A Study of Water Quality of Kaushalya River In The Submountaneous Shivalik Region

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Abstract - Water is a valued natural resource for the existence of all living organisms. Indian rivers are polluted due to the discharge of untreated sewage and industrial effluents. Management of the quality of this precious resource is, therefore, of special importance. In this study river water samples were collected and analysed for physicochemical and bacteriological evaluation of pollution of Kaushalya River in Parwanoo. The water quality was studied quarterly at two sites at upstream and downstream regions during 2011 in the months of January, April, July and October. Physico-chemical and microbiological analyzed. Also the correlation coefficients between parameters of river water samples were parameters of the samples were measured, moreover, possible sources of contamination were determined. Most of the parameters analysed for Kaushalya river were in acceptable range except COD, Alkalinity, Hardness, Total Coliform and Faecal Coliform which showed human, animal and agricultural activities as the main sources of pollution. Trace metal and pesticides levels were low suggesting low contamination of the river by industrial wastes and toxics. However due to presence of a water treatment plant in the village Kamli from where the water of Kaushalya river is supplied to different sectors of Parwanoo, the river is suitable for drinking, bathing, recreation, irrigation and industrial uses, etc. Thus the overall water quality of the study site remained within the safe limits throughout the study period. Though the river is safe, still some of the conservation and management plans are proposed to reduce the sewage and the agricultural impacts on the river.

Index Terms - bacteriological analysis, correlation , Kaushalya river, Parwanoo, physiochemical analysis, seasonal variation, spacial variation, water quality

1. INTRODUCTION

Water is super abundant on the planet as a whole, but fresh potable water is not always available at the right time or the right place for human or ecosystem use. Water quality refers to the physical, chemical and biological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose. It is most frequently used by reference to a set of standards against which compliance can be assessed. The most common standards used to assess water quality relate to health of ecosystems, safety of human contact and drinking water. Environmental water quality, also called ambient water quality, relates to water bodies such as lakes, rivers, and oceans. Rivers are vital and vulnerable freshwater ecosystems that are critical for the sustenance of all life. Rivers are waterways of strategic importance across the world, providing main water resourcees for domestic, industrial and agricultural purposes.

STUDY AREA

Some natural waters in the areas of Dharampur and Dakshai contribute to form Kaushalya river which flows through Jabli, Koti, Parwanoo, Kalka, Pinjore and Panchkula and finally joins Ghaggar river. Kaushalya River is an important source of water supply for Parwanoo town. The major environmental concerns are erosion, siltation and pollution of the river from domestic discharge from Kamli village, agricultural activities, bathing and washing. Its water quality data will not only help to ascertain the nature and extent of the requirement for pollution control measures but will also indicate its impact on water quality.

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SAMPLING STATIONS

The sampling sites were carefully selected to include the upstream and the downstream regions, namely

- U/S Parwanoo Town - S1 Below Timber Trail
  - S2 Near village Kamli
- D/S Parwanoo Town - S3 Beginning of Kalka city
  - S4 Intake Channel of WSS Kalka

Each station was sampled quarterly during the year 2011 so that seasonal fluctuations in the values of various physiochemical parameters in the river can be known. The sampling covered the months of January, April, July and October.

SAMPLING AND FIELD WORK

Samples were collected following the standard sampling guidelines and methods. At each sampling location, water samples were collected at the region of good mixing in the river and stored in clean jericane bottles. For dissolved oxygen (DO) determinations, separate samples were collected into 300 ml plain glass bottles and the DO fixed using the azide modification of Winkler's method. Samples for bacteriological analyses were collected into sterilized plain glass bottles. The most accurate measurements of water quality are made on-site, because water exists in equilibrium with its surroundings. Measurements commonly made on-site and in direct contact with the water include temperature, pH, conductivity, Dissolved Oxygen (DO) and turbidity. Apart from the field observations other parameters- Alkalinity, Total solids, Dissolved and Suspended Solids, Total Hardness, Sulphate, Phosphate, Chloride, Fluoride, Nitrate, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Coliform, Sodium, Potassium, Calcium and Magnesium, trace metals- Boron, Cadmium, Lead, Copper, Nickel, Zinc, Iron and pesticides- Dieldrin, Aldrin, Carboryl, Malathion, Methyl parathion were analysed in a laboratory. The samples were kept in ice on the field and thereafter refrigerated at 4°C in the laboratory. The physiochemical analyses of water samples were performed using standard analytical methods. All samples were transported to Pollution Control Board Parwanoo for analyses.

2. MATERIALS AND METHODS

The physiochemical analyses of water samples were performed using standard analytical methods according to procedures outlined in the Standard Methods for the Examination of Water and Wastewater (APHA).

PARAMETER	TEST METHOD
Temperature	Mercury thermometer
pH	Digital electrode pH meter
Electrical Conductivity	Digital conductivity meter
Dissolved Oxygen	Winkler's method with azide modification
Biochemical Oxygen Demand	Azide modification of winkler's titration method
Chemical Oxygen Demand	Reflux titrimetry
Total Dissolved Solids	Gravimetrically after drying in an oven
Total Suspended Solids	Membrane filteration method
Total Hardness	EDTA complexometric titration method
Total Alkalinity	Titration with standard acid using methyl orange indicator (pH = 4.5)
Phenolphthalein Alkalinity	Titration with standard acid using phenolphthalein indicator (pH= 8.3)
Flouride	SPADNS Spectrophotometry
Nitrate – Nitrogen	Acid treatment followed by spectrophotometry
Ammonia – Nitrogen	Distillation titrimetric method
Total Kjeldahl Nitrogen	Kjeldahl titrimetric method
Chloride	Argentometric titration
Sulphate	Nephlometry
Phosphate	Ascorbic acid spectrophotometry
Sodium	Flame emission photometry
Potassium	Flame emission photometry
Calcium	EDTA titrimetric method
Magnesium	Calculation from total hardness and calcium
Trace metals	Atomic absorption spectrophotometry
Pesticides	Chromatographic techniques

BACTERIOLOGICAL ANALYSIS

Quantitative bacteriological analysis of the water samples are carried out by using the membrane filtration method to enumerate total coliforms and faecal coliforms. In the membrane filter technique, a known volume of water sample is passed through the filter that has pores which do not exceed 0.45 µm. Bacteria are retained on the filter that is then placed on selective media to promote growth of coliform bacteria while inhibiting growth of other species. The membrane and media are incubated at 35 ± 0.5 ºC for 24 ± 2 h, allowing coliform bacteria to grow into visible colonies that are then counted. The results are reported in number of organisms per 100 mL of water.

3. RESULTS AND DISCUSSIONS

The results of the physicochemical and biological parameters of the water samples from the two sampling sites on the river segment are presented in table:

Parameters	Jan-11				Apr-11			
	U/S		D/S		U/S		D/S	
	S1	S2	S3	S4	S1	S2	S3	S4
Temp	14.9	15	15.2	15.5	22.5	23	22.9	23
pH	7.6	7.8	8	8.11	7.77	7.96	7.81	7.75
Cond.	222	222	224	225	258	260	283	286
D.O	9.9	9.8	9.5	9.5	9.2	9	9	8.9
BOD	0.4	0.5	0.5	0.5	0.1	0.2	0.2	0.3
COD	3.8	4	18	20	4.5	4.8	23.7	24.4
F.C.	7	8	16	18	50	52	61	66
T.C.	27	30	46	48	127	130	149	152
TDS	210	210	217	218	158	159	184	189
TFS	200	201	221	222	9	9	9	10
TSS	2	2	25	27	2	3	3	3
NO_3-N	0.924	0.938	1	1.02	0.3	0.31	0.08	0.11
NH_3-N	1.64	1.68	1.09	1.12	1.01	1.06	3.06	3.19
TKN	2.22	2.24	2.24	2.25	3.2	3.19	5.28	5.32
Total Hardness	145	148	159	160	130	134	146	150
T. Alkalinity	250	247	238	234	306	300	260	255
P. Alkalinity				13				
Turbidity								
F^-	0.13	0.15	0.33	0.34	0.014	0.016	0.025	0.028
Cl^-	9.26	9.44	13	13.21	10.32	10.44	15.65	15.88
SO_4^-	23.1	23.33	27.18	27.27	11.58	12	14.22	14.6
PO_4^-	0.19	0.21	0.3	0.32	0.16	0.18	0.44	0.45
Na^+	15.8	15.3	14.2	14.4	20.5	20.3	15	15
K^+								
Ca^{2+}	48.44	49.6	55.87	56	47.98	49.64	55.63	56.85
Mg^{2+}	6.2	5.8	5.2	4.8	2.33	2.43	1.85	1.94
Boron								
Ni								
Cu								
Cd								
Zn					0.49	0.53	0.68	0.71
Pb								
Fe					5.62	5.57	2.81	2.77
Dieldrin								
Carboryl								
Aldrin								
Malathion								
Methyl parathion								

Parameters	**Jul-11**				**Oct-11**			
	U/S		**D/S**		**U/S**		**D/S**	
	S1	**S2**	**S3**	**S4**	**S1**	**S2**	**S3**	**S4**
Temp	23.5	24	24	24.2	21	21	21.3	21.4
pH	8.1	8.12	8.16	8.19	7.33	7.46	8.2	8.29
Cond.	305	308	314	317	238	240	245	247
D.O	7.6	7.4	7.2	7.2	8.9	8.7	8.5	8.5
BOD	0.1	0.2	0.1	0.1	0.4	0.5	1	1
COD	0.4	0.4	0.9	1	3	4	8	8
F.C.	3	4	6	8	60	61	52	51
T.C.	18	20	32	34	123	120	109	105
TDS	233	237	248	252	175	180	148	152
TFS	71	74	77	80	180	172	150	148
TSS	4	5	7	9	2	2	9	10
NO_3-N	0.142	0.144	0.21	0.23	0.2	0.22	0.29	0.31
NH_3-N							0.5	0.56
TKN								1.12
Total Hardness	155	158	173	176	140	144	152	156
T. Alkalinity	283	280	275	273	290	300	325	330
P. Alkalinity								
Turbidity								
F^-	0.03	0.031	0.037	0.039	0.009	0.012	0.018	0.021
Cl^-	10.29	10.44	15.45	15.74	9	9.3	12.89	13.02
SO_4^-	21	21.2	25.33	25.47	19.68	20.36	27.2	28.59
PO_4^-					0.1	0.1	0.2	0.2
Na^+	16.2	15.9	12.96	12.83	20	20.2	18.1	18.3
K^+								
Ca^{2+}	59.83	60.85	68.29	70.25	30	32	37	40
Mg^{2+}	1.49	1.46	1.07	1.04	16	15.5	13.9	13.6
Boron								
Ni								
Cu								
Cd								
Zn								
Pb								
Fe								
Dieldrin								
Carboryl								
Aldrin								
Malathion								
Methyl parathion								

DISCUSSIONS

DISSOLVED OXYGEN: In the present study maximum DO was recorded 9.9 mg/L in the winter season and minimum value of 7.2 mg/L in the monsoon season. However, in downstream lower DO values were found as compared to upstream which indicates little level of pollution due to anthropogenic activities. Lower temperature is known to favour greater dissolution of oxygen in water. DO levels are important in the natural self-purification capacity of the river. A good level of DO in sampling sites of the river indicated a high re-aeration rate and rapid aerobic oxidation of biological substances. Thus, in Parwanoo the DO levels indicate good quality water.

BIOCHEMICAL OXYGEN DEMAND: The maximum value of BOD was observed 1mg/L in the month of October and minimum 0.1 mg/L in the month of July. The unpolluted water has BOD value of 3 mg/L or less and industrial waste water has BOD value 25000 mg/L. The value of BOD in the present study was highest in downstream than upstream but still the maximum BOD observed was 1mg/L which indicates certain degree of self purification in the river. Thus the river is unpolluted as suspended solids are not of organic origin and do not possess high oxygen demand.

CHEMICAL OXYGEN DEMAND: The highest value was noted 24.4mg/L in summer season and minimum 0.4mg/L in monsoon season. The dilution by the large volumes of river water at the peak of the rainy season could also be responsible for the lower COD values. A trend of increasing COD level was observed at downstream sites in all the seasons showing the population load and activities caused by the mixing of sewage water, garbage dumping and industrial discharges. This increase in COD indicates that the pollution may increase and hence need exercise of monitoring, abatement and control.

pH: During the course of study it was recorded that pH varied from neutral to alkaline i.e. 7.33 to 8.29. Thus the pH obtained in the river waters was within the permissible ranges. In general, the pH of downstream was more alkaline than upstream. The domestic sewage and agricultural run-off are usually alkaline in nature due to presence of ammonical compounds whereas industrial waste can be acidic or alkaline. The increase in pH in downstream seems to be due to greater input of waste from sewage of Parwanoo. Alkaline pH is considered to be good for promoting high primary productivity. Thus, the lower Kaushalya stretch showed more congenial conditions for primary production of algal blooms resulting into the precipitation of carbonates of calcium and magnesium from bicarbonates.

TEMPERATURE: Temperature fluctuations, both diurnal and seasonal, are more evident in fresh water habitats. Flowing waters, however, lack wide fluctuations in temperature. Temperature is known to influence the pH, alkalinity and DO concentration in the water. The temperature showed an upward trend from winter to summer season followed by downward trend from monsoon season onwards. The overall range in the water temperature was minimum 14.9^{o}C in January and maximum 24.2^{o}C in July.

ELECTRICAL CONDUCTIVITY: In present study, electrical conductivity values varied between 222 and 308 µS/cm. It was seen that the EC was maximum in the month of July and minimum in the month of January which can be attributed to silts which it brings during its course in the rainy season. The average value of typical, unpolluted rivers is approximately 350 µS/cm. Therefore, the parameter does not give cause for concern and it makes the water suitable for direct domestic use.

HARDNESS: Hardness of the river water fluctuated between 130 mg/L and 176 mg/L. The trend of variation was non-uniform in all the seasons but it increased in downstream waters. The results indicate that the Kaushalya river is hard based on water hardness classification. The hardness was relatively less showing their suitability for drinking but limits its use for industrial purposes where hardness of less than 1 mg/L is required, as it may cause scaling in boilers.

ALKALINITY: In the present investigation, the alkalinity ranged between 234mg/L and 330mg/L. Alkalinity in all the seasons at all the sites was above the desirable limit prescribed for drinking water which is 120 mg/L (WHO). The high value of alkalinity indicates the presence of weak and strong base such as carbonates, bicarbonates and hydroxides in the water body. The high values of alkalinity may also be due to increase in free carbon dioxide in the river which ultimately result in the increase in alkalinity. Water samples from all the sites did not show a positive test to phenolphthalein alkalinity determination. A comparison of the results of total hardness and alkalinity revealed that the alkalinity values in all of the sampling locations were higher than the corresponding total hardness values. This implies that the presence of basic salts (such as sodium and potassium salts) other than calcium and magnesium salts is likely to be prevalent in the river water. High alkalinity may cause problems if water is used for irrigation purposes as high alkalinity leads to increase in relative proportion of sodium in soil by precipitating Ca and Mg ions.

TOTAL DISSOLVED SOLIDS AND TOTAL SUSPENDED SOLIDS: TDS and TSS are common indicators of polluted waters. TDS values ranged from 152mg/L to 252 mg/L and TSS values ranged from 2 mg/L to 27 mg/L. The values are low as compared with the IS Standards. Therefore the palatability of water with TDS and TSS can be considered to be good. The lower values of suspended and dissolved solids are indicative of non industrial pollution. At all the sites in all the seasons it was observed that the dissolved solid contents were found to be greater than the suspended solid levels. Higher TDS values were observed in the month of July which is indicative of erosion that has taken place during the course of river.

MICROBIOLOGICAL ANALYSIS: In the present study, the maximum number of total coliform and faecal coliform were in the month of April and October. The minimum number was recorded in the month of January and July. The total coliform ranged between 18 cfu/100 ml and 152 cfu/100 ml while the faecal coliform ranged between 3 cfu/100 ml and 66 cfu/100 ml. All of the samples analysed during the year did not meet the WHO guidelines for water intended for drinking. The results suggest that the general sanitary qualities of the water source were unacceptable, thus the microbial water quality of the Kaushalya river is poor and the entire river basin as sampled is not suitable for domestic use without treatment. For agricultural purposes there is a possibility of contamination from vegetables and other crops eaten in their raw state. The poor microbiological quality might be due to contamination caused by human activities and livestock. It is a common practice for people living along the river catchment to discharge their domestic and agricultural wastes as well as human excreta/wastes into rivers. In addition to using the river as a source of drinking water people use the source for bathing, washing of clothes and for recreational purposes such as swimming. Wild and domestic animals seeking drinking water can also contaminate the water through direct defaecation and urination.

CATIONS: Ca^+, which is a major component of natural waters, comes mainly from the rocks, seepage, drainage, wastewater etc. Ca^+ varied from 30 mg/L to 70.25 mg/L. The levels remained high in the downstream which indicates more solubilisation of calcium in the downstream water. Mg^{2+} is required as an essential nutrient for plants as well as for animals and the concentration of 30 mg/L is recommended for drinking waters. The concentration of Mg^{2+} ions varied from 1.04 mg/L to 16 mg/L. The percentage of Na^+ ions is often taken as important parameter deciding the suitability of water for irrigation .The Na^+ levels were quite low (14.2 - 20.5 mg/L). Thus, the water is suitable for drinking or irrigation. Presence of K^+ in the natural waters is very important since it is an essential nutrient element. The concentration of potassium was undetectable in the present study. The NH_4^+ contents in the river varied between 0.5 mg/L to 3.19 mg/L. The values were well within the desirable limits of 10 mg/L respectively for domestic applications.

ANIONS: In this study, the chloride contents were ranged from 9 mg/L to 15.88 mg/L. Chloride content was lower than the accepted limit of 250 mg/L at the sampling sites in the river. The levels downstream were slightly higher than those obtained upstream in all the seasons. Values indicate low seasonal variation of chlorides which show that there is little variation in domestic activities with change in the seasons. Overall, chloride concentration was within the acceptable limits Sulphate concentration in the river varied from 11.58 mg/L to 28.59 mg/L. The concentration of SO_4^{2-} was much lower in the month of April as compared to other seasons. The concentration in the river increased downstream which might be contributed by agricultural runoffs in the downstream region. From the observations it can be seen that sulphate was present under acceptable limits. This shows that the percentage contributions from domestic as well as industrial activities are minimal.

NUTRIENT LOADS: NO^{3-} in river water promotes high primary productivity and excess of NO^{3-} in surface water is taken as a warning for algal blooms. In this study, the NO^{3-} levels were quite low, varying from 0.08 mg/L to 1.02 mg/L. Thus, there was no indication of NO^{3-} pollution in Kaushalya waters in Parwanoo in general. In the present study concentration of available PO_4^{3-} varied from 0.1 mg/L to 0.45 mg/L respectively with higher levels in the downstream stretch. These values may cause eutrophication of water which could be attributed to the addition of surface runoff from the adjoining fields which bring fertilizers into the river. However negligible values of phosphates were found during monsoon season and this might be because of inflow of rain water which decreases the phosphate concentrations in the river.

IONIC DOMINANCE: The ionic dominance pattern recommended for fresh water sources is Ca > Mg > Na > K and HCO_3 >SO_4 > Cl.
Cationic dominance observed
Ca> Na> Mg> NH_4> K
Anionic dominance observed
HCO_3> SO_4> Cl> NO_3
The trend of ionic distribution is consistent without any abrupt change throughout the seasons. In the river, bicarbonate, sulphate and chloride constitute the bulk anions and calcium, magnesium and sodium the bulk cations. The trend was a characteristic of a freshwater system because of the dominance of Ca and HCO_3.

FLOURIDE: Flouride is seldom found in appreciable quantities in surface waters and appears in groundwater in only a few geographical regions. The concentration of F- in the Kaushalya waters ranged from 0.009 mg/L to 0.34 mg/L.

HEAVY METALS: Nickel (Ni), Copper (Cu), Cadmium (Cd) and Lead (Pb) were undetectable at both the sites in all the season therefore the river water is free from toxic metals. Hence there is no danger with respect to these metals. Iron (Fe) and Zinc (Zn) were also below the detection limit in January, July and October. Zn values fell within the background level in the month of April as its values ranged between 0.49 mg/L at the upstream and 0.71 mg/L in the downstream. The concentrations of Fe in the water ranged from 2.77 mg/L in the downstream and 5.62 mg/L in the upstream in the month of April. Both the points exceeded the background level and the WHO limit of 0.3 mg/L. Fe being non toxic presents no health hazards at concentrations normally found in natural waters, but in significant concentrations can cause colour problems. Additionally, some bacteria use Fe compounds for an energy source, and the resulting slime growth may produce taste and odour problems.

PESTICIDES: The concentration of pesticides such as Dieldrin, Carboryl, Aldrin, Malathion and Methyl parathion were undetectable indicating that the river is free from them and hence safe for drinking purposes. In fact, the industrial as well as domestic wastes of Parwanoo are mostly discharged into Sukhna nallah.

WATER QUALITY OF KAUSHALYA RIVER: On the basis of Primary Water Quality Criteria, it can be concluded that quality of river water falls under '**A**' category with respect to pH, DO and BOD in general. The critical parameters observed is Total Coliform according to which category of river comes down to either category '**B**' when the Total Coliform are more than **50** /100 ml. Therefore the quality of the river falls under 'A' category during the months of January and July, and under 'B' category during the months of April and October.

INTER- RELATIONSHIPS: Inter – relationships between different parameters were determined from the correlation matrix formed in Microsoft Excel. From the correlation matrix between various parameters, most of the parameters were found to bear statistically significant correlation with each other indicating close association of these parameters with each other. The temperature and conductivity of the water however, showed a highly positive correlation (r = 0.843). Dissolved oxygen showed negative correlation with temperature (r = -0.784). Positive correlation was seen between Ca^{2+} and TDS (r = 0.786) which shows that the Kaushalya waters are alkaline in nature. Significant correlation does occur between Ca^{2+}/ PO_4^{3-} (r = 0.797) and NH_4^+/ PO_4^{3-} (r = 0.816) which indicates the probable sources of pollutants from leachates of wastewaters generated and wastes from agricultural practices from the surrounding area of village Kamli.

4. CONCLUSIONS

Most of the parameters analysed for Kaushalya river were in acceptable range except COD, Alkalinity, Hardness, Total Coliform and Faecal Coliform and hence cannot be used for household and commercial purposes, unless prior purification is provided. Since the hardness was quite high, water could not be prescribed for boiler feeders, food processing industries, textiles and laundry but the water could be used on limited scale for irrigation and industrial cooling. However there is a water treatment plant in the village Kamli from where the water of Kaushalya river is supplied to different sectors of Parwanoo. Hence the river is suitable for drinking, bathing, recreation, irrigation and industrial uses, etc. Thus it can be concluded that the river water is within the safe limits and is fit for consumption.

5. RECOMMENDATIONS

Though the river is safe, still there is a need of a Conservation and Management Plan to reduce the sewage and the agricultural impacts on the river. It was quite evident from the findings that the river is receiving lot of organic waste. The solution of this problem lies in the treatment of sewage and disposable of fully or partially treated sewage waste. We should go for alternative methods for the sewage disposal. Dry sanitation or the sanitation which uses less or almost no water for the waste disposal is what which we should adopt for. The modern sanitations systems should be based upon traditional science of recycling but should use the latest technologies to do so. People, particularly those living along the banks of river, should realize that the river is for them and they are for the river and not a waste disposable site. People have to change their mindset with regard the river nature's gifts to us. Any plan to control pollution can succeed only if the people feel initiated and involved in its working and are able to participate in its implementation. The public participation is needed towards awareness, experience sharing, domestic refuse, recycling, waste bin, avoid cattle grazing near river, in house sanitary system, avoid open defaecation and use lavatories. River pollution due to sewage and agricultural impacts can be controlled by considering the following aspects for clean-up:

- Domestic sewage due to residential colonies in the adjoining areas .
- Animal waste due to cattle grazing.
- Garbage dumps by citizens all along its course.
- Inefficient farming practices. The steps to be taken to minimize pollution are as follows:
- Provide sewerage system on both the banks of the river so that the sewage is collected and treated.
- Provide proper garbage collection system on both banks of the river and disposal arrangement, so that garbage is not dumped in the river.
- To improve the quality of water in the downstream of the river, sewage treatment plant is recommended due to slight sewage impact from the areas of sector-1 and surroundings.
- Provide lavatories to prevent open defaecation.
- Promote a national focus on water sector reform
- Improve and expand the delivery of water services, mainly water supply and sanitation (urban and rural), irrigation and drainage
- Foster the conservation of water and increase system efficiencies
- Improve governance
- Water quantity and quality assessment
- Comprehensive assessment of water resources in a river basin context
- Socio-economic assessment; role of water in sustainable development
- Valuing water
- Reforming water-related institutions
- Promotion of effective and efficient implementation of water pollution control laws and regulations
- Introduction of less water-consuming agricultural technologies and methods to mobilize people to take action and how to value water for equitable use for people and the environment.

- Establishment and operation of cost-effective water quality monitoring systems for agricultural water uses.
- Prevention of adverse effects of agricultural activities on water quality for other social and economic activities through optimal use of on-farm inputs and the minimization of the use of external inputs in agricultural activities.
- Establishment of biological, physical and chemical water quality criteria for agricultural water users for the riverine ecosystems.
- Prevention of soil runoff and sedimentation.
- Proper disposal of manure produced by intensive livestock breeding.
- Minimization of adverse effects from agricultural chemicals by use of integrated pest management.
- Education of communities about the pollution impacts of the use of fertilizers and chemicals on water quality and food safety.
- Erosion control
- Pesticide management and control (importation, manufacture, sales and application, and disposal)
- Irrigation management

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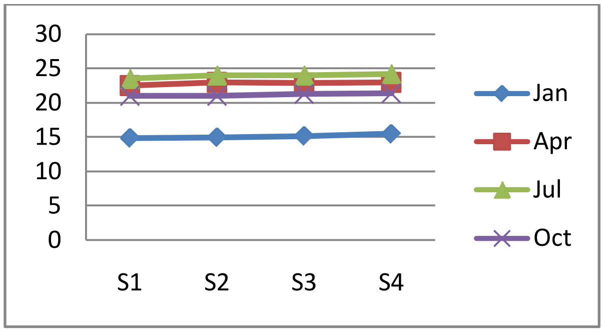
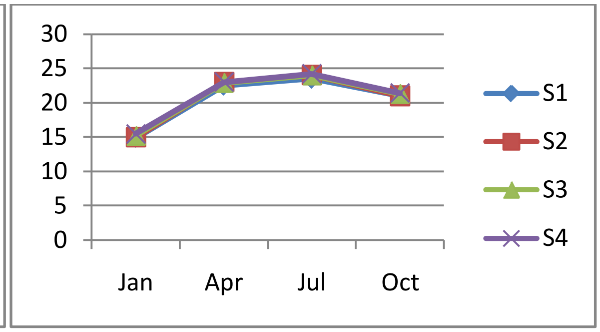
APPENDIX

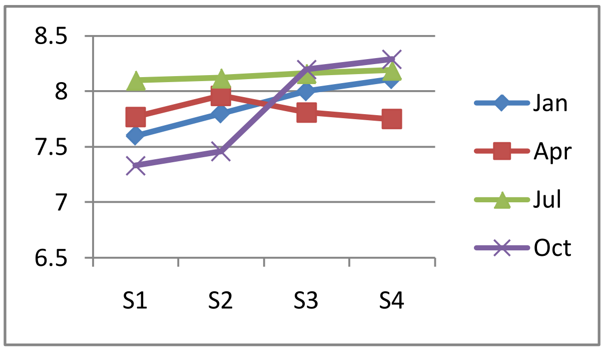
Spatial And Seasonal Variation of Various Physiochemical And Biological Parameters of Kaushalya River



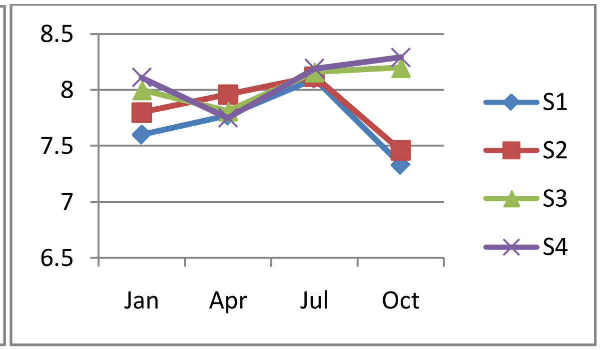
Spatial variation of Temperature



Seasonal variation of Temperature



Spatial variation of pH



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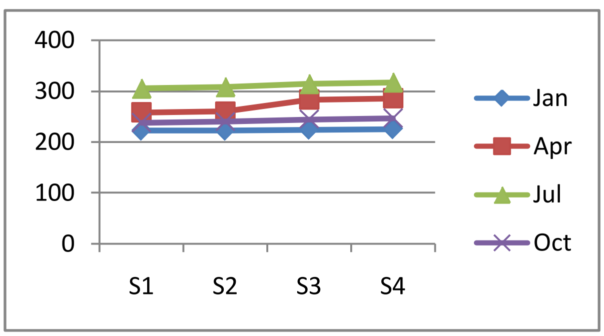
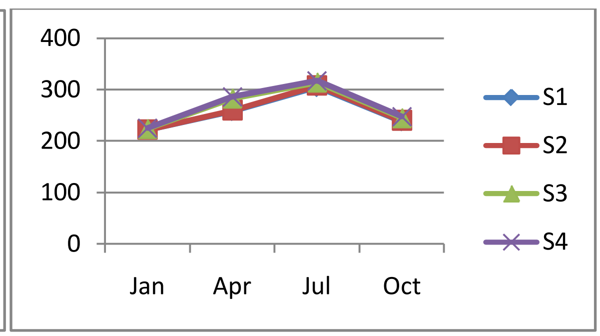


Spatial variation of Conductivity



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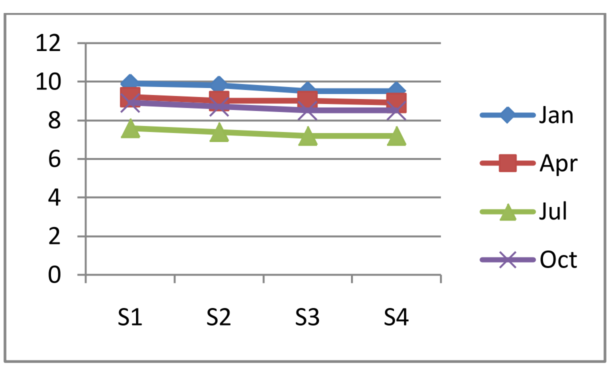

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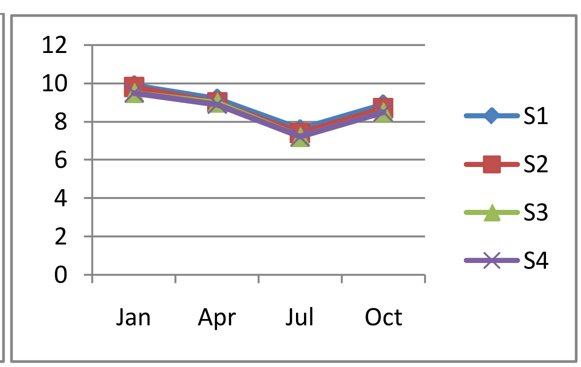

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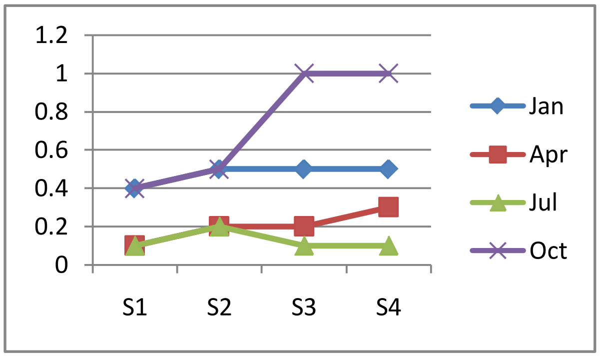

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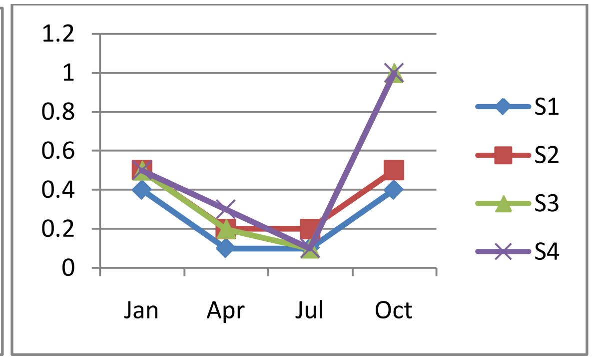

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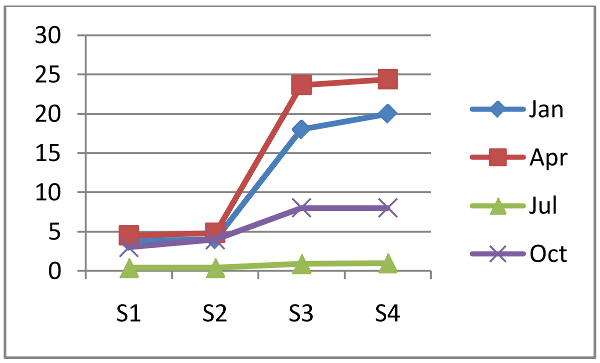
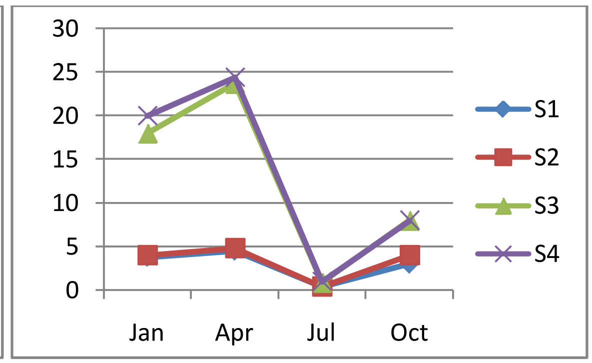


Spatial variation of COD



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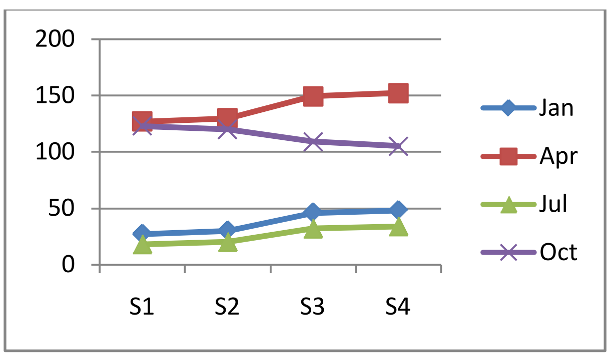
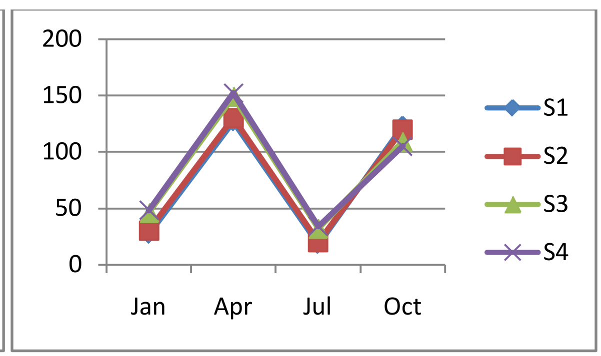
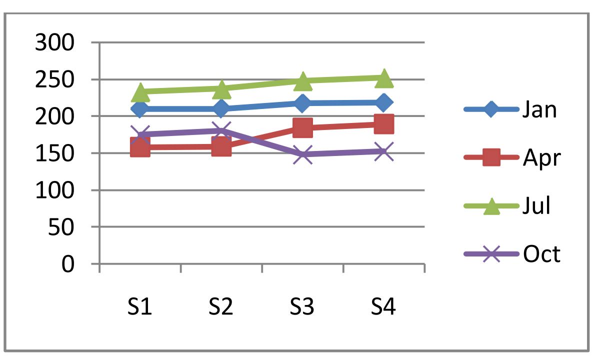


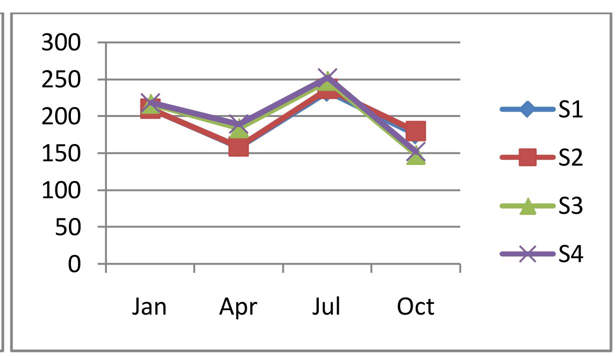
Spatial variation of T.C.



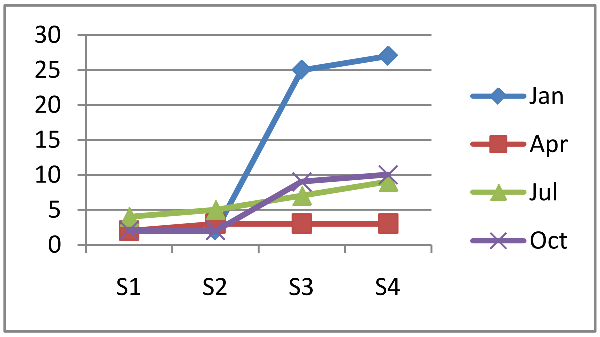
Seasonal variation of T.C.



Spatial variation of TDS



Seasonal variation of TDS



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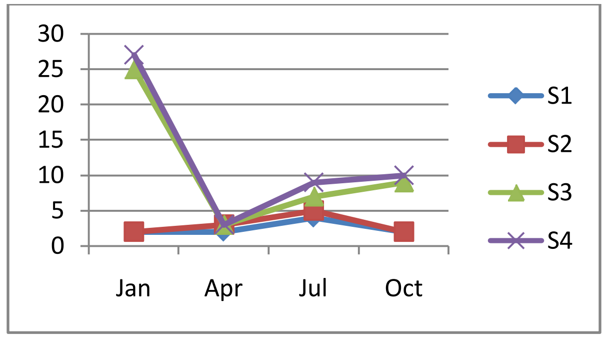

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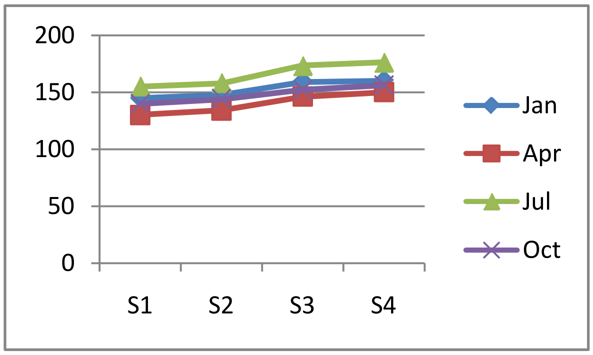
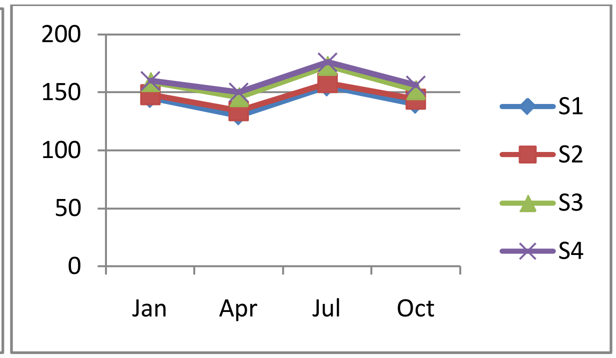


Spatial variation of Total Hardness



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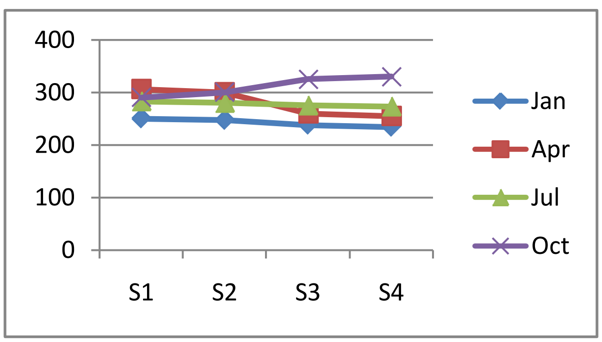
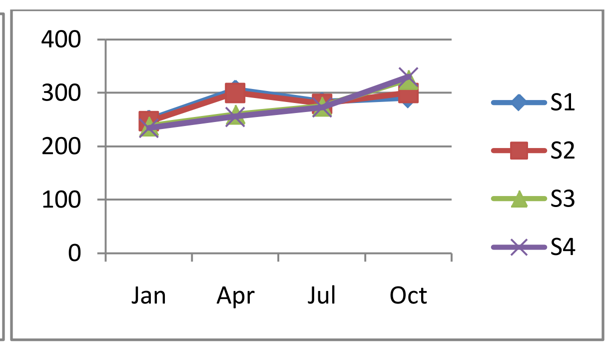
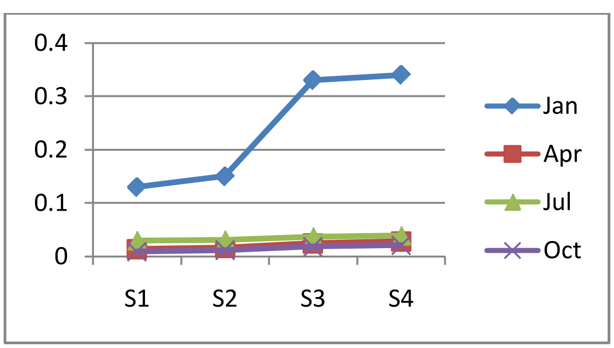


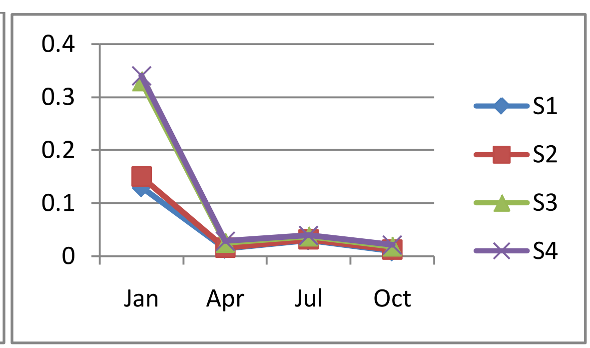
Spatial variation of Total Alkalinity



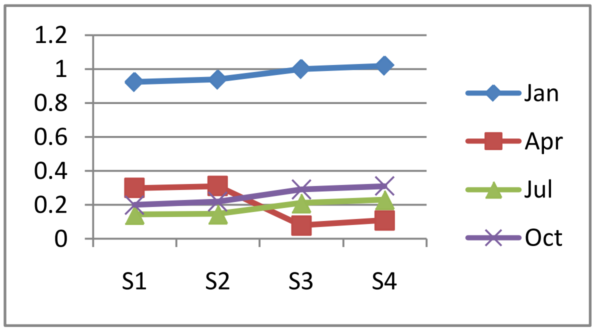
Seasonal variation of Total Alkalinity



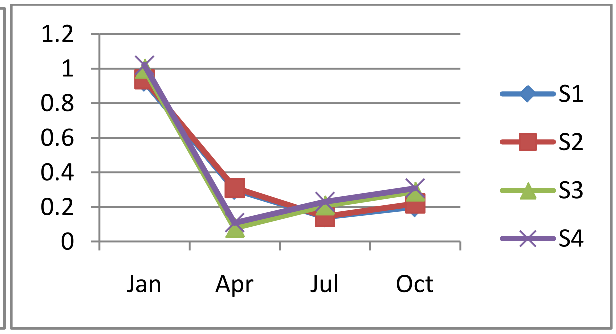
Spatial variation of Fluoride



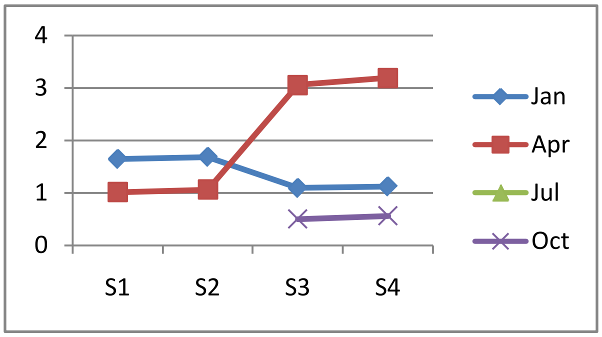
Seasonal variation of Flouride



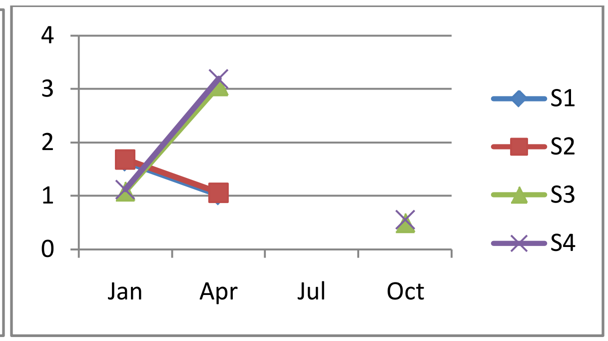
Spatial variation of Nitrate



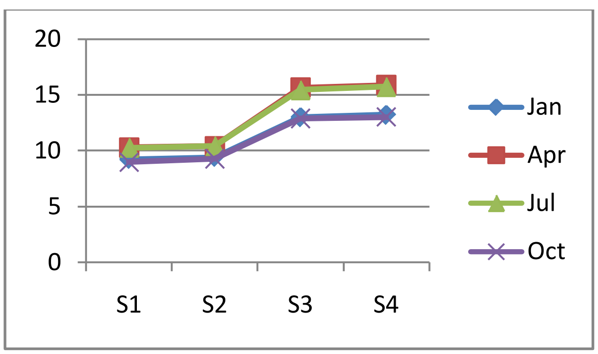
Seasonal variation of Nitrate



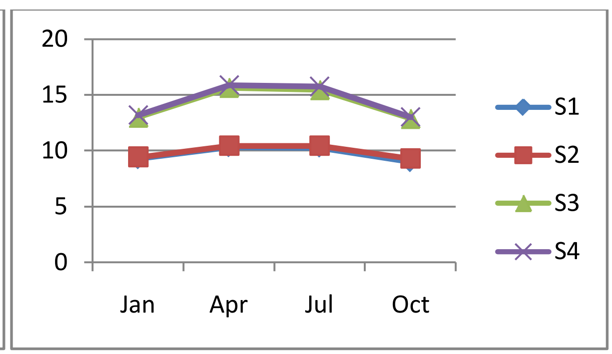
Spatial variation of Ammonia



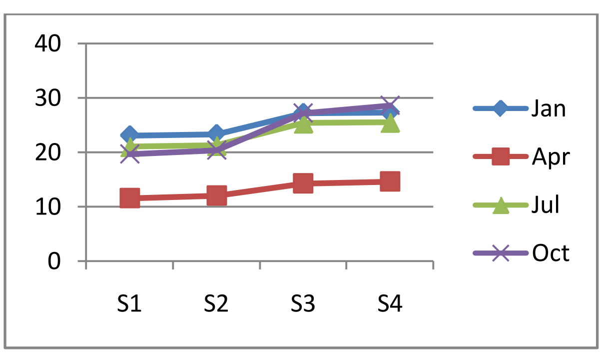
Seasonal variation of Ammonia



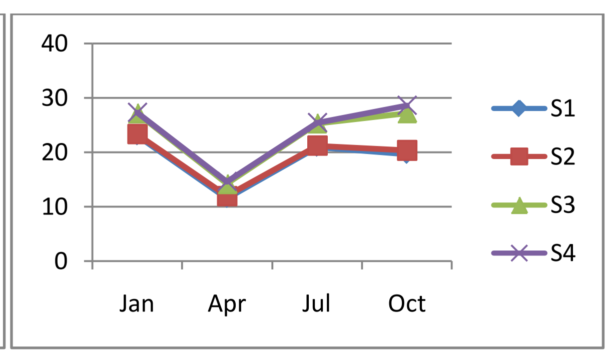
Spatial variation of Chloride



Seasonal variation of Chloride



Spatial variation of Sulphate



Seasonal variation of Sulphate

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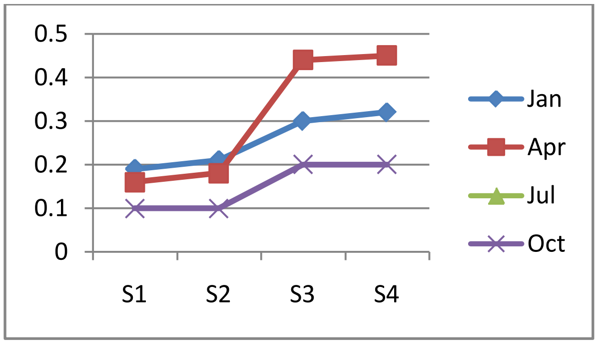

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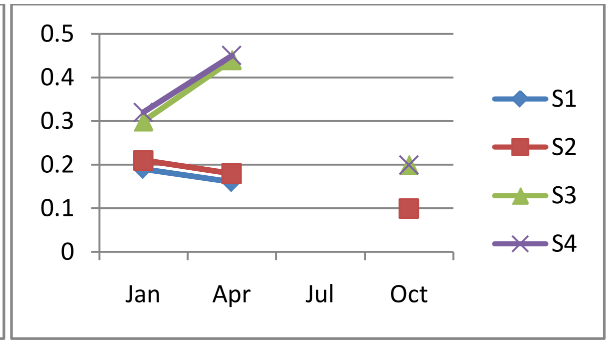
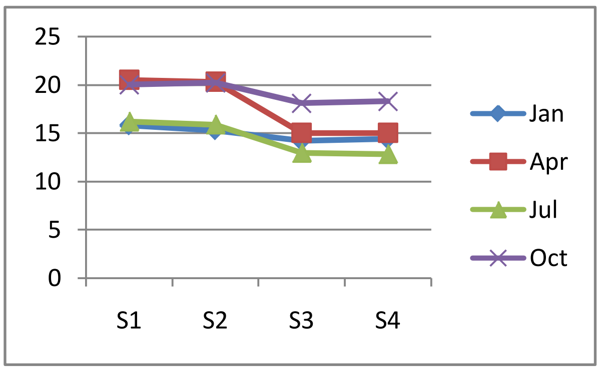
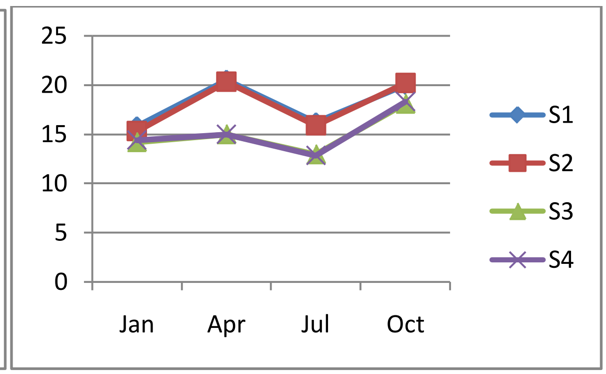


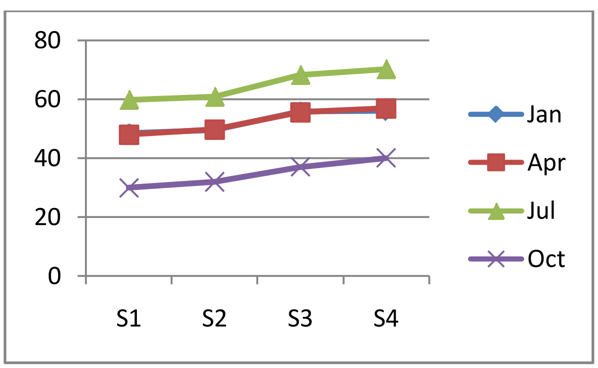
Seasonal variation of Phosphate



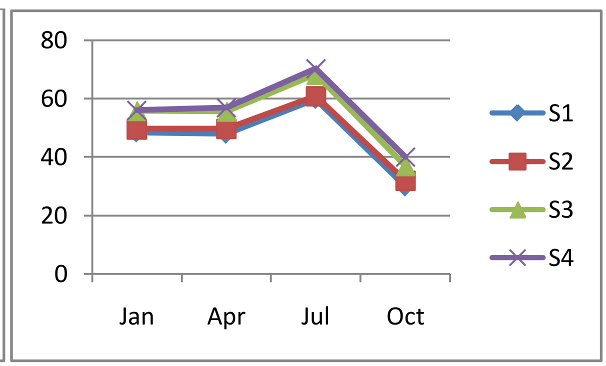
Spatial variation of Sodium



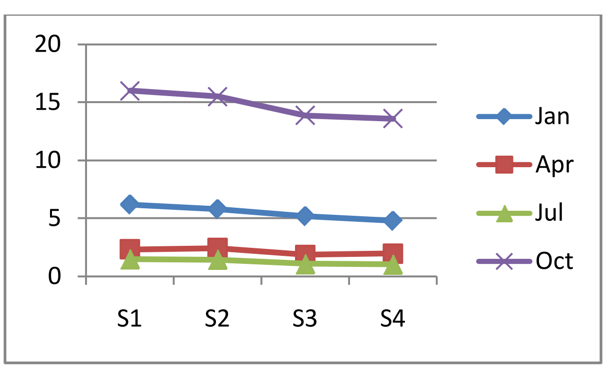
Seasonal variation of Sodium



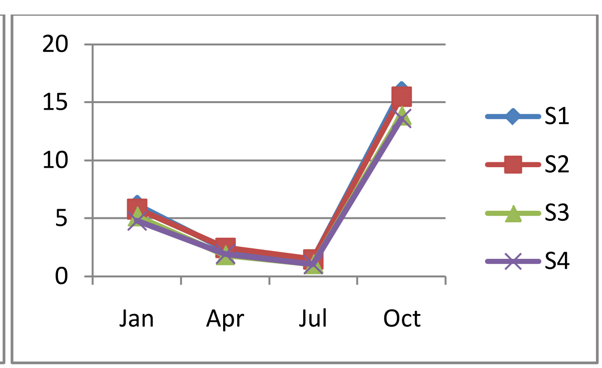
Spatial variation of Calcium



Seasonal variation of Calcium



Spatial variation of Magnesium



Seasonal variation of Magnesium

CORRELATION MATRIX

	Temp	pH	Cond.	D.O	BOD	COD	F.C.	T.C.
Temp	1							
pH	0.22265	1						
Cond.	0.84369	0.40374	1					
D.O	-0.7846	-0.5029	-0.8766	1				
BOD	-0.3967	0.15265	-0.6098	0.31755	1			
COD	-0.2442	-0.0251	-0.2201	0.45901	0.17409	1		
F.C.	0.27068	-0.415	-0.2066	0.27011	0.29056	0.40101	1	
T.C.	0.3103	-0.3896	-0.1403	0.2746	0.1741	0.44194	0.98501	1
TDS	-0.0293	0.26504	0.47604	-0.4514	-0.5351	-0.1998	-0.8434	-0.8169
TFS	-0.8117	-0.1305	-0.7199	0.40688	0.58461	-0.0414	-0.2928	-0.412
TSS	-0.4582	0.46997	-0.2759	0.13495	0.29618	0.43333	-0.2813	-0.3001
NO_3-N	-0.9543	-0.0155	-0.7233	0.67398	0.2777	0.18451	-0.4411	-0.4531
NH_3-N	0.20207	-0.6423	0.5932	0.14268	-0.5527	0.62939	0.266	0.33974
TKN	0.59321	-0.504	0.83851	-0.2543	-0.6987	0.60067	0.64508	0.70818
Total Hardness	0.09679	0.6425	0.46886	-0.6111	-0.0263	-0.0471	-0.5971	-0.6131
T. Alkalinity	0.55753	0.14485	0.12616	-0.3503	0.34321	-0.4445	0.46827	0.41435
F^-	-0.8088	0.13184	-0.5213	0.49552	0.16295	0.42297	-0.4303	-0.4326
Cl^-	0.31724	0.50174	0.48126	-0.337	-0.0691	0.54532	0.06245	0.12805
SO_4^-	-0.406	0.48158	-0.1953	-0.1591	0.56318	-0.1194	-0.5011	-0.6011
PO_4^-	0.04294	0.29613	0.51877	0.1051	-0.203	0.95073	0.03263	0.14226
Na^+	0.1482	-0.4373	-0.3583	0.2458	0.23931	-0.2671	0.63982	0.59096
Ca^{2+}	0.22298	0.54462	0.67218	-0.4601	-0.6265	0.06019	-0.6406	-0.531
Mg^{2+}	-0.2322	-0.3509	-0.5901	0.24287	0.76232	-0.1127	0.47282	0.32547

TDS	TFS	TSS	NO_3-N	NH_3-N	TKN	Total Hardness	T. Alkalinity
1							
0.10191	1						
0.23498	0.49249	1					
0.17132	0.73763	0.57604	1				
0.33378	-0.4475	-0.3684	-0.3045	1			
-0.0943	-0.752	-0.3993	-0.6499	0.88255	1		
0.73768	0.1742	0.4752	0.04294	-0.0688	-0.3031	1	
-0.6162	-0.2685	-0.3796	-0.598	-0.5226	-0.1858	-0.26250353	1
0.32562	0.63987	0.83441	0.88414	-0.1592	-0.4167	0.249711359	-0.717716
0.22482	-0.3441	0.33623	-0.2244	0.50707	0.59376	0.60805519	-0.188676
0.3481	0.73937	0.6047	0.44585	-0.5127	-0.7534	0.708678183	-0.090038
0.35505	-0.3424	0.28266	-0.01	0.81644	0.73641	0.43921518	-0.551878
-0.8005	-0.0894	-0.4172	-0.2693	-0.5086	-0.1389	-0.8104518	0.7000452
0.78622	-0.3739	0.22795	-0.0006	0.66921	0.62203	0.647012811	-0.502131
-0.5719	0.57675	-0.0289	0.02813	-0.637	-0.7778	-0.25863571	0.4794132

F^-	Cl^-	SO_4^-	PO_4^-	Na^+	Ca^{2+}	Mg^{2+}
1						
0.04822	1					
0.46633	0.14724	1				
0.27189	0.8974	-0.1221	1			
-0.4512	-0.6429	-0.444	-0.7702	1		
0.20134	0.57063	0.05632	0.79771	-0.8081	1	
-0.1151	-0.387	0.32272	-0.6421	0.56738	-0.903	1