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SURFACE AND GROUNDWATER QUALITY STUDIES IN GHATAPRABHA REPRESENTATIVE BASIN

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Preface

Water quality is a consequence of the natural physical and chemical state of the water as well as any alterations that may have occurred as a consequence of human activity. The usefulness of water for a particular purpose is determined by the water quality. If human activity alters the natural quality so that it is no longer fit for a use for which it has previously been suited, the water is termed as polluted or contaminated. Pollution of surface water frequently results in a situation where the contamination can be seen or smelt. However, contamination of ground water often results in a situation that cannot be detected by human senses.

Part of the water supply to Belgaum City is from Ghataprabha reservoir. Therefore, it is necessary to assess chemical quality of the water flowing through the basin and suitability for various uses. Knowledge of ground water quality is also essential because farmers use excessive fertilisers for agriculture that may cause water pollution. The present study has been carried out by Dr. B. K. Purandara, Sc 'B' and Mr. N. Varadarajan, SRA under the guidance of Sri. C. P. Kumar, Scientist 'E1' and Head and Dr. B. Soni, Sc 'F' and Technical Coordinator. Sri. P. R. S. Rao, RA has assisted in the preparation of graphics presented in the report.

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Abstract

In recent years continuous growth in population, rapid industrialization, and accompanying technologies involving waste disposal has endangered the very existence of human race. Eventually, the rate of clearance of forests for the purpose of different land uses is far higher than the methods that are implemented for afforestation. Among the different types of pollution, water pollution is one of the major causes, which creates immense public health hazards.

Agricultural practice as a source of pollution has not been addressed as extensively as that of other sources of pollution. It is important to understand the impact of irrigation return-flow, use of pesticides, fertilizers and manure, changes in vegetation through conservation tillage and the application of waste effluents, because these factors cause changes in surface as well as ground water quality. Ground water is used for domestic supply, industries and agriculture in most parts of our country. The rapid growth of urban areas has affected the ground water due to over exploitation of resources and improper waste disposal practices. Ground water quality problems related to agricultural practices can only be resolved using a more holistic approach to management and research. Hence, there is always a need for and concern over the protection and management of ground water and surface water quality. In the present study both surface and ground water quality of Ghataprabha representative basin has been analysed during Pre-monsoon and Post-monsoon seasons. In addition to this, Streeter-Phelp's model is applied to understand the variation of Dissolved Oxygen along the course of the river from a point source.

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1.0 INTRODUCTION

1.1 General:

Although any environment impact could be either beneficial or adverse, in environmental analysis, impacts are historically considered only to be of adverse type caused by our developmental activities. Impacts can be generally categorized as primary, secondary or tertiary. Primary impacts are those caused directly by project inputs such as loss of forests, or changing of a river regime due to the construction of a dam. As such primary impacts can be attributed directly to a project activity. They are usually easy to measure. Secondary impacts are those caused by project outputs such as water flow regulation and channelization. In other words, they are indirectly attributed to the project activity. If one of the project outputs is availability of irrigation water, secondary impacts could be more severe than primary impacts and, unfortunately, often more difficult to predict and measure. Secondary impacts in turn may lead to tertiary impacts.

It should be noted that the distinction between primary, secondary and tertiary impacts could often be arbitrary. Various types of water-related activities can cause beneficial or adverse impacts on the environment. These activities may include land clearance, construction, water impoundment, water channelization, flood land alteration and changes in land-use patterns.

Impacts could also be conceptually divided into two broad categories: short term and long-term. Short-term impacts occur during the planning, construction and immediate post-construction phases. Longer-term impacts stem from the presence of large manmade lakes, development of perennial irrigation instead of seasonal irrigation, alteration in the ecosystem of the area, and the changing of socio-economic situation.

Water quality is a very important consideration for all water development projects as it affects all aspects of water use-for humans, for animals, for crops, and even for industry. All natural waters containing soluble inorganic ions are mainly from the weathering of soil and rock minerals. The weathering products of the rock minerals are released and transported by the action of water. Hence the nature and concentration of an ion in water depends upon the nature of rock mineral, its solubility, and its resistance to weathering in fresh water or carbonated water (due to dissolution of atmospheric carbon dioxide in rain water) climate and local topography. Apart from these major causes, solubility of minerals is influenced by pH, particularly of iron and manganese hydroxides that decrease, and aluminium hydroxide which increase with the increase of pH.

In highly polluted waters, containing organic materials, these released ions are likely to interact again forming organo-metallic complexes depending upon the nature of the environment. And several processes such as ion exchange, fixation and release, chelation, precipitation, and dissolution, oxidation and reduction, coagulation and aggregation are operating simultaneously which altogether make polluted waters a more complex system. The variable and dynamic gas-liquid-solid interfacial relationships further complicate the system.

Ground waters in arid and semi-arid regions more irrigation water must be applied to soil to avoid accumulation of salts in the root zone, than is needed for evapotranspiration. Therefore, the ground waters get contaminated due to fertilizers and pesticides percolating from irrigation water. Large water storage may raise the ground water level having contacts with permeable and polluted beds, thus affecting the quality of ground water. Once the ground water table is within several centimeters from the surface and evaporates, water begins to move upwards by capillary action, pulled by the dry air and soil above. As water reaches the surface and evaporates, a deposit of salt is left behind. Agricultural, industrial and human settlement, development around the new water project area may exacerbate the problem of water quality deterioration.

All over the world during the last few decades, there has been a massive anthropogenic change in the hydrological cycle (fig. 1), affecting water quality as well as global water budget. The extent of water resources, their spatial and temporal distribution is determined not only by natural climatic variations but also by man's economic activities. In many parts of the world, water resources have become so depleted and much contaminated that they are already unable to meet the ever-increasing demands made on them. In India, ground water resources play a key role in meeting the water needs of various sectors. The contribution of groundwater to irrigated agriculture is about 50% and it meets a major part of drinking and industrial needs (Prasad, 1995). It shall continue to

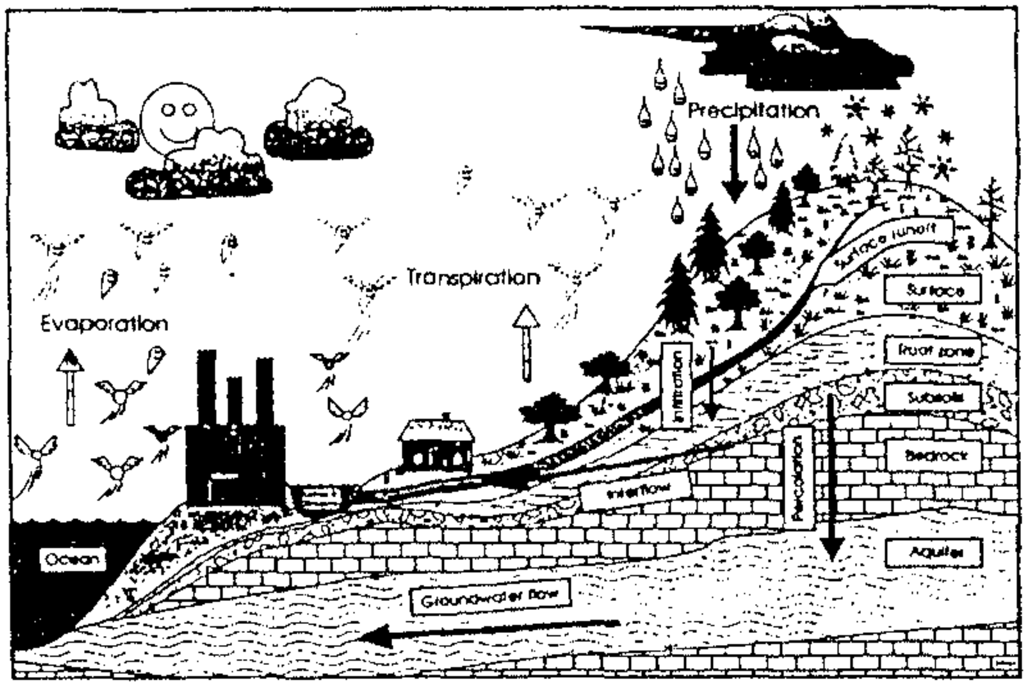

Figure 1 : Hydrologic Cycle

play a key role in meeting the water needs of irrigated agriculture and related fields in a big way in the next millennium also.

Among sources of water dams and reservoirs play a vital role in meeting the demands of human race. Dams and reservoirs, as they get water from the catchments, which, depend mainly on basin's geology, soil and land use pattern. Therefore, the change or disturbance on the catchment will undoubtedly influence the quality of both surface as well as ground water.

1.2 Impact of land use on water quality:

The quality of surface waters is often affected by heavy sediment loads and turbidity levels, particularly in rivers and lakes following high intensity rainfall. This naturally occurring problem is made worse by human activity, such as uncontrolled land clearing for agriculture, which causes additional sediment loads to be transported into river systems. High sediment loads cause problems such as the blockage of river or lake intakes for water supply. High turbidity levels, caused by colloidal suspensions (very fine clay particles) often associated with high sediment loads, make water treatment more costly.

The rising salinity of ground water used for water supply and irrigation is a major problem. There are many examples of salinity increases due to seawater intrusion as a result of over pumping of fresh water lenses. This is generally caused by localized over pumping from wells, boreholes and infiltration galleries. In other cases, the problem is far more widespread and severe and is caused by general over-abstraction from many different systems.

In some cases, ground water or surface water sources may be unpolluted, yet the water supplied to consumers may be polluted. This is due to contamination occurring in distribution systems, which can be caused by the ingress of polluted ground water through faulty joints or defective pipes when the pipeline is not pressurized. Other sources of water contamination are cross connections between potable and non-potable water distribution systems, contaminated tools and fittings during operation of pipes and fittings.

Man's agricultural activities in the course of several millennia have changed the original ecosystem. The gradual transformation of the land caused by agricultural management such as ploughing, sowing, fertilizing, deforestation, irrigation and drainage affected interactions between vegetation, soil, water and rock. Deep ploughing, the uses of heavy machinery, uses of fertilizers and pesticides and irrigation have improved agricultural activity. However, there is a negative impact on the direct consequences of this activity.

Some of the harmful result due to soil losses and further sedimentation due to erosion derived from poor water management practices are the following :

- Soil salinization because of water logging in areas with insufficient drainage.
- Deterioration of drainage water and irrigation return flows through salinization.
- Pollution by mobilization of toxic elements from the soil.
- Point and nonpoint pollution from agricultural chemicals.
- Changes in ground water systems.

1.3 Scope of the study

In recent years continuous growth in population, rapid industrialization and accompanying technologies involving waste disposal has endangered the very existence of human race. Eventually the rate of clearance of forests for the purpose of different land uses is far higher than the methods that are implemented for afforestation. Among the different types of pollution, water pollution is one of the major causes, which creates immense public health hazards.

Therefore, regional variations in surface and ground water quality can be determined only by sampling water at sites intended to give representative coverage of the various conditions of occurrence. Partial analysis to determine the concentrations of the principal chemical constituents in water may provide sufficient data for many investigations and modeling studies. Especially in urban areas increase in demand creates the high potential requirement with possibility of pollution of groundwater. The present study highlights the hydro-chemical characteristics of surface as well as ground waters in Ghataprabha representative basin. Further, the information obtained from the study will be useful for local people, environmental departments, Public health departments etc. The present study also provides the primary impact of land use and cropping pattern on water quality.

1.4. Objectives of the study:

The present study is an attempt to understand the water quality variations in Ghataprabha catchment up to Hidkal reservoir. The main objectives of the current study are the following:

1. Monitoring of surface water quality during pre-monsoon and post-monsoon seasons.
2. Physico- chemical analysis of groundwater samples collected during pre-monsoon and post-monsoon season.
3. Assessment of water quality variation due to Land use and agricultural impacts.
4. Geo-chemical classification of ground water samples.
5. Application of Streeter-Phelp's model for DO modelling.

2.0 LITERATURE REVIEW

In India, many scientists have contributed to the field of Environmental Hydrology. Hora in 1942 published a short note on the pollution of streams and its likely effect on fisheries. Ganapati and Chacko (1951), made an investigation on the river Godavari and examined the effects of paper mill pollution at Rajamundry. Chakrabarthy et. al. (1959), studied the physico-chemical condition and planktonic population of river Yamuna at Allahabad between 1954 and 1955. Water quality of some of the Indian rivers (Ganga, Kosi, Brahmaputra, Kaveri, Bias, Sutlej and Narmada), were reported by earlier workers based on the studies carried out during 1955 to 1966. The study revealed that the water quality is good as their EC values fall below 350 μmhos/cm, while salinity of those of Chambal, Yamuna, Tapti, Godavari and Krishan ranged from 450 to 1400 μmhos/cm. In south India, waters of Hagari and Tunga Bhadra rivers were of moderate salinity. Mohan and Sarakar (1961), made preliminary investigations on the pollution of river Yamuna.

In some arid and salt affected areas of Gujarat, waters of some seasonal rivers show that the salt concentration goes up to 700 ppm (Paliwal, 1980). Mohan Rao (1972), studied the characteristics of dairy waste with reference to Indian standards. Arora et. al. (1973 and 1974), made a survey of sugar mill effluent treatment and disposal in some typical sugar mills of Uttar Pradesh, which is the largest sugarcane producing state in India and reported that effluents are rich in suspended solids, BOD and grease and hence, have great pollution potential.

In Western district of Uttar Pradesh (U.P), mainly Sahranpur, Muzaffar nagar, Meerut and Bulandshahar, large number of water resources are present which are used for irrigation, fisheries and recreation. The same water resources are also utilized for the disposal of industrial wastes of more than 20 different industries Verma et. al. (1974) studied the characteristics and disposal problems of various industrial effluents with reference to Indian Standards. Verma and Delela (1975) studied the pollution of Kalinadi by Industrial wastes near Mansurpur. In 1980, Verma et. al. made a detailed study on the pollution of Hindon river in relation to fish and fisheries and stream Khala by the Sugar factory effluent near Laksar in district Sahranpur.

Agarwal et. al. (1976), studied the physico-chemical characteristics of the Ganges at Varanasi. Apart form groundwater quality and pollution problems emanating due to activity of man, there are water quality problems due to natural causes in several areas of the country. Fluoride concentrations in groundwater are high in several parts of the country particularly in semi-arid and arid tracts. In parts of Rajasthan, Southern Punjab, Haryana, U.P., Gujarat, cases of mottling of teeth, dental and skeletal flourosis were reported from many places. In certain exceptional cases like Sagalia in Gujarat, the fluoride concentration has been found to be 19 mg/l (Raghava Rao, 1977).

Bilgrami and Datta Munshi (1979), made limnological survey of the river Ganga in relation to the human activities from Baruni to Farakka. Kudesia in 1980, published a book on water pollution, in which he reviewed his findings on water quality of different rivers in India. Mahatre et. al (1980), studied the effect of industrial pollution on the aquatic ecosystem of Kali river. The studies conducted in our countries have shown that ground water pollution from discharge of untreated or inadequately treated industrial effluent has reached alarming proportion in several parts of the country. Various researchers have found in their case studies that groundwater has been severely affected due to industrial pollution in India (Naram, 1981; Krishnaswamy, 1981; Das and Kidwai, 1981; Kachwaha, 1981). Kakkar (1981) has carried out geohydrological investigation in North and South-West Haryana and observed the localized rise in nitrate concentration from 43 mg/l (at Singhani) to 1920 mg/l in natural groundwater. This nitrate pollution is likely to be caused by sewage and agricultural waste because due to absence of any geological source of nitrate in the area and non-uniform distribution of nitrate along the direction of groundwater movement.

Kakkar and Bhatnagar (1981) conducted field studies in Ludhiana (Punjab) and observed that ground water at shallow depths of aquifer near bicycle factories had been polluted by hexavalent chromium and cyanides in concentrations ranging from 3.5 to 12.9 mg/l and 0.05 mg/l to 0.98 mg/l respectively. Other trace elements such as copper, zinc, cadmium, cobalt, molybdenum, strontium, lithium and silver were also detected in ground water in different concentrations (less than the permissible limits) in drinking water. Patil and Patil (1983), published their findings on water quality of Ulhas river with reference to mercury, cadmium and copper. Muralikrishna and Sumalatha (1983) have conducted some preliminary studies on the water quality of ground water of Kakinada town and recommended that any water source must be thoroughly analysed and studied before being used for domestic purposes. Water quality investigations in various parts of the country, have shown that most industries produce waste products also (gaseous, liquid and solid) as by-products, which can harm the environment, unless treated properly and confirm to specified standards laid down by health authorities (Handa, 1977, 1983, 1994; Joshi et al., 1982; Singh, 1986; CGWB, 1991; Moitra, 1991).

National Institute of Hydrology, Roorkee has carried out study to work out groundwater quality variations in Saharanpur District (U.P) for shallow wells which are generally used for agriculture and domestic purposes. The results indicate that the quality of groundwater in the area under study is in general good for irrigation as well as for drinking purposes. However, temporal variations of ground water quality have also been reported (Kumar, et al., 1988). Narayana and Suresh (1989) have studied the chemical quality of ground water of Mangalore City, Karnataka and reported two distinct ground water zones in the city.

Chidambaram (1990) carried out studies on the effect of irrigated agriculture on groundwater quality in north of Madras state. According to him, intensive irrigation in about 20 years had raised the Cl concentration of ground water from pre-irrigation level of 110 – 125 mg/l to 210 – 240 mg/l, during the post irrigation period, an annual increase of about 4 – 5 mg/l. Govardhan (1990) carried out the study on ground water pollution in different mandals of district Nalgonda in Andhra Pradesh.

A very high concentration of nitrate was found in ground water around North Railway City Station in Lucknow. The main source of this nitrate pollution was septic tanks, which are located in the study area (Singh, et al., 1991).

Ramaswami and Rajaguru (1991) have conducted study on groundwater quality at Tirupur town in Coimbatore district of Tamil nadu and reported that several parameters exceeded the permissible limits for various uses pointing out to the necessity of proper treatment and disposal of wastes in the area. Ravichandran and Pundarikanthan(1991) have studied ground water quality in Madras with the context of polluted waterways of the city and confirmed the increasing concentration of chloride towards coast due to saline intrusion.

Elengo(1992) has studied groundwater quality in coastal regions of South Madras and reported that a few places the water is not suitable even for irrigation purposes. Satyaji Rao et al (1998 and 1999) studied the spatial variation of ground water quality in Kakinada town and also made attempts to relate water quality with ground water level fluctuations.

Seth and Singhal (1994) have carried out studies in order to assess status of ground water quality of upper Hindon Basin, Saharanpur (UP) due to large scale Industrial and agricultural activities. The results indicate that the ground water of the area is marginally affected comparing the chemical results of water as per World Health Organization and Indian Standards norms. In their investigation, the concentration of toxic metals (lead, cadmium and total chromium) was high, however its erratic concentration at few localities were also observed.

The ground water quality studies in the Jammu & Kashmir State are hardly reported. The Central Ground Water Board (CGWB), Jammu is doing fields investigations to measure the condition and trends of ground water quality and quantity in the State. This organization is monitoring depth of water levels four times in a year in open wells during January, May, August and November since 1986 for Jammu, Kathua, Udhampur, Srinagar, Phulwama, Budgam, Kupwada, Anantnag and Baramula Districts in J & K.

The National Institute of Hydrology, Western Himalayan Regional Centre located at Jammu has conducted ground water quality monitoring and evaluation study in Jammu district during 1994 – 95. The study was aimed at (i) to delineate the contaminated zones for drinking and for irrigation purposes, (ii) to monitor seasonal variation in the ground water quality, and (iii) to identify possible sources of pollution. The Centre has extended it water quality monitoring and evaluation program from Jammu district to Kathua district in the Jammu and Kashmir State and study was continued to subsequent years (Jain et al., 1994; Omkar et al., 1998). Ground water quality studies in Western Uttara Pradesh were studied by Jain et al (1996) during Pre-monsoon and Post-monsoon seasons to evaluate the suitability of water for irrigation and domestic purposes. Jain and Sharma (1997) observed significant correlation between conductivity and total dissolved solids , alkalinity hardness, chloride, nitrate, sulphate, sodium and potassium although the quality of ground water varied widely. Pradeep (1998) studied the hydrochemistry of sub-surface water of upper Urmil Basin in Chhatrapur district of Central India. Purandara (1998) studied the Ground quality of Belgaum city and indicated the impact of urbanization on ground water quality. Purandara (1999) reported the ground water quality variation in various parts of Belgaum district. Varadarajan (2000) studied the ground water quality in parts of Belgaum district and reported the fluoride concentration from saundatti taluk in Belgaum district. Madhurima (2000) carried out surface water quality studies in Ghataprabha river and showed the impact anthropogenic activity on DO variations. Jayashree (2000) studied the impact of sewage on surface and ground water quality in Belgaum city area.

From the above review, it is noted that the studies on water quality are quite limited in hard rock catchments. In order to develop water quality index, it is necessary to go for basin-wise studies rather than area-wise. The present study is a preliminary attempt in this direction to systematically determine the variation in both surface and ground water quality parameters which are found to vary with various man-made changes and agricultural practices.

3.0 MATERIALS AND METHODOLOGY

3.1. Sampling Techniques and Preservation:

Sampling is the first of a series of steps leading to the generation of water -quality data and is an exceedingly important one. Care must always be taken to ensure obtaining a sample that is truly representative. Further the integrity of the sample must be maintained from the time of collection to the time of analysis. If the sample is not representative of the system sampled or if the sample has changed in chemical composition between sampling and analysis, all care taken to provide an accurate analysis will be lost.

3.2. Site Selection:

Ground water samples were collected from various points based on land use and agricultural pattern. 10 micro-hydrological regions were mapped based on soil, lithology and land use pattern. Ground water samples representing each micro-hydrological region were sampled during pre-monsoon and post-monsoon season (fig.2).

3.3. Sample Handling and Preservation:

Samples from the observation wells were collected during Pre-monsoon and Post-monsoon and subjected to various physico-chemical tests. Sampling is restricted to one sub-basin and about 15-20 samples were collected from dug wells/bore wells. While collecting the samples, the depth of water in the well was also measured. The samples were collected in clean plastic (polyethylene) bottles fitted with screw caps. Some parameters like temperature, pH and conductance were measured at the spot by means of portable meters. For other parameters, samples were preserved by adding an appropriate reagent. The samples thus preserved were stored at 4^0C in sampling kits and brought to the laboratory for detailed analysis.

For complete sampling at a point the following bottles should be filled:

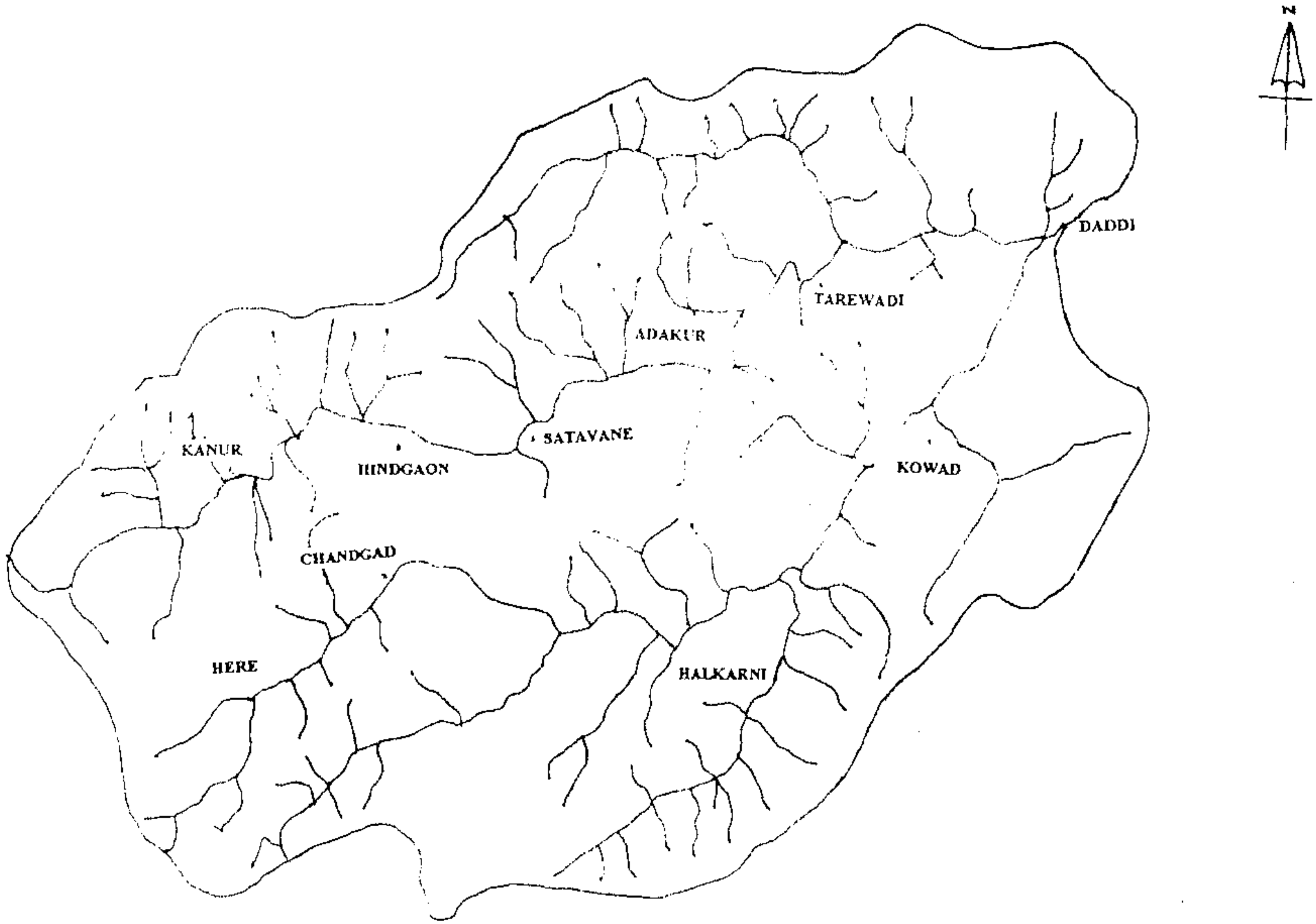

Figure. 2. Ghataprabha Representative Basin with Sampling Locations

i) One bottle of 500 ml for direct measurement of pH, conductivity and temperature at the time of sample collection.

ii) One bottle of 500 ml for laboratory analysis of nitrate and ammonia. Preserve sample by adding 2 ml conc. Sulfuric acid (A.R. Grade) per liter.

iii) One bottle of 250 ml for trace element analysis. Preserve sample by adding 5 ml conc. Nitric acid (A. R. Grade) per liter.

iv) One bottle of 1000 ml for laboratory analysis of acidity/alkalinity, hardness, chloride, fluoride, sulphate, phosphate, sodium, potassium, calcium and magnesium.

Hence at each site 4 bottles with total sample volume of 2250 ml shall be collected, out of which 500 ml (one bottle) will be analyzed at the site.

All the samples were anlaysed using standard methods (APHA, 1985). Equipments and methods followed are summarised in table 1.

3.4. Streeter-Phelp's Model:

Most of the dissolved oxygen models in current use relate in some way to the model developed by Streeter-phelp in 1925. This model predicts changes in the dissolved oxygen deficit as a function of BOD exertion and stream reaeration.

3.4.1. Rate of Oxygen Removal

The rate at which DO disappears from the stream coincides with the rate of BOD exertion.

i.e., $$\frac{dy}{dt} = \frac{dc}{dt} \qquad \text{---------- (1)}$$

When the concentrations of DO drop below the equilibrium value, the net movement of oxygen will be from the atmosphere into the water. This addition of oxygen from atmosphere to the water is termed as reaeration. The difference between the equilibrium DO concentration and actual DO concentration is called oxygen deficit and is represented mathematically by,

Table 1: Analytical Methods and Equipments used in the study

Sl.No	Parameters	Methods	Equipments
1.	pH	Electrometric	pH Meter (AQUA LYTIC)
2.	Total Dissolved Solids	Electrometric	Ion Meter (JENWAY 4320)
3.	Conductivity	Electrometric	Ion Meter (JENWAY 4320)
4.	Temperature	Thermometric	T 100 N LCD - Thermometer
5.	Calcium	Titration by EDTA	
6.	Magnesium	Titration by EDTA	
7.	Sodium	Flame emission	Flame Photometer (Model Chemito 1000)
8.	Potassium	Flame emission	Flame Photometer (Model Chemito 1000)
9.	Carbonate	Titrimetric	
10.	Bicarbonate	Titrimetric	
11.	Chloride	Titration by Silver nitrate	
12.	Sulphate	Turbidimetric	Photoelectric Colorimeter (Model AE - 11S, Erma.Inc)
13.	Phosphate	Instrumental	Spectrophotometer.
14.	Fluoride	Electrometric	Ion Meter (JENWAY 340)
15.	Hardness	Titration by EDTA	
16.	Nitrates	Instrumental	UV- vis Spectrophotometer.

$$D = Cs - C \text{ ---------------- } (2)$$

Where, D = Dissolved oxygen deficit, mg/l.

Cs = Equilibrium DO concentration, mg/l.

C = Actual DO concentration, mg/l.

For constant equilibrium conditions, the rate of change in deficit is,

$$\frac{dD}{dt} = \frac{dC}{dt} \text{ ------------(3)}$$

From (1) and (3),

$$\frac{dy}{dt} = \frac{dD}{dt} \text{ ------------(4)}$$

Confirming that an increase in the rate of BOD exertion results in an increase in the rate of change of oxygen deficit.

Now,

BOD exerted is given by the equation,

$$y = L_0 - L_t \text{ ---------------------- } (5)$$

Where, y = BOD exerted, mg/l.

L_0 = Initial total oxygen equivalent of the organics, mg/l.

L_t = The amount of oxygen remaining at time 't', mg/l.

As L_0 is the ultimate BOD and therefore a fixed value,

$$\frac{dy}{dt} \quad \frac{dL_t}{dt} \text{ ----------------(6)}$$

But,

$$\frac{dL_t}{dt} = - k_1 t \text{ ----------------(7)}$$

From equations (6) and (7)

$$\frac{dD}{dt} = k_1 L_t \quad \text{-----------(8)}$$

Which states that the rate of change in DO deficit at time 't' due to the BOD is a first order reaction proportional to the oxygen equivalent of the remaining organics. Thus,

$$r_D = k_1 \, L_t \quad \text{---------------(9)}$$

Where, r_D = rate of deoxigenation.

k_1 = deoxygenation constant.

The deoxygenation constant 'k_1' for temperatures other than 20^0C can be computed by :

$$k_{1(T)} = k_{1(20)} \, \theta^{(T-20)} \quad \text{--------(10)}$$

where, $k_{1(T)}$ = Deoxygenation constant at temperature 'T', day^{-1},

$k_{1(20)}$ = Deoxygenation constant at temperature 20^0 C, day^{-1},

θ = Temperature coefficient, its value is taken as 1.047.

3.4.2 Rate of Oxygen Addition:

The rate of reaeration is a first order reaction with respect to the magnitude of the oxygen deficit. This is expressed mathematically by,

$$r_R = - k_2 \, D \quad \text{------------------ (11)}$$

Where, r_R = rate at which oxygen becomes dissolved from the atmosphere.

k_2 = reaeration constant.

The negative sign reflects that an increase in the oxygen supply due to reaeration reduces the oxygen deficit.

The reaeration constant 'k_2' for temperatures other than 20^0C can be computed by:

$$k_{2(T)} = k_{2(20)}\, \theta^{(T-20)} \quad \text{------------(12)}$$

where, $k_{2(T)}$ = Reaeration constant at temperature 'T', day^{-1},

$k_{2(20)}$ = Reaeration constant at temperature 20^0 C, day^{-1},

θ = Temperature coefficient, its value is taken as 1.024.

3.4.3 Oxygen Sag Curve:

The oxygen deficit in a stream is a function of both oxygen utilization and reaeration.

The rate of change in the deficit is the sum of the two reactions,

$$\frac{dD}{dt} = r_D + r_R \quad \text{------------------(13)}$$

i.e.,

$$\frac{dD}{dt} = k_1 L_t - k_2 D \quad \text{------------ (14)}$$

therefore,

$$\frac{dD}{dt} = k_1 L_0\, e^{-k1\,t} - k_2 D \quad \text{-------------(15)}$$

which has the solution,

$$D = \frac{k_1 L_0}{k_2 - k_1} \left(e^{-k1\,t} - e^{-k2\,t} \right) + D_0\, e^{-k2\,t} \quad \text{---------------- (16)}$$

This is the Streeter Phelp's oxygen sag equation first described in 1925. In this equation, 't' represents the time of travel in the stream from the point of discharge to the point in question downstream. If the stream has constant cross sectional area, and it is traveling at speed 'u', then time and distance downstream are related by,

$$x = ut \quad \text{--------------------------}(17)$$

Where, x = distance downstream, (L)

u = stream speed, (L/T)

t = elapsed time between discharge point and distance 'x' downstream, (T)

Therefore,

$$D = \frac{k_1 L_0}{k_2 - k_1} \quad e^{-k1\,x/u} - e^{-k2\,x/u} \quad + D_0\, e^{-k2\,x/u} \quad \text{----------------}(18)$$

Subtracting the oxygen deficit (D) from the saturation value (Cs), gives DO as a function of time or distance downstream. A plot of this DO is given in fig. 3. As can be seen, there is a stretch of river immediately downstream of the discharge point ($x = 0$ or $t = 0$) where the decomposition process withdraws oxygen at a faster rate than reaeration can replace it, causing DO to drop. DO reach a minimum at particular location and time, called the critical point. At this point, the rate of decomposition equals the rate of reaeration. Beyond the critical point, reaeration exceeds de-oxygenation and the stream naturally recovers.

The location of the critical point and the corresponding minimum value of DO are of obvious importance. It is at this point where stream conditions are at their worst. Setting the derivative of the oxygen deficit equals to zero and solving for the critical time yields,

$$t_c = \frac{1}{k_2 - k_1} \quad \ln \{k_2 / k_1 \, (1 - \frac{D_0 \, (k_2 - k_1)}{k_1 \, L_0})\} \text{------}(19)$$

The maximum deficit can be then found by substituting the value obtained for the critical time 't_c' into equation (16).

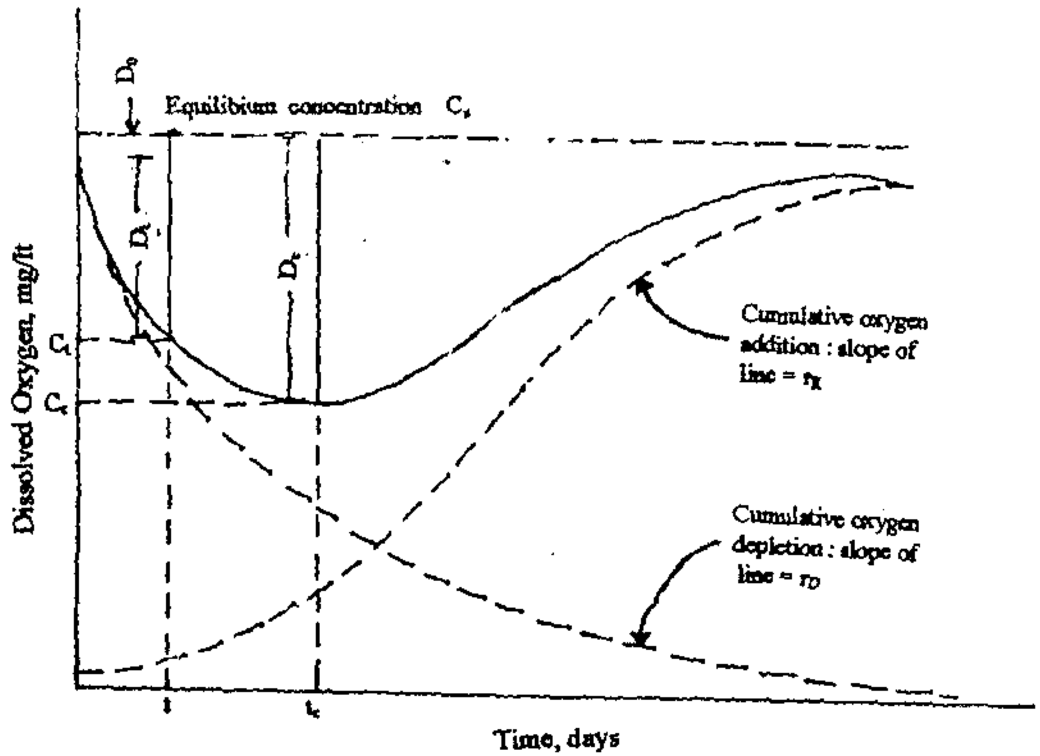

Figure. 3. Oxygen Sag Curve (Peavy, 1985)

3.5. Mass Balance to Upstream / Down stream River Water Quality Data:

Everything has to go somewhere in a simple way to express on the most fundamental engineering principle. More precisely the law of conservation of mass says that when chemical reactions take place, matter is neither created nor destroyed, that is how pollutants move from one place to another with mass balance equations. A substance that enters the region has three possible fates. Some of it may leave the region unchanged; some of it may accumulate within the boundary and some of it maybe covered tom other substance. The materials balance equation can be written for each substance,

Input rate = Output rate + Decay rate+ Accumulation Rate ---------------(20)

Assuming steady state or equilibrium conditions and pollutant, as conservative, the decay rate and accumulation rate will be zero.

Hence, Input rate = Output rate -------------------------(21)

One of the most important aspect of water quality engineering is the determination of 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 input load is given by the equation,

$$L(t)=Q(t)C(t) \text{ ---------------(22)}$$

Where C(t) is the concentration of the 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), all quantities occurring simultaneously 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:

1 mg/l = 1 g/m^3=10^{-3}kg/m^3

Then, L=Q.C ------------------------ (23)

Where, L is in g/s

Q is in m^3/s

C is in mg/l (= g/m^3)

The basic idea in describing the discharge of materials into a river is to write a mass balance equation for various reaches of the river. The principal statement for rate mass balance assuming complete mixing is,

Load of substance upstream + Load added by outfalls

= Load of substance immediately downstream from outfall----(24)

Recalling that the load is the product of flow and concentration, the mass balance is therefore given by,

$$QuCu + \sum_{i=1}^{n} L_i = Q_D C_D \quad \text{----------------------(25)}$$

Where Qu and Q_D are upstream and down stream flows, Cu and C_D are upstream and downstream concentration in the receiving water, and $\sum_{i=1}^{n} L_i$ is the sum of all individual loading to the receiving water.

For understanding the relationship between the water quality found and the source of natural and man-made pollution, the drawing up of mass balance for certain water constituents is determined i.e the weight of the substance transported through a cross-section of the river bed per second.

When two or more rivers come together at one point, the sum of the loads carried by the streams above the confluence must be equal to the load of the river downstream of this point.

4.0 STUDY AREA

Representative basins are the basins, which are selected as representative of a hydrological region, i.e., the region within which the hydrological similarity is presumed. They are used for intensive investigations of specific problems of hydrological cycle under relatively stable, natural conditions. Thus sparse network of representative basins may reflect general hydrological features of a given region and their variations over large natural zones.

The total stream length of the Ghataprabha representative basin is 1102 km. The Ghataprabha river arises from the Western Ghats at an altitude of 884m, flows eastwards for a length of 283 km before joining the Krishna at Kudalasangam about 35km north-east of Kaladgi at an elevation of 500m. The river flows for about 60 km in the Ratnagiri and Kolhapur districts of Maharashtra State before entering the Belgaum district of Karnataka State. A dam is constructed at Hidakal in Hukkeri taluk to impound 2200 MCM water running two canals on either bank and coupled with weirs and lift irrigation schemes on the foreshores.

4.1 Geology

The geological formations (fig 4) found within the catchment are, (i) Deccan trap of Tertiary age, (ii) Sedimentary formations known as "Kaladgi group" comprising limestone, shale and quartzite.

4.2 Land use Pattern

Land use pattern has a significant influence on the quality and quantity of run off available from it. It plays an important role in determining the various hydrological phenomena like infiltration, overland flow, evaporation and interception. The spatial distribution of land use in Ghataprabha representative basin is shown in (fig 5).

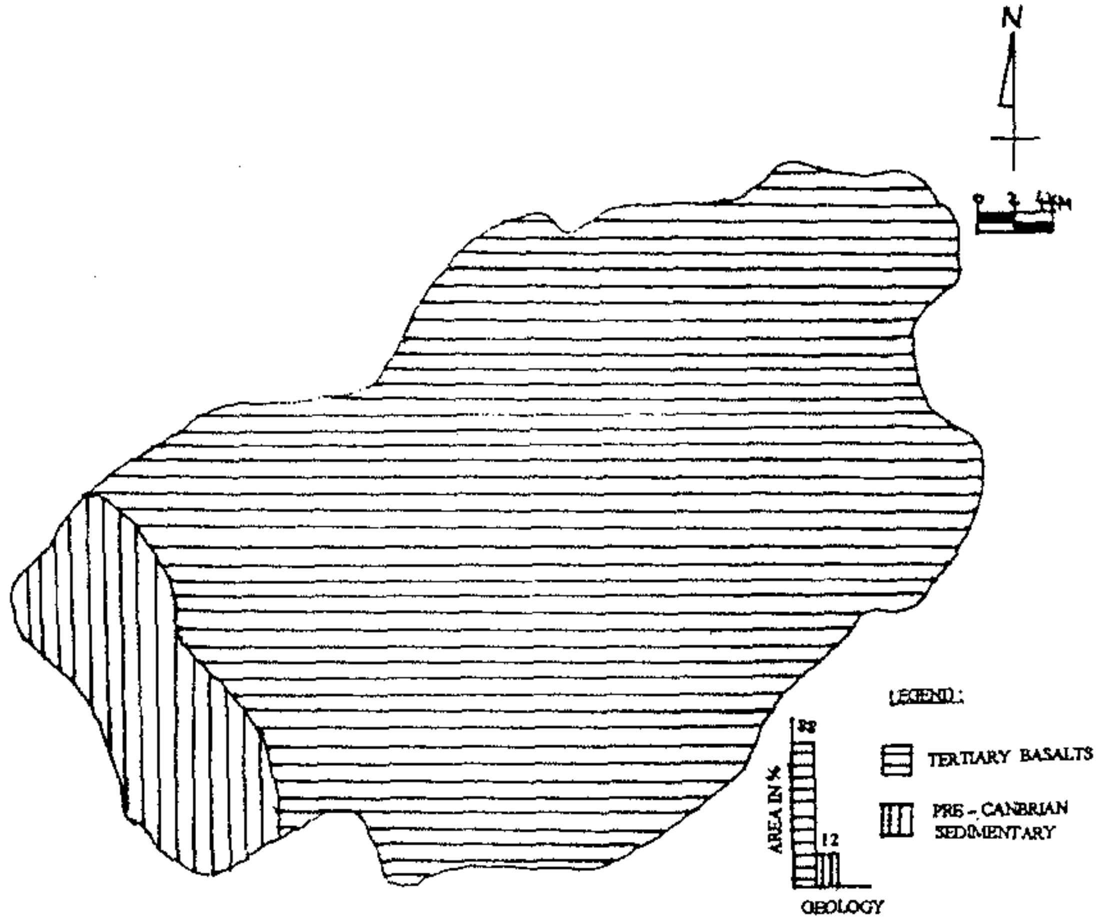

Figure. 4. Geological Map of Ghataprabha Representative Basin.

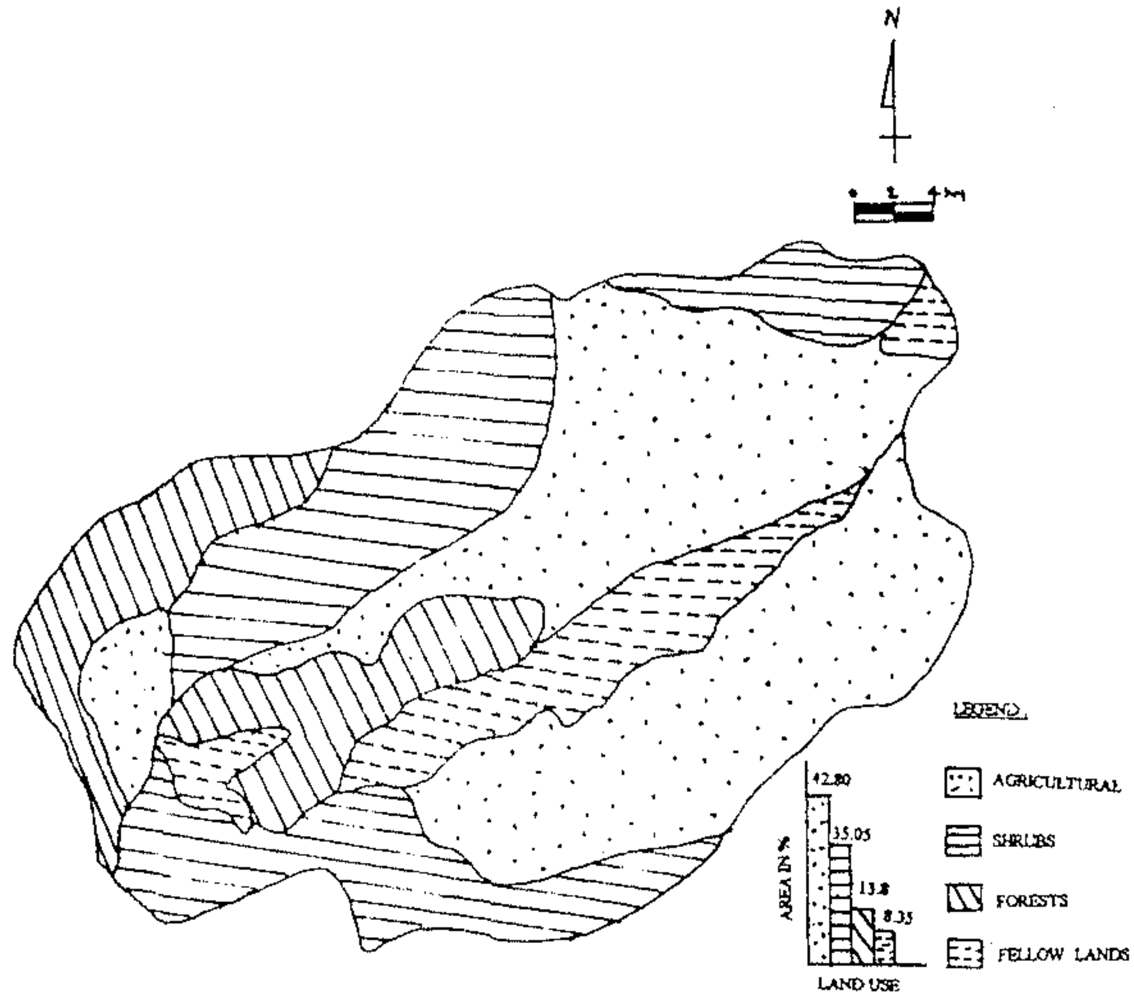

Figure. 5. Land Use Map of Ghataprabha Representative Basin

4.3 Soils

The major soil groups found in the catchment are (fig 6), (a) Laterite soils (coarse shallow soil, 22.3% and medium deep soil, 21.40%).Coarse shallow black soil, (10.70%), Medium black soil (45.80%).

4.4. Geomorphology:

Geomorphologically the catchment is relatively flat and gently undulating with isolated hillocks intervened by valleys. The catchment is somewhat oval in shape. The relief of the basin varies between 682 m and 1039m.

4.4.1 Drainage Density:

Density of the network varies widely between 0.5 km/sq.km to 2.5 km/sq.km. it is observed that the less resistant rocks confined in the western part of the catchment has the higher values of drainage density than that of the flat areas in the central part.

4.5. Basin Input Parameters:

i) Air Temperature

The data on temperature shows that the April is the hottest month (34.4^0C) and January is the coldest month (14^0C). The average maximum temperature in the catchment is 34.4^0C and minimum average temperature is 18.6^0C.

ii) Rainfall

The maximum rainfall is observed during July (37. 7% of total rainfall) and minimum is observed during February (0.05%). The maximum rainfall is noted at Chandagad (3011 mm) and minimum is (885.7 mm) is recorded at Daddi.

(iii) Humidity

The relative humidity is high during the monsoon period and low during the non-monsoon period. In the summer the weather is dry and humidity is low. The maximum

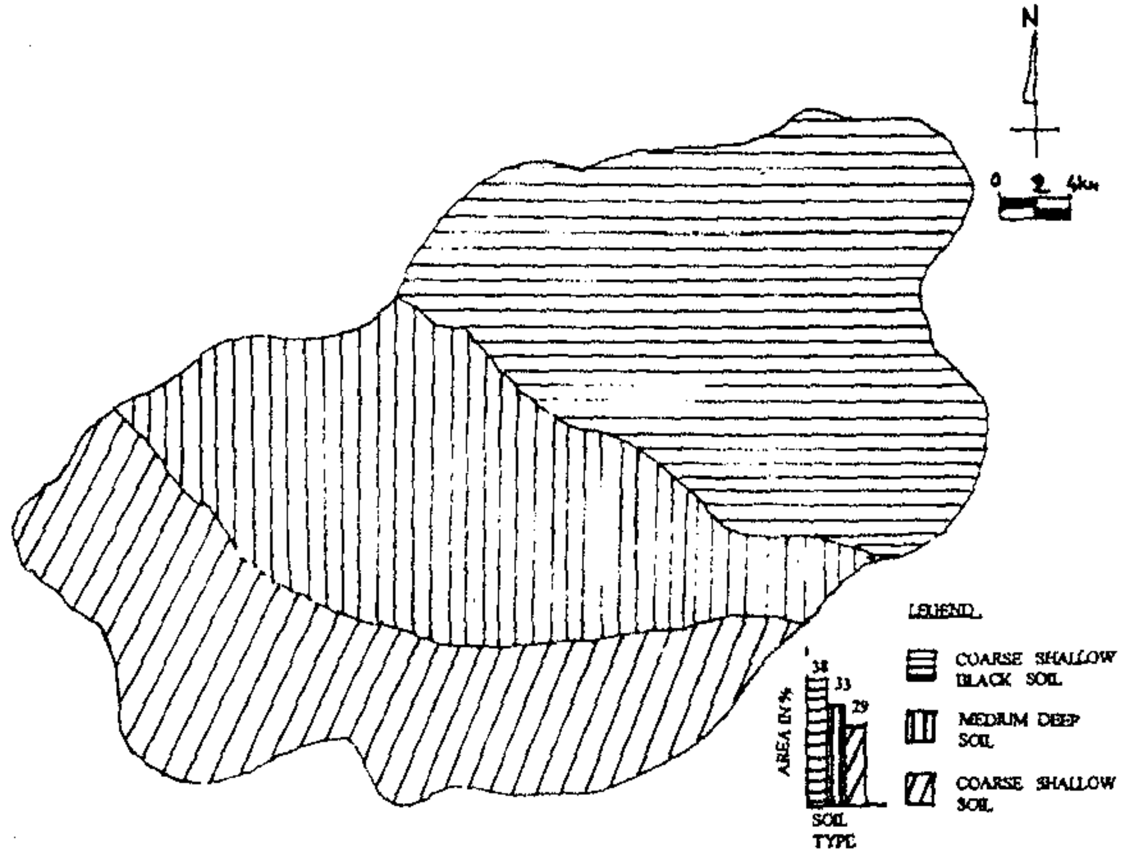

Figure. 6. Soil Map of Ghataprabha Representative Basin

relative humidity is noticed in July and minimum in the March (53.7%). The average relative humidity from 1989 to 1992 is 71%.

iv) **Wind velocity**

Maximum wind velocity is experienced during July (15.3 km/hr). In November and December, it experiences North-Easterly wind. The minimum is observed in October.

5.0 RESULTS AND DISCUSSION

Water quality problems cannot be solved by isolated means, or for only a particular or region. Water quality is a nationwide problem that needs examining from all points of view. Although some problems are more acute in some parts of the country than others. There are some essential common problems such as drinking water supplies and sanitation treatment. In order to develop a water quality index, it is necessary to go for monitoring the water quality which is an essential input in developing water quality index for each hydrological unit.

5.1. Chemical Quality:

Control of the quality of water must be based on standards for incoming effluent waters. The standards so far developed through out the world are deduced from knowledge of the effects of chemical constituents on animals and human beings and also from empirical methods. However, the toxic effects of specific pollutants have not been studied extensively in many parts of the country. Therefore, as in many other parts of the country, investigations are required to obtain precise and useful threshold standards. It is also necessary to develop a regional characteristic of water depending on local conditions such as temperature and solar radiation inputs, oxygen contents, (the frequency and quantity of toxic discharges), their type and amount of accumulation at various levels in the sediments and the biota may call for a modulation of standards.

Surface water samples collected during Pre-monsoon and Post-monsoon seascn in the year 2000, have been analysed for chemical parameters and the results are presented in table 2 and 3 . The ionic balance of each sample is observed to be less than +/- 10%.

32 ground water samples were analysed for its physico-chemical characteristics collected during Post-monsoon of 2000 and Pre-monsoon 2001. Summarised results of the analysis are shown in table 4 and 5.

Table 2 : Physico-Chemical Characteristics of Surface water (Pre-monsoon).

Parameters	Min.	Max.	Average.
pH	6.3	7.6	6.9
Electrical Conductivity (μ mhos / cm)	32.8	230	90.8
Total Dissolved Solids (mg/lt)	19.7	138.9	54.5
Sodium (Na) (mg/lt)	9	18	12
Potassium (K) (mg/lt)	0	69	8.4
Alkalinity as $CaCO_3$ (mg/lt)	23.2	58	39.8
Carbonates (mg/lt)	--	--	--
Bicarbonates (mg/lt)	28.3	70.7	48.5
Chlorides (mg/lt)	8.9	33.7	13.3
Total Hardness as $CaCO_3$ (mg/lt)	12	32	21.8
Cacium as Ca (mg/lt)	2.4	8.8	5.2
Magnesium as Mg (mg/lt)	1.0	2.93	2.1
Sulphates (mg/lt)	1.0	33	10.5
Phosphates (mg/lt)	1.0	3.5	2
Fluoride (mg/lt)	0.2	0.4	0.3

Table 3 : Physico-Chemical Characteristics of Surface water (Post-monsoon).

Parameters	**Min.**	**Max.**	**Average.**
pH	5.9	7.7	6.9
Electrical Conductivity (μ mhos / cm)	36.8	183.3	104.2
Total Dissolved Solids (mg/lt)	22.2	110	62.3
Sodium (Na) (mg/lt)	8	18	12
Potassium (K) (mg/lt)	0	3	1.4
Alkalinity as $CaCO_3$ (mg/lt)	16	42	30.2
Carbonates (mg/lt)	2.4	4.8	--
Bicarbonates (mg/lt)	19.5	52	36.8
Chlorides (mg/lt)	5.3	45.9	10.9
Total Hardness as $CaCO_3$ (mg/lt)	10	44	22.8
Cacium as Ca (mg/lt)	1.6	8	5.3
Magnesium as Mg (mg/lt)	1.0	5.76	2.2
Sulphates (mg/lt)	8	25	14.8
Phosphates (mg/lt)	2	5.8	5.2
Fluoride (mg/lt)	0.2	0.4	0.3
Nitrates (mg/lt)	7.2	8.6	7.9

Table 4 : Physico-Chemical Characteristics of Ground water (Pre-monsoon).

Parameters	**Min.**	**Max.**	**Average.**
pH	5.6	7.5	6.4
Electrical Conductivity (μ mhos / cm)	107.1	788.3	307.8
Total Dissolved Solids (mg/lt)	64.3	473	185.1
Sodium (Na) (mg/lt)	11	40	25
Potassium (K) (mg/lt)	0	6	2
Alkalinity as $CaCO_3$ (mg/lt)	20	108	57.8
Carbonates (mg/lt)	--	2.4	--
Bicarbonates (mg/lt)	24	132	70.6
Chlorides (mg/lt)	7.09	46	24.2
Total Hardness as $CaCO_3$ (mg/lt)	18	106	53.4
Cacium as Ca (mg/lt)	4.8	28	12.6
Magnesium as Mg (mg/lt)	1.5	14.1	5.3
Sulphates (mg/lt)	10	220	45
Phosphates (mg/lt)	2	6.5	4.6
Fluoride (mg/lt)	0.2	0.8	0.4

Table 5 : Physico-Chemical Characteristics of Ground water (Post-monsoon).

Parameters	Min.	Max.	Average.
pH	5.5	7.5	6.3
Electrical Conductivity (µ mhos / cm)	48.3	451	204.6
Total Dissolved Solids (mg/lt)	29.5	271	122.1
Sodium (Na) (mg/lt)	6	35	20.4
Potassium (K) (mg/lt)	0	8	2.1
Alkalinity as $CaCO_3$ (mg/lt)	12	124	44.3
Carbonates (mg/lt)	--	--	--
Bicarbonates (mg/lt)	14	151	53.8
Chlorides (mg/lt)	7.1	37.2	19
Total Hardness as $CaCO_3$ (mg/lt)	10	104	44
Cacium as Ca (mg/lt)	1.6	25.6	10.7
Magnesium as Mg (mg/lt)	1.5	10.7	4.2
Sulphates (mg/lt)	7	180	43
Phosphates (mg/lt)	2	6.1	3.7
Fluoride (mg/lt)	0.2	0.6	0.3
Nitrates (mg/lt)	8.5	34.6	12.7

5.2. Discussion

The pH value of water is very important indicator of its quality. It influences to a great extent the growth of plant and soil microorganisms. Hence, it affects the suitability of water for irrigation. The pH values of water are controlled by the amount of dissolved carbon dioxide, carbonate and bicarbonates. Worsely (1939) stated that the addition of salts to water may cause reduction in its pH value depending on the quality and type of the added salts. The presence of considerable content of $CaCO_3$ increases the pH value of water, making it alkaline. Therefore, the distribution of various anions and cations are important factors in controlling the chemistry of water. The percentage contribution of individual cations and anions in the surface and ground water samples are shown in figures 7 to 14.

pH in the study area varies from 5.5 to 7.7. In most of the area pH is within the permissible limit. The low pH (less than 7.0) values recorded for ground water in certain localities, like Halkarni (5.8), Kanur (5.7) and Daddi (5.6) shows acidic nature of water. It can also be explained that, at Halkarni, the excessive application of fertilizers may be responsible for low pH, where as, at Karve and Kanur due to higher concentration of suspended sediments (observed during field investigation) could be the reason. At Daddi, low pH is observed for bore wells, where underlying rocks may give rise to such an effect.

The high values of pH in the study area may be attributed to the presence of rock formations rich in calcium bearing rocks, such as 'Kankars' which are observed in the soil profile. The pH of pure water content in contact with air having an average carbon dioxide of $10^{-3.53}$ is given as 5.65 (Hem, 1985). It is obvious that this rainwater, part of which infiltrates and becomes ground water finally, shows increase in pH to different levels. This is because of its mineral species in the aquifer materials and the process is known as hydrolysis. The low pH value is also an indication of absence of carbonates in most of the water samples analyzed.

The electrical conductivity observed for water samples in the catchment is an indicator of salinity hazard. It is observed that electrical conductivity of all samples lies

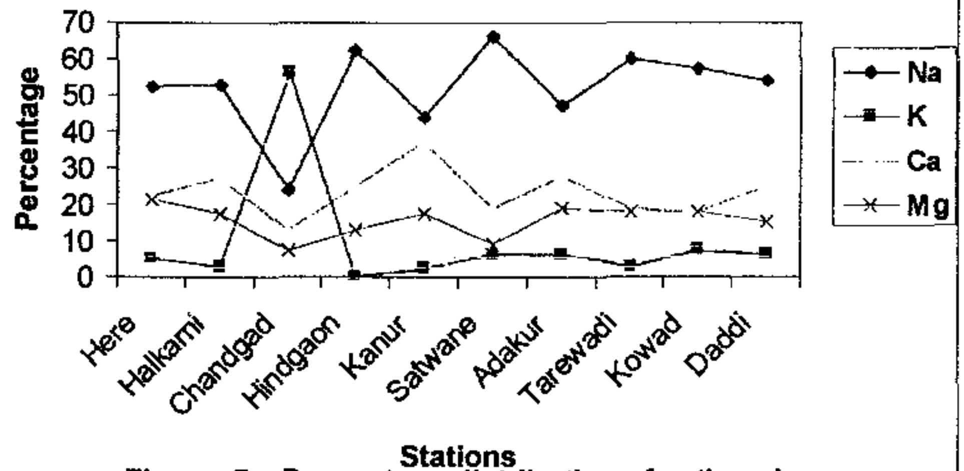

Figure. 7 : Percentage distribution of cations in surface water samples (pre-monsoon)

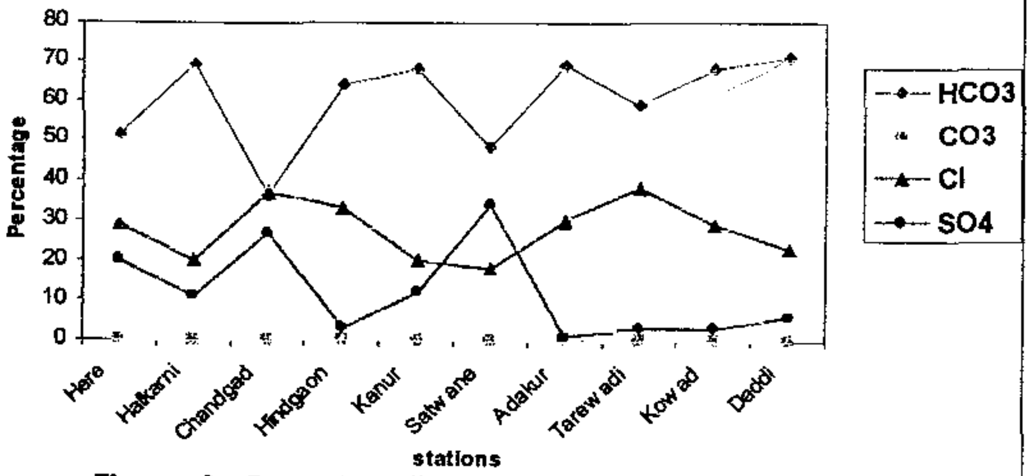

Figure. 8 : Percentage distribution of anions in surface water samples (pre-monsoon)

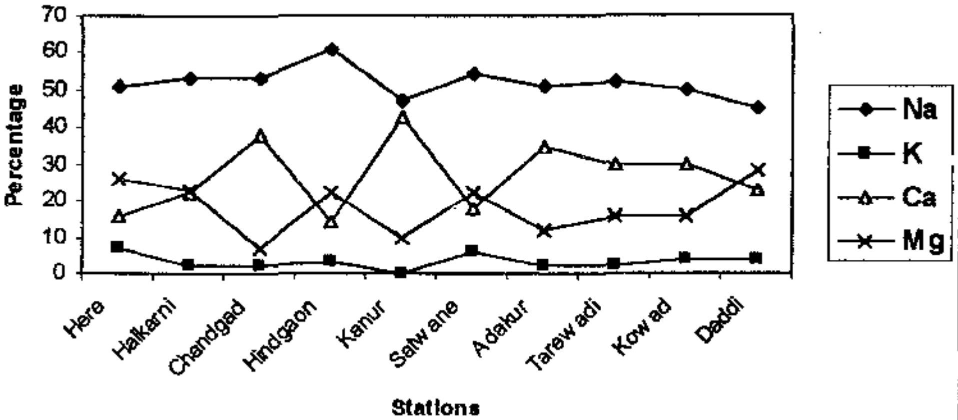

Figure. 9 : Percentage distribution of cations in surface water samples (post-monsoon)

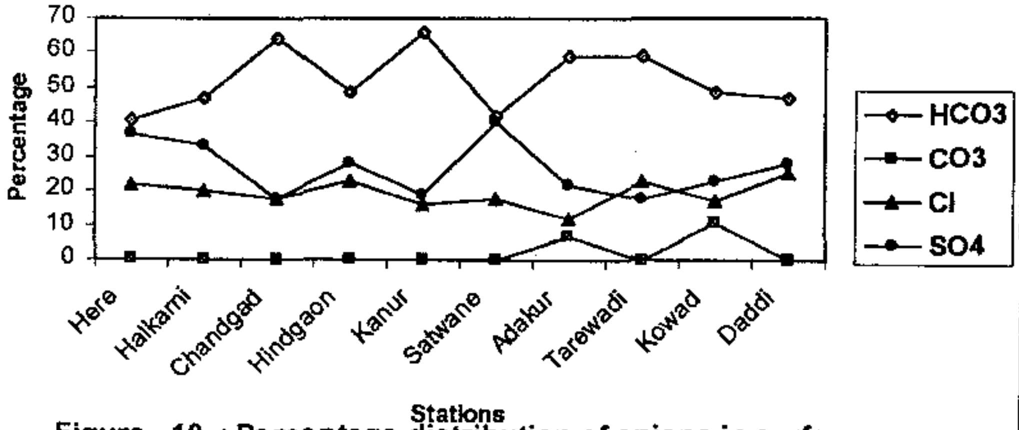

Figure. 10 : Percentage distribution of anions in surface water samples (post-monsoon)

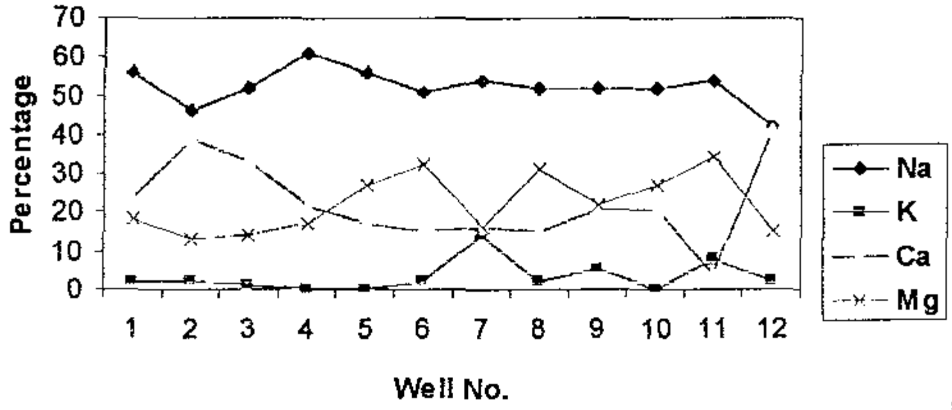

Figure. 11 : Percentage distribution of cations in Ground water samples (post-monsoon)

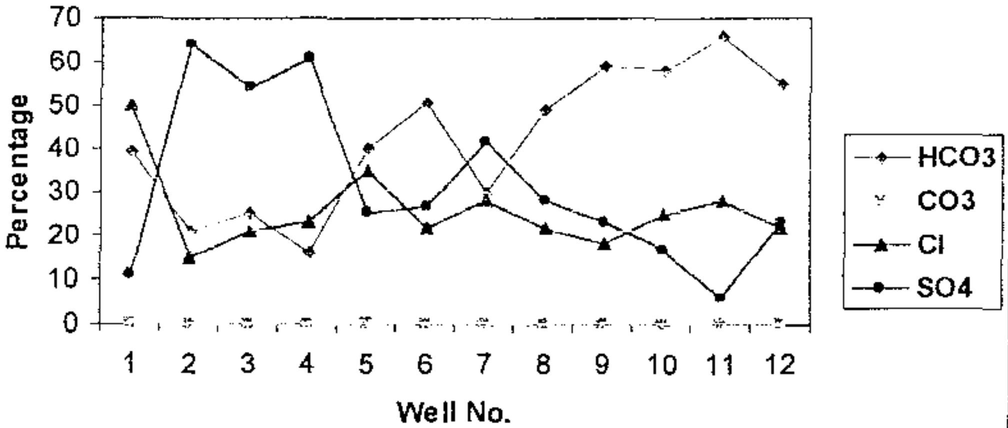

Figure. 12 : Percentage distribution of anions in Ground water samples (post-monsoon)

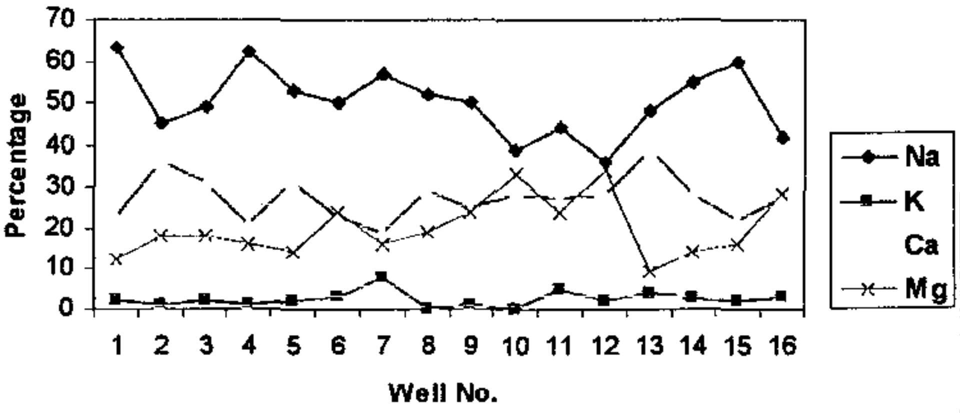

Figure. 13 : Percentage distribution of cations in Ground water samples (Pre-monsoon)

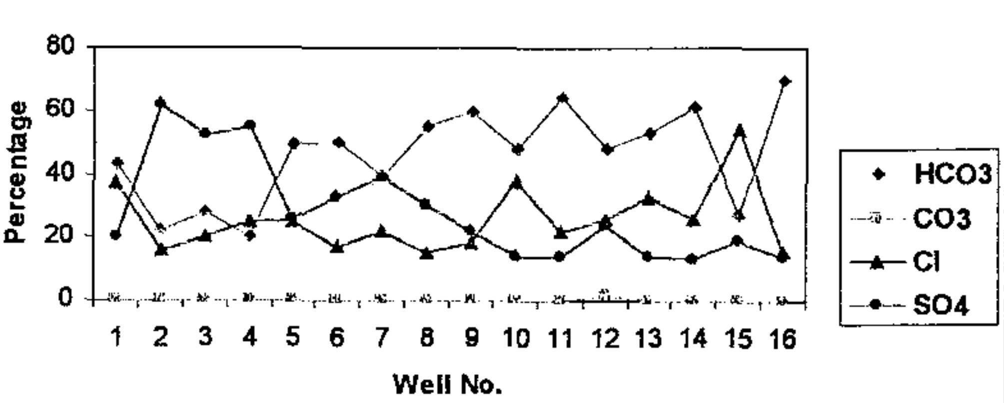

Figure. 14 : Percentage distribution of anions in Ground water samples (pre-monsoon) within the permissible limits. This is in contrary to the Malaprabha catchment, which showed salinization problem in the downstream area (Varadarajan, 2000). In general, waters with conductivity values below 750 mmhos/cm are satisfactory for irrigation for salt sensitive crops that may be adversely affected by the use of such waters. Irrigation waters having conductivity values in the range 250 – 750 mmhos/cm are widely used and satisfactory crop growth is obtained under good management and favorable drainage condition. As per the data available for soil hydraulic properties it is clear that the catchment area has both controlled management and drainage conditions, which shows that there is no reported salinity hazard in the area.

Water naturally contains a number of different dissolved inorganic constituents. The major cations are calcium, magnesium, sodium and potassium; the major anions are chlorides, sulphates, carbonate and bicarbonates. These major constituents constitute the bulk of the mineral matter contributing to total dissolved solids. The TDS value of both surface and ground waters varies between 19.7 mg/l and 473 mg/l which is well within the permissible limits. This is a good indication of pollution free water. However, it is reported that during monsoon season, in the surface water there is a considerable increase in TDS due to excessive overland flow. In general, in the case of ground waters in areas of high rainfall, i.e; above 75 cm per annum and with good drainage are of good quality. This is clear from the present study that, due to high rainfall in the area, there is less probability of contamination.

Presence of carbonates is insignificant in majority of the samples. Concentrations of carbonates are observed at Adakur (in the surface water) and Kowad in the case of ground water. Carbonate concentration in the ground water is 2.4 mg/l at Kowad and in the surface water it varies between 2.4 mg/l at Adakur to 4.8 mg/l at Kowad. The concentration of carbonate ions is, however, a function of the pH value. The carbonate ions are mainly derived from calcium carbonate rocks, where the solubility is very low, but increases markedly in presence of CO_2 in water and in turn on its presence in the atmosphere over water. However, in the present case, such situations are rarely present. In general, the pH value is dependent on carbonate concentration. Carbonates are present when pH is above 8.2 indicating the increase of carbon dioxide content with the increase of groundwater alkalinity. The present results also show that, the carbonates are absent in all the samples where the pH is below 8.2, except at Kowad and Adakur. The presence of carbonates under low pH (less than 8.2) could be a local affect occurred immediately before sampling.

On the other hand, the bicarbonates range from 14 mg/l to 151 mg/l when considered both surface and ground waters. Carbon dioxide, which is dissolved in the natural circulating water, appears in chemical analysis principally as bicarbonate and carbonate ions. Carbon that follows this path represents a linkage between the carbon cycle and hydrological cycle. The large supply of carbon dioxide is partly intercepted by photosynthesizing vegetation and converted to cellulose, starch and related carbohydrates. These products are later returned to carbon dioxide and to water with a release of stored energy (Hem, 1985). Water in equilibrium with calcite and atmospheric carbon dioxide, which constitutes about 0.03 % of the atmosphere, should contain approximately 60 mg/l of bicarbonates. This is true as far as the present results are concerned. High carbonate concentration may stem from biological activity of plant roots, from the oxidation of organic matter induced in the soil and in the rock and from various chemical reactions.

Bicarbonates and sodium dominant water normally indicates ion-exchanged waters, although the generation of CO_2 at depth can produce bicarbonates where sodium is dominant under certain circumstances. However, in the present study, it is observed that there is no localized generation of carbon dioxide due to above processes and therefore, the concentrations of both sodium and bicarbonate are well within the permissible limits. In general, Na^+ and HCO_3^- concentration increase in the direction of flow. In the present study, there is no definite trend of increase in both the cases. This indicates the influence of local factor in the distribution of the above ionic concentration.

Analysis of percentage distribution of cations and anions with total ion concentration, indicate that bicarbonates and sulphate ions are the dominating anions, when compared to carbonates and chlorides. Among the cations Na and Ca are the major ions. Anion and cation distribution in the study area shows the evidence for exchange reactions that take 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 mineral 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 may mean that other hydrological processes are active.

Potassium content in natural waters is usually low as compared to its abundance in the earth's crust. Natural water usually contains less than 12 mg/l of potassium. Chemical analyses carried out for ground water samples collected under various investigation programmes from different parts of the state showed that the average content of potassium in exploratory bore well and tube well water is about 2.6 mg/l, whereas it is 56.1 mg/l, K in dug well water. Results of the present analysis indicate that, the concentration of potassium is very less in ground waters. There is no marked change in concentration in dug wells and bore wells. Potassium tends to remain in solution once brought into solution. Content of potassium in rainwater, in regions receiving rainfall more than 900 mm is less than 0.1 mg/l. Present results recorded a maximum concentration of potassium of 69 mg/l at Chandgad. This abnormally high content of potassium depict that this accretion is due to human and animal activities, particularly, agricultural activity. In all other location, it is evident that there is no additional source of potassium other than rainwater. Inspite of the active agricultural activity and management processes, there is no indication of excess potassium. This could attribute to heavy rainfall and highly permeable soils present in the area.

Degree of nitrate pollution largely depends upon the quantity and concentration of pollutants, porosity, permeability, and hydraulic gradient besides the residence time with aquifer. Nitrates like potassium is more of non-lithologic origin than geologic. The nitrate and chloride are common constituents of city waste, sewage, manure etc. Based on the analysis, nitrate concentration is less than the permissible limits in all the water samples. Most of the chemical ions added in fertilizers are returned to some degree by soils as a result of chemical interaction, and this reduces their potential for loss to ground water. Two ions, however, nitrate and chloride, undergo virtually no chemical attachments to soils and are highly mobile in water. That is why it is observed that the concentration of nitrogen as nitrate is higher in the ground water than in surface water. In the case of surface water, due to various chemical processes, it may occur in any form, which is not observed in the present study.

Highest concentrations of sulphates are observed in Halkarni area. Sulfur as such is used for acidification. Under the influence of certain soil microorganisms, sulfur interacts with oxygen and water to produce sulfuric acid, which increases the soil acidity. The sulfuric acid reacts with the soil to produce sulfate salts that can contribute to the salinity of the water draining from the soil and entering the ground water. Sulphate is an indicator of high recharge taking place in the area.

Distribution of phosphates in the study area also is within the acceptable limits. Major contributor of phosphates is through agricultural activity. However, it is understood that farmers are using only recommended quantity of fertilizers thereby protecting the environment.

The distribution and variation of physico-chemical parameters analysed for pr-monsoon and post-monsoon season (both surface and ground water) are shown in figures 15 to 32.

5.3. Diagrammatic Representation of Geochemical data :

5.3.1. Piper's Trilinear classification:

Piper's diagram has been widely used to study similarities and differences in the composition of waters and to classify them into certain chemical types. The water types demonstrated by the Piper's diagram, as described by Karanth (1987) show the essential chemical character of different constituents in percentage reacting values, expressed in milligrams equivalent. Based on the diagram (fig 33 & fig 34), majority of the samples fall basically under two categories, i.e; Area 7, representing non-carbonate alkali exceeds 50 %- i.e; chemical properties are dominated by alkalies and strong acids. Secondly, Area 9, which is characterized by no one cation-anion pair exceeds 50 %. In addition, to this, a small group is represented by Area 4, which is characterized by strong acids exceed weak acids. An isolated sample represents Area 5, in which carbonate hardness exceeds 50 %, i.e; alkaline earth's and weak acids dominate chemical properties of the water.

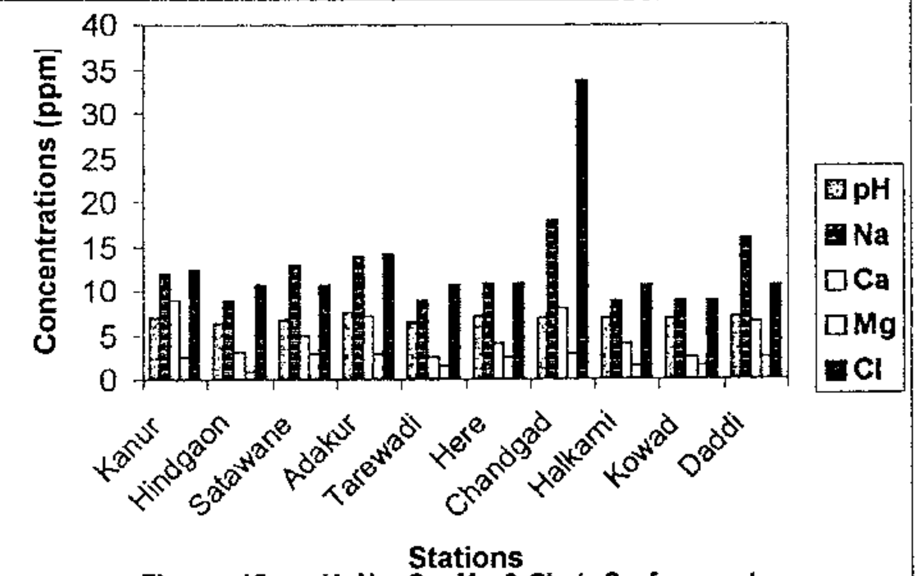

Figure. 15 : pH, Na, Ca, Mg & Cl v/s Surface water samples
(pre-monsoon)

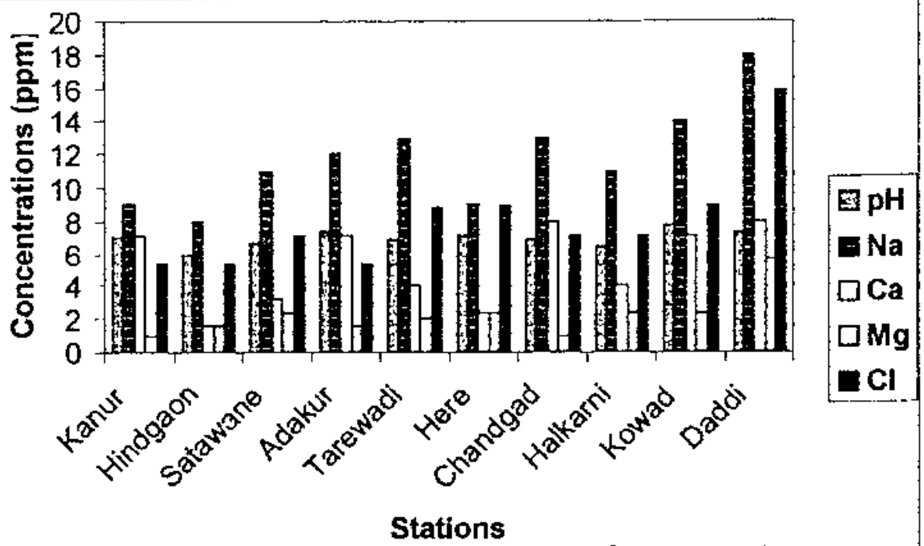

Figure. 16 : pH, Na, Ca, Mg & Cl v/s Surface water samples (post-monsoon)

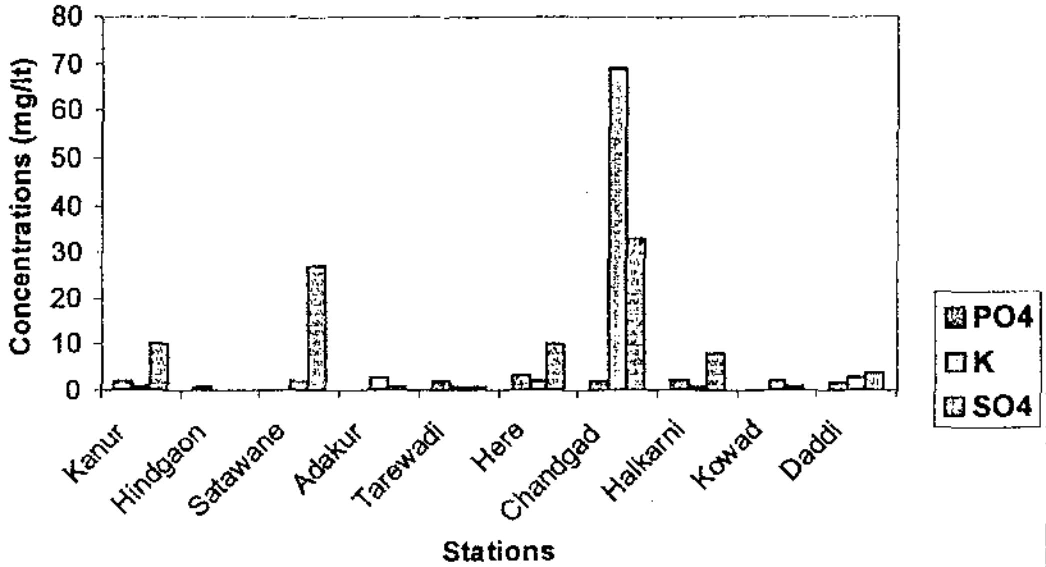

Figure. 17 : PO4, K, & SO4 v/s Surface water samples (pre-monsoon)

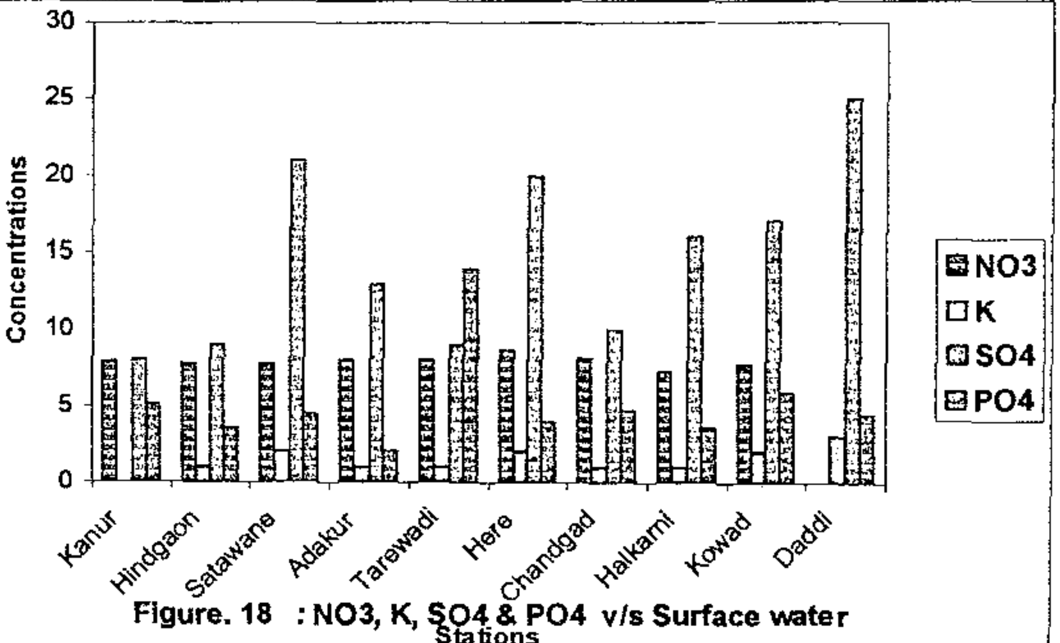

Figure. 18 : NO3, K, SO4 & PO4 v/s Surface water samples (post-monsoon)

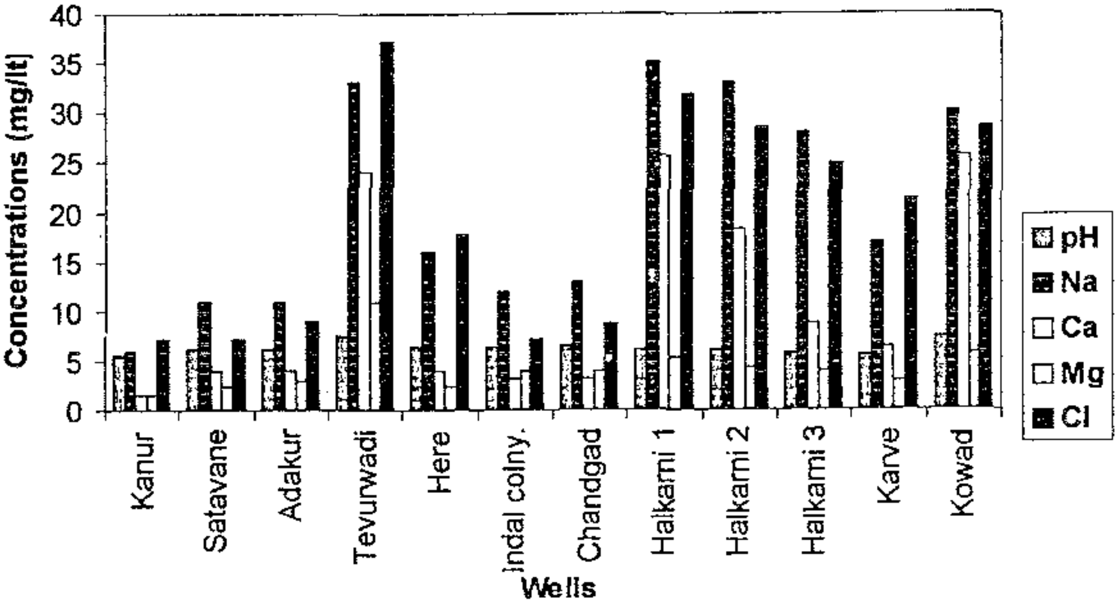

Figure. 19 : pH, Na, Ca, Mg & Cl v/s Ground water samples (post-monsoon)

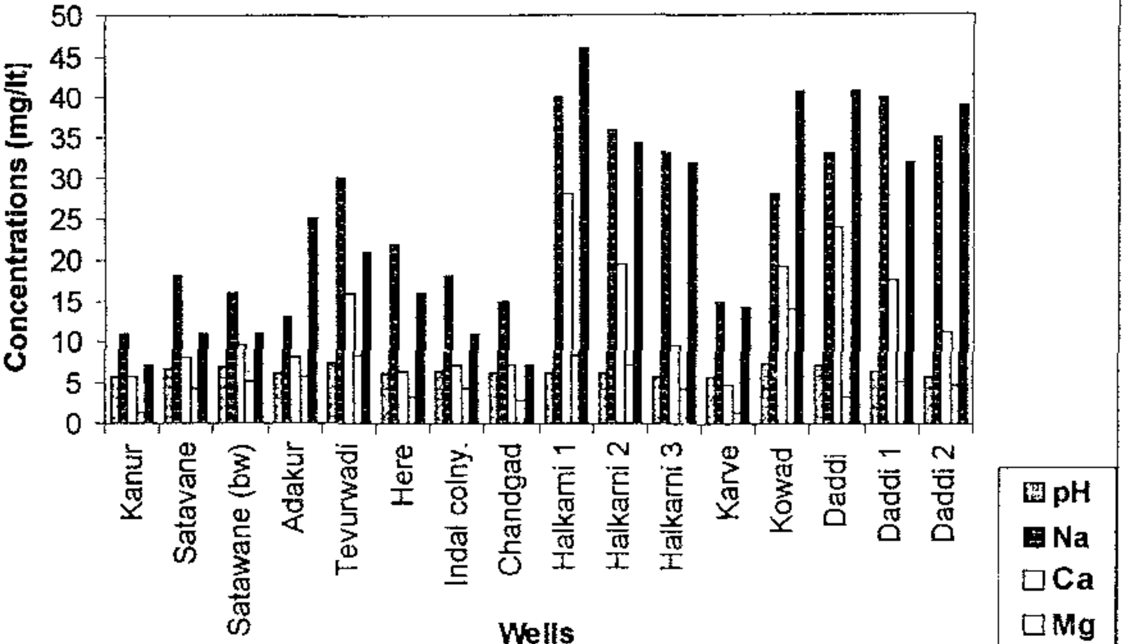

Figure. 20 pH, Na,Ca, Mg & Cl v/s Ground water samples (pre-monsoon)

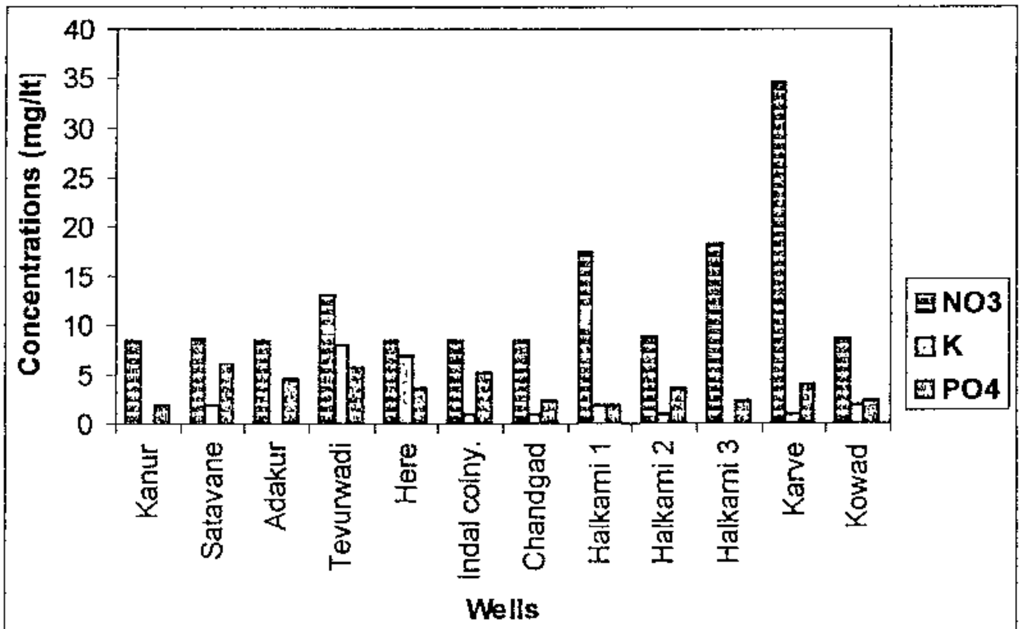

Figure. 21 : NO3, K & PO4 v/s Ground water samples (post-monsoon)

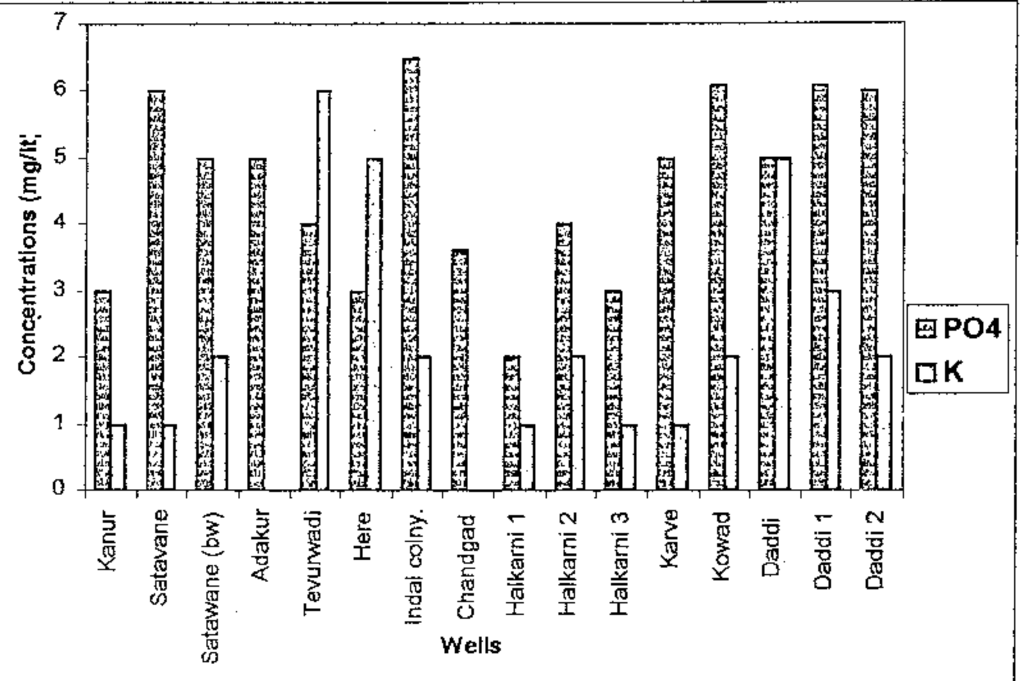

Figure. 22 : PO4 & K v/s Ground water samples (pre-monsoon)

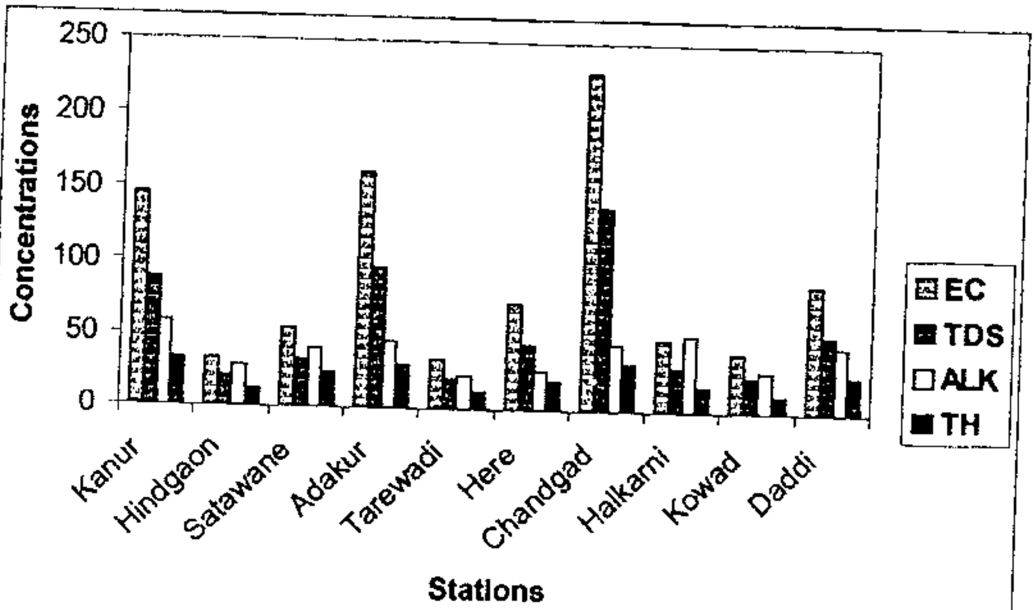

Figure. 23 : EC, TDS, Alk & TH v/s Surface water samples (pre-monsoon)

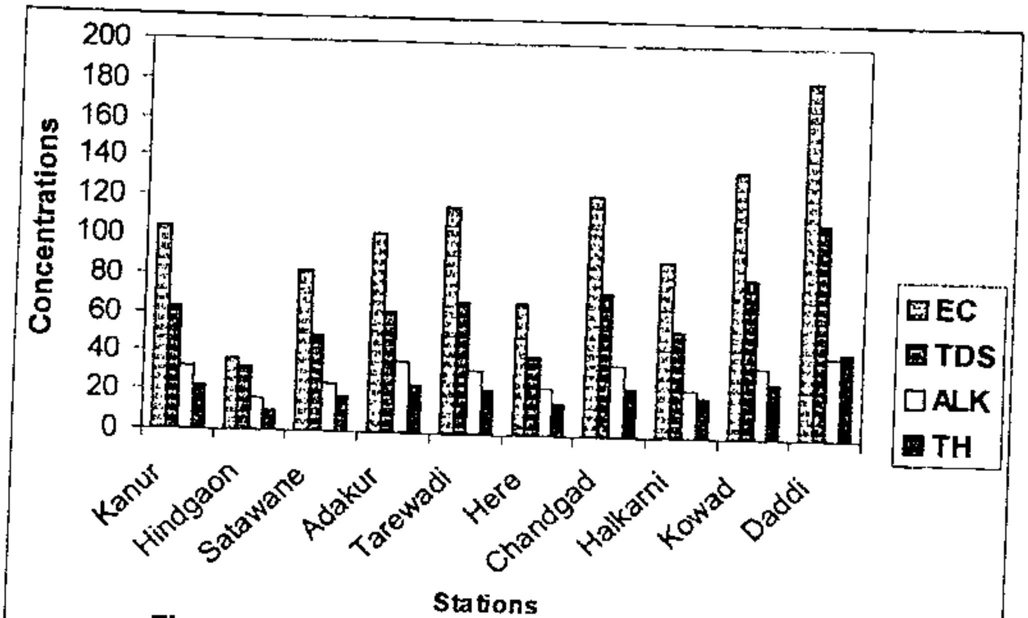

Figure. 24 : EC, TDS, Alk & TH v/s Surface water samples (post-monsoon)

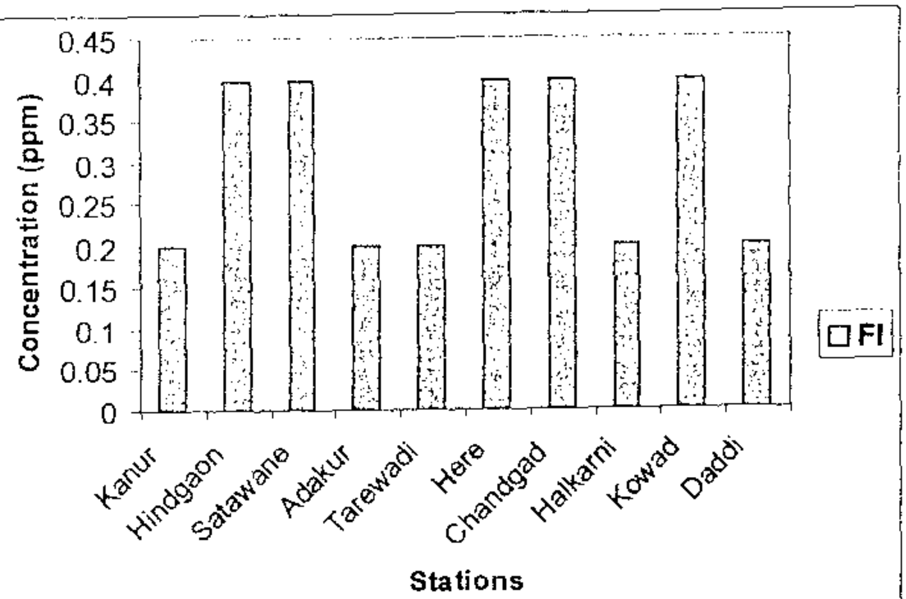

Figure. 25 : Variation of Fluoride concentration in surface water (pre-monsoon)

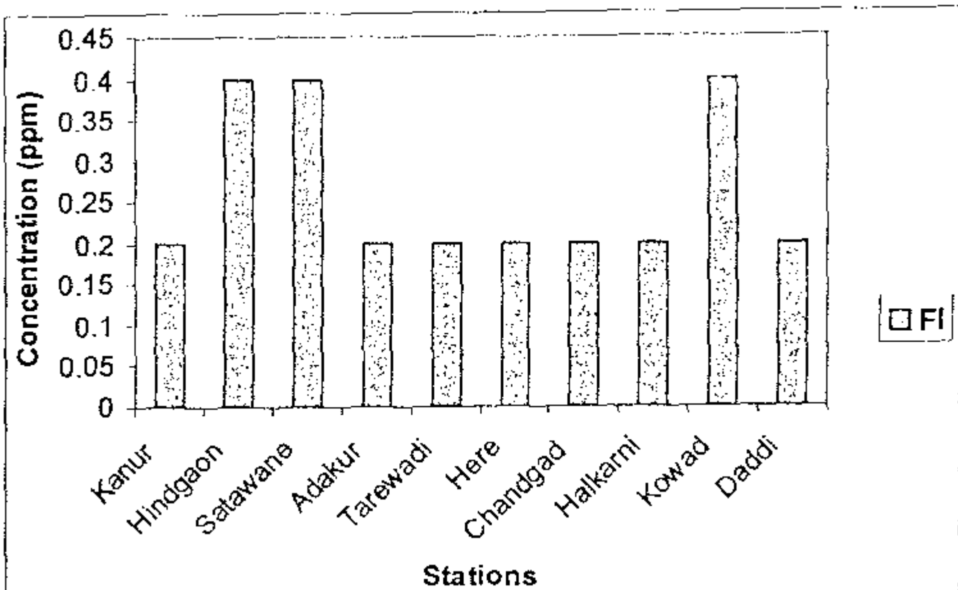

Figure. 26 : Variation of Fluoride concentartion in surface water (post-monsoon)

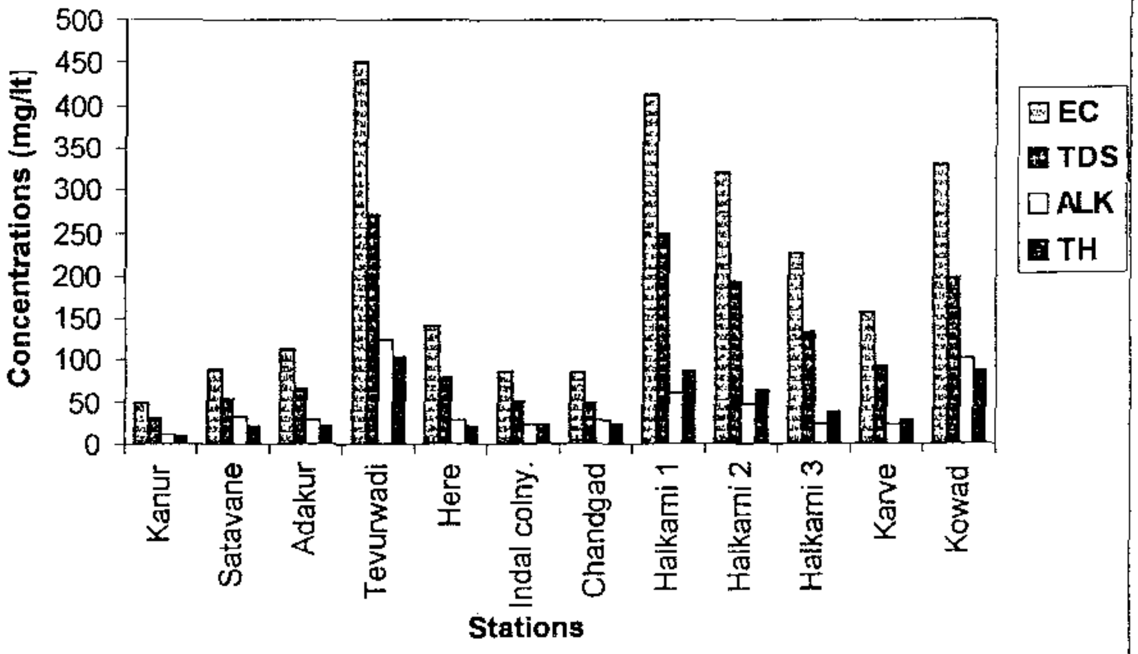

Figure. 27 : EC, TDS, ALK &TH v/s Ground water samples (post-monsoon)

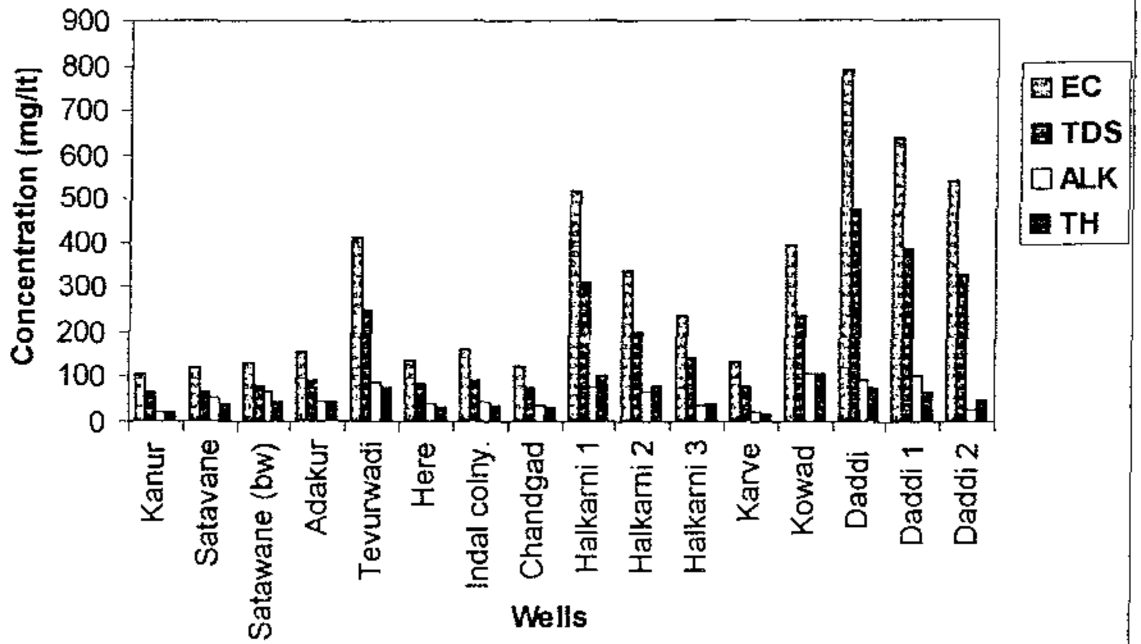

Figure. 28 : EC, TDS, Alk & TH v/s Ground water samples (pre-monsoon)

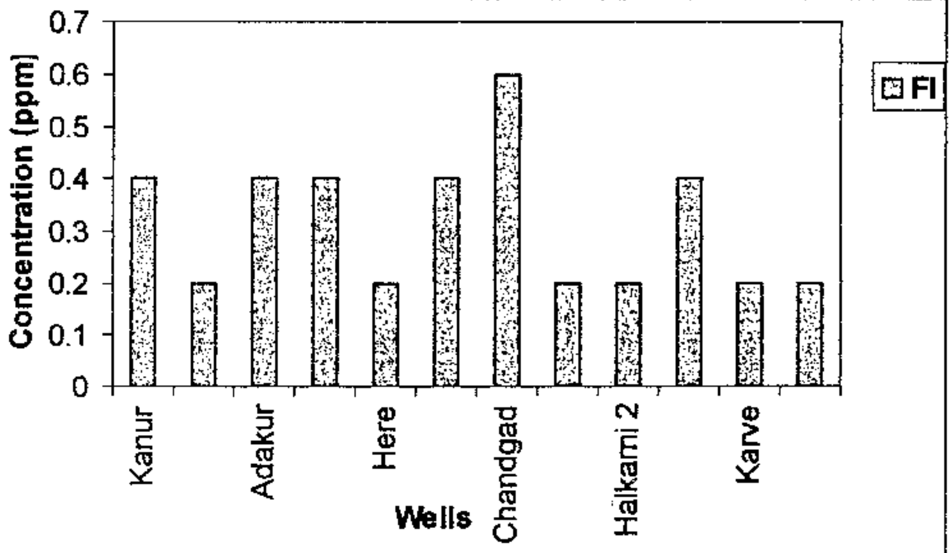

Figure. 29 :Variation of Fluoride in Ground water samples (post-monsoon)

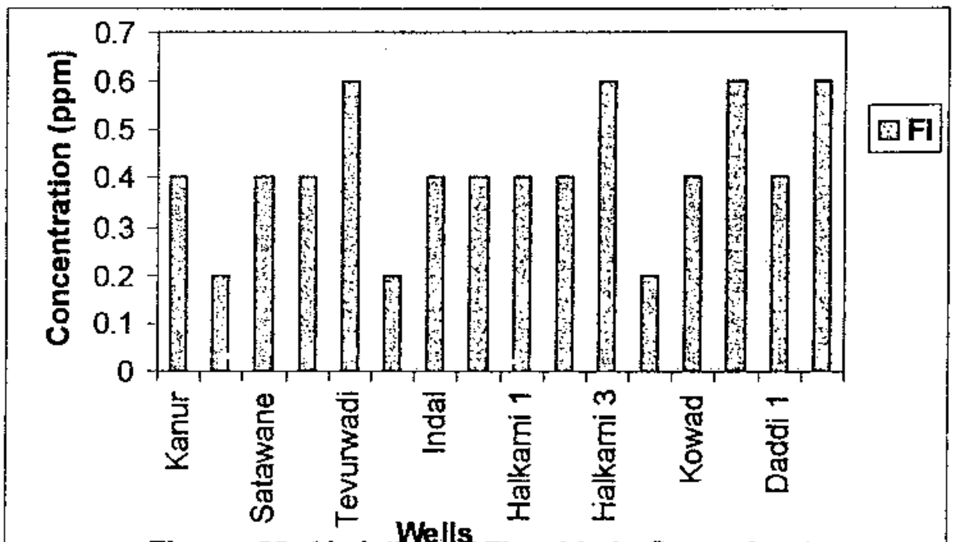

Figure. 30 : Variation of Fluoride in Ground water samples (pre-monsoon)

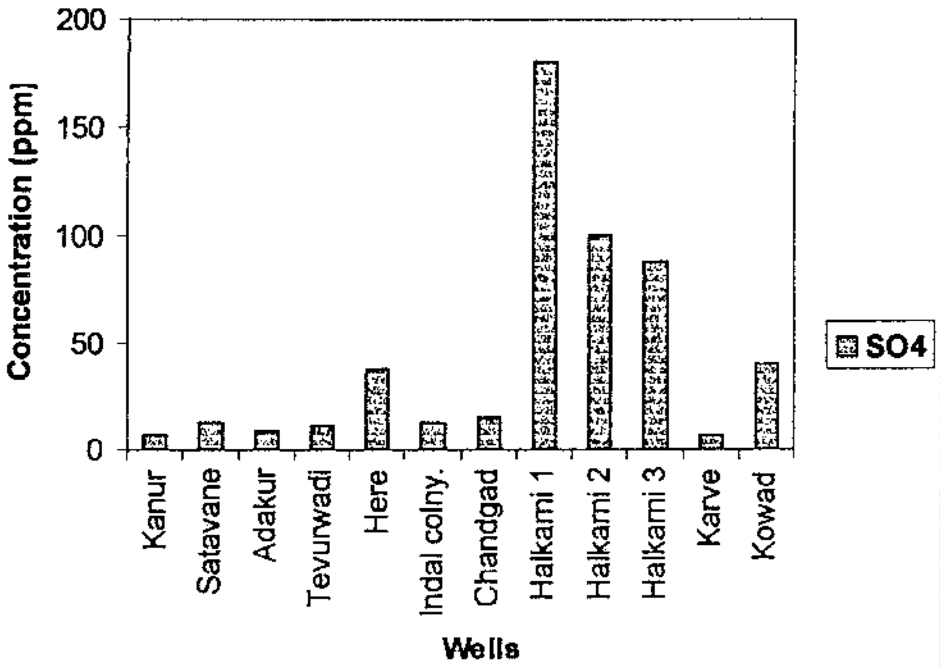

Figure. 31 : Variation of SO4 in Ground water samples (post-monsoon)

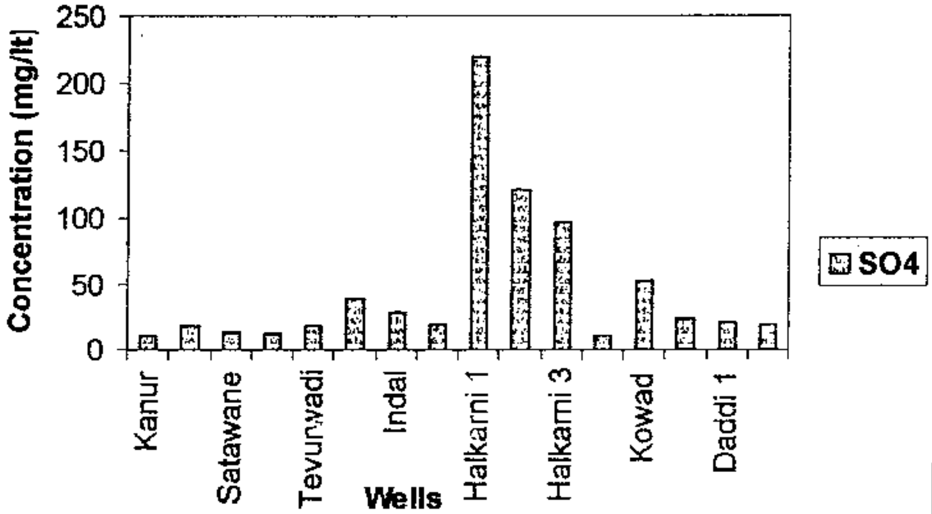

Figure. 32 : Variation of SO4 in Ground water samples (Pre-monsoon)

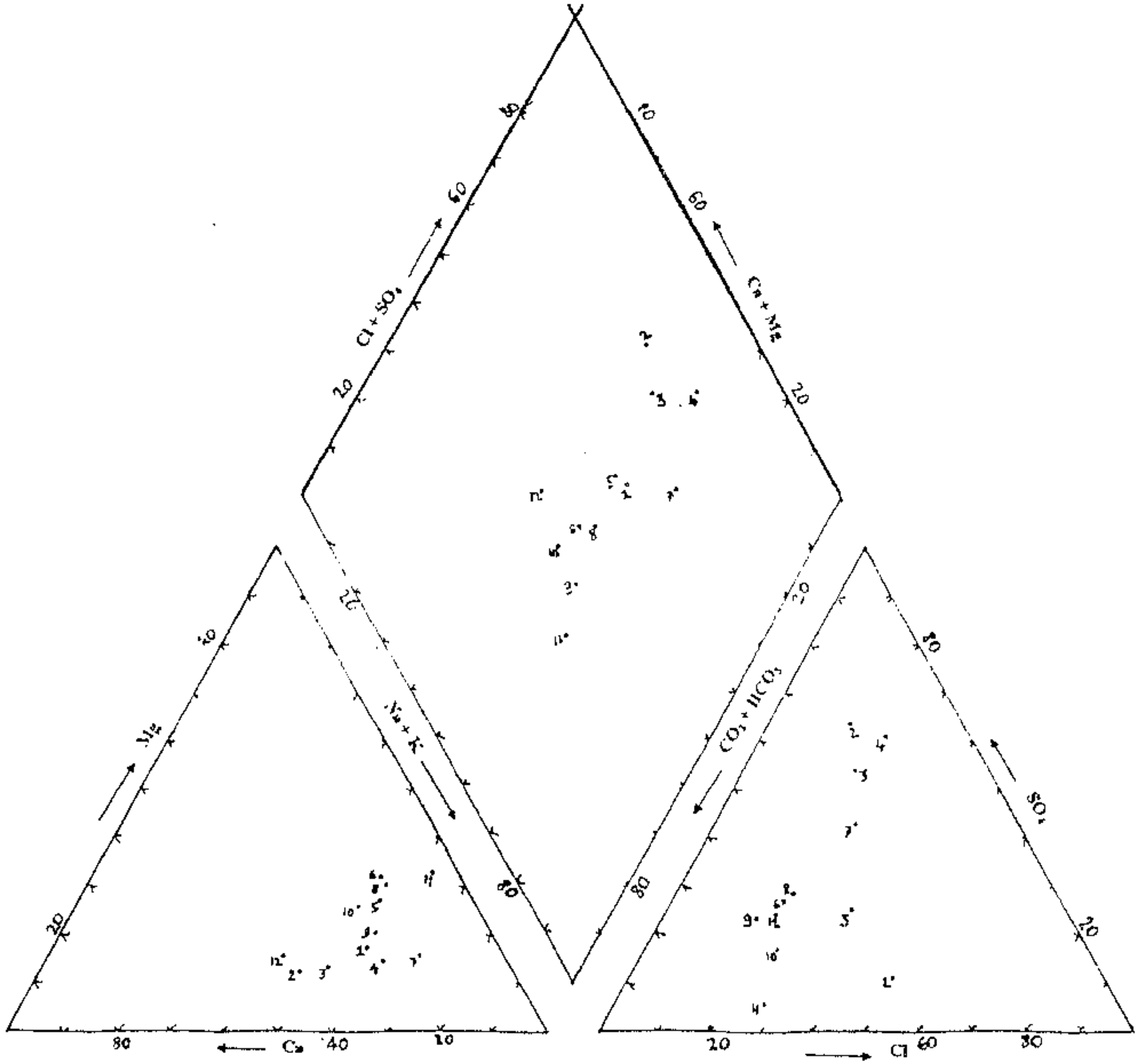

Figure. 33. Piper's Trilinear Diagram showing Groundwater Chemistry(Post Monsoon)

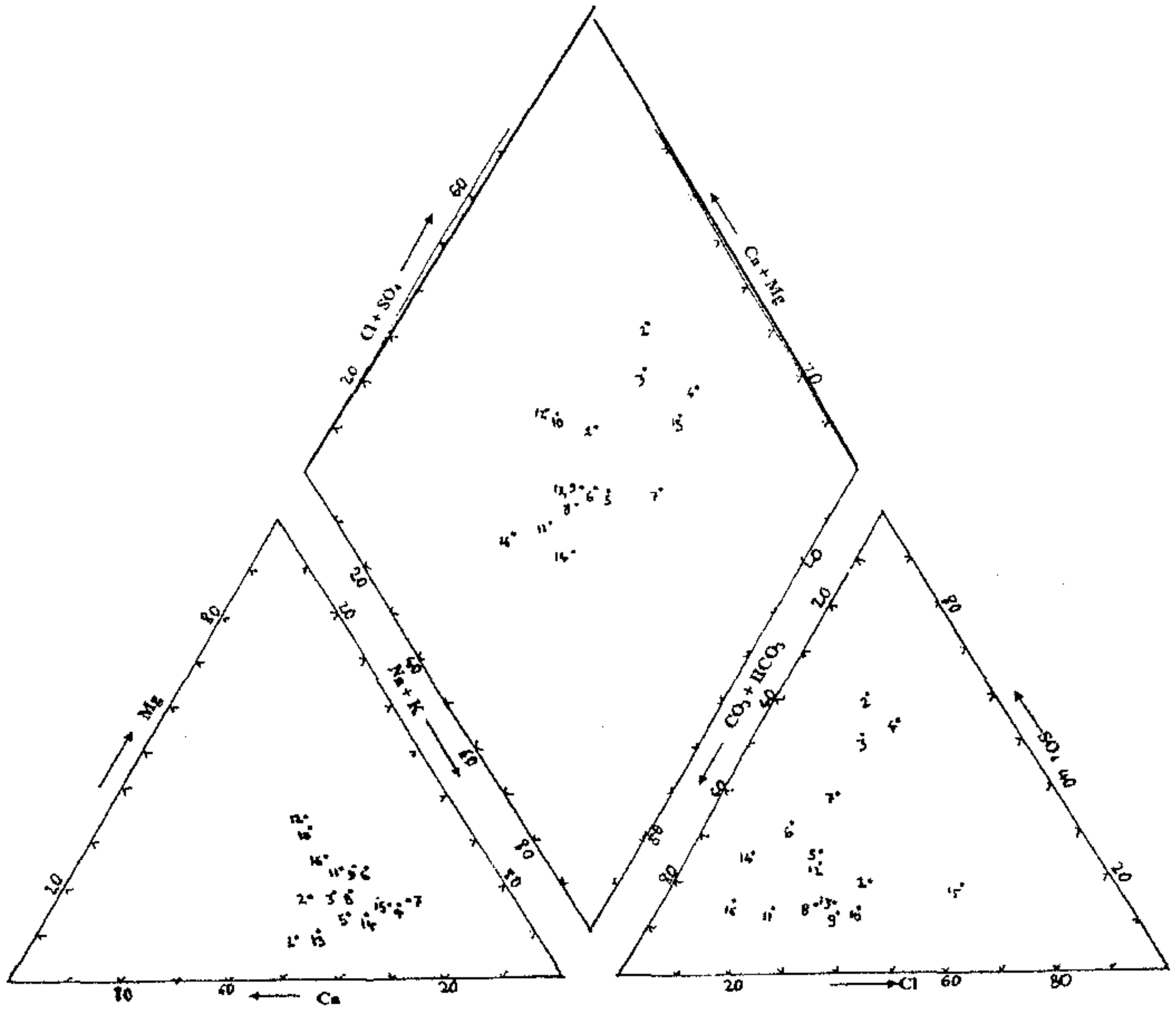

Figure. 34. Piper's Trilinear Diagram Showing Groundwater Chemistry(Pre Monsoon)

5.3.2. Gibb's diagram :

The Gibb's diagram is being used to understand the factors controlling ground water chemistry also. The results of the chemical analysis are represented in figures 35 & 36. It is observed that the major part of the study area, ground water contamination is controlled mainly by the rock types as most of the samples fall under rock dominance class under pre-monsoon and post-monsoon condition.

5.3.3. Chadha's diagram :

Chadha's diagrams are shown in figures 37 & 38 for ground water samples of Post-monsoon and Pre-monsoon seasons. This is a some what modified version of Piper's diagram. In the Chadha's diagram the difference in milliequivalent percentage between alkaline earth's (calcium plus magnesium) and alkali metals (sodium plus potassium) expressed as percentage reacting values is plotted on the X-axis and the difference in milliequivalent percentage between weak acidic anions (carbonate plus bicarbonate) and strong acidic anions (chloride plus sulphate) is plotted on the Y-axis. The milliequivalent percentage differences between alkaline earths and alkali metals and between weak acidic anions and strong acidic anions would plot in one of the four possible sub-fields of the proposed diagram.

In the Chadha's diagram, the square or rectangular field describes the overall character of the water. The diagram can be used to study various hydro chemical processes, such as base cation exchange, cement pollution, mixing of natural waters, sulphate reduction, saline water and other related hydro chemical problems. In the present study, the ground water samples are dominated by two fields. The predominant field is 4, i.e; strong acidic anions exceed weak acidic anions. This is followed by field 3, which is characterized by weak acidic anions exceed strong acidic anions. A small proportion is characterized by field 5. This group indicates that alkaline earths and weak acidic anions exceed both alkali metals and strong acidic anions respectively. Such water has temporary hardness. The above diagrams give the characteristic of ground water in the Ghataprabha representative basin.

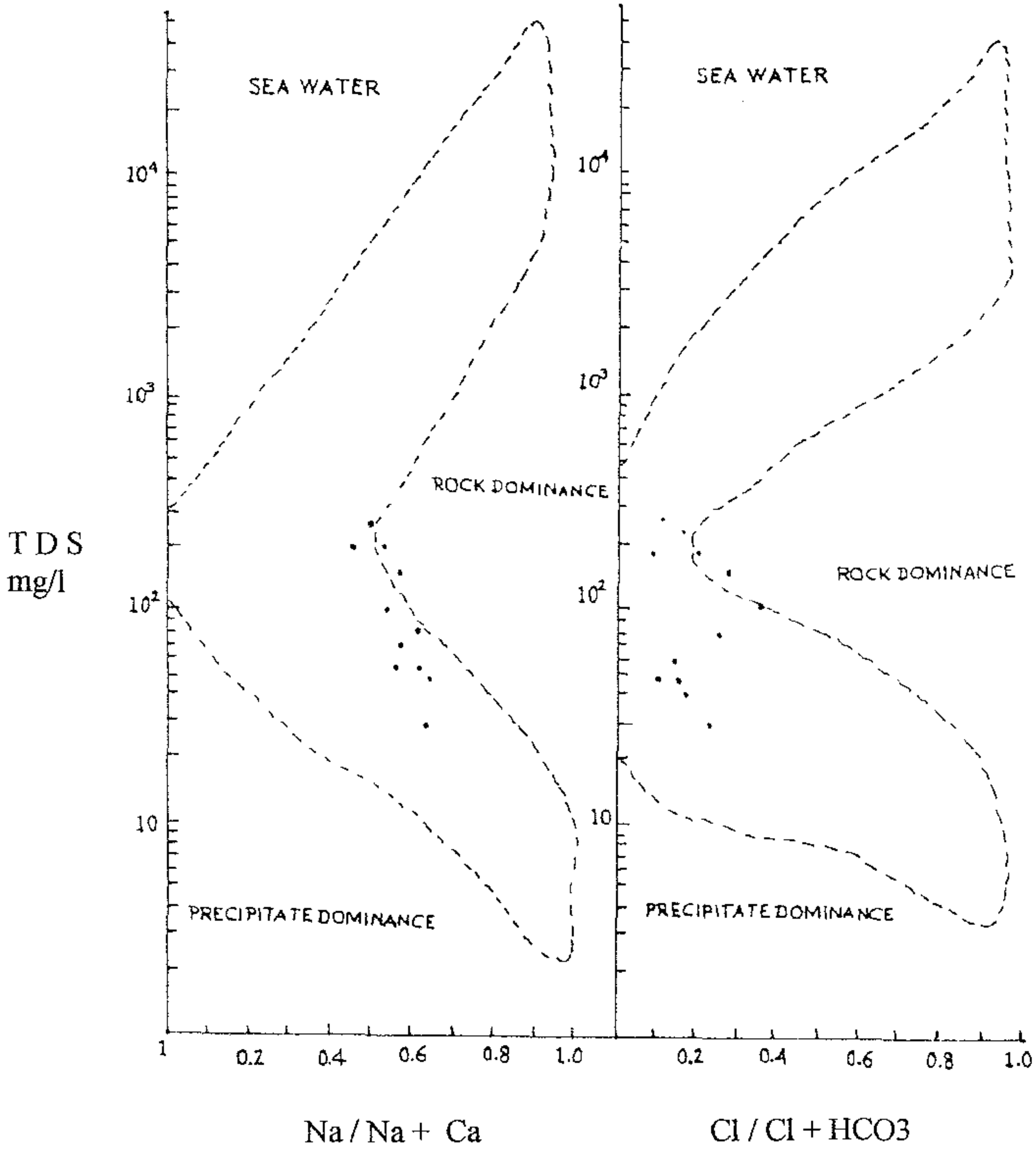

Figure. 35. Gibb's Diagram for Ghataprabha (Post Monsoon)

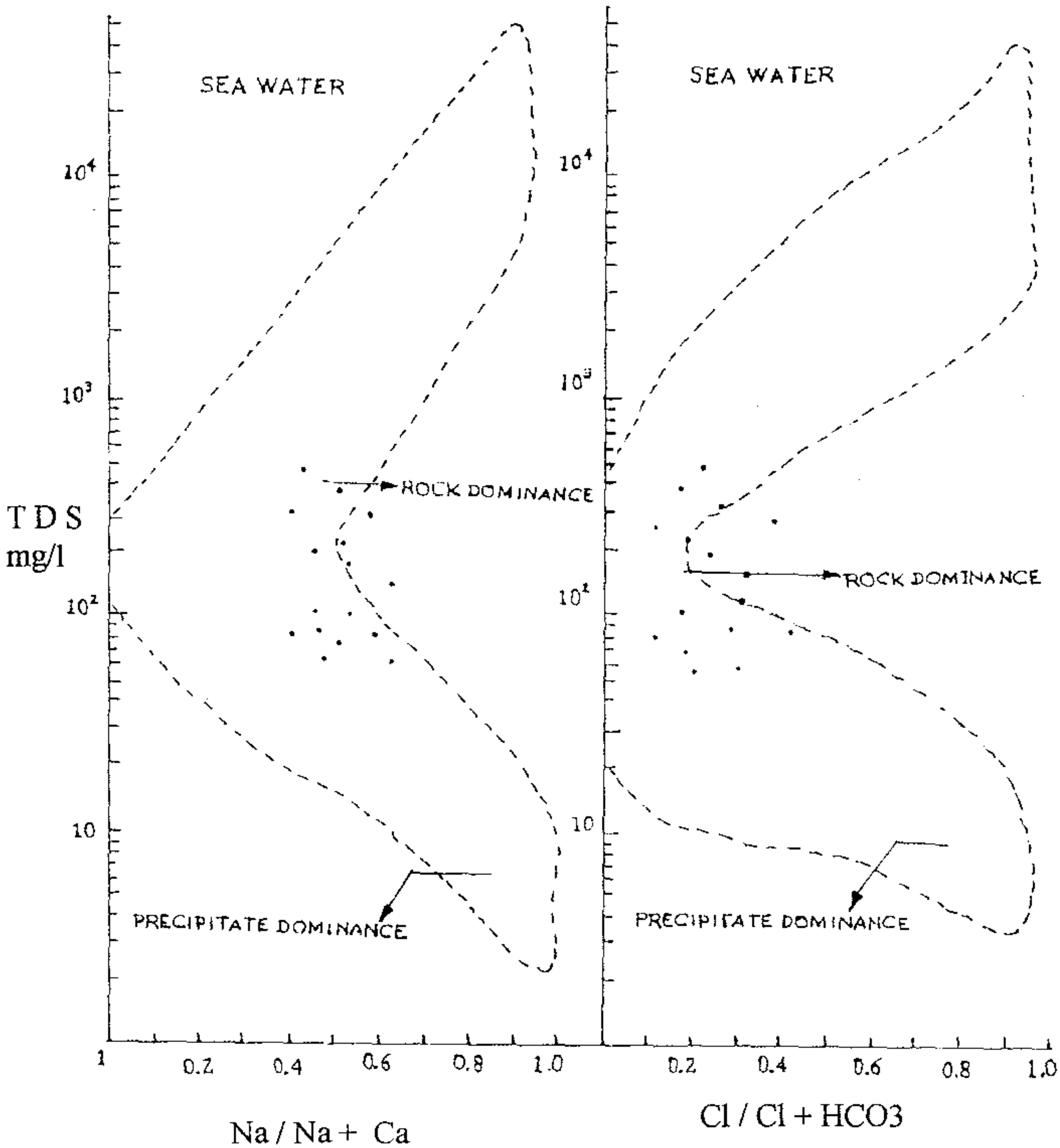

Figure. 36. Gibb's Diagram for Ghataprabha (Pre Monsoon)

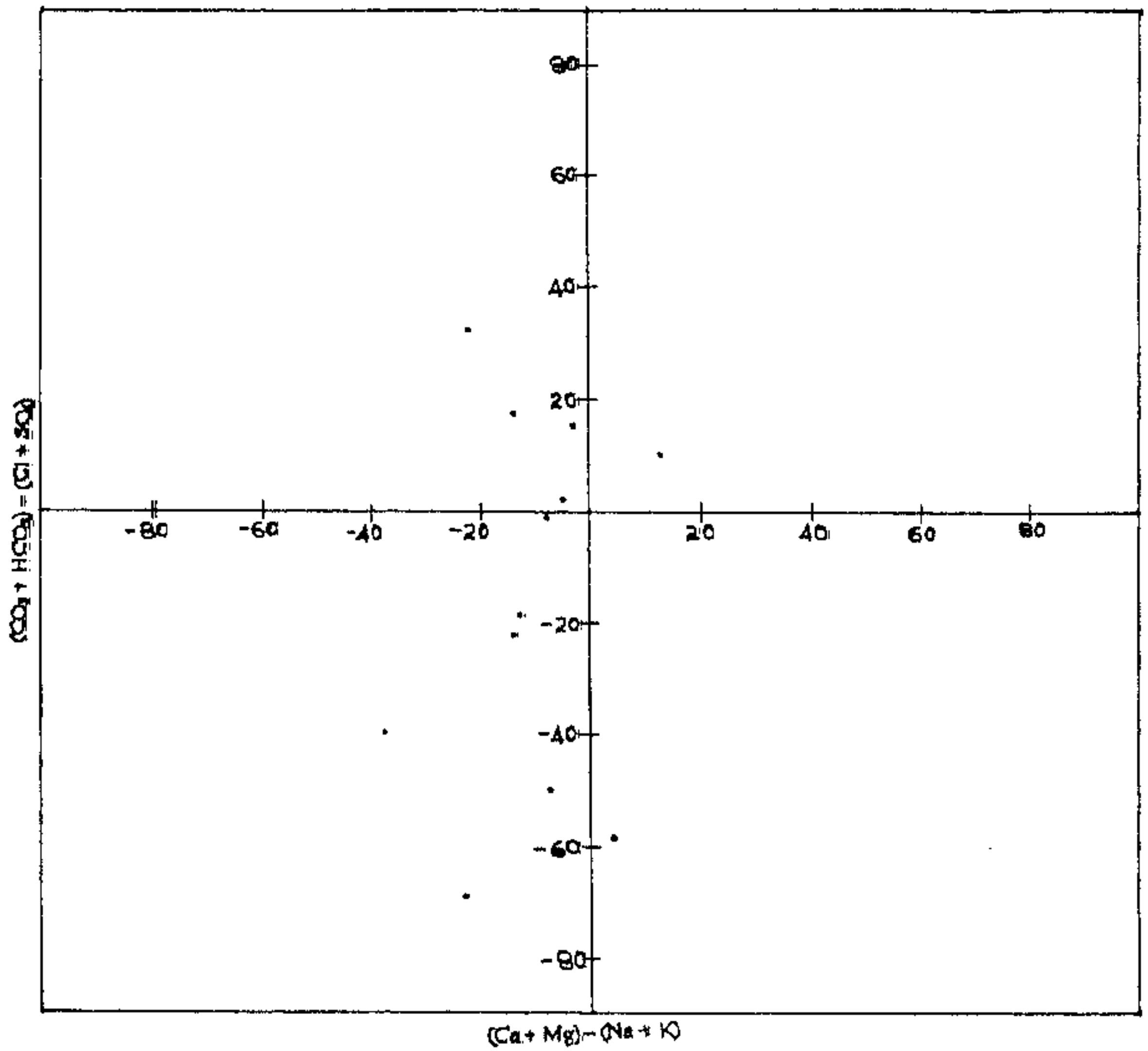

Figure. 37. Chadha's Diagram for Groundwater Classification (Post Monsoon)

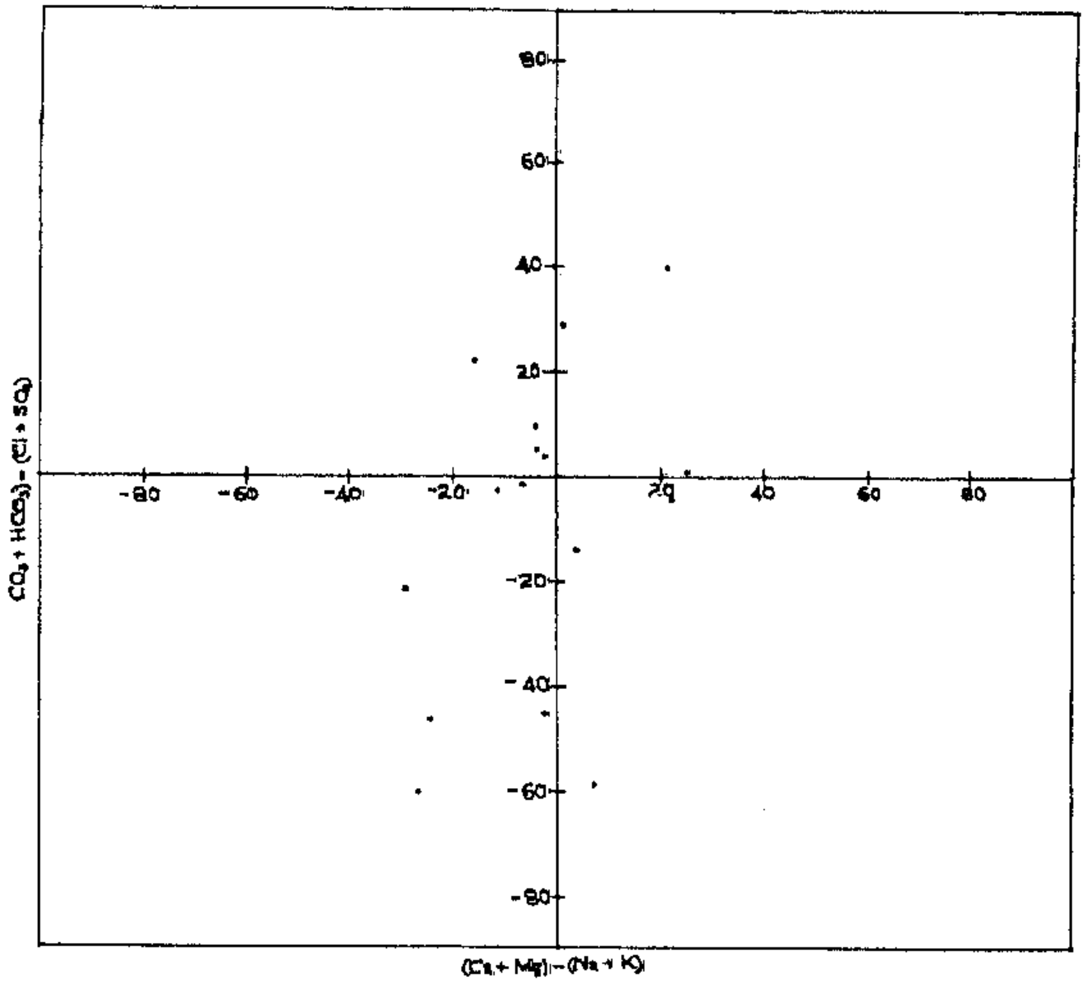

Figure. 38. Chadha's Diagram for Groundwater Classification (Pre Monsoon)

5.3.4 U. S. Salinity Laboratory Classification :

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). The SAR is calculated from the formula :

$$SAR = \frac{Na}{\frac{Ca + Mg}{2}}$$

A diagram for use in studying the suitability of ground water for irrigation purposes, named after Wilcox (1955), is based on the SAR and electrical conductivity of water (table 6). The chemical analysis data of all the water samples have been plotted on Wilcox diagram for the ground water samples of pre-monsoon and post monsoon seasons (fig 39 & fig 40).

In the study area, salinity hazard falls under C_1 and C_2 category. C_1 represents Low-Salinity water, which can be used for irrigation of most crops on most soils, with the little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability. C_2 is Medium-Salinity water, which can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases, without special practices for salinity control.

The water of the catchment comes under Low-Sodium Hazard (S_1) zone, which may be used for irrigation on almost all soils, with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stone fruit trees may accumulate injurious concentrations of sodium.

Table 6 : SAR and Na % Values for Ground water samples.

		Pre-monsoon		Post-monsoon	
No.	**Wells**	**SAR**	**Na %**	**SAR**	**Na %**
1.	Karve	1.53207	65	1.39	57.5
2.	Halkarni (SF1)	1.70212	45.7	1.63	47.5
3.	Halkarni (SF2)	1.75514	50	1.78	53
4.	Halkarni (SFQ)	2.19352	63	1.97	61
5.	Kanur	1.07331	55.5	0.81	56
6.	Indal colony	1.29107	53	1.05	52
7.	Here	1.75271	64	1.54	68.5
8.	Chandgad	1.18673	52	1.13	54
9.	Satavane	1.25708	51	1.07	57
10.	Adakur	0.84423	39	1.01	51.6
11.	Tevurwadi	1.50614	49	2.01	61.7
12.	Kowad	1.18218	37	1.38	43
13.	Daddi	1.66234	51	--	--
14.	Daddi (bw1)	2.14179	58	--	--
15.	Daddi (bw2)	2.18259	62	--	--
16.	Satwane (bw)	1.04021	45.7	--	--

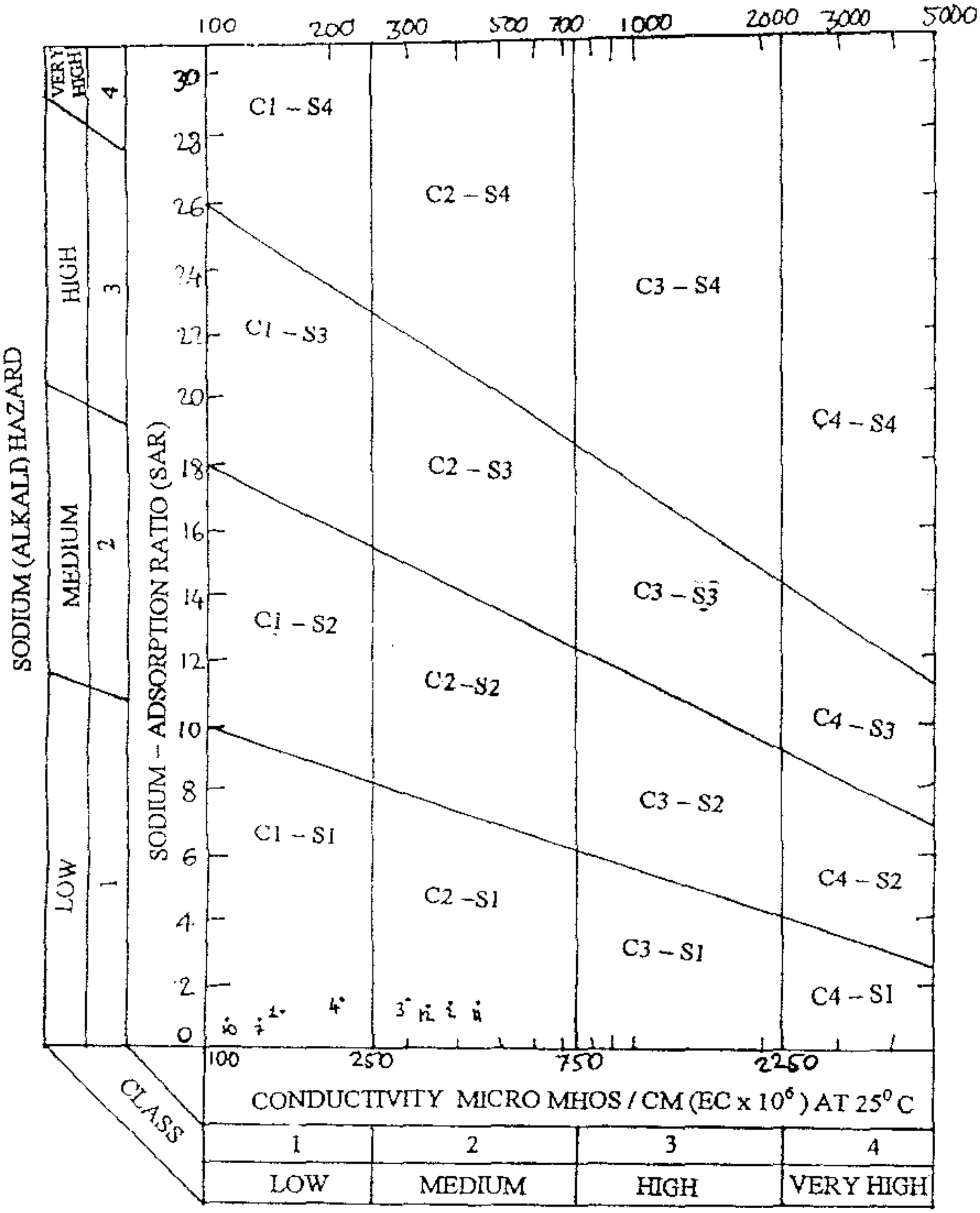

Figure. 39. U.S. Salinity Diagram(Post Monsoon)

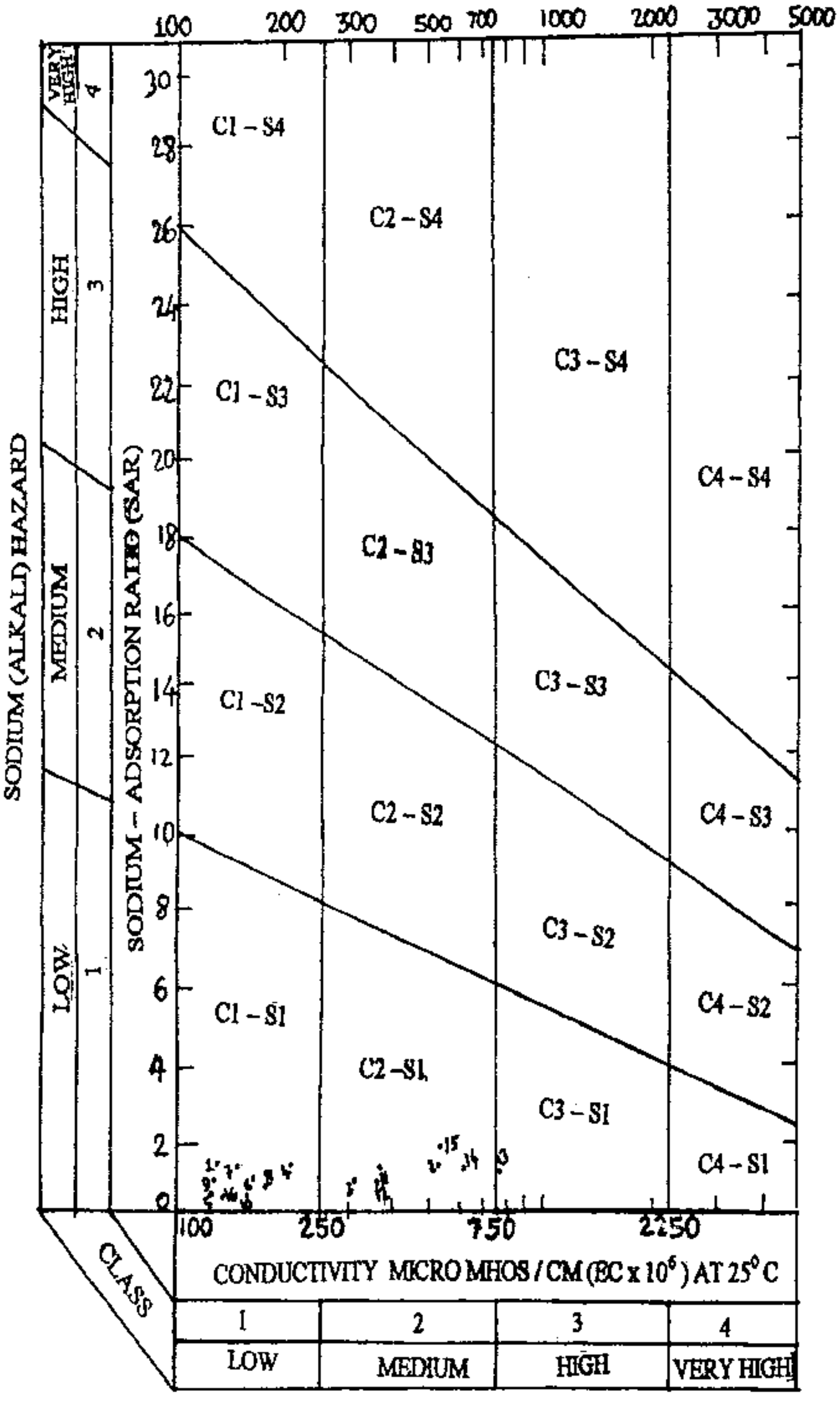

Figure. 40. U.S. Salinity Diagram (Pre Monsoon)

5.3.5. Sulphate / Chloride Ratio:

Sulphate / chloride ratio is a useful tool for assessing the impact of land use on ground water quality. Based on the land use map of the study area samples have been collected, which were analyzed for various anions and cations. The ratio of SO_4 / Cl is calculated for all samples. The figure 41 & 42 show the variation of SO_4 / Cl ratio between 0.35 and 7.69. Significant deviation is observed in the SO_4 / Cl ratio indicating that ground water has been affected by fertilizer use and high values of the ratio may be accompanied by high nitrate or ammonia concentrations (Pionkee, 1990). Though there is limited quantity of nitrate is observed here, there is a chance for concentration of ammonia, which is not determined in the present study. The SO_4 / Cl ratio may be more sensitive indicator of contamination than ammonia or nitrate concentrations as it is relatively unaffected by chemical processes that can remove ammonia concentration from ground water.

5.3.6. Potassium / Sodium Ratio:

Potassium content in natural waters is usually low as compared to its abundance in earth's crust. Natural water usually contains less than 12 mg/l of potassium. In the present study also all ground water samples shows the potassium concentration below 12 mg/l, irrespective of the land use pattern. The K / Na ratio are shown in fig 43 & 44. From the figure it is evident that potassium concentration is relatively very low indicating that the waters are free from potassium contamination. This could be due to the reason that, potassium tends to remain in solution once brought into solution and therefore there is a possibility that it may be moved along with runoff, as it is observed in surface water one of the location. However, to confirm any of these results detailed investigations are required. At present there are deficiencies in the basic information about the chemistry of potassium in ground water.

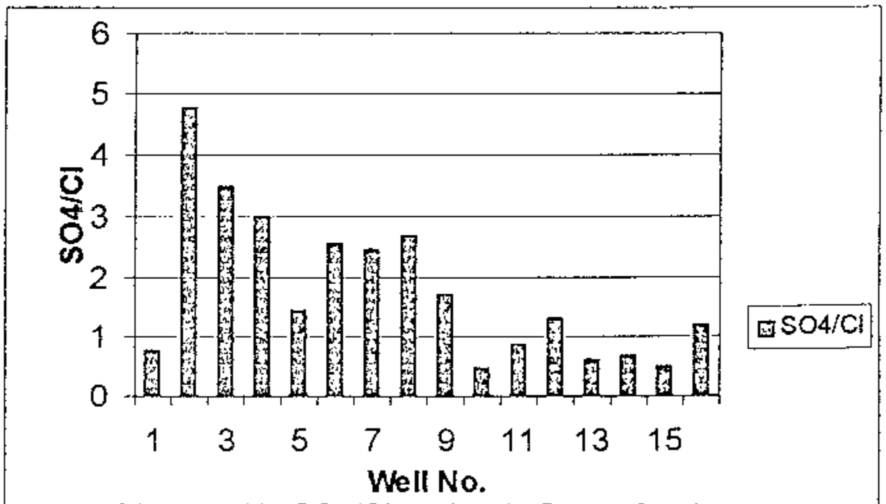

Figure. 41 : SO4/Cl Ratio v/s Ground water samples (pre-monsoon)

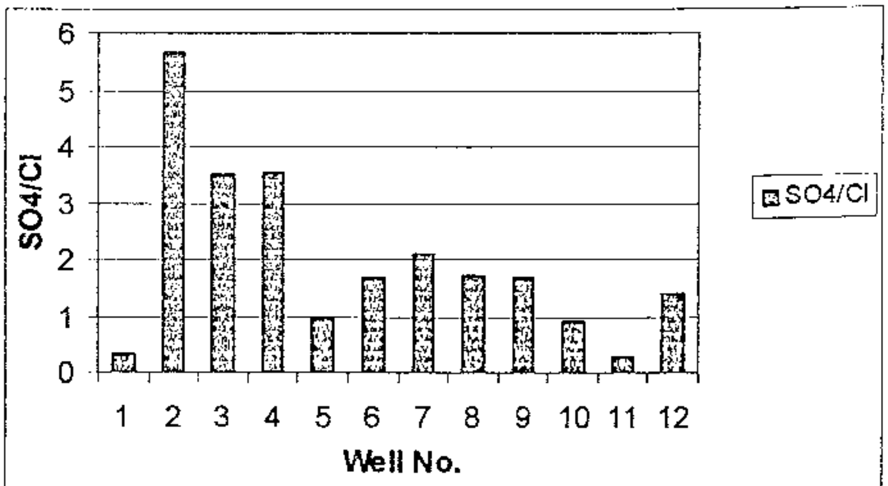

Figure. 42 : SO_4/Cl Ratio v/s Ground water samples (post-monsoon)

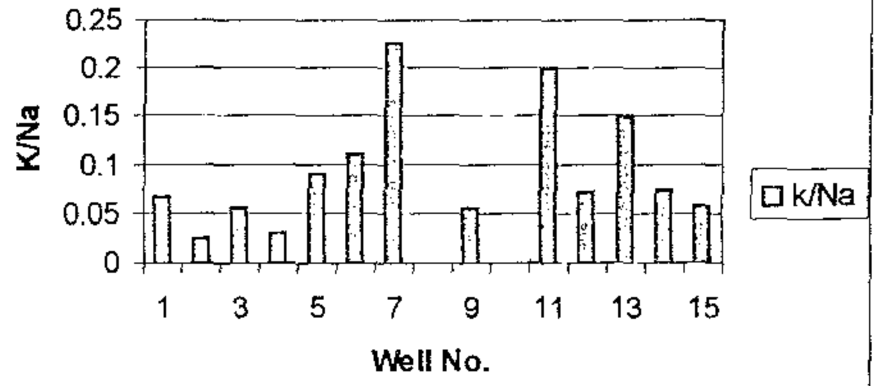

Figure. 43 : K/Na Ratio v/s Groundwater samples (pre-monsoon)

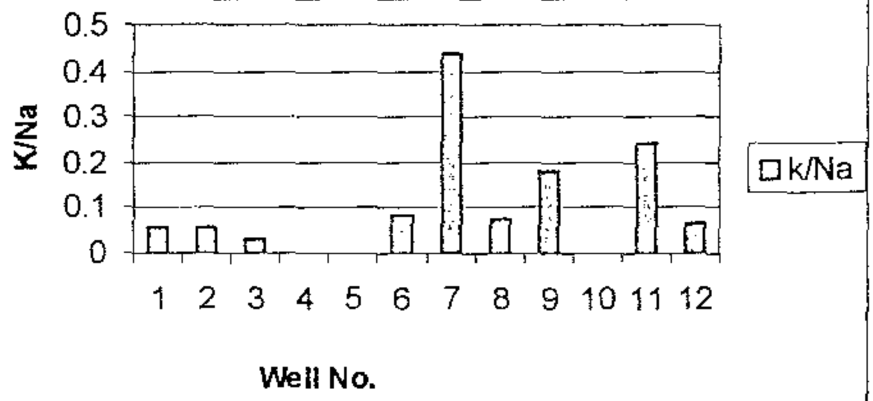

Figure. 44 : K/Na Ratio v/s Ground water samples (post-monsoon)

5.4. Mass Loading Analysis:

Physical processes play an important role in determining the fate of solutes in surface water environments. Although advection and dispersion are the dominant physical processes affecting solutes in many surface waters, other physical processes may be of importance for a given water body. Many small streams and rivers gain significant amounts of water from lateral inflows. As defined here, lateral inflow is any water that is added to the stream due to ground water inflow, overland flow, interflow or via small springs and seeps. 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 waters added by lateral inflow.

The present results indicate that (table 7 & table 8) in the upstream region during pre-monsoon, the contribution of Na and Ca through Ghataprabha river is more when compared to Tamraparni river. The percentage contribution of sodium and phosphates is considerably less from upstream region. This shows that there is a localized effect on these elements, which increase the concentration in the downstream. Out of 91.58% of potassium, found in the downstream area, 61.84% is through Tamraparni and 29.74% is through Ghataprabha. This shows that in the Tamraparni catchment, agriculture activities are more when compared to Ghataprabha. The main source of potassium is likely from fertilizers and agriculture. Ca and Mg both are almost in equal proportions and contribute more than 70% through upstream load. Rest of the 30% is through lateral inflows and local effects.

Concentration of chloride is quite comparable with that of the downstream load, (96% is supplied from the upstream). In the case of sulphates also, this is true both upstream and downstream loads shows an equilibrium stage.

During post-monsoon season, the loading rate shows a distinct variation. However, one of the interesting point is that contribution of Na is almost constant both during pre-monsoon and post-monsoon indicating a common source. In the case of phosphates also this is true up to a certain extent. Contribution of phosphate increased during post-monsoon, which is mainly due to overland flow. Another important observation is that though there is decline in percentage contribution from upstream the enrichment observed at the downstream region could be due to the dam effect.

Based on the above results, it is worth mentioning that solute sources and loading rates also vary with respect to time. Sources may be roughly classified according to their duration. Some sources are continuous while others may be viewed as being instantaneous. Continuous sources introduce solutes to the stream for extended periods of time. One of the continuous sources is the wastewater treatment plant. Although mass-loading rates may vary in time, many of these plants continuously discharge effluent into receiving waters, resulting in a continuous addition of solutes to the stream. Similar observations were made by Madhurima (2000) for Ghataprabha representative basin.

5.5. Streeter-Phelp's Model:

Streeter-Phelp's (1925) model describes the BOD - DO relationship in a stream. DO is estimated by along the course of the river by using the Streeter-Phelps equation and the variation in DO concentration upto Daddi (the confluence point of Ghataprabha and Tamraparni rivers) is shown in figure 45. The estimation was done by considering a sewage discharge point at Halkarni (sugar factory discharge). From the point of conceptualization, the river reach was taken as the defined system as shown in figure 46. (stretch from Halkarni to Kowad) and some of the assumptions in modeling are :

1. Saturation DO is considered as 7.96 mg/lt.
2. Temperature considered is 27^0C.
3. Deoxygenation constant 'k_1' varies from 0.04 /day to 0.197 /day and the reaeration constant 'k_2' varies from 0.122 /day to 1.05 /day (source: Pawar, 200)
4. Critical DO assumed is 4.5 mg/lt.
5. Streeter-Phelp's model works on constant pollution load discharged at a single given point along a stream having constant flow rate and uniform cross-sections. The lateral and vertical concentration of oxygen and BOD here assumed through out any cross-section.

Table 7 : Mass Balance to Upstream / Downstream River Water Quality Data (Pre-monsoon)

Stations	**Flow (cumecs)**	**Parametres (mg/lt)**						
1. U/S Section		**Na**	**K**	**Ca**	**Mg**	**Cl**	**SO_4**	**PO_4**
a. Tamaraparni stretch								
Chandgad	2.552	18	69	8	2.93	33.7	33	2
Halkarni	20.509	9	1	4	1.5	10.6	8	2
Kowad	22.665	9	2	2.4	1.5	8.9	1	0
b. Ghataprabha stretch								
Kanur	24.006	12	1	8.8	2.4	12.4	10	2
Adakur	24.006	14	3	7.2	2.93	14.2	1	0
Tarewadi	20.31	9	1	2.4	1.5	8.9	1	2
2.D/S section								
Daddi	130.4	16	3	6.4	2.44	10.6	4	1.5

Table continued

Stations	Loads (kg/day)						
1. U/S Section	**Na**	**K**	**Ca**	**Mg**	**Cl**	**SO_4**	**PO_4**
a. Tamaraparni stretch							
Chandgad	3968.87	15214	1763.942	646.0439	7430.607	7276.262	440.9856
Halkarni	15947.8	1771.978	7087.91	2657.966	18782.96	14175.82	3543.955
Kowad	17624.3	3916.512	4699.814	2937.384	17428.48	1958.256	0
Total Load	37540.97	20902.49	13551.67	6241.394	43642.05	23410.34	3984.941
b. Ghataprabha stretch							
Kanur	24889.42	2074.118	18252.24	4977.884	25719.07	20741.18	4148.237
Adakur	29037.66	6222.355	14933.65	6077.167	29452.48	2074.118	0
Tarewadi	15793.06	1754.784	4211.482	2632.176	15617.58	1754.784	3509.568
Total Load	69720.13	10051.26	37397.38	13687.23	70789.13	24570.09	7657.805
Total U/S Load	107261.1	30953.75	50949.04	19928.62	114431.2	47980.43	11642.75
2.D/S section							
Daddi	180265	33799.68	72105.98	27490.41	119425.5	45066.24	16899.84

Table 8 : Mass Balance to Upstream / Downstream River water Quality Data (Post-monsoon)

Stations	Flow (cumecs)	Parametres (mg/lt)						
1. U/S Section		Na	K	Ca	Mg	Cl	SO_4	PO_4
a. Tamaraparni stretch								
Chandgad	5.926	13	1	8	1	7.092	10	4.7
Halkarni	24.508	11	1	4	2.4	7.092	16	3.6
Kowad	29.665	14	2	7.2	2.4	8.865	17	5.8
b. Ghataprabha stretch								
Kanur	32.506	9	0	7.2	1	5.319	8	5.1
Adakur	32.506	12	1	7.2	1.5	5.319	13	2
Tarewadi	24.405	13	1	4	2	8.865	9	4
2.D/S section								
Daddi	165.85	18	3	20	5.76	15.8	25	4.5

Table continued

Stations	Loads (kg/day)						
1. U/S Section	Na	K	Ca	Mg	Cl	SO_4	PO_4
a. Tamaraparni stretch							
Chandgad	6656.083	512.0064	4096.051	512.0064	3631.149	5120.064	2406.43
Halkarni	23292.4	2117.491	8469.965	5081.979	15017.25	33879.86	7622.968
Kowad	35882.78	5126.112	18454	6151.334	22721.49	43571.95	14865.72
Total Load	65831.27	7755.61	31020.02	11745.32	41369.89	82571.88	24895.12
b. Ghataprabha stretch							
Kanur	25276.67	0	20221.33	2808.518	14938.51	22468.15	14323.44
Adakur	33702.22	2808.518	20221.33	4212.778	14938.51	36510.74	5617.037
Tarewadi	27411.7	2108.592	8434.368	4217.184	18692.67	18977.33	8434.368
Total Load	86390.58	4917.11	48877.03	11238.48	48569.69	77956.21	28374.85
Total U/S Load	152221.9	12672.72	79897.05	22983.8	89939.58	160528.1	53269.97
2.D/S section							
Daddi	257929.9	42988.32	286588.8	82537.57	226405.2	358236	64482.48

phosphates also this is true up to a certain extent. Contribution of phosphate increased during post-monsoon, which is mainly due to overland flow. Another important observation is that though there is decline in percentage contribution from upstream the enrichment observed at the downstream region could be due to the dam effect.

Based on the above results, it is worth mentioning that solute sources and loading rates also vary with respect to time. Sources may be roughly classified according to their duration. Some sources are continuous while others may be viewed as being instantaneous. Continuous sources introduce solutes to the stream for extended periods of time. One of the continuous sources is the wastewater treatment plant. Although mass-loading rates may vary in time, many of these plants continuously discharge effluent into receiving waters, resulting in a continuous addition of solutes to the stream. Similar observations were made by Pawar (2000) for Ghataprabha representative basin.

5.5. Streeter-Phelp's Model:

Streeter-Phelp's (1925) model describes the BOD_DO relationship in a stream. From the point of conceptualization, the river reach was taken as the defined system as shown in fig 46 & fig 47 (stretch from Halkarni to Kowad) and some of the assumptions in modeling are :

1. Saturation DO is considered as 7.96 mg/lt.
2. Temperature considered is 27^0C.
3. Deoxygenation constant 'k_1' varies from 0.04 /day to 0.197 /day and the reaeration constant 'k_2' varies from 0.122 /day to 1.05 /day (source: Pawar, 200)
4. Critical DO assumed is 4.5 mg/lt.
5. Streeter-Phelp's model works on constant pollution load discharged at a single given point along a stream having constant flow rate and uniform cross-sections. The lateral and vertical concentration of oxygen and BOD here assumed through out any cross-section.

Based on the model results (table 9), the maximum sewage flow that river can carry is 17.55 cusecs at Kanur and minimum sewage flow estimated is at Tarewadi 13.99 cusecs. Though at Daddi, the stream has the maximum carrying capacity of 91.85 cusecs,

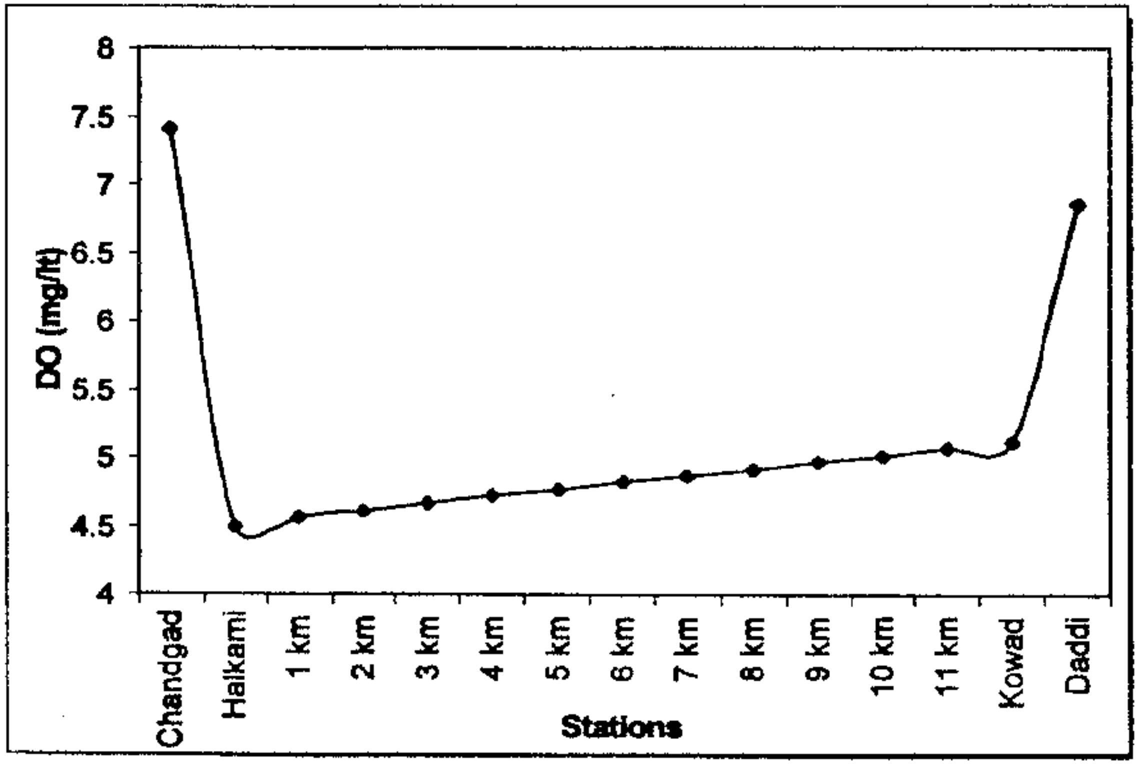

Figure 45. Estimated DO using Streeter Phelp's Model

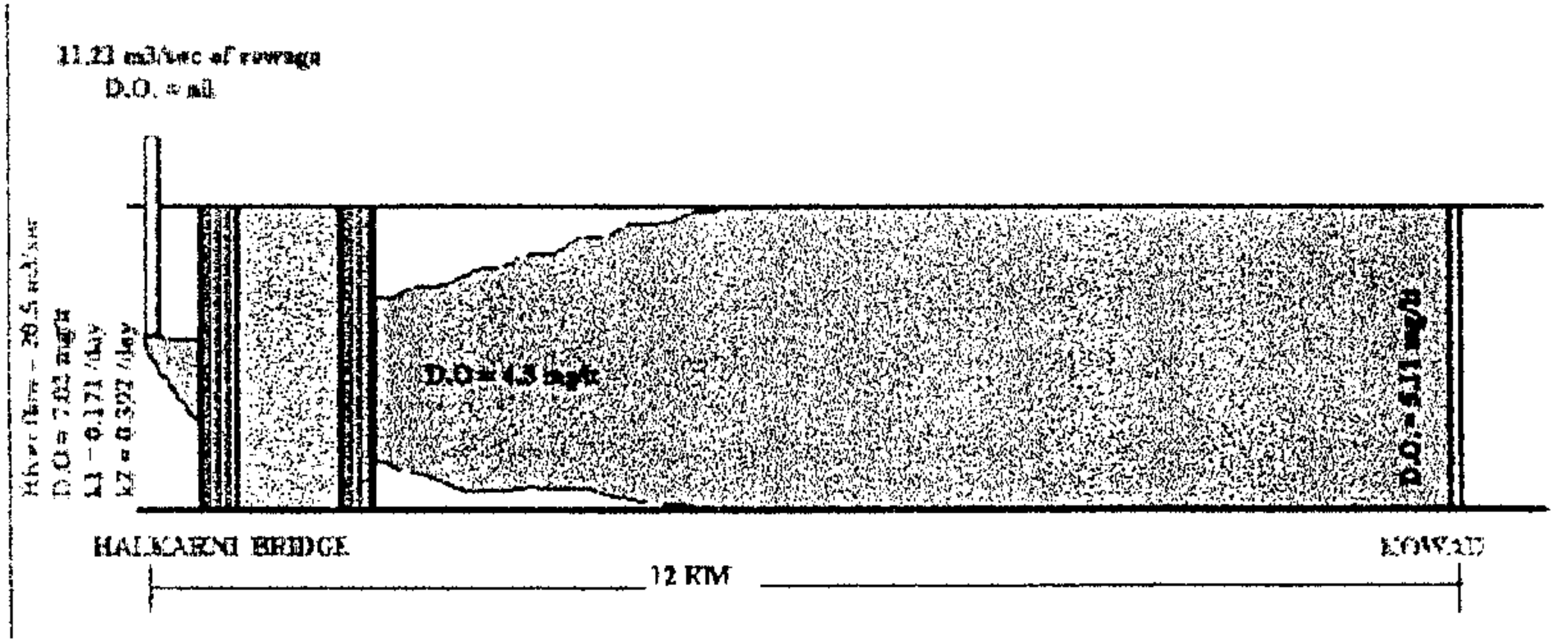

Figure. 46. Schematic Representation of Input of Sewage Quantity at Halkarni

Based on the model results (table 9), the maximum sewage flow that river can carry is 17.55 cusecs at Kanur and minimum sewage flow estimated is at Tarewadi 13.99 cusecs. Though at Daddi, the stream has the maximum carrying capacity of 91.85 cusecs, due to the backwater of Ghataprabha reservoir, there is a chance for deposition of various constituents without any active movement.

It is reported that the variation of DO is quite minimal along both Ghataprabha and Tamraparni stretch (Madhurima, 2000). The present results obtained by Streeter-Phelp's are compared with the observed values of Tamraparni and Ghataprabha rivers(fig 47 and 48). However, there is a wide variation in observed and calculated values. This could be attributed to the fact that in Streeter- Phelp's model, it is not possible to predict streams DO sag immediately after the sewage outfalls, because of the non-accountability of the term bio-flocculation and sedimentation of the settleable BOD in the models as reported by earlier researchers. It is understood from the above study that there is no marked difference in DO values in Ghataprabha basin. The main reason is that the self-purification capacity of Ghataprabha is very good. Similar observation was made by Madhurima (2000) for Ghataprabha and Tamraparni rivers.

Table 9 : Allowable sewage quantity computed using Mass balance equation:

Stations	Distance (km)	Minimum flow (Qr) (m^3/sec)	Th. D.O. (mg/lt)	Critical D.O. (mg/lt)	Sewage Flow (Qw) (m^3/sec)
1) Ghataprabha Stretch:					
Kanur	15	24.006	7.79	4.5	17.55
Hindgaon	13.5	24.006	7.69	4.5	17.01
Satavane	9.5	24.006	7.63	4.5	16.69
Adakur	9.5	24.006	7.62	4.5	16.64
Tarewadi	13	20.31	7.6	4.5	13.99
Daddi	12	130.4	7.67	4.5	91.85
2) Tamraparni Stretch:					
Here	5.4	2.552	7.65	4.5	1.78
Chandagad	10	2.552	7.45	4.5	1.67
Halkarni node	9.5	20.509	7.21	4.5	12.35
Halkarni	15	20.509	6.96	4.5	11.21
Kowad	12	22.665	7.26	4.5	13.90
Daddi	10	130.4	7.31	4.5	81.42

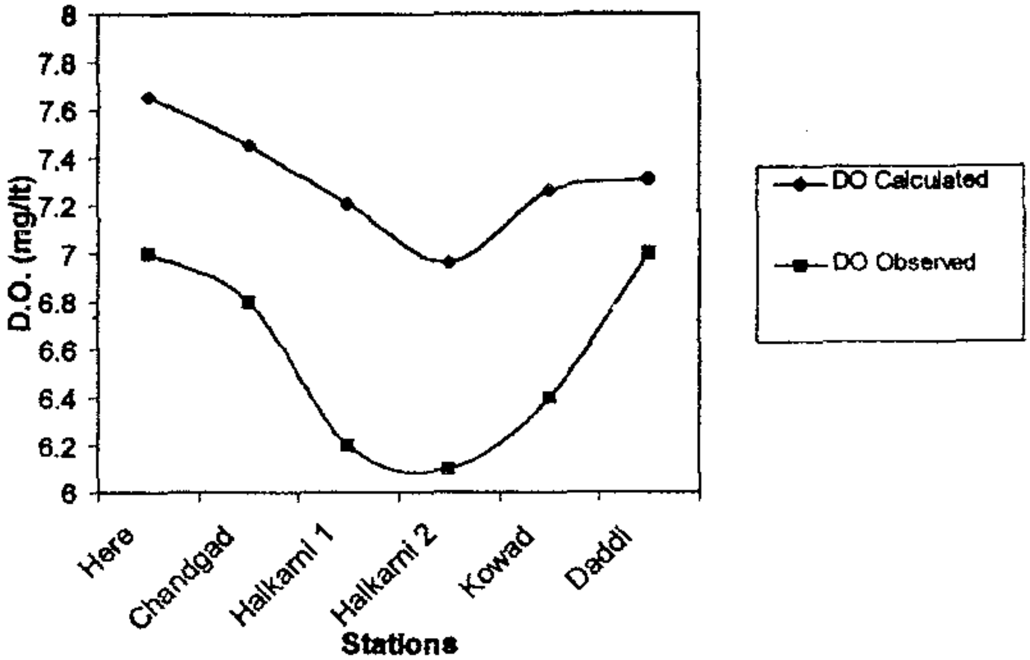

Figure. 47. Comparison of DO Sag curves for Tamraparni River

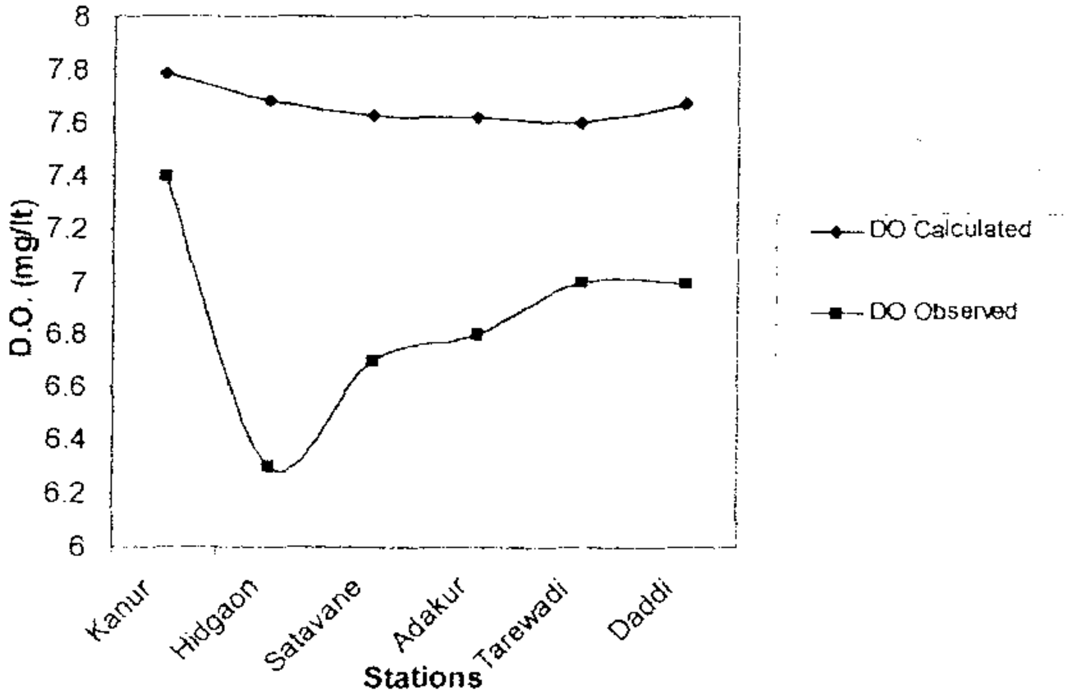

Figure. 48. Comparison of DO Sag curves for Ghataprabha River

6.0 CONCLUSIONS

Water quality is a very important consideration for all water development projects as it affects all aspects of water use-for humans, for animals, for crops, and even for industry. All natural waters containing soluble inorganic ions are mainly from the weathering of soil and rock minerals. The weathering products of the rock minerals are released and transported by the action of water. Hence the nature and concentration of an ion in water depends upon the nature of rock mineral, its solubility, and its resistance to weathering in fresh water or carbonated water (due to dissolution of atmospheric carbon dioxide in rain water) climate and local topography. Apart from these major causes, solubility of minerals is influenced by pH particularly of iron and manganese hydroxides which decreases and that of aluminium hydroxide which increases with the increase of pH.

In highly polluted waters, containing organic materials, these released ions are likely to interact again forming organometallic complexes depending upon the nature of the environment. And several processes such as ion exchange, fixation and release, chelation, precipitation, and dissolution, oxidation and reduction, coagulation and aggregation are operating simultaneously which all-together make polluted waters a more complex system. The variable and dynamic gas-liquid-solid interfacial relationships further complicate the system.

The conversion of forests to other landuse, mining exploitation and various management practices connected with agriculture, all increase erosion thereby enhancing turbidity and sedimentation in streams. The weaker penetration of light diminishes the photosynthesis of aquatic plants and the functions of phyto-plankton. Subsequent sedimentation of the suspended load also modifies physico-chemistry of the bottom, disturbs the gas exchanges with plants and animals(fish) limit growth and reproduction at different levels of the food chain. Suspended matter also absorbs micro-toxics whose effects can be more harmful, depending on the mineralogy of the particles (Garman, 1983). Such phenomenon requires more detailed investigation during the monsoon months. In the present study it is understood that there is no direct impact on surface water quality parameters. Further it is observed that in Ghataprabha representative basin, land use changes are quite minimal. It is a known fact that, land alterations modifies the chemical and nutrient cycles and balances. These important aspects should be studied within the framework of an experimental drainage basin project involving process hydrology studies. This study may be considered as a primary database in the above direction and should be continued in future.

Release of untreated sewage into hydrological systems causes major biological and chemical pollution. It is also observed that there are localized effects on surface water as indicated by D.O concentration, which shows that proper measures must be taken to save the water quality. Therefore, it is imperative that, development of water supply, sanitation and waste disposal systems must be urgently pursued in a coordinated fashion. Otherwise, even ground water systems may be destroyed in future. The re-use or recycling of water must be strongly supported with the qualification that monitoring be continued to ensure that the water quality is maintained within the permissible limits.

Some of the important conclusions of the study are the following:

1. It is observed that both surface and ground water in the Ghataprabha representative basin are good for drinking, irrigation and for all domestic and recreational purposes.
2. There are indications of sulphate enrichment in ground waters due to excessive application of fertilizers, which is attributed to high recharging capacity of soils in such locations.
3. High content of potassium observed at Chandgad, is in the vicinity of heavily cultivated agricultural land, densely populated human and animal settlements, which shows the impact of land use, and anthropogenic activity.
4. From the geochemical classification of water, it is evident that, all the samples are quite suitable for all purposes. It is also observed that there is an enrichment of nitrate during post-monsoon season at certain locations, which need attention. High values of Sulphate / Chloride ratio showed that ground water has been affected by fertilizer use.
5. Streeter-Phelp's model showed that the DO concentration does not vary much indicating the higher self-purification capacity of the river.

7.0 RECOMMENDATIONS

From the physical standpoint, it is understood that knowledge on impact of land use and cropping pattern on water qualitv is essential part of hydrological cycle. These have to do with the behaviour of agricultural chemicals in the environment. The interactions of the various processes and factors are not well understood. Therefore, for improving quantitative predictions in the future include the following aspects for further study:

1. It is important to study the movement of chemicals through soil and the unsaturated zone below and in ground water.
2. It is necessary to understand the hydro chemical processes taking place within the water soil zone.
3. Information is needed on the conditions favorable for breakdown of chemicals by soil microorganisms, including the importance of microbial activity at lower depths in soils and possible ways to manipulate the soil microbial population to decompose pesticide residues in soils and waters.
4. It is important to know the management techniques to reduce the potential for downward movement of agricultural chemicals.
5. Modern methods should be adopted to asses hydrological and environmental variability.
6. Mathematical models suitable for making accurate computerized projections of long-term movement of chemicals in the environment under different circumstances are needed.

It is important to note that water management projects can significantly change water quality in negative way. To minimize the destruction of hydro-systems and the degradation of their water quality, multidisciplinary studies are required at the design stage of the project, and at each step continue for several years to make certain decision that sustainable management can be assured.

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