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Application of Chemical Mass Balance to Water Quality Data of Malaprabha River

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Abstract

Mass balance calculations carried out for Na, K, Ca, Mg, Cl, SO_4 and HCO_3 for the study area showed that the major source of contamination is through non-point sources. It is also observed that the river water quality during the non-monsoon season (February, 2000) almost resembles with the groundwater quality of the adjoining aquifer. However, during post-monsoon period (October, 1999) a wide variation was found between groundwater and surface water quality which can be attributed to the movement of fertilizers and agricultural ashes with monsoon flows reaching the stream along with overland flow. The major source of contamination in the Malaprabha river was found to be due to the non-point sources (more than 90%). An immediate attention from the concerned authorities is required in order to protect the land from further salinization.

(key words: Mass balance, Salinity, advection, base flow)

Introduction

Physical and chemical processes play an important role in distributing solutes to various reaches of a stream or river. Although advection and dispersion are the dominant physical processes affecting solutes in many surface waters, other physical processes are also important for a given water body. Many small streams and rivers receive large quantities of water from lateral inflows. Lateral inflow is referred to any water that is added to the stream due to effluent seepage from ground water, overland flow, inter-flow or via small springs and seeps (Singh, 1995). As a result of lateral inflows, the volumetric flow rate of the stream increases in the downstream direction. It is important to note that these lateral inflows are not only a source of water to the stream, but also a source of solute mass. For a given stream reach, the lateral inflow concentration represents the average solute concentration associated with the water added by lateral inflow. Therefore, concentration of any chemical ion at a given point in the stream depends upon the hydrological parameters and can be estimated through chemical mass balance studies.

Extensive studies have been carried out in many parts of the world to understand the in-stream reactions and sediment dynamics (Plummer and Back, 1980; Christopherson and Wright, 1981; Elder, 1985; Yuretich and Batchelder, 1988; Latimer et al., 1988). Large retention of pollutants in stream sediments has been reported in a number of studies. Imhoff et al. (1980) studied the heavy metals in the Ruhr basin and reported that about 31% of the total load of heavy metals in the river basin are retained in the stream sediments. Katz et al. (1985) established the mass balance for major constituents in precipitation and stream water and reported that dissolved solutes from precipitation input account for 12 to 19% of the total dissolved load in stream water. Paces (1985) used mass balance models to estimate elemental budgets in the Elbe river basin. Berndtsson (1990) established water budgets and chemical mass balances of some water quality constituents for a 5-km long reach of the Hoje river in the southern Sweden and reported that half of the transported zinc is retained within the stream sediments.

During recent years non-point sources of pollution are being recognized as a major source of pollution to surface waters. Deletic and Maksimovic (1998) studied water quality of storm runoff at two experimental catchments, in Belgrade, Yugoslavia, and Lund, Sweden. The results indicate that the antecedent dry weather period length has only a minor effect upon road sediments wash-off, but it has impact on conductivity. The `first flush effect' of suspended solids appears only in a limited number of events. Cross correlation coefficients of rainfall, overland flow, and water quality were calculated for each event, taking into account the time lag between observed characteristics. These coefficients showed that suspended solids loading rate is influenced by rainfall intensity and overland flow rate. Barrett et al. (1998) studied water quality of highway runoff in the Austin, Texas, by monitoring runoff at three locations on the MoPac

Expressway. The daily traffic volumes, surrounding land uses, and highway drainage system types were different at each site. The concentrations of constituents in runoff at all sites were similar to median values compiled in a nationwide study of highway runoff quality. The pollutant loads discharged from the pipe draining the Swale were lower than those observed at the sites where runoff drained directly from the pavement. A `first flush effect' was evident during selected events, but was generally limited to a small volume. The overall effect was negligible when all monitored events were considered.

Jain (1996) carried out chemical mass balance studies for river Kali, Western Uttar pradesh (India), and based on the study it is concluded that the river is subjected to a varying degree of metal contamination due to numerous outfalls of untreated municipal and industrial wastes of the region. The discharge of municipal and industrial wastes into the river at regular intervals do not allow any self purification to occur. He estimated the percentage increase in point sources from 61.5 % to 66.9 % (Fe), 57.1% to 77.8% (Zn) and 65.2% to 78.3 (Cu) during the period of study from (October 1993 to December, 1993). Jayashree (2000), applied the Chemical mass balance approach to Bellary nala in Belgaum (Karntaka), a waste water stream flowing through the city. Studies were carried out during monsoon and Post monsoon season and observed that during monsoon there is a good match between ionic concentrations of upstream and down stream. However, in Post-monsoon samples, large variations in ionic concentration is attributed to the addition point sources. Madhurima (2000). carried out a mass balance study for Ghataprabha river, a tributary of river Krishna (India) and observed the variation in ionic concentration to a tune of 1.5 times, between upstream and downstream indicating the impact of agricultural activities in the catchment. Similar study has been carried out by Hiremath (2001) for Ghataprabha during pre-monsoon and post-monsoon period.

Malaprabha and Ghataprabha are the two major tributaries of river Krishna (India). These two rivers are the main source of water for irrigation in Belgaum, Dharwad, Bagalkot and Bijapur districts in Karnataka state. In these river systems, both catchments and command areas have been subjected to extensive irrigation that resulted in salinisation problems at many places. Malaprabha river does not have any major out-falls except the one from a sugar factory located at M.K. Hubli. Other out-falls are only municipal drains located at various places. Water quality monitoring at a number of stations along the river course is very difficult and time consuming. Therefore, in such cases, application of chemical mass balance approach, for measuring the changes in concentration and/or load to the river, provides a viable alternative. In the present study, chemical mass balance approach has been applied to understand the influence of groundwater to stream flow loads especially during the lean periods.

Description of the Study area

The Malaprabha sub-basin lies in the extreme western part of the Krishna basin. It extends between 74 °15′ and 75° E longitudes and 15°30′ and 15° 45′ N latitude in Belgaum district of Karnataka (Figure 1). Malaprabha river originates from the Chorla ghats (a section of the western ghats) about 35 km south-west of Belgaum district in Karnataka, at an elevation of 792 m. The total catchment area up to the first dam site (study area) is 3300 sq km. However, number of open wells and bore wells available are quite limited.

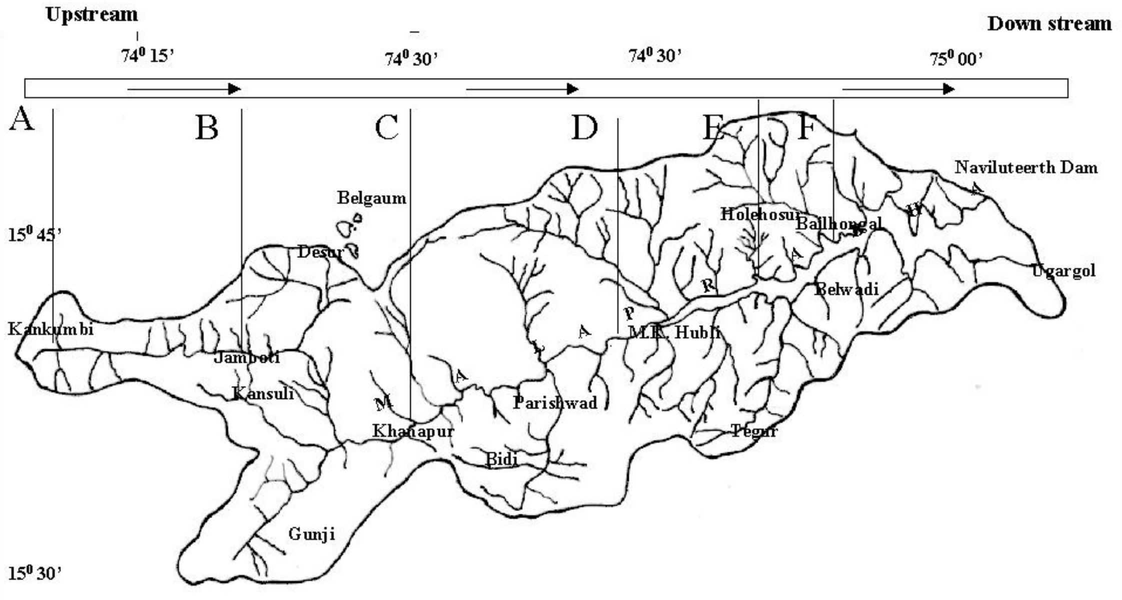

Figure 1. Location map of Study Area

The Malaprabha catchment is approximately triangular in shape. The terrain is flat to gently undulating except for a few hillocks and valleys. The northern boundary is the common ridge between Malaprabha and Ghataprabha river catchments and the eastern ridge is separated between Malaprabha, Krishna and Tungabhadra river catchments. The southern and western boundaries are the common ridge between the Malaprabha and catchments of west flowing rivers. The important rock formations in the sub-basin are (i) sedimentary rock formations (Kaladgi group) comprising limestone, shale and quartzites, and (ii) schistose rock formations (Dharwad super group) comprising granite, gneiss and crystalline rocks.

There are three distinct seasons prevailing in the catchment, the summer from March to April, the monsoon from May to November and the winter from December to February. The Malaprabha catchment mainly experiences the south-west monsoon season. Rainfall during non-monsoon is very insignificant. Normal annual rainfall in the catchment is 769 mm for the period from 1901-1985. Climate of the catchment is generally dry except for the monsoon months. Annual average maximum and minimum temperatures are 32° C and 18°C respectively.

Land use pattern of the study area is shown in Figure 2. Table 1 shows the change in landuse pattern from 1989 and 1995 as reported by (Purandara et al., 1999). It is evident that, there is a considerable change in landuse pattern which may pose a severe problem to river environment.

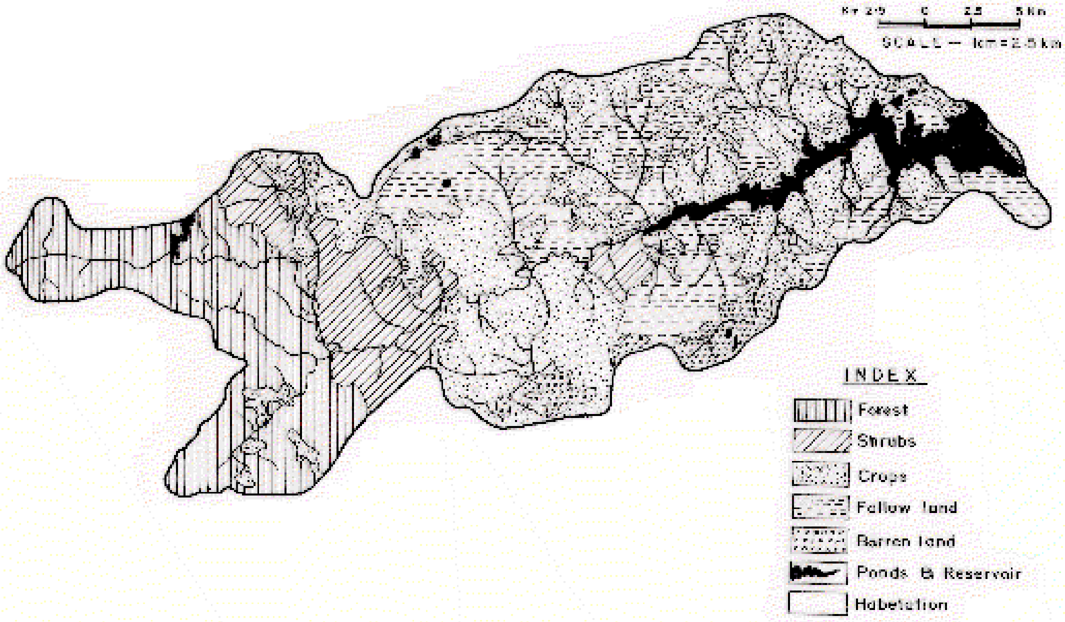

Figure 2. Land Use map of Malaprabha sub basin.

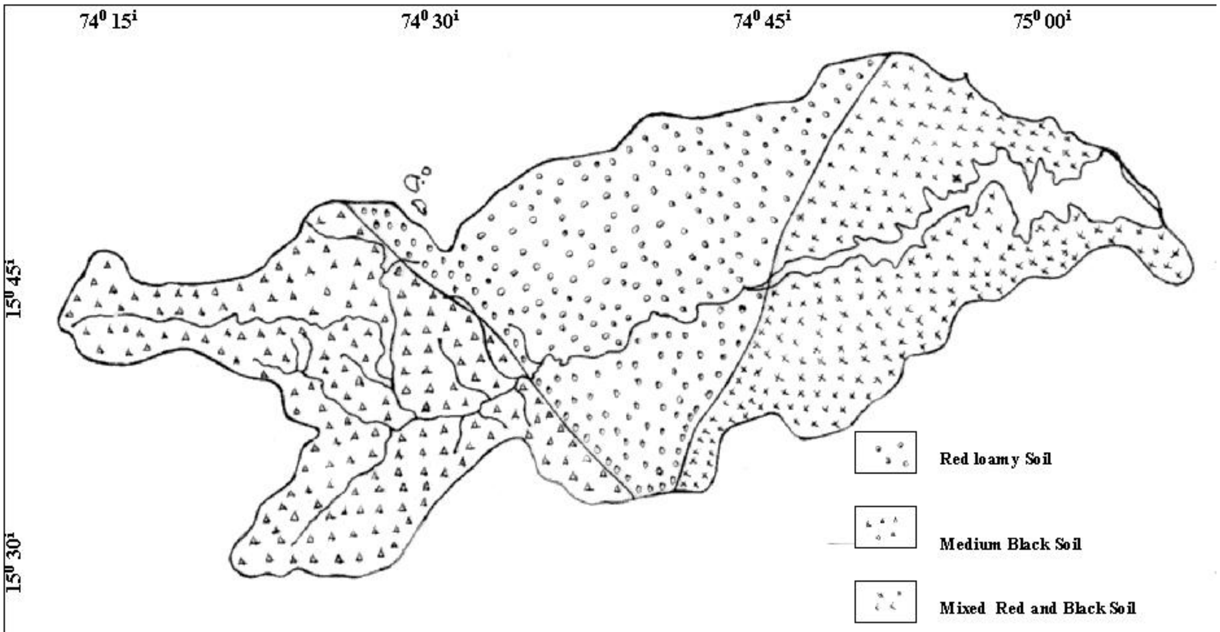

Figure 3. Soil Map of Malaprabha Sub-basin

Table 1. Change in Land use pattern (after Purandara et al 1999)

Sl No.	Landuse pattern	% area covered under each category (in year 1989)	% area covered under each category (in year 1995)
1	Forest	16.00	12.90
2	Scrubs	16.75	14.50
3	Agriculture	32.25	45.70
4	Fallow land	20.00	11.70
5	Barren land	7.40	7.40
6	Ponds & Reservoirs	6.40	6.40
7	Waterlogged	1.20	1.20

Figure 3 shows the distribution of soils in the catchment. Major soil types include red loamy soil, medium black soil and mixed red and black soil.

Red Loamy Soils

Red loamy soils occur on hilly to undulating land on granites, granitic gneisses and Dharwar schists as long strip along the western ghats in the transitional tracts of Belgaum and Khanapur. These soils are very deep and dark brown to dark red in color. Texturally, soil is sandy loam to clay loam on the surface and loam to clay loam (interrupted by gravelly sandy clay in isolated patches) in the sub-surface horizon, with distinct argillic (clay rich) horizon. These are composed of kaolinitic and hydrous oxides of iron and alumina minerals. Soil is neutral to weakly acidic in reaction, low in cation exchange capacity and medium to high in water holding capacity. Soils are well drained with moderate permeability and respond well to irrigation manure and other water and land management practices. These soils are classified under ustalfs, udalfts, ustults and udults. Crops like wheat, jowar, millets, groundnut and pulses are grown under rainfed cultivation. Under irrigation, crops like paddy, sugarcane, chilly, sweet potatoes, vegetables and plantains are grown.

Medium Black Soils

These soils usually occur in the Deccan traps, schist, lime-stone and shale regions of the catchment, occupying areas in parts of Belgaum and Bailahongal. . Soils are moderately deep (23-90 cm) to dark to very dark greyish brown, dark reddish brown or black in color, usually calcareous, cracking and clayey. The

texture of the surface horizon is clayey. These soils usually occur on very gently sloping midlands. Soils are highly retentive, neutral to alkaline and are well supplied with bases. They contain high percentages of clay with clay fraction dominated by montmorillonitic type of clay mineral. These are moderately well drained with low permeability. At places, lime concretions are found scattered on the surface as well as in the sub-surface hoizons; powdery lime pockets are also seen in the sub-surface horizons. These soils are classified under the order: inceptisols and vertisols with sub-orders: ochrepts and usterts. These soils are fertile and produce good yields, when moisture is not limiting factor. These soils are moderately susceptible to erosion. The crops grown in these soils under rainfed conditions are jowar, wheat, millets, cotton, sunflower, tobacco, groundnut, linseed, chilly, gram and other pulses.

Mixed Soils

Mixed soils usually occur on gently undulating plain or on complex geological materials such as gneisses, Dharwar schists and sedimentary rock formations and occupy areas in parts of

Bailahongal and Saundatti. The red and black soils are found in association with each other in this area. These soils are classified under orders:alfisols, vertisols and entisols with suborders:ustalfs, usterts and orthents. Soils are moderately susceptible to erosion and crops usually suffer due to lack of moisture during the growing period in the absence of irrigation facilities. The crops grown under rainfed conditions are jowar, cotton, groundnut, chillies, wheat and pulses, and the crops grown under irrigation are cotton, pulses, paddy, sugarcane, maize, wheat and tobacco.

Methodology

River water samples were collected from upstream and downstream sections (stations A and F) during the post-monsoon period October, 1999 and non-monsoon period (February, 2000). Out-fall samples were collected at 4 locations (B, C, D, E – as marked in Figure 1). Groundwater samples (30 numbers which includes both Pre-monsoon and Post-monsoon) from the adjoining aquifers have been collected from selected locations in addition to the effluent samples from major out-falls. All containers used for collection of samples were soaked in nitric acid and rinsed with de-ionized water prior to use. Samples were preserved by acidifying with concentrated ultra pure nitric acid having $pH<2$, and stored at 4°C in polyethylene bottles. River discharges at all points were determined by measuring the velocity using current meter and taking cross-sections at each point.

All glassware was thoroughly cleaned by soaking first in detergent and then in nitric acid for 24 hours and finally rinsed with de-ionized water several times. Ultra pure quality chemicals were used and all samples were analyzed by using standard methods (APHA, 1985).

One of the most important aspect of water quality engineering is to determine the impact of mass loading on the total mass of material discharged per unit item into a specific body of water for defined sources with continuous flow. The mass balance method as described by Runkel and Bencala (1995) is applied in this study. i.e. Accumulation = Mass In – Mass Out or in otherwords, the input load is given by the equation,

$$L(t) = Q(t)\,C(t) \text{ ---------------}(1)$$

where $C(t)$ is the concentration of input (M/L^3), $Q(t)$ is the input flow (L^3/T) and $L(t)$ is the mass rate (load) of input (M/T) at a given time ‘t’. In metric units, the concentration and flow are often expressed in mg/l and m^3/s respectively. Also, for almost all practical purposes:

L=Q.C ----------(2)

where, ` L ‘ is in g/s ; Q is in m^3/s; and C is in mg/l (= g/m^3)

The principal statement for rate mass balance assuming complete mixing is,

Load of substance upstream + Load added by out-falls
= Load of substance downstream ---------(3)

Since load is the product of flow and concentration, the mass balance equation can be written as,

$$QuCu + \sum_{i=1}^{n} L_i = Q_D C_D \quad \text{-------------(4)}$$

Where Qu and Q_D are upstream and down stream flows, Cu and C_D are upstream and downstream concentrations, and $\sum_{i=1}^{n} L_i$ is the sum of all individual loading from out-falls.

Results and Discussion

Ground water Chemistry

The pH value of water is an important indication of its quality and it is dependent on the carbon-dioxide–carbonate–bicarbonate equilibrium. Acid-base reactions are important in groundwater because of their influence on pH and the ion chemistry. Thus, we can express hydrogen activity as [H3O+]. The pH value in the study area varies between 7 and 9.4. Maximum pH is observed for open well samples. In the bore wells the maximum value observed is 8.75. A pH value of 7.5 to 8.0 usually indicates the presence of carbonates of calcium and magnesium, and a pH of 8.5 or above shows appreciable exchangeable sodium. Therefore, the results clearly indicate the dominance of bicarbonate, sodium and chloride towards downstream as compared to upstream.

The electrical conductivity is a useful parameter of water quality for indicating salinity hazards. Electrical conductivity of groundwaters of Malaprabha catchment varies from 0.36 to 29.6 ds/m. 42 % of the samples showed EC values more than 4 ds/m, and 28% samples had EC less than 2.5 ds/m, thereby indicating that salinity is more prevalent than sodicity in the study area. Earlier studies carried out by Sehgal et al. (1992) also reported similar trend in the area. Electrical conductivity was found to be highly correlated (negatively) with Na (r=-0.96) and Cl (r=-0.94) and also positively with sulphate (0.71). The soluble carbonates and bicarbonates in the water samples analysed varied from 1.044 to 8.118 meL^{-1}(including both carbonate and bicarbonate) during pre-monsoon and 0.58 to 12.525 me L^{-1} during post-monsoon. The concentration of carbonate and bicarbonate is important because these affect the precipitation of calcium and thereby resulting in excessive saturation in soil. The RSC of waters indicate that about 71% samples had RSC between 2.5 meL^{-1} and 5 meL^{-1}. The results indicated that the continuous and indiscriminate use of these underground waters is expected to build up excessive sodium in soil solution and exchange complex and will also clog the soil pores which may lead to drainage problem (Sood et al., 1998). Soluble sodium is the dominant cation varying in concentration from 0.39 to 17.5 me L^{-1} in these waters. However, the SAR values of all samples are less than 10.

It is observed that waters of high electrical conductivity values are predominant with sodium and chloride ions. This is evident at places like Holehosur, Belawadi and Desur. Further it is observed that saline waters also have relatively more calcium, magnesium and bicarbonate ions. This is observed especially at Holehosur. Potassium and carbonate ions are mostly confined up to a range of 5 % of the total salt concentration. It is rather difficult to draw a general conclusion on the ionic composition of the water in relation to geographical conditions. In general, waters in areas of high rainfall, i.e. above 1000 mm per annum and with good drainage are of good quality. This is clear from the present study that, in the upstream where the rainfall is more (above 1000 mm) the quality of water is good whereas in the downstream area various parameters exceeds the acceptable limits.

The diagrammatic representation (Figures 4 to 7) showing percentage distribution of anions and cations with total ion concentration, indicate that bicarbonates and sulphate ions are the dominating anions in the upstream, whereas towards downstream, concentration of chloride increases over bicarbonates indicating salinity problems in black cotton soil area. Similarly among cations calcium and magnesium are the predominant ones. It is also observed that potassium shows a significant increase in its concentration in Saundatti area. This is attributed to rock types and clay minerals rich in potassium.

In the downstream of Malaprabha catchment (from M. K. Hubli up to dam site) it is expected that, the most important exchange reactions involved are the removal of Ca^{2+} and Mg $^{2++}$ out of water and replace them with Na^{+}. The main requirement for this process is a large reservoir of exchangeable Na^{+}, which is most often provided by clay minerals deposited. When ion exchange takes place, its effects on the cation chemistry of water should be unmistakable. However, an equivalent increase in Na^{+} concentration that is matched by an increasing Cl^{-} concentration. Further, an increase in $HCO3^{-}$ and Na^{+} concentrations indicate the presence of ion-exchanged waters.

Sodium concentration is an important criterion in irrigation-water classification because sodium reacts with the soil to create sodium hazards by replacing other cations. The extent of this replacement is estimated by Sodium Adsorption Ratio (SAR). Sodium Adsorption Ratios of all the samples in the study area can be grouped under low-sodium hazard zone, however, the conductivity varies considerably from low to very high. Further, the ground water samples collected from deep black cotton soil areas showed a shift towards medium hazard zone due to continuous use of poor quality ground water. This clearly indicate the future trend of soil and ground water salinization in these areas and therefore proper attention should be given to take immediate measures to control the possible impact.

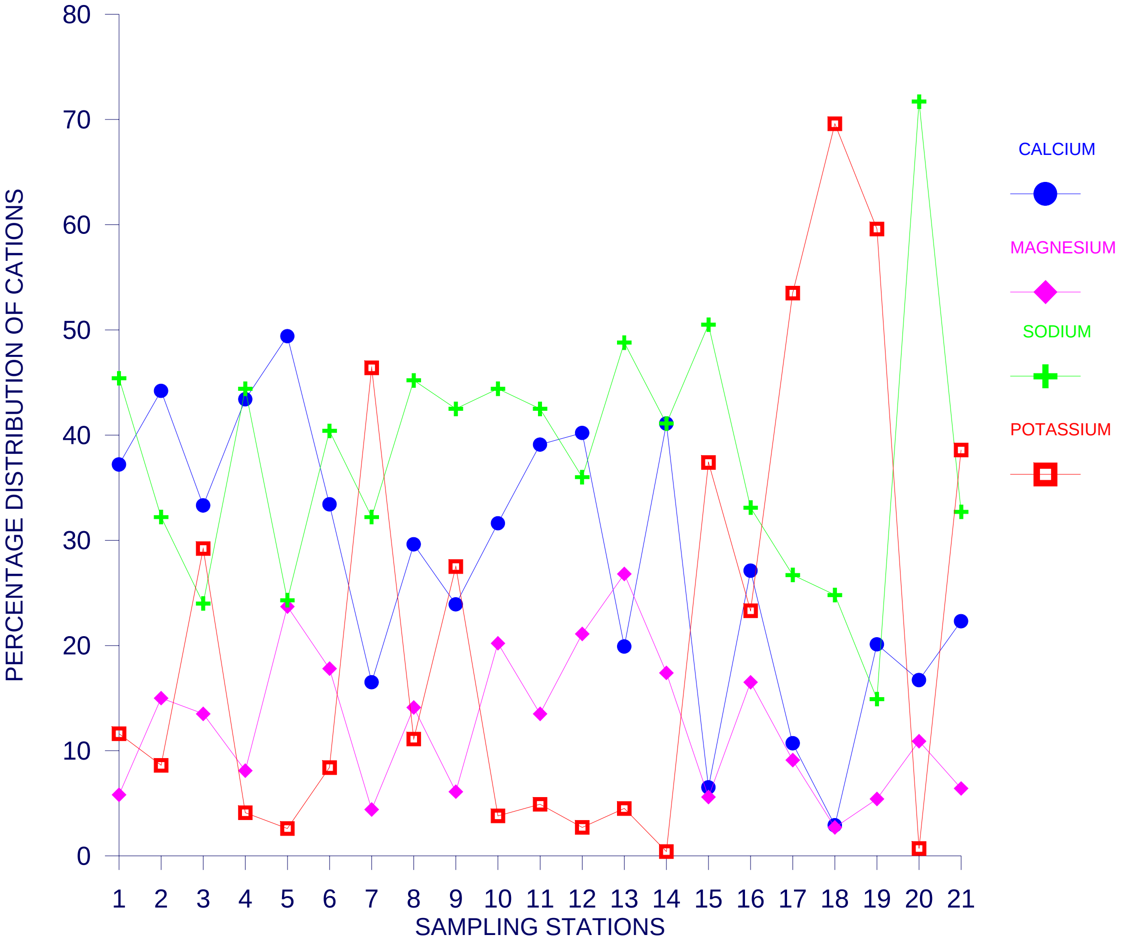

Figure 4. Graph Showing Percentage Distribution of Cations (Pre-Monsoon)

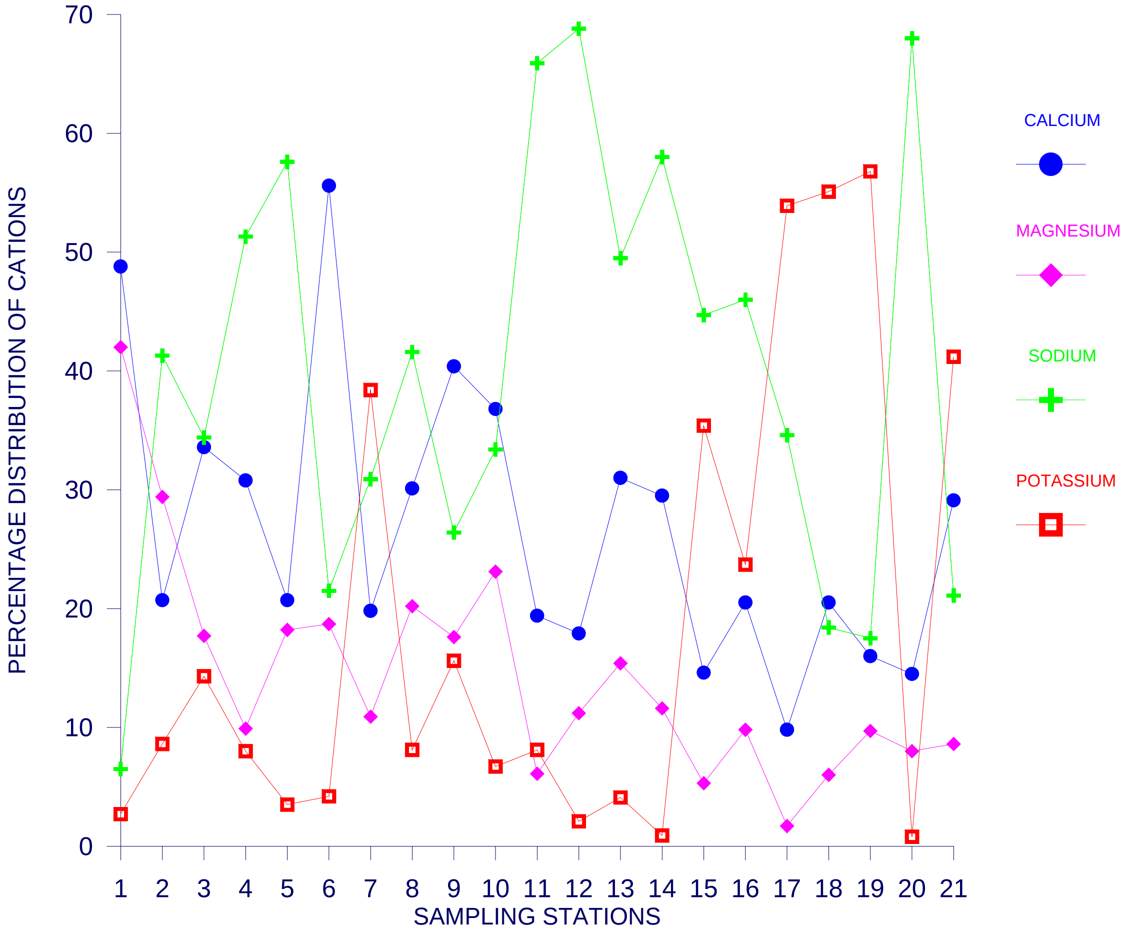

Figure 5. Graph Showing Percentage Distribution of Cations (Post-Monsoon)

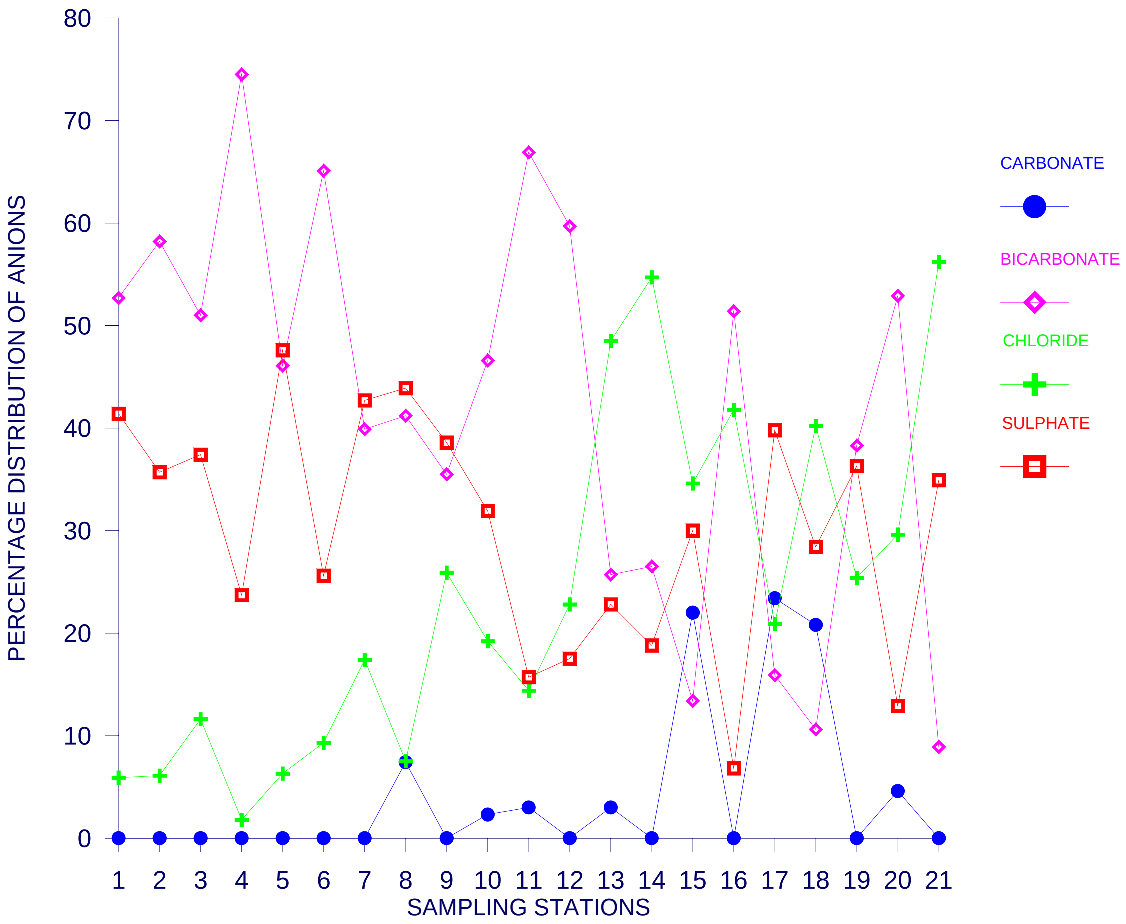

Figure 6. Graph Showing Percentage Distribution of Anions (Pre-Monsoon)

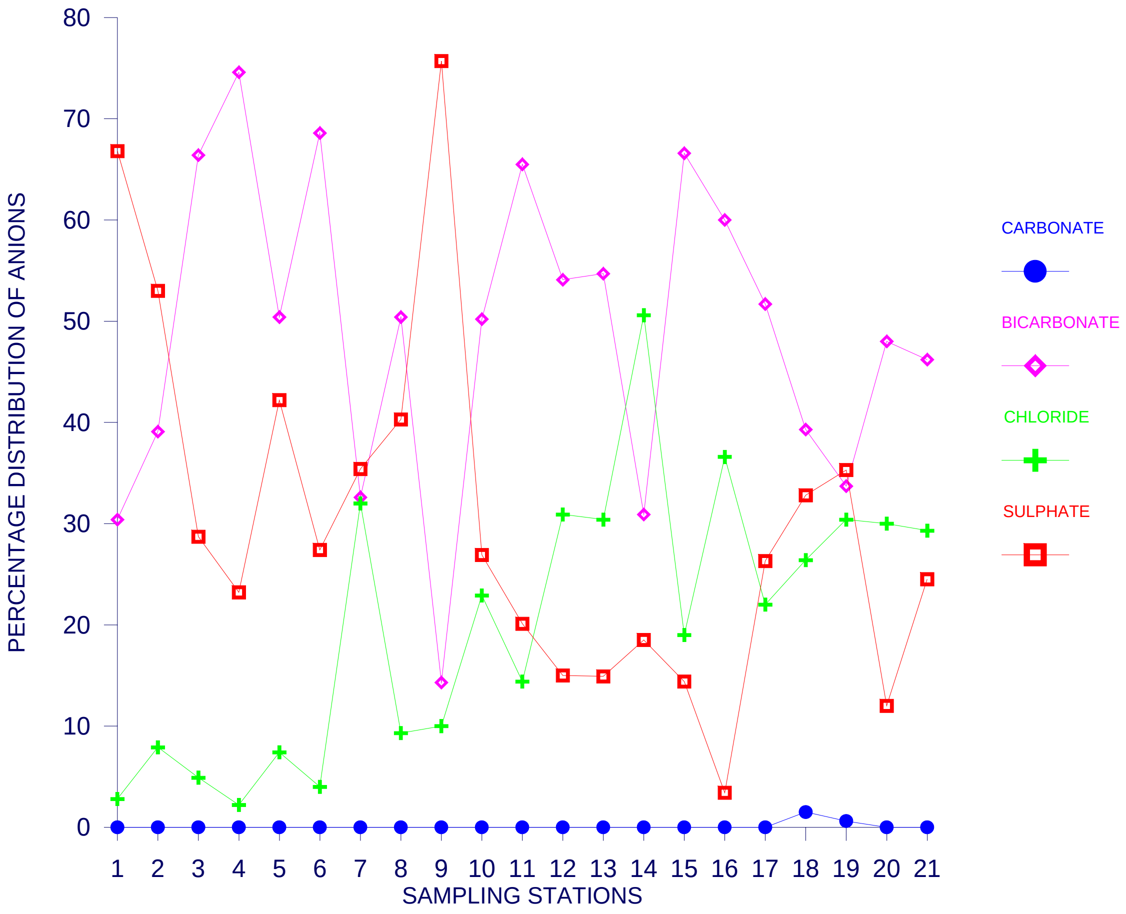

Figure 7. Graph Showing Percentage Distribution of Anions (Post-Monsoon)

Surface Water Chemistry

Figure 8 & 9 represent the concentrations of major anions and cations in the river water (upstream/downstream) and the out-falls under varied flow conditions (flow varies between 0.1 m^3/s and 2.45 m^3/s during non-monsoon and during post-monsoon from 0.2 m^3/s to 7.5 m^3/s). The increase in stream flow between stations A and F (upstream and downstream) was caused by the outfalls of municipal and industrial wastes incoming from various towns located in the catchments. Table 2 contains the upstream/downstream loadings of major anions and cations. The differential loading between upstream (A) and downstream (F) sections varies considerably high (from less than 10 times in the case of bicarbonate and sulphate and more than 100 times in the case of chloride and potassium) during non-monsoon period. However, during post-monsoon period the variation of loading between A and F are quite acceptable, which is less than ten times except for chloride (11 times) and sodium (17 times). The wide variation in non-monsoon and post-monsoon period could be due to the dam effect (back water effect) which lead to dilution of anions and cations in the downstream section. During non-monsoon period, higher concentration of anions and cations were observed which could be attributed to base-flow components (supplied from adjoining aquifer) and also due to the drying of reservoir during non-monsoon period (dilution effect becomes negligible).

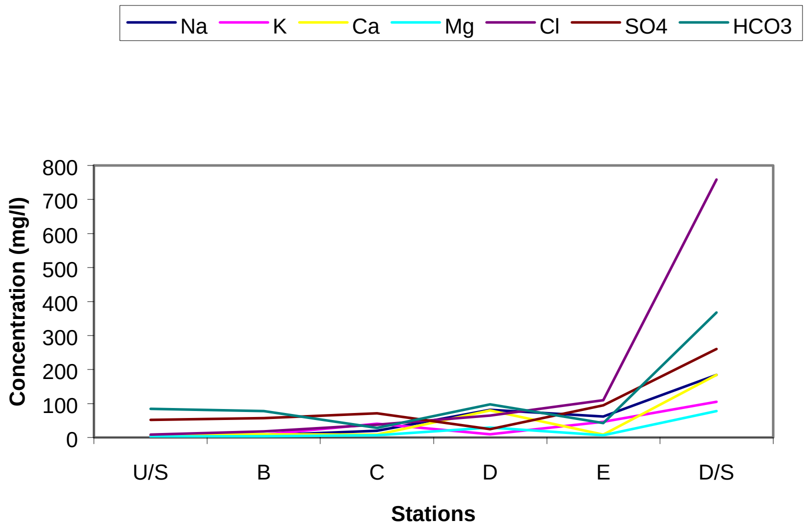

Figure 8 . Concentration of anions and cations under varied flow conditions (Non-monsoon)

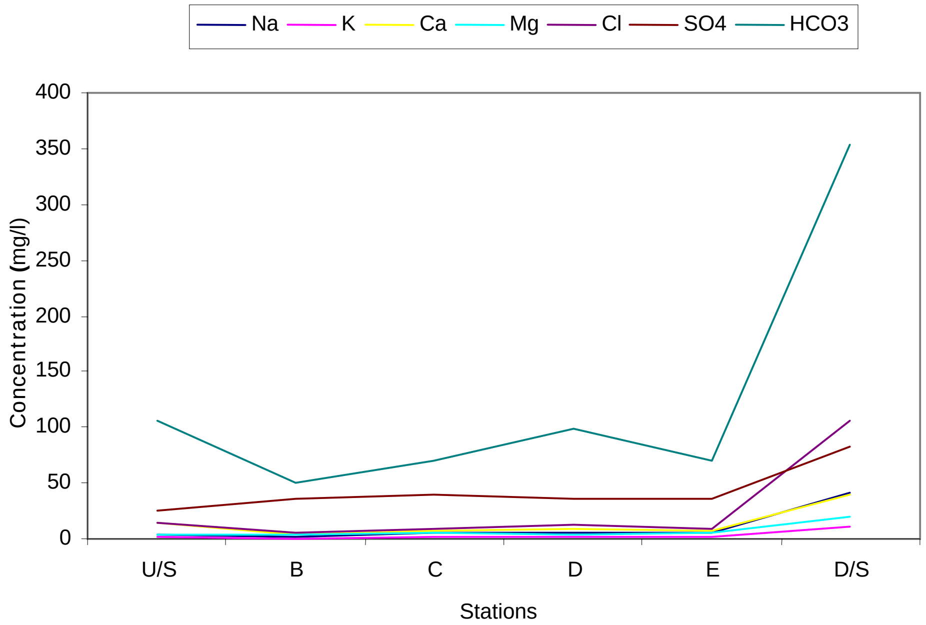

Figure 9. Concentration of anions and cations under varied flow conditins (Post-monsoon)

Table 2 shows the loading of major anions and cations (during October 1999 and February 2000) for the out-fall that enter river Malaprabha. It is observed that during both the seasons (non-monsoon and post-monsoon), there are significant variations in the loading. However, the ratio between point and non-point sources, during non-monsoon and post-monsoon period is minimal. This lead to the conclusion that the contributors through point sources are relatively negligible during the entire study period and variation in loading during post-monsoon season is a result of large scale erosion of agriculture land. This is evident from the land use statistics shown in table 1, that shows a large scale degradation and forest land conversion to agriculture land (Purandara et al .1999).

Table 2 : Loadings and Mass balance calculations for major anions and cations

Source	Load kg/day						
	Na	K	Ca	Mg	Cl	SO_4	HCO_3
Non-monsoon							
U/s	589.70	157.25	808.70	274.05	995.15	5840.60	9536.00
B	59.60	72.60	82.90	33.70	153.10	492.50	672.50
C	345.60	691.20	138.25	118.00	643.20	1226.90	489.00
D	708.50	77.75	691.20	248.80	561.60	207.35	ND
E	803.50	596.20	103.70	88.50	1424.30	1231.20	550.15
U/s+ b to e	2506.90	1595.00	1824.75	763.05	3777.35	8998.55	11247.65
D/s	5013.80	22226.40	38949.1	16532.20	160586.8	55036.80	77898.25
Post-monsoon							
U/s	1556.90	1144.80	6594.05	1785.90	6493.30	11448.0	48603.60
B	43.20	7.80	55.30	76.00	91.60	630.70	855.90
C	172.80	48.40	248.80	186.00	306.20	1347.85	2445.50
D	149.00	36.30	228.10	114.05	321.40	946.10	2568.70
E	216.20	57.00	380.20	231.90	421.00	1734.50	3362.50
U/s+b to e	2138.10	1294.30	7506.45	2394.45	7633.50	16107.15	57836.20
D/s	4276.20	6480.00	25401.6	12960.0	68914.8	53784.00	229262.40

Figure 10 shows the percentage contribution of point and non-point sources. The results further indicate that during post-monsoon, the percentage contribution of point source varies between 2.5 % and 18%, whereas during non-monsoon period it varies from 3% to 11%. This clearly shows the impact of agricultural activities and man made disturbances on water quality parameters. It is also observed that there is a marked increase in loading of all ions towards downstream which indicate that there is a severe degradation of quality in the downstream areas than the upstream area. The major input for such an increase in ions is through non-point sources like fertilizers and chemicals. Certain chemicals applied as fertilizers and pesticides in the soil water are attracted to the surfaces of clay minerals, organic matter, or both through the process of adsorption. Adsorption decreases the rate of transport of chemicals because it reduces the amount in solution (van Genuchten and Wierenga, 1976). Positively charged ions (cations) such as Calcium, magnesium, potassium, ammonium and sodium, are adsorbed by both clay minerals and organic matter. Because of the chemical equivalence of the exchange, the positively charged ions added to soil may be adsorbed by the soil in exchangeable form and lead to the enrichment of certain ions depending upon the cation exchange capacity. In the downstream area because of the semi-arid climate, the solubility limits of calcium and magnesium carbonate are exceeded. As a result of this they are precipitated with a corresponding increase in the relative proportion of sodium in the soil solution. Among the negatively charged ions, chloride is not adsorbed appreciably and are directly added to river water leading to salinization process. Neutral non-ionic orgainic compounds, such as many pesticides, are adsorbed primarily by soil organic matter (Green, 1974; Weed and Weber, 1974). As a consequence, the transport of many pesticides to ground water is restricted in soils having a high content of organic matter. However, Ethylene dibromide and 1,2 –dibromo-3-chloropropane are both volatile liquids commonly used for nematode control, and both are relatively soluble in water. The solubility together with typically large quantities applied for agriculture purpose lead to contamination of both surface and ground water.

Mass balance study carried out for Malaprabha river shows that an enormous quantities of chemical ions are added to the river water due to non-point sources like agricultural activities and forest degradation. Since, most of the areas in the downstream are covered by black cotton soils which are characterized by low infiltration and hydraulic conductivity (Purandara et al , 1995), the excess application of fertilizers remaining in the top soil layer flows into the stream due to overland flow. Varadarajan (2000) highlighted the problem of soil salinity and water quality deterioration with special reference to groundwater environment. Study further reported the influence of ground water during non-monsoon season. This indicate that the major cause of surface water contamination is due to groundwater influx and agricultural inputs.

In recent years non-point sources of pollution are being recognized as a major source of pollution to surface waters. There are number of studies which highlighted the pollution problems due to non-point sources. Apart from the agriculture resources, there are chances of getting pollution from sediment sources resulting from the erosion unpaved roads. Mac Donald et al. (1997) reported that unpaved roads resulting from rapid development during the past few decades is the main cause of erosion and increased sedimentation of the aquatic ecosystems. Durand et al (1999) studied major solute concentrations in overland flow water in an agriculture field of Brittany (Western France). Two storms events were monitored in detail to examine the short time scale process. It is concluded that vegetated buffer strips designed to reduce the sediment load only, and not the amount of overland flow, will have little effect on the transfer of dissolved pollutants to the water courses. Therefore, it is reasonable to expect contamination through sediment sources in the study area. However, in the present study the attempt is not made to quantify the different sources of non-point pollution. Heathwaite and Johnes (1996) studied contribution of nitrogen and phosphorous from agricultural runoff for both surface and subsurface flow pathways. A range of land uses (grazed and un grazed grassland, cereals, roots) in intensive agricultural systems was studied at scales from hill slope plots (0.5 m^2) to large catchment (>300 km^2). By fractionating the total nutrient load it was possible to establish that most of the phosphorous was transported in the unreactive (particulate and organic) fraction via surface runoff. It is reported by local farmers that the concentration of nitrogen and phosphorous is quite high in groundwater, in areas close to the agriculture land due to overland flow from intensive agriculture lands. However, systematic data pertaining to nitrogen and phosphorous are not available. Non-point sources of pollution account for more than 50 % of the total water quality problems, and they are being recognised and investigated nationally and internationally. Similar observation is made In the present study, i.e., 90% of the pollution is due to non-point sources. In addition, in many areas, non-point pollution, such as runoff from cropland, urban storm water, strip mining and runoff from construction sites are becoming major water quality problems (Alexander, 1976). Agriculture is often considered as the largest contributor to non-point source pollution of both surface and sub-surface systems as evident from the present study. It is mainly responsible for degrading the river water quality by generating runoff from animal husbandry units, which contain predominantly organic compounds from the use of mineral fertilizers and chemical pesticides. In this context, processes in soils associated with nitrogen and phosphorous losses to water receive much attention. Rai and Sharma (1995) stated that exponential growth in population and fragmentation of farm families have caused a reduction in land holding size, consequently forcing the farmers towards intensive cultivation leading to enhanced soil and nutrient loss. A study carried out by Hiremath (2002), carried out a study on the impact of land use changes on water quality and reported that the major cause of contamination in Ghataprabha sub-basin, of Krishna basin is due to non-point sources, that include soil erosion and sedimentation and erosion of stream banks, washing out nutrients and organic material from livestock wastes and agricultural lands. Tejaswini (2002) also observed water quality deterioration in Ghataprabha sub basin due to the cumulative watershed effects.

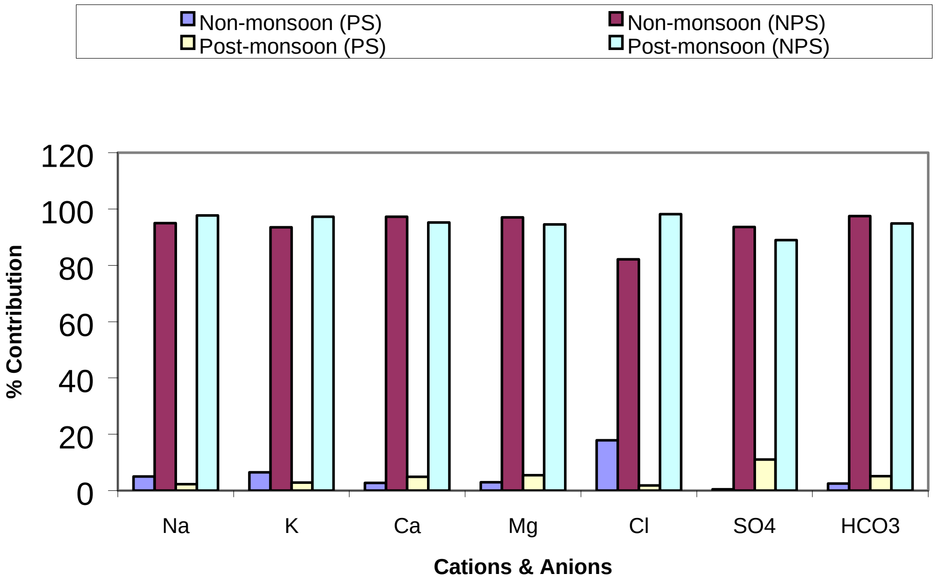

Figure 10 : Percentage Estimate of Point and Non-Point Sources

Conclusions

The present study is an attempt to differentiate between point and non-point sources of pollution using upstream river water quality data. This approach is useful to estimate the load to the river and detect changes in the water quality characteristics within the river system. The levels of various major anion and cation at the downstream section indicate that additional inputs account for the observed differences in load along the river. Indirect monitoring of non-point sources using upstream/downstream sampling locations provides a better alternative over other conventional techniques. An additional advantage of this approach is the substantial reduction in cost involved in the analysis of a large number of individual samples. At the outset, the study revealed that there are additions of large quantities of effluents due to base flow and irrigation return flow. This approach may be well utilized for measuring the changes in the differential concentration and/or load to the river from year to year.

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