies. Nitrate is a common water contaminant in agricultural Karst areas (Kastrinos and White[49]; Boyer and Pasquarell[50]). In the present study domestic sewage, agricultural activities and decomposing organic matter contribute as nitrogen sources. The nitrate values indicate the influence of agricultural activities due to application of urea as a major inorganic fertilizer. Storage of nitrate in the soil zone can delay and prolong the release of nitrate due to which less seasonal variations of nitrate concentrations in karst basins than non-karst basins has been reported (Panno and Kelly)[51]. Presence of nitrogen of mineral origin is rare in natural waters hence the presence of nitrogen compounds like ammonia, nitrites or nitrates in the lake waters indicates pollution with domestic sewage and agricultural wastes. Presence of Ammonia in the lake waters which varied from 28-1713 μgL^{-1} indicates pollution of recent origins as a result of ammonification, whereas nitrates in water suggest that some time has already elapsed during which nitrification has taken place and water has got purified itself to some extent (Metcalf and Eddy)[52]. Relatively higher concentration of ammonia may be attributed to the release of Ammonia from decomposition of algal mats, zooplankton and fishes which occur in higher densities in these water bodies. However, it is difficult to say precisely whether the main source of ammonia dissolved in the waters comes from bacterial mineralization of dead plants and animals or whether it is excreted by living animals. Amount of ammonia and ammonium compounds in unmodified natural waters is very small (less than $0.1 mgL^{-1}$) while quantities of more than $1 mgL^{-1}$ are indicative of organic pollution (Ellis et al.)[53].

Phosphorous is a key element in the process of lake eutrophication and enrichment of aquatic ecosystems (Vollenweider)[54]. The orthophosphate (Po_4-P) concentration in the two lakes ranged from $30 – 414 \mu gL^{-1}$. The importance of orthophosphate in natural water bodies has been stressed by many workers such as Juday[55] et al., Owle[56], Sawyer[57], Cooper[58] etc. The orthophosphate content of Dal and Nigeen lakes is much higher and may be related to discharge of human, agricultural and animal wastes. The total phosphorous concentration in the two lakes ranges from 108-1165 μgL^{-1} during the investigation period. To avoid biological nuisance total phosphorous should not exceed $100 \mu gL^{-1}$ at any point (Sawyer)[57] but has crossed this limit in both the lakes investigated. Total dissolved solids (TDS) which refer to the position of total solids present in the water column that pass through a filter of 2.0 μm or smaller pore size along with the filtrate under specified conditions (A.P.H.A) varied from 57-326 mgL^{-1} in study. The highest TDS values at site D_5 during the study in the month of January is plausible owing to the fact that the former site represents the Dal lake catchment area of Telbal Nallah and the Dal Lake catchment area of the densely populated Hazratbal Shrine area, being highly polluted site with high concentration of various soluble species.

Table 3: Pearson correlation coefficient matrix (r) for mean physicochemical characteristics in Dal & Nigeen lake water.

	WTP	Depth	TPY	pH	Cond	DO	ALK	Ca	Mg	Na	K	Cl	Fe	SO4	NO3	NH3	OP	TP
WTP	1																	
Depth	0.052	1																
TPY	0.041	.208(**)	1															
pH	0.007	0.044	.174(**)	1														
Cond	-.531(**)	-.160(**)	-.156(**)	-.173(**)	1													
DO	-.220(**)	.393(**)	.215(**)	.198(**)	-.121(*)	1												
ALK	-.512(**)	-.188(**)	-0.068	0.031	.610(**)	-.122(*)	1											
Ca	-0.013	-0.108	-0.103	-.269(**)	.342(**)	-.519(**)	.233(**)	1										
Mg	0.078	-.185(**)	-.179(**)	0.034	0.017	-.246(**)	-.128(*)	.324(**)	1									
Na	-.183(*)	-0.102	-.224(**)	-0.084	-0.045	-0.104	-0.058	0.05	0.125	1								
K	-0.006	-0.12	-.282(**)	-0.117	0.044	-.331(**)	-0.079	.218(**)	0.123	.561(**)	1							
Cl	0.021	-0.038	0.037	-.225(**)	.293(**)	-.342(**)	.243(**)	.583(**)	-0.058	-0.09	-0.002	1						
Fe	.154(**)	-0.098	-.277(**)	-0.096	0.056	-.203(**)	-0.012	.145(*)	0.004	0.01	0.089	0.046	1					
SO4	-0.101	-0.097	-.161(**)	-.219(**)	.314(**)	-.256(**)	.181(**)	.342(**)	.192(**)	0.159	.279(**)	.223(**)	-0.007	1				
NO3	0.002	-.211(**)	-.242(**)	0.03	.179(**)	-.209(**)	.152(**)	.263(**)	.325(**)	0.035	.345(**)	0.046	.136(*)	.150(*)	1			
NH3	0.104	-.289(**)	.240(**)	0.009	0.112	-.397(**)	0.005	.397(**)	.530(**)	-0.001	.257(**)	0.092	0.032	.160(**)	.506(**)	1		
OP	0.082	-.250(**)	-.215(**)	-.159(**)	.119(*)	-.348(**)	.129(*)	.206(**)	.206(**)	0.151	0.156	.213(**)	-0.021	.165(**)	0.092	.207(**)	1	
TP	0.112	-.260(**)	-.283(**)	-0.102	0.1	-.308(**)	.124(*)	.151(*)	.345(**)	0.096	0.145	0.057	0.064	.158(**)	.188(**)	.345(**)	.817(**)	1
TDS	-.531(**)	-.185(**)	-.187(**)	-.167(**)	.901(**)	-.121(*)	.606(**)	.360(**)	0.062	0.023	0.033	.288(**)	0.075	.327(**)	.174(**)	.134(*)	.136(*)	.128(*)

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Correlation analysis: Pearson correlation coefficients for the data were evaluated to determine the level of inter-water chemistry parameters association and the values are shown in Table 5. Many parameters are correlated with each other, whereas the rest of the pairs are not correlated. Very high BOD and very low DO in the lake water suggest pollution by organic matter and decomposition as a self purification mechanism. This phenomenon results into a reducing condition inorganic rich stream water. These results are in line with those done by Igbinosa and Okoh, (2009). The development of reducing condition in lake water promotes the reduction of iron and anganesehydroxides (Linnik and Zubenko, 2000). Under slightly acidic to alkaline condition, Cd specifically adsorbed proportion is high in solid phase and Pb may occurbonded to poorly crystalline oxides (Fergusson 1990).The pH values (slightly acidic to alkaline), may limit the degree of desorption of heavy metals into solution and can promote co-precipitation except Pb at pH > 6 the solubility is governed by soluble organic ligands under reducing conditions (Muwanga, 1997).Contaminants released to flow in restricted water bodies at the mixing event can promote co-precipitation.

Cluster analysis was performed on the data using Average linkage and correlation coefficient distance. Results of cluster analysis are shown in Fig. 3,4.. Water chemistry parameters were fused into clusters because of their relative concentrations at each site and their similarity coefficients. Biplot of water chemistry parameters suggest in tune with observed values . Organic factor may indicate point sources such as municipal and industrial effluents and adsorption by TDS as well as flocculation or co-precipitation which is pH controlled (Balachandran *et al.,* 2005; Karbassi *etal.,* 2007; Abdel-Ghani and Elchaghaby, 2007; Abdel- Ghani *et al.,* 2009) TDS and TDS seems to play a major role in the adsorption of metals in lake water rich with organic matter.
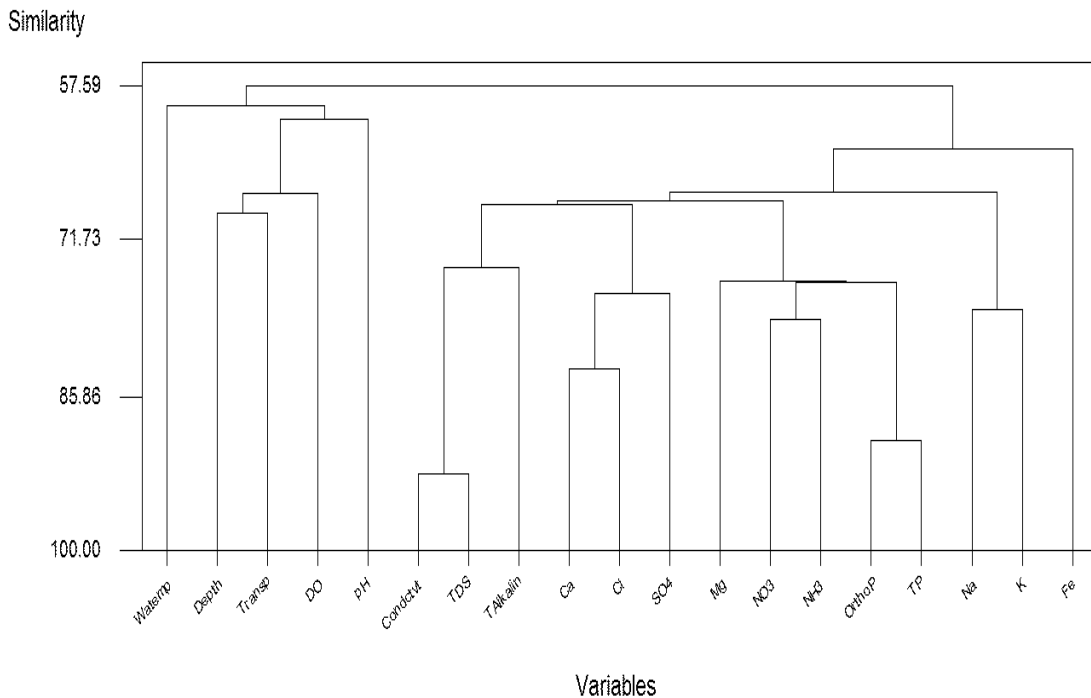

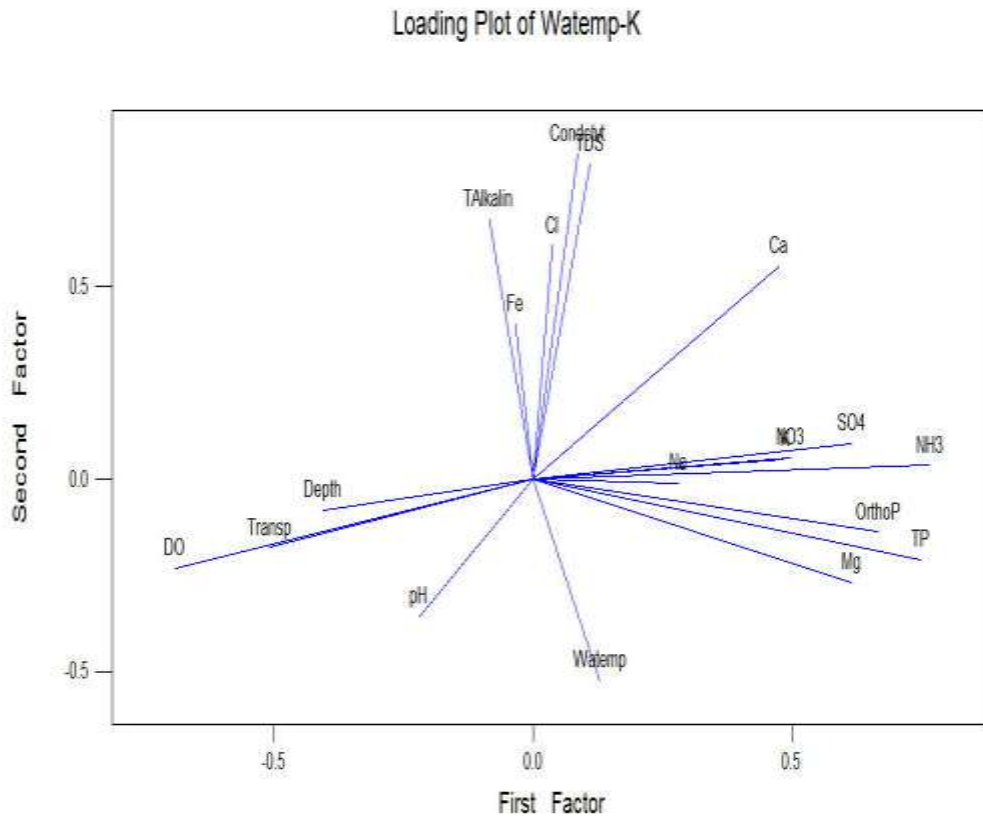*Fig:-3: Dendogram of hydrochemistry parameters of Dal lake & Nigeen Lake .*

Fig:-4: Biplot of hydrochemistry parameters of Dal lake & Nigeen Lake .

CONCLUSION

The lakes investigated are essentially medium and small sized shallow water bodies under great stress as a result of rapid urbanization, misutilization and over-exploitation. Their maximum and mean water depths are very low as result of which their water volumes are easily reduced. Moderate to large quantities of water flows into these two lakes from northern side and equally good amounts are discharged through the lake exists, leading to low water retention and dilution factor enhancement which does not actually happen due to complex water flow pattern that takes narrow routes, leaving large areas of stagnant waters usually with increased levels of pollutants. The present studies have clearly shown that there is a definite horizontal variability in the water chemistry of these lakes, which could be related to a host of factors like excessive agricultural practices, densely populated human settlements, point and non-point sources of polluting waters discharged into these water bodies, house boat areas and other places close to hotels and tourist spots in and around these two lakes. Since the waters of these areas do not get regularly circulated and renewed, the rate of pollution magnifies with time.

Human interference with the aquatic environment of the two lakes have resulted into their zonation into off shore areas and in shore areas showing varied pollution levels as can be seen from the results presented in this article. Most of the samples were found within limits of maximum allowable concentrations for aquatic life. From these observations it can be inferred that the two lakes have similar sources of contaminants both the natural and the anthropogenic ones which is true as both the lakes are situated in the same geographical area and have similar anthropogenic stress as well.

REFERENCES

1. Abdel-Ghani, N. T.; Elchaghaby, G. A., (2007). Influence of operating conditions on the removal of Cu, Zn, Cd and Pb ions from wastewater by adsorption. Int. J. Environ. Sci. Tech., 4 (4), 451-456 (6 pages).
2. Abdel-Ghani, N. T.; Hefny, M.; El-Chaghaby, G. A. F., (2007). Removal of lead from aqueous solution using low cost abundantly available adsorbents. Int. J. Environ. Sci. Tech., 4 (1), 67-74 **(8 pages)**.
3. Abhishek, M. and V.K. Mishra, 2008. Bioaccumulation of heavy metals in crops irrigated with secondary treated sewage waste water in surrounding villages of Varanasi city. Res. Environ. Life Sci., 1: 103-108. http://rels.110mb.com/volumes/vol1no3.htm
4. Agbozu, I. E.; Ekweozor, I. K. E.; Opuene, K., (2007). Survey of heavy metals in the catfish synodontis clarias. Int. J. Environ. Sci. Tech., 4 (1), 93-98 **(6 pages)**.
5. Akcay, H.; Oguz, A.; Karapire, C., (2003). Study of heavy metal pollution and speciation in Buyak Menderes and Gediz river sediments. Water Res., 37 (4), 813-822 **(10 pages)**.
6. Ahmad, M. K.; Islam, S.; Rahman, S.; Haque, M. R.; Islam, M. M., (2010). Heavy metals in water, sediment and some fishes of Buriganga River, Bangladesh. Int. J. Environ. Res., 4 (2), 321-332 **(12 pages)**
7. Aktar, M. W.; Paramasivam, M.; Ganguly, M.; Purkait, S.; Sengupta, D., (2010). Assessment and occurrence of various heavy metals in surface water of Ganga river around Kolkata: a study for toxicity and ecological impact. Environ. Monitor. Assess., 160 (1-4), 207-213 **(7 pages)**.
8. Akoto, O.; Bruce, T. N.; Darko, G., (2008). Heavy metals pollution profiles in streams serving the Owabi reservoir.African J. Environ. Sci. Tech., 2 (11), 354-359 (6 pages).
9. Akan, J. C.; Abdulrahman, F. I.; Ayodele, J. T.; Ogugbuaja, V.O., (2007). Studies on the effect of Municipal waste and Industrial effluents on the Pollutant level of River Challawa, Kano State, Nigeria. Res. J. Appl. Sci., 2 (4), 530-535 **(6 pages)**.
10. Al-Juboury, A. I., (2009). Natural Pollution By Some Heavy Metals in the Tigris River, Northern Iraq. Int. J. Environ.Res., 3 (2), 189-198 **(10 pages)**.
11. Ammann, A. A.; Michalke, B., Schramel, P., (2002).Speciation of heavy metals in environmental water by ion chromatography coupled to ICP-MS. Anal. Bioanal. Chem., 372 (3), 448-452 **(5 pages)**.
12. Anderson, D., (2003). Introduction to heavy metal monitoring. UK.
13. Anon., (1999) Jammu and Kashmir lakes and waterways Development Authority (LWDA) Srinagar
14. APHA, (1998) Standard methods for examination of water and waste water (20th. Ed.). Washington DC: American Public Health Association.
15. ATSDR (2000) (Agency for Toxic Substances and Disease Registry); United States, Department of Health and Human Services; 1-466.
16. Ballukraya, P.N. and Ravi, R. (1999) Characteristics of ground water in the unconfined aquifier of Chennai city, India; *J. Geol. Soc. India*, **54**: 1-11.
17. Banerjee, A. C. and Choudry, (1966) R. Physico chemical features of Chilka lake; *Ind. J. Fish.*, **13**: 395-429.
18. Berg, K. K. and Anderson, (1958) Furesundersgeker 1950 – 54; *Limnologiske. Folialimnol scand*, **10**: P – 189.
19. Bhat, S. A. et al., (2001) Impact of effluents from Shari Kashmir Institute of Medical Sciences (SKIMS), Soura on Anchar Lake, *J. Res., Dev.*, **1** : 30-27.
20. Bhat. S. A. and Pandit, A. K. (2003) Phytoplankton Dynamics in Anchar Lake, Kashmir; *J. Res., Dev.*, **3** : 71-96.
21. Bharathi, P. (2008) Molecular toxicity in relation to Neurodegeneration; *Indian J. Med. Res.*, **128**: 545 – 556.
22. Blum, J. L. (1957) An Ecological Study of the Algae of the Saline River, Michigan; *Hydrobiol.*, **9**: 361 – 408.
23. Cenci, R. M.; Martin, J. M., (2004). Concentration and fate of trace metals in Mekong River Delta. Sci. Total Environ., 332 (1-3), 167-182 **(16 pages)**.
24. Chopra, A.K., C. Pathak and G. Prasad, 2009. Scenario of heavy metals contamination in agricultural soil and its management. J. Applied Nat. Sci., 1: 99-108. http://ansfoundation.org/aspx_file/reportAbstract.a spx?v=1&i=1&pp=%2099-108.
25. Cole, G. R. (1979) A Text Book of Limnology 2ⁿᵈ ed. The Mosley Co. London, New York.
26. Crumrine, J. P. and Beeton, (1975). A. M. Limnology of lakes, Ottawa national forest special report no. 25,Centre for Great lake studies; University of Wisconsin (USA).
27. CSIR, (1974) Analytical Guide (Laboratory Techniques); CSIR, Pretoria, South Africa.

28. Drever, J. I. (1982) The Geo-Chemistry of Natural Waters; Prentice Hall, London.
29. Davis, H. S. (1938) Instructions for Conducting Stream and Lake Surveys; U.S. Bureau of Fisheries. *Fishery Circular*, **26**; 1-55.
30. European Union: (2002) Heavy metals in water, European Commission on Environment .
31. Freiser, H. and Fernando, O. (1966) Ionic equilibria in analytical chemistry; Willey and Sons New York.
32. Fergusson, J. E., (1990). The heavy elements: Chemistry, environmental impact and health effects. Pergamon Press, Oxiford, 614.
33. Ferner, D. J. (2001) Toxicity, heavy metals; *e. med. J.*, **2(5)**: 1.
34. Golterman, H. Z. and Clymo. (1969) R. S. Methods for Physical and chemical Analysis of Freshwaters, IBP Handbook No. 8. Blackwell Scientific Publication, Oxford, Edinburgh.
35. Hatje, V.; Bidone, E. D.; Maddock, J. L., (1998). Estimation of the natural and anthropogenic components of heavy metal fluxes in fresh water Sinos river, Rio Grande do Sul state, South Brazil. Environ. Tech., 19 (5), 483-487 **(5 pages)**.
36. Hejabi, A.T. and S.L. Belagali, 2009. Survey of trace metal contaminants in sediments of Kabini River in the Nanjangud industrial area, Mysore District. Nat. Environ. Pollut. Tech., 8: 49-52. http://www.neptjournal.com
37. Joshi, B. K. and Kothyari, B. P. (2003) Chemistry of perennial springs of bhetagad watershed a case study from central Himalaya; *Environmental Geology*, **44** : 572 – 578.
38. Jumbe, A.S. and N. Nandini, 2009. Heavy metals assessment of wetlands around peenya industrial area, Bangalore, India. J. Res. Environ. Life Sci., 2: 25-30. http://www.geocities.com/rel_sci/issues/vol2no1.html
39. Jumbe, A.S. and N. Nandini, 2009. Impact assessment of heavy metals pollution of Vartur Lake, Bangalore. J. Applied Nat. Sci., 1: 53-61. http://ansfoundation.org/aspx_file/reportAbstract.a spx?v=1&i=1&pp=%2053-61
40. Kar, D.; Sur, P.; Mandal, S. K.; Saha, T.; Kole, R. K., (2008). Assessment of heavy metal pollution in surface water.,
41. Int. J. Environ. Sci. Tech., 5 (1), 119-124 **(6 pages)**.
42. Karbassi, A. R.; Monavari, S. M.; Nabi Bidhendi, G. R.; Nouri, J.; Nematpour, K., (2008). Metal pollution assessment of sediment and water in the Shur River. Environ. Monitor. Assess., 147 (1-3), 107-116 **(12 pages)**.
43. Kaul, V. (1977) Limnological survey in Kashmir lakes with reference to trophic status and conservation; *Int. J. Ecol. Environ. Sci.*, **3**: 29-44 .
44. Kaul, V., Handoo, J. K. and Rains, R. (1981) Physico chemical characteristics of Nilnag, a high altitude forest lake in Kashmir; Proc. *Indian Nati. Sci. Aced*. **8 46(4)**: 528-541
45. Kraft, C.; Tumpling, W.; Zachmann, D.W.; (2006). The effects of mining in Northern Romania on the heavy metal distribution in sediments of the rivers Szamos and Tisza (Hungary). Acta Hidrochim. Hhydrobiol., 34, 257- 264 **(8 pages)**.
46. Lenntech;(2004) Water Treatment and Air Pollution, Published by Lenntech, Rotterdamsewag, Netherlands.
47. Linnik, P. M.; Zubenko, I. B., (2000). Role of bottom sediments in the secondary pollution of aquatic environments by heavy metal compounds. Lakes and Reservoirs. Res. Manag., 5 (1), 11-21 **(10 pages)**.
48. Mackreth, F. J. H. (1963) Chemical Analysis, Some methods for Limnologists; *Fresh water Boil. Ass. Science* **21**: 1-70.
49. Marin, A.; Lopez-Gonzalvez, A.; Barbas, C., (2001). Development and validation of extraction methods for determination of zinc and arsenic speciation in soils using focused ultrasound: Application to heavy metal study in mud and soils. Anal. Chim. Acta., 442 (2), 305-318 **(14 pages)**.
50. Muwanga, A., (1997). Environmental impacts of copper mining at Kilembe, Uganda: A geochemical investigation of heavy metal pollution of drainage waters, stream, sediments and soils in the Kilembe valley in relation to mine waste disposal. Ph.D. Dissertation, Universitat Braunschweig, Germany.
51. Mc Cready, R. G. L. and Krouse, H. R. (1980) Sulphur Isotope fractionation by Dsulforibrio Vulgaris during Metabolism of $BaSO_4$. *J. Geomicrobiol.*, **2**: 55-62.
52. Mohiuddin, K. M.; Zakir, H. M.; Otomo, K.; Sharmin, S.; Shikazono, N., (2010). Geochemical distribution of trace metal pollutants in water and sediments of downstream of an urban river. Int. J. Environ. Sci. Tech., 7 (1), 17-28 **(12 pages)**.

53. Nicolau, R.; Galera-Cunha, A.; Lucas, Y., (2006). Transfer of nutrients and labile metals from the continent to the sea by a small Mediterranean river. Chemosphere, 63 (3), 469-476 (**8 pages**).

54. Samarghandi, M. R.; Nouri, J.; Mesdaghinia, A. R.; Mahvi, A. H.; Nasseri, S.; Vaezi, F., (2007). Efficiency removal of phenol, lead and cadmium by means of UV/TiO2/H2O2 processes. Int. J. Environ. Sci. Tech., 4 (1), 19-25 (**7 pages**).

55. Paramsivam, M. and Srinivasan, A. (1981) Changes in Algal Flora due to Pollution in Kawery River; *Indian, J. Environ. Health*, **23(3)**: 222-238.

56. Phuong, P.K., C.P.N. Son, J.J. Sauvain and J. Tarradellas, (1998). Contamination by PCB's, DDT's and heavy metals in sediments of Ho Chi Minh City's canals. J. Bull. Environ. Contam. Toxcol., 60: 347-354. DOI: 10.1007/s001289900633.

57. Pechlaner, R. (1968) Beschlevnigte eutrophierung inpiburgeesee, Tirol, Ber. ; *Nat. Med. Var. Insbruch*. **56**: 143-161.

58. Ramesam, V. Geo-Chemistry of Ground Water from a typical hard rock terrain; *J. Geol. Soc., India*, **23**: 201-204.

59. Reid, G. K. and Wood, R. D. (1976) Ecology of Inland waters and estuaries; Season Ed. D. Van Nostrand and Co. New York 485 P.

60. Riley, G. A. (1939) Limnological studies in Connecticut. *Ecol. Mongr*., **9**: 53-94.

61. Ruttner, F. (1953). Fundamentals of Limnology; University of Toronto, Press.

62. Sabah, U. S. and Wanganeo, (2008) A. Excessive phosphorous loading to Dal lake, India, implications for managing shallow eutrophic lakes in urbanized watersheds; *International Rev. of Hydrobiol*. **93(2)**: 148-166 .

63. Sarika, P.R. and Chandramohankumar, 2008. Geochemistry of heavy metals in the surficial sediments of Mangroves of the southwest coast of India. Chem. Ecol., 24: 437-447. DOI: 10.1080/02275540802491312.

64. Sheikh, M. A.; Noah, N. M.; Tsuha, K.; Oomori, T., (2007). Occurrence of tributyltin compounds and characteristics of heavy metals. Int. J. Environ. Sci. Tech., 4 (1), 49-60 (**12 pages**).

65. Shrestha, R.; Fischer, R.; Sillanpaa, M., (2007). Investigations on different positions of electrodes and their effects on the distribution of Cr at the water sediment interface. Int. J. Environ. Sci. Tech., 4 (4), 413-420 (**7 pages**).

66. Singh, A. K.; Mondal, G. C.; Kumar, S.; Singh, T. B.; Tewary, B. K.; Sinha, A., (2008). Major ion chemistry, weathering processes and water quality assessment in upper catchment of Damodar River basin, India. Environ. Geo., 54 (4), 745-758 (**13 pages**).

67. Stumm, W. and Morgan, J. J. (1970). Aquatic Chemistry, Wiley Inter-science, New York.

68. Sundaray, S. K., (2009). Application of multivariate statistical techniques in hydro-geochemical studies- a case study: Brahmani–Koel River (India). Environ. Monitor. Assess., 164 (1-4), 297-310 (**14 pages**).

69. Suthar, S.; Singh, S., (2008). Vermicomposting of domestic waste by using two epigeic earthworms (*Perionyx excavates and Perionyx sansibaricus*). Int. J. Environ. Sci. Tech., 5 (1), 99-106 (**8 pages**).

70. Vass, K. K. and Zutshi, D. P. Limnological studies on Dal lake, Morphometry and Physical features; *J. Inld. Fish. Soc. India*, **2**: 12-21 (1979).

71. Thresh, J. C. et al., (1944) The examination of Water and Water Supplies 6ᵗʰ edition (E. W. Taylor, ed.) London.

72. Venugopal, T.; Giridharan, L.; Jayaprakash, M., (2009b). Characterization and risk assessment studies of bed sediments of River Adyar-An application of speciation study. Int. J. Environ. Res., 3 (4), 581-598 (**18 pages**).

73. Whiteside, P. J. (1979) An introduction to A.A.S.; Pye Unicom Ltd. England.

74. WHO., (2008). Guidelines for drinking - water Quality 3rd. Edition incorporating the first and second agenda volume 1 Recommendations, World Health Organizations Geneva.

75. Zutshi, D. P. and Vass, K. K.(1978) Limological studies on Dal lake; *Indian J.Ecol*., **51**:90-97.

76. Zutshi, D. P. and Khan, M. A. (1980) High altitude limnology of the Himalayan system; *Hydrobiological*, **75**: 103-122.

77. Zvinowanda, C. M.; Okonkwo, J. O.; Shabalala, P. N.; Agyei, N. M., (2009). A novel adsorbent for heavy metal remediation in aqueous environments. Int. J. Environ. Sci. Tech., 6 (3), 425-434 (**11 pages**)