CHEMISTRY OF WATER AND SUSPENDED SEDIMENT IN NARMADA AND TAPTI RIVERS

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CERTIFICATE

This is to certify that the research work embodied in this dissertation entitled "**Chemistry Of Water And Suspended Sediment In Narmada And Tapti Rivers**" has been carried out in the School of Environmental Sciences, Jawaharlal Nehru University for the partial fulfillment of the award of the degree of Master of Philosophy. This work is original and has not been submitted in part or full for any other Degree or Diploma in any other University.

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INTRODUCTION

INTRODUCTION

Water:

A river is an open ecosystem with strong interaction with its drainage basin. Various biotic and abiotic processes, such as tectonic dynamics, weathering, erosion and sedimentation, evaporation, biological activity, adsorption, and desorption, flushing etc.as well as human interferences interact within the watershed, the river floodplains, the riparian zone and the water body itself, determining its hydro-chemical composition (Webb and Walling 1996). Integrated and sustainable catchment management requires knowledge and understanding of the spatial and temporal variations and trends of river water quality and of the factors and processes controlling them.

Rivers have always been the most important fresh water resources along the banks of which our ancient civilizations have flourished and most development activities are still dependent on them. As a result, the ancient civilization became known by the name of the rivers which flowed past them; like the Nile River Civilization, Indus Valley Civilization, etc.Mankind acutely needs water to survive. This is the reason why almost all the major cities of the world are located and developed on the banks of rivers or sea-shores. For example, London on the river Thames, Paris on the river Seine, Moscow on river Moscova and Cairo on the river Nile.

Being the largest store-house of water (95-96% of all available water) and occupying more than two third of the surface of the earth, ocean dominates anything related to water. In comparison the biosphere stores only 0.0001% of all water. Rivers have only 0.0001% of all water where as ground water contributes 1.05% of water to the hydrological cycle. The largest store-house of fresh water is the ice caps and glaciers, including the polar region, contributing 2.92% to the water budget. (Berner and Berner, 1996).

There are rivers that flow throughout the year and some flow for limited periods. Generally, peninsular rivers flow fully during the monsoon periods and partly in non-monsoon times; they may even trickle places due to limited ground water recharge into the river during such dry periods.

The primary source of water for all the rivers are either dry (snow) or wet (rain) precipitation. Source for both rain and snow has its origin in ocean-atmosphere interaction. Hence the west flowing rivers like Narmada and Tapti have high flow rate due to high precipitation rate in that part of the region.

Water carried in the streams is often considered to consist of a base flow fraction made up of ground water that infiltrates into the channel and direct run-off fraction that inters the drainage system during and soon after the precipitation. In addition to mixing of ground water and run-off, the natural factors that influence stream composition including reactions of water with mineral solids in the streamed and in suspension, reaction among solutes, losses of water by evaporation growing in and around streams and effects of organic matter and water dwelling biota. This latter set of natural factors results in fluctuation in composition that bears little relation to the discharge rate.

Superimposed on all these factors are the influences of humans on stream pollution and waste disposal by all kinds of activities within the river basin and flow diversion and augmentation. River water finds multiple uses in every sector of development like agriculture, industry, transportation, aquaculture, public water supply, etc. However, since old time rivers have also been used for cleaning and disposal purposes. Huge loads of wastes from industries, domestic sewage and agriculture practices find their way into rivers resulting in the large scale deterioration of the water quality. Thus, the growing problem of degradation of our river ecosystem has necessitated the monitoring of water quality of various rivers to evaluate their production capacity, utility potential, and to plan restoration measures.

Chemistry of river water:

Rivers are, in way, veins of continent draining 3500 km3 water (Milliman, 1991), 15.5 billion tones sediment (Milliman and others, 1995), and 3.5billion tones Total Dissolved Solids (Meybeck, 1976) every year to the world ocean.

The chemistry of river water is a cumulative reflection of catchment geology, rainfall, erosion processes and anthropogenic interventions. The chemical composition of the surface water mainly depends upon the chemical composition of the rocks and soils and the shape of the basin, climatic conditions and the existing fauna and flora and the human activities (Gorham, 1961; Matthess, 1973; Fostner and others, 1974; Holl, 1979, Drever, 1997). Thus, the composition of the crustal rocks of the Earth and the composition of the ocean and the atmosphere are significant in evaluating sources of solutes in natural fresh water (Hem, 1991). The surface water apart from the dissolved organic and inorganic substances also contains clastic particles of various sizes which are mainly transported at the bottom of rivers. These result from the erosion of various rocks, which constitute the basin and also from human interventions.

Natural water is a complex solution containing numerous chemical elements. As Ca2+, Mg2+, Na+, K+, Cl-, SO42-, HCO3- and CO32- account for 98% of ions in natural fresh waters. Along with ion concentrations, total salinity, water chemical type and Ph are used as the main indicators in the analysis and evaluation of river water chemistry and its spatio-temporal evaluation (Greiner, 1997). Major cations and dissolved solids vary in accordance with precipitation. (Neill and Gutierrez, 2004).

The way in which solutes are taken up or precipitated and the amount present in the solution are influenced by many environmental factors, especially, climate structure and position of rock strata and biochemical affects associated with life cycles of plants and animals, both microscopic and macroscopic. Taken together and in application with the further influence of the general circulation of all water in the hydrological cycle, the chemical principles and environmental factors form a basis for the developing science of natural water chemistry.

Chemical equillibria probably control a few properties of water in flowing streams. For example the ion exchange reaction of solutes and suspended sediment probably are rapid enough that they are at equilibrium. Certain oxidation, ferrous to ferric, for example also normally may reach equilibrium quickly. The equilibrium approach, however, seems inadequate for studies of most biologically mediated process such as use and production of carbon dioxide and oxygen.

A river is by nature a dynamic system and kinetic principles would seem much better suited to stream chemistry than the steady state equilibrium approach. For example, the process whereby biota consume organic pollution loads of streams often can be most effectively studied by application of kinetic and non-equilibrium models. (Hem, 1991).

The chemical quality of water requires detailed discussion since there are many parameters desirable limits vary depending upon the usage of water. Water derives some of the dissolved chemicals such as HCO3-, Na+, K+, Ca2+, Mg2+, SO42-, F- SiO2 and several others due to chemical interaction between soil mineral matter and also rocks below the soil. The solute load of the water determines the Total Dissolved Solids (TDS) that, in turn, affects the hardness of water. Generally there are more dissolved solids in peninsular rivers compared to Himalayan River system. Key parameters such as acidity, hardness, conductivity, Sodium Absorption Ratio (SAR), plant available nutrients, all depend on solutes derived from the intensity of chemical interaction with the soil particles. Certain toxic elements such as Arsenic (As), Cadmium (Cd), Chromium (Cr) also enter the water either due to such reactions or a number of anthropogenic activities.

Dissolved load of river water could be inorganic or organic in origin. Soil mineral reactions give the water most of the inorganic constituents whereas decomposition of plant debris contributes most of the organic constituents such as Dissolved Organic Carbon(DOC), Dissolved Humic Acids and many other organic compounds. Dissolved Organic Carbon (DOC) is used to describe the thousands of dissolved compounds found in water that derive from organic materials (such as decomposed plant matter). DOC is organic material from plants and animals broken down into such a small size that it is "dissolved" into water. Some DOC molecules have a recognizable chemical structure that can easily be defined (such as fats, carbohydrates, and proteins) however most have no readily identifiable structure and are lumped under the term humic or tannin substances. The more recognizable types of DOC such as soluble fats, proteins, and carbohydrates are often created within the stream or lake from animal faeces or decomposition of fish and insects. This type of DOC is not pigmented and does not influence the color of a lake or stream. However, DOC imported from outside a lake or stream is created by the decomposition of leaves and woody debris that have fallen around or in water. The plant material is slowly broken down by organisms into very small particles that are dissolved into water. Because they are not quickly fed on, they have more time to hang out in the water and react with other molecules to form complex structures that as explained above, are difficult to define as any one type of compound. These humic or tannin substances also often have natural acids associated with them (which can influence pH levels). Yellow to black in color, this humic type of DOC is the most abundant kind found in lakes and streams and can have a great influence on watercolor.

There are also solid particles either as sediments or as debris from soil washes out carried by river collectively known as Total Suspended Matters (TSM). These TSM, actually, are important as storehouse of many nutrients that required for many biological systems.

The Ganges River, for example, carries an enormous amount of silt as TSM and this silt is very rich in nutrients such as C,N,P that support many life forms. The total sediments carried by rivers such as Narmada and Tapti are much lesser in quantity as compared to the Himalayan Rivers such as Ganga and Brahmputra.

The TSM also is useful in regulating the dissolved load of river due to interaction in the river environment and may also control some of the pollutants such as the heavy metals (Hg, As, Cd, etc.).

Sediment:

Origin and source of sediments:

Sediments are the product of the physical and chemical weathering on the continents (Holland, 1978). There origin may be igneous, metamorphic or sedimentary. The physical and chemical weathering and the erosion of the exposed rock depend upon the kind of rock as well as the physical and chemical properties of the agents.

Water is of prime significance in the weathering and erosion of landmass. The transfer of the denudation product from the place of its origin to the river channel takes place at different span of time. Meade and Parker (1985) has mentioned that 90% of the soil eroded in the uplands in the U.S. are kept stored mostly in hill slopes, floodplains and other parts of the stream valley somewhere between erosion sites and sea and only 10% of the total sediments eroded from the uplands are delivered to the ocean by the rivers.

Thus in terms of geological age materials in the weathered upland bed may be the original sources of sediments in the river channel but in a contemporary time scale the sediments lying at different storage sites along the way between the upland and the estuaries forms the major and the important sources for rivers(Meade, 1982). These sediments enter a river channel through overland flow in which sediments have entrapped earlier or through bank scour (Statham, 1977).

The amount of sediment annually delivered to the world oceans has been estimated by a number of workers (Holeman, 1968; Sundberg, 1973; Meybeck, 1976-77; Milliman and Meade1983 and others). Rivers presently discharge about 35*10 3 km3 of fresh water and 15*10 tons of sediments in the world rivers annually (Milliman, 1991).About 65% of the water and 80% of the sediments come from southern Asia, Oceania and Northeastern South America (Milliman, 1991).The Himalayan drainage system, comprising the Ganges, Brahmputra, Irrawadi and Indus (before large dames were built) rivers supplies nearly 20% of the river sediments to the oceans (Subramanian et. al., 1987). These figures highlight the importance of river basin study.

The Ganges, Brahmputra and Meghna rivers together transport an estimated 971 km3 of water and more than 1000 million tons of sediments annually to the bay of Bengal where the sediment load is more than 6% of the total fluvial sediments reaching the world oceans (Milliman et.al.,1989) The sediment rate can be described quantitatively by their discharge or transport rate by the density and size distribution of the particle transported and by there chemical and mineralogical composition(Nordin jr., 1985).It depends upon the age and morphology of the surface composition of the bed rock material, tectonic uplift, climates, vegetation cover(Irion, 1991) and size and volume of the drainage basin(Martins and Probst).

Running waters erodes particles up to certain size, corresponding to the water velocity. The eroded materials consist of single minerals, polycrystalline grains and rock fragments. Striking changes in sediment composition occur in high relief headwaters. In river sediments a whole range of known minerals can be found: salt minerals in very restricted areas, carbonates, heavy minerals, feldspars, Quartz, and clay minerals.

Amorphous particles of volcanic origin and of skeleton and shells from organisms contribute to river sediments. The alteration of transported minerals and rock fragments is mainly restricted to the upper reaches (Irion, 1991). River plays a significant role in the global biogeochemical cycling by transporting elements from terrestrial environment to the sea. Rivers contribute 89% of the total material transport to the ocean. In the recent past these fluxes have undergone marked changes due to human intervention and this trend continue till date. Owing to a growing world population and consequently, excessive use of water in household, industry agriculture, maintaining or changing the quality and quantity of river discharge becomes critically important. All this gives enough reason to make a full-fledged study of the river system.

The investigation of sediments from the hydrosphere has recently become a major subject of interest in research on aquatic systems, as they reflect the current quality of the system and provide information on the impact of man. Sediments are increasingly recognized as carriers and possible sources of contaminants in the system. Human activities (urbanization, industrialization, mining etc.) promote the accumulation of polluted sediments in the nearby river system, which is considered to be a safe disposal site for contaminated sediments.

Contaminants in river system can be investigated by analyzing either the water and the suspended material or the sediments. The measurements of pollutants in water are not conclusive due to water discharge fluctuations and low residence time. The same holds true for the suspended material. In this situation, the study of the sediments plays an important role, as they have a long residence time. River sediments, therefore, are important sources for the assessment of man made contamination in rivers (Fostner and Wittmann, 1983; Muller, 1979).

Sediments play major role in the pollution pattern of river system. Metals in surface waters have a strong affinity for the particulate phase, which facilitates their elimination from the water column and their accumulation in sediments (Ramamoorthy and Rust, 1978). While sediments are important sinks for pollutants, they can also release them back into the ecosystem when changes occur in the environmental conditions such as Ph, redox-potential or the presence of organic chelators (Fostner and Wittmann, 1981).The sediments, therefore, may become "Reservoirs" for toxic elements and heavy metals created from anthropogenic activities. The sediment should also be subject to investigation for environmental pollution when plans for reconstruction or dredging of polluted canals are made (Huy, et.al. 2003).

Thus sediment quality is widely utilizable method of environmental assessment (Fostner and others, 1990; Long and Morgan, 1990; Miko and others, 2003).Sediment integrate contaminant concentration overtime, rendering a longer term picture of the effects of e.g., mining, agriculture and urbanization than that obtained with water samples (Gutierrez, et. al, 2004).

Suspended sediment:

Suspended sediments play an important role in the transport of nutrients and contaminants, in water-sediment interactions influencing the river water quality, and as non-point source pollutants (Martin and Meybeck, 1979); Muller and Sigg, 1990; Fuller and others, 1990). Hence the knowledge of nature and properties of suspended sediments is fundamental to efforts to preserve and improve the quality of natural water systems (Oscacarson and others, 1981).

Asian rivers supply 30% of the sediment input to the world ocean and, within Asia, the rivers draining the Himalayas supply as much as 20% of the global sediment input (Milliman and Meade, 1983). Determination of sources and an improved understanding of the dynamics of the suspended sediments in river system is a challenging but essential endeavor due to its manifest importance in many fields of environmental sciences, including water quality (Langedal, 1997; Swank and others, 2001), the fate and transport of pollutants (Batson and others, 1996; Macklin and others, 1997; House and others, 1997; Marcus and others, 2001; Rice and others) and ecological health and diversity (Ryan, 1991; Rice and others, 2001) as examples.While hydrodynamics and flow regimes are critical controls on sediment transport processes at all scales, the supply of available materials derived from either upland erosion within the drainage basin or channel margin can be of equal or greater importance (Van Sickle and Beschta, 1983; Asselman, 1999; Bronsdon and Naden, 2000).

Delineation or fingerprinting of fluvial suspended sediment sources has been accomplished using a variety of tools including elemental composition (Kelly and Nater, 2000), sediment mineralogy, morphology and geochemistry (de Boer and Crosby, 1995; de Boer, 1997; Hiller, 2001), combination of lithogenic and fallout radio nuclides (Olley and others, 1993; Feng and others, 1999), and heavy metals (Collins and other 1998). Different sediments source areas within a watershed have different physiochemical, mineralogical and other distinct properties that may allow an estimate of the relative contribution of these sources to suspended sediments in transport or in transient storage in fluvial systems.

A large part of the anthropogenic discharge of heavy metals into the environment is incorporated in the suspended sediments in rivers, which acts as efficient scavenger for these metals (Salomons and Forstners, 1984). Therefore, sediment can be an indicator of the extent of pollution in a given area. Suspended sediments in a river contain significantly higher levels of heavy metals than those present in dissolved form. So far several attempts have been made to understand the river transport of heavy metals on regional and global scale (Gibbs, 1977; Forstner and Wittman, 1981; Subramanian and others, 1987; Ramesh and others, 1988). Metals in our environment receive increasing interest because of significant inputs from industrial and urban sources (Nrigur and Pacyna, 1988) and because some are potential hazards. In order to assess the natural and anthropogenic inputs the chemical composition of river borne sediments needs to be known.

The majority (around 90%) of the particles transported by rivers are carried in suspension. Suspended sediment account for more than 90% transport of Al, Fe, Ti, Mn, Si, and P and a major proportion of flux of other elements. Suspended sediment also accounts for a major proportion of transport of organic substances such as organic phosphorus and organic nitrogen (Meybeck, 1984).

Heavy metals in water and sediment: Nature and effects:

Heavy metals today have a great ecological significance due to there toxicity and accumulation. These elements, contrary to most pollutants, are not bio-degradable and undergo a global eco-biological cycle in which natural waters are the main pathways (Nurnburg, 1984). River sediments, by precipitation, adsorption, and chelation processes provide the major sink for heavy metals in the aquatic environments. Metals are not fixed permanently by the sediments but may be recycled via biological and chemical agents, both within the sedimentary components and also back into the river column.

The presence of increased levels of heavy metals in the aquatic environment has been of much concern during last few decades due to the adverse effects of some metals on living organism in food-chain leading to man. The first case of acute poisoning of heavy metal contamination in marine coastal area was the outbreak of a mysterious, non-infectious neurological illness among the inhabitants (who mainly depend on sea food) living around Minamata-Bay in southwestern Kyushu, Japan.

The water in river can become enriched in heavy metals which, if incorporated into aquatic food-chains may cause serious health hazards and even death (Forstner and Muller, 1973). Elements like Cu, Zn, Fe, Mn, and Co which are required for normal biochemical functions could become toxic when present in anomalous concentrations and according to Bowen (1966), may result in poisoning of enzymes.

Chapter II

LITERATURE REVIEW

LITERATURE REVIEW

The studies on the major ion chemistry of the river water and sediment have received wide attention in the last two decades primarily with a view to understand the nature of materials transported by rivers into the world oceans. The major ion chemistry of the river water and sediment reveals the nature of weathering on a basin wide scale and gives us knowledge about the biogeochemical cycles of elements operating in the continent – river and ocean systems.

Sedimentological, mineralogical and chemical data on major world rivers have been published since the first decades of this century. (Katzer 1903, Clanker and Steiger, 1914; Russell, 1937; Holmes 1942; Naidu, 1966; Gibbs, 1967; Depetris and Griffin, 1968; Potter et al, 1975; etc.).

Studies regarding river geochemistry have progressed during last three decades in broadly two directions:

1. Geochemical processes in individual river basins (Gibbs 1967; Stellard and Edmond 1981 & 1983; Subramanian et al, 1988; Ramesh & Subramanian 1988; Ramanathan et al. 1988;
2. Overall balance of dissolved and sediment load carried to the oceans has been computed on the basis of large river studies (Holeman 1968; Mebeck 1979; Milliman and Heade 1983).

WATER CHEMISTRY:

Geochemical studies of river water in India were initiated by Ray & Maheswary (1970), followed by Harde (1972) for Ganga River.

Studies carried out by several workers on the chemical composition of surface waters indicate that on an average, Calcium (Ca^{++}) and bicarbonate (HCO_3^{-}) ions represent the dominant cation and anion respectively. The ionic composition of the water bodies is dominated by four major cations: Calcium (Ca^{++}), Magnesium (Mg^{++}), Sodium (Na^{+}) and

Potasium (K^+) and four major anions such as Carbonate (CO_3^{--}), bicarbonate (HCO_3^-), sulphate (SO_4^{--}) and Chloride (Cl^-). Other elements like Nitrogen (N) and Phosphorus (P) are important biologically but are minor components of ionic composition of water. In general, proportions of major cations in world waters are $Ca^+ > Mg^+ > Na^+ > K^+$ and proportions of the major ions are in the order $HCO_3^- > CO_3^{--} > SO_4^{--} > Cl^-$.

The major ions are further classified into two main groups:

- Conservative elements, which include Mg^{++}, Na^+ and Cl^-.Their concentration in water are normally high, but relatively conservative and undergo minor spatial and temporal variations due to biotic utilization or biotically mediated changes in the environment.
- Dynamic elements, Ca^{++}, CO_3^{-} and SO_4^{--}. Their concentrations are lower but are dynamic i.e. their concentrations are strongly influenced by biotic metabolisms.

In recent years, numerous papers have been published, addressing the chemical composition of surface waters in river systems throughout India (Subramanian 1979; Ray et al, 1984; and Subramanian et al 1985 & 1987 and Subramanian 1988a; Chakrapani and Subramanian 1990a). These studies have shown that river chemistry is largely controlled by regional geology, with Indian rivers collectively being alkaline and on average with about 25 % more total dissolved solids (TDS) than the world river average (Subramanian 1979). These concentrations are however, disproportionate, because some of the highest elemental concentrations are found in the southern peninsular rivers e.g. Godavari, Krishna, Mahanadi, Narmada, Cauvery and Tapti, compared to those northern rivers e.g., Ganges, Brahmaputra, and Indus, draining the Himalayan Mountains (Subramanian 1979).

The peninsular rivers, characterized by TDS, which on average is 4 times higher than the total suspended matter (TSM), are dominated by HCO_3^-, Cl^-, SO_4^{2-}, Ca^{2+} and Na^+. The bicarbonate and calcium values are indicative of intense chemical weathering in the Indian subcontinent, whereas the high sulphate, chloride and sodium values are largely due to proximity of sea (Subramanian et al, 1987).

These previous publications provide a general characterization of the major cation and anion concentrations of Indian River waters. Analysis of these ions in a river system is essential for estimation of various sources influencing river chemistry and the partitioning of elements between water column and sediment.

Studies of major element chemistry of Orrisa state rivers such as Mahanadi have been done by Subramanian 1979 & 1980; Ray et al, 1984; Subramanian et al 1987; Chakrapani and Subramanian 1990 a, b, 1993& 1994. As shown in previous studies of river systems (Stallard and Edmond 1983), the chemical composition of waters is primarily determined by the geological sources and erosional regime. While this assumption was shown to be valid for major cations and anions (Subramanian et al, 1987).

Gupta and Subramanian (1994) studied the water chemistry of the River Gomti and explained that the almost monotonous spatial distribution of various chemical species is due to uniform presence of alluvium Dun gravels through out the basin. Na+, Cl-, and SO4 2- concentrations were shown to be built up downstream. They concluded that the regional geology of the Gomti River basin favors dissolution of carbonates as a probable source for Ca 2+ and Mg 2+ in the river water. They also inferred that the Na+ and K+ required to balance part of carbonate alkalinity, could be supplied from the silicate weathering.

The trace element concentrations in Mahanadi River and its tributaries, the Brahmani River and its tributaries and the Baitarani River and its tributaries differ intensively although the three rivers drain in similar geological terrains. The disparity in concentrations sometimes approached (or exceeded) one order with the higher concentrations typically belonging to the surface waters of the Brahmani rivers. Of the 48 trace elements studied, the Brahmani River had the highest concentration for all except Br, Co, Cr, I, Mn, Ni and Sc, which were higher in the Baitarni River and Ag, was found higher in Mahanadi River. In the Baitarni and Mahanadi rivers, most elements were also found in higher concentrations, with the exception of Ag, Cd, Mo and Zn for the Baitarni and Ag, Cd, Mo, Pb and Zn for the Mahanadi (Konhauser et al 1997).

Temporal variability in trace metal concentration (Cu, Pb, and Zn) and total suspended solids were examined in three rivers (Lane Cove, Paammata rivers and Haslams creek), drain into the Port- Jackson Estuary, Australia by Vanessa et.al.(2001).Various physio-chemical characteristic of Yamuna flowing in Haryana through Delhi were studied by Ravindra et.al.(2003). Ecological parameter like D.O. ,Ph, No3-, SO4 2-and PO4 3- were analysed and compared with standard permissible limits to assess the best- designated use of the river water for various purposes. The river in Delhi upstream was found of better quality whereas, downstream was polluted, as indicated by very low D.O. and high TDS, EC, total hardness, Na+, K+, Cl-, F-and SO4 2-. Fernandez-Turiel et.al.(2003) studied the spatio- temporal variability of Na, Mg , Si, K, Ca, SO4 2-, Cl-, HCO3-, and various trace metals to determine the main aspects influencing the surface water quality in Sali watershed, NW, Argentina. Sali River was found with higher concentrations of major and trace metals. The Tapia and Loro rivers belonging to the same watershed present higher concentration too.

Hydrochemical character and spatio-temporal variability in a heavily modified river (Acheloos) of western Greece were studied by Skoulikidis (2003). The hydrochemical characters of Acheloos River were reported as Calcium-Bicarbonate type. The surface water chemistry in Hieth river basin was assessed by Feng et.al.. He concluded, based on the assessment, the river as HCO3- Ca2+ type.

SEDIMENT CHEMISTRY:

The study of sediment chemistry is essential for calculation of individual elemental fluxes and their mass balance studies. The sediment chemistry of major rivers has been reported by Garrels & Mackinzie (1971); Turekian & Scott (1977), Gibbs (1977) and martin & Meybeck (1979).

The continental contribution of heavy metals to the world ocean is large, and more than 97% of the mass transport of metals is associated with sediments (Gibbs, 1997; Martin and Meybeck, 1979) made a comparative review of the particulate forms in increasing sequence Al, Mn, Co, Zn, Ni, Cu, Cd and the same tendency has also been reported by Yeasts and Bewers (1982) from St.Lawrences river in Canada. Metal pollution has been studied by analyzing the sediment in a number of rivers (Forstener and Wittman 1997; Knutson et.al. 1987; Barcellos et.al. (1988), Campbell et.al. (1988), Kremlin and Pohl (1989).

In India, Naidu et.al. (1967); Rao and Rao (1973); Sarin et.al (1979); Kalesha et.al. (1980) have studied the geochemistry of sediment on eastern continental shelf and shore. During the last decade, some research work had been carried out mainly on elemental concentrations in water, suspended and bed sediments of the Ganga River and its tributaries. The magnitude of the suspended load and their elementary concentrations in the Himalayan Rivers has been the focus of several works (Abbas and Subramanian, 1984; Jha etal., 1988). Ajmal and others (1985) demonstrate that waste effluent of various cities like Delhi Agra Mathura and Allahabad on the bank of Yamuna river (a tributary of Ganga) have deteriorated the quality of water and sediments by the addition of various metals such as Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn. Subramanian and others (1987a) studied heavy metals (Fe, Mn, Ni, Cr Cu, Zn) in suspended and bed sediments of Ganga and Brahmaputra rivers. They report on the pronounced spatio-temporal variations in heavy metal distributions in Ganga River. Another study of Subramanian and others (1987b) demonstrates that the increase of contents of Mn (40%), Fe (76%), cu (62%), Zn (90%) and Pb (50%) in sediment of Yamuna River around Delhi is caused by the anthropogenic contributions from the wastes of the city drains.

It is documented that 40% of the pollution of Ganges River is due to sewage discharge and 13%, due to chemical wastes released from the factories (Anon, 1985). More then 50% of the contents of Cd, Co, Cr, Cu, Hg, Ni, Pb, Sn, Zn and of organic carbon in sediment and soils of the Kanpur – Unnav region of the Ganga plain are derived from anthropogenic sources (Ansari et.al. 1996).

Kumar (1992) studied heavy metals in the clay fraction of the river sediments from the middle section of Ganga River from Kanpur city to Patna city. Heavy metal distribution in bed and suspended sediments of Mahanadi river basin has been discussed by Chakrapani and Subramanian (1993). Chander and others (1994) demonstrate that the river sediments of the Pandu river (a tributary of Ganga near kanpur city) are contaminated by fly ash derived copper from a coal based thermal power plant. M.singh (1996) has also carried out a study on the status of heavy metal pollution. They conclude that Pb, Zn, and Cr have been accumulated in recent years in the sediments and Si, Al, Fe, Ca and Mg dominate in the bed as well as suspended sediments. They observed that some major and trace elements increase in concentration with finer size and there is no significant variation in K, Al, and Pb with change in grain size. Suspended sediments were found to contain increased concentrations of metals as compared to the bed sediments except Si, Na, K, and Cr.

Considering the significance of river systems both qualitatively and quantitatively, a number of studies have been reported recently (Allan, 1986; Castaing etal., 1986; Subramanian et.al., 1987; Yeoman et.al., 1989; Viksham et.al.,1991; Schintei and Foster, 1991; Ostrander and Clark, 1991; Mantei and Foster, 1991; Orson et.al., 1992; Tanizaki et.al., 1992; Berggren, 1992).

According to Gupta and Subramanian (1994), Si makes up about 36.5% of the elemental chemistry of Gomti River showing only minor fluctuations in concentrations throughout the river course. They observed that Al, Na, K, and Mg account for 4.5, 1.6, 1.6, and 0.5% of the elemental chemistry of the bed sediment. They use metal /Al ratio as an index to determine the relative mobility of different metals and concluded, as per the downstream variations in the ratio, that high Si/Al ratio in bed sediments is due to addition of silica from detrital quartz, which is in abundance in the river sediments. Fe, Ca, Mg, K and Mn/Al ratio were observed a dip in downstream site. Anodic et.al. (1999) investigated elevated concentrations of some trace metals in bed as well as in suspended sediments. Generally, suspended sediments were found with higher concentration of trace metals than bed sediments for Blue river basin.

Major ion composition and the chemical parameters were determined in the Saluki River, Argentina by Galindo et.al. (2001) .Bed and suspended sediments in River Blue have been studied for the concentrations of more than 60 elements in each sample with respect to space and time by Aligner et.al. (2002). Subramanian et.al. (2003) studied on bed and suspended sediments of the river Yamuna and reported that the mercury levels at various locations show from 0.01 to 25.5 microgm/gm in suspended and 0.01 to 2.6 microgm/gm in the surface sediments. They concluded that the sediments of Yamuna River supply significant levels of toxic mercury in mobile fractions and the concentration increases in downstream direction particularly in the last 50 years.

The concentrations of heavy metals and metalloids in sediments from the river Llobregat and its tributaries (Anoia and Cardener) were studied by Caes et.al. (2003). No significant differences were found for As, Hg, Ni, Pb, Sb, and Zn concentrations in Llobregat, Cardener, and Anoia Rivers. On the other hand, the Cardener river was found to have higher concentration of Cd and lower concentration of Cu than the Llobregat and Anoia rivers. Gutierrez et.al.(2004) investigated the content of heavy metals and Arsenic in sediments of Karst streams in southern Missouri for its potential use as an indicator of pollution. Among the trace metals only Cu and Zn correlated while Pb correlated with Ca, Al, Mn, and Fe. Spatial variability analysis confirmed that natural variations among adjacent sediment samples is a common occurance. The urban spring branch showed the highest levels of Cr, Zn, Pb , and As.

Yeager et.al.(2005) worked on characterization of the dynamics of fluvial sediment sources over space and time using radio nuclides which was concluded as critical in identifying human impacts on fluvial sediment.

Sources of trace metals in the environment

Metals are naturally occurring elements that ultimately originate from weathering of rock substrate. Large inputs of metals of natural origin reach coastal areas and water bodies through rivers and streams. These metals are mainly chemically bound to aluminosilicates; and therefore are not readily available (Villares *et. al.,* 2003). Human activities however considerably increased inputs of these elements in the environment with estuaries, coastal areas and other water bodies being particularly affected. Metals of anthropogenic origin are loosely bound in sediments and therefore, more readily available to organisms (Schropp and Windom, 1988).

The principal anthropogenic sources of trace metals in the atmosphere are smelting of metallic ores, industrial fabrications, and commercial application of metals and burning of fossil fuels (Haque and Subramanian, 1982). Lead and arsenic are notable exceptions, the principal sources of these elements being the use of leaded gasoline and the spraying of arsenic pesticides. Metal pollution in soils is derived mostly from atmospheric fallout, coal fly ash, urban refuse, animal wastes and agricultural & food wastes. On the other hand, the principal sources of pollutant metals in natural waters are the discharge of domestic and industrial wastewaters and the damping of sewage sludge.

The most important feature which distinguishes metals from other toxic pollutants is that they are not bio-degradable and once they have entered the environment their potential toxicity is controlled to a large extent by their physicochemical forms. From the view point of public health, it is important to know whether the trace metals are in a readily available or unavailable form to any process in the environment, thus giving us its biological significance (Lacerda *et. al.*, 1992; Puente *et. al.*, 1996).

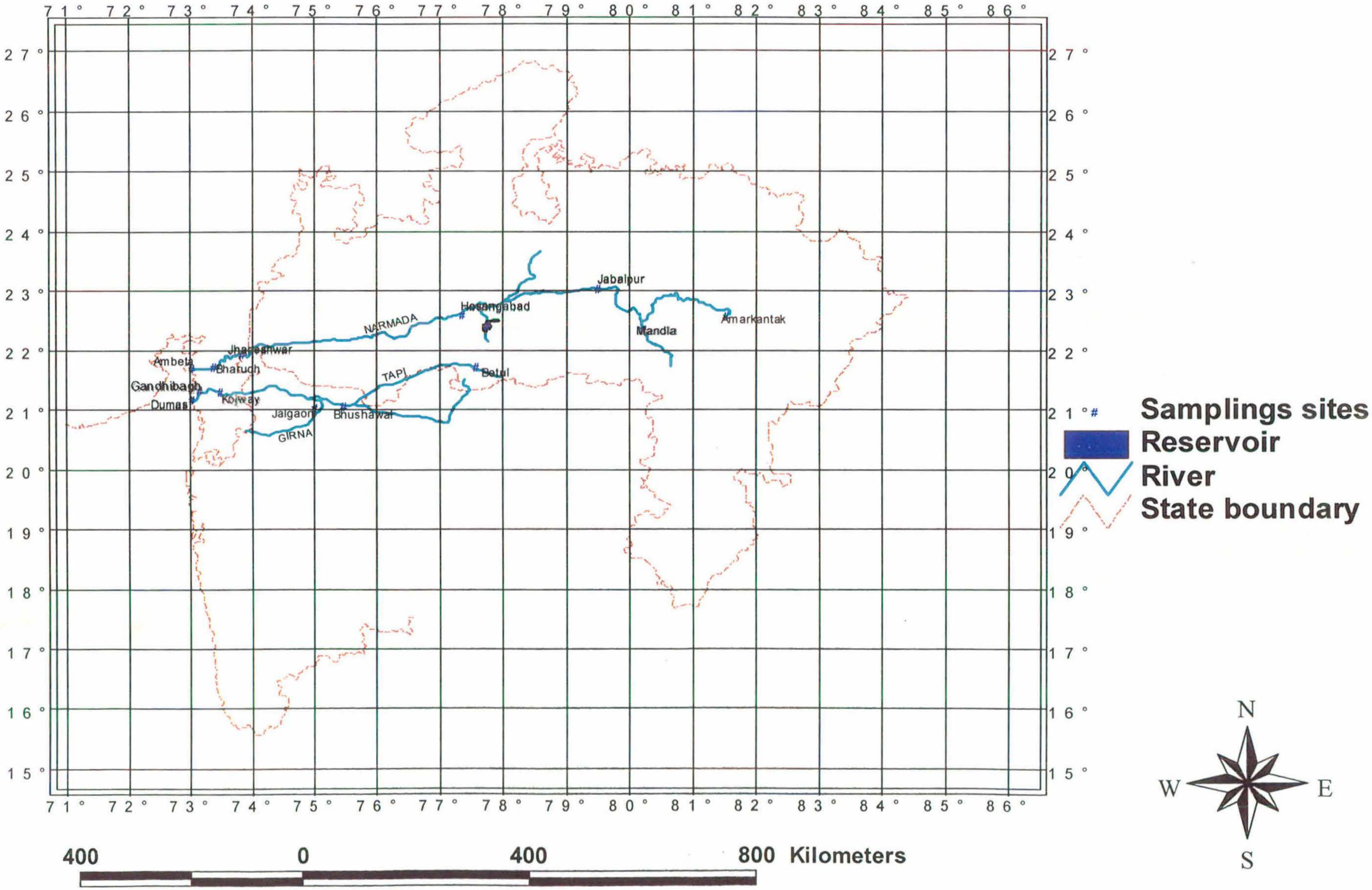
The distribution of the metals among different sedimentary components will affect the passage of metals from particles to organisms (Luoma, 1986). Andrews and Fritchko (1987) demonstrated that oxides of both Mn and Fe provide the main source of metals to benthic dwellings. Luoma and Jenne (1977) found that Ag associated with Mn oxides was 100 times more available to biota than that associated with other components. Fernex *et. al.*, (2001), observed that the amount of cadmium loss from sediment to water in the Mediterranean was approximately 0.005 mol/cm, which amounts to 17% of the total loss from the sediments to overlying water. Tessier *et. al.*, (1989), observed that sorption reactions are important for zinc concentration and that most of the mobile zinc is present in the water column at pH less than 5 and in sediment at pH greater than 7.

Hence when assessing the availability of sediment bound metals to benthic dwelling organisms, it is important to identify how the metal is partitioned among the various sedimentary components.

Chapter III

STUDY AREA

Sampling locations of Narmada and Tapti River basins



STUDY AREA

River basin

Location

Narmada and Tapti rivers are the two important peninsular rivers of central India, which are west flowing. The Narmada and the Tapti are the only major rivers that flow into the Arabian Sea. The Narmada rises in Madhya Pradesh and crosses the state, passing swiftly through a narrow valley between the Vindhya Range and spurs of the Satpura Range. It flows into the Gulf of Khambhat (or Cambay). The shorter Tapti follows a generally parallel course, between 80 kilometers and 160 kilometers to the south of the Narmada, flowing through the states of Maharashtra and Gujarat on its way into the Gulf of Khambhat.

Narmada (1312km):

Narmada is the fifth largest river in India and largest west flowing river of Indian peninsula originating from Maikal ranges in the Shahdol district of Madhya Pradesh at Amarkantak at an elevation of 900 m. Narmada River is known as the "Life Line" of Madhya Pradesh. 87% of the basin lies in Madhya Pradesh covering the districts, Shahdol, Balaghat, Rajnandgaon, Mandla, Seoni, Dindori, Katni, Jabalpur, Damoh, Sagar, Narsinghpur, Chhindwara, Betul, Hoshangabad, Harda, Raisen, Sehore, Khandwa, Indore, Dewas, Khargone, Dhar, Jhabua, & Barwani.

Not only upstream but also the downstream along the course of the Narmada, there are many waterfalls in this river of which Jabalpur at 404 kms, Gandhar at 806 kms Thari at 853 kms and Maheshwar at 966 kms are located. Near Jabalpur, the Narmada, at Bhera Ghat reaches the higher plain through the Dhuadharfalls. Flowing west, the Narmada then reaches through the Panghat in east Nimar. Flowing further down the central region, the Narmada flows through the Vindhya and the Satpura valleys, and reaches the Gujarat plains where adopting a meandering course, it reaches Bharuch. Here severe floods occur during the rainy season. After reaching Bharuch, the Narmada forms a broad delta and flows into the Gulf of Cambay.

Among the main tributaries of the Narmada along its upper course are the Bamer and Banjer, where as, along its central course it assimilates the Kiran, Sher, Shakkar, Tava, Chhoti Tava, Barna and Kundi. Along its lower course the tributaries are Uri, Hathine, Curzan and Orsansh.

It flows westwards over a length of 1,312 km before draining into the Gulf of Cambay, 50 km west of Bharuch city. The basin lies between east longitudes 72° 32 and 81° 45' and north latitudes 21° 20' and 23° 45'. Vindhya hills in the north, Satpura ranges in the south, Maikala ranges in the east and the Arabian Sea in the west form the boundaries of this basin. The basin has an elongated shape almost like a thin ribbon with a maximum length of 953 km east to west and a maximum width of 234 km north to south. The first 1,077 km of the river flows in Madhya Pradesh and the next 35 km stretch of the river forms the boundary between the State of Madhya Pradesh and Maharashtra. Again for the next 39 km, it forms the boundary between Maharashtra and Gujarat. The last stretch of 161 km lies in Gujarat.

Tapti: (724 km)

The second biggest river to flow west in the peninsula is the Tapti. Its origin is in the Betul district of the Madhya Pradesh near Multai at an altitude of 752 meters. From 241 kms. this river flows through the open and fertile plains. Then flowing through the Satpura Mountains, it again reaches the plain near Burhanpur. Thereafter, the Tapti River reaches Khandeshin in Maharashtra. Here, the principle tributary, the Purna flows into it from its left.

From here for 80 kms it flows through he thickly forested area. Later on, for 32 kms the river flows through small waterfalls, and descends by 4-6 meters. During the last stage of its flow between Kakrapar and Kamalpur, the river flows for 113 kms. through the Gujarat plains and flowing through the city of Surat, it reaches the Arabian Sea. There is a tidal effect in the river for 42 kms. from the Gulf of the Cambay. From its origin, to the sea, the total length of the river is 724 kms of which 228 kms is in Madhya Pradesh 228 kms in Maharashtra, 214 kms in Gujarat and the remaining 54 kms is in the form of the

Maharashtra- Madhya Pradesh boarder. Among the main tributaries of the Tapti are the Purna, Vadhur Girna, Bori, Panjher, Bure, Amer, Arunavati, and the Gornai.

Apart from the Narmada, the Tapti is the only river that flows westward and falls into the Arabian Sea, in the Gulf of Khambat, to be precise. The 724 km long Tapti is agriculturally very important as it drains an area of over 65,145 sq km spread over Madhya Pradesh, Maharashtra and Gujarat. The Tapti journeys almost parallel to the Narmada, though it is much shorter in length than the Narmada and has a smaller catchment area.

Description:

Narmada

The Vindhyachal range of mountains criss-crosses the central part of India. From the traditional and geological point of view, it is regarded as the dividing line between north and south India or as its melting point. From the highlands of this plateau area, flow many streams. The plateau of Amarkantak is the origin of Narmada .The turbulent Narmada originates from Amarkantak and sliding down over the marble rocks of Bhera ghat flows west and enters the Gulf of Cambay near Bharuch.

The main source of water in Narmada is **South-west monsoon**. The area belongs to what UNESCO would define as **Tropical Humid zone**. The total length of the river is 1312 kms and a total basin area is 98796 Sq.km comprising about 88 % area in Madhya Pradesh; 2 % in Maharashtra and 10 % in Gujarat. The total basin area is nearly 3 % of the total area of the country. Physicogrophically, it is divided into hilly and plain regions and dominated by **Black cotton soils** (Vertisols and Vertic sub groups). The utilization of this river is hardly about 4 % and thus the vast quantity of water find the way in the Arabian Sea.

The plain regions in between the hilly tracts and in the lower reaches are broad and fertile areas and thus well suited for cultivation. In the basin black soils are predominant. The coastal plains are composed of alluvial clays with a layer of back soil on top.

An average annual surface water potential of 45.6 km^3 has been assessed in this basin. Out of this, 34.5 km^3 is utilizable water. Cultivable area in the basin is about 5.9 M.ha, which is 3.0 % of the total cultivable are of the country.

Geographical Description of The Basin

Physical:

The Narmada basin is bounded on the north by the Vindhyas, on the east by the Maikala range, on the south by the Satpuras and on the west by the Arabian sea. The basin has an elongated shape with a maximum length of 953 Km. from east to west and a maximum width of 234 Km. from the north south. The basin has five well defined physiographic zones. They are:

(i) The Upper hilly areas covering the distt. of Shahdol, Mandla, Durg, Balaghat and Seoni

(ii) The Upper Plains covering the districts of Jabalpur, Narsimhapur, Sagar, Damoh, Chhindwara, Hoshangabad, Betul, Raisen and Sehore

(iii) The middle plains covering the districts of East Nimar, part of west Nimar, Dewas, Indore and Dhar (iv) the lower hilly areas covering part of the west Nimar, Jhabua, Dhulia and parts of Baroda and

(iv) The lower covering mainly the districts of Broach and part of Baroda. The hilly regions are well forested. The upper, middle and lower plains are broad and fertile areas well suited for cultivation. The Narmada basin consists mainly of black soils. The costal plains in Gujarat are composed of Alluvial clays with a layer of black soils on the surface.

Climate:

The tropic of Cancer crosses the Narmada Basin in the Upper plains area and a major part of the basin lies just below this line. The climate of the basin is humid and tropical, although at places extremes of heat and cold are often encountered. In the year, four distinct seasons occur in the basin. They are:

1. Cold weather
2. Hot weather
3. South west monsoon and
4. Post monsoon.

In the cold weather, the mean annual temperature varies from 17° 5 C to 20° C and in the hot weather from 30°C to 32° 5C. In the South west monsoon the temperature ranges from 27° 5 C to 30° C. In the post monsoon season, the temperatures between 25 C to 27.5 C are experienced.

Rainfall:

According to the Indian Meteorological Dept., there were ten rain gauges in 1867 in the entire Narmada basin. The number rose to 21 rain gauges in the year 1891, the year from which published rainfall data are available. Thereafter, there has been a study growth of the rain gauge network in the basin. In 1965, the number of reporting rain gauges above Garudeshwar was 69.

Nearly 90% of this rainfall is received during the five monsoon months from June to October about 60% is received in the two months of July & August.

The rainfall is heavy in the upper hilly and upper plains areas of the basin. It gradually decreases towards the lower plains and the lower hilly areas and again increases towards the cost and south western portions of the basin.

In the upper hilly areas, the annual rainfall is, in general, more than 1400 mm (55") but it goes up to 1650 mm (65") in some parts. In the upper plains from near Jabalpur to near Punasa dam site, the annual rainfall decreases from 1400 mm (55") to less than 1000 mm. (40") with the high rainfall zone around Pachmarhi where the annual rainfall exceeds 1800 mm (70"). In the lower plains the annual rainfall decreases rapidly from 1000 mm.

(40") at the eastern and to less than 650 mm. (25") around Barwani, and this area represents the most arid part of the Narmada Basin in the lower hill areas, the annual rainfall again increases to a little over 750 mm. (30")

Tapti:

The **Tapti River** is a river of central India. It rises in the eastern Satpura Range of southern Madhya Pradesh state, and flows westward, draining Maharashtra's Kandesh region in the northwest corner of the Deccan Plateau before emptying into the Gulf of Cambay in Gujarat. The watershed lies mostly in northern Maharashtra state, but covers portions of Madhya Pradesh and Gujarat as well.

The Basin extends over an area of 65,145 km^2 which is nearly 2.0% of total geographical area of the country. The basin lies in the states of Maharashtra (51,504 km^2), Madhya Pradesh (9,804 km^2) and Gujarat (3,837 km^2).

The basin consists plain areas which are broad and fertile, suitable for cultivation. The principal soils found in the basin are **black soils**, alluvial clays with a layer of black soil above. An average annual surface water potential of 18 km^3 has been assessed in this basin. Out of this 14.5 km^3 is utilizable water. Cultivable area in the basin is about 4.3 Million ha, which is 2.2% of the total cultivable area of the country

Madhya Pradesh

Except for the valleys of the Narmada and the Tapti, Madhya Pradesh consists of a plateau with a mean elevation of 1600 ft above sea level, interspersed with the mountains of the Vindhya and the Satpura ranges.

CLIMATE

The **climate** is extreme in the north of Madhya Pradesh. It is **cool** and **breezy** in the **central parts** and humid in the eastern and southern regions

Temperature

The temperature starts rising in Madhya Pradesh from March onwards, varying from region to region. In summer, the mean maximum temperature goes up to around 42.5°C in northern MP at places like Gwalior. It is 40°-42.5°C in places like Bhopal, Sagar, Rewa, Bilaspur and Raigarh, to name a few. In other places, it ranges from 35°-40°C. May is hotter than June when moisture-laden clouds arrive and bring down the temperature considerably. The monsoon begins in June and last till end-August. The temperature remains more or less the same till September-October, after which, it starts falling, announcing the arrival of winter. Winter reaches its peak in the month of December in some places, and in January, in others. The average temperature in winter is as low as -10°C in the northern half of MP, while in the southern half the average temperature varies from 10°-15°C.

Based on its climate, Madhya Pradesh can be divided into six parts:

1. The Northern Plains
2. The Hilly Region of the Vindhyas
3. The Narmada Valley
4. The Malwa Plateau
5. The Plains of Chhattisgarh
6. The mountainous region of Bastar.

Due to their distance from the sea, the Northern Plains have an extreme climate. If they are extremely hot in summer, they are equally cold in winter. The Hilly Region of the Vindhyas is better. It does not become unbearably hot in summer or excessively cold in winter like the Northern Plains do. The Narmada Valley is very hot in summer, and cool in winter. In the Malwa Plateau it is neither very hot in summer nor very cold in winter.

Rainfall

Madhya Pradesh gets maximum rainfall from June to September, and in some places, it rains in December and January due to a low-pressure build up. Both, the Bay of Bengal and the Arabian Sea, feed the clouds reaching this state. The western parts of the state get their monsoon from the Arabian Sea and the eastern parts get theirs from the Bay of Bengal. However, by the time these clouds reach Madhya Pradesh, a major part of their moisture is spent as they travel over many places before reaching this state. Eastern Madhya Pradesh gets an average rainfall of over 112cm, whereas the northern and western areas get much less, ranging from 50-62.5cm. In the eastern parts of Madhya Pradesh, the monsoon is comparatively more predictable than in the western parts, making cultivation in dry periods almost impossible in the western areas.

Maharashtra

CLIMATE

The climate of Maharashtra is typically monsoonal in character, with 'hot' rainy and cold weather seasons. The months of March-April and May are maximum heat. During this season, especially in April and May thunderstorms are a common feature all over the state. The first week of June is the time for the onset of the south-west monsoon. Rains spread out from the south western and western sides all over Maharashtra. July is the wettest month and August is substantially rainy, by September the south west monsoonal current weakens. October marks the transition from the rainy season to winter. The general drying up of the land and greater sunshine, accompanied by high humidity, produce familiar phenomenon of 'October heat'. From November to February there is a cool dry spell, with clear skies gentle breezes and pleasant weather, though the eastern margins of Maharashtra receive some rainfall.

In the general March of seasons in Maharashtra, the dominant natural factor that affects basically the life and economy of the peoples is the rainfall in its regime amount and variability. In regime quite major part of the rain is received during the four months from

June to September. This concentration is particular to the Konkan and Sahyadrian Maharashtra. In central Maharashtra, though the total precipitations are much lower, there is a wider spread over the months of June to October with a noticeable maximum in September. From Maharashtra, the total rainfall steadily increases towards the east under the influence of the Bay of Bengal monsoon and hence eastern Vidarbha receives its major rains in the month of July August and September. The heaviest rainfall in Maharashtra occurs in the main Sahyadris. Different regions have different rainfalls. This regional difference in the total annual rainfall help in distinguishing three zones of Maharashtra; the wet, the intermediate and semiarid zones. The variability of monsoonal rains is common all over Maharashtra. These unpredictable monsoonal rains affect the agriculture and this will impact economic distress and human suffering. The rainfall in Maharashtra is not fully utilized. A major portion goes waste to the sea in torrents during rainy season. While in the summer months many of these areas suffer acute shortage even of drinking water.

Temperature variations in Maharashtra are not of that consequence as those in rainfall. Tropical conditions are common all over and even the hill stations are not that cold. But lower winter temperature on the plateau does help the growth of some important crops like wheat, gram, linseed and grapes. High summer temperatures induce local thunder showers. Dew, frost, hail and other local weather phenomena are not absent from the climate.

The state is bounded by the Arabian Sea in the west, Gujarat in the North West, Madhya Pradesh in the north and the east, Andhra Pradesh in the south east and Karnataka and Goa in the south.

PHYSIOGRAPHY

Maharashtra consists of two major relief divisions. The plateau which is a part of the Deccan tableland and the Konkan coastal strip abutting on the Arabian Sea. The state of Maharashtra forms a huge irregular triangle with its base on the west coast of India, overlooking the Arabian Sea. The coastal strip, about 720 km, long and not more than 80 km wide, is the Konkan dotted with paddy fields and coconut gardens. The Sahyadris or the Western Ghats running almost parallel to the sea coast flank the Konkan on its east. To the east of the Sahyadris stretches a vast plateau forming the apex of the triangle. The major parts of Maharashtra is underlined by rocks of volcanic origin the lavas. These lava beds are a distinctive feature of landscape in Maharashtra and many of them present as black and massive girdles a spectacular display on the scarp face of the Sahyadri.

The drainage system of Maharashtra consists of both west-flowing rivers draining to the Arabian Sea and east flowing one which drain to the Bay of Bengal after traversing Andhra Pradesh and Mysore. The major rivers of the plateau are Tapi, The Godavari, the Bhima, the Krishna, the Wardha, and Wainganga. The Godavari is the principal river of Maharashtra.

Gujarat

CLIMATE:

The climate of Gujarat is moist in the southern districts and dry in the northern region. The Arabian sea and the Gulf of Cambay reduce the temperature and render the climate more pleasant and healthy. The year can be divided into: the winter season from November to February, the hot season from March to May, the south-west monsoon season from June to September and the intervening month of October.

The average rainfall in Gujarat varies from 33 to152cms. The southern region of the state has an average rainfall ranging from 76 to 152cms, Dangs district having the highest average of about 190cms. The northern districts have a rainfall varying from 51 to 102cms. The rainfall in the southern highlands of Saurashtra and the Gulf of Cambay is approximately 63cms while the other parts of Saurashtra have a rainfall less than 63cms.

The semi-desert area of Kutch has a very low average rainfall. Certain areas in Ahmedabad, Mehsana, Banaskantha, Panchmahals, Surendranagar, Jamnagar and Kutch districts face chronic scarcity conditions for want of adequate rains.

As the Tropic of Cancer passes through the northern border of Gujarat, the state has an intensely hot or cold climate. But the Arabian sea and the Gulf of Cambay in the west and the forest covered hills in the east soften the rigors of climatic extremes.

The Environmental Setting

The state of Gujarat [lat. 20°01' to 24°07'N] and [Long.68°04' to 74°04' E], covers an area of 195,984 sq. km and accounts for six percent of the total geographical area of the country.

Geological History

The geological evolution of Gujarat began with the breaking up of the Gondwanaland. Its subsequent geological history is related to the northward drift of the Indian sub-continent and breaking up of the western continental margin.

The important rock formations of the State are metamorphosed quartzites, slates and limestones in Aravallis, sandstone in Kachchh and in the north-eastern part of Saurashtra and as outcrops in parts of Wadhwan and Sabarkantha, basaltic flows in the Saurshtra Peninsula, tertiary rocks along the coastal region of Surat, Bharuch and south-east of Saurashtra and Kachchh, gypsiferous clay in the Dwaraka beds and large alluvial tract from Surat to Banaskantha.

Climatic conditions

Located on the Tropic of Cancer, the State falls in the sub-tropical climatic zone and has a varied climate and can be divided into five climatic regions [Annexure-IV].

Rainfall and Humidity

Gujarat receives its rainfall from the south-west monsoon [June to September], its maximum intensity being in the months of July and August. The annual rainfall varies between 300mm in the North and Northwest gradually increasing to 2500 mm in the South.

The relative humidity in all parts of the State is low. Winds are generally light to moderate, increasing in intensity during the late summer and monsoon seasons.

Physiographic Zones of Gujarat

Mainland Gujarat

Mainland Gujarat, consists of the eastern rocky highlands [alt. 300 to 1000 meters], the extensions of the mountains of western India, and the western alluvial plains including the coastal plains [alt. 25 to 75 meters].

Saurashtra Peninsula

The peninsula of Saurashtra forms a rocky tableland [alt.300-600meters] fringed by coastal plains, with a central part made up of an undulating plain broken by hills and considerably dissected by various rivers that flow in all directions. The eastern fringe of Saurashtra is a low-lying ground marking the site of the former sea connection between the Gulfs of Kachchh and Khambhat. An elevated strip of ground connecting the highlands of Rajkot and Girnar forms the major water divide of Saurashtra.

Kachchh

The Kachchh region consists of:

[a] *the Ranns,* salt-encrusted wasteland rising only a few meters above sea-level, and inundated during monsoon, divided into the Great Rann to the north and the Little Rann to the east

[b], t*he Banni plains* between the Great Rann and the rocky mainland,

[c] *Hilly region* with the island belt of four rocky projections rising above the Rann,

[d], *the Kachchh mainland*

[e], *the southern coastal plains.*

Drainage system

The rivers Banas, Sabarmati, Mahi, Narmada and Tapi are the important drainage lines of the Gujarat plain draining into the Gulf of Khambatt while the rivers Bhadar, Ojat and Shetrunji are those of the Kathiawar peninsula draining into the Arabian Sea. There are few seasonal and small rivers draining into the Gulf of Kachchh.

Geo-hydrology

On the mainland, the hilly tracts in the northeast, east and south provide an erratic groundwater scenario. Groundwater accumulates only in the secondary porosity zone i.e. zone of weathering, joint planes, cracks and fissures. Water table in these rocky areas varies from 4 to 10 meter below the ground level and is mostly unconfined.

The alluvial plains provide better conditions for the storage of groundwater. The junction between the eastern hill areas and the well-demarcated alluvial plains is the principal site for recharge of groundwater.

In Saurashtra and Kachchh, the areas of sandstone and alluvial cover yield moderate quantities of water while the basalt areas hold good amount of water. Here, the Zones of weathering between successive lava flow also act as aquifers.

Coastal and marine environment

The Arabian Sea and the Gulfs of Khambhat and Kachchh wash the shores of the State. The State has a coastline of 1,659 km. Tidal and saline flats generally characterize the coast of Gujarat. The coast of Kachchh, both on the west and on the South, is surrounded by 10-13 km wide marshy zone.

There are innumerable creeks dotting the coastline of Gujarat. They are shallow and have mostly got silted up.

The Gulf of Kachchh, [7,350 sq km] is aligned in an east-west orientation. Its depth extends from less than 20 m at the head (eastern end) to about 60m at the mouth (western end). The coastal geomorphology is marked by a number of islands, coral reefs, marshy islands, mangroves, sandy stretches, creeks and bays.

The Gulf of Khambhat, [3,120 sq km] is aligned in a north-south orientation. It is marked by the huge interaction of saline and freshwaters, providing it the characteristics of an extended estuarine system. It is a high-energy regime, with large quantities of sediment transport, extensive mud banks and rapid changes in the coastal geomorphology.

The southern coast of mainland Gujarat is generally sandy.

Soils

Deep black and coastal alluvium soils are predominant in South Gujarat, medium black is prevalent in middle Gujarat, grey brown and coastal alluvial soils are in north and north-west while the Saurashtra peninsula has calcareous medium black and to some extent coastal alluvial soils.

Only about 28% of the total geographical areas of the State have soil of over 150 cm depth, while about 15% have soil of 100-150 cm depth. In terms of its texture, loamy soils cover about 37% of the State while 40% is clayey and 7% is sandy.

The Bhal region has a type of soil that is clayey in texture preventing percolation of water making large parts marshy during monsoon and extensively saline.

Satpura Range

The **Satpura Range** is a range of hills in central India. The range rises in eastern Gujarat state near the Arabian Sea coast, running east through Maharashtra and Madhya Pradesh to Chhattisgarh. The range parallels the Vindhya Range to the north, and these two east-west ranges divide the Indo-Gangetic plain of northern India and Pakistan from the Deccan Plateau to the south. The Narmada River runs in the depression between the Satpura and Vindhya ranges, and draining the northern slope of the Satpura range and running east towards the Bay of Bengal. The Tapi River drains the southern slopes of the western end of the Satpura Range. The Godavari River and its tributaries drain the Deccan plateau, which lies south of the central and eastern portions of the range, and the Mahanadi River drains the easternmost portion of the range. The Godavari and Mahanadi rivers flow into the Bay of Bengal. At its eastern end, the Satpura range meets the hills of the Chota Nagpur Plateau.

The Satpura Range was formerly heavily forested; most of the forests have been cleared, but some significant stands of forest remain. These forest enclaves provide habitat for some of India's remaining large mammals, including tiger (*Panthera tigris*), gaur (*Bos gaurus*), wild dog (*Cuon alpinus*), sloth bear (*Melursus ursinus*), chousingha (*Tetracerus quadricornis*), and blackbuck (*Antilope cervicapra*). The eastern portion of the range receives more rainfall than the western portion, and the eastern range, together with the Eastern Ghats, constitute the Eastern highlands moist deciduous forests ecoregion. The seasonally dry western portion of the range, together with the Narmada valley and the western Vindhya Range, are within the Narmada valley dry deciduous forests ecoregion.

Gulf of Cambay

The **Gulf of Cambay** (also the **Gulf of Khambat**) is an inlet of the Arabian Sea along the west coast of India, in the state of Gujarat. It is about 80 miles in length, and divides the Kathiawar peninsula to the west from the eastern part of Gujarat state on the east. The Narmada and Tapti rivers empty into the Gulf. The Gulf is shallow and abounds in shoals and sandbanks. The Gulf is known for its extreme tides, which very greatly in height and run into it with amazing speed. At low tide the bottom is left nearly dry for some distance below the town of Cambay.

Chapter IV

MATERIAL &METHODS

MATERIALS AND METHODS

FIELD METHOD

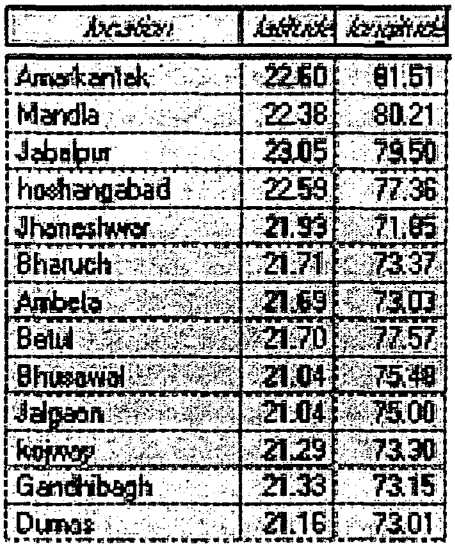
WATER SAMPLING

Water samples were collected in polypropylene bottles during, monsoon and post-monsoon seasons of Narmada and Tapti river basins. Collected water samples were brought to the laboratory and stored in cold room at 1-4°C temperature in order to avoid any major chemical alteration (APHA, 1995).

SEDIMENT SAMPLING

Total of Sixteen Samples of Sediment (0-15 cm) were collected in polypropylene bags from the study areas during monsoon and post-monsoon seasons. All these Sediment samples, after being brought to laboratory, were kept in cold room at 4^0C.

Table4.1: SAMLING SITE ON RIVER NARMADA



location	latitude	longitude
Amarkantak	22.60	81.51
Mandla	22.38	80.21
Jabalpur	23.05	79.50
hoshangabad	22.59	77.36
Jhaneshwar	21.93	71.85
Bharuch	21.71	73.37
Ambela	21.69	73.03
Betul	21.70	77.57
Bhusawal	21.04	75.48
Jalgaon	21.04	75.00
Kojmag	21.29	73.30
Gandhibagh	21.33	73.15
Dumas	21.16	73.01

LABORATORY METHODS

WATER ANALYSIS:

pH AND CONDUCTIVITY

The pH and conductivity were measured in unfiltered water samples. The pH was measured by "**Rachho (model no.123) pH meter**. The glass electrode was conditioned (4M KCl as filling solution) and calibrated with buffer solution of pH 4, 7and 9.2. The temperature knob was set in accordance with the temperature of the water samples. The samples were stirred continuously in order to maintain homogeneity before noting down the pH.

Conductivity was measured in micro-Siemens/cm (mS/cm) using '**Systronics Conductivity meter**. The instrument was calibrated and set for 0.01M KCl solution (1.413µS/cm at 25°C).

BICARBONATE

The bicarbonate content was determined following the **potentiometric titration method** (APHA-1995). Bicarbonate standards ranging from 100-1000ppm were prepared from $NaHCO_3$. 50 ml sample and a series of bicarbonate standards were titrated against 0.02N HCl. The end point was noted at pH 4.5. A standard graph was plotted between bicarbonate standards and volume of the acid consumed. The reading of samples was noted down from the graph.

PHOSPHATE

Phosphate was determined by the **Ascorbic acid method** (APHA, 1995). Phosphate standards ranging from 0.01-0.5 ppm were prepared from KH_2PO_4. 40 ml of each sample and standard solution was pipetted out in 50 ml volumetric flask and 5ml of molybdate antimony solution (prepared by dissolving 4.8gm of ammonium molybdate and 0.1gm potassium antimony tartarate in 400ml 4N H_2SO_4 and making the total volume to 500 ml with the same acid) and 2 ml of ascorbic acid solution (2.0% w/v) was added and mixed well. The mixture was diluted to 50ml and optical density was measured at 650 nm using **Cecil Spectrophotometer (model no.594).** A graph was plotted between standard concentration and optical density and sample concentration was recorded directly from the graph.

DISSOLVED SILICA

The dissolved silica content was determined by the **Molybdo-silicate method** (APHA, 1995). Silica standards were prepared, ranging from 5 to 20 ppm from natrium silicate (Na_2SiO_3). 20 ml each sample and standard was pipette out in 50 ml volumetric flask and 10 ml of ammonium molybdate solution (prepared by dissolving 2 gm ammonium molybdate in 10 ml of distilled water; 6 ml of concentrated HCl was added and final volume was raised to100 ml by distilled water) and 15 ml of reducing reagent (prepared by mixing 100 ml metol sulphite solution, 60 ml 10% oxalic acid and 120 ml 25% sulphuric acid, and making the total volume 300 ml by adding distilled water) was added and mixed well. (Metol sulphite solution was prepared by dissolving 5 gm metol in 210ml distilled water and 3 gm sodium sulphite was added and the volume was made up to 250 ml by adding distilled water). The samples was stirred properly and kept for 3 hours to complete the reaction .The optical density was measured at 650 nm using **Cecil Spectrophotometer (model no.594).** A Graph between standard concentration and optical density was drawn and concentrations of samples were recorded from it.

DISSOLVED ORGANIC CARBON:

The 100-ppm stock solution was prepared from potassium perpthalate ($C_8H_5O_4$) salt. Then standards ranging between 5-25 mg/l were prepared by serial dilution of stock solution.

10 ml. of sample and standard were added to Erlenmeyer flask, 0.4ml of buffer solution of pH was added and stirred it at a moderate speed for 10 min. Persulphate

powder pillow was added to sample and reagent blank vial. 0.3 ml Deionized was added to reagent and 0.3 ml prepared sample was added to sample vial and stirred to mix. Blue indicator ample was inserted in each vial. The vial assemblies were capped tightly and placed in the COD reactor for 2 hours at 103-105Oc. The vial assemblies were removed carefully from the reactor and placed them in a test tube rack. The vials were allowed to cool for 1 hour for accurate results. The optical density of these vials was taken at 430nm.using **Cecil Spectrophotometer (model no.594).**

ANION (Fluoride, Chloride, Nitrate, Phosphate, and Sulphate)

These anions were analyzed using Metrohm 732 Ion Chromatography.

CATION (Sodium, Potassium, Calcium and Magnesium)

These cations were analyzed using Flame-Photometer.

Trace metals

Metal analysis was done by using Shimadzu-AA-6800, Atomic absorption Spectrophotometer. First the instrument was calibrated by using known concentration of metal sample (standard) and a standard curve was drawn between Absorbance and concentration. From this graph, concentration of water sample was calculated. Flame used for metal analysis was Air-Acetylene.

Metal	**Wavelength**
Iron	248.3 nm
Manganese	279.5 nm
Nickel	232.0 nm
Lead	283.3 nm
Zinc	213.9 nm
Copper	324.7 nm
Cadmium	228.8 nm

Sediment analysis:

The sediment samples were analyzed for Total carbon, Total Nitrogen, Total Phosphorus, Total sulphure and Major % Minor element. Samples were air dried and grinded for analysis.

TOTAL NITROGEN:

Nitrogen was determined by **Kjeldahl method** by using Steam distillation. Free ammonia was liberated from the solution by steam distillation in the presence of excess alkali. The distillate was collected in a receiver (50ml conical flask) containing excess Boric Acid with indicator and nitrogen was determined by acid titration.

A steam distillation apparatus was set up and steam was passed through the apparatus for 30mts. Steam Blank (25ml distillate) was titrated with N/140HCl. 10 ml aliquot of sample solution (digested in block digester) was transferred to the reaction chamber of the Nitrogen still and 10 ml of 40% NaOH (prepared by dissolving 400gm NaOH in distilled water and making 1L cool solution finally) was added. Steam distill immediately into 5ml of boric acid containing 4 drops of the mixed indicator (prepared by dissolving 0.099gm Bromocresol green, 0.066gm Methyl red, and 0.011gm Thymol blue in 100ml ethanol). Now 25ml of the distillate was titrated against N/140HCl to the end point when the indicator was changed from initital green through grey to a definite pink and the volume of standared HCl consumed was noted down using micro-burette.

Kjeldahl- Nitrogen was calculated using the following equation:

$$\%N = \frac{\text{Corrected vol. (ml) of N/140HCl} * 0.1}{\text{Weight of the sample (in gm)}}$$

Corrected vol. (ml) of N/140HCl = (A-B)

A =ml of Standared acid required for the Blank

B =ml of Standared acid required for the Sample

Carbon and Sulfur analysis

Carbon and Sulfur were analyzed using **ELTRA** (CS 1000) Carbon- Sulfur analyzer. Before analysis, sediment samples were made free of halogens by washing with distilled water. Untreated samples were used for determining Total carbon. For removing organic carbon, samples were treated with 30% H_2O_2.

The measuring method is based on the principle of sample combustion and analysis of gases given off through infrared absorption. The sample was put in a ceramic boat, which is made free of any carbon and pushed into silicon carbide furnace set at a temperature of 1100°C. The combustion occurs in presence of oxygen supplied and the carbon present in the sample is converted to CO_2 and is carried to the infrared absorber by oxygen, which also act as a carrier gas. The flow of oxygen was maintained to a constant value through an electronic flow regulator. The moisture traps ensure that dry gas mixture reaches the infrared cell. The infrared cell signals are selective and respond to CO2 concentratration in the gas mixture. The signals are electronically linearised, integrated and percentage of carbon in the given weight of sample is consequently shown digitally.

Analysis of major and minor elements:

Fine ground homogengenized sediments were taken in the beaker and heated with 30% (v/v) H2O2 **(Jackson, 1973)** for removal of organic matter. The treatment was repeated until the CO2 emission stopped. Analyses of Major and Minor elements were carried out by the two solution methods (Shapiro, 1975). Solution "A" was used for silica, Alumina and Phosphorus analysis and solution "B" was used for metal analysis.

Solution 'A'

0.025 gm of finely powdered sediment was taken in 50ml Nickel crucible and 3-4 pellets of NaOH were added to it. The crucible was gently heated on a furnace in order to mix sediment melt pellets, and then the crucible was constantly heated to dull redness for 30 mts. Then the crucible was allowed to cool down to room temperature. 10 ml of distilled water was added in the crucible and kept overnight. The solution was transferred to 250ml volumetric flask with the help of a policeman. 5ml of (1:1) HCl and 25ml of water was added. This solution was boiled till it was clear and the total volume was made up to 250 ml by adding distilled water.

Silica Analysis:

0.8ml of solution 'A', Standared solution (Canadian soil standared i.e.SO1, SO2, SO3, SO4) and reagent blank were transferred to 50ml Teflon beaker. 20ml of distilled water was added to each beaker. 0.2ml of Ammonium molybdate solution (prepared by dissolving 1.875 gm. ammonium molybdate in 19ml distilled water and adding 6ml 20% (v/v) H_2SO_4) was added and kept for 10 minutes. 0.4ml of 10 %(w/v) Tartaric acid was added by swirling the beaker. 0.1ml of reducing reagent (prepared by dissolving 0.07gm sodium sulphite in 1.0ml-distilled water and then 0.015gm 1-amino-2-naphthol-4-sulphonic acid was added and stirred well until dissolved. 9ml of 10 %(w/v) sodium bisulphite solution was added to it and mixed well) was added and samples properly stirred and kept for 30 minutes. Optical density was measured at 650 nm by **Cecil Spectrophotometer-594**.

Alumina Analysis:

15 ml of solution 'A' (Sample, Standared and Blank) was taken in 100 ml volumetric flasks. 2 ml calcium chloride solution (prepared by dissolving 7gm $CaCO_3$, 100ml of water, and 15ml of conc. HCl and diluted to 500ml) was added. 1 ml of Hydroxylamine hydrochloride solution (prepared by dissolving 5gm of hydroxylamine hydrochloride in 50ml) was added by swirling the flask. 1 ml of potassium ferricynide (0.75%) was added to each flask and mixed. 2 ml of Thioglycolic acid solution (4%) was added and kept for 5 mts. 10ml of Buffer solution (prepared by dissolving 100gm of sodium acetate in water and adding 30gm glacial acetic acid and diluted to 500ml) was added and kept 10mts. 10ml of Alizarin Red-Solution (0.05%) was added to each flask and the volume was diluted to 100ml

by adding distilled water. The samples were properly stirred and kept for 50 minutes. The absorbance was measured at 470 nm using **Cecil Spectrophotometer-594.**

PHOSPHATE ANALYSIS:

Total phosphorus in sediment was determined by **Ascorbic acid method (APHA, 1985)**. Phosphate Standard solution ranging from 0.1 to 3 ppm was prepared using KH_2PO_4. 40 ml of each sample and standared solution was pippeted out in 50 ml volumetric flask and 5ml of Ammonium Antimony solution (prepared by dissolving 4.8 gm ammonium molybdate and 0.1 gm potassium antimony tartarate in 400ml 4N H2SO4 and making the total volume to 500 ml with the same acid) and 2 ml of ascorbic acid solution (2%w/v) was added and mixed well. The mixture was diluted to 50 ml and optical density was measured at 650 nm. using **Cecil Spectrophotometer (Model No. 594)**. A graph was plotted between concentrations of the standards and optical density and sample concentrations were obtained from this graph.

Solution 'B'

0.1gm of finely ground sample was transferred to the Teflon crucible and 2ml of aqua regia (HNO3 and HCl ratio 1:3) and 5ml HF were added to each crucible, these were then sealed in metallic cases. The crucible was heated for 1.5 hrs at 100°C and then allowed to cool down to room temperature. 5.6gm of Boric acid crystal (H3BO3) was dissolved in 20 ml distilled water and then added to the bomb content that was made up to 100ml. The solution was transferred to polypropylene bottles for storage. The sample was left undisturbed overnight to allow the formation and setting of borosilicate from the solution. The gelatinous precipitate is separated by centrifugation. The solution thus obtained was used for analysis of metals by using Shimadzu-AA-6800, Atomic absorption spectrophotometer using air-acetylene flame.

Chapter V

RESULT &DISCUSSION

RESULT & DISCUSSION

RIVER WATER CHEMISTRY

NARMADA RIVER:

pH, EC and TDS:

The pH, which is a measure of the hydrogen ion activity in water, is controlled by chemical reactions that produce or consume hydrogen ions. Therefore, the pH of natural water is an index of the state of equilibrium reactions in which the water participates. pH in the water bodies can be explained fundamentally by the natural processes of weathering, evaporation and CO_2 gas equilibrium (Garrels and Mackenzies, 1967).

With an average pH 7.66 (range 6.72 – 8.12) in monsoon and 7.57 (range 6.76 – 8.16) in post monsoon, the Narmada river water is almost alkaline in nature. pH shows a downstream increase, though not very systematically (table 5.1a,b). The short-term control of pH in natural water is dominated by the carbonate equilibria. Several workers (Goel *et. al.,* 1985; Sarana and Adoni, 1982) have demonstrated the dependence of pH on the biological activity. Increase of pH in surface water is also related to metabolic activities of autotrophs, which by utilizing carbon dioxide (CO_2) during photosynthesis reduce hydrogen ion concentration in the water system. Subramanian (1979) observed that pH was higher than the additional pH – buffering mechanism operated in the Indian River systems.

Conductivity is a numerical expression of the ability of an aqueous medium to carry an electric current. This ability depends on the presence of ions; there total concentration, mobility, valance and relative concentrations and the temperature of measurement (APHA 1985). Thus Electrical Conductivity (EC) of any water reflects the dissolved constituents in the water. Average conductivity of Narmada river water is 420.22 μs/cm [range 390-150]. There is a downstream increase in conductivity but it is not uniform (table 5.1a, b).

The total dissolved solid (TDS) is the net effect of all cations and anions present in water, though it can be calculated by multiplying conductivity, expressed in proper units, by 0.7 (Davis and De Weist, 1962). Average TDS in Narmada (monsoon) is 169.56 ppm (range 105 -273 ppm). TDS shows a downstream increase almost uniformly. Average TDS in Narmada (post monsoon) is 96.83 ppm (range 51.10 – 151.20 ppm). TDS shows a fluctuating value all along the river course.

Fig 5.1 to 5.4 depicts the variation of the various parameters in both the seasons (monsoon and post monsoon) in Narmada and Tapti rivers all along its course.

BICARBONATE, CALCIUM AND MAGNISIUM

The bicarbonate content of the river Narmada (monsoon) ranges from 20.51 to 143.24 ppm with an average value of 102.33ppm, which is about 65% of the TDS. Calcium and magnesium, which are invariably associated with the occurrence of bicarbonate in the water, represents approximately 13% and 9% of the TDS. On an average, bicarbonate makes about 72% of the anions and calcium and magnesium makes 49% of the cations. In the post monsoon, bicarbonate makes 64% of the anions and calcium and magnesium makes about 41% of cations. The observation is in tune with the conclusion arrived at by Subramanian (1979) that in Indian rivers, bicarbonate is the most abundant ion. This also indicates that intense chemical weathering is taking place in the entire river basin.

The possible of sources of bicarbonate in surface water are atmospheric CO_2, dissolution of flying stones and dolomite, weathering of primary and secondary minerals and organic minerals (Garrels and Mackenzie, 1971). The regional geology of the Narmada river basin can be considered to favor dissolution of carbonates as probable source for calcium and magnesium in the river.

Raymahashay (1986) has shown that the variation in the bicarbonate in the Indian rivers is primarily controlled by varying silicate fraction resulting from kaolinization reactions.

The predominant compound in most inland waters is $CaCO_3$. However it is one of the least soluble compounds. Only a small amount of $CaCO_3$ can be dissolved in water. But in presence of carbonic acid (H_2CO_3), $CaCO_3$ got converted to calcium bicarbonate ($CaHCO_3$) In standard fresh water, calcium is the dominating cation.

Calcium and magnesium have similar behavior as observed in hydrosphere. The source of calcium consists mainly of calcite, dolomite, calcium plagioclase and gypsum, while magnesium comes from amphiboles, pyroxenes, olivine and biotite as well as dolomite. Calcium and magnesium show correlation (Table 5.2) among themselves(r =0.68) and also with bicarbonate (Ca-HCO_3: 0.80 and Mg-HCO_3: 0.94) (fig. 5.5 – 5.7). In the post monsoon also, Ca and Mg show good correlation among themselves (table: 5.3) and only Mg shows good correlation with bicarbonate (Ca-HCo_3: 0.40 and Mg-HCo3: 0.79) (fig 5.8 – 5.10).

Table 1.1a - **NARMADA WATER (MONSOON)**

All values are in ppm except EC and pH															
samp.sites	***pH***	***E.C.(μ**S)/cm*	***Na***	***K***	***Ca***	***Mg***	***flouride***	***chloride***	***nitrate***	***HCO3-***	***SO4***	***PO4***	***SiO2***	***DOC***	**TDS**	***TSM***
Amarkantak1	6.72	240	9.19	4.57	31.1	9.30	0.10	11.52	3.20	79.60	10.41	0.11	6.40	33.88	168	20.00
Amarkantak2	7.12	150	4.34	0.16	4.01	4.60	0.08	5.67	2.15	20.51	16.95	0.23	7.42	3.47	105	20.00
Mandala	7.74	160	11.52	1.15	11.9	13.63	0.16	8.86	1.82	75.05	18.82	0.38	11.14	4.66	112	153.33
Bhera Ghat	7.67	220	7.45	0.52	22.9	15.38	0.10	5.06	1.35	120.51	21.62	0.27	12.40	0.29	154	6.67
Guari Ghat	7.83	200	7.25	0.52	22.1	14.66	0.11	4.39	0.18	93.24	16.95	0.12	12.40	3.76	140	6.67
Tilwara Ghat	7.75	220	11.33	0.70	22.9	15.32	0.07	2.61	0.52	125.05	16.95	0.00	11.88	5.16	154	6.67
Hosangabad	7.61	260	11.71	1.15	29.6	16.82	0.14	4.95	0.71	111.42	12.28	0.18	12.12	4.03	182	26.67
Jhaneshwar	8.12	340	21.22	1.15	31.9	20.25	0.11	11.01	0.49	152.33	7.61	0.27	12.21	1.71	238	433.33
Bharuch	8.05	390	266.78	9.07	29.4	22.23	1.25	150.48	11.52	143.24	9.48	0.40	14.21	0.03	273	53.33
meannarmada	**7.62**	**242.22**	**38.98**	**2.11**	**22.85**	**14.69**	**0.23**	**22.73**	**2.44**	**102.33**	**14.56**	**0.22**	**11.13**	**6.33**	**169.56**	**80.74**
max	**8.05**	**390**	**266.78**	**9.07**	**29.42**	**22.23**	**1.25**	**150.48**	**11.52**	**143.24**	**9.48**	**0.40**	**14.21**	**0.03**	**273.00**	**53.33**
min	**6.72**	**150.00**	**4.34**	**0.16**	**4.01**	**4.60**	**0.07**	**2.61**	**0.18**	**20.51**	**7.61**	**0.00**	**6.40**	**0.03**	**105.00**	**6.67**
s.d.	**0.44**	**78.86**	**85.56**	**2.92**	**9.45**	**5.31**	**0.38**	**48.00**	**3.54**	**40.53**	**4.76**	**0.13**	**2.54**	**10.49**	**55.20**	**140.14**

Table 1.1b - NARMADA WATER (POST MONSOON)

All values are in ppm except EC and pH																
samp.sites	***pH***	***E.C.(μ**S)/cm*	***Na***	***K***	***Ca***	***Mg***	***flouride***	***chloride***	***nitrate***	***HCO3-***	***SO4***	***PO4***	***SiO2***	***DOC***	TDS	***TSM***
Amarkantak1	6.76	125.00	14.23	3.58	30.99	10.17	0.95	52.03	3.18	59.64	1.55	0.01	8.91	11.76	87.5	26.67
Amarkantak2	6.91	89.00	7.83	0.61	4.11	4.32	0.67	8.69	3.04	81.46	1.64	0.02	1.93	7.21	62.3	40.00
Mandala	7.96	178.00	8.80	0.25	12.24	15.64	0.16	14.99	1.72	130.03	12.28	0.12	12.91	6.88	124.6	6.67
Bhera Ghat	7.50	73.00	7.06	0.16	22.63	15.39	0.09	28.18	1.93	87.80	94.24	0.01	14.30	6.66	51.1	6.67
Guari Ghat	7.77	142.00	22.77	0.79	24.12	14.68	0.05	1.93	0.70	101.87	1.73	0.11	15.28	5.15	99.4	26.67
Tilwara Ghat	7.42	136.00	284.98	8.44	23.49	15.29	0.08	2.72	0.88	115.95	5.37	0.00	12.67	4.50	95.2	40.00
Hosangabad	8.14	177.00	17.34	0.70	29.83	18.46	0.04	2.72	0.50	165.23	78.18	0.08	10.72	6.56	123.9	40.00
Jhaneshwar	8.16	109.00	23.74	1.15	32.00	20.55	0.08	5.63	0.57	179.31	11.54	0.19	10.81	5.80	76.3	13.33
Bharuch	7.75	216.00	92.42	11.14	30.18	27.26	1.74	269.92	1.34	158.19	2.85	0.03	10.30	8.62	151.2	100.00
mean_n_Pm	**7.60**	**138.33**	**53.24**	**2.98**	**23.29**	**15.75**	**0.43**	**42.98**	**1.54**	**119.94**	**23.27**	**0.06**	**10.87**	**7.02**	**96.83**	**33.33**
max	**8.16**	**216.00**	**284.98**	**11.14**	**32.00**	**27.26**	**1.74**	**269.92**	**3.18**	**179.31**	**94.24**	**0.19**	**15.28**	**11.76**	**151.20**	**100.00**
min	**6.76**	**73.00**	**7.06**	**0.16**	**4.11**	**4.32**	**0.04**	**1.93**	**0.50**	**59.64**	**1.55**	**0.00**	**1.93**	**4.50**	**51.10**	**6.67**
s.d.	**0.50**	**45.91**	**90.84**	**4.05**	**9.46**	**6.38**	**0.59**	**86.66**	**1.02**	**41.28**	**36.14**	**0.07**	**3.92**	**2.14**	**32.14**	**28.48**

Table 5.2 Narmada monsoon water

Correlation Matrix

	PH	EC	NA	K	CA	MG	F	CL	NO3	HCO3	SO4	PO4	SIO2	DOC	TDS	TSM
PH	1.000	.492	.390	.055	.232	.844	.377	.346	.124	.713	-.084	.366	.932	-.794	.492	.463
EC	.492	1.000	.734	.709	.776	.806	.701	.719	.608	.798	-.779	.304	.519	-.123	1.000	.403
NA	.390	.734	1.000	.896	.291	.568	.997	.998	.955	.416	-.433	.533	.474	-.231	.734	-.025
K	.055	.709	.896	1.000	.450	.409	.895	.912	.941	.329	-.574	.392	.168	.217	.709	-.073
CA	.232	.776	.291	.450	1.000	.677	.264	.278	.189	.798	-.663	-.144	.347	.255	.776	.239
MG	.844	.806	.568	.409	.677	1.000	.552	.532	.343	.936	-.404	.321	.887	-.451	.806	.405
F	.377	.701	.997	.895	.264	.552	1.000	.997	.959	.381	-.402	.564	.472	-.232	.701	-.054
CL	.346	.719	.998	.912	.278	.532	.997	1.000	.969	.379	-.436	.548	.429	-.191	.719	-.034
NO3	.124	.608	.955	.941	.189	.343	.959	.969	1.000	.208	-.391	.547	.222	-.023	.608	-.133
HCO3	.713	.798	.416	.329	.798	.936	.381	.379	.208	1.000	-.409	.086	.763	-.285	.798	.397
SO4	-.084	-.779	-.433	-.574	-.663	-.404	-.402	-.436	-.391	-.409	1.000	-.085	-.008	-.276	-.779	-.496
PO4	.366	.304	.533	.392	-.144	.321	.564	.548	.547	.086	-.085	1.000	.313	-.402	.304	.361
SIO2	.932	.519	.474	.168	.347	.887	.472	.429	.222	.763	-.008	.313	1.000	-.742	.519	.180
DOC	-.794	-.123	-.231	.217	.255	-.451	-.232	-.191	-.023	-.285	-.276	-.402	-.742	1.000	-.123	-.189
TDS	.492	1.000	.734	.709	.776	.806	.701	.719	.608	.798	-.779	.304	.519	-.123	1.000	.403
TSM	.463	.403	-.025	-.073	.239	.405	-.054	-.034	-.133	.397	-.496	.361	.180	-.189	.403	1.000

a Determinant = .000

b This matrix is not positive definite.

Table 5.3: Narmada post monsoon water

Correlation Matrix[a,b]

		PH	EC	NA	K	CA	MG	F	CL	NO3	HCO3	SO4	PO4	SIO2	DOC	TDS	TSM
Correlat	PH	1.000	.452	-.066	-.121	.327	.717	-.372	-.003	-.867	.877	.288	.740	.537	-.545	.452	-.051
	EC	.452	1.000	.176	.513	.283	.645	.412	.582	-.382	.536	-.216	.135	.200	.110	1.000	.614
	NA	-.066	.176	1.000	.722	.130	.193	.006	.103	-.307	.096	-.262	-.372	.176	-.374	.176	.342
	K	-.121	.513	.722	1.000	.348	.502	.660	.744	-.103	.177	-.387	-.435	.006	.151	.513	.807
	CA	.327	.283	.130	.348	1.000	.653	.127	.302	-.464	.398	.152	.169	.439	.185	.283	.212
	MG	.717	.645	.193	.502	.653	1.000	.247	.618	-.672	.785	.126	.315	.494	-.128	.645	.458
	F	-.372	.412	.006	.660	.127	.247	1.000	.894	.430	-.064	-.395	-.406	-.426	.690	.412	.793
	CL	-.003	.582	.103	.744	.302	.618	.894	1.000	.066	.227	-.200	-.267	-.071	.438	.582	.834
	NO3	-.867	-.382	-.307	-.103	-.464	-.672	.430	.066	1.000	-.777	-.183	-.549	-.609	.713	-.382	-.068
	HCO	.877	.536	.096	.177	.398	.785	-.064	.227	-.777	1.000	.102	.627	.196	-.383	.536	.265
	SO4	.288	-.216	-.262	-.387	.152	.126	-.395	-.200	-.183	.102	1.000	-.109	.295	-.144	-.216	-.284
	PO4	.740	.135	-.372	-.435	.169	.315	-.406	-.267	-.549	.627	-.109	1.000	.256	-.349	.135	-.361
	SIO2	.537	.200	.176	.006	.439	.494	-.426	-.071	-.609	.196	.295	.256	1.000	-.388	.200	-.277
	DOC	-.545	.110	-.374	.151	.185	-.128	.690	.438	.713	-.383	-.144	-.349	-.388	1.000	.110	.218
	TDS	.452	1.000	.176	.513	.283	.645	.412	.582	-.382	.536	-.216	.135	.200	.110	1.000	.614
	TSM	-.051	.614	.342	.807	.212	.458	.793	.834	-.068	.265	-.284	-.361	-.277	.218	.614	1.000

[a] Determinant = .000

[b] This matrix is not positive definite.

Table 5.4:

Narmada monsoon metal

Correlation Matrix[a,b]

		FE	NI	CU	ZN	CR	CD	PB	MN	AS
Correlation	FE	1.000	-.274	.269	-.016	-.497	.587	.233	.306	.500
	NI	-.274	1.000	.084	-.195	.409	.182	-.825	-.176	-.555
	CU	.269	.084	1.000	.769	-.565	.595	-.160	-.240	-.068
	ZN	-.016	-.195	.769	1.000	-.544	.243	.027	-.423	-.269
	CR	-.497	.409	-.565	-.544	1.000	-.547	-.341	.156	-.287
	CD	.587	.182	.595	.243	-.547	1.000	.125	-.218	.084
	PB	.233	-.825	-.160	.027	-.341	.125	1.000	.022	.476
	MN	.306	-.176	-.240	-.423	.156	-.218	.022	1.000	.779
	AS	.500	-.555	-.068	-.269	-.287	.084	.476	.779	1.000

a. Determinant = .000

b. This matrix is not positive definite.

CHLORIDE, SODIUM AND POTASSIUM

Chloride ion is one of the major inorganic anions in useful water and wastewater. It usually ranks third among the anions in the chemical composition of rivers, lakes and other water bodies. The concentrations are extremely variable and depend for the most part on the soil and rock through which the river flows and also on its flow-rate. Average chloride content of the river Narmada (monsoon) is 22.73ppm (range 2.61 -150.48 ppm). Chloride shows fluctuating concentrations along the river. In the post monsoon, the average chloride concentration is 42.98ppm and it varies from 1.93 to 269.92 ppm. Here in this case also, chloride shows a fluctuating along the stream. The site Bharuch shows a sudden jump in chloride concentration in both monsoon and post monsoon, which is nothing but a reflection of sea, water influence. Presence of high chloride concentration in water has also been attributed to pollution (Gupta, 1994). Pollution from industries and domestic effluents could also be a contributing factor to the high chloride content in the water bodies. The monovalent cation sodium is the sixth most abundant element in the lithosphere. Sodium is very reactive and soluble, when leached from the rocks; its compounds tend to remain in solution. Sodium has therefore been reported to be the third most abundant metal in lakes and streams. With an average concentration of 38.98ppm, Na (monsoon) accounts for 22.98% of TDS and 46.53% of total cations. In the post monsoon, Na shows an average concentration of 53.24ppm (range 7.06 - 284.98ppm), Na accounts for 54.98% of TDS and 55.45% total cations.

For monsoon, K shows an average concentration of 2.11ppm (range 0.16 - 9.07 ppm), accounts for 0.012% of TDS and 0.025% of total cations. In the post monsoon, the average concentration of K is 2.98ppm (range 0.16 - 11.14 ppm) and makes 0.03% of TDS and also 0.03% of total cations. Na and K both fluctuate in their respective concentrations down the stream.

Depending upon the environmental settling of the river basin and the ionic constituents involved, the significance of atmospheric inputs to the river solute content varies Meybeck (1976) concluded that natural wet and dry fall out contribute 53% sodium ion and 72% chloride ion. Garrels and Mackenzie (1971) have estimate that 55% chloride ion in the river water is derived from rocks and the rest 45% from the atmosphere.

For a short period of time i.e. during monsoon, the rain water will significantly contribute Na and Cl to the river. Subramanian (1993) has already explored the considerable influence of rain water on the Indian River water chemistry. The other possible sources of these ions are ground water and surface runoff. Na^+ and K^+ together make 24% and 58% of TDS in monsoon and post monsoon respectively in the river Narmada. Millot (1970) concluded from has studies on the behaviour of Na^+ and K^+ in the hydrosphere that in the course of continental weathering. Na^+ turns out to be more mobile than K^+ and dominates in natural solutions. The present work shows results in tune with this conclusion. Little dissolved material is derived from the alteration of K-feldspar, and most of the K^+ comes from the dark silicate minerals like biotite and hornblende etc. only 15% of the river transport of K^+ is in dissolved form, while rest in particulates (Berner and Berner, 1987). The low level of K^+ content compared to Na+ may be due to its uptake by clay minerals.

Table 5.5: Ratio of Ca + Mg / Na + k in Narmada river

Narmada monsoon	Narmada Post Monsoon
(Ca + Mg)/(Na + K)	(Ca + Mg)/(Na + K)
0.52	1.00
0.50	0.32
0.21	0.19
0.31	7.57
0.21	0.61
0.34	0.43
0.28	0.37
5.34	0.47
0.43	1.80
1.09	1.44

The ratio (Ca^+ + Mg^+): (Na^++ K^+) has been used as an index to understand carbonate and silicate weathering in the river basin (Sarin and Krishnaswamy, 1984). Table 5.5. Shows this ratio in the Narmada basin. In monsoon, chloride ion shows good correlation with sodium ion (r = 1) obviously because of their similar origin that is atmospheric precipitation and ground water. In the post monsoon, the correlation is low (r=0.13). The correlation of potassium ion with bicarbonate ion (r=0.8) can be explained by silicate weathering in the following way.2K-feldspar + $2CO_2 + H_2O$ = Kaolinite+$2K^+$ +$2HCO_3^-$ + $2H_4SiO_4$

DISSOLVED SILICA

Silica Occurs in fresh waters in the forms of dissolved silicic acids that form stable solutions of H_4SiO_4 at much higher concentration than are encountered in fresh waters. The major source of silica is from degradation of aluminosilicate minerals. In rivers and lakes silicon which is usually expressed as silica SiO_2 or silicic acid (H_4SiO_4) in water analysis; commonly ranges from 2 to 25 mg/l. The world average of SiO_2 is 13 mg/l with relatively little variation among the continents. It has been observed by Siever and Woodforde (1973) that SiO_2 exist as H_4SiO_4 (monomeric silicic acid) at pH less then 9.

Dissolved silica (SiO_2) in the monsoon makes six to five percent of the TDS in the Narmada. In the post monsoon silica is 11.2% of the Silica concentration is almost uniform through out the river basin in the monsoon except the origin which shows comparatively less concentration then the average. In the post monsoon also uniformity maintain to some extent but the origin alike the monsoon shows less concentration then the average. The possible sources of dissolved silica seems to be Kaolinization of silicates such as feldspar, augite, biotite etc.Quartz has a solubility, at the earth surface temperature of 6.5ppm of dissolved silica whereas other form of silica have higher solubilities up to 115 ppm (Garrel and Mackenzie, 1971). Meybeck (1980) found out that the dissolved silica content of the river is controlled by the average temperature and geology of the basin. Rather monotonous geology of the river Narmada indicates that the mineral water reactions are primarily responsible for buildup of dissolved silica content in the river water.

SULPHATE, PHOSPHATE AND FLUORIDE:

The Sulphate ions are usually second to carbonate as the principal anion in freshwaters. However chloride occasionally surpasses it. The major source of sulphate in water is the weathering of rocks particularly pyrites, anhydrites and gypsum (Barner and Barner, 1987). Although volcanic emissions have added sulphur compounds to the air for many years; atmospheric source of sulphate have increased substantially since the onset of mans industrial activities. Man is now reported to contribute ten times more SO_4^{2-} than the annual contribution from volcanoes to the atmospheric load of this gas (Stoiber and Japsen, 1973). Coal combustion and paper manufacturing also produces gases and run off rich in sulphur compounds. These factors could have contributed to the sulphate content in the river.

These anions combined make 9% of TDS in the river Narmada in monsoon and in post monsoon they make 24% of TDS. The average concentration of SO_4^{2-}, PO_4^{3-} and F^-, in monsoon are 14.56, 0.22 and 0.23 ppm respectively while in post monsoon the concentration are 23.27, 0.06 and 0.43 ppm respectively SO_4^2 concentration shows decrease in downstream in river water in monsoon but in post monsoon it shows fluctuating concentration down the stream. SO_4^2 in river water is derived from various sources. Weathering of sulphide and sulphate minerals are the major sources of primary sulphur. Berner and berner in 1987 estimated that sulphur comes from cyclic salt (2%), rock weathering (33%), pollution (2%), fertilizers, industrial waste, fuel burning etc. and natural biogeochemically derived sulphate in rain (17%) with a minor fraction (5%) from volcanic activity. In Narmada River, weathering can be attributed for sulphate concentration in the river water.

PO_4^3 concentration increases down the stream of the river in monsoon as well as post monsoon. Its concentration increases drastically at Mandla and Jhaneswar. The obvious reason is effluent from agricultural and industrial waste respectively. Under natural condition the dissolved PO_4^3 concentration should not exceed 0.5ppm, as the solubility of PO_4^3 mineral is limiting (Subramanian 1984). The reported high values reflect addition of PO_4^3 from anthropogenic sources.

Fluoride is the most electronegative of all known elements ((electro negativity- 4.0; Pauling, 1960)) and it is the most reactive element in the environment. It rarely occurs free in nature but combines chemically to form fluorides. Therefore, in minerals, fluorine is generally found as the fluoride ion (F^-). The only rock-forming minerals that have fluorine as an essential constituent in the formula are topaz and fluorite. The other minerals in which fluorine is an essential component are accessory mineral fluoraphite, fluosmica, cryolite and villianmite. These fluoride minerals are sparingly soluble in water

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The variation in fluoride content is considered to be the result of the interplay of a number of factors of which the more important is factors determining the residence times of dissolved fluorides in the water i.e. chemical reactions especially involving species of Ca^2+ and F^-; atmospheric precipitation and dissolution of salt crust (Gaciri and Davies, 1992)

The F^- concentration shows asymmetric downstream fluctuations, both in monsoon and post monsoon season in the river basin. Bulk of F^- in water is derived from phosphate or fluorite minerals. The common F^- scavenging minerals are fluorite and CaF_2 (48.67% of F^-), topaz (20.7% of F^-) apatite (3.8% of F^-) and hydroxy apatite (deshmukh, 1974).

DISSOLVED ORGANIC CARBON (DOC):

DOC concentration in monsoon season is on an average 5.92 ppm (range,.03 - 3.88 ppm) where as in post monsoon its average value is 7.79 ppm ranging from 4.50 to 14.36 ppm. There is almost decreasing trend downstream except for few places where its value is little bit high as compared to the adjoining sites. At the origin it shows the highest value in the monsoon but in the post monsoon season the mouth is showing the highest value. In these cases the probable reason can be anthropogenic influences as well as death and decay of biota in the river basin.

TOTAL SUSPENDED MATTERS (TSM):

There are also solid particles either as sediments or as debris from soil washes out carried by river collectively known as Total Suspended Matters (TSM). TSM shows the average value of 116.00 ppm ranging from 6.67 to 433.33 ppm in the monsoon season In the post monsoon the average concentration is 44.85 ppm ranging from 60.67 to 66.67ppm. The trend downstream is fluctuating in both seasons.

TAPTI RIVER:

PH, conductivity, total dissolved solids (TDS):

With an average pH 7.94 (range 6.7 – 8.05) in monsoon and 8.16 (range 7.43 – 9.10), the Tapti river water is obviously alkaline in nature. PH shows fluctuating values in monsoon and decreasing but not very systematically in post monsoon (table5.6a, b) the average conductivity of Tapti river water are 242.22 µS/cm (range 150 - 390 µS/cm) and 138.33 µS/cm (range 73 - 216 µS/cm) in monsoon and post monsoon respectively. There is downstream increase in conductivity in both monsoon and post monsoon seasons. The conductivity shows correlation (table 5.7) with Na^+ (r =0.87); K^+ (r = 0.83); and F^- (r = 0.72); Cl^-(r = 0.68); HCO^{3-} (r = 0.67) in monsoon but in post monsoon it shows correlation (table 5.8) with Na^+ (r = 0.86); F^-(r = 0.87); Cl^-(r = 0.94); HCO^{3-}(r = 0.95); SO^{4-}(r = 0.96).

Table 5.6 (a): Tapti River Monsoon water

Tapti	*pH*	*E.C.(mS)/cm*	*Na*	*K*	*Ca*	*Mg*	*flouride*	*chloride*	*nitrate*	*HCO3-*	*SO4*	*PO4*	*SiO2*	*DOC*	TDS	*TSM*
Betul(Tapti)	7.94	240	10.16	1.24	20.39	17.33	0.08	6.22	0.73	147.78	8.55	0.71	13.19	9.61	168	46.67
Bhushaval	8.07	430	34.22	2.59	17.71	20.27	0.21	31.61	2.29	147.78	11.35	0.47	20	5.66	301	13.33
Jalgaon	7.91	410	27.62	2.14	15.6	19.80	0.08	67.28	4.68	134.15	14.15	0.39	17.74	5.19	287	33.33
Kojway	8.12	490	31.50	2.14	29.19	21.13	0.08	17.51	0.17	93.24	12.28	0.40	14.12	5.30	343	0.00
Ghandhi Bag	7.64	1430	463.16	12.67	17.43	21.93	1.39	149.79	3.15	193.24	15.08	0.61	14.26	3.60	1001	373.33
mean tapti	7.94	600.00	113.33	4.16	20.06	20.09	0.37	54.48	2.21	143.24	12.28	0.52	15.86	5.87	420.00	93.33
max	8.12	1430.00	463.16	12.67	29.19	21.93	1.39	149.79	4.68	193.24	15.08	0.71	20.00	9.61	1001.00	373.33
min	7.64	240.00	10.16	1.24	15.60	17.33	0.08	6.22	0.17	93.24	8.55	0.39	13.19	3.60	168.00	0.00
s.d.	0.19	473.18	195.78	4.79	5.38	1.75	0.57	58.02	1.83	35.79	2.56	0.14	2.89	2.23	331.23	157.55

Table 5.6 (b): Tapti River Post Monsoon water

Tapti	***pH***	***E.C.(mS)/cm***	***Na***	***K***	***Ca***	***Mg***	***flouride***	***chloride***	***nitrate***	***HCO3-***	***SO4***	***PO4***	***SiO2***	***DOC***	**TDS**	***TSM***
Betul(Tapti)	8.00	280.00	24.32	4.21	20.78	18.07	0.07	16.86	0.44	130.03	17.98	0.42	15.00	7.96	196.00	40.00
Bhushaval	9.10	660.00	98.84	2.32	18.49	20.28	0.09	33.07	0.68	242.66	27.87	0.21	3.00	11.22	462.00	13.33
Jalgaon	8.44	260.00	138.86	10.78	15.24	18.96	0.03	11.50	3.96	179.31	9.95	0.17	13.47	3.74	182.00	26.67
Kojway	7.82	430.00	92.42	3.67	30.41	22.18	0.17	20.26	1.32	221.54	14.99	0.00	13.33	9.81	301.00	173.33
Ghandhi Bag	7.43	1010.00	608.76	11.52	18.00	18.27	1.98	102.35	2.84	334.17	41.69	0.09	11.60	13.93	707.00	4086.67
mean_t_pm	**8.16**	**528.00**	**192.64**	**6.50**	**20.58**	**19.55**	**0.47**	**36.81**	**1.85**	**221.54**	**22.49**	**0.18**	**11.28**	**9.33**	**369.60**	**868.00**
max	**9.10**	**1010.00**	**608.76**	**11.52**	**30.41**	**22.18**	**1.98**	**102.35**	**3.96**	**334.17**	**41.69**	**0.42**	**15.00**	**13.93**	**707.00**	**4086.67**
min	**7.43**	**260.00**	**24.32**	**2.32**	**15.24**	**18.07**	**0.03**	**11.50**	**0.44**	**130.03**	**9.95**	**0.00**	**3.00**	**3.74**	**182.00**	**13.33**
s.d.	**0.64**	**313.32**	**236.23**	**4.31**	**5.84**	**1.70**	**0.85**	**37.49**	**1.51**	**76.30**	**12.56**	**0.16**	**4.78**	**3.81**	**219.32**	**1800.43**

Table 5.7: Tapti monsoon water

Correlation Matrix

		PH	EC	NA	K	CA	MG	F	CL	NO3	HCO3	SO4	PO4	SIO2	DOC	TDS	TSM
Correlation	PH	1.000	-.340	-.305	-.226	.265	.453	-.215	-.113	.161	-.192	-.629	.194	.326	-.099	-.340	-.037
	EC	-.340	1.000	.867	.830	-.372	.571	.720	.682	.118	.670	.339	.455	.137	-.182	1.000	.558
	NA	-.305	.867	1.000	.991	-.188	.615	.967	.908	.519	.698	.192	.399	.009	-.440	.867	.477
	K	-.226	.830	.991	1.000	-.188	.677	.981	.945	.607	.665	.144	.433	.093	-.461	.830	.406
	CA	.265	-.372	-.188	-.188	1.000	.027	-.071	-.215	-.007	-.459	-.466	-.435	-.633	-.525	-.372	.126
	MG	.453	.571	.615	.677	.027	1.000	.628	.716	.546	.362	-.269	.494	.408	-.514	.571	.383
	F	-.215	.720	.967	.981	-.071	.628	1.000	.941	.685	.635	.069	.350	.009	-.547	.720	.378
	CL	-.113	.682	.908	.945	-.215	.716	.941	1.000	.804	.590	.112	.382	.218	-.536	.682	.287
	NO3	.161	.118	.519	.607	-.007	.546	.685	.804	1.000	.247	-.132	.165	.257	-.580	.118	-.085
	HCO3	-.192	.670	.698	.665	-.459	.362	.635	.590	.247	1.000	-.055	.510	.154	-.142	.670	.688
	SO4	-.629	.339	.192	.144	-.466	-.269	.069	.112	-.132	-.055	1.000	-.370	.062	.108	.339	-.220
	PO4	.194	.455	.399	.433	-.435	.494	.350	.382	.165	.510	-.370	1.000	.372	.362	.455	.164
	SIO2	.326	.137	.009	.093	-.633	.408	.009	.218	.257	.154	.062	.372	1.000	.150	.137	-.263
	DOC	-.099	-.182	-.440	-.461	-.525	-.514	-.547	-.536	-.580	-.142	.108	.362	.150	1.000	-.182	-.413
	TDS	-.340	1.000	.867	.830	-.372	.571	.720	.682	.118	.670	.339	.455	.137	-.182	1.000	.558
	TSM	-.037	.558	.477	.406	.126	.383	.378	.287	-.085	.688	-.220	.164	-.263	-.413	.558	1.000

a Determinant = .000

b This matrix is not positive definite.

Table 5.8: Tapti Post Monsoon Water

Correlation Matrix[a,b]

		PH	EC	NA	K	CA	MG	F	CL	NO3	HCO3	SO4	PO4	SIO2	DOC	TDS	TSM
Correlat	PH	1.000	-.287	-.573	-.460	-.332	.183	-.654	-.517	-.214	-.305	-.286	.283	-.711	-.317	-.287	-.656
	EC	-.287	1.000	.858	.290	-.151	-.118	.871	.946	.084	.952	.964	-.399	-.442	.891	1.000	.859
	NA	-.573	.858	1.000	.717	-.292	-.362	.981	.960	.491	.868	.815	-.417	-.009	.617	.858	.984
	K	-.460	.290	.717	1.000	-.550	-.546	.620	.509	.910	.385	.239	-.243	.379	-.106	.290	.644
	CA	-.332	-.151	-.292	-.550	1.000	.766	-.191	-.220	-.480	-.072	-.233	-.408	.230	.208	-.151	-.215
	MG	.183	-.118	-.362	-.546	.766	1.000	-.372	-.335	-.260	.061	-.307	-.639	-.241	.080	-.118	-.395
	F	-.654	.871	.981	.620	-.191	-.372	1.000	.980	.340	.841	.858	-.347	.035	.704	.871	.999
	CL	-.517	.946	.960	.509	-.220	-.335	.980	1.000	.234	.891	.939	-.321	-.156	.797	.946	.976
	NO3	-.214	.084	.491	.910	-.480	-.260	.340	.234	1.000	.276	-.045	-.410	.288	-.339	.084	.364
	HCO	-.305	.952	.868	.385	-.072	.061	.841	.891	.276	1.000	.839	-.646	-.392	.791	.952	.829
	SO4	-.286	.964	.815	.239	-.233	-.307	.858	.939	-.045	.839	1.000	-.148	-.408	.894	.964	.848
	PO4	.283	-.399	-.417	-.243	-.408	-.639	-.347	-.321	-.410	-.646	-.148	1.000	.075	-.299	-.399	-.336
	SIO2	-.711	-.442	-.009	.379	.230	-.241	.035	-.156	.288	-.392	-.408	.075	1.000	-.419	-.442	.051
	DOC	-.317	.891	.617	-.106	.208	.080	.704	.797	-.339	.791	.894	-.299	-.419	1.000	.891	.681
	TDS	-.287	1.000	.858	.290	-.151	-.118	.871	.946	.084	.952	.964	-.399	-.442	.891	1.000	.859
	TSM	-.656	.859	.984	.644	-.215	-.395	.999	.976	.364	.829	.848	-.336	.051	.681	.859	1.000

[a] Determinant = .000

[b] This matrix is not positive definite.

Table 5.9: Tapti monsoon metal

Correlation Matrix[a,b]

		FE	NI	CU	ZN	CR	CD	PB	MN	AS
Correlation	FE	1.000	-.308	-.267	.694	-.623	.275	.069	.389	-.229
	NI	-.308	1.000	.545	-.296	.742	.294	.835	-.993	.821
	CU	-.267	.545	1.000	.265	.017	.487	.063	-.618	-.030
	ZN	.694	-.296	.265	1.000	-.747	.114	-.269	.303	-.561
	CR	-.623	.742	.017	-.747	1.000	-.248	.703	-.730	.895
	CD	.275	.294	.487	.114	-.248	1.000	.161	-.297	-.009
	PB	.069	.835	.063	-.269	.703	.161	1.000	-.764	.939
	MN	.389	-.993	-.618	.303	-.730	-.297	-.764	1.000	-.766
	AS	-.229	.821	-.030	-.561	.895	-.009	.939	-.766	1.000

a. Determinant = .000

b. This matrix is not positive definite.

The average TDS in river Tapti is 420 ppm (range 168 – 1001 ppm) in monsoon and 369 ppm (range 182 – 707 ppm) in post monsoon. TDS shows fluctuating values down the stream in monsoon as well as post monsoon.

BICARBONATE, CALCIUM AND MAGNESIUM

In monsoon, HCO^{3-} content of river Tapti ranges from 93.24 – 193.24 ppm with an average value of 143.24 ppm, which is about 35% of the TDS. Calcium and magnesium which are invariably associated with the occurrence of bicarbonates in the water represent approximately 5% each of the TDS. On an average, calcium and magnesium make about 30%of cations and bicarbonates make approximately 58% of anions. In post monsoon, the bicarbonate content ranges from 130.03 to 334.17 ppm with an average value of 221.54. Calcium and magnesium represent approximately 6%and 5%respectivly of the TDS. On an average, calcium and magnesium make 17% and 75%.

CHLORIDE, SODIUM AND POSTASSIUM

In monsoon the average chloride content of the river Tapti is 36.81ppm ranging from 11.50 – 102.35 ppm. Chloride shows a gradual increase except one site, which is the reflection of less municipal waste disposal. In the post monsoon season, there are fluctuations in the chloride concentration along the stream. The average concentration is 36.81 ppm ranging from 11.50 to 102.25 ppm.

With an average concentration of 113.33 ppm, sodium in monsoon season account for 26.98% of TDS and 81% of total cation. These figures cannot be considered to define the characteristics of the river basin because of the sudden jump in the value in Gandhibagh side, which is near to the estuary, down the stream the sodium concentration fluctuates. In the post monsoon season also the same trend was observed, with average concentration 192.64 ppm ranging from 24.32 to 608.7ppm.

Table 5.10: Ratio (Ca + Mg)/(Na + K)

tapti Monsoon (Ca + Mg)/(Na + K)	tapti post monsoon (Ca + Mg)/(Na + K)
0.84	4.38
0.30	17.10
0.97	2.61
0.67	0.73
12.09	1.83
2.93	4.96

Potassium concentration fluctuates in both of the season but with in a narrow range. Its average value is 4.16 ppm and 6.50 ppm in monsoon and post monsoon seasons respectively.

Sodium and potassium together make 28% and 54% of the TDS respectively in monsoon and post monsoon season in the basin. In the course of continental weathering, sodium turns out to be more mobile than Potassium then potassium and dominates in the natural solutions. The low level of potassium content compared to sodium may be due to its uptake by clay minerals.

The ratio (Ca^{2+} + $Mg^{2+)}$ / (Na^{+} + K^{+}) has been used to understand carbonate and silicate weathering in the river basin. (Table 5.10) shows this ratio in the basin. High abundance of silica and lower (Ca^{2+} + $Mg^{2+)}$ / (Na^{+} + K^{+}) suggest that the contribution of these ions is by silicate weathering.

Chloride shows a good correlation with sodium ($r = 0.96$ for monsoon and $r = 0.97$ for post monsoon). Obviously because of their similar origin that is atmospHeric precipitation and ground water.

DISSOLVED SILICA (SiO_2)

Dissolved silica makes 3.7% and 3.1% of the TDS in monsoon and post monsoon respectively, in the river Tapti. The SiO_2 concentration fluctuates asymmetrically throughout the river basin. The possible source of dissolved silica seems to be kaolinization of silicates. Mineral water reactions are primarily responsible of buildup of dissolved silica content in the river water.

SULPHATE, PHOSPHATE AND FLUORIDE

These ions combined make 3.1% and 5.5% of TDS in monsoon and post monsoon season respectively in the river Tapti. The average concentration of SO_4^{2-}, PO_4^{3-} and F^- are 12.28, 0.52 and 0.37 ppm in monsoon and 22.49, 0.18 and 0.7 ppm in post monsoon respectively.

SO_4^{2} concentration shows almost increasing trend in monsoon and fluctuating trend in post monsoon down the stream. The reasons may be rock weathering, pollution, fertilizers etc. The strong correlation ($r = 0.94$) between sulphate and chloride in the post monsoon explains their similar origin from ground water (table. 5.8).

PO_4^{3-} shows fluctuating trends in monsoon and decreasing trend in post monsoon. The reported high value at the upstream sites reflects addition of PO_4^{3} from anthropogenic sources.

F^- Concentration shows asymmetric downstream fluctuation in the river, the source may be phosphate or fluoride mineral.

DISSOLVED ORGANIC CARBON (DOC):

The average DOC concentration is 5.86 ppm ranging from 3.60 to 9.61 ppm in the monsoon season. In the post monsoon, its average concentration is 8.65 ppm ranging from 3.74 to 13.93 ppm. There is almost constancy down the stream except at the origin, which is showing the highest concentration. But in the post monsoon there is no definite trend along the river stretch i.e. fluctuation in DOC values is observed down the stream. The high concentration is due to death and decay of plants and animals in the basin.

TOTAL SUSPENDED MATTERS (TSM):

There are also solid particles either as sediments or as debris from soil wash out carried by river collectively known as Total Suspended Matters (TSM). The average TSM concentration is 205.56 ppm ranging from 0.00 to 766.67 ppm in the monsoon season where as in post monsoon 755.56 ppm ranging from 13.33 to 4086.67 ppm. Both the highest value is detected for Gandhi bag in Surat where the water is muddy. There is almost increasing trend downstream in both seasons.

The comparison between various parameters in monsoon and post monsoon season in Narmada and Tapti rivers respectively, has been depicted in fig 5.11 – 5.13. Fig 5.14 – 5.15 show the variation in metal, nonmetals and anions in Tapti and Narmada River in both these seasons.

MINERAL STABILITY

Mineral stability offers an opportunity to study the equilibrium between silicate minerals and natural waters. The principle behind such an approach is that water derives its composition from the parent rock in the weathering region and suspended sediments owe their mineralogical composition partly to the parent rock and partly to the chemical reaction of rock and water (Garrels and Christ, 1965).

Thus by studying the water chemistry stable mineral assemblages can theoretically be predicted

In the current study an attempt has been made to apply this approach to the studied Riverine environment.

The mineral stability diagram (Figures 5.16a,b,c,d,e) gives the following information:
Narmada river waters are mainly in the range of stability field of kaolinite with a few points in the chlorite range. This implies that the chemistry of the waters in Narmada river basin is favoring kaolinite formation.

The mineral stability diagram (Figures 5.17 a, b, c, d, e) gives the following information:

Tapti river waters are mainly in the range of stability field of kaolinite with a few points in the chlorite range. This implies that the chemistry of the waters in Tapti is similar to Narmada river basin and is favoring kaolinite formation. Thus independent of the cation considered, kaolinite is expected as stable assemblages.

Mechanisms controlling water chemistry:

Since the source of ions in water is diverse, one can use the water chemical data to arrive at some common controlling factors. Gibbs (1970) evolved a set of chemical factors that regulate the chemical composition of water bodies. (Figure 5.18, 5.19) shows the Gibbs diagram that depicts the major parameter such as sodium, potassium, calcium and TDS that has bearing on the origin of the major chemicals in the given water bodies.

Thus, the source of major ions in water can be defined by plotting the samples according to the variations in weight ratios of (Na+K) / (Na+K+Ca) as function of total dissolved solids (TDS) (Gibbs, 1970). Gibbs diagrams have been used in the current study to decipher the major mechanisms controlling the ion chemistry in the study area.

The important natural factor, which has been recognized, is weathering of individual minerals in soil and rocks. Therefore, rock weathering is the main controlling mechanism of the water chemistry.

FACTOR ANALYSIS:

Factor analysis aims to explain observed relations among numerous variables in terms of simpler relations. It is also a way of classifying manifestations or variables but not the producer of taxonomy.

A Statistical Packages for Social Sciences (SPSS) software was used to extract the factors governing water chemistry for monsoon and post monsoon season in Narmada river. Factors were extracted by using varimax rotation. Factor rotation gives values close to -1, 0, +1, which means negative, no and positive contribution respectively by a variable towards a factor.

Communalities attached to each row of a matrix gives an appreciation of how well each variable is explained by m factors. If more communalities are less than 0.8, it means more no. of factors are required. Factor score is related to the intensity of the chemical process described by each factor sample wise. Extreme negative values reflect essentially unaffected by the process and positive score reflects area most affected. Near zero scores mean, areas affected to an average degree. This interpretation becomes otherwise if the factor (varimax rotated) has negative value.

Monsoon season

Table 5.9 shows the varimax rotated component matrix for the Narmada River. After the rotation 5 factors were extracted from principle factor matrix (eigen values ≥ 1).

Factor 1: This consists of Na, K, F, Cl, NO_3^-, electrical conductivity and TDS. This factor explains the complex interplay of these variables. Atmospheric precipitation, chemical weathering and ground water seepage are the main source responsible for this factor. This factor accounts for the ~39% of the total variance.

Factor 2: SO_4^{2-}, SiO_2 and Ni are the main components of this factor. It controls the pH of the river water and explains 21.78% of the total variance.

Factor 3: This factor explains the bicarbonate dissolution. Ca, Mg and HCO_3^- constitute this factor. It explained 18.224% of the total variance.

Factor 4: Fe, Cd and As constitute this factor, which indicated towards some anthropogenic sources.

Factor 5: Cu, Zn and TSM are the major component of this factor. As compared to the above four this factor only explains 9.8% of the total variance and have least influence over river chemistry.

Post Monsoon

For this season 4 components were extracted using the very same varimax rotation methods (table 2).

Factor 1: K, F, Cl, DOC, TDS and TSM are the major inputs in this factor, which explains 35.8 % of the total variance of the sample population. This factor points towards the organic load in the river system and also indicates the influence of domestic discharge. 3

Table 5.9: rotated component matrix for monsoon season in Narmada River

	1	2	3	4	5	Communality
pH	0.18	0.82	0.49	0.04	0.23	0.971
EC	0.68	0.08	0.53	0.39	0.26	0.971
Na	0.97	0.17	0.13	0.00	-0.02	0.993
K	0.94	-0.27	0.18	-0.03	0.04	0.995
Ca	0.25	-0.27	0.84	0.32	0.12	0.952
Mg	0.41	0.45	0.74	0.14	0.21	0.998
F	0.97	0.17	0.11	-0.02	-0.04	0.992
Cl	0.98	0.13	0.10	-0.02	0.00	0.995
NO3	0.99	-0.04	-0.04	-0.09	-0.02	0.999
HCO3	0.27	0.29	0.86	0.13	0.21	0.956
SO4	-0.46	0.32	-0.27	-0.67	-0.38	0.950
PO4	0.56	0.41	-0.29	-130.00	0.45	0.777
SiO2	0.28	0.75	0.59	-0.03	-0.04	0.953
DOC	-0.06	-0.99	0.03	-0.07	0.06	0.999
TDS	0.68	0.08	0.53	0.39	0.26	0.970
TSM	-0.07	0.23	0.14	0.34	0.90	0.995
Fe	-0.17	-0.11	-0.31	0.82	0.10	0.816
Ni	-0.11	0.96	0.17	-0.07	-0.06	0.970
Cu	-0.09	0.10	0.22	0.40	0.83	0.921
Zn	0.18	-0.16	0.28	-0.03	0.92	0.994
Cr	-0.46	0.32	-0.27	-668.00	-379.00	0.900
Cd	-0.22	0.18	0.32	0.82	0.26	0.911
Pb	-0.06	-0.89	0.11	0.22	-0.15	0.874
Mn	0.11	-0.05	-0.92	0.19	-0.18	0.918
As	0.08	-0.49	-0.61	0.51	-0.17	0.903
Eigen values	**9.74**	**5.44**	**4.58**	**2.47**	**1.60**	
%variance	**38.92**	**28.78**	**18.23**	**9.90**	**6.40**	
Cumulative Variance	**38.92**	**60.71**	**77.93**	**88.83**	**95.28**	

Factor 2: This is the second most important factor, which explains 29.8% of the total variance. This explains the bicarbonate dissolution into the river system. Mg and phosphate are the other variables present in this factor.

Table 5.10: Rotated component matrix for post monsoon in Narmada River

	Components				
	1	2	3	4	Comunality
pH	-0.02	0.94	-0.02	0.309	0.977
EC	0.73	0.51	0.06	-1.47E-02	0.799
Na	0.19	-0.04	0.96	3.24E-05	0.95
K	0.8	-0.11	0.58	3.69E-02	0.975
Ca	0.37	0.21	0.02	7.04E-01	0.672
Mg	0.57	0.6	0.12	4.93E-01	0.944
F	0.9	-0.33	-0.17	-1.75E-01	0.907
Cl	0.94	-0.04	-0.03	1.02E-01	0.892
NO3	0.04	-0.82	-0.39	3.57E-01	0.916
HCO3	0.26	0.87	0.05	1.48E-01	0.845
SO4	-0.32	-0.02	-0.19	7.19E-01	0.658
PO4	-0.25	0.84	-0.33	-7.57E-02	0.878
SiO2	-0.15	0.38	0.26	6.68E-01	0.68
DOC	0.51	-0.55	-0.58	1.07E-02	0.888
TDS	0.73	0.51	0.06	-1.47E-02	0.799
TSM	0.89	-0.01	0.24	-1.14E-01	0.814
Eigen values	**5.73**	**4.77**	**1.83**	**1.41E+00**	
%variance	**35.81**	**29.81**	**11.43**	**8.79E+00**	
Cumulative Variance	**35.81**	**6.62**	**77.06**	**8.58E+01**	

Factor 3: Only Na comes under this factor and explains the 11.43% of the total variance.

Factor 4: Ca, SO_4^{2-} and SiO_2 comes under this factor. The sources for these components are may be the agricultural practices in that area or the lithology of that area. But this factor influences the river chemistry the least as it explained only the 8.8 % of the total variance.

For Tapti river analysis of collected samples remain inconclusive due to paucity of time. Therefore factor analysis and further examination could not be carried out. We propose it to do it in future.

River Sediment Chemistry:

Narmada

Carbon, Sulphur and Nitrogen:

On an average in monsoon and post monsoon, the total carbon content in Narmada are 0.73% (range 0.35 – 1.39%) and 2.43% (range 0.59 – 9.74%); out of this, the organic and inorganic, fractions are 0.25% (range 0.01 – 0.81%) and 0.88% (range 0.06 – 3.37%) and 1.54% (range 0.19 – 9.67%) respectively (table 5.11 and 5.12). But the trend is asymmetrical downstream of the river in both season. In monsoon, the maximum concentration of TC and IC are at Mandla, and OC at Tilwana ghat. In post monsoon, the maximum concentration of TC and IC are detected at Bhera Ghat and OC is at Amarkantak II. Almost the same trend is observed in case of IC and OC downstream.

Suspended sediments were found from only four sites although samples were collected from all the mentioned sites but in monsoon only. The carbon was analysed only at one site that is Hoshangabad (1.55%). The OC and IC are 0.78% and 0.88% respectively. Sulphur was not detected at any site except Mandla (0.003%) in monsoon but in post monsoon sulphur was not detected at any site. More significant spatial variation was observed in TN all along the river basin in monsoon but in post monsoon at origin TN was found high comparatively. The average concentration is 0.49%(range 0.33 – 0.67%) and 0.56% (range 0.27 – 0.93%) in monsoon and post monsoon respectively. Higher concentration of IC compared to OC almost all along the basin reflects that influence of anthropogenic sources is less and there is very low biota load.

Table 5.11: Carbon, Sulphur and Nitrogen along with Alumina, Silica and Phosphate(x10 mg/g) concentration in Narmada River for Monson season

sample sites	*SiO_2*	*Al_2O_3*	*PO_4^{3-}*	*T.C.%*	*I.C.%*	*O.C.%*	*T.S.%*	*I.S.%*	*O.S.%*	*T.N.%*	*C/N*
Narmada											
Amarkantak1	23	15.22	0.497	0.47	0.22	0.24	0	0.00	0.00	0.40	1.94125
Amarkantak2	19.25	25.79	0.781	0.35	0.21	0.14	0.00	0.00	0.00	0.67	0.88025
Mandala	17.5	15.12	0.476	1.39				0.00	0.0033	0.53	4.333438
Bhera Ghat	17.75	17.16	0.402	0.83	0.79	0.04	0	0.00	0.00	0.47	2.97
Guari Ghat	26.25	24.08	0.328	0.48	0.30	0.17	0	0.00	0.00	0.47	1.710357
Tilwara Ghat	17.5	9.10	0.602	1.07	0.26	0.81	0	0.00	0.00	0.60	2.985833
Hosangabad	21	16.17	0.781	0.45	0.44	0.01	0.0014	0.00	0.0014	0.33	2.2315
Jhaneshwar	15	13.22	0.539	1.07	0.74	0.33	0.0013	0.00	0.0013	0.47	3.810714
Bharuch	22.75	14.23	0.528	0.51	0.28	0.23	0	0.00	0.00	0.47	1.825357

Table 5.12: Carbon, Sulphur and Nitrogen along with Alumina, Silica and Phosphate(x10 mg/g) concentration in Narmada River for Post Monson season

sample sites	***SiO_2***	***Al_2O_3***	***PO_4^{3-}***	***T.C.%***	***I.C.%***	***O.C.%***	***T.S.%***	***I.S.%***	***O.S.%***	***T.N.%***	***c/n***
Narmada											
Amarkantak1	33.75	13.46	0.084	1.67	0.41	1.25	0.0035	0.0018	0.0017	0.27	10.43125
Amarkantak2	20	30.38	0.061	3.75	0.38	3.37	0	0.00	0.00	0.93	6.688036
Mandala	17	18.59	0.036	1.16	0.90	2.23	0.0031	0.00	0.00	0.67	2.887625
Bhera Ghat	5	2.18	0.6	9.74	9.67	0.06	0.0008	0.00	0.0008	0.53	30.43313
Guari Ghat	23	15.13	0.064	0.59	0.26	0.33	0	0.00	0.00	0.67	1.464
Tilwara Ghat	16.75	8.59	0.021	1.50	0.30	1.21	0	0.00	0.00	0.47	5.371071
Hosangabad	147	5.77	0.049	0.85	0.19	0.67	0	0.00	0.00	0.47	3.0525
Jhaneshwar	26	21.92	0.083	1.29	1.18	0.11	0	0.00	0.00	0.60	3.570833
Bharuch	25.5	2.95	0.087	1.34	0.60	0.74	0	0.00	0.00	0.40	5.569583
Ambeta	42.75	20.90	0.049	1.42	0.91	0.51	0	0.00	0.00	0.27	8.864375

On an average aluminum concentration are 166.8 mg/gm (range 91 –257.9mg/gm). The trend downstream fluctuate in monsoon and post monsoon, the average concentration for this element is 132 mg/gm (range 21.8 – 303.8mg/gm). Thus, the fluctuation in concentration downstream the river is more. The source of aluminum is clay minerals. Phosphate shows asymmetrical trend down the stream. With average concentration 5.5mg/gm (range 3.3 – 7.8mg/gm) in the monsoon. In the post monsoon also there is no definite trend downstream. The average concentration is 1.2 mg/gm (range 2 – mg/gm). Thus there has been decrease in concentration in post monsoon.

In suspended sediment, the average concentration of silicon, aluminum and phosphate are 159.2, 175.4 and 4.2 mg/gm respectively. Thus less concentration of silicon and phosphate but more of aluminum was observed in suspended sediment then bed sediments.

Tapti

Carbon, nitrogen and sulphur:

The average concentration of total carbon is in the river for monsoon and post monsoon are 1.59% (range 0.7 – 30.1%) and 2% (range 1.008 – 3.44%) respectively there is more IC then OC. This reflects less influence on anthropogenic sources and biota load then natural.

Sulphur was not detected at any site except at one site, but in very less concentration each in monsoon and post monsoon season.

The average concentration of TN is 0.45% (range 0.33 – 0.6%) and 0.59% (range 0.27 – 1.20%) respectively. The sequence both sown the stream in both monsoon and post monsoon is of fluctuating kind.

C/N ratio

The average ratios are 6.28 and 6.33 respectively in monsoon and post monsoon. Thus no significant temporal change has occurred. Down the stream, the trend is highly asymmetrical.

Carbon / nitrogen ratio:

In bed sediment the average C/N ratio are 2.52(range 0.88-4.33) and 7.72(range 1.46 – 30.4) in monsoon (table 5.11) and post monsoon (table 5.12) respectively. There are no defined trends observed downstream the river in both seasons. The ratio values show increment in post monsoon because of higher value in TC on an average in post monsoon (table 5.12).

Silicon, Aluminum and Phosphate:

Bed sediment

The average concentration of silicon in monsoon is 200 mg/gm (range 150-262.5mg/gm) there is no symmetrical trend down the stream. In the post monsoon the trend downstream is highly fluctuating with average concentration 348.9 mg/gm (range 50 -1470 mg/gm) (table 5.11 – 5.12). The highest concentration of silica may be due to dominance of quartz.

Table 5.13: Carbon, Sulphur and Nitrogen along with Alumina, Silica and Phosphate(x10 mg/g) concentration in Tapti River for Monson season

sample sites	*SiO_2*	*Al_2O_3*	*PO_4^{3-}*	*T.C.%*	*I.C.%*	*O.C.%*	*T.S.%*	*I.S.%*	*O.S.%*	*T.N.%*	*C/N*
Tapti											
Betul(Tapti)	17.75	17.60	0.497	0.70	0.39	0.32	0.0026	0.0011	0.0015	0.60	1.956667
Bhushaval	10.25	15.16	0.655	1.75	1.69	0.06	0.0015	0.00	0.0015	0.33	8.7315
Jalgaon	12.5	20.23	0.539	1.17	1.13	0.03	0	0.00	0	0.33	5.8365
Kojway	14.5	14.33	0.592	3.01	1.28	1.73	0.0075	0.00	0.0075	0.47	10.74821
Ghandhi Bag	21.5	22.23	0.413	1.33	0.84	0.48	0.001	0.0009	0.0001	0.53	4.1425

Table 5.14: Carbon, Sulphur and Nitrogen along with Alumina, Silica and Phosphate(x10 mg/g) concentration in Tapti River for Post Monson season

sample sites	*SiO_2*	*Al_2O_3*	*PO_4^{3-}*	*T.C.%*	*I.C.%*	*O.C.%*	*T.S.%*	*I.S.%*	*O.S.%*	*T.N.%*	*c/n*
Betul(Tapti)	15.75	30.77	0.067	3.44	1.78	1.66	0.0033	0.0026	0.0007	1.20	4.782222
Bhushaval	8.75	29.23	0.029	2.45	2.30	0.16	0	0.00	0.00	0.40	10.22375
Jalgaon	3.25	10.51	0.056	1.08	1.07	0.02	0	0.00	0.00	0.27	6.76125
Kojway	7.75	14.23	0.095	1.44	0.94	0.49	0.0012	0.00	0.0012	0.40	5.985833
Ghandhi Bag	5.5	19.62	0.38	1.56	0.62	0.95	0	0.00	0.00	0.67	3.90925
Dumas	5.75	18.97	0.093	1.73	0.35	1.38	0	0.00	0.00	0.33	8.639

Silicon, aluminum, phosphate

The average concentration of silicon in monsoon and post monsoon are 153 mg/gm (range 102.5- 215mg/gm) and 80mg/gm (range 32.5 – 157.5mg/gm) respectively. The trend downstream is not defined in both monsoon as well as post monsoon (table 5.13 – 5.14).

Aluminum concentration along the river shows an asymmetric trend in both seasons. On an average, the concentration is 179.1mg/gm (range 14.33 – 22.23mg/gm) and 208.mg/gm (range 105.1 – 307.7 mg/gm).

The phosphate concentration varies from 4.1 to 6.5 mg/gm average value 5.4mg/gm in monsoon and from 0.3 to 3.8mg/gm with average value of 1.3mg/gm.

Narmada

Sodium and potassium

The average concentration of sodium (Na) is 119.1mg/gm (range 96.5 – 160.9mg/gm) and 98.7mg/gm (range 56.9 – 131.2mg/gm) in monsoon and post monsoon (table 5.15 – 5.16) respectively. The trend downstream almost symmetrical but in post monsoon there is increase with few exceptions.

Potassium concentration remains almost constant with average value39mg/gm (range 31.1 –48.9mg/gm) in monsoon. In post monsoon there is little spatial variability. The average concentration of potassium is 44.2mg/gm (range 27.5-59.6mg/gm) in the monsoon. Thus there has been increase in potassium concentration but decrease in concentration in post monsoon.

Table 5.15: Major element concentration (x10mg/g) for monsoon in Narmada River

Narmada	*Na*	*K*	*Ca*	*Mg*
Amarkantak1	11.63	3.82	10.82	20.35
Amarkantak2	10.64	4.89	11.27	18.93
Mandala	12.62	3.82	10.17	14.26
Bhera Ghat	10.15	3.11	8.89	15.11
Guari Ghat	11.63	3.46	6.056	13.21
Tilwara Ghat	13.61	4.89	2.834	10.97
Hosangabad	9.65	4.18	7.087	15.18
Jhaneshwar	16.09	3.82	13.01	18.62
Bharuch	11.14	3.11	10.43	17.68
Ambeta	17.57	4.18	20.35	21.44

Table 5.16: Major element concentration (x10mg/g) for Post monsoon in Narmada River

Narmada	*Na*	*K*	*Ca*	*Mg*
Amarkantak1	5.69	2.75	9.97	23.42
Amarkantak2	5.69	5.9643	12.01	19.12
Mandala	9.16	3.8214	12.23	17.47
Bhera Ghat	9.16	3.4643	8.68	15.52
Guari Ghat	10.64	3.8214	8.14	13.54
Tilwara Ghat	13.12	4.8929	3.01	12.73
Hosangabad	10.64	4.5357	5.28	15.76
Jhaneshwar	12.62	5.9643	18.37	20.59
Bharuch	12.13	4.5357	15.47	20.31
Ambeta	29.95	4.1786	21.05	25.34

Table 5.17: Major element concentration (x10mg/g) for monsoon in Tapti River

Tapti	*Na*	*K*	*Ca*	*Mg*
Betul(Tapti)	9.65	2.75	5.669	13.11
Bhushaval	15.10	1.32	34.66	22.63
Jalgaon	11.63	2.39	33.63	26.3
Kojway	9.65	2.39	4.767	14.64
Ghandhi Bag	16.09	3.46	21	29.42
Dumas	18.07	4.54	7.86	18.44

Table 5.18: Major element concentration (x10mg/g) for Post monsoon in Tapti River

Tapti	*Na*	*K*	*Ca*	*Mg*
Betul(Tapti)	7.18	3.4643	7.29	13.56
Bhushaval	10.64	1.6786	31.45	38.99
Jalgaon	12.62	2.75	32.97	24.72
Kojway	12.13	4.1786	4.81	14.88
Ghandhi Bag	11.63	4.5357	22.31	28.79
Dumas	19.06	5.6071	8.01	19

Calcium and magnesium

The average concentration of calcium is 89.5mg/gm (range 28.3 – 130.1mg/gm) and 103.5 mg/gm (range 30.1- 183.7mg/gm) in monsoon and post monsoon (table 5.17 – 5.18). The average concentration of magnesium is 160.3mg/gm (range 109.7 – 203.5mg/gm) and 176.1mg/gm (range 127.3- 234.2 mg/gm) in monsoon and post monsoon respectively.

In post monsoon, there is increase in concentration both for calcium and magnesium. Calcium is present in very low concentration at origin at mouth but at very concentration comparatively in midstream. Magnesium shows varying trend.

Tapti

Sodium and potassium

Sodium shows average value 124.3mg/gm (range 96.5 – 160.9mg/gm) and 108.4mg/gm (range 71.5-126.2mg/gm) in monsoon and post monsoon respectively. The source of sodium is alkaline and saline patches along the basin and sodium rich feldspar along the basin and sodium rich feldspar in sediment. Relatively high concentration of potassium at some sites is due to potassium rich clay minerals. Sodium as well as potassium spatially show fluctuating trend.

Calcium and magnesium

The average concentration of calcium is 119.5mg/gm (range 47.7 – 346.6 mg/gm) and 197.7mg/gm (48.1 –329.7mg/gm) in monsoon and post monsoon respectively. Spatial variability is highly fluctuating maximum concentration in midstream. The average concentration of magnesium is 212.2mg/gm (range 131.1 – 294.2mg/gm) and 197.7 mg/g (48.1 – 329.7 mg/g). There is spatial variability with higher concentration in midstream.

Suspended Sediment, Narmada and Tapti:

Na and K:

The average concentration of Na in Narmada River is 136.6 mg/g (range 120 – 168.6 mg/g) (table 5.19). In Tapti river, the only site covered for suspended sediment i.e. Gandhi Bag (mouth) shows Na concentration of 187.7 mg/g. The concentration of K is 41.9 mg/g (range 36.8 – 49.7 mg/g) in Narmada and the only site in Tapti at Gandhi Bag show the K concentration 45.35 mg/g. The data shows that suspended sediment contains higher concentration of Na and K than suspended sediment.

Ca and Mg:

The average concentration of Ca are 106.6 (range 36.8 – 49 mg/g) in Narmada river and the only site i.e. Gandhi Bag shows Ca concentration 231.4 only. The average concentration of magnesium is 174.7 mg/g (149.8 – 192.5 mg/g) and Gandhi Bag site in Tapti River shows Mg concentration 302.6 mg/g.

Table 5.19 Major element concentration in suspended sediment of Narmada and Tapti rivers for monsoon season

Narmada	*Na*	*K*	*Ca*	*Mg*
Hosangabad	12.11	4.97	7.831	14.98
Gandhi bag	18.37	4.5357	23.14	30.26
Dumas	19.94	5.24	7.91	18.87
Tapti				
Jhaneshwar	16.86	3.91	13.64	19.25
bharuch	12.00	3.68	10.51	18.11
Ambeta	17.93	5.12	22.37	21.65

Estuaries of Tapti and Narmada River:

The Na, K and Mg concentration in Ambeta, estuary of Narmada River, are 175.7, 41.8, 203.5 and 214.4 mg/g. respectively in monsoon and in post monsoon the same parameters show concentration 299.5, 41.8, 210.5 and 253.4 mg/g respectively. The Dumas estuary shows concentration for the same above mentioned parameters (Na, K, Ca and Mg) are 180.7, 45.4, 78.6 and 184.4 mg/g in monsoon. In post monsoon these parameters show concentration 190.6, 56.1, 80.1 and 190 mg/g.

Suspended sediment:

Ambeta estuary shows Na, K, Ca and Mg concentration as 179.3, 57.2, 223.7 and 216.5, mg/g respectively. Dumas estuary shows the concentration of the above mention parameters as 199.4, 52.4, 79.1 and 188.7 mg/g respectively.

CONCLUSIONS

CONCLUSION

The two west flowing rivers Narmada and Tapti are alkaline in nature. Bicarbonate is the dominant ion followed by Ca and Na. Total dissolved solids in the rivers are informally high. Carbonate weathering significantly controls the chemistry of water in the river by silicate weathering and partly. High TDS value over TSM implies for more of chemical weathering than physical weathering. The average abundance of ions in water of river Narmada is as follows (in mg/l)

Bicarbonate > calcium > sodium > magnesium > sulphate > silicate > chloride > potassium > phosphate > fluoride.

The average abundance of ions in the waters of river Tapti is as follows (mg/l)

Bicarbonate > calcium > chloride > magnesium > silicate > sulphate > potassium > phosphate > fluoride.

The chemistry of bed sediment of river Narmada is dominated by silicon followed by aluminum, magnesium, sodium, calcium and potassium. High concentration of silicon is a reflection of detrital quartz, which makes the mineralogy of bed sediment of river Narmada.the average kjeldahl nitrogen concentration, and organic carbon reflects the amount of organic mater present in the bed sediment.

Similarly in Tapti River the chemistry of bed sediment is dominated by silicon followed by aluminum, magnesium, calcium and sodium. The kjeldahl nitrogen and the organic carbon concentration indicated the organic mater in bed sediment. The suspended sediment, off course, from very few numbers of sites from both the river are also analysed for almost all parameter mentioned above. Generally suspended sediment shows higher concentration as compared to bed sediment. In the absence of water discharge data and data about various other parameters, the conclusion made out in the preceding paragraph are having inherent limitations. In order to have complete geochemical understanding of these rivers under consideration more detailed study accounting for comprehensive spatial variability as well as for other parameters like toxic metal (Hg, As, Cd and Pb etc.) would be needed.

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Appendix I

Graphs and figures

fig 5.1: concentration of anions along downstream of narmada river(in monsoon)

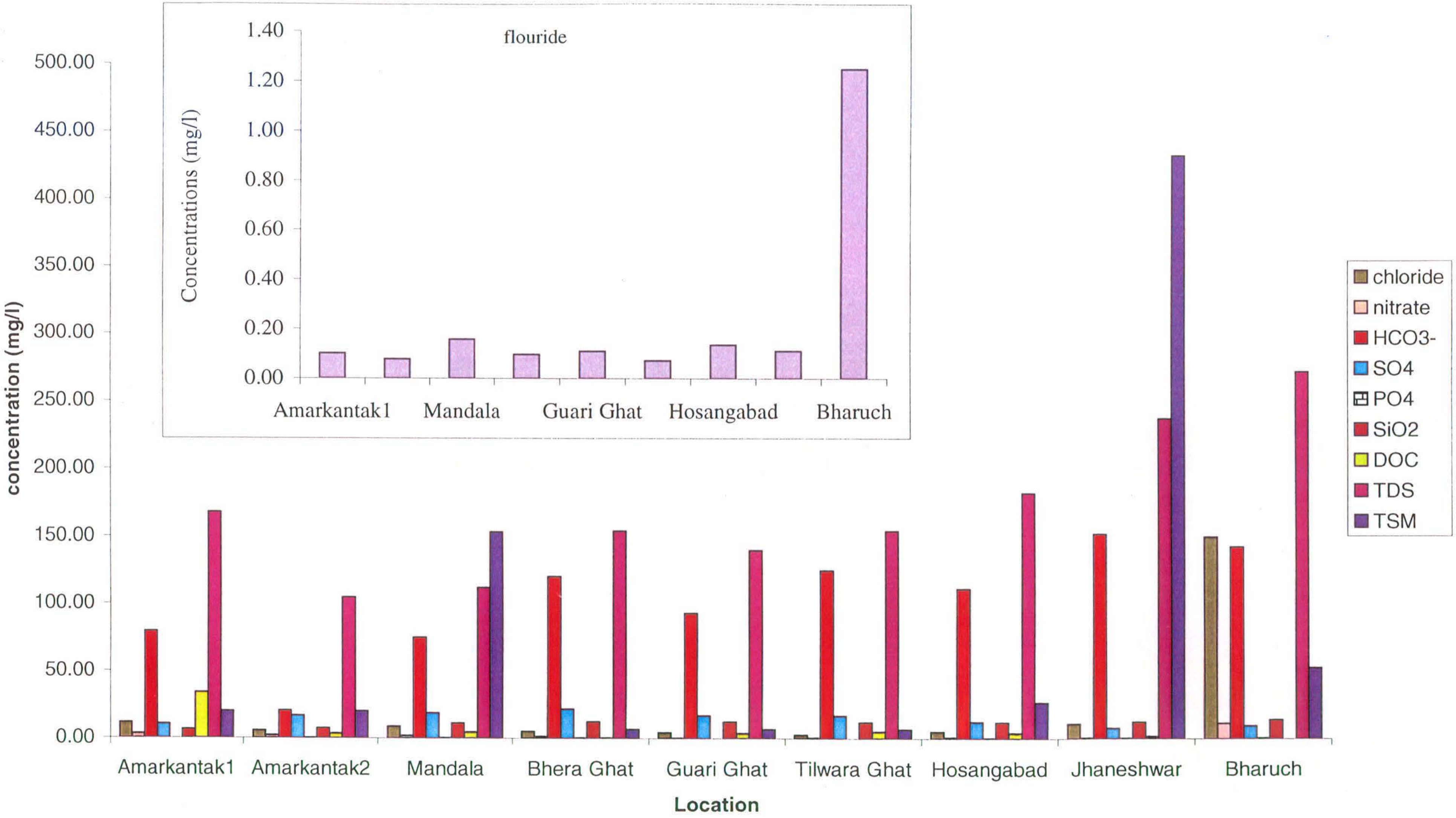


fig 5.2: concentration of anions in river Narmada (postmonsoon)

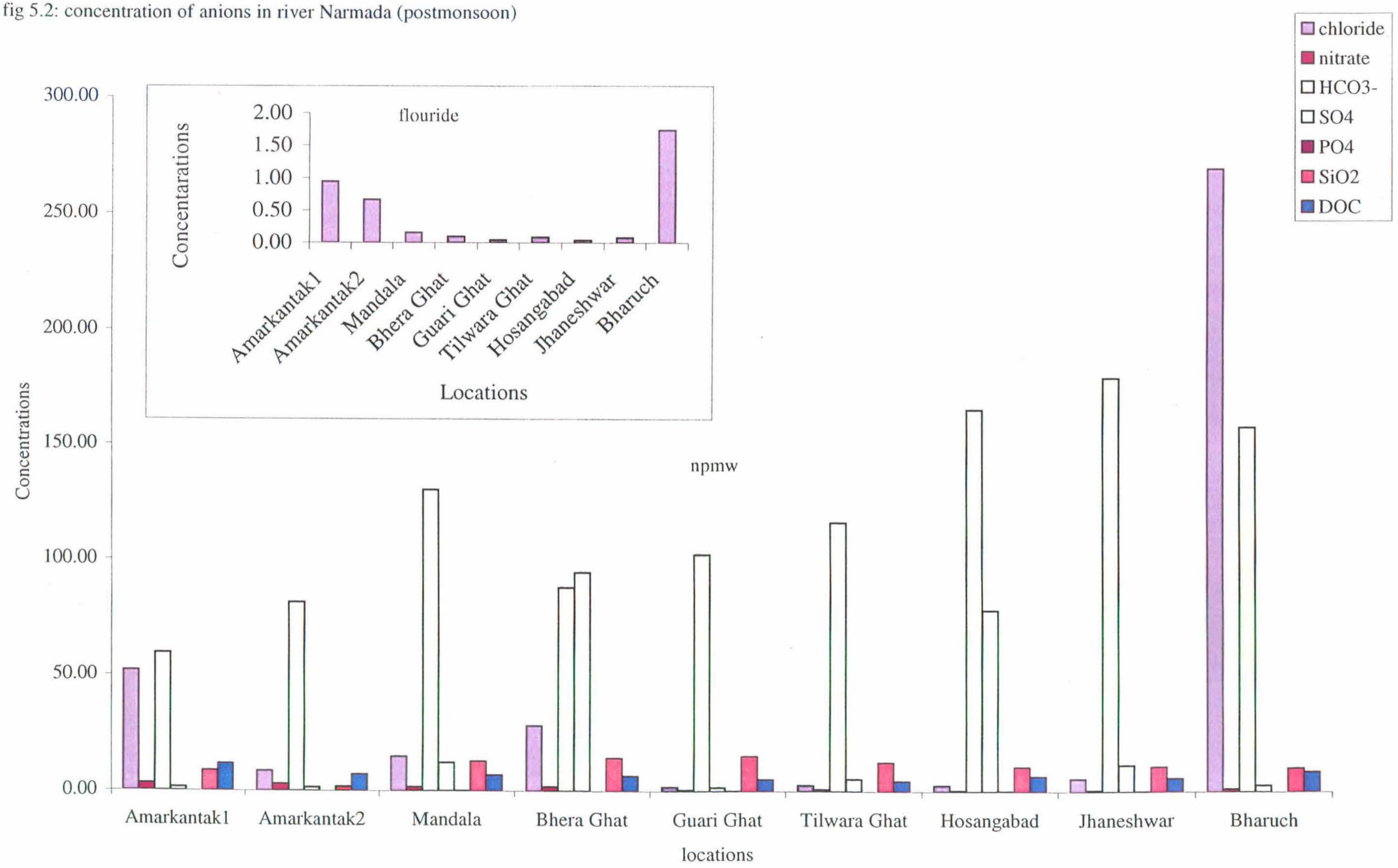


fig 5.3: concentration of anions in river Tapti (monsoon)

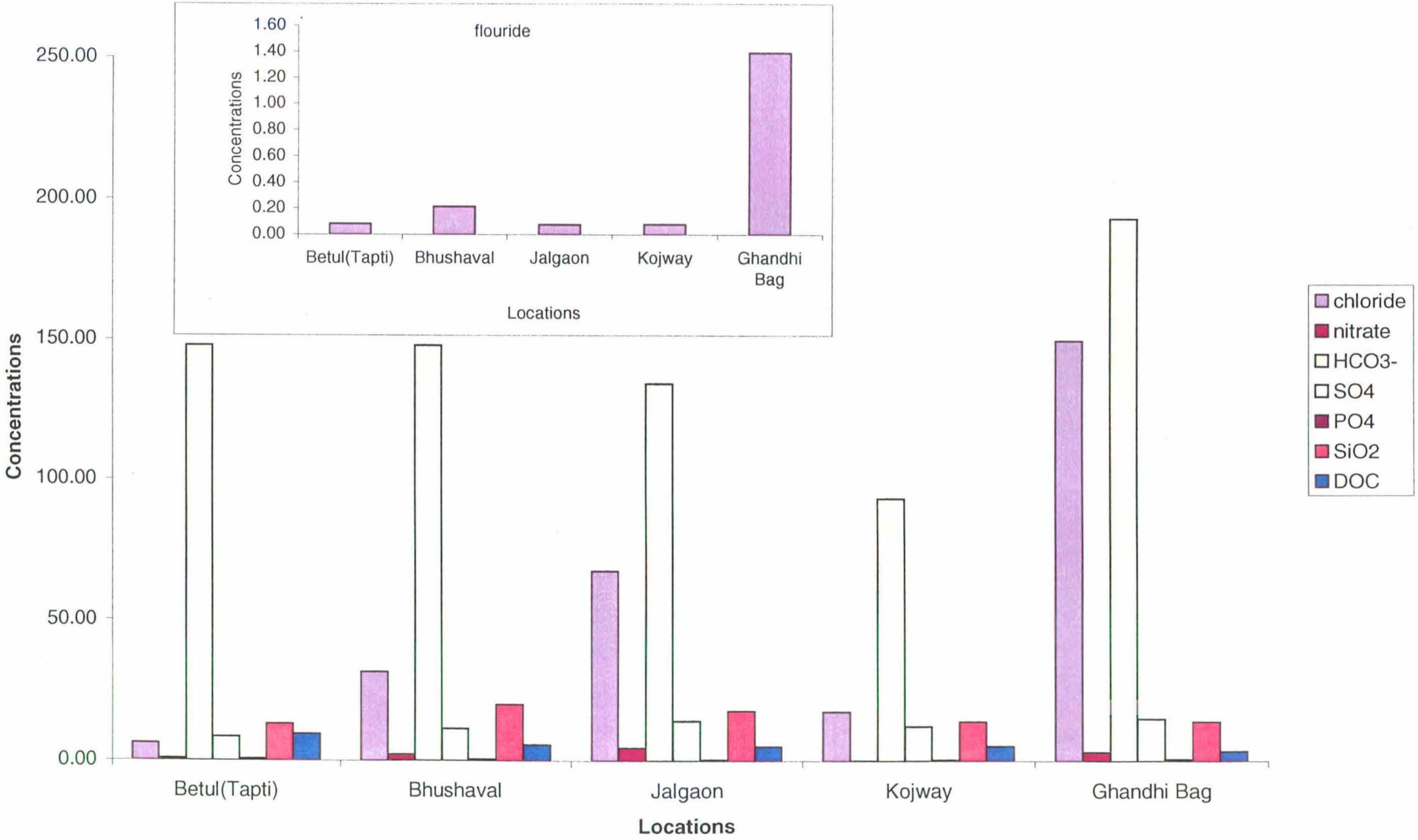


fig 5.4 : concentration of anions in river Tapti (post monsoon)

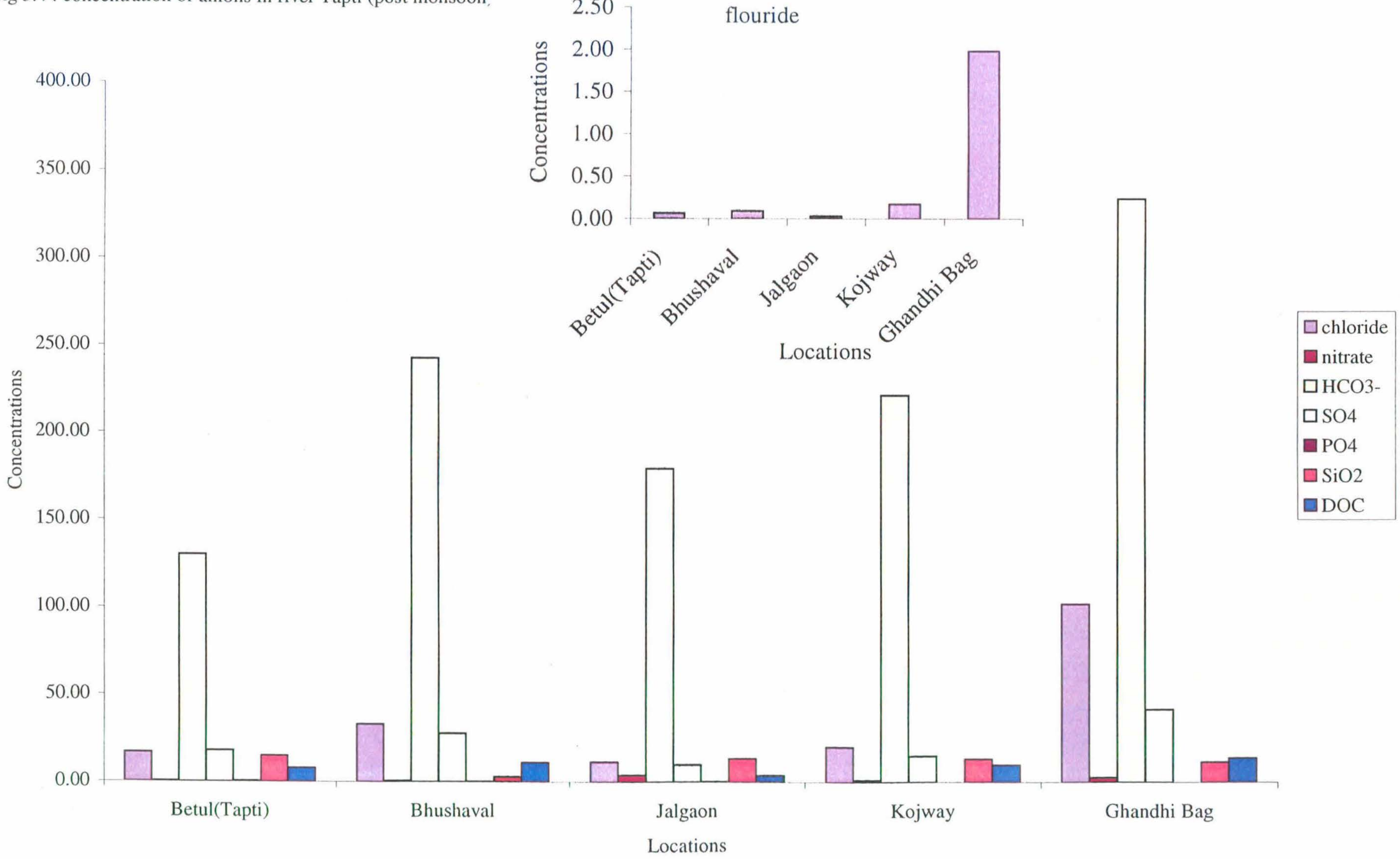


fig 5.5 : regression plot of magnesium and calcium in river Narmada (monsoon)

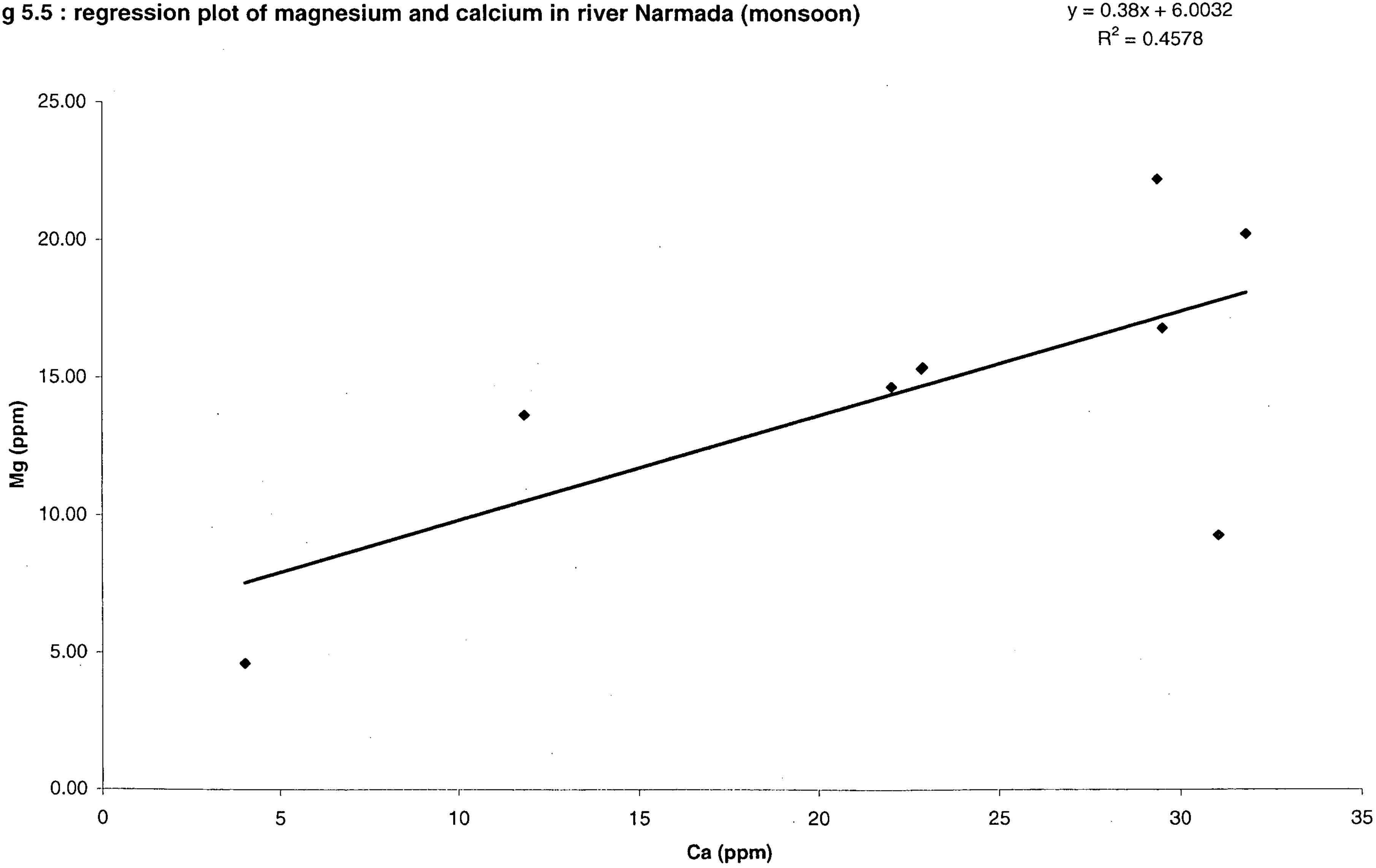


fig 5.6 : regression plot of calcium and bicarbonate in river Narmada (monsoon)

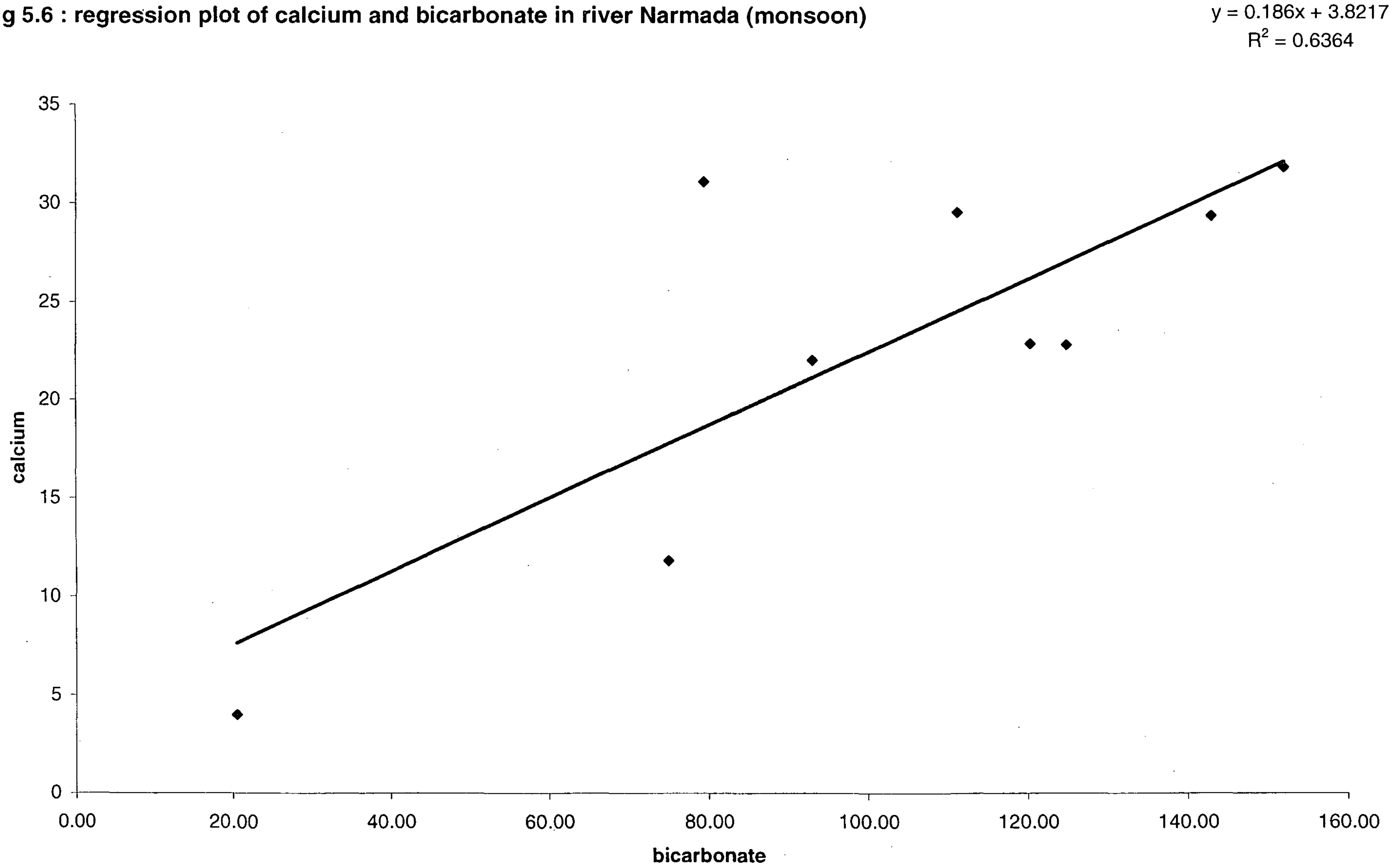


fig 5.7 : regression plot of magnesium and bicarbonate in river Narmada (monsoon)

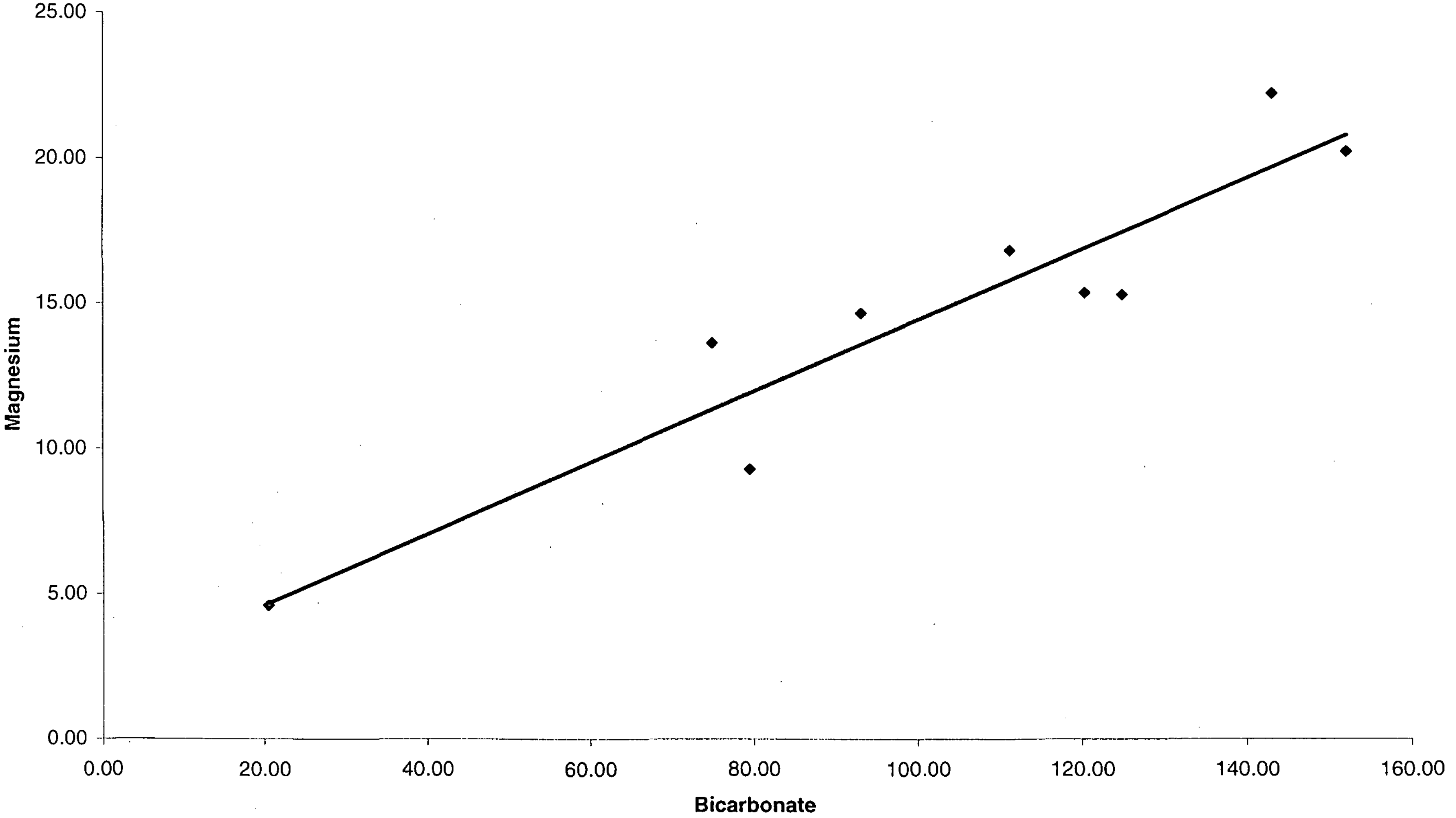


fig 5.8: regression plot of magnesium and calcium in river Narmada (post monsoon)

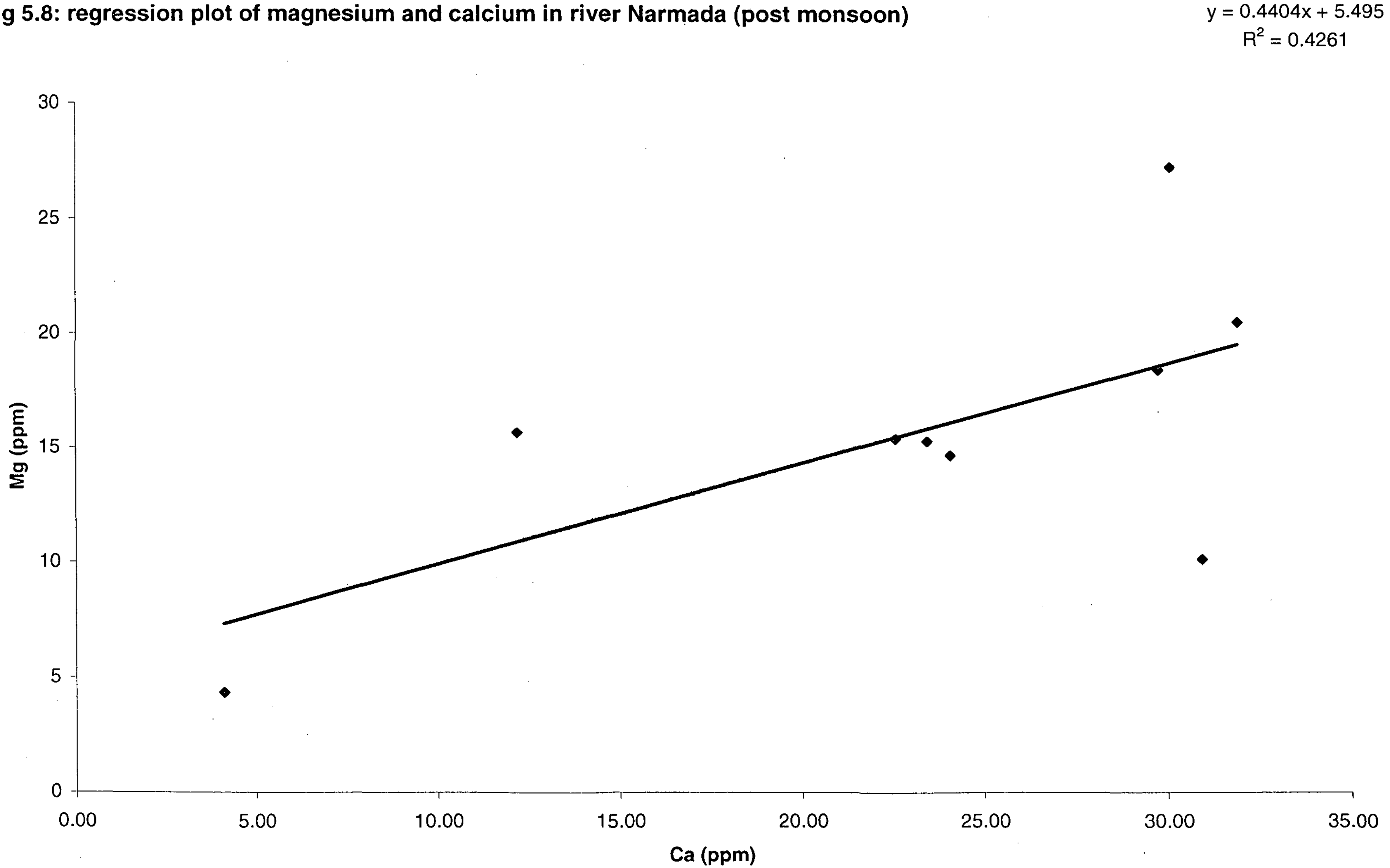


fig 5.9 : regression plot of calcium and bicarbonate Narmada (post monsoon)

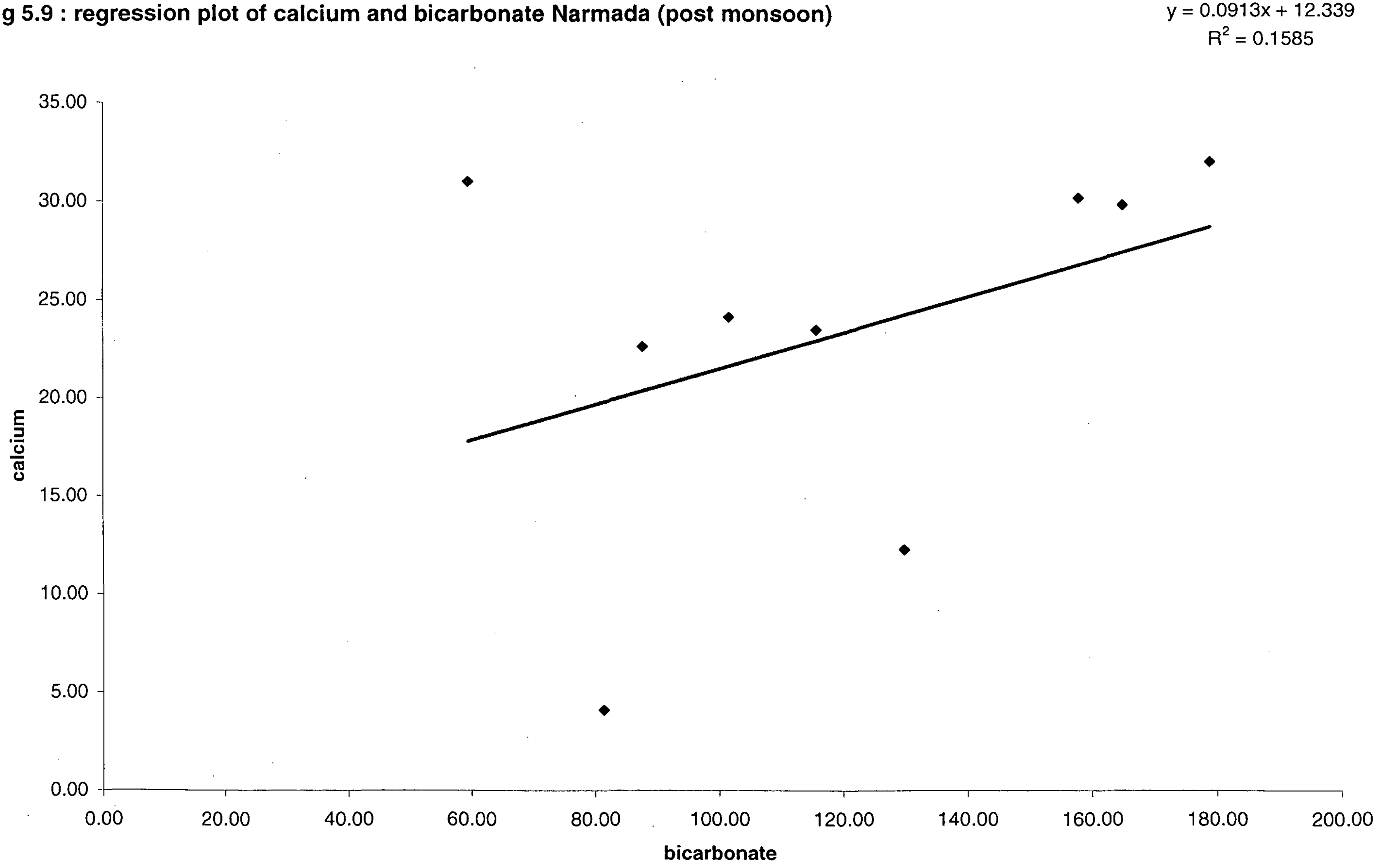


fig 5.10 : regression plot of magnesium and bicarbonate in river Narmada(post monsoon)

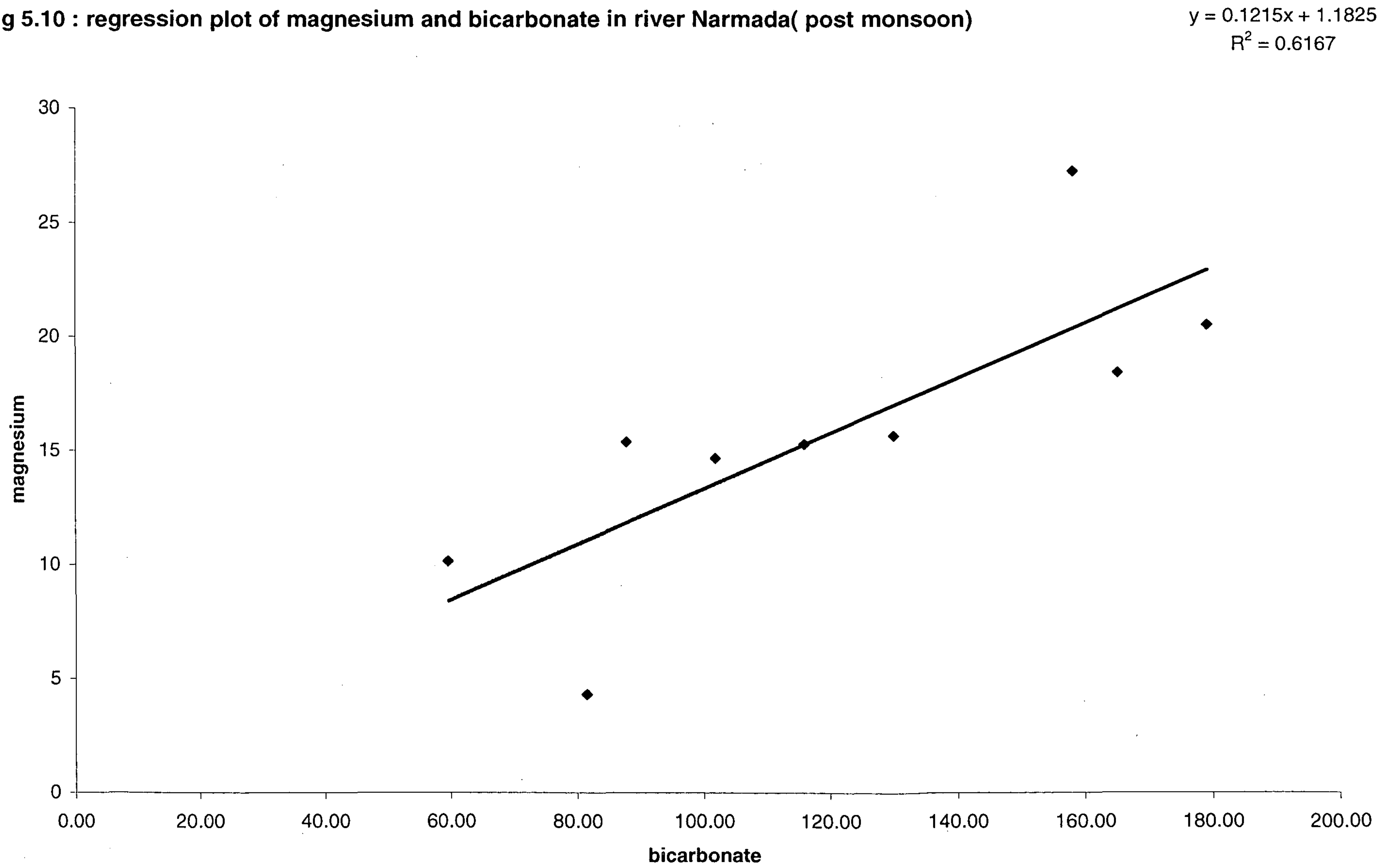


fig 5.11 :variation of cations and anions in Narmada river(in monsoon and post monsoon

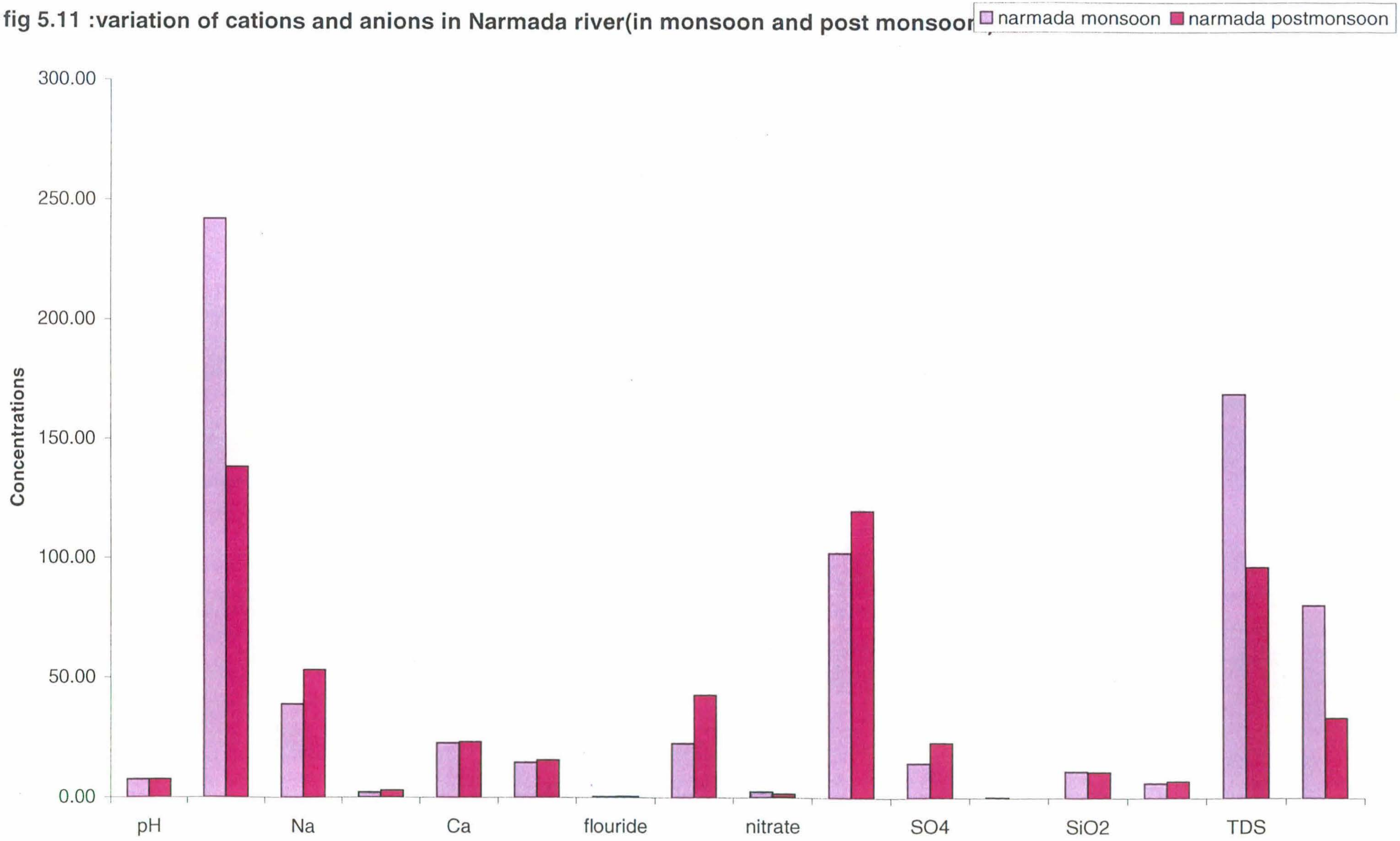


fig 5.12: variation of cations and anions in river tapti river(in monsoon and post monsoon)

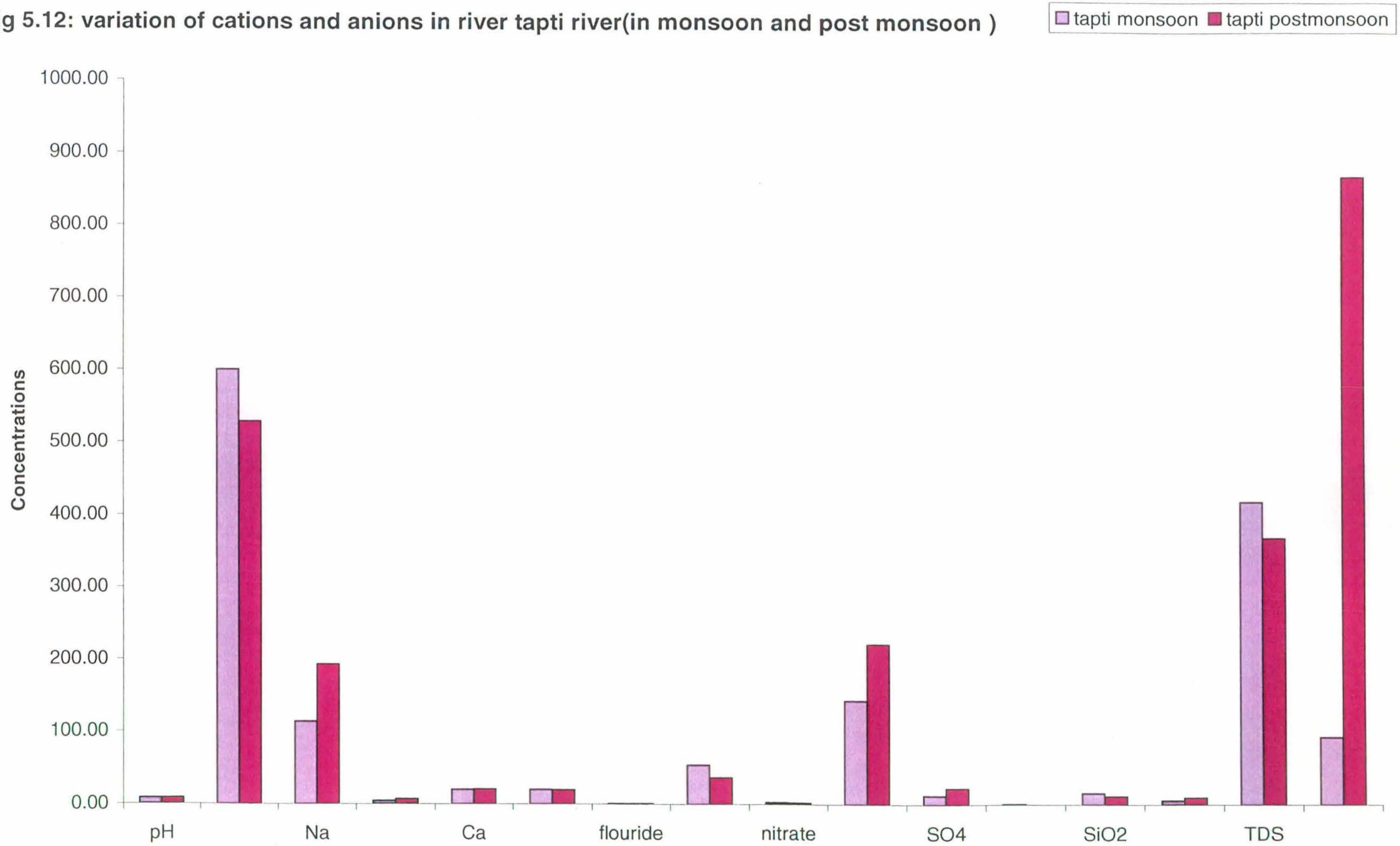


fig 5.13 : Comparison between Narmada and Tapti river for Monsoon Season

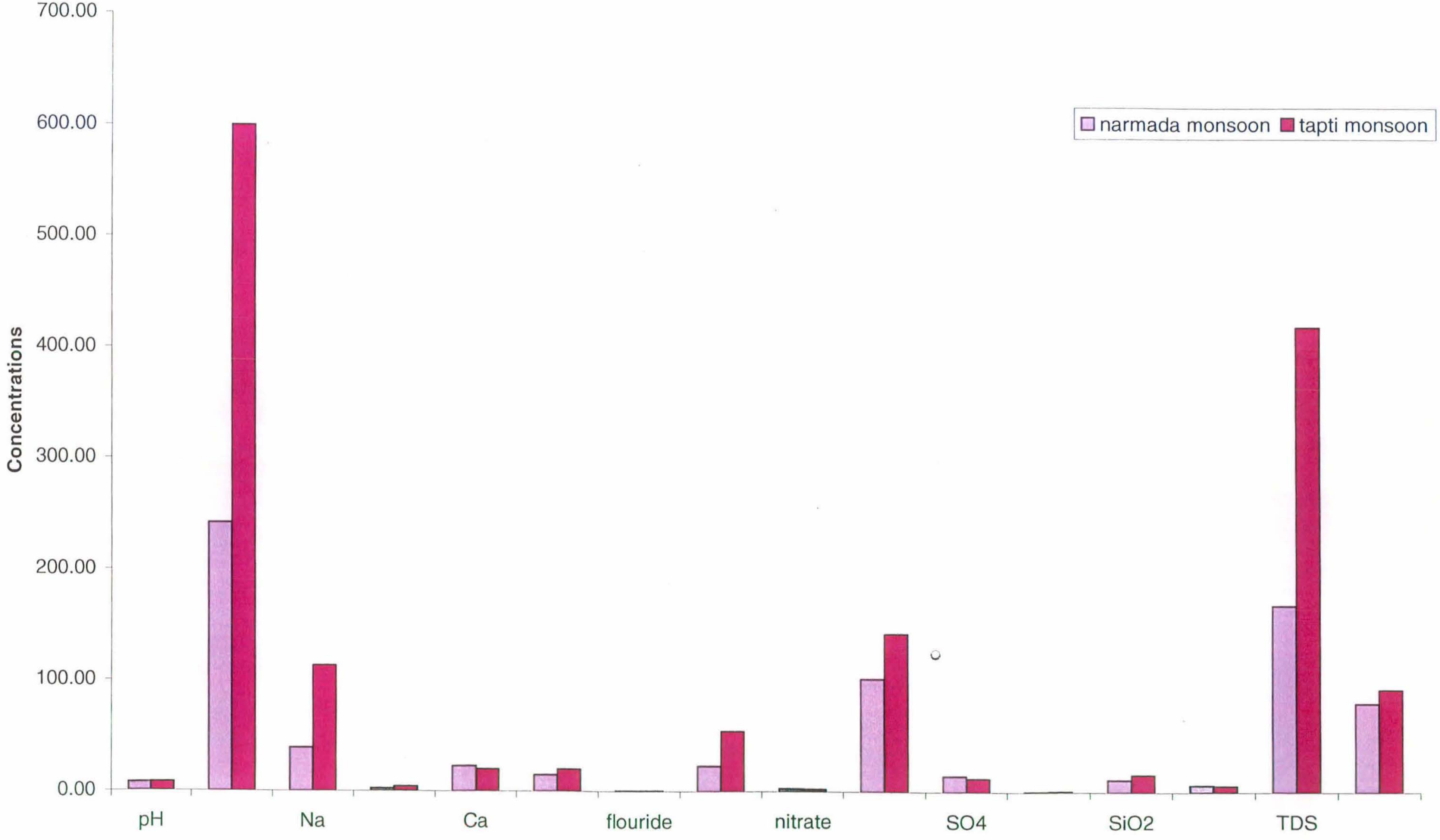


fig 5.14 : Comparision between Narmada and Tapti river for Post monsoon season

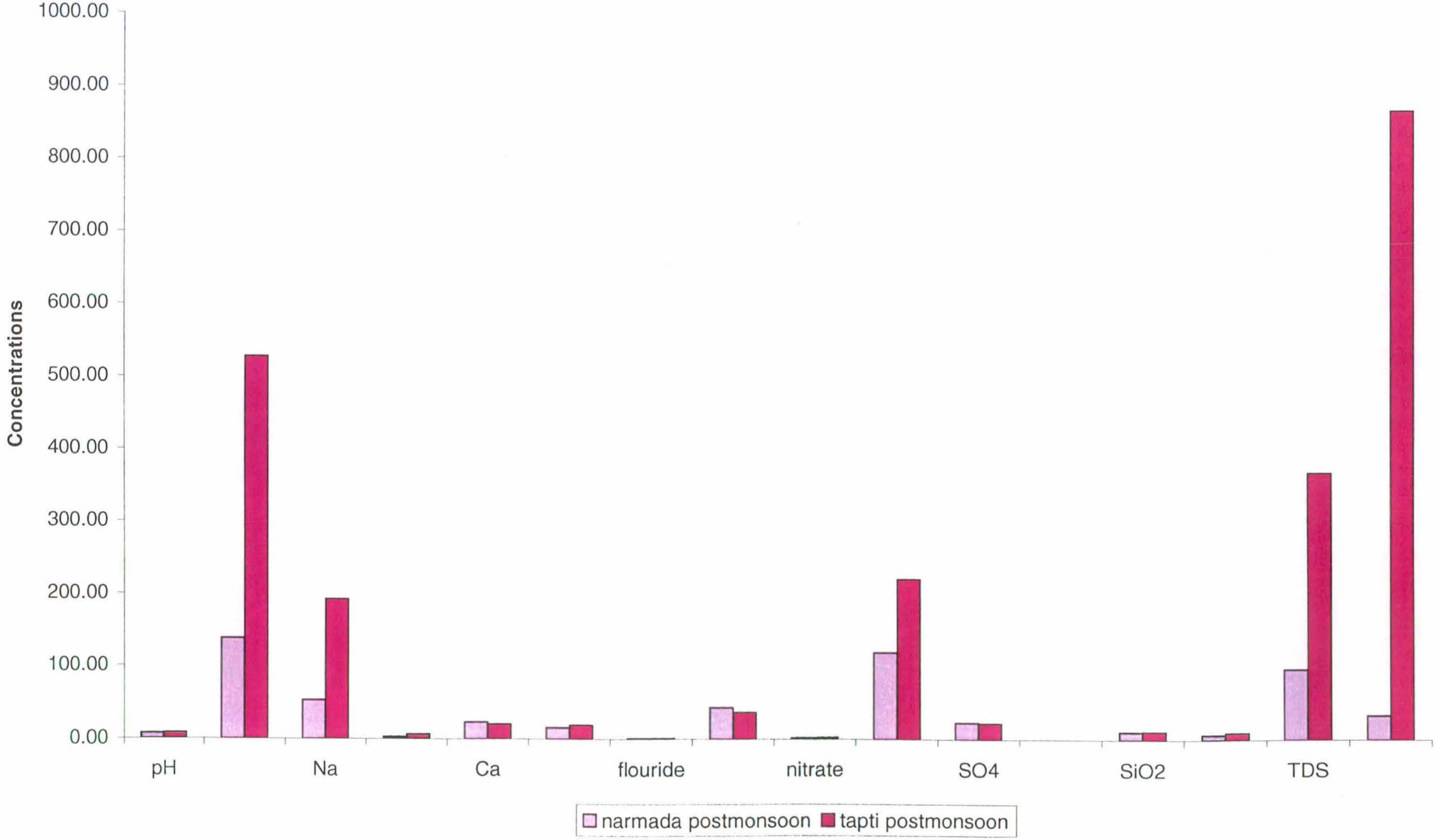


fig 5.15 : metal concentrations in narmada and Tapti river in monsoon season

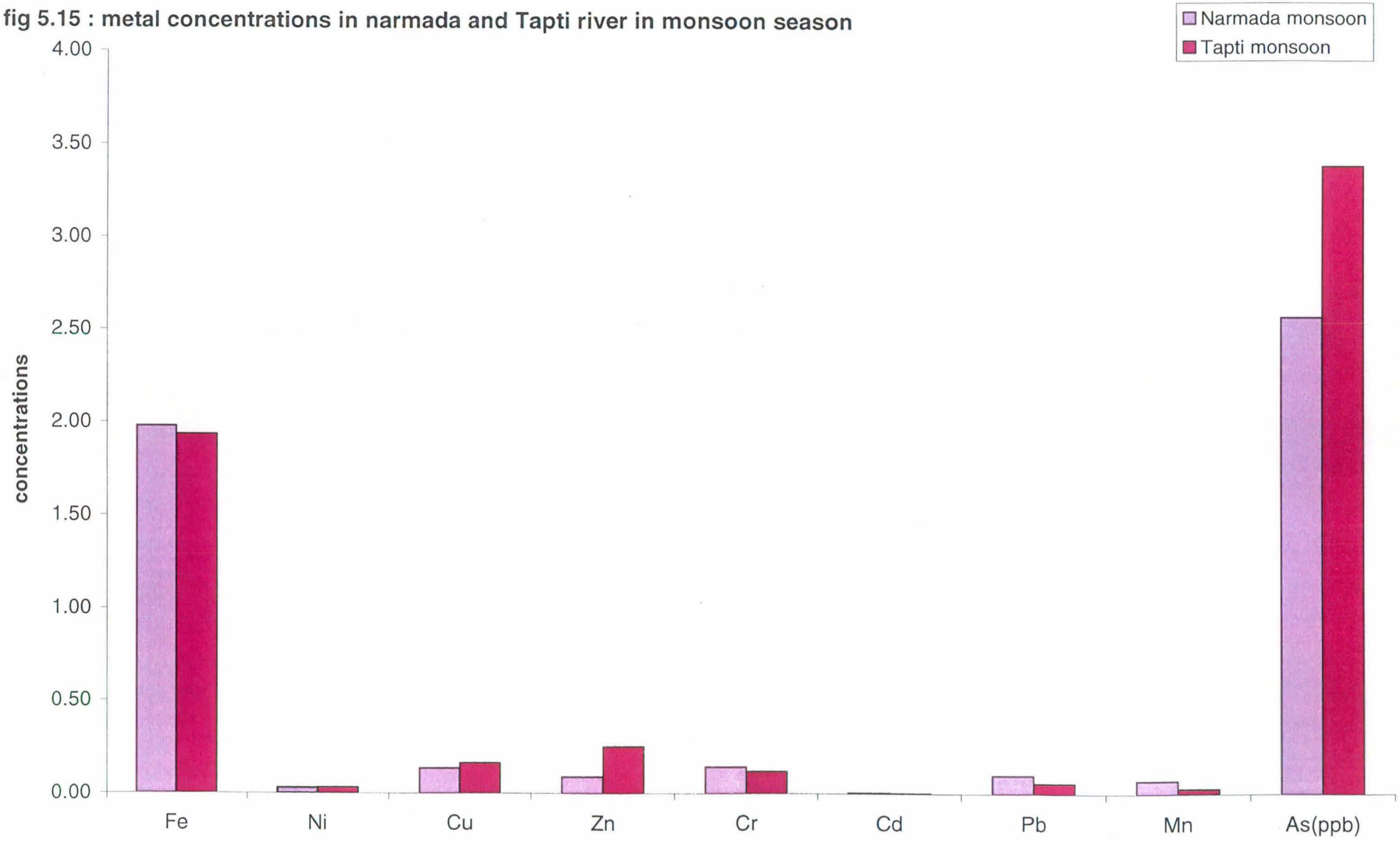


FIG. 5·16a MINERAL STABILITY DAIGRAM IN RIVER NARMADA(MONSOON SEASON)

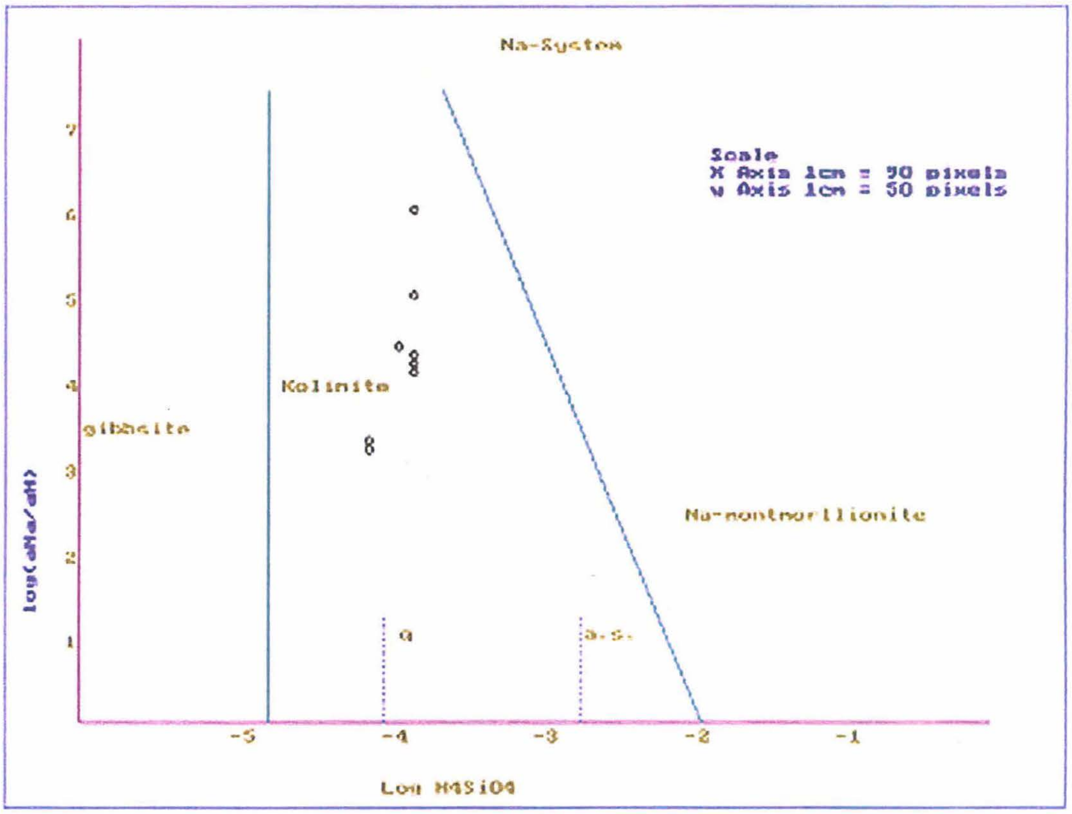


FIG. 5.16b MINERAL STABILITY DIAGRAM IN RIVER NARMADA(POASTMONSOON SEASON)

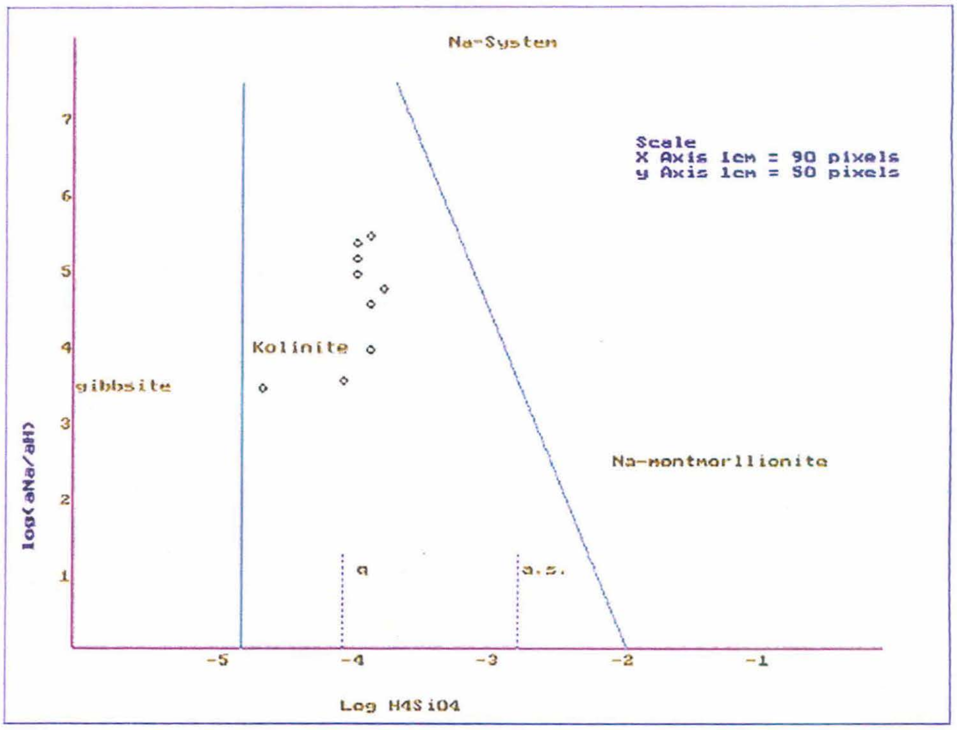
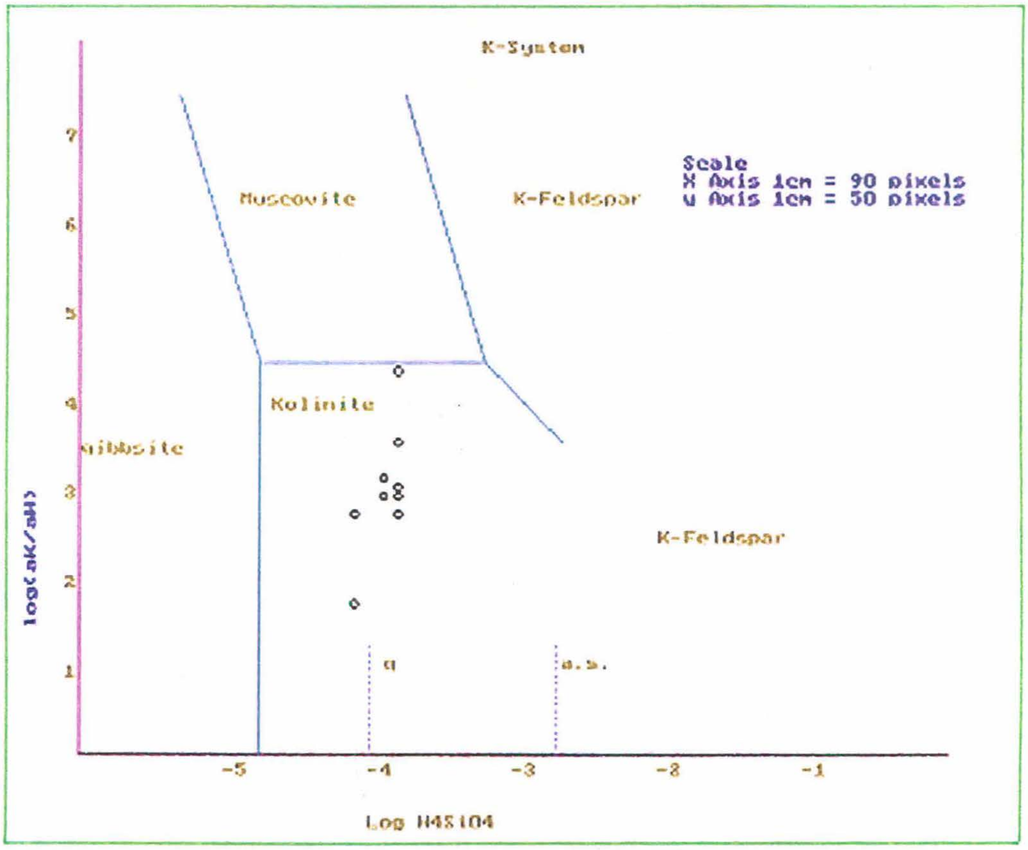


FIG. 15·16 b MINERAL STABILITY DAIGRAM IN RIVER NARMADA(MONSOON SEASON)



MINERAL STABILITY DIAGRAM IN RIVER NARMADA(POSTMONSOON SEASON)

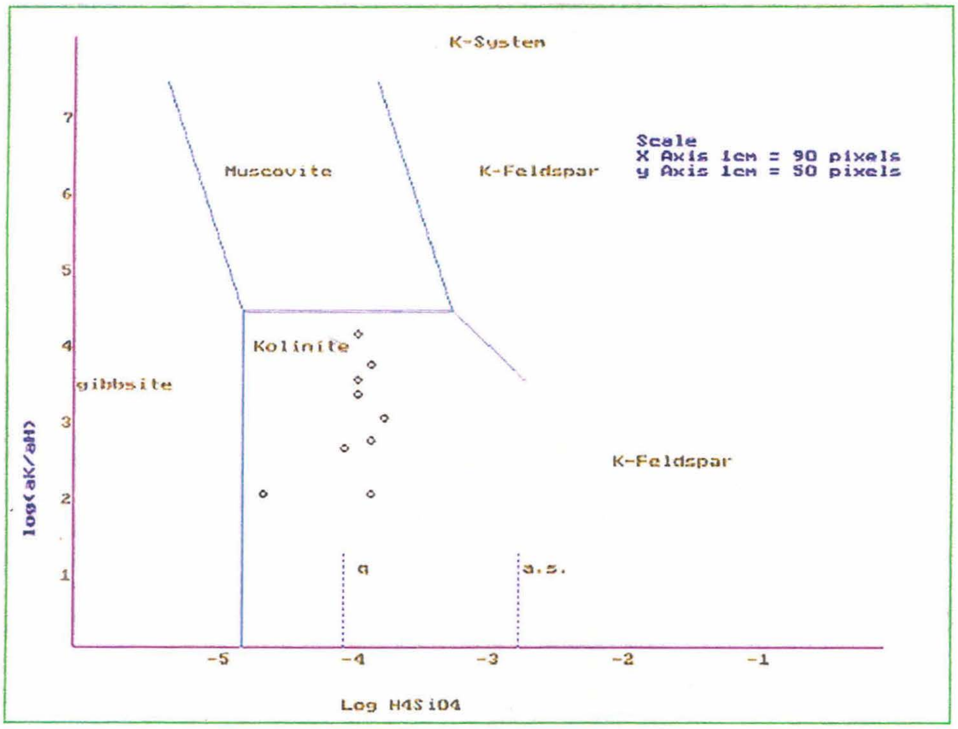
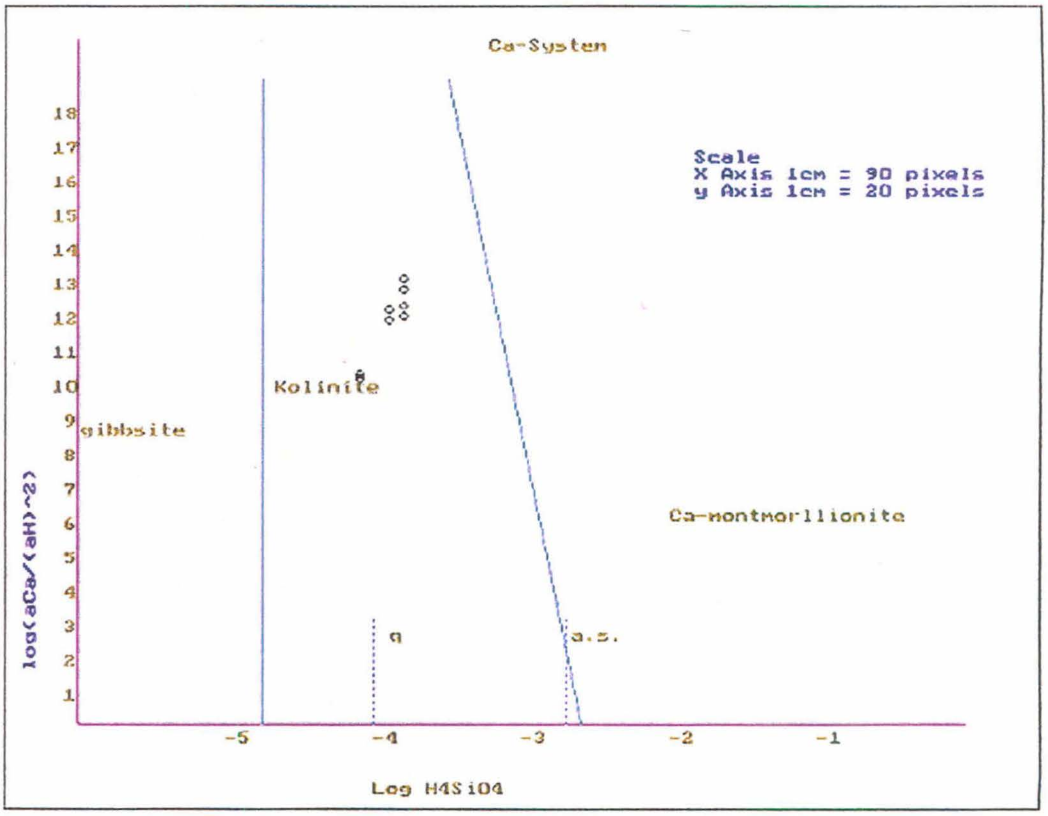


FIG. 15.16 C MINERAL STABILITY DAIGRAM IN RIVER NARMADA(MONSOON SEASON)



MINERAL STABILITY DIAGRAM IN RIVER NARMADA(POSTMONSOON SEASON)

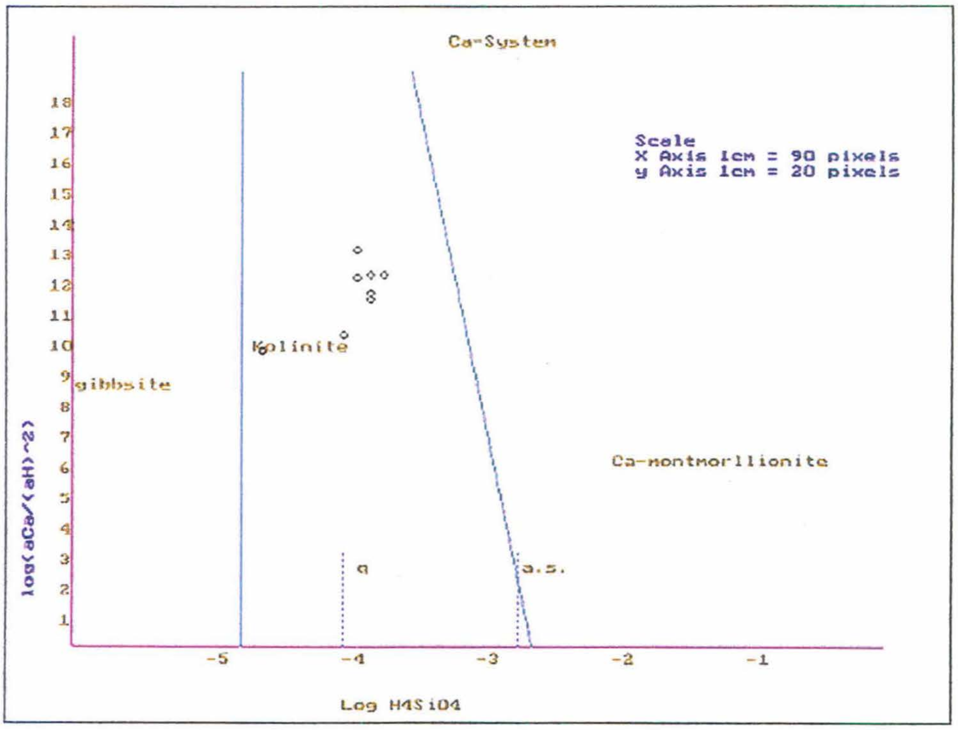
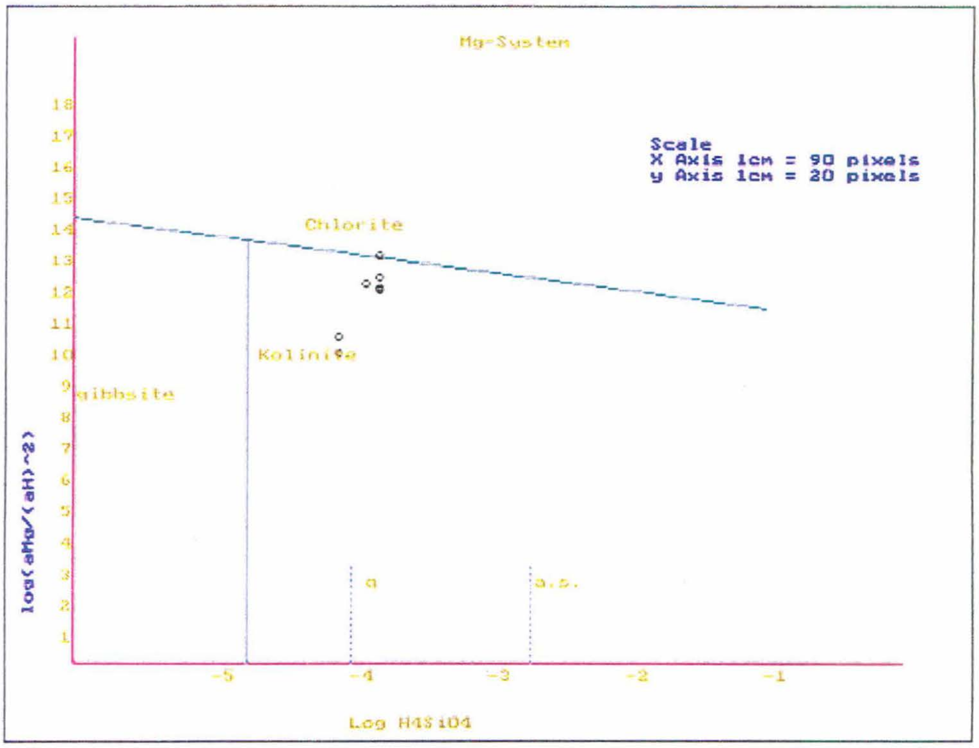
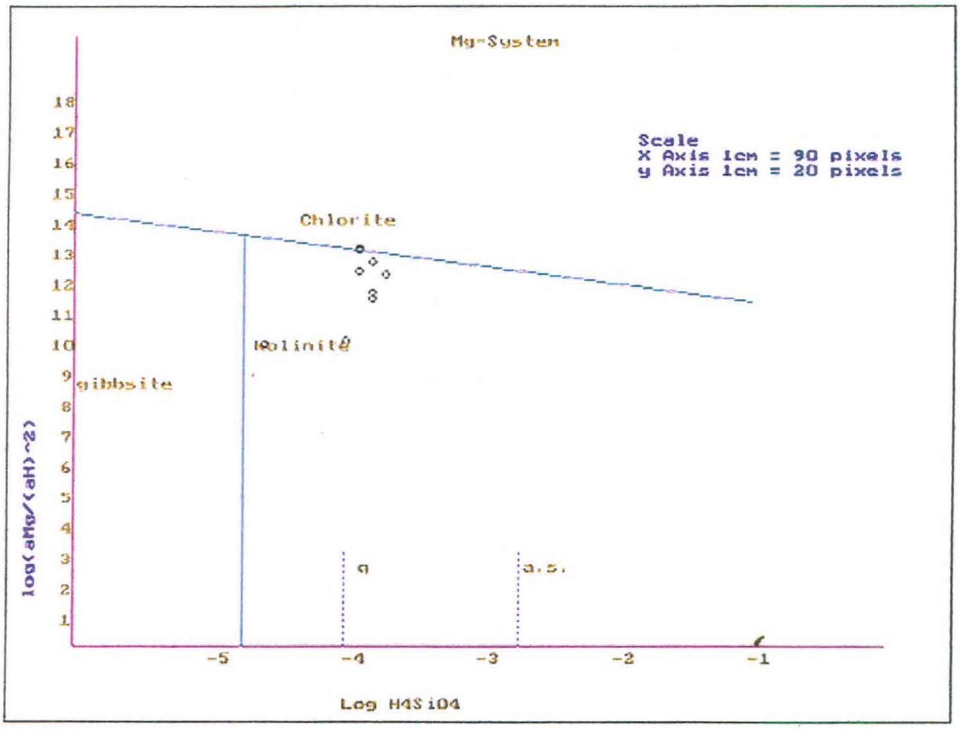


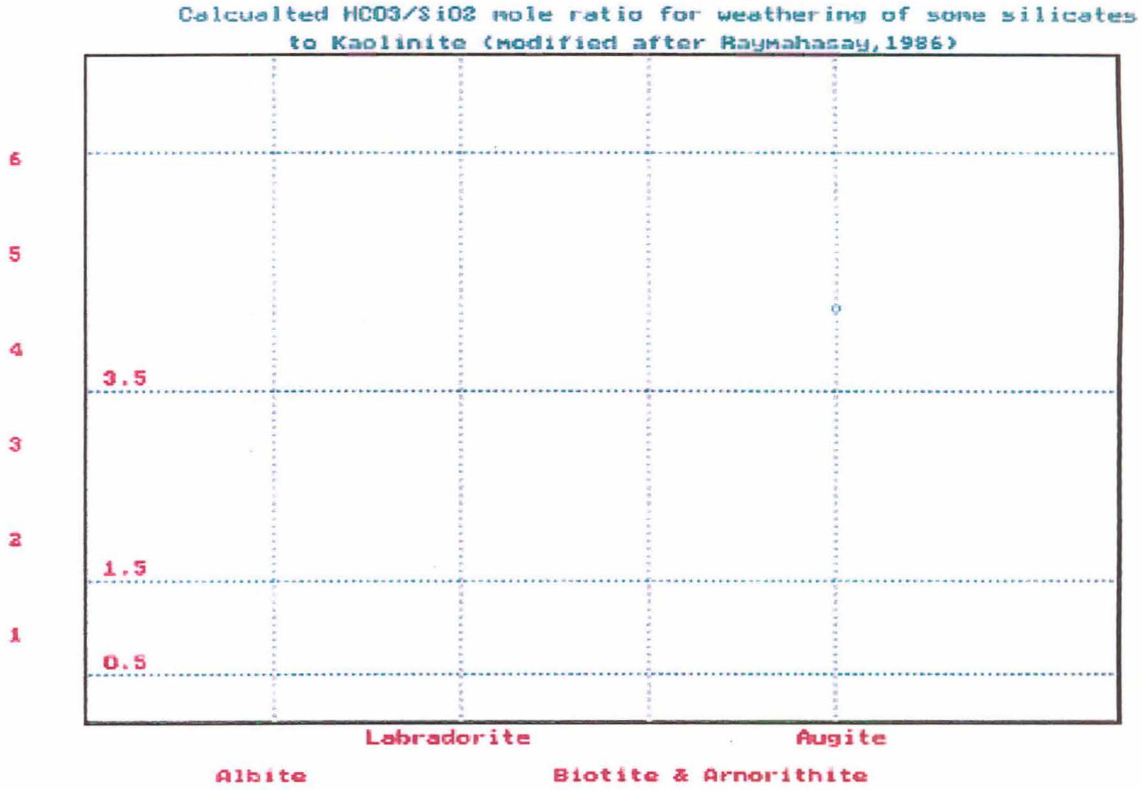
FIG. 15.16 d MINERAL STABILITY DAIGRAM IN RIVER NARMADA(MONSOON SEASON)



MINERAL STABILITY DIAGRAM IN RIVER NARMADA(POSTMONSOON SEASON)

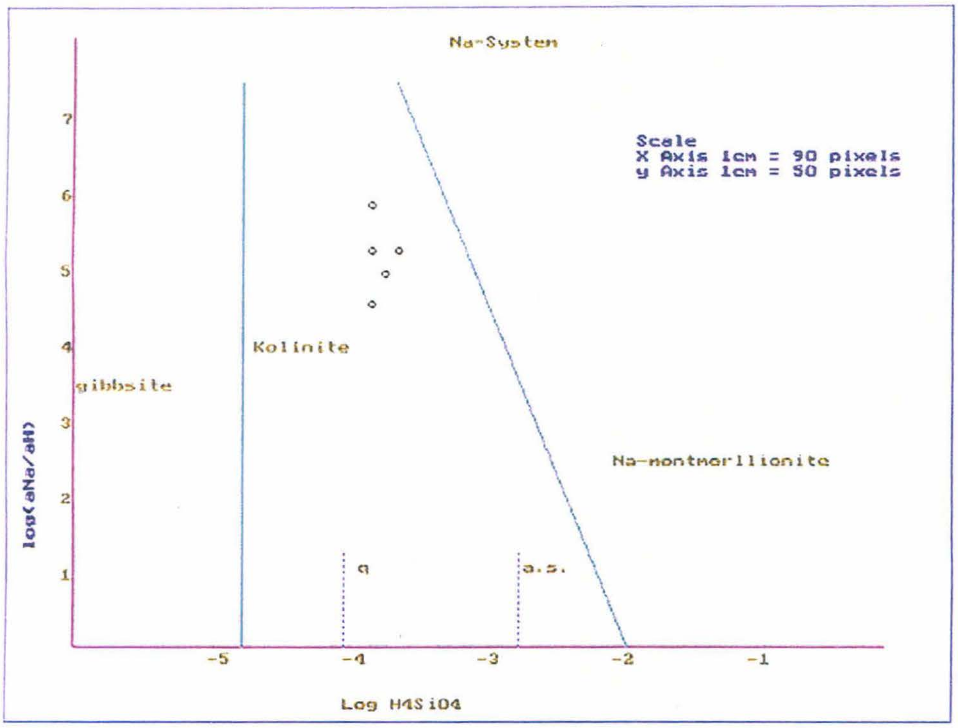


FIG·15.16e MINERAL STABILITY DAIGRAM IN RIVER NARMADA(MONSOON SEASON)



MINERAL STABILITY DIAGRAM IN RIVER NARMADA(POSTMONSOON SEASON)

FIG. 15.17 a Mineral stability diagram of river Tapti (monsoon season)



Mineral stability diagram of Tapti river (post monsoon season)

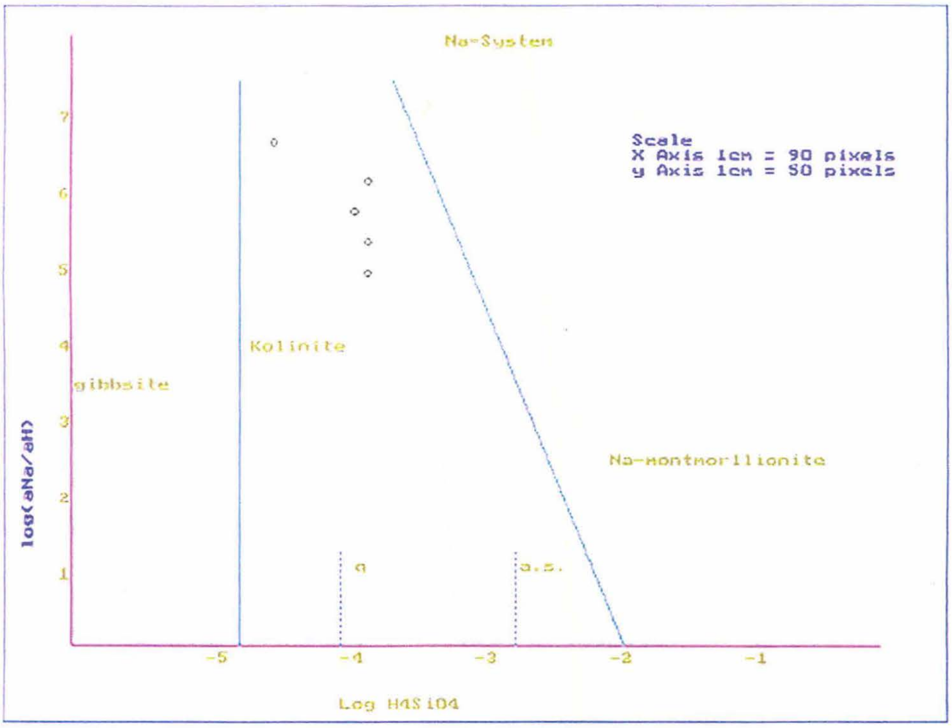
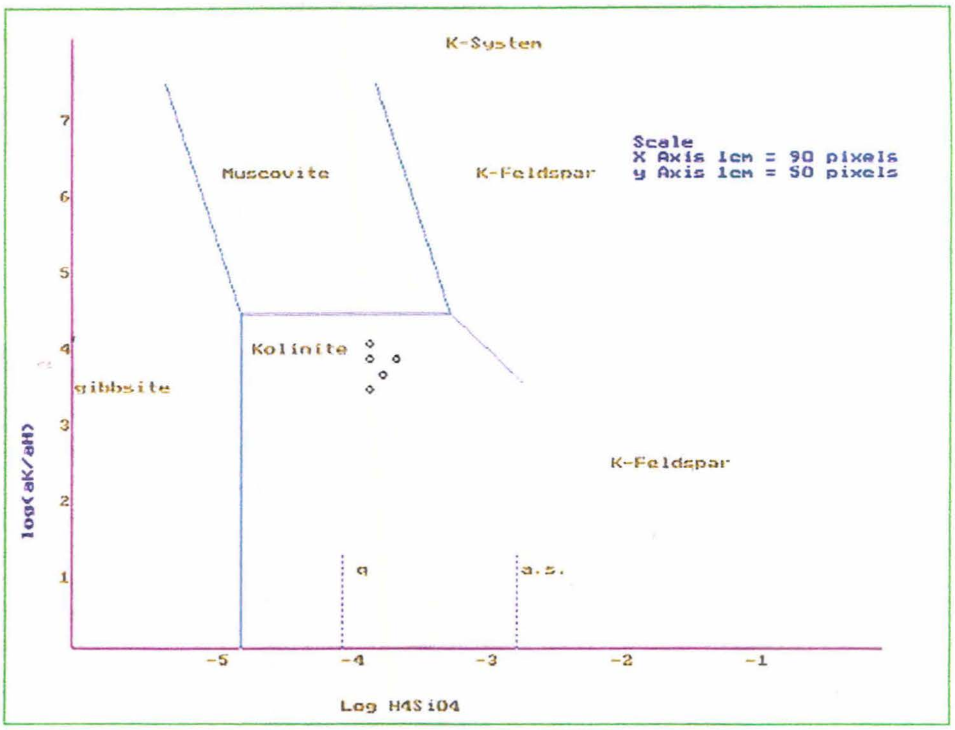


FIG. 15.17 b Mineral stability diagram of river Tapti (monsoon season)



Mineral stability diagram of Tapti river (post monsoon season)

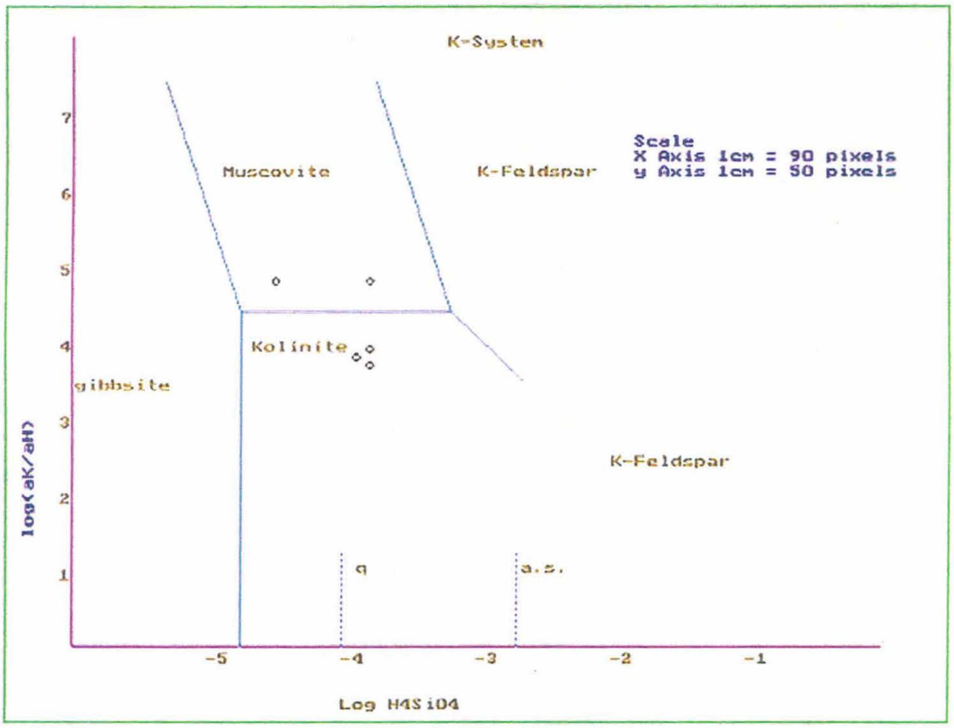
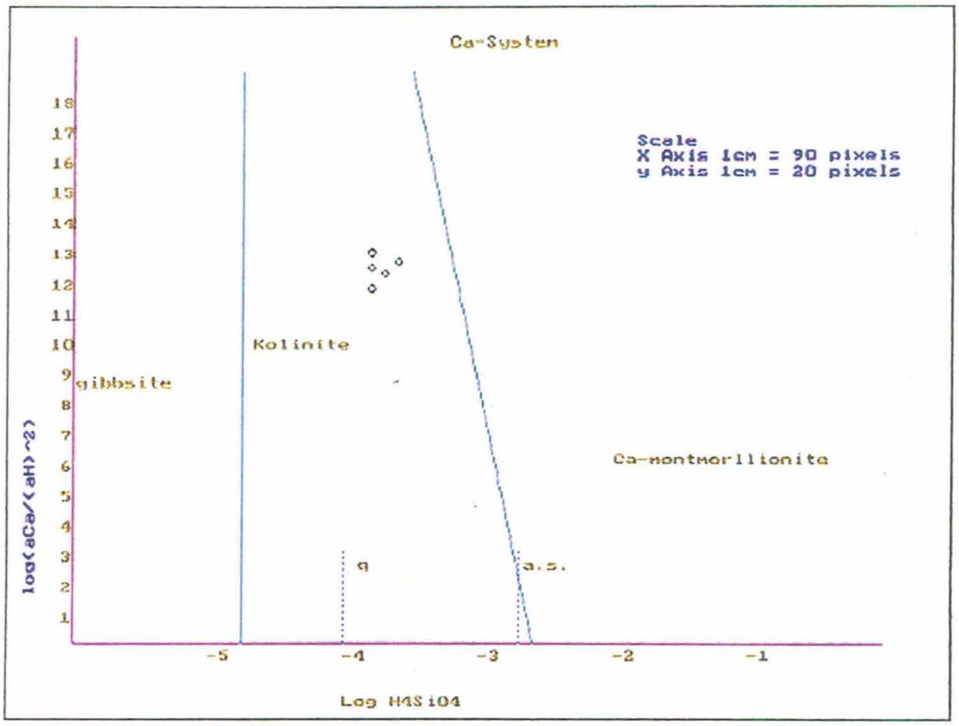


FIG. 15.17 C Mineral stability diagram of river Tapti (monsoon season)



Mineral stability diagram of Tapti river (post monsoon season)

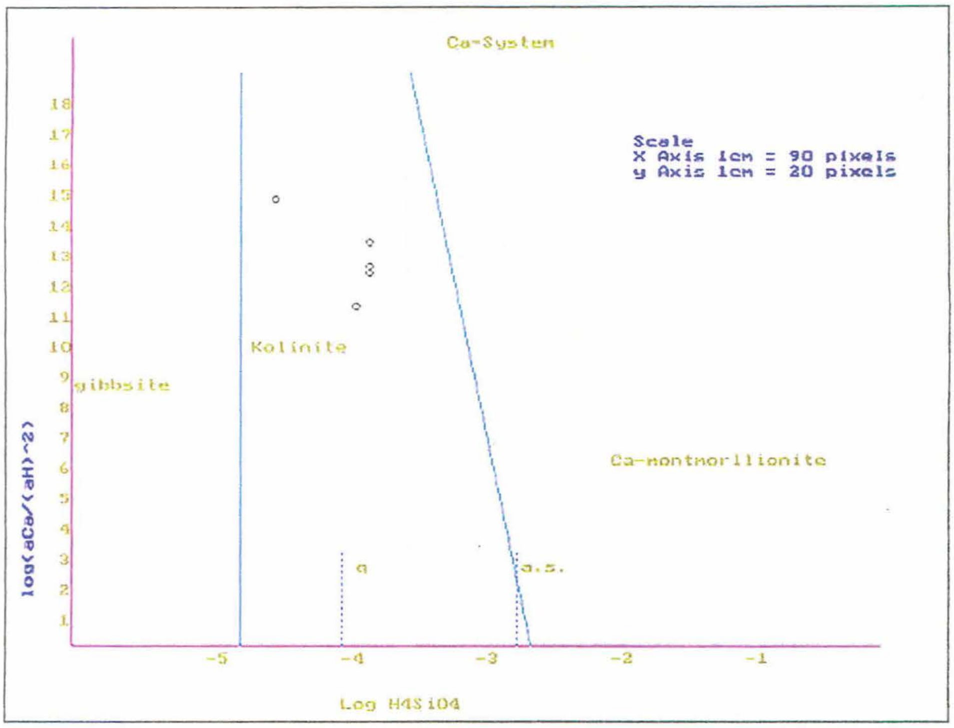
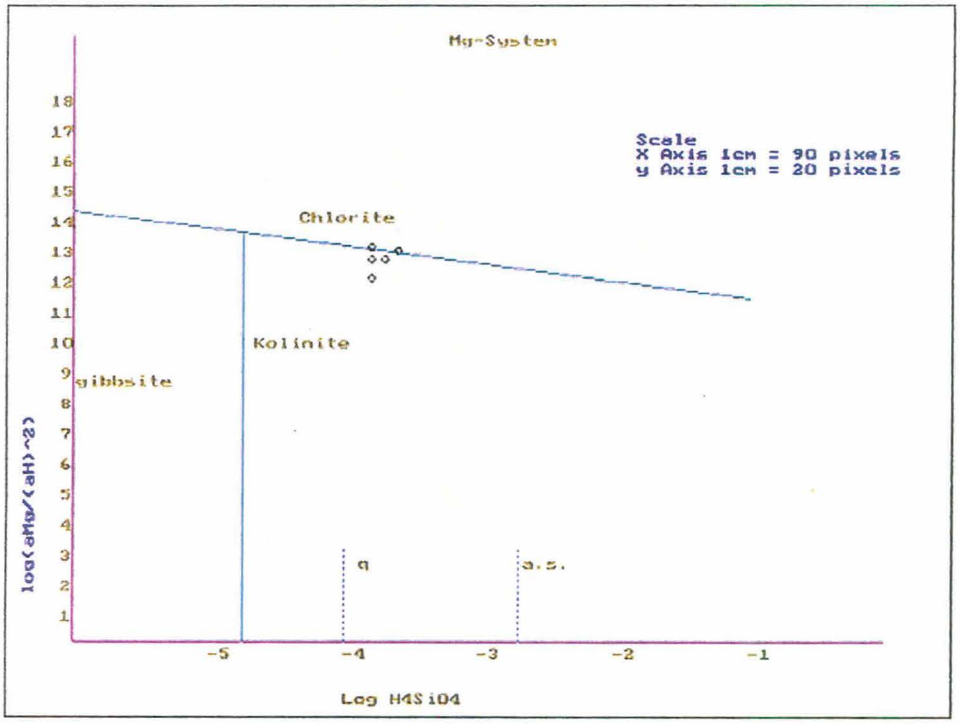


FIG. 15.17a Mineral stability diagram of river Tapti (monsoon season)



Mineral stability diagram of Tapti river (post monsoon season)

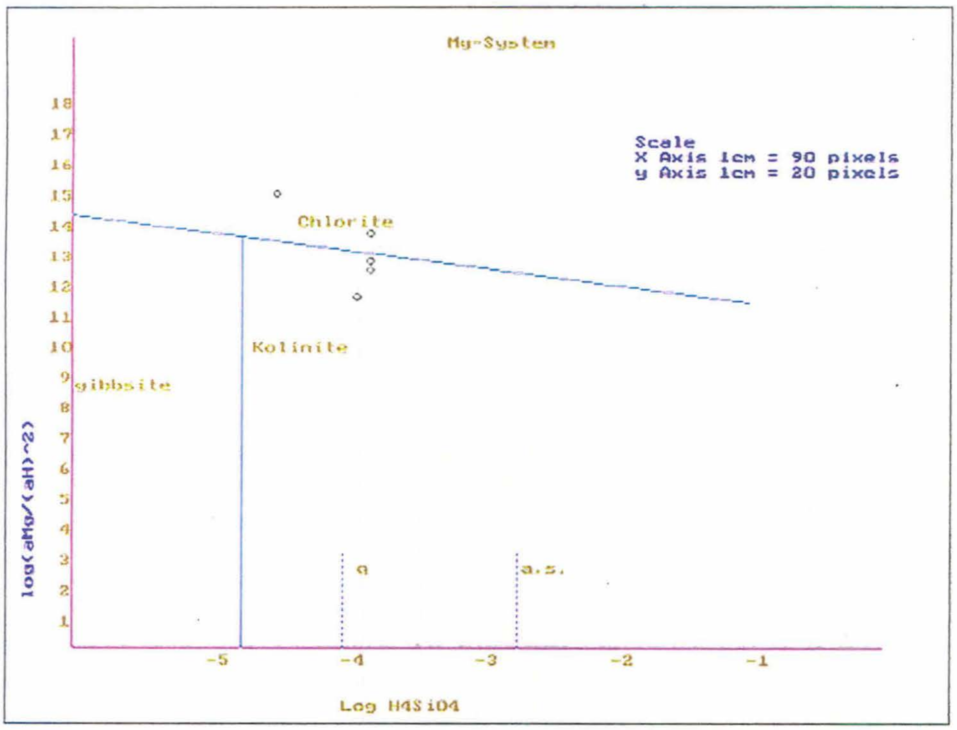
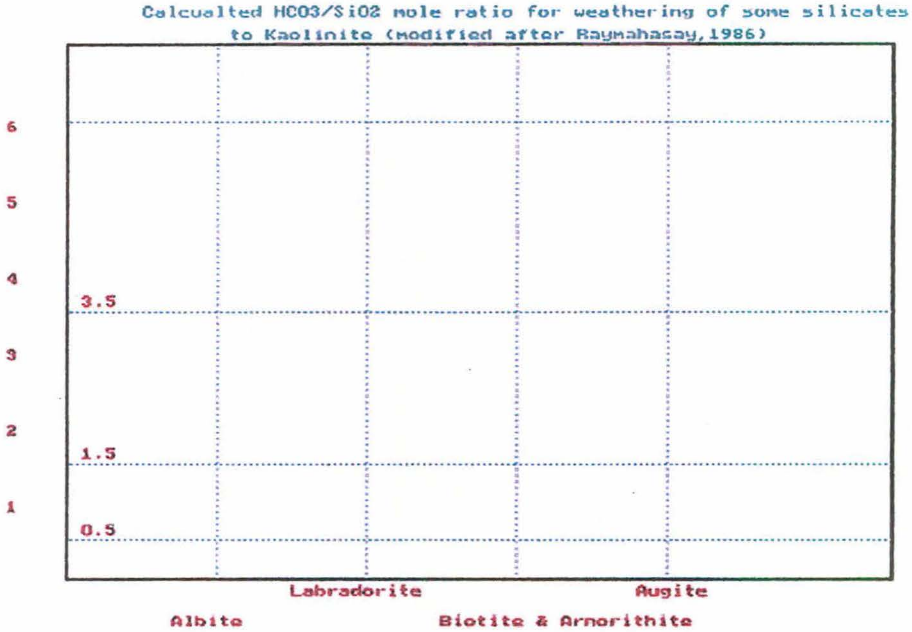


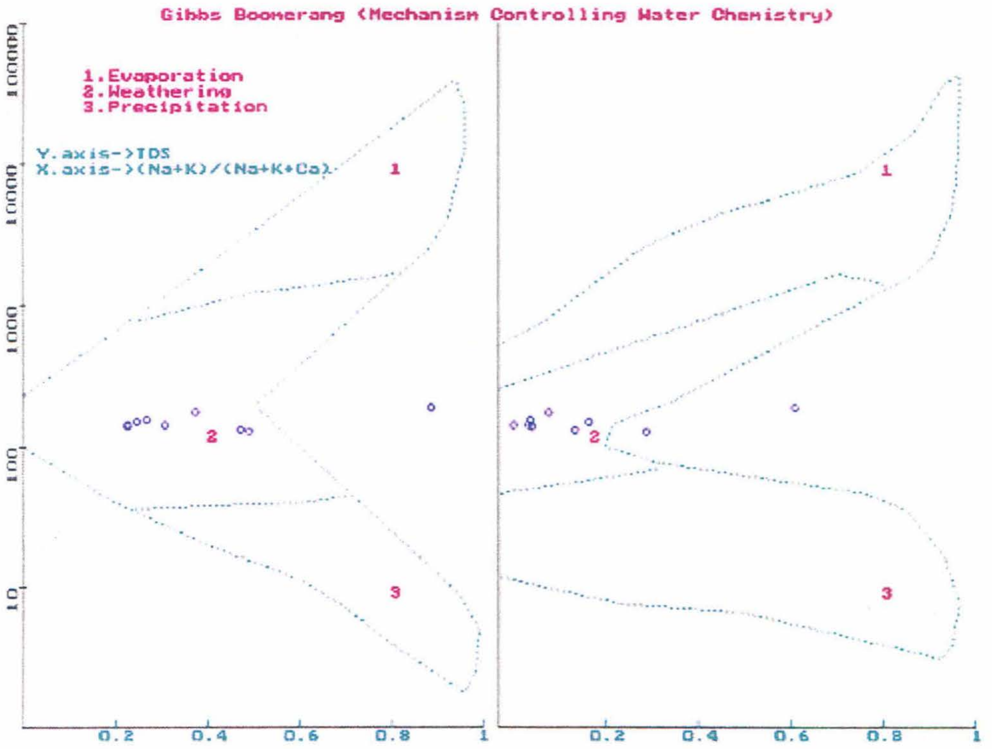
FIG. 15.17 e Mineral stability diagram of river Tapti (monsoon season)



Mineral stability diagram of Tapti river (post monsoon season)


Calcualted HCO3/SiO2 mole ratio for weathering of some silicates to Kaolinite (modified after Raymahasay,1986)

FIG. 15.18 Gibbs diagram of river Narmada (monsoon season)



Gibbs diagram for river Narmada (post monsoon season)

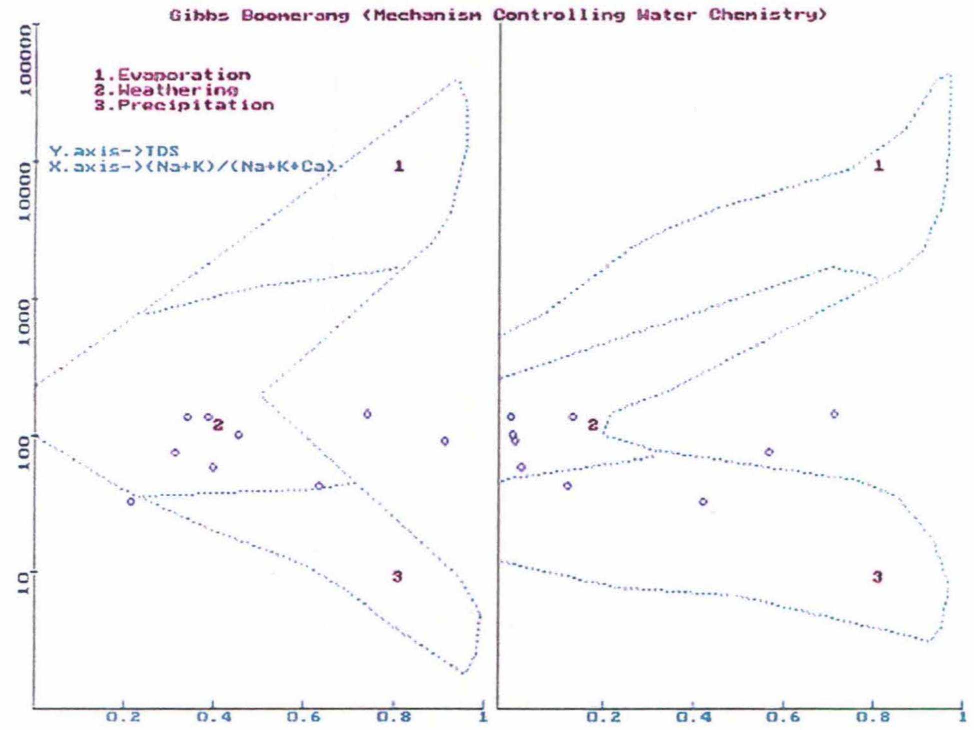
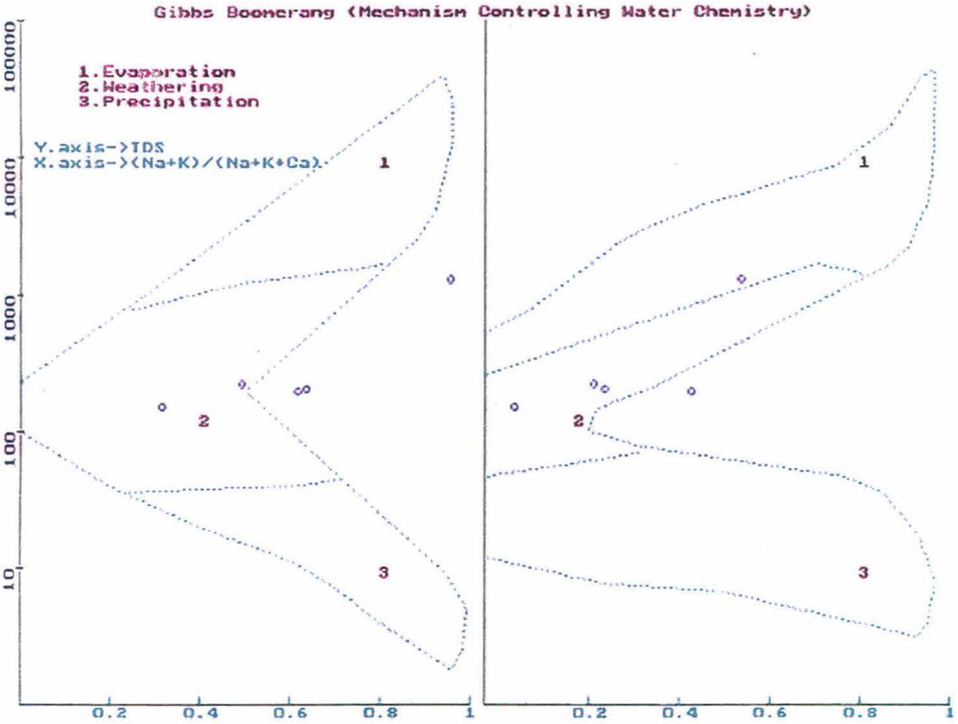


FIG. 15.19

Gibbs diagram of river Tapti (monsoon season)



Gibbs diagram of river Tapti (post monsoon season)