PRELIMINARY STUDY ON THE ENVIRONMENTAL GEOCHEMISTRY OF THE KUSHESHWAR--ASTHAN AND KABAR-TAL WETLANDS OF DARBHANGA AND BEGUSARAI DISTRICTS OF BIHAR

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MASTER OF PHILOSOPHY

Submitted By

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CERTIFICATE

This is to certify that the research work embodied in this dissertation entitled **"Preliminary Study on the Environmental Geochemistry of The Kushshewar-asthan and Kabar-Tal Wetlands in the Darbhanga and Manjhaul, Begusarai, Districts of Bihar"** has been carried out in School of Environmental Sciences, Jawaharlal Nehru University, New Delhi for partial fulfillment of the award of the Degree of Master of Philosophy. This work is original has not been submitted part or full for any degree or diploma in any university.

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CHAPTER 1:

INTRODUCTION

1. INTRODUCTION

Wetlands are areas where water is the primary factor controlling the environment and the associated plant and animal life. They occur where the water table is at or near the surface of the land, or where the land is covered by shallow water.

The Ramsar Convention takes a broad approach in determining the wetlands which come under its aegis. Under the text of the Convention (Article 1.1), wetlands are defined as:

> *"areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters".*

In addition, the Convention (Article 2.1) provides that wetlands:

> *"may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands".*

As a result of these provisions, the coverage of the definition extends to a wide variety of habitat types, including rivers and lakes, coastal lagoons, mangroves, peat lands, and even coral reefs.

In addition there are human-made wetlands such as fish and shrimp ponds, farm ponds, irrigated agricultural land, salt pans, reservoirs, gravel pits, sewage farms, and canals. Wetlands occur in every country, from the tundra to the tropics. How much of the earth's surface is presently composed of wetlands is not known exactly. The World Conservation Monitoring Centre has suggested an estimate of about 570 million hectares (5.7 million km^2) – roughly 6% of the Earth's land surface – of which 2% is lakes, 30% bogs, 26% fens, 20% swamps, and 15% floodplains. Mitsch and Gosselink, (1993); suggest that 4 to 6% of the Earth's land surface is wetland. Mangroves cover some 240,000 km^2 of coastal area, and an estimated 600,000km^2 of coral reefs remain worldwide.

India has a rich variety of wetland habitats. The total area of wetlands (excluding rivers) in India is 58,286,000ha, 70% of which comprises areas under paddy cultivation. A total of 1,193 wetlands, covering an area of about 3,904,543 ha, were recorded in a preliminary inventory coordinated by the Department of Science and Technology, of which 572 were natural (Scott, 1989).

India's 19 most important wetlands covering total area of 648,507 hectares have been designated under the Convention of Wetlands of International Importance (Ramsar Convention) as being especially significant waterfowl habitats. But taking in to consideration its vastness, 19 Ramsar sites are very less in number in compare to 1456 world wide covering area 125,396,812 hectares (Mitsch and Gosselink, 1993).

The country's wetlands are generally differentiated by region into eight categories (Scott, 1989): the reservoirs of the Deccan Plateau in the south, together with the lagoons and the other wetlands of the southern west coast; the vast saline expanses of Rajasthan, Gujarat and the gulf of Kachchh; freshwater lakes and reservoirs from Gujarat eastwards through Rajasthan (Kaeoladeo Ghana National park) and Madhya Pradesh; the delta wetlands and lagoons of India's east coast (Chilka Lake); the freshwater marshes of the Gangetic Plain; the floodplain of the Brahmaputra; the marshes and swamps in the hills of north-east India and the Himalayan foothills; the lakes and rivers of the mountain region of Kashmir and Ladakh; and the mangroves and other wetlands of the island arcs of the Andamans and Nicobars.

Wetlands are among the world's most productive environments. They are cradles of biological diversity, providing the water and primary productivity upon which countless species of plants and animals depend for survival. They support high concentrations of birds, mammals, reptiles, amphibians, fish and invertebrate species. Of the 20,000 species of fish in the world, more than 40% live in fresh water. Wetlands are also important storehouses of plant genetic material. Rice, for example, which is a common wetland plant, is the staple diet of more than half of humanity (Mitsch and Gosselink, 1993).

The interactions of physical, biological and chemical components of a wetland, such as soils, water, plants and animals, enable the wetland to perform many vital functions, for example: water storage; storm protection and flood mitigation; shoreline stabilization and erosion control; groundwater recharge (the movement of water from the wetland down into the underground aquifer); groundwater discharge (the movement of water upward to become surface water in a wetland); water purification through retention of nutrients, sediments, and pollutants; and stabilization of local climate conditions, particularly rainfall and temperature.

Wetlands provide tremendous economic benefits, for example: water supply (quantity and quality); fisheries (over two thirds of the world's fish harvest is linked to the health of coastal and inland wetland areas); agriculture, through the maintenance of water tables and nutrient retention in floodplains; timber production; energy resources, such as peat and plant matter; wildlife resources; transport; and recreation and tourism opportunities.

In addition, wetlands have special attributes as part of the cultural heritage of humanity: they are related to religious and cosmological beliefs, constitute a source of aesthetic inspiration, provide wildlife sanctuaries, and form the basis of important local traditions. These functions, values and attributes can only be maintained if the ecological processes of wetlands are allowed to continue functioning. Unfortunately, and in spite of important progress made in recent decades, wetlands continue to be among the world's most threatened ecosystems, owing mainly to ongoing drainage, conversion, pollution, and over-exploitation of their resources.

Wetlands are ecosystem quite distinct from the Lakes, though the two may be associated with each other. Wetlands are generally dominated by macrophytes vegetation and are high productive shallow water, where as Lake Systems are relatively deep, permanent water bodies, where substantial growth of algae or macrophytes is undesirable. From a functional view point, wetlands have high biodiversity, high productivity and an important role in biogeochemical cycles. Wetlands are often known for their potential for wastewater treatment. Water play very significant role in wetland formation.

Natural Lakes and wetlands are not mere storage of water. They are dynamic ecosystems with complex interactions between geology, geomorphology, climate, hydrology and biology besides anthropogenic influences in their entire drainage basins. Natural Lakes perform several hydrological, biological and biogeochemical and other ecological functions at both ecosystems and landscape levels, depending upon their location, nature, age, size depth, turnover rate and Lake Area to catchment area ratio. Most riverine wetlands and Lakes (oxbows) play a very important role in flood mitigation and ground water recharge. Water is the most important natural resources that Mother Earth has gifted the mankind. Benign life supporting in normal times, menacing during floods, and desperately sought in times of drought, the water of the rivers, aquifers, springs; lakes, wetlands, etc. have been part of our daily life.

Water is vital to all forms of life on earth from the simplest living organisms to the most complex of human systems. In modern world all developmental activities i.e. economic and political conditions, technological progress, and the environment aspects of human life are inherently related to water quality. Therefore proper assessment and understanding of the resource is of utmost importance for economic and social development.

In all, the Earth's water content is about 1.39 billion cubic kilometers and the vast bulk of it about 96.5% is in the global oceans. Approximately 1.7% is stored in the polar icecaps, glaciers, and permanent snow, and another 1.7% is stored in groundwater, lakes, rivers, streams, and soil. Finally, a thousandth of 1% exists as water vapor in the Earth's atmosphere, which may seem surprising because water plays such an important role in weather. The annual precipitation for the earth is more than 30 times the atmosphere's total capacity to hold water. This fact indicates the rapid recycling of water that must occur between the earth's surface and the atmosphere (Committee on Earth Observation Satellites, 2004).

Although water is the most abundant resource on the earth's surface (70% of the earth is covered by water) it is ironically the most scarce commodity in as far as living organisms are concerned. This is because renewable fresh water is very less on the earth's surface. Out of the total world water resources, 97.5% is salt water and the remaining 2.5% is the global fresh water. Of the global fresh water (2.5%); 69% is in the form *of* glaciers and permanent snow cover, 30% is in the form of ground water, 0.3% in wetlands, lakes and river flows and the remaining amount account for other forms including soil moisture atmosphere, etc (Navalawala,1995). Thus the renewable water is only about 0.01% of the world water resources.

Of all the water present on our planet, only 2.5% is fresh, and only 0.007% is readily available to people via rivers, lakes, and reservoirs. Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment, and management of this resource is expected to emerge as one of the greatest challenges facing mankind during the 21st century. (WW 2010, The Weather World 2010 Project, October, 1999)

Humans currently appropriately use more than half of accessible freshwater run-off, and this amount is expected to increase significantly in the coming decades. A substantial amount, 70%, of the water currently withdrawn from all freshwater resources is used for agriculture. With the world's population set to increase significantly by 2050, the additional food required to feed future generations will put further pressure on fresh water resources. According to recent global water assessments, around 70% of the future world population will face water shortages and 16% will have insufficient water to grow their basic food requirement by 2050. Future management of freshwater resources will be complicated by the uncertainties in rainfall patterns introduced by climate change, with observations and models suggesting increased frequency and intensity in both extreme precipitation and drought events – depending on the region. (Indian Water Resource Society, 1999).

Water bodies contain a wide array of molecules and ions derived from the weathering of rocks in the watershed, the atmosphere and the water bodies' bottom. Therefore, the chemical composition of a body of water is fundamentally a function of its climate and its basic geology. Even though the natural environment undergoes a continuous natural change, man's activities have exerted pressure on the environment and have accelerated the concentration of various pollutants in the environment.

Water, the most vital resource for all kinds of life, is most adversely affected by the pollutants. Domestic waste, industrial effluents and runoff from agricultural land which contains substances varying in characteristics from simple nutrients to highly toxic substances all find their way into the aquatic systems. This has adversely affected not only the quality and the chemistry of many water bodies but also aquatic life supported by the water systems. For example, excessive nutrient fertilization has resulted in excessive algal growth in most water bodies. This process (eutrophication) is one of the most significant sources of water quality deterioration in the world (Birch *et. al.,* 1996; Zutshi, 1989; Carpenter *et. al.,* 1998).

The eutrophication process causes undesirable changes in plants, reduces the aesthetic quality and economic value of the water system and threatens the destruction of water resources (Selinger *et. al.,* 1985; Carpenter *et. al.,* 1997). Therefore a study on the water chemistry of a body of water would not be complete without evaluating the nutrient levels in the water system.

Although a lot of studies have been carried out on Wetland systems and it is indicated lack of holistic approach to the whole water body thus the researchers have tended to concentrate on evaluation of major anion, cations and heavy metal pollution of both water and sediment. An attempt has been made in this direction in this dissertation.

If the lake and wetland resources are to be exploited to the maximum it is important that chemical composition of the body of as a whole is assessed together with all other parameters. The current study was therefore carried out to investigate the ionic composition of two tropical wetlands namely, Kabar-Tal (India) and Kusheshwar-Asthan (India). The major controlling parameters of water chemistry, pH, electrical conductivity (EC), dissolved oxygen and nutrients were investigated. The effect of anthropogenic activities on these natural resources has also been discussed.

In the centre of interest of environmental sciences lies the question about the relationship between the forms, properties and quantities of specific physical and chemical forms of an element in the environment and the effect of these forms on the biota and geochemical cycle.

In a wetland and lake system, the sediment reservoir plays an important role in helping to elucidate the many processes occurring within the whole water bodies system, including its surrounding surface and ground water drainage basin. For a long time however, the lake bottoms have been recognized as the depositional sites of both mineral and organic matter that are transported to the lake from the drainage basin, as well as the matter which forms and settles within the water body.

Early studies of wetlands tended to treat the sediment as simply a repository having little or no additional reaction with the lake once deposited. The sediments were viewed primarily as a record of the wetland history. In recent years however, there has been a growing awareness of the role the sediments play in the dynamics of the wetland system, Sediments have now been widely used as environmental indicators (Allan, 1979; Choudri and Chavadi, 2000). Their ability to trace contamination sources and monitor contaminants is now largely recognized (Birch *et. al.,* 1996).

Sediments are viewed as important sinks for land derived contaminants especially heavy metals, and have been widely used to identify source of pollution, to evaluate its extent and diagnose the environmental quality of aquatic systems. Sediments have been reported to play an important role in the assessment of metal contamination natural water (Jha et al., 1990; Goncalves *et. al.,* 1992, 1994; Huang *et. al.,* 1994; Borovec, 1996; Wardas *et. al.,* 1996). Sediments play an important role in maintaining water quality by removing contaminants from the water column. Sediments also act as a source of nutrients, both for bottom organisms and plankton growth in the water column. However, the subsequent release of both nutrients and contaminants from the sediment can keep concentration of contaminants in water elevated long after the external source has been removed.

In some cases, high quantities of trace elements have been found to re-enter water column via sediment- water exchange (Croot and Hunter, 2000). Internal loading of phosphorus from the lake sediment has been identified as one of the controlling factors in determining the trophic status of Lakes (Connor and Martin, 1989). Since the wetland sediments are formed from the terrestrial surrounding of the wetland and from materials synthesized in the wetland water, the chemical structure of wetland sediment is therefore a function of the characteristics of the catchment area and the wetland water. The chemical composition of wetland and lake sediments therefore, is largely controlled by proportions of minerals and elements within particles, which are a product of the geology within the source area. Studies on the mineralogical and chemical make up of sediment particles (sediments geochemistry) supplied to the water bodies by streams, shore erosions, atmospheric fallouts and cultural sources can therefore yield important information about the bedrock and surface geology of the drainage basin, weathering, and the relative importance of the various inputs and quantitative estimates of cultural loading on the wetland system. Consequently, studies of the geochemistry of the wetland sediments would help us to understand the crustal weathering processes of the area surrounding the wetland.

The influence of human activities on aquatic systems is of special interest as the anthropogenic activities have been found to greatly affect the geochemical variations and fluxes of the sediment. There has been increasing awareness that subtle and possibly irreversible changes are occurring in the environment as a result of human activities. During the recent past, the amount of heavy metals released to the aquatic environment as a result of human activities has surpassed the amount released by natural weathering (Villaescusa *et. al.,* 2000). Pollution from chemicals has become all-pervasive and now there are no parts of the globe that have been spared. Our ability to manufacture persistent chemicals has not been maintained by our ability to monitor their effects.

Among the various contaminants, heavy metals are of particular concern due to their environmental persistence and biological recycling as well as ecological risks. Analysis underlying sediment and soil can be used to evaluate long term accumulation of conserved pollutants (Boyd et al., 1997; Niskavaara et al., 1997; and Reimann et al., 2000). The heavy metals enter into the aquatic environment through industrial, domestic and agricultural wastes. Pesticides and agricultural runoff contain significant amounts of heavy metals and create serious threat to the aquatic flora and fauna since they do not degrade easily but undergo a global ecological cycle in which natural waters are the pathway (Copper, 1993). Toxic metals such as Hg, Cu, Pb, As and Cd, tend to accumulate in the bottom sediment from where they may be released by various processes of remobilization and in changing form, can move up the biologic chain, thereby reaching human beings where they produce chronic and acute ailments.

The processes that contribute to the accumulation of these elements in the bottom sediment include, adsorption to the surface of the organic particles, clay and silt particles, particles settling from overlying water and bio-accumulation by benthic organisms (Solomons and Forstner, 1984; Elder, 1988, 1994; Horwitz, 1991; and Farrah and Pickering, 1993). Metals are not fixed permanently by the sediment but may be recycled by both biological and chemical agents both within the sedimentary component and also in the water column. Thus, sediments may be both carriers as well as potential sources of the pollutants (Forstner and Muller, 1974).

Sediments also play an important role in the accumulation and regeneration of nutrients. Phosphorus associated with eroded sediment from agricultural land as well as phosphorus discharges from urban and industrial areas, sewage effluent and other wastes are the major causes of eutrophication in water bodies. It is well established that phosphate dissolved in water is adsorbed to sediment under aerobic conditions and is released back to the overlying water under anaerobic conditions (Chakrapani and Subramanian, 1996). However other than determination of total heavy metals in the lake sediment (Asthana, 1976; Pande and Das, 1980; Gupta and Pant, 1989; Gupta *et. al.,* 2001; Sujatha *et. al.,* 2001; Sreenivanas *et. al.,* 2001 and Chakrapani, 2002), very little work has been done on heavy metals on the lake and wetland sediments in India. Even hardly any significant study is done regarding water chemistry and sediment in wetland and flood plain of Bihar.

India contains a great wealth of biological diversity in its forests, its wetlands and in its marine areas. Out of 9,723 bird's species known world wide, 1,295 species are found in India 12.6% of the world total. According IUCN Red List of Threatened Animals, out of these 75 birds species are endemic to India and 78 species are endangered species (Annual Report 2002-03, Salim Ali Centre for Ornithology and Natural History).

Both the study area are notified as Birds Sanctuary by the government.There is no baseline data available on the environmental geochestry of these wetland, therefore current study, has tried to quantify various physicochemical parameters and estimation of heavy metals in water and sediment samples of study area in view to understand its environmental condition and find out the possibility of getting it incorporated into Ramsar site for conservation and development in near future.

CHAPTER 2

LITERATURE REVIEW

2. LITERATURE REVIEW

The chemistry of natural water and sediment has attracted attention in the last five decades. Among others, chemical oceanographers, geologists, hydrologists, limnologists, fish farmers, ecologists, water chemists and water engineers have put a lot of effort to formulate adequate experimental and theoretical description of the chemical behavior of wetland like ocean, estuaries, rivers, lakes, and also of ground water and soil water systems.

2.1. Water

Research carried out on water chemistry include, Beadle, 1979; Meybeck, 1979, 1981; Rai and Rothore, 1993; Gottennan, 1995. Studies carried out by several workers on the chemical composition of inland 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 ($S0_4^{--}$) 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 $HCO_3^{-} > CO_3^{--} > S0_4^{--} > Cl^{-}$.

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.

2.2. Processes controlling the water chemistry

Water Chemistry of wetland depend on rock weathering (Cole, 1974; Drever, 1982) and other processes include climatic, biotic and anthropogenic.

2.3. Rock weathering process

Weathering process is the chemical decay and physical fragmentation of minerals that fanned at high temperature and pressure in the interior of the earth and on the earth surface conditions. The composition of the rocks and soils and their ion exchange capacities influence both the rate of weathering and the ionic supply to the runoff and percolating waters.

2.4. Climatic processes

Climatic factors include temperature, wind and rainfall. Climatic factors exert an important influence on weathering via its control on vegetation and organic matter in the soil. Rainfall for example affects flushing of the rocks.

2.5. Biotic processes

Aquatic organisms are influenced by the chemistry of the surrounding environment. For example, phytoplankton extract nutrients from the water and the zooplankton feed on the phytoplankton. Nutrients are redistributed from the upper water to the bottom water as the dead plankton gradually sinks to lower depths and get decomposed.

2.6. Anthropogenic processes

Since industrial revolution, humankind activities have caused severe alteration in the structure and functions of the environment. Growth of human population has placed ever increasing demands on both aquatic and terrestrial ecosystems. Smith *et. al.,* 1998; reported that between one third and one half of the ecosystem has been transformed. Human beings have dramatically changed the globe through land clearing, agriculture and urbanization; which has resulted in altering hydro-geochemical cycles (Cole *et al.*, 1993; Caract *et al.,* 1995; Jaworsk *et. al.,* 1997; Vitousek, 1998). They have also had profound impact on biogeochemical cycles of Carbon (C), Nitrogen (N) and Phosphorus (P), (Scheleisinger, 1991; Howarth *et al.*, 1996; Vitousek, 1997). This also has Environmental Impacts on the water quality of the watershed (Gulbahar and Elhatip, 2005). A variety of compounds released from various industries, motorized vehicles, and fossil fuel burning have also had tremendous effect on the chemistry of water systems. It is well documented that any chemical input to a wetland as pollutant causes significant changes to the water body.

2.7. Eutrophication

Nutrients input to the wetland, hastens the eutrophication process. In many wetland ecological changes, which might have naturally occurred over thousands of years, have occurred in a decade as a result of eutrophication. Documented cases include Lake Michigan and Washington in U.S.A. (Scheleske and Steimer, 1972; Edmonson, 1972; Barton and Scheleske, 1982); Lakes Fonstance and Zurich in Central Europe (Vollenweider and Dillon, 1974); Lakes Biwa and Kasumigawa (Nakanishi *et.al.*, 1992) and lakes Vanern and Malar in Sweden (AtiI, 1975).

2.8. Sediments

Over the past two decades, considerable attention has been paid to the use of the lake and reservoir bottom sediment as proxy sources of data on sediment yield and sediment associated contaminant history. These studies provide an opportunity to reconstruct environmental changes; which have occurred within the lake or reservoir and within the surrounding catchment. The potential of the lake and reservoir bottom sediment has been recognized in the reconstruction of catchment sediment yields (Foster and Walling, 1994; Foster, 1995) and in the characterization of bottom sediment to identify temporal changes in sediment provenance (Yu and Oldfield, 1993; Foster *et. al.*, 1998). Thus sediments have been widely used as environmental indicators and their ability to trace contamination sources and monitor contaminants is largely recognized (Forstner and Wittmann, 1983; Birch, 1996; Soares *et. al.*, 1999).

The sediment provides an archive of environmental changes both within the wetland ecosystem and the surrounding region and therefore, has been used across the world in order to study natural environmental changes or human impacts. The sediments play an important role in the assessment of metal contamination in natural water (Jha *et. al.,* 1990; Goncalves *et. al.,* 1992, 1994; Huang *et. al.,* 1994; Borovec, 1996 and Wardas *et. al.,* 1996). Freshwater sediments, for example, are one of the endpoints for trace metals emitted from anthropogenic sources, and provide an archive for studying trace metal pollution history (Birch *et. al.,* 1996; Yang and Rose, 2004). They show a high capacity to accumulate and allow concentration of trace elements in water and therefore, they allow the determination of metals even when the levels in water are extremely low and undetectable (Soares *et. al.,* 1999). Thus sediments play a crucial role in water quality because they remove elemental pollutants from the water.

Although most adsorbed pollutants on the sediments are not readily available for aquatic organisms, the variance of some physical and chemical characteristics (pH, salinity, redox potential and the content of organic chilators) of the overlying water may provoke release of the metals back to the aqueous phase. Therefore, under changing environmental conditions, the sediments may themselves become an important pollution source (Soares *et. al.,* 1999; Huy *et. al.,* 2003). Distribution of trace elements in different geochemical phases in sediments and their remobilization have been studied and discussed by various authors (Solomons *et. al.,* 1987; Saeki *et. al.,* 1993; Lopez-Sanchez, 1996; Heyvaert *et. al.*, 2000). A number of reasons ranging from, a need for identification of the origin of the sediment, to a need to know the source of contaminant, has led to the investigation of sediment in the aquatic systems.

2.9. 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.

2.10. Studies carried out in India

India is a country quite rich in its water resources. It has a dense network of 14 major, 45 medium and 120 minor rivers with thousands of tributaries (Malvika and Gopal, 2001). However, there are only a few natural lakes mostly confined to the Himalayan belt. A few other lakes include those of fluvial origin (ox-bow), fresh water lakes, salt lakes and coastal lagoons. Studies carried out in India; indicate that due to over exploitation of both living and non living resources and dumping of waste from land to various water bodies and other human activities; the environmental conditions and water resources have been significantly affected. A few have become hyper sensitive to further human intervention (Panigrahy, 2001). The water pollution has many sources but the most polluting are the sewage and industrial discharge into the rivers. Since the facilities to treat the wastewater and industrial effluents are inadequate in any city in developing countries, untreated sewage discharge and industrial effluents are therefore released directly into rivers and reservoirs. This has resulted in pollution of most of these water bodies and has significantly affected the water chemistry.

Lot of work on the geochemistry in river sediment and estuaries has been carried out in India (Subramanian and Mohanachandra, 1990; Bhiksham *et. al.,* 1991; Gupta and Subramanian, 1994; Chakrapani and Subramanian, 1996; Ramanathan *et. al.,* 1996 and Datta and Subramanian, 1998). Several other studies on the geochemistry of river sediment have been reported by various authors (Subramanian *et al.* 1987; Jha *et.al.*, 1990; Chakrapani and Subramanian, 1990).

The sediment geochemistry of a number of lakes has also been carried out by various researchers, (Narasimha, 1971; Asthana, 1976; Pande and Das, 1980; Gupta and Pant, 1989; Gupta *et. al.,* 2001; Sujatha *et. al.,* 2001; Sreevanas and Ramamohan, 2001).

Several studies have been carried out on Indian water systems. They include Eutrophication gradient of the Dal Lake (Zutshi and Khan, 1988) and geochemistry of the Pulicat Lake waters (Nagaraju *et. al.,* 1994), water chemistry and control of weathering of Pichola Lake (Das and Singh, 1996) and Pollution of Udaisaga Lakes (Das and Singh, 1996; Das, 1999) and Degradation of water quality, (Sreenivanas *et. al.,* 1999).

Other important work on water system includes; eutrophication of lakes (Mathur *et. al.,* 1984 and Zutshi, 1989); limnology studies (Zutshi *et. al.,* 1980; Unni, 1983; Shastree *et.al.*, 1991; Jain and Seetapath, 1995; Agadi *et. al.,* 1999); physicochemical characteristics of Visishta Godavari estuary (Shastree and Chandra Mohan, 1990); hydrochemistry of lakes (Gupta *et. al.,* 2001); biogeochemical studies in Cauvery estuary (Ramanathan *et. al.,* 1996); trace metals in water (Urfi, 1985; Nag and Das, 1993); geochemistry of Pulicat Lake water (Nagarjun *et.al.*1990); hydrochemical studies of ground water (Karanth, 1989; Elampooranan *et. al.,* 1991); quality of Kolleru lake (Mangapathi, 1987; Sreevanas, 1999); quality of drinking water (Sreevanas *et al.* 2001); pesticide pollution, ecology and weed biology (Sethavatharam *et. al.,* 1978; Sreevanasn *et. al.,* 2001).

2.11. Studies carried out in Kabar-Tal and Kusheshwar-Asthan (focus of the current study)

Till now work reported on Kabar–Tal are Ecology of birds (Singh and Roy,1990); Ecology of fishes (Sharma *et. al.,* 1994), Ecology of gastropods in relation of macrophytes(Pandey *et. al.,* 1994); Fresh water gastropods (Singh *et. al.,* 1994); Biodiversity and Pollution status in relation to physicochemical factors (Singh *et. al.,* 1994); Conservation management and sustainable development for rehabilitation of the migratory birds (Sharma, 1995); Territorial behavior in water pollution (Sinha and Roy, 1995); Community structure and their periodicity (Sanjer and Sharma, 1995); Seasonal variations of biomass of mollusks, (Sharma *et. al.,* 1996); Assessment of secondary productivity of insects (Prakash *et. al.,* 1996); Interaction of nutrient between biotic and abiotic components (Sinha and Sharma, 1996); Role of macrophytes in the ecosystem (Sharma, 1995); Study of spatial-temporal changes (Ghose *et. al.,* 2004).

Physiography of Kosi river basin and formation of wetlands (Munshi and Munshi, 1991); Inlands fish culture in Kosi division (Verma, 1995); Fresh water diatoms of Darbhanga, (Siddiqui and Ahmad, 1995); Systematic survey of cynobacteria from paddy fields of Darbhanga, (Ranjana and Siddiqui, 1995).No study information is available on Kushewhwar –asthan wetlands except one primary study done by Dr, B.L.Gupta(lecturer J.K. College, Biraul, Darbhanga, Bihar) and M. A Hussain., .(Ecology of wetland of Kusheshwar-Asthan

PhD thesis L.N. Mithila University, Darbhanga, 1992). The above discussion does not cover the geochemistry of the water and sediment of the current study area. No work has also been carried out on the availability, mobility and transport of the elements or nutrients in these ecosystems.

The current study is a modest attempt to fill these gaps.

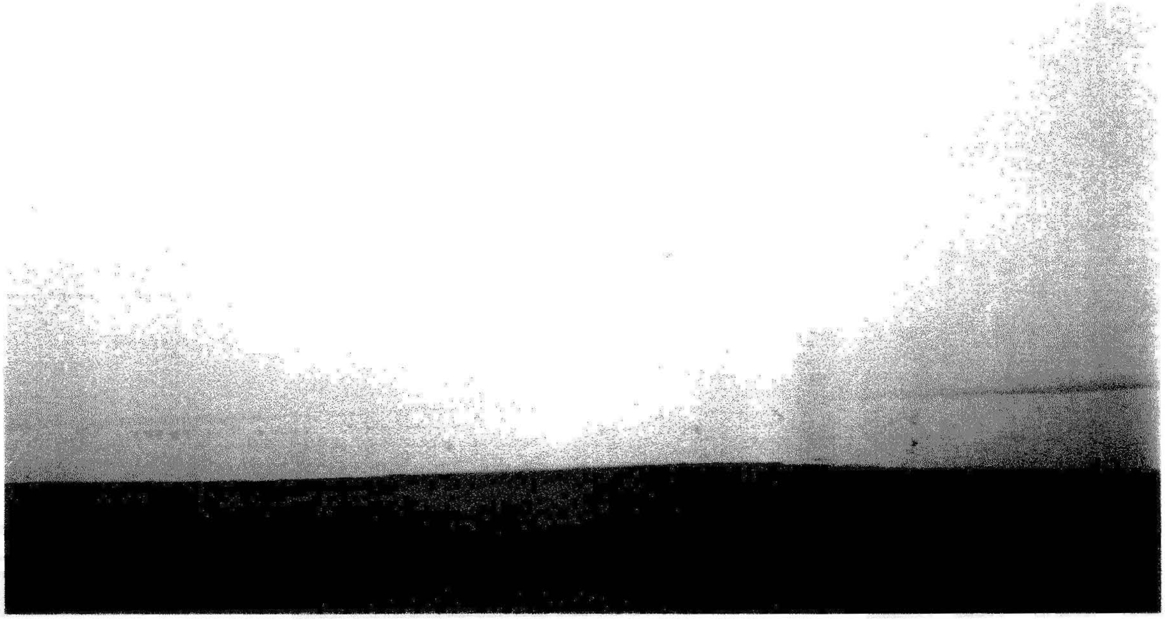
CHAPTER 3

STUDY AREA

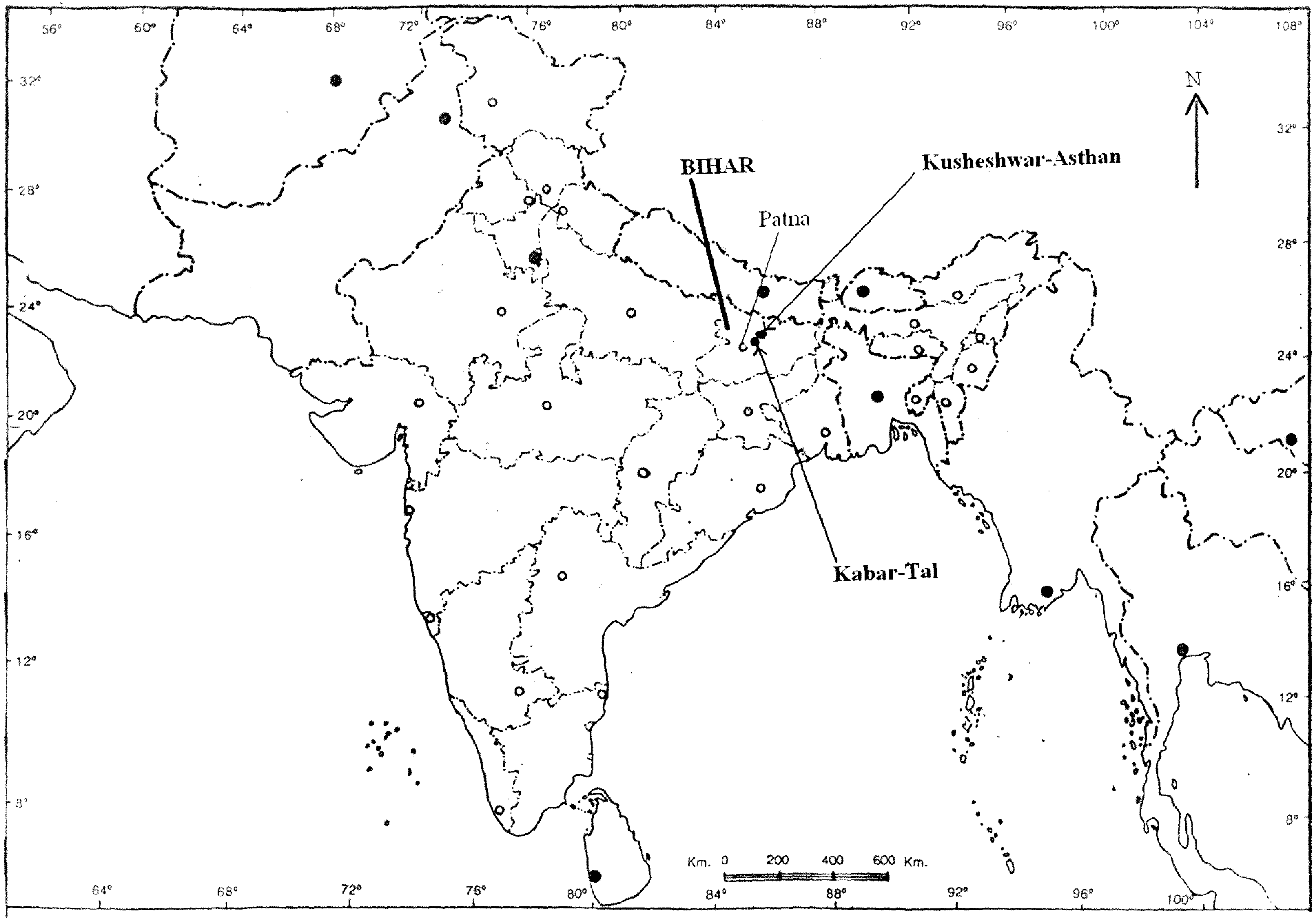
Panoramic View of the Study Sites

Kabar-Tal

Kusheshwar-Asthan



INDIA


BIHAR
Patna
Kusheshwar-Asthan
Kabar-Tal
N
Km. 0 200 400 600 Km.
56° 60° 64° 68° 72° 76° 80° 84° 88° 92° 96° 100° 104° 108°
32° 28° 24° 20° 16° 12° 8°

3. Study Area

3.1 Kabar-Tal, Begusarai, Bihar, India

3.1.1 Geographical Profile

The district Begusarai, an important district in the state of Bihar lies on the northern bank of river Ganga. Geographically, lying between latitudes $25^0$15'N & $25^0$45'N and longitudes $85^0$45'E & $86^0$36'E. It covers an area of 1918 km ^{2}. It is situated in a part of Middle Gangetic plains, locally known as North Bihar plains.

The Kabar-Tal is located in Majhaul village of Cheria Bariarpur block of Begusarai district. It is 22 km North of Begusarai Town. It lies at $25^0$36'N latitude and $86^0$09'E longitude.

3.1.2 Demographic Profile

The 2001 census count placed the Begusarai population at 2,342,989 as on the first of March. The average population density is 1,222 persons per square km according to 2001 census. The population has grown at an annual average rate of 2.9 %. There are many stages in the demographic transition beginning with a declining mortality and continuing fertility to a stage where both mortality and fertility rates decline more or less at the same rate and keep the population stable over a period of time.

3.1.3 Sources of Livelihood

Agriculture is the mainstay of the economy of this area. 88.33 % people depend upon agriculture. The major crops are wheat, maize, paddy etc. and the main cash crops of the district are oilseeds, tobacco, jute, sugarcane, potato, red chilies, tomato and andi (a kind of oil seed).

The traditional occupation in this area has been the rearing of milch cattle. Animals are used in agricultural work even today. In urban areas rearing of cows of hybrid quality has increased. Despite domestic use of milk, a huge quantity of milk is sold to the Barauni Milk

Composite Dairy Industry. This gives lucrative income and employment to the people of Begusarai.

3.1.4 Industry

Begusarai is nationally and internationally known for its industrial recognition. Major industrial units are: Indian Oil Refinery- Barauni, and Hindustan Fertilizer Limited–Barauni. Along with these two Public sectors, hundreds of small industrial units in the private sector and Thermal power station, Barauni are on the verge of closure.

This district has the vast potential for agro- based industries where the grain crops and cash crops constitute the major component of it.

3.1.5 Mines and Minerals

The district is poor in the field of mines and minerals.

3.1.6 Flora & Fauna

This district does not comprise of any forest. In contrast to the eastern portions of the old district of Munger, this district lying south to the Ganga does not comprise of any forest of sal and other large trees. At most of the places, there are gardens of mango and litchi. Chakmuzaffar, a village of Naokothi block is famous for banana. Apart from these, Babul, Neem, Guava, Lemon, Gamahar, Peepal, Bamboo, shirish are also found. Shisham is one of the most important ones of them. Wild animals are scarcely found in this district. However, birds are seen in large numbers in various colors, particularly in the bird sanctuary of Kabar-Tal.

3.1.7 Climate Profile

Being a part of Gangetic plain of Indian subcontinent, the district experiences three climatic seasons – hot and humid summer from late March to mid June, rainy season from mid June to October and the winter season from November to February. The month of February & March fall in the transitional season from winter to summer described as spring or "Basant".

Similarly the months of September & October falls in the transitional season from rainy season to winter season described as “Shishir”.

During summer, temperature may rises up to 42 ^{0}C. Due to high temperature, this becomes an area of low pressure. During this period, Bay of Bengal, due to its geographical characteristics, serves as homeland for cyclones. Being an area of low presser, the plains of Begusarai and its associated areas attract these cyclonic winds. This leads to the dust storms. These dry, hot, dusty storms are locally termed as ‘Loo’. These are prevalent in the month of May-June.

The average annual rainfall in this belt of Ganga- Burhi Gandak is 1384 mm of which 83% falls between Mid June and Mid-October (Indian Metrological Department). Monsoon normally starts in June and lasts till October. The early monsoon currents, channeled to the north westerly (NW) are the principal source of rainfall of the region. 17 % of pre monsoonal rains, which is spread in the different months of the year (especially in the months of November- December-January), have been explained as due to NW affect and rest during monsoons due to Himalayan affect. Heavy rain, supplemented by physiographic/geomorphic features lead to heavy flood.

The chilling winter starts in mid-October and continues till initial periods of March. Most part of the winter is dry except some sporadic rains as mentioned above. The migratory birds start coming from the last week of October and generally reside up to March.

3.1.8 Physiography and Relief

North Ganga plain is a major physiographic unit of the Indian landmass. It extends from the Himalayan terrain in the north to the river Ganga in the south covering about 56,980 km^2, roughly quadrilateral in shape. Generally recognized as "a water-surplus area", this quadrilateral region is bounded by a northern piedmont belt where water oozes to the surface, followed by a broad belt of swampy lands, depressions and lakes, and finally an aggregation of alluvial fans as all these northern streams bend to form confluence points with the Ganga (Singh & Kumar, 1974).Hence, the surface is characterized by palaeo levees, swamps or flood basins locally called "Chaurs", relict palaeo channels aggraded in varying degrees, meander belts, ox-bow lakes and cut-of loops. Its fluvial geomorphology is dominated from west to east by the Ganga-Gandak Interfluves, the Gandak-Kosi Interfluves and the western Kosi Fan Belt. Some of these rivers frequently change their channels. Their channels are called by different names in different parts of their courses. According to a study in 1976 on Wetlands in Bihar by Government of Bihar, natural wetlands of more than 100 ha each, covered about 46,828 ha (Directory of Wetlands, Govt. of Bihar, 1976)

The district of Begusarai lies in the middle part of this great plain known as mid Gangatic plain. In general, it is a low-lying flat terrain (Mean Sea Level 45-32m) having a southerly to southeasterly slope. This factor governs the flow of streams. Geomorphologically it is a part of the Gandak- Kosi interfluves. The southern part of the district, except those of low-lying flood plains of Ganga, appears to be an elevated landmass when compared to the adjoining districts of Khagaria and Samastipur. Hence, being a safer destination amidst the flood drained region, it supports the human activities in a better way.

The district Begusarai is divided into three flood plains namely

i. Kareha-Old Bagmati flood plains,
ii. Burhi Gandak Flood plain and
iii. Ganga Flood plain.

The first two flood plains of the district are very low lying areas and are prone to the flood. The floods owe their origin to the complex interplay of fluvial geomorphic elements in the upstream sections of the Kosi, Bagmati-Kareh-Budhi Gandak and related rivers. These two flood plains converge in the southeastern part of the district, which is lowland. The streams flowing in the region show a shifting tendency. In the course of their shifting, the rivers leave behind their scars of their previous channels. Thus due to shifting nature of streams and physiographic characteristic, this part is full of wetlands, back swamps and oxbow lakes. However, in the southern part, the flood plains of Ganga are least prone to flood. Interestingly the Railway track passing through the district marks a prominent divider line for Ganga flood plain and Kareha- old Bagmati flood plains & Burhi Gandhak flood plain. The Flood plains of Burhi Gandak and Kareha are marked by the presence of palaeo levees, oxbow lakes, paleochannels, relict streams and Chaurs (Oxbow Lakes in Bihar flood plain)viz Kaulachaur and Bhagwanpur chaur. These Chaurs serve as excellent fertile agricultural lands during summer and are submerged during rains. Also the areas around these Chaurs face the problem of submergence for around three-four months a year. Kabar-Tal, a large fresh water lake which is basically a huge wetland, presents an important physiographic feature of this part.

In the Ganga flood plain, which is approximately 50-55 km long and 5-6 km wide, in the southern part of the district, except those low lying areas of "Taals and Chaurs", the typical fluvial characteristics of North Bihar rivers are not visible, which are prominent in the north of Railway track. This is the least flood prone area of the district, which gets drowned only in cases of exceptional floods in Ganga and Burhi Gandak. This relatively upland area appears to be the levee of river Ganga. (Mahadevan, 2002)

3.1.9 Geomorphic Setup

The mid-Ganga plains may be broadly divided into a number of major geomorphic units. The northernmost part is the region of the Siwalik ranges and is followed by the piedmont fan surface fringing the foothills 10-30 km wide, built up by coalescing fan surfaces of major Himalayan Rivers. This surface includes both the bhabar and tarai land. Built upon these surfaces are fluvial regimes classified into megafans and interfluves, characterized by upland terraces, river valley terraces and active flood plain surfaces (T0),(Singh,1996). The entire district of Begusarai falls in this T0 surface. The southern and northern banks of the Ganga, in and around Begusarai are characterized by tributaries that flow parallel to the Ganga for long distances over the floodplain itself, before it joins at deferred junctions. This belt is named as the Ganga Yazoo belt (Sinha *at. et.*, 1994).The Gandak-Kosi interfan has been divided into an upper area of gently converging rivers that flow South East (SE), perpendicular to the mountain front and a downstream area (the district of Begusarai and neighboring area) where the more sinuous channels of the Burhi Gandak, Bagmati, Kamla and Balan systems flow gently to the SE.

3.1.10 Drainage

The district is drained by a number of rivers viz. Ganga, Burhi Gandak, Bagmati and Balan Rivers; and in addition, small rivulets, dhars, nalas which are originated locally and preserve rain water, mark the landscape. Among the rivers, Ganga, Burhi Gandak, Kosi, Kareha and Bagmati are perennial, whereas Channa River, Baintia nadi, Kachna nadi, Monrya nadi and Malti nadi are seasonal.

All the types of streams i.e. the mountain fed, foothill fed, plain fed and mixed fed, drains the district. Ganga is a mountain fed river while Bagmati is a foothill fed river. Burhi Gandak, Baya, Balan, Baintia, Channa etc are originated in the plains and present examples of plain fed rivers. The small rivulets serve as tributaries to the streams of higher order. These rivulets are often dry lowlands during summer and flooded during rainy season.

In general, the drainage pattern of the rivers of this region forms a part of the greater Gangetic Plain, which is characterized as dendritic drainage pattern. However, locally they exhibit their typical characteristics. The Ganga River here shows Yazoo pattern of drainage and the area is known a Ganga Yazoo belt. Yazoo pattern of drainage is defined by the streams, which travel in a parallel fashion before confluence (Parkas and Kumar, 2000). Burhi Gandak, Bagmati, Kareha, Balan and Baintia, shows very high sinuosity and are typically meandering rivers.

River Ganga enters into the southwest part draining the Chamtha block in the district. This river along with its flood plains, "Chaurs" and "Taals" determines the boundary of the district in the southern part.

The Burhi Gandak, the 2nd most important river in this area, also known as Sirkahana *in its* upper reaches, enters the district near Parihara about 10 km upstream of its confluence with the Balan River. It forms the boundary with Samastipur district in Khodawandpur and Cheriabariyarpur blocks. This is a river showing very high sinuosity and has characteristically low slit content than other Himalayan rivers. After traversing a distance of approximately 100 Km. it drains in Ganga near Khagaria .The river cause periodic floods in the western part of the district.

River Balan enters the district in the Bachhwara block. After taking a course of approximately 30 km, it drains into Burhi Gandak River 5 km west of Majhaul. This is also a highly sinuous stream.

Bagmati – A very Juvenile stream of North Bihar plains, drains only the northeastern corner of district. It enters into the district near Bakhri and is well known for its unstable nature and spill channels. After traversing the low-lying valley areas, it meets the Kosi near Sankosh outside the territories of the district. It is responsible for floods in the northern part of the district.

Baintia River is a plain fed stream originated in the adjoining district of Samastipur and enters in Bhagwanpur block of the district. Upstream, in the Samastipur district, it is known as Jamwari Nadi. This drains into Burhi Gandak after joining the Balan River. It is also a stream having water round the year. Baya Nadi drains the district's Teghra, Bachhwara and Barauni block. It merges with river Ganga at Roopnagar near Barauni fertilizer factory. This is a stream which does not show any sinuosity in the Begusarai district and is a perennial stream. In the mid of the Burhi Gandak flood plain lies a vast fresh water lake known as Kabar-Tal, which is formed by shifting of river Burhi Gandak. Kabar-Tal gets its water either due to rains or due to near-by overflowing rivers such as Burhi Gandak, Bagmati

3.1.11 Geology

The geology of the area constitutes the highest alluvial plain in the domain of the Himalayan Rivers to the north of the Ganga. It is a part of the Great Gangetic Basin. The basin was formed during late Paleogene-Neogene times and is related to the upheaval of the Himalayas viz a viz flexural down warp of the Indian Lithosphere under the supracrustal load of the Himalayas (Wadia, 1949). The entire segment abounds in buried faults and grabens. The basin came into existence as a result of the collision of India and China continental Plates during the Paleocene (Dewcy and Bird, 1970). Collision resulted in intraplate subduction along the Main Central Thrust (MCT), lying in the Himalayas, raising the Higher Himalaya to form source rocks and "popping through" of the more southerly part of the Indian plate to form the basin. This "popping through" might have lead to the development of longitudinal and transverse lineaments throughout the basin. With time more southerly areas were raised and by mid-Paleocene subduction also started along the Main Boundary Fault (MBF) lying in the Himalayas. These phenomena are reflected in the presence of a coarsening up megacycle, with at least two superimposed minor cycle and in the composition of the sandstone and conglomerates of the basin. Latter folding of the northern edge of basin to form the Siwalik Ranges during the Early Pleistocene led to cannibalism of this part of the basin.

The basin had east west elongated shape and started with a shallow marine environment, which changed to estuarine and deltaic one with time. By Mid-Miocene, continental sedimentation marked by fluvial environment dominated the scene and this set up has continued to the recent with minor modifications. The basin had predominantly transversal pattern controlled by southerly flowing rivers emerging from the Himalaya and during Neocene period, a master stream along the southern margin of the basin drained into the Bay of Bengal. The fluvial sedimentation took place the form of mega-alluvial cones. Sedimentation in the basin was influenced by tectonism through out its evolution.

The Indogangatic Basin, still an active one, needs to be studied for detailed stratigraphic correlation, sedimentary facies relationship, and change in climate through space and time and modern sedimentation.

A Quaternary fault system has been identified in the region. This is an echelon pattern of surface faults associated with Begusarai fault. Within this fault zone, various geomorphic features are found which have their origin in both the lateral and vertical movement of fault-bounded slices, as well as in the persistent strike-slip. In regions where tectonic activity is less pronounced, streams generally flow more or less perpendicular to the adjacent highlands.

The Quaternernay sediments of the Indogangatic plains have been traditionally subdivided into the older and younger alluvium and locally called Bhanger and Khader. Entire area of Begusarai falls in the domain of "Khader" sediments. (Mahadevan, 2002)

3.1.12 Soil System

The soil of this land unit is primarily unaltered alluvium, which is yet to undergo pedogenesis (process of soil formation). Texturally it varies from sandy loam to loam in the meander scroll and levee(the upland bounding the flood plains of the river) areas, to silty loam and silt in flood basin areas of the Himalayan rivers and from loam in the levees of Ganga to clayey loam and clay in the basin of Burhi Gandak and Bagmati river. The soil of the area is sandy loam rich with humus and is also very fertile. (Mahadevan, 2002)

3.1.13 Kabar-Tal

Kabar-Tal is one of the examples of excellent wetlands, which are found in the flood plains, and is the largest freshwater lake in Northern Bihar. The lake has been declared and notified as a closed area and protected area under section 37 of the Wild Life Protected Act 1972 and also it has been declared as one of the "Bird Sanctuary'' in 1989 by the State Government of Bihar. The Ministry of Environment and Forest, Government of India has also selected this lake as one of the 16 wetland of the country for conservation and management, mainly due to its greater and enormous productive potential for attracting numerous migratory birds coming from remote part of the country and from beyond the Himalayas, Siberia. It lies between Burhi Gandak, Old Bagmati and Kareh rivers.

The lake is formed by the meandering action of Gandak River and is now a residual ox-bow lake, one of the thousands in Bihar and Uttar Pradesh flood plains. In years of high rainfall, vast areas of these two states get flooded. This causes coalescing of wetlands and forms one huge expanse of water. During these times the wetlands of the Kabar-Tal region may cover hundreds of sq. km. The floods leave behind deposits of sand, slit and clay in layers of varying thickness. In years of average rainfall, Kabar-Tal is connected with Burhi Gandak (a tributary of River Ganga) and with nearby Nagri Jheel and Bikrampur Chaurs, unites to form a lake of about 7400 ha. By late summer however, the water is confined to the deeper depressions and only about 300-400 ha of Kabar-Tal remains flooded and cut off from the adjacent floodplains (Chaurs). As the water level recedes, over 2800 ha of the exposed mudflats are converted into rice (paddy) fields. Its altitude is 43.7 m. Its water depth varies from 30 cm to 4 m. The deepest part is known as "Mahalay". The depth varies in different seasons of the year. Kabar- Tal gets mostly all its water from rain in its catchment area between July & September. During flood months it also gets water from Burhi Gandak, Bagmati and Kareh River. Between January to July its water was generally found to be so transparent that even a person can see its submerged vegetation from above the surface. The annual range of water temperature is 19.7°C to 28.5 °C, shows narrow variation through out the year, which helps fishes to maintain their life.

In 1951, a drainage channel was excavated to expose additional areas for agricultural purposes, but the channel silted up in few years, and the lake reverted to its former condition. In recent years, further siltation of the overflow channel has resulted in sight fluctuation in water levels throughout the lake. There is a permanent island (Jaimangal Garh) of about 130 ha in the Southeast corner of the lake. As this lake area remains wet and submerged for a longer period, it has developed specially adopted wetland vegetation and organisms. The emergent, submerged and floating plants present some unique type or representative flora and fauna particularly of this lake and its adjoining areas. Hence, it is a spectacular wetland habitat and perhaps one of the largest freshwater inland wetlands in the country.

Kabar wet land in some or other way is the life-line of the people of the surrounding area. The anthropogenic pressure in the lake area is very high. There are 16 villages are located in and around Kabar-Tal Lake. Thousands of people are living in the vicinity of the lake area. Main occupation of people living around is agriculture, but per capita land holding is very poor. There is good number of "Sahanis" (a fishing caste) population living around the area; they are very expert in catching fish and trapping birds. They are dependent on lake for their livelihood. Due to this type of socio-economic structure of the area, flora and fauna of this lake is in danger.

Kabar Lake due to its shallowness and good light intensity through out the year is infested with profuse growth of macrophytes. The luxuriant growth of weeds particularly Paragmitis Karka is one of the severest problem, which shows gradual transformation of the lake in to terrestrial ecosystem. This lake has very dense submerged vegetation which looks like mini forest.

The Kabar Lake is very rich in terms of biodiversity. Here, altogether 51 species of fishes belonging to 15 families and 10 orders were recorded (Sharma *et. al.*, 1994). Study shows that the lake has rich biotic potential with 55 species of macrophytes (Sharma, 1995); 93 species of planktons, 87 species of macro invertebrates (Sinha *et. al.*, 1994); 65 species of insects (Parkash *et.al.*, 1996) and 11 species of gastropods (Sharma *et. al.*, 1996) were recorded. As of now according to various study reports, 59 species of migratory birds and 107 species of local birds have been recognized here.

3.2 Kusheshwar-Asthan, Darbhanga, Bihar, India

3.2.1 Geographical Profile

Darbhanga district is having the total geographical area of 2,502 sq km. It is situated between longitudes 85^{0} 40’E - 86 ^{0} 25’E and latitude 25 ^{0} 40’N - 26 ^{0} 30’N. The district consists of vast low laying plains intersected by numerous streams & marshes and contained some uplands. The average elevation of the district is 100 m above mean sea level. Exact name of the place of the study is Naral Chaur, which is situated in village Rampur Raut of Kusheshwar-Asthan block of Darbhanga district. Kusheshwar-Asthan is popularly known as ‘Venice of Bihar’ due to its Lakes and Chaurs.

Kusheshwar-Asthan is 60 km away from Darbhanga town. It is situated on longitude 86^{0} 19’ E and latitude 25^{0} 45’ N.

The total area of the district is 241443.20 hectares, out of which 198415 hectares is cultivable. 19617 hectares is upland, 37660 hectares is medium and 38017 hectare is low land. There is 29706 hectare of Chaur areas.

3.2.2 Demographic Profile

The population of Darbhanga is 3,285,473 according to 2001 census. The average population density is 1442 person per sq km.

3.2.3 Source of Livelihood

Agriculture is the main source of livelihood in this area. 82.17 % of the total area is cultivable. Paddy is the main crop in this area. Other crops taken are wheat, maize, pulses, oil seeds, sugarcane and maruwa. Average holding size in the district is 0.6 hectares per capita. The district is full of mango orchards. Sisoo, Khair, Palm, Khajur, Jackfruit, Litchi, Pipal, Jamun and Guava; trees are found near human settlements. Many ponds can be seen full of Makhana and Lotus. The district also has some tracts of grasslands.

The farmers depend mainly on monsoon for irrigation. About 20% of the area is only irrigated by other sources. The main source of irrigation is tube wells, which cover about 61.35 % of the total irrigated area.

Fertilizer consumption per hectare in Darbhanga is more than Bihar's per hectare consumption.

3.2.4 Industry

Industry in this area is very poorly developed. Only two small-scale industries, 426 tiny industries and 181 artisan-based industries are registered in this District. Ashok Paper Mill at Hayaghat which was not functional for the last 18 years has been restarted on 16 August, 2000. The two sugar mills in the area at Raiyam and Sakri are sick. Most of the rice mills are not functional. However, Mithila and Sita flourmills are in working condition. Though the district is famous for Mango and Makhana production, there are no processing industries for these products. However, blanket weaving, bangle making, pottery & mats-basket making have survived from old times.

Dense population, low literacy level, traditional cropping pattern, absence of big and small industries and the resultant migration of man power has led to weak state of economy of the district. The per capita income of the people in the district is Rs 4272.

3.2.5 Mines and Minerals

The district is formed of thick alluvial soil. Beds of Kankar or nodular lime stones of inferior quality are occasionally seen. The riverbanks are generally made up of new alluvial formed by continuous deposit of silt by the rivers. Salt petre is the only mineral found in the district.

3.2.6 Flora and Fauna

The land in Darbhanga District is generally very fertile and there are hardly any uncultivated areas. The district is therefore, devoid of any forests. Among the trees found in the district are Sisam, Khair, Palmyra and Khajur. Mango, Jackfruit, Pipal and Tamarind are found near village settlements. The district also has some tracts of grasslands.

Many aquatic fruits are found here, namely Makhana (*Euryale ferox*), Saurki (*Alternanthera pungeus*), Singhara (*Trapa bispinosa*), Chickor and Barri.

Wild animals existed in the district up to the end of the 18th century. But with the progressive use of land and rapid growth of population, the forest areas were cleared and the wild animals became almost extinct. Wolves and hyenas are rare, while jackals are commonly seen in this area. Fox and wild cats are also met occasionally.

Among the birds found in the district are various kinds of quails, partridges and ducks, snipes, cranes, storks and sparrows are commonly seen. Fish are plentiful. The common varieties are Rohu, Bachwa, Tangra, Katla, Singhi and Boari. Hilsa is found only occasionally. Kusheshwar-Asthan area is very rich in fish and avia-fauna.

3.2.7 Climate Profile

The District has somewhat dry and healthy climate. There are three well-marked seasons, the winter, the summer and the Rainy season. The cold weather begins in November and continues up to February, with a minimum temperature up to 5.8°C, though March is also somewhat cool. Westerly winds begin to blow in the second half of March and temperature rises considerably. May is the hottest month when the temperature goes up to 42°C. The mean annual temperature is 25^0 C. Rain sets in towards the middle of June. With the advent of the Rainy seasons, temperature falls and humidity rises. The moist heat of the Rainy season is very oppressive up to August .The rain continues until the middle of October. Average rainfall is 1261 mm. Around 92% of rainfall is received during monsoon months i.e. between second half of July and first half of August. The district also gets some winter showers. (Indian Metrological Department)

3.2.8 Geological Profile

Darbhanga belongs to North Gangetic Plains. The District of Darbhanga can be divided into four natural divisions. The eastern portion consisting of Ghanshyampur, Biraul and Kusheshwar-Asthan blocks contain fresh silt deposited by the Kosi River. This region was under the influence of Kosi floods till the construction of Kosi embankment in the Second Five Year Plan. It contains large tracts of sandy land covered with wild marsh.

The second division comprised of the anchals lying south of the Burhi Gandak river and is the most fertile area in the district. It is also on higher level than the other part of the district and contains very few marshes. It is well suited to the rabbi crops.

The third natural region is the doab between the Burhi Gandak and Bagmati and consists of the low-lying areas dotted over by chaur and marshes. It gets flooded every year.

The fourth division covers the Sadar sub-division of the district. This tract is watered by numerous streams and contains some up-lands.

Geologically the district is formed of alluvium, clay, sand and gravel etc., during quaternary period. The ground water sources are regionally extensive, confined and unconfined aquifers up to 200 m and below.

The district has a vast alluvial plain devoid of any hills. There is a gentle slope from north to south with a depression on the centre. (Singh, 1996)

3.2.9 Drainage System

It is watered by numerous rivers originating in the Himalayas. The district contains four main river systems, viz, the Bagmati, little Bagmati, Kamla and Kosi. The Bagmati, which enters this district form Muzaffarpur, forms a natural boundary between it and Samastipur district and pursues a southeasterly course till it empties itself into the Burhi Gandak River near Rosera. The little Bagmati enters the district from Madhubani near Pali and turns past the town of Darbhanga down to Hayaghat, where the Bagmati properly joins it. The Kamla enters the district at Singar Pandaul, and flowing east of Darbhanga joins the Kosi at the southeastern corner of Rosera block. The Kosi skirts the eastern boundary of the district. (Srivastav, 2003)

3.2.10 Soil System

The soil of the district is highly calcareous and a mixture of clay and sand, which makes it suitable for rice and Rabbi, crops. In the low laying central area banger soil is found. It is a mixture of clay and sand in almost equal proportions. This soil too is suitable for the cultivation of rice and rabbi crops. (Mahadevan, 2002)

3.2.11 Kusheshwar-Asthan

It is an important religious place, with a height of 49 meters from sea level, situated about 16 Km. east of Singhia and 22 Km. northeast of Hasanpur railway station on the Samastipur-Khagaria Branch line of North Eastern Railway. It is noted for the temple of Lord Shiva known as Kusheshwar-Asthan. Pilgrims visit this place all the year round for worship. The origin of this temple is traced to the epic period.

Kusheshwar-Asthan is a vast wetland made up of the spilled water and river bed of the Kosi (Sorrow of Bihar), the Kareh and the Kamla Balan besides of innumerable seasonal channels and gullies. The rivers and gullies bring in tiny silt alluvial deposits very rich in detritus and organic matters, such loads after the slow down are deposited on mouth of the rivers blocking its out flow. Hence, the rivers get broken down into innumerable channels and rivulets that further cause the spill over water delousing vast area making silted riverbeds, river diversions and ox bow lakes. In the lean period when water recedes, the upland emerged but the innumerable ditches and lakes (Chaurs) are left filled in water round the year.

The drainage system of the area merged with river Ganga at Kursela in the Katihar district of Bihar. In flood conditions over swollen Ganga accepts water slowly. That is why the water of the drainage system deluges the area everywhere and remains for long. During rainy seasons, the water fills most parts of Kusheshwar-Asthan. 90 % of total area generally submerged during that time.

The water logged fourteen villages of Kusheshwar-Asthan block covering an area of 7019 acres and 75 decimals. Due to their greater ecological, faunal, floral, and natural importance this area has been declared as Kusheshwar-Asthan Bird Sanctuary under Wild Life Protection Act 1972 (as amended up to 1991) on 25th August 1994 by state government of Bihar. Sanctuary area consists of 6700 hectares. This is one of thirteen sanctuaries of Bihar with Kabar-Tal Bird sanctuary, which is included in the international list by Bird Life International and Royal Society for Protection of Birds, United Kingdom.

Due to fresh alluvial deposits and rich in manures and nutrients, the soil of this area is very fertile and its support a variety of life both terrestrial and aquatic. The village cultivates garma dhan (Paddy) in March and harvest in May-June before flood water inundates the field. The flood water so accumulates support a variety of population of flora and fauna in different niches. A number of species of fish, small and big thrive in this lake ecosystem. Many fishes like Bhunna, Sui, and Tengra seems to be endemic. A variety of zooplankton and phytoplankton thrive in this wetland under warm and humid condition. This ecosystem attracts a lot of birds of different species and varieties far feeding and breeding. Many such birds are endemic and local. But there are certain migratory birds. The migratory birds begin alighting in the beginning of October and they reside here up to March. According to one study 87 species of fishes belonging to 20 different families and 28 species of mollusks (Gastropods 18 species and Bivalves 10 species) have been recorded in this area so far (Munshi and Munshi, 1991).

In this area there has been a long tradition and custom of the preying on these helpless birds for meat. Even the state government of Bihar recognizes this as earning option and used to auction the right of poach on the birds to the highest bidder through the circle office of the Kusheshwar-Asthan Block. Due to this anthropogenic influence now these days birds are witnessing in less number. But in recent times many steps has been taken by administration to prevent hunting of migratory birds. Native Countries of Migratory Birds: Nepal, Tibet, Bhutan, Afghanistan, China, Pakistan, Mongolia & Siberia and others.

Wet land areas of Darbhanga district in general and Kusheshwar-Asthan block (Biraul Sub-division) in particular is the WINTER CAPITAL of approx 15 rare and endangered species of MIGRATORY BIRDS (Munshi and Munshi, 1991).

CHAPTER 4

MATERIAL AND METHODS

4. MATERIAL AND METHODS

4.1 Field Method

4.1.1 Water Sampling

Thirty Water samples were collected in polypropylene bottles during post-monsoon season in January, 2005; fifteen from Kabar-Tal and fifteen from Kusheshwar-Asthan. All containers used for sampling were washed with 10% nitric acid solution followed by distilled water. 100 ml of the water samples were vacuum filtered using 0.45 μm Millipore Membranes (the filter papers are weighed before filtration) and than acidified with phosphoric acid. Another sample of 100 ml was filtered but not acidified, while third sample of 250 ml unfiltered kept as the raw sample. All the three water samples and the suspended matter (used filter paper) were brought to the laboratory. Collected water samples were brought to the laboratory and stored in cold room at 4°C temperatures in order to avoid any major chemical alteration (APHA, 1995).

4.1.2 Soil Sampling

Eight Samples of Sediment (0-15 cm) were collected in polypropylene bags; four from Kabar-Tal and four from Kusheshwar-Asthan during post-monsoon season in January, 2005. All these Sediment samples, after being brought to laboratory, were kept in cold room at 4^0C.

4.2 Water Analysis

4.2.1 Field Analysis

4.2.1.1 pH

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, 7 and 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.

4.2.1.2 Electric Conductivity (EC)

The Electric Conductivity was measured in Micro-Siemens per centimeter (μS/cm), using Conductivity meter (model EI). The instrument was calibrated and set for 0.01m KCl solution (1413 µS/cm at 25°C) (Todd, 1980).

4.2.1.3 Dissolved Oxygen (DO)

Dissolved oxygen was measured in milligrams per liter (mg/l) by using Basic DO Orion (805 A+) Thermo electrode.

4.2.1.4 Oxygen Reduction Potential (ORP)

ORP was measured by using ORP Quick check model 108 electrodes in milli volt (mV).

4.2.1.5 Total Dissolved Solid (TDS)

TDS was measured by using TDS Quick Check Model 116 in mg/l.

4.2.1.6 Total Suspended Matter (TSM)

TSM was calculated by measuring weight difference between pre and post filtered Millipore Membrane.

4.2.2 Laboratory Methods

4.2.2.1 Bicarbonates

The bicarbonate content was determined following the Potentiometer Titration Method (APHA, 1995). Bicarbonate standards ranging from 100-1000 mg/l were prepared from $NaHCO_3$. 50 ml of sample and a series of bicarbonate standards were titrated against 0.02 N HCL. The end point was noted at pH 4.5. A graph was plotted between bicarbonate standards and volume of acid consumed. The readings for samples were noted down from this graph.

4.2.2.2 Chloride

Chloride was estimated by Argentometric Method for which K_2CrO_4 indicator was used which prepared by dissolving 5 gm K_2CrO_4 in distilled water and subsequent adding of $AgNO_3$ solution till the appearance red precipitate. Mixed indicator solution was left for 12 hrs.; than filtered and make up to 100 ml. Than, $AgNO_3$ of 0.0141 N was prepared by dissolving 1.1975 gm of $AgNO_3$ in 500 ml distilled water and was stored in brown bottle. Than standard was prepared from NaCl (dried at 140^0 C).

Samples + Indicator were titrated with $AgNO_3$ and at end point volume of $AgNO_3$ consumed was noted. (APHA, 1995)

4.2.2.3 Fluoride

Fluoride concentration was determined by measuring absorption by Spectrophotometer by using SPADNS reagent. Residual chlorine free samples were used for fluoride determination. Samples were made chlorine free by using AsO_3. 50 ml Samples +5 ml Zirconyl Acid+ 5 ml SPADNS reagent solutions were mixed well. Then its absorbance was measured at 570 nm wavelength (APHA, 1995).

4.2.2.4 Sulphates

The Sulphates concentration was determined by Turbiditeric Method. The method is based on the principle that Sulphates is precipitated in acidic medium with barium chloride, to form barium Sulphates crystal of uniform size. Light absorbance of barium Sulphates suspension is measured by spectrophotometer at 420 nm and the concentration is determined by comparison of the reading with standard curve.

20 ml of buffer solution (prepared by dissolving 30gm of $MgCl_2.6H_2O$; 5gm of $CH_3COOH.3H_2O$; 1gm of KNO_3; 0.111 gm of Na_2SO_4; and 20 ml of 99% acetic acid) in 500 ml distilled water and then a total volume made up to 1000 ml was added and mixed with the

help of magnetic stirrer. While starting, a spoon full of $BaCl_2$ crystal was added. This was stirred for 60 seconds with constant speed. After the stirring period, solution was poured into the absorbance cell of the spectrophotometer and absorbance reading was taken after 5 minutes.

Sulphates ion concentration was determined by comparing reading with calibration curve prepared by carrying Sulphates standard through the entire procedure. (APHA, 1995)

4.2.2.5 Nitrate

Nitrate was estimated by Brucine Method on spectrophotometer. For that, Brucine reagent was prepared by dissolving 0.25 gm of Brucine in 10 ml of $CHCl_3$, then final sample was prepared by mixing 10 ml of water sample, 0.2 ml Brucine reagent and 20 ml H_2SO_4; then total volume made up to 50 ml. Yellow colour was developed and absorbance was measured at 410 nm.

4.2.2.6 Phosphate

Phosphate was determined by the Ascorbic acid Method (APHA, 1995). Phosphate standards ranging from 0.01 – 0.5 mg/l were prepared from KH_2PO_4. 40 ml of each sample and standard solution was pipette out in 50 ml volumetric flask and 5 ml of Molybdate antimony solution (prepared by dissolving 4.8 gm of ammonium Molybdate and 0.1 gm potassium antimony tartrate in 400 ml 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 50 ml and optical density was measured at 880 nm using Cecil Spectrophotometer (model no. 594). A graph was plotted between standard concentrations and optical density and sample concentration was recorded directly from this graph.

4.2.2.7 Dissolved Silica

The dissolved silica content was determined by the Molybdo silicate Method (APHA, 1995).

Silica standard was prepared ranging from 5 to 20 mg/l 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; then 6 ml of concentrated HCl was added and final volume was raised to 100 ml by distilled water) and 15 ml of reducing reagent (prepared by mixing 100 ml metal sulphite solution, 60 ml 10% oxalic acid and 120 ml 25% sulphuric acid, and making the total volume 300 ml by adding distilled water) were added and mixed well. Metol sulphite solution was prepared by dissolving 5 gm metal in 210 ml distilled water and 3 gm sodium sulphite was added and the volume was made up-to 250 ml by adding distilled water. The samples were stirred properly and kept for 3 hours to complete the reaction .The optical density was measured at 650nm using Cecil Spectrophotometer-594. Graph between standard concentration and optical density was drawn and concentration of sample was recorded from it.

4.2.2.8 Sodium and potassium

Sodium and Potassium were analyzed by using AIMIL Flame Photometer (PEI).

4.2.2.9 Calcium and magnesium

The analysis of Calcium and Magnesium were carried out on Shimadzu-AA-6800, Atomic Absorption Spectrophotometer. Calcium and Magnesium were analyzed in absorption mode at the wavelength of 422.7 nm and 285.2 nm respectively. The instrument was calibrated with standard chemical solution as written in APHA, (1995).

4.2.2.10 Heavy Metals (Fe, Mg, Mn, Cu, Zn, Pb and Ni)

Using Shimadzu-AA-6800, Atomic Absorption Spectrophotometer for metal analysis. Instrument was calibrated by using respective standard provided by MERC for respective metals as required. Standard curve were drown between absorbance and concentration; from this graph concentration of water sample was calculated. Flame used for metal analysis was Air-Acetylene. Cathode lamp of respective metals was used at following wavelength.

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

4.3 Sediment analysis

The sediment samples were analyzed for Total carbon, Total Sulfur, Total Nitrogen, major and minor elements Samples were air dried and grinned for analysis.

4.3.1 Carbon and sulfur analysis

Carbon was analyzed by using Eltra (CS 1000) Carbon Analyser. Before analysis, sediments were made free from halogen by washing it with distilled water. Than, untreated samples were analyzed for determining Total carbon and Total sulfur percentage.

For analysis of Inorganic carbon and Inorganic sulfur distilled water washed sample was further treated with 30% (v/v) H_2O_2 for making it organic matter free. For this put distilled water washed sample on hot plate and pour 30% (v/v) H_2O_2 in it and stir continuously till the sample stop showing any reaction. Amount of Organic Carbon and Organic Sulfur was calculated by calculating difference between Total Carbon & Total Sulfur and Inorganic Carbon & Inorganic Sulfur percentage.

The measuring method is based on the principle of sample combustion and analysis of gases given off through IR absorption. The sample is put in a ceramic boat, which is made free of any carbon and pushed into the silicon carbide furnace set at a temperature 1300 °C. The combustion occurs in the presence of oxygen supplied and the carbon present in the sample was converted to CO_2 and is carried to the IR absorber by oxygen, which also acts as a carrier gas. The flow of oxygen is maintained to a constant value through and electronic flow regulator. The moisture traps ensure that dry gas mixture reaches the IR cell. The IR cell signals are selected and respond to CO_2 concentration in the gas mixture. The signals are electronically laniaries integrated and percentage of carbon and sulfur in the given weight of sample is shown digitally.

4.3.2 Kjeldahl Nitrogen Analysis

Nitrogen was analyzed by Kjeldahl digestion method of Anderson (1993). 0.3 gm sediment was taken in digestion tube and 4.4 ml of digestion mixture was added to each tube. This was digested at 360 °C till the solution became colorless. The solution was allowed to cool down to room temperature. Than, 50 ml of distilled water was added in each tube and stirred. The final volume was made up to 100 ml by adding distilled water. The clear solution was used for analysis.

Digestion mixture was prepared by dissolving 0.42 gm Selenium powder and 14 mg Lithium Sulphate in 350 ml 30 % (V/V) H_2O_2 and mixed. In this mixture 420 ml H_2SO_4 was added carefully while cooling it in ice bath. The digestion mixture was kept at 4 °C for further use. Nitrogen was determined by stream distillation. Free ammonia is liberated from the solution by stream distillation in the presence of excess of alkali. The distillate was collected in the receiver containing excess of Boric acid and indicator and finally Nitrogen is determined by Acid titration.

Alkali solution was prepared by dissolving 400 gm NaOH in 1000 ml distilled water. Mixed Indicator was prepared by adding 0.099 gm Bromocresol Green, 0.066 gm Methyl Red and 0.011 gm Thymol Blue, dissolved by shaking in 100 ml 95% ethanol. 1% Boric Acid solution was prepared by dissolving 10 gm Boric Acid in 1 litter distilled water.
Transferring 10 ml of aliquot to reaction chamber and adding 10 ml of alkali and starting distillation immediately does distillation process. About 50 ml of distillate was collected in 5 ml Boric Acid Indictor solution. The distillate was titrated against N/140 HCl to gray end

point, changing from green to gray using micro burette.

Kjeldahl Nitrogen present in the sample was calculated by using the following equation:

$$\% \text{ Nitrogen} = \frac{(A - B) * N \text{ of HCl} * 1.4 * V}{\text{Weight of sample in gm} * W}$$

A =volume (ml) of HCl used against sample.
B= Volume (ml) of HCl used against sample.
V= Total volume (ml) prepared after digestion.
W = Volume (ml) of digested sampled distilled.

4.3.3 Analysis of Major and Minor Elements: - Final grinded homogenized sediments were taken in the beaker and boiled with 30 % (V/V) H_2O_2 (Jackson, 1973) for removal of Organic matter. The treatment is repeated until the emission of CO_2 stopped.

Analysis of major and minor elements was carried out by the two solution method (Shapiro, 1975). Solution 'A' was used for silica, phosphorous and aluminum.

Solution 'A'

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

4.3.4 Silica Analysis

0.8 ml of solution 'A' standard solution (Canadian standards i.e. SO1, SO2, SO3 and SO4) and sample solution were taken in a test-tube. 0.2 ml Ammonium molybdate solution was added and kept for 10 minute. 4 ml 10% (w/v) of Tartaric acid was added by swirling the beaker. 0.1 ml of reducing agent was added and sample properly stirred and kept for 30 minutes. Absorbency was measured by spectrophotometer at 650 nm.

Ammonium molybdate solution was prepared by dissolving 1.875 gm Ammonium molybdate in 19 ml distilled water and adding 6 ml 20% (v/v) H_2SO_4. The reducing reagent was prepared by dissolving 0.07 gm Sodium Sulfite in 1.0 ml distilled water then 0.015 gm 1- amino-2-naphthol-4-Sulphonic acid was add and stirred well until dissolved 9 ml of 10 % (w/v) Sodium bisulphite solution was added to it and mixed well.

4.3.5 Aluminum analysis

15 ml of solution 'A' (sample, standard and blank) were taken in 100 ml volumetric flask 2 ml of $CaCl_2$ solution (prepared by dissolving 7 gm $CaCl_2$ in 1000 ml distilled water) was added. 1 ml of Hydroxylamine - Hydrochloride (prepared by dissolving 5 gm of Hydroxylamine-Hydrochloride in 50 ml) was added by swirling the flask. 1 ml of potassium ferricyanide (0.75%) was added to each flask and mixed 2 ml of thioglycolic acid solution (4%) was added and left for five minutes. 10 ml of buffer solution (prepared by dissolving 100 gm of sodium acetate in water and adding 30 ml of glacial acetic acid and diluted to 500 ml) was added and kept for 10 minutes .10 ml of Alizarin Red- S solution (0.05%) was added to each flask and the volume was diluted to 100 ml sample were properly stirred and left for 50 minutes. The absorbency was measured at 470 nm using spectrophotometer.

4.3.6 Phosphorus

Phosphorus in sediment was determined by Ascorbic Acid Method. Standard phosphate solution ranging from 0.2 to 2 mg/l was prepared using KH_2PO_4. 5ml of digested samples and standard solution was pipetted out in 50 ml volumetric flask and 20 ml distill water was added in it. Than 10 ml of reducing agent (prepare by dissolving 2.108 gm of ascorbic acid in 400 ml of ammonium molybdate-ammonium potassium tartarate solution (prepared by adding 12 gm of Ammonium molybdate in 250 ml of warm distill water and 0.291 gm antimony potassium tartarate was added in 100 ml distilled water and than both solution were added to 1000 ml of 5N H_2SO_4; final volume makes up to 2000 ml and mixed well.) was added. The mixture was diluted to 50 ml and optical density was measured at 880nm 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.

$$\% P = \frac{C * 0.025}{W}$$

C = corrected concentration (sample- blank)
W = Weight of soil sample taken.

4.3.7 Mineralogy of sediments

For the study of mineralogy of sediments, a slide is prepared by filling organic content free sediments sample which is powdered up to size less than 50 micron. Than, that slide was run through XRD (model Philips X'Pert) at the rate of 2 ° / s. Finely, XRD peaks was analyzed with the help of standard value as given in different literature. For confirmation of minerals we distinguish at least three peaks of each mineral. Percentage of different minerals calculated using percentage area of those particular minerals with respect to total area of peaks of all minerals.

4.3.8 Grain Size of Sediments

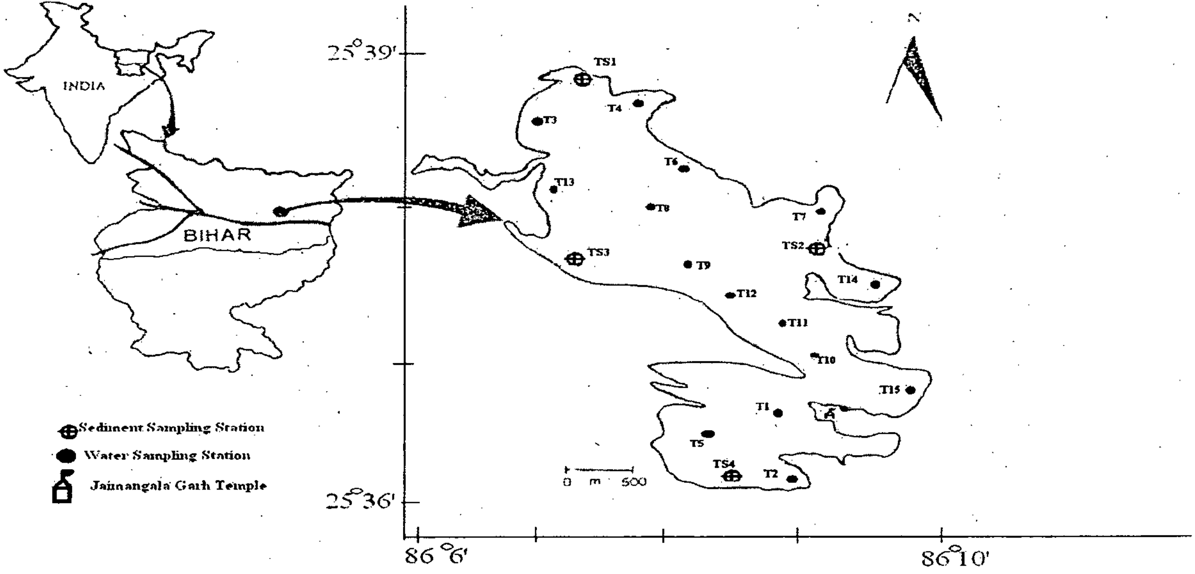
For grain size analysis of sediments first of all samples were air dried then oven dried at 60 ^{0}C for 24 hrs. Then pebbles and very coarse materials were removed. After that, sample was thoroughly homogenized by corning and quartering technique (Ingram, 1970).

Size separation of the sample grains were carried out following the standard sieving and sedimentation methods. (Ingram, 1970). The sample were dry sieved on an electrically controlled electromagnetic sieve shaker.(Frisch Analysette-3) for 45 minutes. Then grain size fraction of 37 to 63micron, and<37 micron (silt and clay); 63 to 125 micron (very fine sand); 125 to 150 micron (fine sand); 250 to 600 micron (medium sand) and >600 micron (coarse sand).were collected. Then weight of all the fraction s was taken. After that statically calculation was done by graph method suggested by (Krumbein and Pettijohn,1938 and Lindholm,1987)

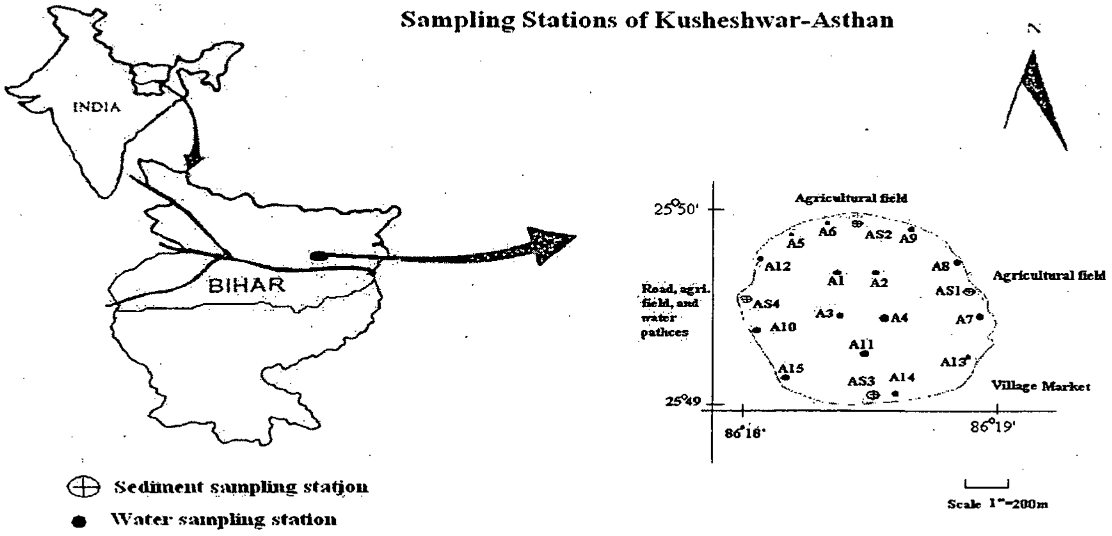
CHAPTER 5

RESULTS AND DISCUSSION

Sampling Stations of Kabar-Tal



Sampling Stations of Kusheshwar-Asthan



5. RESULTS AND DISCUSSION

For study of geochemistry of any wetland and to know about its 'environmental health and status', analysis of various physico-chemical parameter of water and sediment sample of that sediment of the site is essential. Generally, the minerals and other substance found on any wetland usually come from the rocks and soils, surrounding the wetlands or through drainage from the catchments area or by anthropogenic sources. After study of various physico-chemical parameters like pH, EC, TDS, ORP, TSH and DO of water samples, we can estimate its quality and can form an idea about the type of physico-chemical and biological processes that occur in the wetland and its surrounding in catchments area. After estimation of nutrient load, we can understand the various sources of water to the wetland, type of chemical and biological activities going on in its catchments and health of vegetation growth in the wetland. After estimation of major ions like bicarbonate, chloride, sulfate, fluoride and dissolved silica and major cations like sodium, potassium, magnesium and calcium, we can trace the possible source of the minerals in the wetland including the dominant mineral in the catchments of drainage system and weathering characteristics of sediments

From grain size of sediment, we can make a fundamental idea of soil, sediment characteristics, rock type and weathering processes in the study area. It also helps to determine the depositional pattern in the environment. The texture and mineralogy of the sediments in the aquatic environment are useful for interpreting depositional environment, provenance and nutrient occurrence of the aquatic medium.

Analysis of the total Carbon, total Nitrogen and Phosphate of sediment samples shows the nutrients availability in the sediment. Estimation of total carbon and total organic carbon gives a hint about presence and availability of organic matter in the sediments. Estimation of total Sulphur gives an idea about oxidant-reductant and the anthropogenic influence in the study area

5.1 pH

Among the chemical factors, pH plays an important role on the biotic life of a wetland system. 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.

The analytical results of the current study indicate that the water of Kabar-Tal and Kusheshwar-Asthan wetland are alkaline with an average pH 8.18 (Kabar-Tal) and 8.17 (Kusheshwar-Asthan). There was no significant spatial variation in the pH value, which ranged between 7.92 to 8.31 in Kabar-Tal (Table-1) and 7.97 to 8.28 in Kusheshwar-Asthan (Table-2).

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).

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. Several workers (Goel *et. al.,* 1985; Sarana and Adoni, 1982) have demonstrated the dependence of pH on the biological activity.

King, (1970); William *et. al.,* (1984); Olsen and Sommerfield, (1977) and Goldman, (1972) have shown an increase in pH with active growth of phytoplankton. The high pH values observed in Kabar-Tal and Kusheshwar-Asthan can be related to the high photosynthetic activity in the water bodies. Although the concentration of phytoplankton was not carried out during the current study, dissolved oxygen in most of, the sampling sites can be used to substantiate this inference of high photosynthetic activity in the wetlands. The pH remains constant due to buffering effect of sodium carbonate and sodium bicarbonate.

5.2 Electrical conductivity (EC)

The Electrical Conductivity (EC) of any water reflects the dissolved constituents in the water. EC depends upon the presence of ions, their total concentration mobility and relative concentration.

In Kusheshwar-Asthan no significant spatial variations was observed. The range of EC was 388 – 435 µS/cm with a mean value of 418 µS/cm (Table-2). There was some spatial variation in EC in Kabar-Tal, may be due to different type of ecological niches. The range of EC was 294- 476 µS/cm with a mean value of 375 µS/cm in Kabar-Tal (Table-1).

The electrical conductivity of any water is roughly proportional to the concentration of its major elements. In Kabar-Tal, high positive correlation (>0.5) was noted between conductivity and the major cations Mg, Ca and K (Table-3). High negative correlation (more than - 0.5) was also observed with $HCO3^-$ in Kabar-Tal. However, the correlation is not clearly marked in the Kusheshwar-Asthan.

5.3 Total Dissolved Solids (TDS)

TDS in Kabar-Tal ranges between 191 – 317 mg/l with average value 248.6 mg/l (Table-1). In Kusheshwar-Asthan TDS, ranges between 258 – 288 mg/l with avg. value 277 mg/l (Table-2). It is showing some spatial variation in Kabar-Tal, but in Kusheshwar-Asthan value of TDS is almost constant due to smaller size and similar type of ecology.

5.4 Oxygen Reduction Potential (ORP)

ORP in Kabar-Tal ranges between 133 – 146 mV with avg. value 140 mV (Table-1). In Kusheshwar-Asthan range is between 131 – 149 mV with avg. value 149 mV (Table-2). In ORP, some spatial variation is observed in Kabar-Tal and Kusheshwar-Asthan. Average value of ORP is more in Kusheshwar-Asthan than Kabar-Tal.

5.5 Total Suspended Matter (TSM)

TSM value ranges between 0.1 – 0.3 mg/l in Kabar-Tal (Table-1), and 0.2 – 0.6 mg/l in Kusheshwar-Asthan (Table- 2). Avg. value of TSM is 0.15 mg/l in Kabar-Tal and 0.44 mg/l in Kusheshwar-Asthan. This shows that the water of Kabar-Tal is cleaner than Kusheshwar-Asthan.

5.6 Dissolved oxygen (DO)

Dissolved oxygen is considered to be dependent largely upon photosynthetic activity and microbial decomposition of organic matter.

Dissolved oxygen in both the wetlands exhibit appreciable amounts in all the sampling sites with little spatial variation. The mean DO concentration was 8.38 mg/l in Kabar-Tal and 8.25 mg/l in Kusheshwar-Asthan. Dissolved oxygen in Kabar-Tal, ranged between 8.09 mg/l to 8.58 mg/l (Table-1), and in Kusheshwar-Asthan, ranged between 7.61 mg/l to 8.72 mg/l. (Table 2).

The high concentration of DO in Kabar-Tal is due to high photosynthetic activity, because many aquatic plants were observed there, and due to mixing of air in to water.

In Kusheshwar-Asthan the higher DO content can be attributed to mixing of air with water and low microbial activity.

5.7 Nutrients

Biogeochemistry process controlling river water composition depends on the catchments climatic and petrographic features. In wetland like lakes, which are more closed hydrosystems, these factors seem to be masked by primary production, which is controlled by nutrient input from arable land flushing and wastewater discharge. Photosynthesis and respiration regulate the nutrient levels and their species and control the carbonate system; since precipitation and dissolution of carbonates are carbon dioxide (CO_2) dependent. Concentration of nitrates and phosphates determined in both the study area indicate high concentration of both the nutrients. In Kabar-Tal range of nitrate concentration was between 1.56 – 3.91 mg/l, with mean value 2.84 mg/l and phosphate between 0.222–0.396 mg/l, with mean value 0.274 mg/l (Table-1). In Kusheshwar-Asthan range of nitrate concentration ranges between 3.00– 6.89 mg/l, with mean value 5.07 mg/l and phosphate between 0.336–

0.528 mg/l, with mean value 0.433 mg/l (Table-2). Wetzel, (1975) observed that nitrates concentration can rapidly change in a water body due to the prevailing biological activities in the system. Significant increase in the nutrient content in this wetland can be attributed to increased agricultural activities with increased use of fertilizers in the catchment areas. Contribution of the nutrient by animal feces cannot also be ruled out. .The Kabar-Tal is almost completely covered with aquatic vegetation; so here, concentration of nitrate and phosphate is less than Kusheshwar-Asthan may be due to consumption of nutrient by this aquatic vegetation. Problem of prolific growth of aquatic macrophytes in Kabar-Tal was already reported in Conservation of Wetlands in India (Ministry of Environment and Forests, 1989.)

5.8 Anions

5.8.1 Fluoride (F^-)

Fluoride is not major anions in water chemistry. 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. The concentration of fluoride does not vary much in the current study area. The range in Kabar-Tal was 0.074 -0.366 mg/l with a mean value of 0.215 mg/l (Table- 1).In Kusheshwar-Asthan, range is between 0.102 – 0.324 mg/l, with value 0.185 mg/l(Table- 2). The percent contribution of fluoride to the total anions was very low in both Kabar-Tal and Kusheshwar-Asthan, i.e. only 0.09% in Kabar-Tal and 0.08% in Kusheshwar-Asthan (Fig. 1&2).

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).

5.8.2 Chloride

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 on its flow-rate. This is second most abundant anion in both study area (Fig. 11&12). It constitutes about 13% in Kabar-Tal and 20% in Kusheshwar-Asthan of the total anions in the respective wetland (Figure 1&2). Concentration ranges between 26.72–36.51 mg/l in Kabar-Tal (Table- 1), and 42.04-54.29 mg/l in Kusheshwar-Asthan (Table- 2). Mean value is 29.61 mg/l for Kabar-Tal and 49.00 mg/l for Kusheshwar-Asthan.

Presence of high chloride concentration in water has also been attributed to pollution (Thresh *et. al.,* 1990; Parvateesam and Gupta, 1994; Wetzel, 1975). Pollution from industries and domestic effluents could also be a contributing factor to the high chloride content in the wetland. Pollution sources of chlorides have been reported to modify natural concentration greatly e.g. Lake Erie was reported to have a threefold increase in its concentration (Wetzel, 1974) as a result of industrial and municipal pollution of the lake. Therefore, low value of chloride on both the places attributes pollution free environment on those places.

5.8.3 Sulphate (SO_4^{2-})

The Sulphate ions are usually second to carbonate as the principal anion in freshwaters. However, chloride occasionally surpasses it. Same trend has been observed here also.

Contribution of Sulphate to the total anions was not much high on both the places. Sulphate contributed 4.75% in Kabar-Tal, while in the Kusheshwar-Asthan it contributes 11.4% (Fig. 1&2). Higher concentrations were observed in Kusheshwar-Asthan with SO_4^{2-} concentration ranges between 26.02-32.54 mg/l and 10.34-11.52 mg/l in Kabar-Tal (Table-1& 2).

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 man's 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 wetland (Lavoson *et. al.,* 1993).

5.8.4 Silicate

Silicon is the second most abundant element in the lithosphere. Silica is derived through combined effects of nature, river inputs, and absorption by clay and physical mixing. It ranges from 0.1 to 4000 mg/l representing extremes from snowmelt to hot mineral springs. 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.

In the current study, silica ranged between 0.1 to 3.14 mg/l with a mean value of 1.22 mg/l in Kabar-Tal and 5.60 to 8.07 mg/l with a mean value 6.16 mg/l in Kusheshwar-Asthan (Table-1&2).

Although silicate is a useful indicator of weathering inputs (Evons, 1996), its content is normally not high due to resistance to weathering of silica rock. Reduction of silicate in water may also be because of biological utilization and biological absorption to the sediment.

In Kabar-Tal utilization of silicates may be by diatoms, which are present in high concentration, could be the cause of the low observed values. Diatoms have been reported to be the dominant phytoplankton utilizes causing considerable variation in silicate. Still further study is required to explain the silica consumption by diatoms.

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 world average of SiO_2 is 13 mg/l with relatively little variation among the continents. The major source of silica is from degradation of aluminosilicate minerals.

5.8.5 Bicarbonate (HCO_3^-)

It is the most dominant anion in both the study sites. Range of bicarbonate in Kabar-Tal is between 153.40 to 209.91 mg/l with man value of 182.47 mg/l (Table- 1). In Kusheshwar-Asthan range of bicarbonate is 133.54 to 183.18 mg/l with mean value 173.77 mg/l (Table-2). Bicarbonate is showing a good positive correlation with EC, TDS, Ca, Mg, K and good negative correlation with pH in Kabar-Tal (Table-3). In Kabar- Tal, carbonate percentage is more than 80% out of total anion and in Kusheshwar –Asthan bicarbonate percentage is more than 63% (Fig. 1&2).

On both the places, carbonate is showing some spatial variation.

5.9 Cations

5.9.1 Sodium

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, streams and other type of wetland (Cole, 1974). However, in the current study area, sodium ranks second in cation concentration (Fig. 3&4). The percent contribution of sodium in Kabar-Tal was about 30%.In Kusheshwar-Asthan, percent contribution of sodium was about 32% (Fig. 3&4). The concentration in Kabar-Tal ranged between 20.29 to 33.32 mg/l with a mean of. 24.53 mg/l (Table-1). In Kusheshwar-Asthan, the range was between 24.17 t0 37.07 mg/l with a mean value of 26.74 mg/l. (Table- 2). Spatial variation did not vary much.

Cole (1974), further reports that, in arid parts where chemical weathering is practically non-existent, the ionic composition of Lake Water is determined by the occasional precipitation and sodium chloride is predominant in that. Low levels of solutes in both wetlands are thought to be influenced by uptake of solute by sediment and solute loss through underground seepage (Lnros, 1996; Darling, 1990).

5.9.2 Potassium

Potassium contribution to the total cations was low in both wetlands. In Kabar-Tal, it is 2.57% of the total cation and 3.49% in Kusheshwar-Asthan (Fig. 3&4).

Although Kolbe (1995), reported that evaporation plays a greater role in the concentration of potassium in Lake Waters, its resistance to weathering, and its use in the formation of clay minerals causes the concentration of the element to be much lower than that of sodium.

5.9.3 Calcium

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 (Schimalz, 1973). However, 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. In the current study, contribution of calcium (Ca^2+) to the total cation ranked first in both the wetland water (Fig. 13&14). In the percent study contribution of Ca_2+ were about 56% in Kabar-Tal and 52% in Kusheshwar-Asthan.(Fig. 3&4) The spatial variations in mg/l were; 33.48-59.79 in Kabar-Tal and 39.91-54.99 in Kusheshwar-Asthan (Table-1&2).

Correlation coefficient among the parameters indicate a high correlation between calcium and the EC, TDS, Mg, K and bicarbonate in Kabar-Tal (Table-3). Positive correlation is observed between Ca^{2+} and Mg^{2+} in Kusheshwar-Asthan (Table- 4).

5.9.4 Magnesium

Magnesium is the second most abundant cation in the fresh water lakes. In a few cases however Mg++ has been reported to constitute the highest percentage of cations e.g. Lake Tanganyika in Africa. Magnesium was however relatively low in the current study area. It ranked third in both the wetland (Fig13&14). In Kabar-Tal, it has a percentage contribution of 12.89% (Fig 3), with the variations in mg/l ranges between 7.45-14.44, (Table-1) and a mean value of 10.65 mg/l. In Kusheshwar-Asthan, it has a percentage contribution 12.09% (Fig. 4), and its spatial variation did not show much difference among the various sampling points (Fig 8), in which the ranges were 8.88-12.40 mg/l with a mean of 10.02 mg/l (Table-2).

5.10 Correlations among various parameters

The plot of (Ca+Mg) verses($HC0_3^-$ + $S0_4^{2-}$) in equivalent units, show that most of (Ca +Mg) points in Kabar-Tal and Kusheshwar-Asthan lies around the equiline 1: 1 trend (figure), reflecting the requirement of a portion of $HC0_3^-$ + $S0_4^{2-}$ to be balanced by cations (Na+ K) from weathering of silicate rocks.(Fig. 27&28)

(Ca+Mg) verses total cation (TZ+) shows that the data lies below the theoretical line (figure) depicting an increasing contribution of alkalis to the major anions. This is also clearly shown in figure for (Na+K) versus TZ+ where, for both the places all the points lie below the equiline. The observation is also confirmed by the very high percent contribution of (Ca+Na), (>80%) observed in most samples of the wetland water (Fig. 27&28).

A graph of (Ca+Mg) versus (Na+K) also indicates a high ratio of (Ca+Mg): (Na+K) (Fig.27&28) observed excess of Na over K (Table) is because of the greater resistance to weathering of Potassium and its fixation in the formation of clay minerals. The dominance of Na, which is an index of silicate weathering (Rao, 2002) is also observed. Studies carried out on the chemical constituents in the world fresh waters indicate that bicarbonate is the dominant anion and contributes 73% of the total anions while calcium is the dominant cation contributing 61% of the total actions (Cole, 1974). In the current study bicarbonate is the dominant anion, contributing 80% in Kabar-Tal and 63% in Kusheshwar-Asthan and Ca is the dominant cation contributing around 55% & 52% respectively (Fig.1-4).

5.11 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 wetland.

The plot of the silicate diagram (Fig 19-26; 35&36) gives the following information:
Kabar-Tal waters are mainly in the range of stability field of gibbsite with a few points in the kolinite range and in Kusheshwar-Asthan water; it is in the kolinite range only. This implies that the chemistry of the waters in Kusheshwar-Asthan wetland is favoring kolinite formation. In Kabar-Tal, the chemistry of the water mainly favoring gibbsite formation. Thus supporting the fact that potassium and silica are consumed in excess in the Kabar-Tal wetland by biological activity in compared to Kusheshwar-Astan

5.12 Mechanisms controlling water chemistry

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, (Fig 27&28). The data points of Kabar-Tal occupy the field categorized as weathering. Therefore, Rock weathering is the mechanisms controlling the ion chemistry of both wetlands.

5.13 Ratio explanation of various parameters

In both the study area sulfate-chloride ratio is not much high, it shows that very less anthropogenic and not much in situ gypsum weathering on the study site.

In Kusheshwar-Ashtan Sodium- Chloride is low but in Kabar-Tal, it is high. It shows that some additional sodium source must be there other that precipitation.

In both the study site Calcium-Bicarbonate ratio is not much high in both the study sites. It shows that bicarbonate is contribution is natural through carbonate weathering.

Bicarbonate total anion ratio is also low in both places; it seems that there are not much anthropogenic influences on both the study sites.

Nitrate-Total anion ratio is also low in both the places, which indicate the presence of a pollution free environment.

Fluoride - Magnesium ratio is also low in both places, which indicates fluoride is devoid in natural weathering (Table- 9&10).

5.14 Heavy Metal Analysis

According to heavy metal analysis done in this study, concentration of Fe, Mn and Zn is in reasonable limit, which also act as nutrient except in one sample Fe concentration is high may be due to some local disturbances in Kusheshwar-Asthan. Concentration of Ni, Cu and Cd is also well with in permissible limit. Only concentration of Pb is seems to be little higher than the normal permissible limit, may be due to some anthropogenic influences (Table-5&6).

5.15 Interpretation of Durov, Piper and Schoeller Diagram

According to Durov diagram of water sample concentration, Ca and bicarbonate mainly influence water quality. Na,Mg,Cl- and SO42- is also having some influence over water quality. This condition almost same on both sites (Fig. 37&38).

Piper diagram of Kusheshwar-Asthan again indicate the similar trend on both the location (Fig. 39&40).

Scholler diagram of Kusheshwar-Asthan also indicate high concentration of Ca and bicarbonate in both the locations. Na, sulfate and chloride is also present but in low concentration relatively. In Kabar-Tal, it is showing that sulfate concentration is in fewer amounts than Kusheshwar-Asthan but in case of Bicarbonate trend is reverse (Fig.41&42)

Classification of Hydrogeochemical facies, United States Salinity Classification of water and classification of water for solids of medium permeability interpretation is also done through AQUACHEM software(Fig.29-34); the detailed explanation of which have been incorporated in the Chapter Six (*Summary and Conclusion*)..

5.16 Mineralogy of Surface Sediments

As per Mineralogical study done by XRD (Fig.43&44) indicates that the major phases present in the sample of both wetland i.e. Kabar-Tal and Kusheshwar-Asthan , surface sediment shows very high amount of quartz in both the study. Quartz ranges between 34.78-38.02 % in Kabar-Tal and 34.12-37.13 % in the Kusheshwar-Astan. Apart from that in Kabar-Tal Chlorite 10.62-12.13 %); Orthoclase (11.99 - 13.02 %); Calcite (6.94- 8.13 %); Muscovite (6.43 – 7.65 %) are also present. Rest other clay minerals are present in 18.25 - 22.881 range in various samples.

In Kusheshwar-Astan apart from Quartz chlorite (8.12 -11.43 %); Muscovite (12.11-14.07 %); Biotite 12.11- 15.12 %) and Albite (5.12 -7.11 %) and other minerals by the XRD data interpretation. Rest other Clay minerals are present in 20.11 -24.44 % are range in various samples (Table-11&12).

5.17 Grain Size Distribution

The grains distribution in surface sediment of both the places i.e. Kabar-Tal and Kusheshwar-Asthan are poorly shorted. Statistical calculation done by method suggested by (Krumbein and Pettijohn, 1938 and Lindholm, 1987).

In the Kabar-Tal bed sediment grains are fine skewed, while in Kusheshwar-Asthan sediments are very fine skewed. In the Kabar-Tal sediments, grains are leptokurtic but in Kusheshwar-Asthan sediment grains are mesokurtic (Table- 13&14, Fig. 45&46).

5.18 Carbon and Sulphur

According to the surface sediment analysis in Kabar-Tal percentage of Total Carbon (TC) ranges between 2.4034- 3.3772 %, With mean value 2.9956 %; in Kusheshwar-Asthan TC ranges between 1.5319 - 3.2454 %, with mean value 2.3826 %.Percentage of Total Sulphur (TS) ranges between 0.0003-0.0014 %, with value almost similar in both the places.

Sample analysis data shows that Inorganic Carbon (IC) percentage in Kabar-Tal ranges between 0.4190-1.3084 %, with mean value 0.9018 %. In Kusheshwar -Asthan, IC ranges between 0.3874-0.7185 %, with mean value 0.5459 %. In both the places, Inorganic Sulphur (IS) is present in very less quantity; its range is 0.0001-0.0006 % only.

Organic Carbon (OC) and Organic Sulphur (OS) are present in more quantity than IC and IS, in both the study area OC ranges between 1.7264-2.2933 %, with mean value 2.0938% in Kabar-Tal and 1.1445-2.5269 %, with mean value 1.8366 % in Kusheshwar-Asthan OS ranges between 0.0002-0.0009 % in both the places (Table-15&16).

5.19 Nitrogen and Phosphate

Nitrogen percentage is slightly more in Kusheshwar-Asthan than Kabar-Tal. In Kabar-Tal range of nitrogen is 0.50-0.59 %, with mean value 0.55 % and in Kusheshwar-Asthan range is 0.57-0.67 %, with mean value 0.62 %.Phosphate percentage is more in Kabar-Tal than Kusheshwar-Asthan.

Its range is 0.84-1.12 %, with mean value 0.95 %.In Kusheshwar-Asthan its range is 0.64-0.67 %, with mean value 0.64 %.(Table-15&16)

5.20 Carbon / Nitrogen Ratio

In the Kabar-Tal Carbon/Nitrogen ratio is more than Kusheshwar-Asthan. The range of C/N ratio is 4.80-5.92 in Kabar-Tal and 2.43-5.40 in Kusheshwar-Asthan (Table-15&16).

5.21 Silica and Aluminum

Silica concentration in surface sediments of the Kabar-Tal ranges between 34-36 % and in Kusheshwar-Asthan ranges between 31.5-34.5 %. This is due to dominance of quartz in surface bed load. In both the places silica concentration is more than Indian River average i.e.24.5 %.

Aluminum content in the surface sediment of the Kabar-Tal ranges from 6.25-7.00 % and in Kusheshwar-Asthan ranges from 4.45-5.50 %. On both the places concentration of aluminum is less than the world average aluminum concentration of river i.e. 9.40 % in surface sediment (Table-15&16). These indicate that most of sediments are derived from quartz rich components as orthoquartizites in the area. The low aluminum content in the sediments also indicates low amount of clay minerals and hence dominance of quartz in the sediments.

CHAPTER 6

Summary and Conclusion

6. Summary and Conclusion

The results obtained from the current study indicate that Ca and Bicarbonate are the most dominant ions in both the wetland water.

Both the wetlands are alkaline in nature. High concentration of alkaline earth metal i.e. Ca + Mg and high ratio (Ca+ Mg)/ (Na+K), suggest a high concentration of dissolved ions through carbonate weathering and partial input from anthropogenic imbalance in these areas.

Rock weathering is the principle mechanism controlling the water chemistry of both the wetlands. The chemical composition of Kabar-Tal wetlands water indicate that water are in equilibrium with Gibbisite and kolinite, bust in Kusheshwar-Asthan , it is in equilibrium with koilinite. This indicates that the chemistry of water in Kusheshwar-Asthan is favoring Kolinite formation and in Kabar-Tal favoring Giuvsite formation.

Classification of wetland water according to Na % suggested by Wilcox (1955), all the water sample is Kabar-Tal wetland is between 20 – 40 % i.e. “good” range even three samples were recorded in “excellent” quality range i.e. 0 to 20, but in Kusheshwar-Asthan all the water sample is in good quality range.

Based on E.C. suggested by Wilcox, 1955 on both the locations water quality is in 'good' range i.e. 250 to 750μS/cm.

According to Sawyer and McCarty Standard, 'Hardness' of the water of 8 samples of Kabar-Tal and 10 samples of Kusheshwar-Asthan is in slightly 'Hard' range i.e. 75 to 150 and 7 samples in Kabar-Tal and 5 samples in Kusheshwar-Asthan is in moderately hard range i.e. 150 to 300.

According to Scholder, 1965 classification (1967) on the both places water is of type 'one' quality.

According to USSL, 1954 classification on the basis of TDS shows that two water of Kabar-Tal is in 'Excellent' range i.e. <200 but rest 13 sample and all the sample of Kusheshwar-Asthan is in good range i.e. 200 to 500. So it can be used for agriculture purpose

Based on Chloride classification suggested by Stuifzand (1989) shows that ten water sample of Kabar-Tal is in very fresh range i.e. 0.141 to 0.846 and rest 5 samples and all the sample of Kusheshwar-Asthan are in fresh category i.e. 0.846 to 4.23.

EC-TDS relation for both the location is in 0.60 to 0.80 range for the entire sample Cation facies indicates water of the both the wetlands is Calcium –sodium predominant.

Anion facies indicates water of the both the wetlands is Chloride -sulfate -bicarbonate predominant.

Over all we can say that water of the sites are seems to be partially affected by anthropogenic activities.

According to the study of surface sediment, characteristics in Kabar-Tal sediments grain are Leptokurtic while in Kusheshwar-Asthan sediments are mesokurtic.

The grain size distribution of Kabar-Tal sediment is fine skewed while in Kusheshwar-Asthan sediment is very fine skewed. In both the location, surface sediment is poorly shorted.

Quartz is the most dominant mineral in both places. Clay minerals are present in good quantity in both the places.

Total carbons on both the site are high showing good amount of organic matter available for biological activity.

Sulfur is present is very less amount in both places. It implies that both the sites seems to be less affected by sulfur enrichment

Presence of nutrients i.e. nitrogen and phosphates is in good amount in both the places showing ideal environment for vegetation and biological productivity.

Presence of silica concentration in the sediment samples of both the places is more than average Indian rivers. Aluminum is present in less concentration than world average of surface sediments on both the places.

Overall that the environments of both the wetland are still pristine with little anthropogenic influences.

Table: 1 Physiochemical Profiles of Water Samples of Kabar-Tal, Begusarai, Bihar (India)

Station	DO mg/l	TSM mg/l	ORP mV	pH	EC µS/cm	TDS	F^- mg/l	Cl^- mg/l	HCO_3^- mg/l	SO_4^{2-} mg/l	NO_3^- mg/l	PO_4^{3-} mg/l	$H_4SiO_4^-$ mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l
T1	8.57	0.1	137	8.21	320	212	0.114	30.49	174.46	10.42	3.91	0.388	0.07	43.73	10.46	27.10	1.76
T2	8.16	0.1	143	8.25	350	233	0.109	29.28	181.55	10.76	3.26	0.230	2.91	41.49	08.47	33.32	1.80
T3	8.43	0.1	144	8.18	352	232	0.185	27.48	190.28	11.27	1.56	0.283	3.14	39.84	07.45	31.35	1.79
T4	8.58	0.2	145	8.13	342	227	0.366	31.59	183.18	10.85	2.18	0.265	0.86	40.00	08.48	28.23	1.69
T5	8.43	0.2	145	8.17	415	276	0.276	36.51	186.73	11.01	3.73	0.396	2.44	51.93	12.44	25.88	2.33
T6	8.77	0.1	141	8.24	289	191	0.331	28.71	178.82	11.36	3.46	0.248	0.12	38.51	09.43	23.69	2.66
T7	8.09	0.3	137	8.14	294	196	0.081	29.49	174.11	11.27	2.53	0.336	0.16	34.23	08.38	27.76	1.71
T8	8.28	0.1	140	8.10	440	290	0.088	26.72	197.37	10.76	3.28	0.257	1.37	54.76	13.38	21.35	2.39
T9	8.26	0.2	146	8.25	455	302	0.213	27.84	209.91	10.48	2.71	0.222	1.88	59.79	14.44	20.88	2.50
T10	8.44	0.2	145	7.92	473	314	0.317	32.58	204.98	10.42	3.52	0.297	1.00	56.36	13.90	20.29	2.41
T11	8.42	0.2	137	8.04	476	317	0.172	30.79	196.09	11.52	3.08	0.283	1.14	56.67	13.45	22.29	2.39
T12	8.38	0.1	135	8.27	460	305	0.074	29.09	193.18	10.42	2.67	0.266	1.70	57.05	13.40	20.88	2.51
T13	8.36	0.1	136	8.30	328	218	0.255	27.84	154.82	10.85	2.53	0.222	0.49	37.14	09.36	21.82	2.28
T14	8.29	0.1	133	8.31	320	211	0.317	28.91	158.18	10.34	2.07	0.239	0.81	33.48	08.44	21.82	1.78
T15	8.31	0.1	134	8.27	309	205	0.331	26.84	153.40	10.51	2.11	0.230	0.21	35.52	08.32	21.35	1.85

Table: 2 Physiochemical Profile of Water samples of Kusheshwar-Asthan, Darbhanga, Bihar (India)

Station	DO mg/l	TSM mg/l	ORP mV	pH	EC µS/cm	TDS mg/l	F^- mg/l	Cl^- mg/l	HCO_3^- mg/l	SO_4^{2-} mg/l	NO_3^- mg/l	PO_4^{3-} mg/l	$H_4SiO_4^-$ mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l
A1	7.61	0.4	136	8.10	388	258	0.324	50.09	172.55	26.78	6.18	0.406	6.16	45.15	10.59	37.07	2.72
A2	8.05	0.2	139	8.18	427	284	0.303	45.05	147.01	27.12	5.24	0.493	5.79	40.13	10.79	35.89	3.27
A3	7.86	0.3	139	8.21	435	288	0.206	47.09	139.92	28.13	5.06	0.336	5.74	41.35	10.38	26.04	3.04
A4	8.26	0.4	140	8.10	416	278	0.178	54.04	153.40	26.44	4.80	0.459	8.07	45.65	10.11	26.98	3.07
A5	8.24	0.4	138	8.23	427	282	0.109	42.04	176.09	27.97	5.48	0.38	6.40	42.53	10.32	27.92	2.82
A6	8.16	0.2	131	7.97	421	281	0.116	49.29	161.91	32.54	6.89	0.467	6.77	44.56	10.11	25.10	2.97
A7	8.72	0.5	135	8.14	429	283	0.158	54.29	154.82	26.44	5.97	0.379	5.74	42.59	09.76	25.10	3.07
A8	8.44	0.5	137	8.28	413	276	0.178	47.89	183.18	27.37	5.56	0.485	6.35	45.52	10.34	24.17	3.05
A9	8.55	0.6	136	8.26	412	270	0.123	51.61	158.36	26.02	3.00	0.510	5.98	39.91	09.39	24.17	2.99
A10	8.18	0.5	137	8.23	413	275	0.185	46.01	143.47	29.15	4.56	0.476	5.60	43.03	09.56	24.17	2.78
A11	8.35	0.6	150	8.18	429	284	0.137	52.71	154.82	27.71	4.43	0.458	5.65	54.99	12.40	23.07	2.73
A12	8.41	0.5	149	8.06	420	280	0.220	49.21	147.72	26.86	4.89	0.528	6.21	40.80	09.45	26.04	2.74
A13	8.38	0.6	148	8.14	427	283	0.102	51.21	133.54	28.73	4.93	0.265	5.93	39.91	09.30	24.63	2.73
A14	8.17	0.4	146	8.23	407	270	0.213	47.81	140.63	26.61	4.28	0.476	5.84	40.33	08.88	25.10	2.68
A15	8.45	0.5	147	8.27	402	262	0.227	46.71	139.21	26.69	4.86	0.336	6.16	42.20	08.92	25.10	2.71

Table: 3 Correlation among various physiochemical parameters of water samples of Kabar-Tal

	pH	EC	TDS	Ca	Mg	Na	K	Cl-	HCO$_3$-	SO$_4$2-	NO$_3$-	PO$_4$3-	F-
pH	1.00												
EC	-0.52	1.00											
TDS	-0.52	1.00	1.00										
Ca	-0.47	0.96	0.96	1.00									
Mg	-0.44	0.90	0.90	0.96	1.00								
Na	0.07	-0.43	-0.43	-0.41	-0.61	1.00							
K	-0.17	0.61	0.61	0.68	0.76	-0.64	1.00						
Cl-	-0.43	0.26	0.27	0.27	0.27	0.13	0.07	1.00					
HCO3-	-0.60	0.81	0.80	0.85	0.73	-0.07	0.50	0.23	1.00				
SO42-	-0.24	-0.13	-0.13	-0.14	-0.20	0.36	0.09	0.09	0.08	1.00			
NO3-	-0.33	0.28	0.29	0.45	0.53	-0.09	0.44	0.50	0.32	-0.03	1.00		
PO43-	-0.36	0.03	0.03	0.12	0.13	0.26	-0.15	0.70	0.13	0.15	0.49	1.00	
F-	-0.01	-0.22	-0.22	-0.28	-0.21	-0.24	0.03	0.23	-0.27	-0.07	-0.19	-0.22	1.00

Table: 4 Correlation among various physiochemical parameters of water samples of Kusheshwar-Asthan

	pH	EC	TDS	Ca	Mg	Na	K	Cl-	HCO3-	SO42-	NO3-	F-	PO43-
pH	1.00												
EC	-0.09	1.00											
TDS	-0.20	0.97	1.00										
Ca	-0.12	0.03	0.07	1.00									
Mg	-0.13	0.32	0.37	0.79	1.00								
Na	-0.21	-0.31	-0.25	-0.12	0.27	1.00							
K	-0.03	0.41	0.44	-0.15	0.22	0.22	1.00						
Cl-	-0.38	0.00	0.01	0.34	0.10	-0.23	0.06	1.00					
HCO3-	-0.01	-0.22	-0.15	0.35	0.39	0.22	0.19	-0.08	1.00				
SO42-	-0.48	0.27	0.34	0.12	0.12	-0.19	-0.02	-0.20	0.02	1.00			
NO3-	-0.58	0.02	0.11	0.13	0.20	0.35	0.17	-0.09	0.39	0.52	1.00		
F-	0.01	-0.49	-0.44	-0.14	0.05	0.76	0.08	-0.21	-0.06	-0.38	0.15	1.00	
PO43-	-0.09	-0.17	-0.07	0.14	0.14	0.04	0.22	0.02	0.30	-0.09	-0.22	0.17	1.00

Table: 5 Heavy Metal Profile of Water samples of Kabar Tal, Begusarai, Bihar (India)

Station	Mn mg/l	Fe mg/l	Ni Mg/l	Cu mg/l	Zn mg/l	Cd mg/l	Pb mg/l
T1	0.017	0.035	0.021	0.002	0.012	0.022	0.544
T2	0.019	0.078	0.068	0.001	0.011	0.024	0.453
T3	0.027	0.053	0.103	0.001	0.010	0.020	0.589
T4	0.025	0.186	0.107	0.001	0.014	0.021	0.408
T5	0.027	0.025	0.038	0.003	0.016	0.016	0.385
T6	0.033	0.089	0.043	0.002	0.024	0.018	0.453
T7	0.021	0.136	0.099	0.002	0.013	0.023	0.340
T8	0.029	0.045	0.056	0.002	0.016	0.026	0.499
T9	0.040	0.064	0.047	0.003	0.025	0.023	0.362
T10	0.035	0.038	0.060	0.002	0.017	0.027	0.499
T11	0.044	0.045	0.068	0.003	0.021	0.029	0.453
T12	0.042	0.035	0.073	0.003	0.018	0.027	0.521
T13	0.031	0.025	0.051	0.001	0.065	0.023	0.544
T14	0.025	0.027	0.030	0.001	0.017	0.020	0.408
T15	0.040	0.021	0.060	0.002	0.014	0.025	0.408

Table: 6 Heavy Metal Profile of Water Samples of Kusheshwar-Asthan, Darbhanga, Bihar (India)

Station	Mn mg/l	Fe mg/l	Ni Mg/l	Cu mg/l	Zn mg/l	Cd mg/l	Pb mg/l
A1	0.027	0.53	0.021	0.001	0.016	0.024	0.589
A2	0.029	0.569	0.051	0.003	0.014	0.01	0.499
A3	0.029	0.738	0.043	0.004	0.017	0.017	0.521
A4	0.038	0.585	0.129	0.004	0.021	0.024	0.499
A5	0.036	0.566	0.038	0.005	0.025	0.022	0.476
A6	0.037	0.845	0.017	0.005	0.017	0.021	0.453
A7	0.044	0.766	0.056	0.003	0.021	0.022	0.408
A8	0.044	0.605	0.06	0.004	0.028	0.024	0.476
A9	0.033	0.616	0.038	0.005	0.021	0.027	0.406
A10	0.025	0.555	0.012	0.004	0.018	0.026	0.499
A11	0.064	1.132	0.094	0.005	0.016	0.022	0.499
A12	0.035	0.605	0.034	0.005	0.038	0.02	0.499
A13	0.064	0.852	0.021	0.005	0.023	0.021	0.521
A14	0.06	0.397	0.056	0.003	0.02	0.025	0.453
A15	0.064	0.344	0.047	0.005	0.017	0.024	0.544

Table: 7 Physiochemical Parameters in milliequivalents per liter of water samples of Kabar-Tal

Station	Ca epm	Mg epm	Na epm	K epm	Cl^- epm	F^- epm	HCO_3^- epm	SO_4^{2-} epm	NO_3^- epm	PO_4^{3-} epm
T1	2.180	0.860	1.180	0.045	0.860	0.006	2.860	0.217	0.063	0.012
T2	2.070	0.700	1.450	0.046	0.830	0.006	2.980	0.224	0.053	0.007
T3	1.990	0.610	1.360	0.046	0.780	0.010	3.120	0.235	0.025	0.008
T4	2.000	0.700	1.230	0.043	0.890	0.019	3.000	0.226	0.035	0.008
T5	2.590	1.020	1.130	0.060	1.030	0.015	3.060	0.229	0.060	0.012
T6	1.920	0.780	1.030	0.068	0.810	0.017	2.930	0.237	0.056	0.007
T7	1.710	0.690	1.210	0.044	0.830	0.004	2.850	0.235	0.041	0.010
T8	2.730	1.100	0.930	0.061	0.750	0.005	3.230	0.224	0.053	0.008
T9	2.980	1.190	0.910	0.064	0.790	0.011	3.440	0.218	0.044	0.007
T10	2.810	1.140	0.880	0.062	0.920	0.017	3.360	0.217	0.057	0.009
T11	2.830	1.110	0.970	0.061	0.870	0.009	3.210	0.240	0.050	0.008
T12	2.850	1.100	0.910	0.064	0.820	0.004	3.170	0.217	0.043	0.008
T13	1.850	0.770	0.950	0.058	0.790	0.013	2.540	0.226	0.041	0.007
T14	1.670	0.690	0.950	0.046	0.820	0.017	2.590	0.215	0.033	0.007
T15	1.770	0.680	0.930	0.047	0.760	0.017	2.510	0.219	0.034	0.007

Table: 8 Physiochemical Parameters in milliequivalents per liter of water samples of Kusheshwar-Asthan

Station	Ca epm	Mg Epm	Na epm	K Epm	Cl^- epm	F^- epm	HCO_3^- epm	SO_4^{2-} epm	$NO3^-$ epm	PO_4^{3-} epm
A1	2.250	0.870	1.610	0.070	1.410	0.017	2.830	0.558	0.100	0.013
A2	2.000	0.890	1.560	0.084	1.270	0.016	2.410	0.565	0.085	0.016
A3	2.060	0.850	1.130	0.078	1.330	0.010	2.290	0.586	0.082	0.011
A4	2.280	0.830	1.170	0.078	1.520	0.009	2.510	0.550	0.077	0.014
A5	2.120	0.850	1.210	0.072	1.190	0.006	2.890	0.582	0.088	0.012
A6	2.220	0.830	1.090	0.076	1.390	0.006	2.650	0.677	0.111	0.015
A7	2.130	0.800	1.090	0.078	1.530	0.008	2.540	0.550	0.096	0.012
A8	2.270	0.850	1.050	0.078	1.350	0.009	3.000	0.570	0.090	0.015
A9	1.990	0.770	1.050	0.076	1.460	0.006	2.600	0.542	0.048	0.016
A10	2.150	0.790	1.050	0.071	1.300	0.010	2.350	0.607	0.074	0.015
A11	2.740	1.020	1.030	0.070	1.490	0.007	2.540	0.577	0.072	0.014
A12	2.040	0.780	1.130	0.070	1.390	0.011	2.420	0.559	0.079	0.017
A13	1.990	0.770	1.070	0.070	1.440	0.005	2.190	0.598	0.080	0.008
A14	2.010	0.730	1.090	0.069	1.350	0.011	2.300	0.554	0.069	0.015
A15	2.110	0.730	1.090	0.069	1.320	0.012	2.280	0.556	0.078	0.011

Table 9

Kabar-Tal

station	EC-TDS Relation	SO_4^{2-}/Cl^-	Na/Cl^-	Ca/HCO_3^-	Ca+Mg	Na+K	Ca+Mg/Na+K	HCO3/ TA^-	NO_3^-/ TA^-	F^-/Mg	Fe/SO_4^{2-}
T1	0.663	0.252	1.372	0.762	3.040	2.040	2.482	0.715	0.016	0.007	0.006
T2	0.666	0.270	1.747	0.695	2.770	2.150	1.852	0.729	0.013	0.008	0.012
T3	0.659	0.301	1.744	0.638	2.600	1.970	1.849	0.750	0.006	0.016	0.008
T4	0.664	0.254	1.382	0.667	2.700	1.930	2.121	0.723	0.008	0.028	0.029
T5	0.665	0.222	1.097	0.846	3.610	2.150	3.034	0.699	0.014	0.014	0.004
T6	0.661	0.293	1.272	0.655	2.700	1.810	2.459	0.727	0.014	0.022	0.013
T7	0.667	0.283	1.458	0.600	2.400	1.900	1.914	0.720	0.010	0.006	0.021
T8	0.659	0.299	1.240	0.845	3.830	2.030	3.865	0.759	0.012	0.004	0.007
T9	0.664	0.276	1.152	0.866	4.170	2.100	4.281	0.766	0.010	0.009	0.011
T10	0.664	0.236	0.957	0.836	3.950	2.020	4.193	0.738	0.012	0.015	0.006
T11	0.666	0.276	1.115	0.882	3.940	2.080	3.822	0.735	0.011	0.008	0.007
T12	0.663	0.265	1.110	0.899	3.950	2.010	4.055	0.746	0.010	0.004	0.006
T13	0.665	0.286	1.203	0.728	2.620	1.720	2.599	0.706	0.011	0.017	0.004
T14	0.659	0.262	1.159	0.645	2.360	1.640	2.369	0.708	0.009	0.024	0.004
T15	0.663	0.288	1.224	0.705	2.450	1.610	2.508	0.712	0.010	0.026	0.003

Table 10
Kusheshwar-Asthan

Station	EC-TDS Relation	SO_4^{2-}/Cl^-	Na/Cl-	Ca/HCO_3^-	Ca+Mg	Na+K	Ca+Mg/Na+K	HCO_3^-/TA^-	NO_3^-/TA^-	F^-/Mg	Fe/SO_4^{2-}
A1	0.665	0.396	1.142	0.795	3.120	1.680	1.857	0.590	0.021	0.020	0.034
A2	0.665	0.445	1.228	0.830	2.890	1.644	1.758	0.568	0.020	0.018	0.036
A3	0.662	0.441	0.850	0.900	2.910	1.208	2.409	0.544	0.019	0.013	0.045
A4	0.668	0.362	0.770	0.908	3.110	1.248	2.492	0.547	0.017	0.011	0.038
A5	0.660	0.489	1.017	0.734	2.970	1.282	2.317	0.621	0.019	0.007	0.035
A6	0.668	0.487	0.784	0.838	3.050	1.166	2.616	0.561	0.024	0.007	0.045
A7	0.660	0.359	0.712	0.839	2.930	1.168	2.509	0.550	0.021	0.010	0.050
A8	0.668	0.422	0.778	0.757	3.120	1.128	2.766	0.609	0.018	0.011	0.038
A9	0.655	0.371	0.719	0.765	2.760	1.126	2.451	0.566	0.011	0.008	0.041
A10	0.666	0.467	0.808	0.915	2.940	1.121	2.623	0.552	0.017	0.012	0.033
A11	0.662	0.387	0.691	1.079	3.760	1.100	3.418	0.552	0.016	0.007	0.070
A12	0.667	0.402	0.813	0.843	2.820	1.200	2.350	0.554	0.018	0.015	0.039
A13	0.663	0.415	0.743	0.909	2.760	1.140	2.421	0.518	0.019	0.007	0.051
A14	0.663	0.410	0.807	0.874	2.740	1.159	2.364	0.547	0.016	0.015	0.026
A15	0.652	0.421	0.826	0.925	2.840	1.159	2.450	0.549	0.019	0.016	0.022

Table: 11 Mineral composition of surface sediments (in %) of Kabar-Tal

Sampling Stations	Quartz	Chlorite	Muscovite	Orthoclase	Calcite	Illite	Other clay minerals
KS1	34.78	11.09	06.74	12.19	08.13	04.19	22.88
KS2	35.43	11.94	06.99	13.02	07.96	05.02	19.65
KS3	38.02	10.62	06.43	11.99	06.94	04.65	21.35
KS4	36.52	12.13	07.64	12.74	07.02	05.69	18.25

Table: 12 Mineral composition of surface sediments (in %) of Kusheshwar-Asthan

Sampling Stations	Quartz	Chlorite	Muscovite	Albite	Biotite	Other clay minerals
AS1	34.12	09.13	13.43	06.79	12.11	24.44
AS2	35.11	10.07	12.11	06.13	15.12	21.43
AS3	33.43	08.12	13.13	07.11	14.07	24.11
AS4	37.13	11.43	14.07	05.12	13.11	20.11

Table: 13 Statistics of Grain Size by using Graphical Method of Kabar-Tal

Station	**Mean**	**Std. Deviation**	**Skewness**	**Kurtosis**
TS1	0.100	1.557	0.250	1.154
TS2	0.115	1.658	0.289	1.179
TS3	0.118	1.712	0.297	1.189
TS4	0.112	1.628	0.265	1.168

Table: 14 Statistics of Grain Size by using Graphical Method of Kusheshwar-Asthan

Station	**Mean**	**Std. Deviation**	**Skewness**	**Kurtosis**
AS1	0.17	1.507	0.817	0.92
AS2	0.15	1.479	0.712	0.91
AS3	0.21	1.673	0.938	0.99
AS4	0.19	1.611	0.898	0.97

Table: 15 Biogeochemical Characteristic of Bed Sediment of Kabar-Tal

Station	TC %	IC %	OC %	TS %	IS %	OS %	N %	PO_4^{3-} %	Si %	Al %	C/N
TS1	3.3772	1.2030	2.1742	0.0011	0.0004	0.0007	0.57	0.97	36.00	7.00	5.92
TS2	3.4897	1.3084	2.1813	0.0014	0.0005	0.0009	0.59	1.12	35.50	6.50	5.91
TS3	2.7123	0.4190	2.2933	0.0004	0.0001	0.0003	0.53	0.89	34.50	6.25	5.11
TS4	2.4034	0.6770	1.7264	0.0003	0.0001	0.0002	0.50	0.84	34.00	6.75	4.80

Table: 16 Biogeochemical Characteristic of Bed Sediment of Kusheshwar-Asthan

Station	TC %	IC %	OC %	TS %	IS %	OS %	N %	PO_4^{3-} %	Si %	Al %	C/N
AS1	2.5594	0.5599	1.9995	0.001	0.0001	0.0009	0.57	0.61	33.50	4.75	4.49
AS2	2.1936	0.518	1.6756	0.0013	0.0006	0.0007	0.67	0.64	32.00	5.50	3.27
AS3	3.2454	0.7185	2.5269	0.0011	0.0002	0.0009	0.60	0.65	34.50	4.50	5.40
AS4	1.5319	0.3874	1.1445	0.0008	0.0001	0.0007	0.63	0.67	31.50	4.45	2.43

Fig: 1 Percentage contribution of each Anion (mg/l) in Water Samples of Kabar-Tal

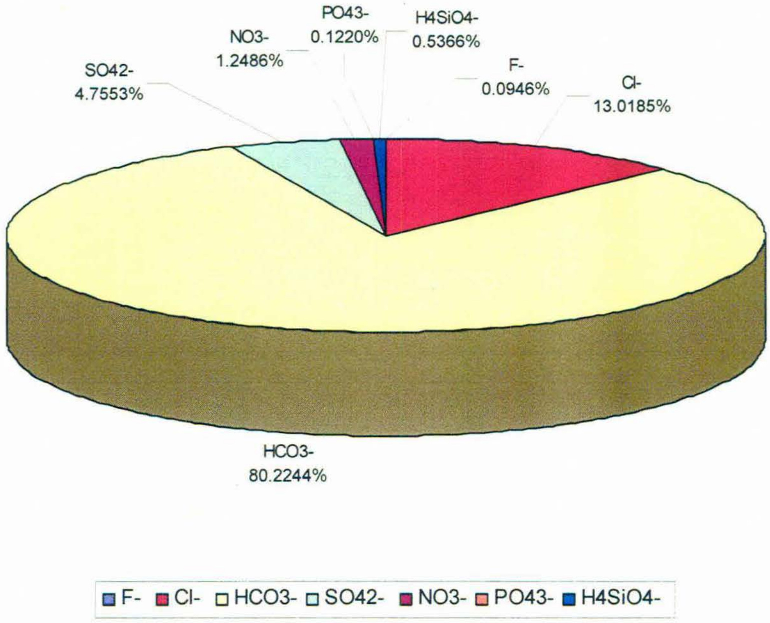


Fig: 2 Percentage contribution of each Anion (mg/l) in Water Samples of Kusheshwar-Asthan

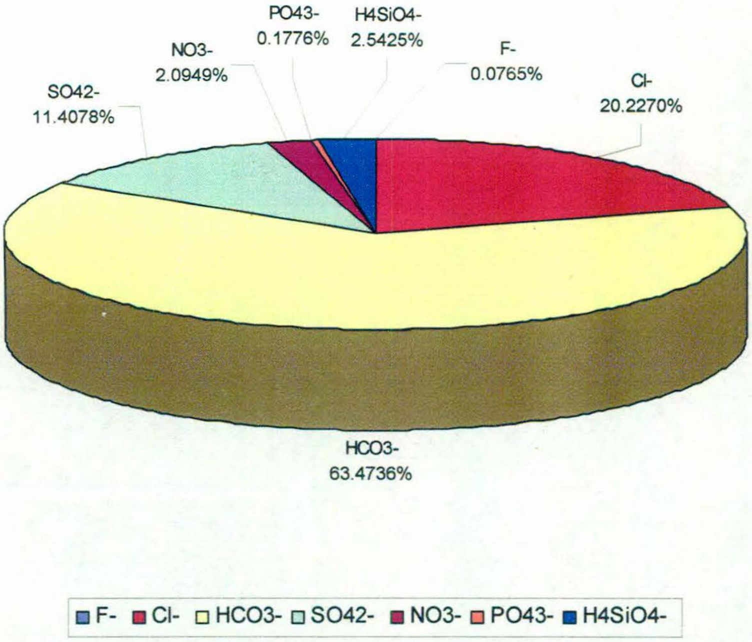


Fig: 3 Percentage contribution of major Cations (mg/l) in Water samples of Kabar-Tal

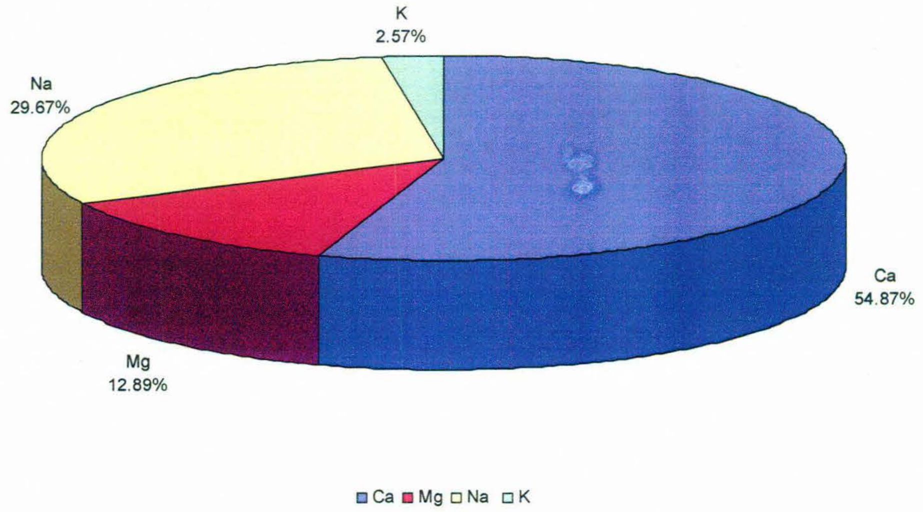


Fig: 4 Percentage contribution of major Cations (mg/l) in Water samples of Kusheshwar-Asthan

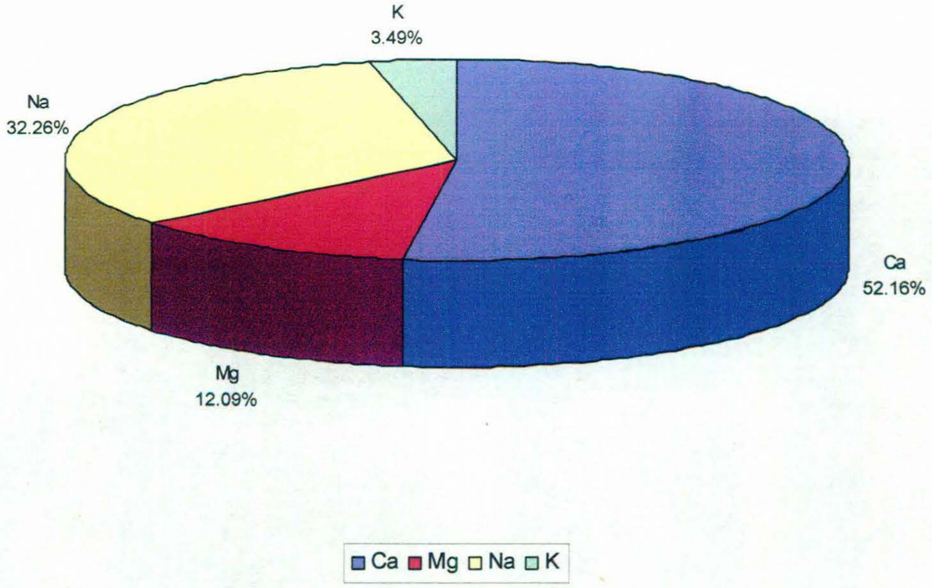


Fig: 5 Concentration (mg/l) of major anions in water sample of Kabar-Tal

Fig: 6 Concentration (mg/l) of major anions in water sample of Kusheshwar-Asthan

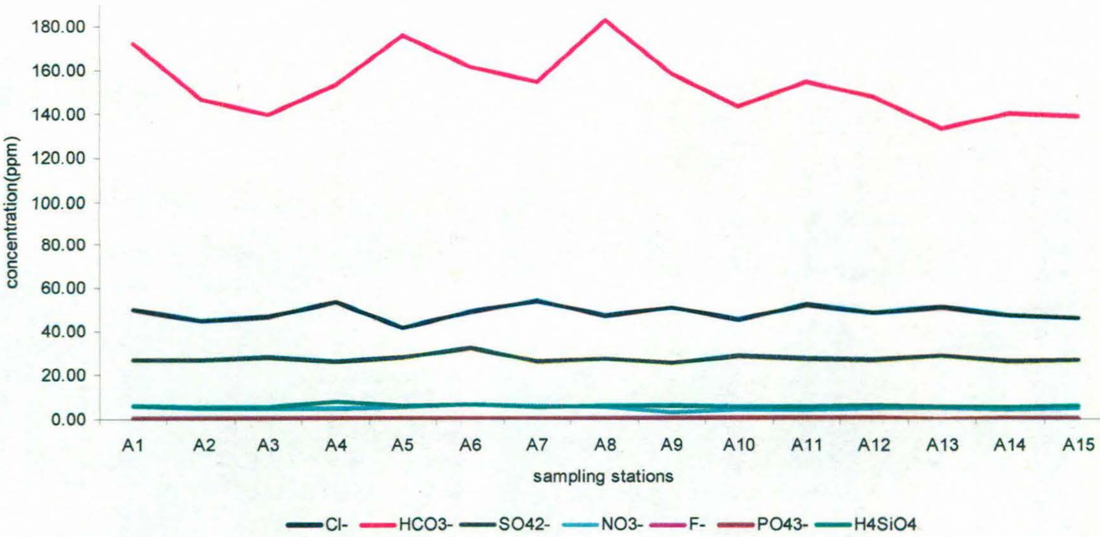


Fig: 7 Concentration (mg/l) of major cations in water samples of Kabar-Tal

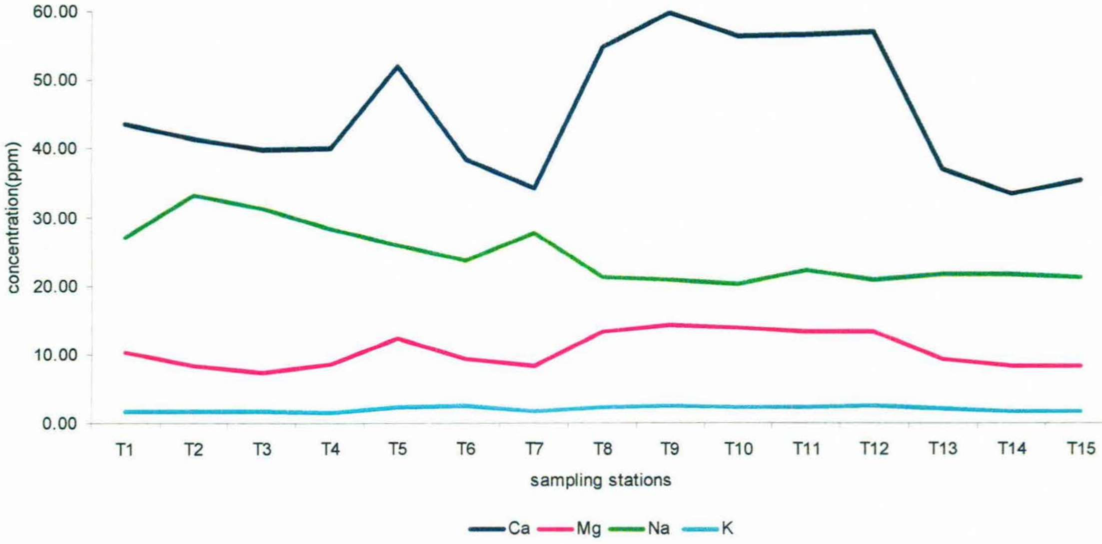


Fig: 8 Concentration (mg/l) of major cations in water samples of Kusheshwar-Asthan

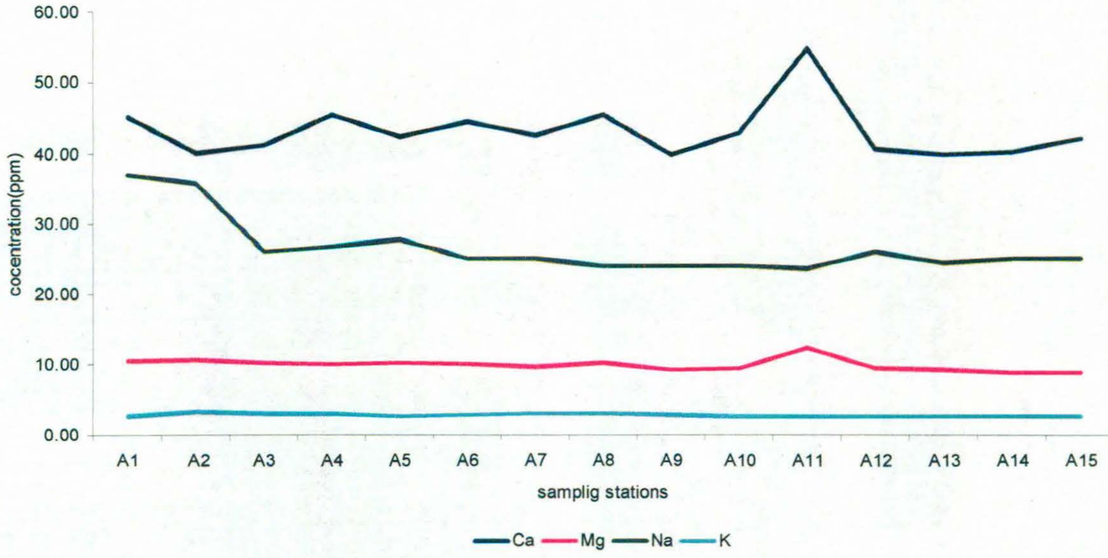


Fig: 9 Concentration (mg/l) of heavy metals in water samples of Kabar-Tal

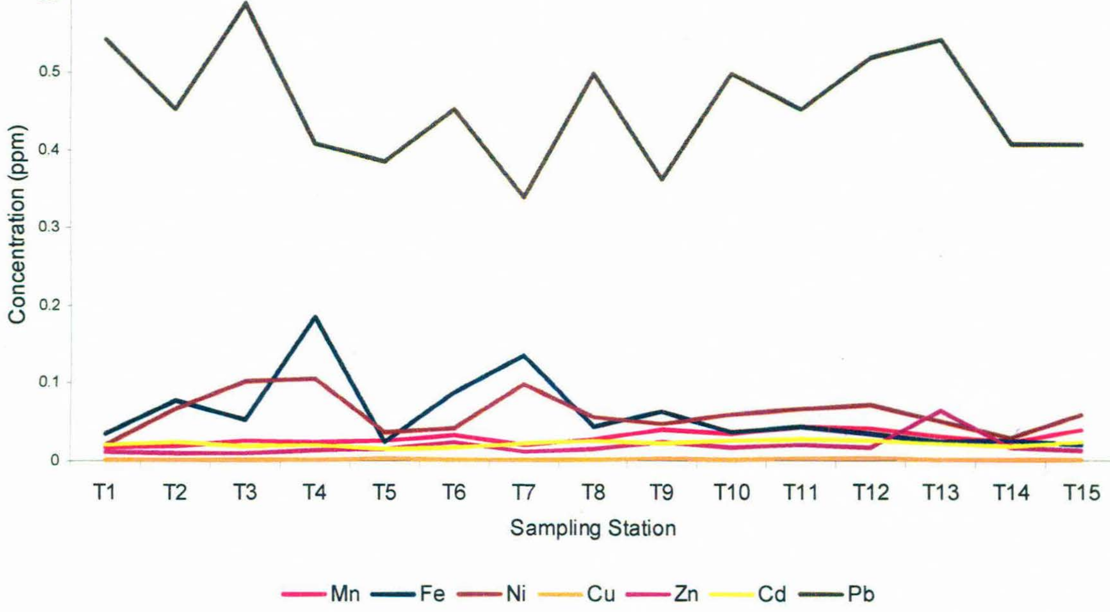


Fig: 10 Concentration (mg/l) of heavy metals in water samples of Kusheshwar-Asthan

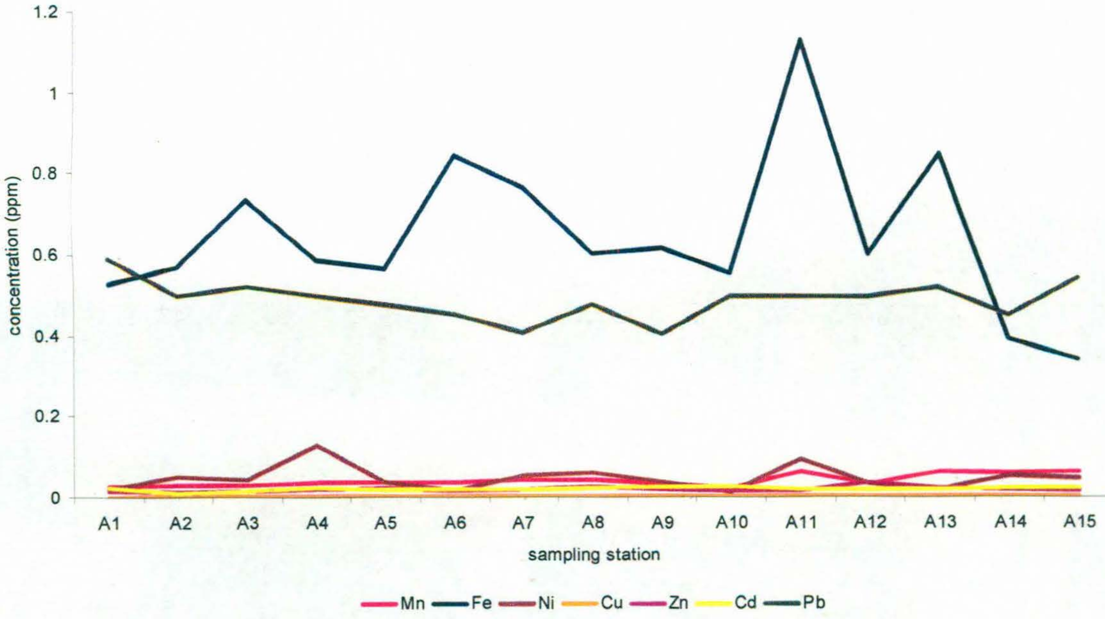


Fig: 11 Percentage contribution of each Anion (epm) in Water Samples of Kabar-Tal

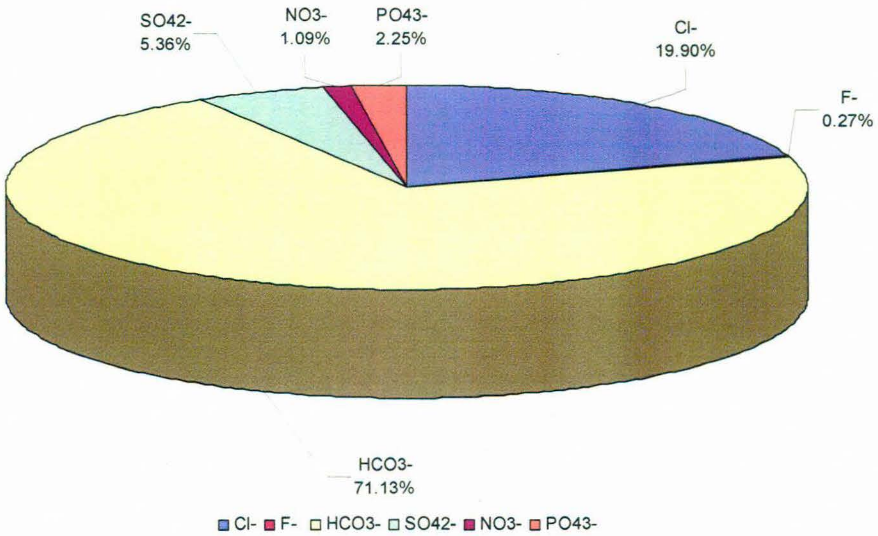


Fig: 12 Percentage contribution of each Anion (epm) in Water Samples of Kusheshwar-Asthan

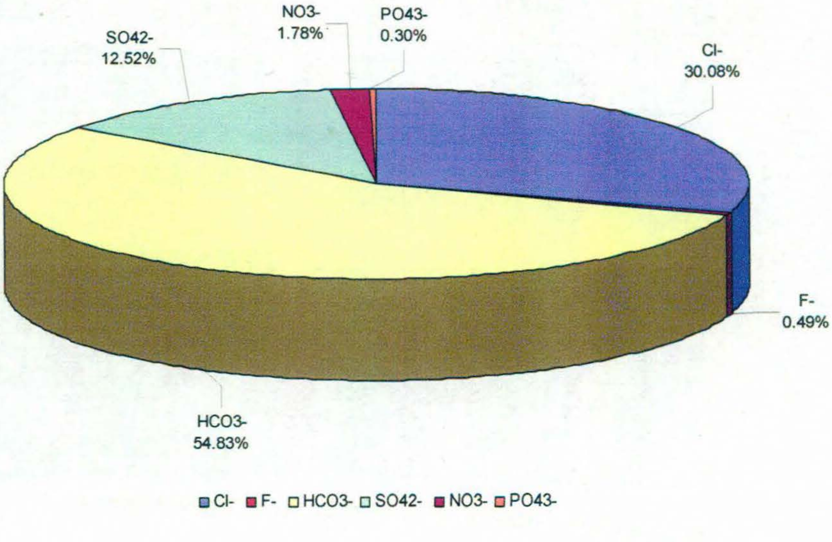


Fig: 13 Percentage contribution of major Cations (epm) in Water samples of Kabar-Tal

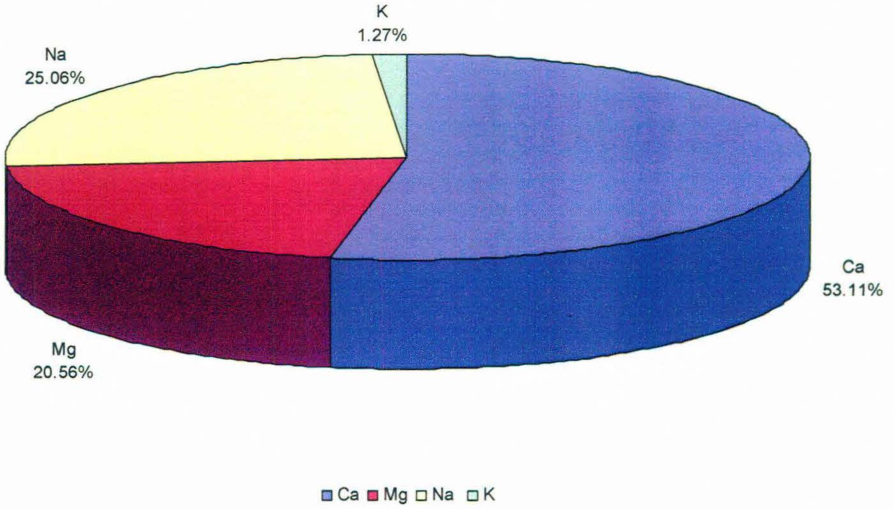


Fig: 14 Percentage contribution of major Cations (epm) in Water samples of Kusheshwar-Asthan

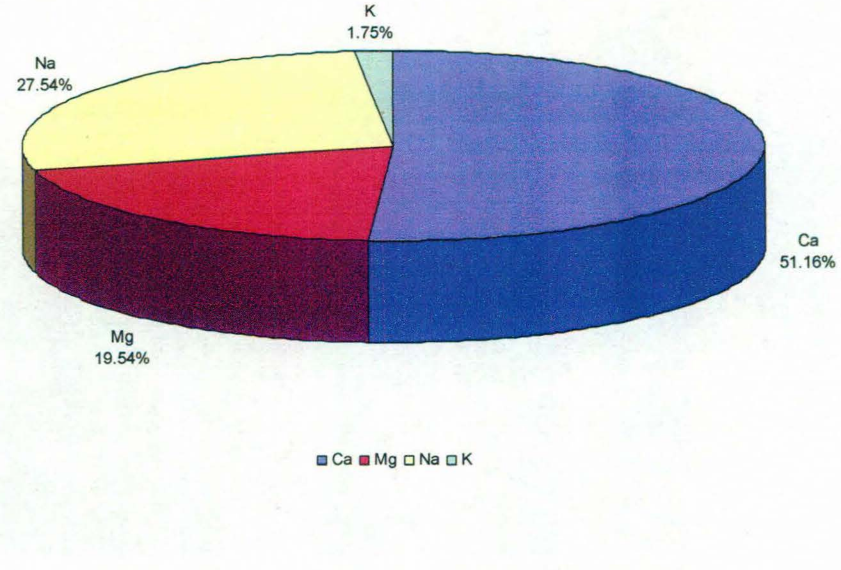


Fig: 15 Concentration (epm) of major Anions in water sample of Kabar-Tal

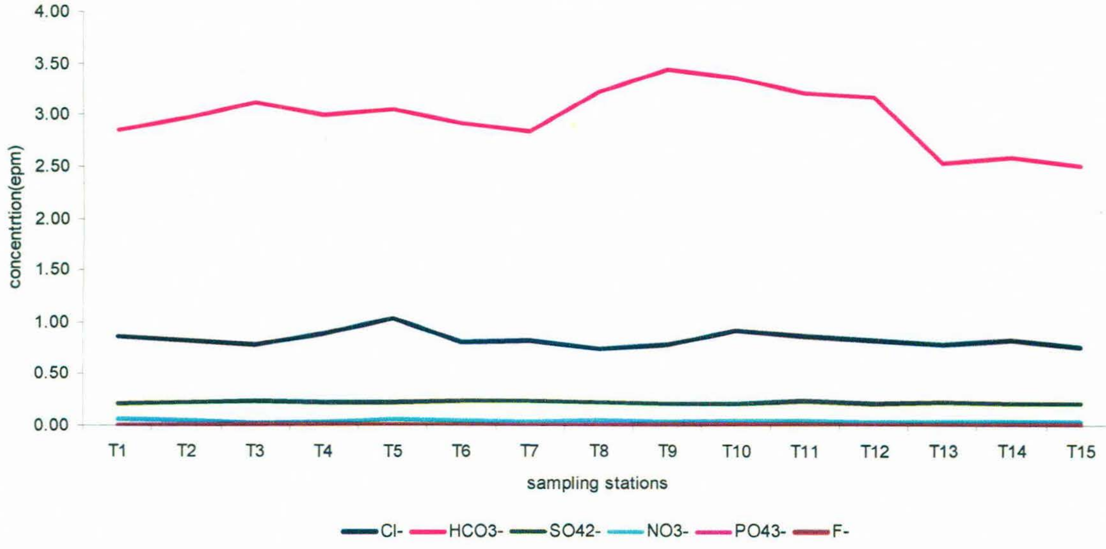


Fig: 16 Concentration (epm) of major Anions in water sample of Kusheshwar-Asthan

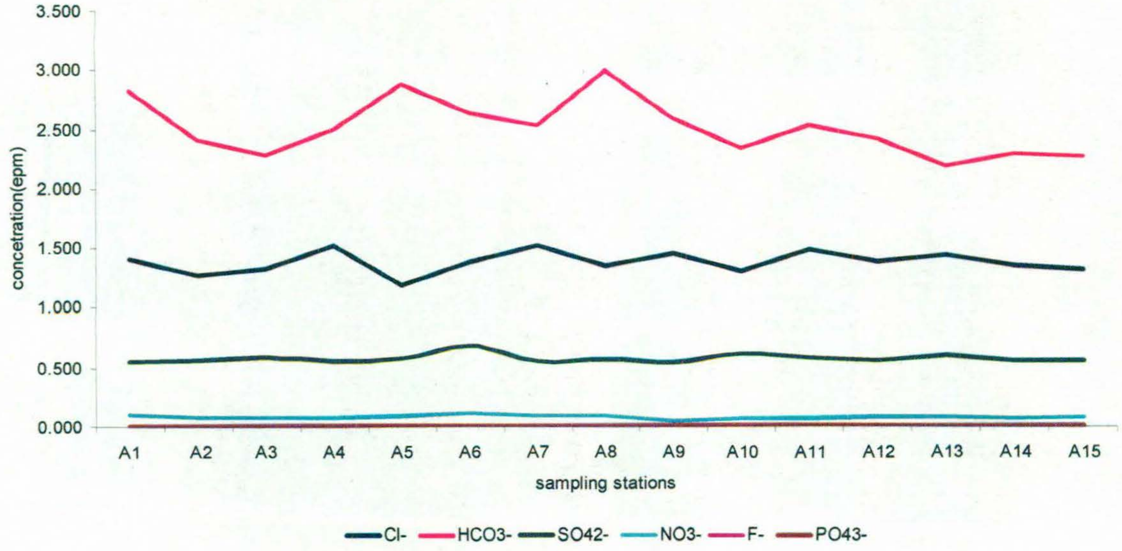


Fig: 17 Concentration (epm) of major cations in water samples of Kabar-Tal

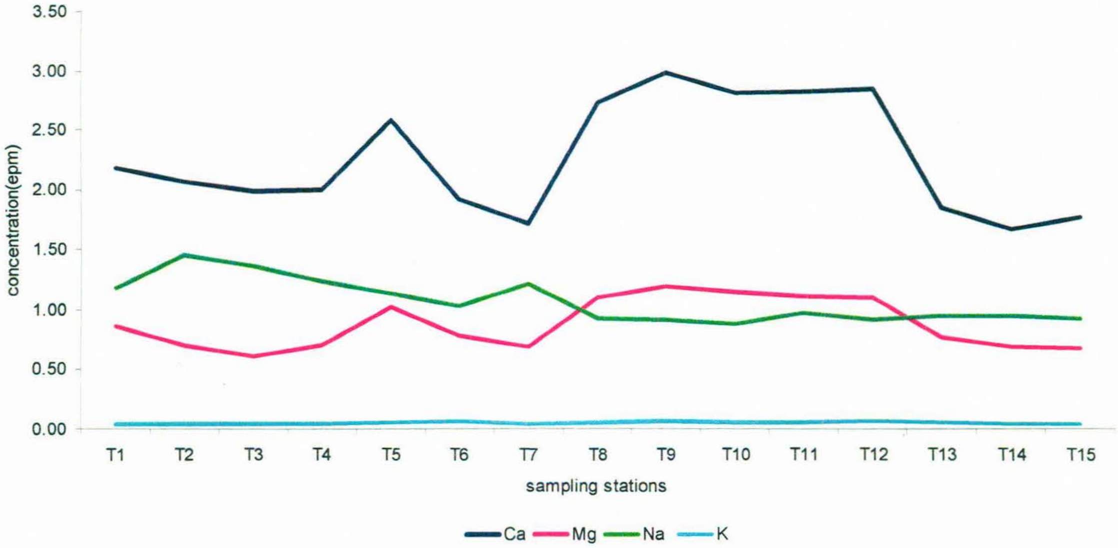


Fig: 18 Concentration (epm) of major cations in water samples of Kusheshwar-Asthan

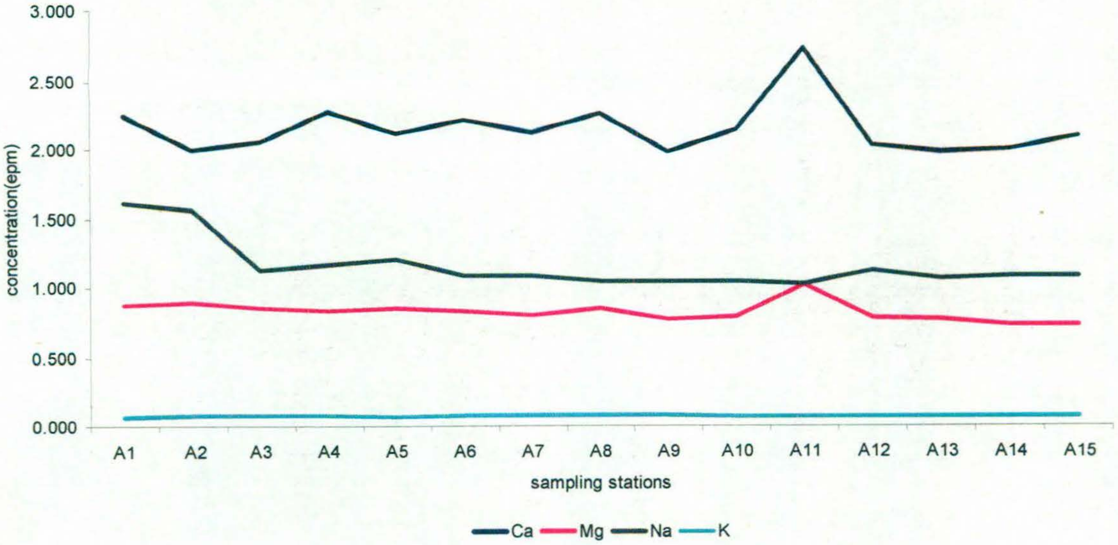
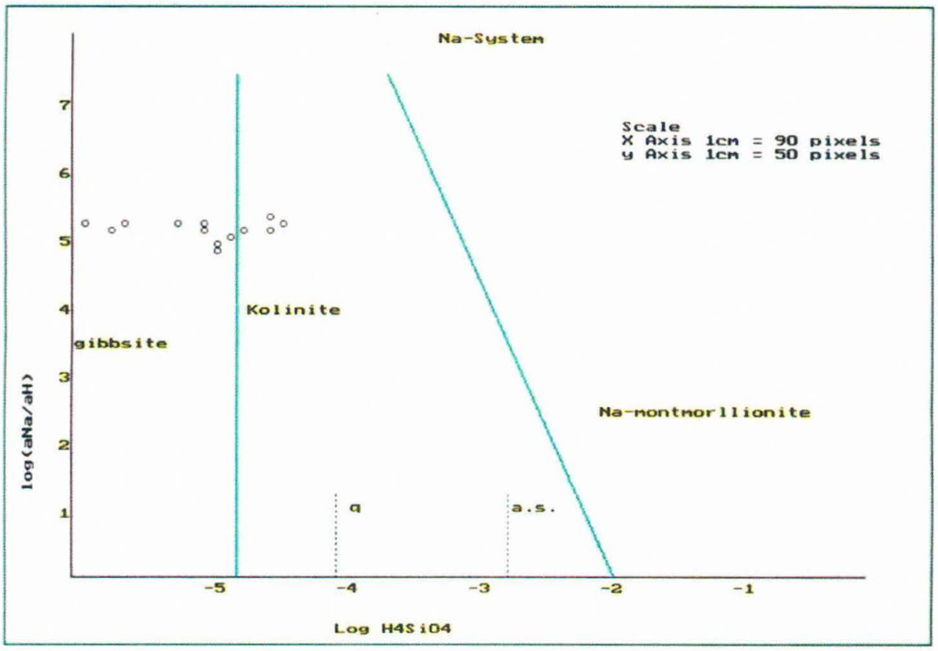


Fig: 19 Kabar-Tal



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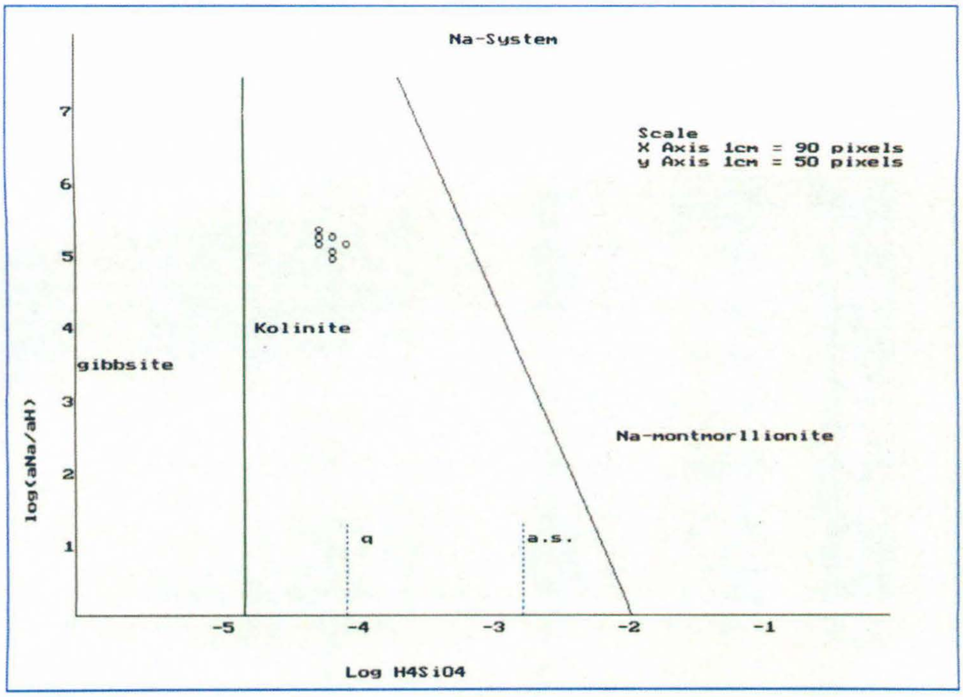

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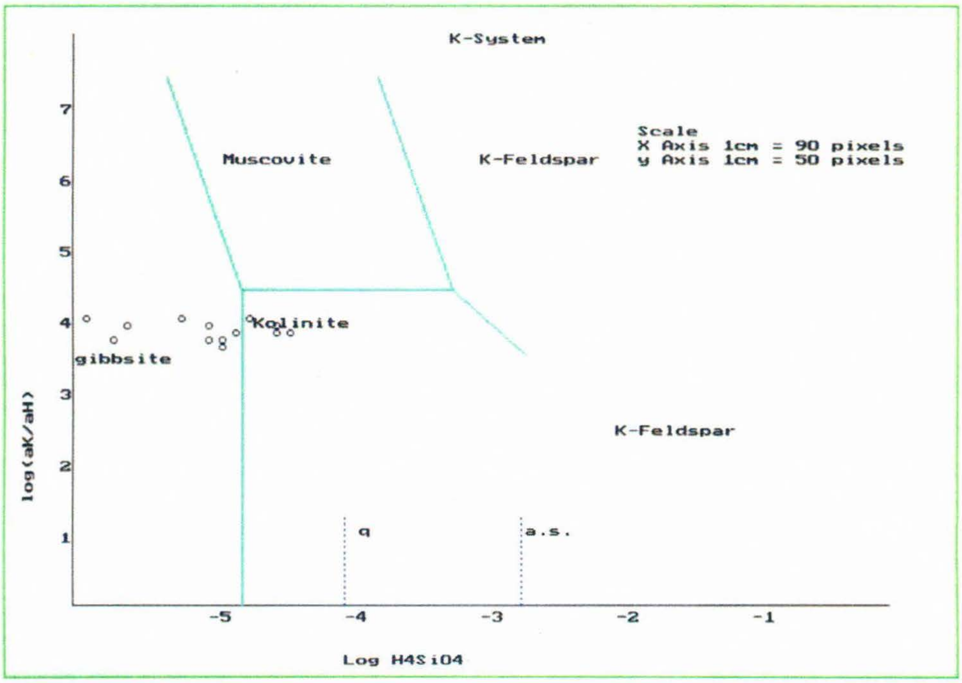

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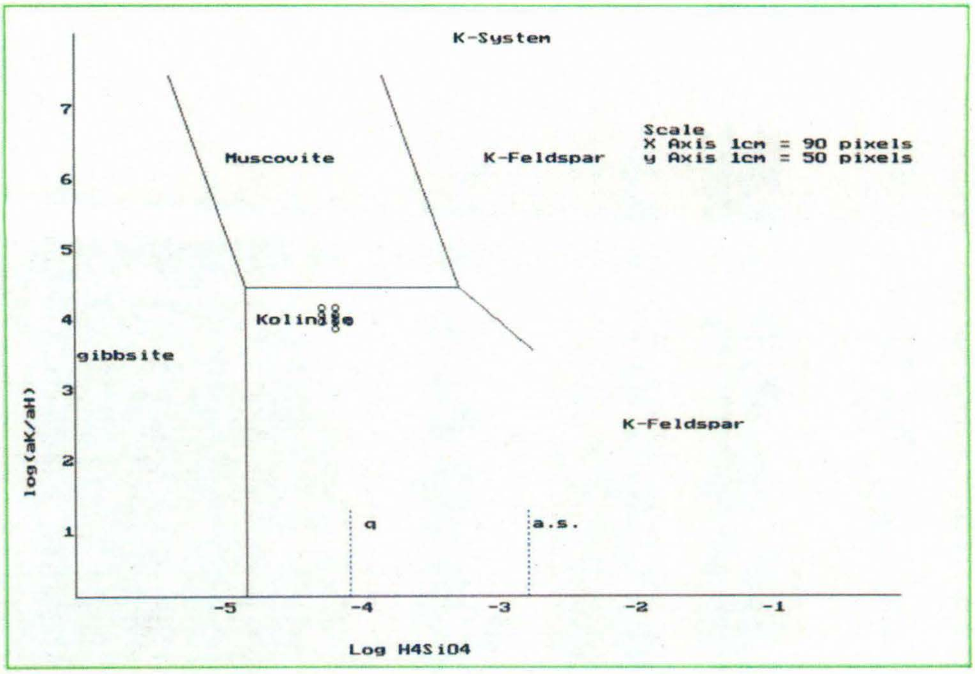

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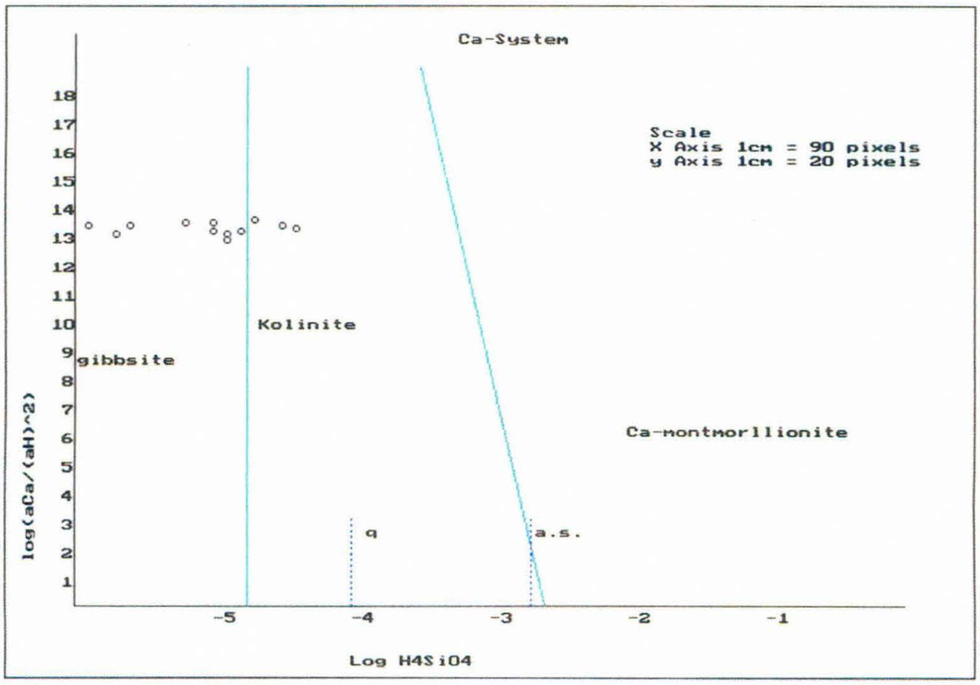

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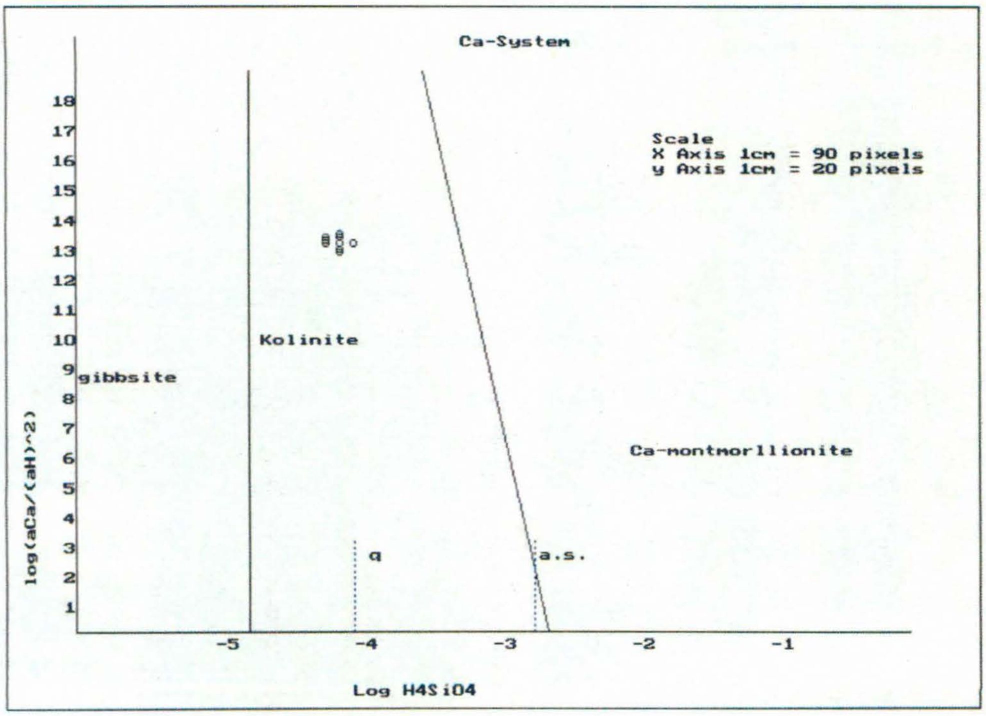

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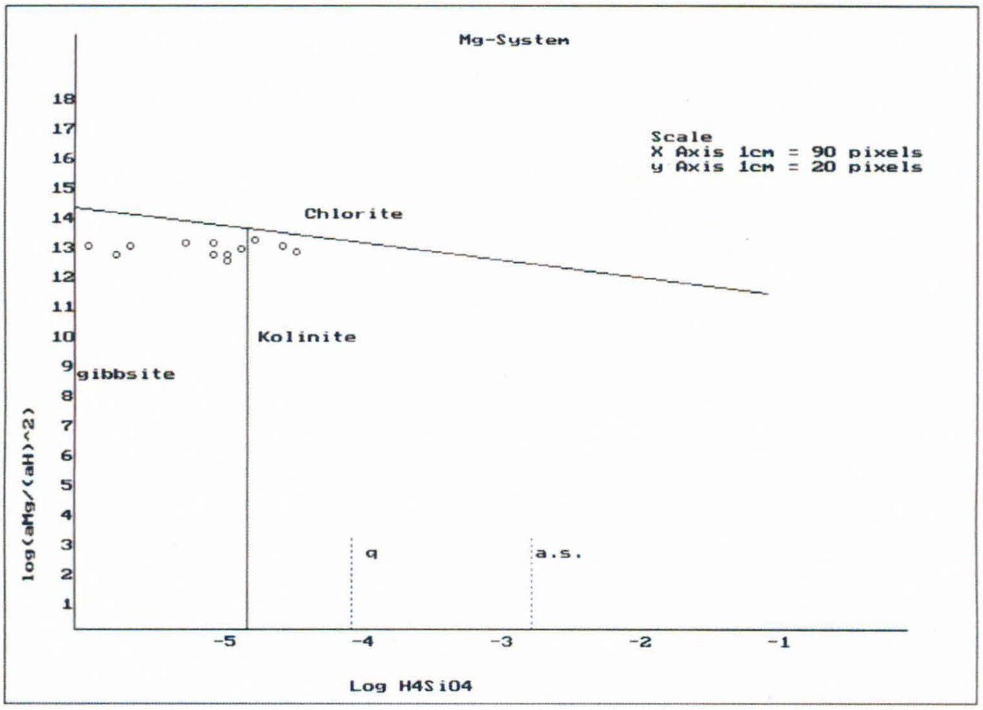

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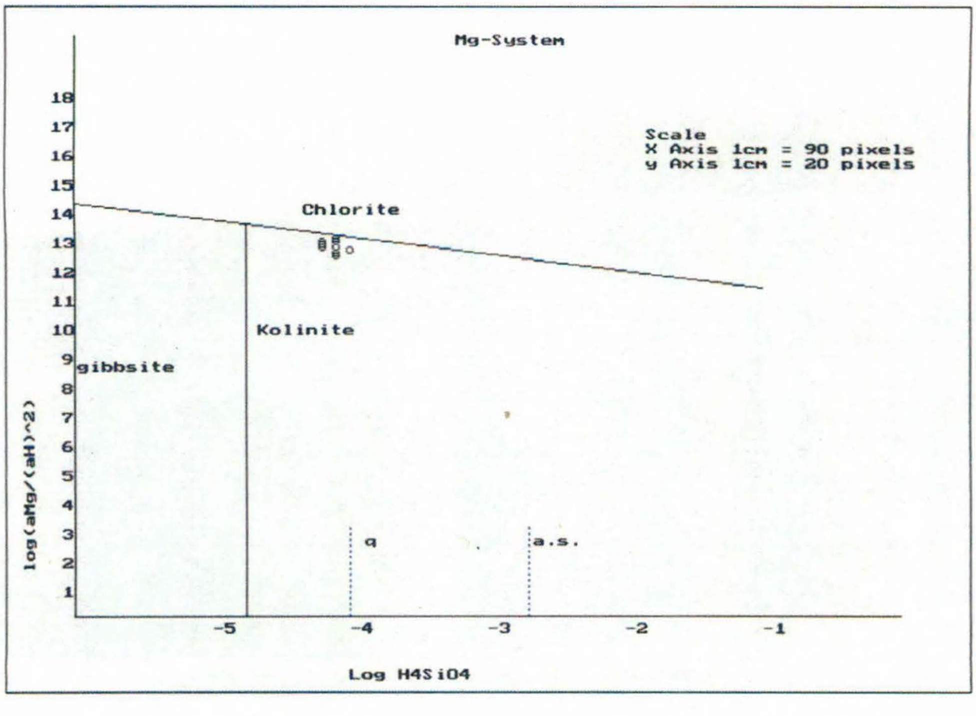

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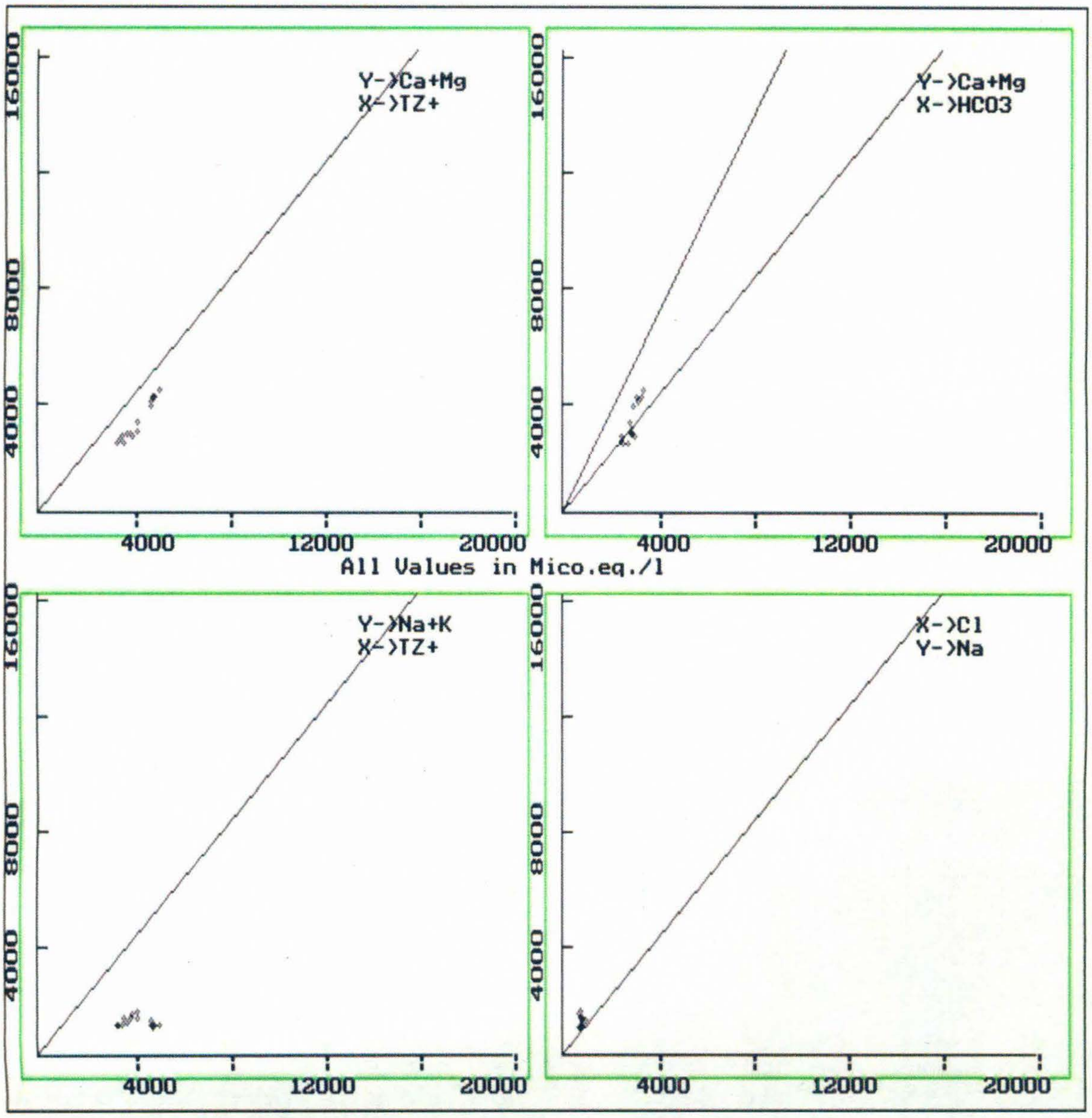


Fig: 28 Kusheshwar-Asthan

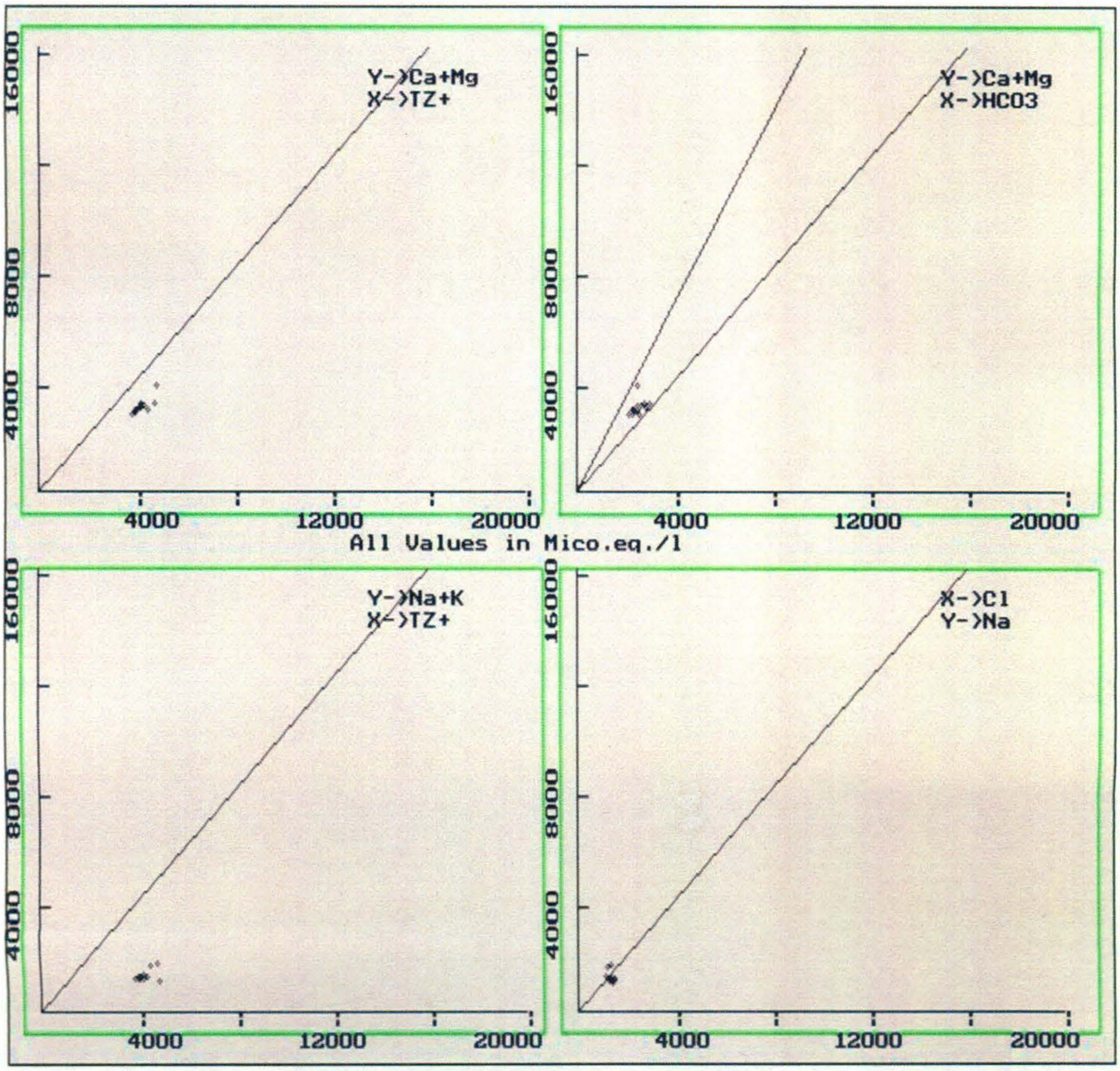


Fig: 29 Kabar-Tal

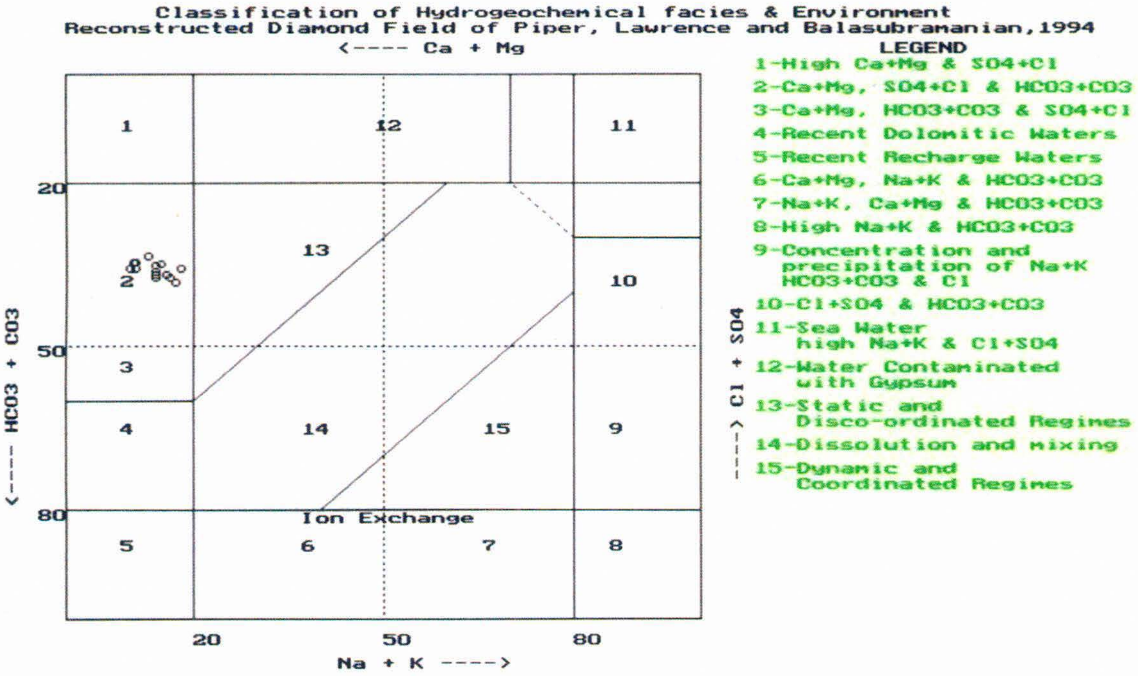
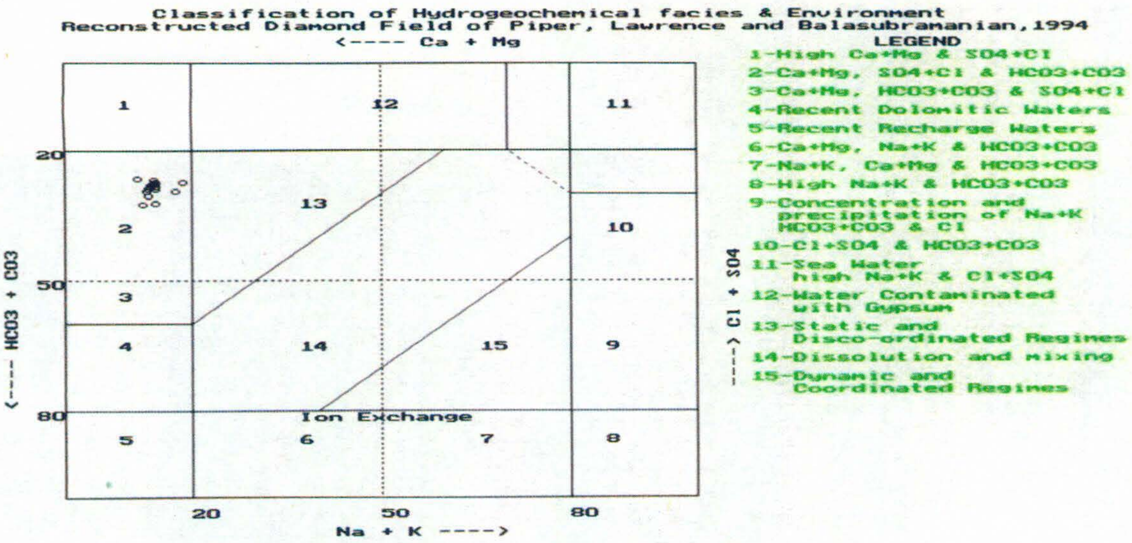


Fig: 30 Kusheshwar-Asthan



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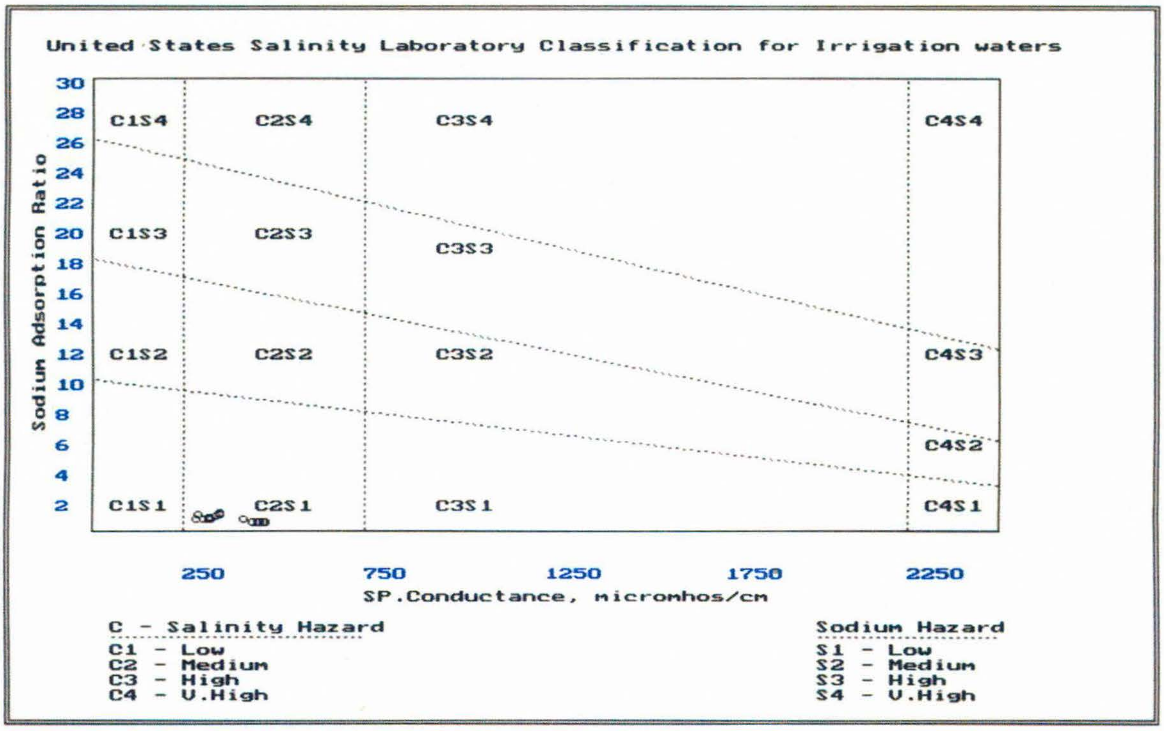
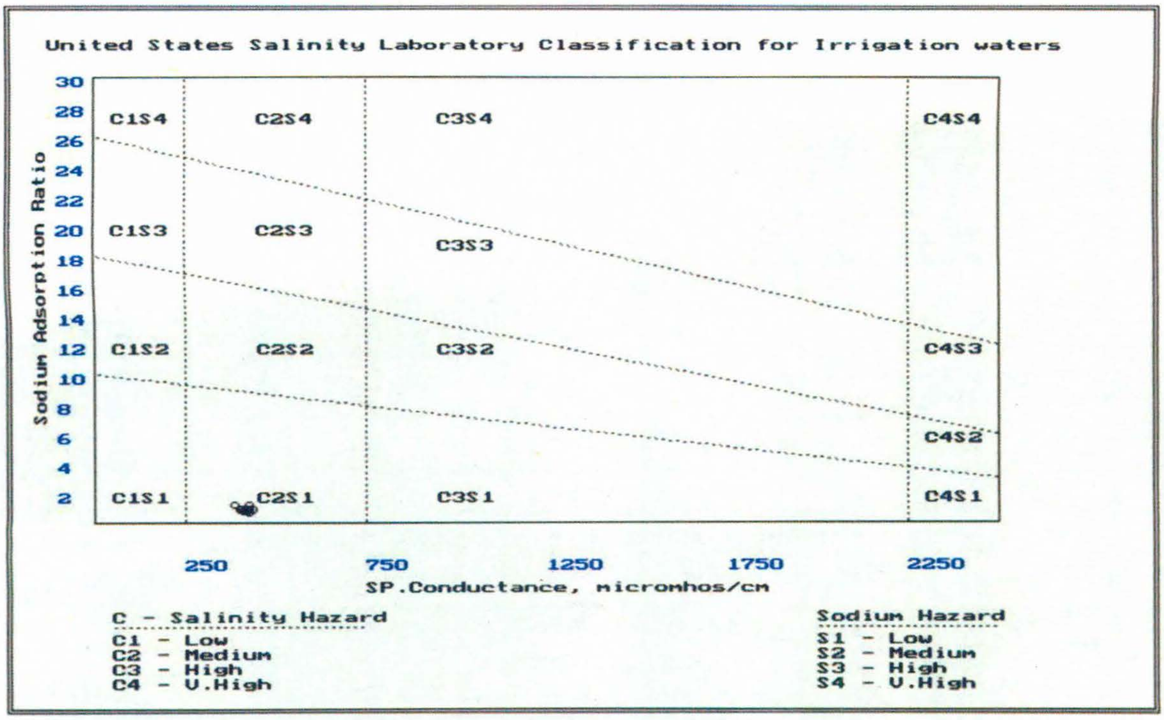


Fig:32 Kusheshwar-Asthan



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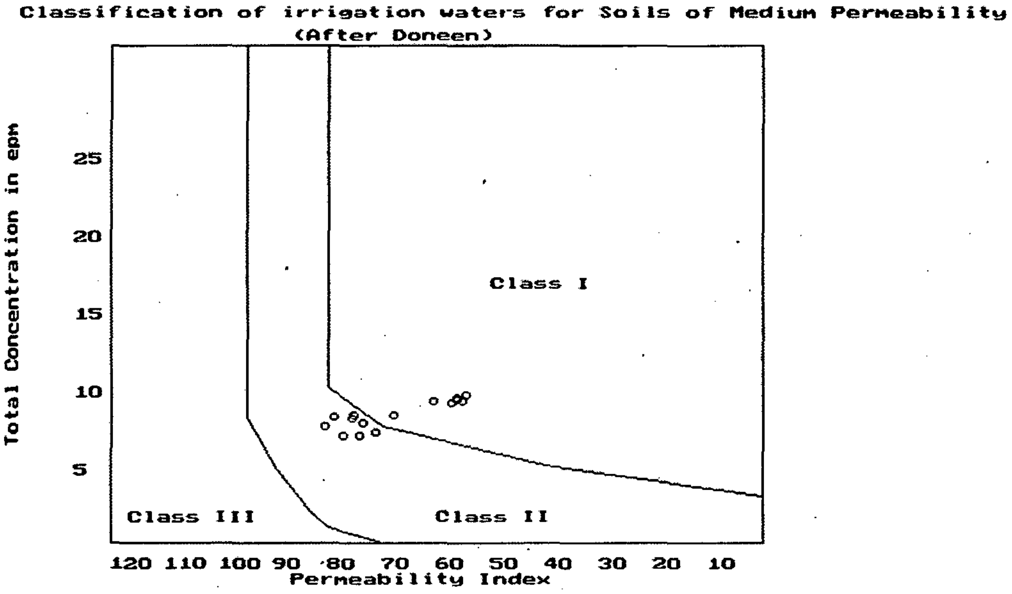

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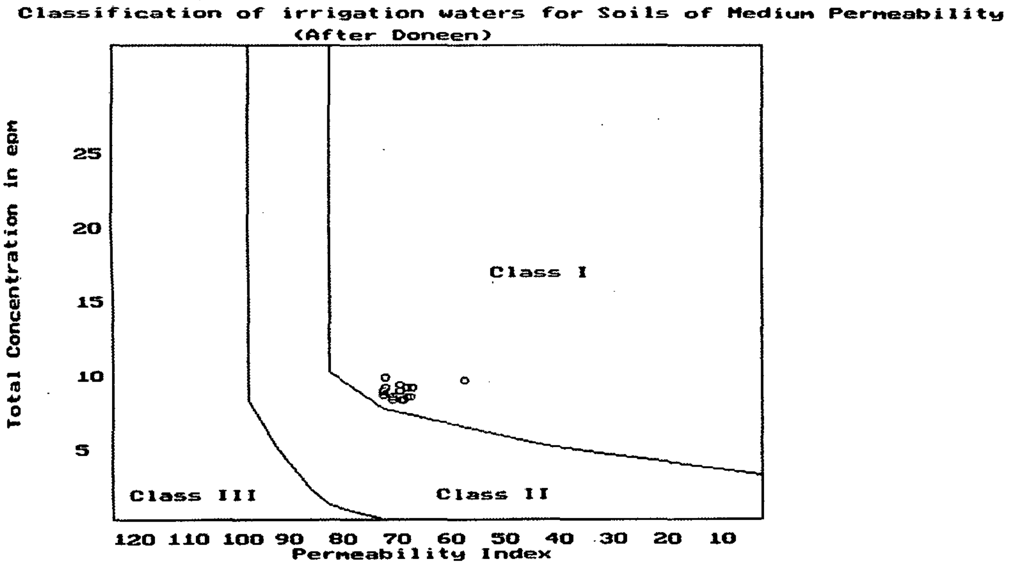
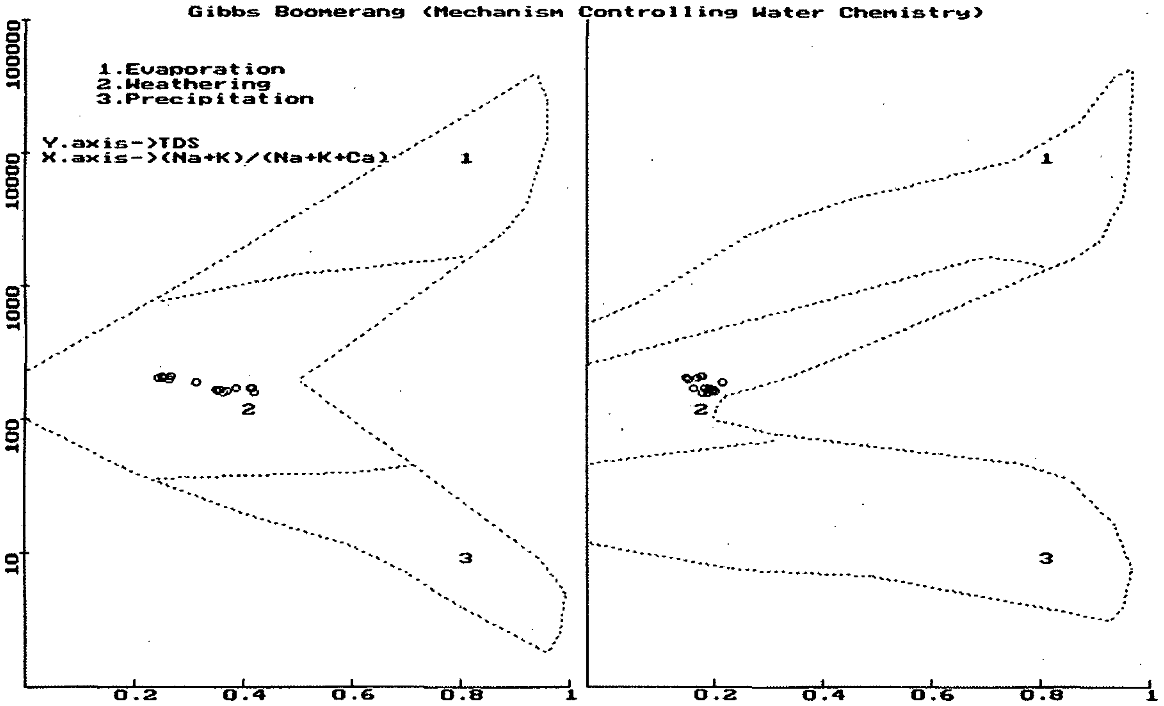


Fig:35 Kabar-Tal



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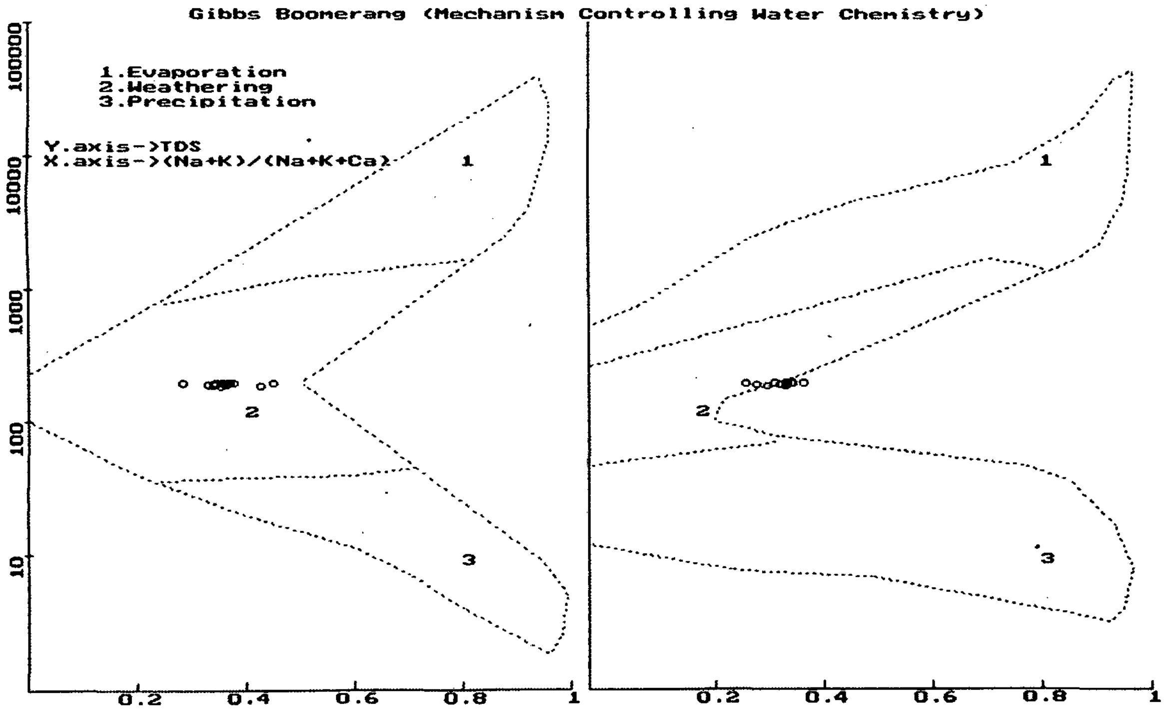


Fig. 37

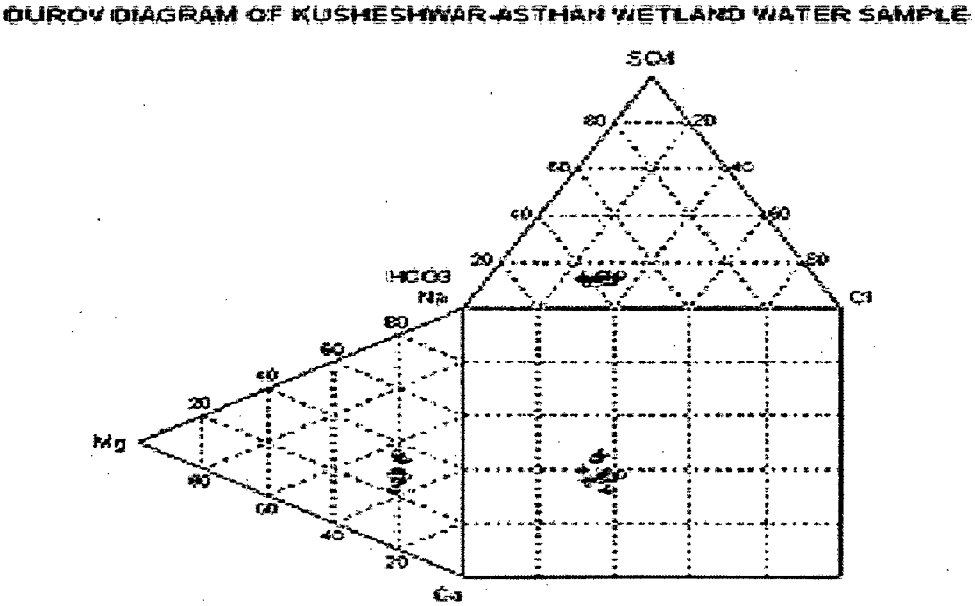

DUROV DIAGRAM OF KUSHESHWAR-ASTHAN WETLAND WATER SAMPLE

Fig. 38

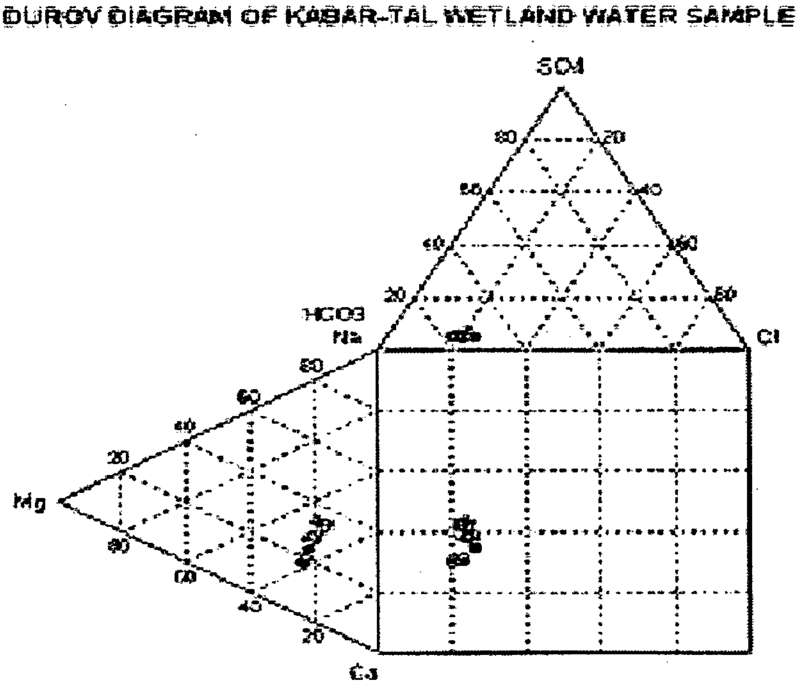

DUROV DIAGRAM OF KABAR-TAL WETLAND WATER SAMPLE

Fig. 39

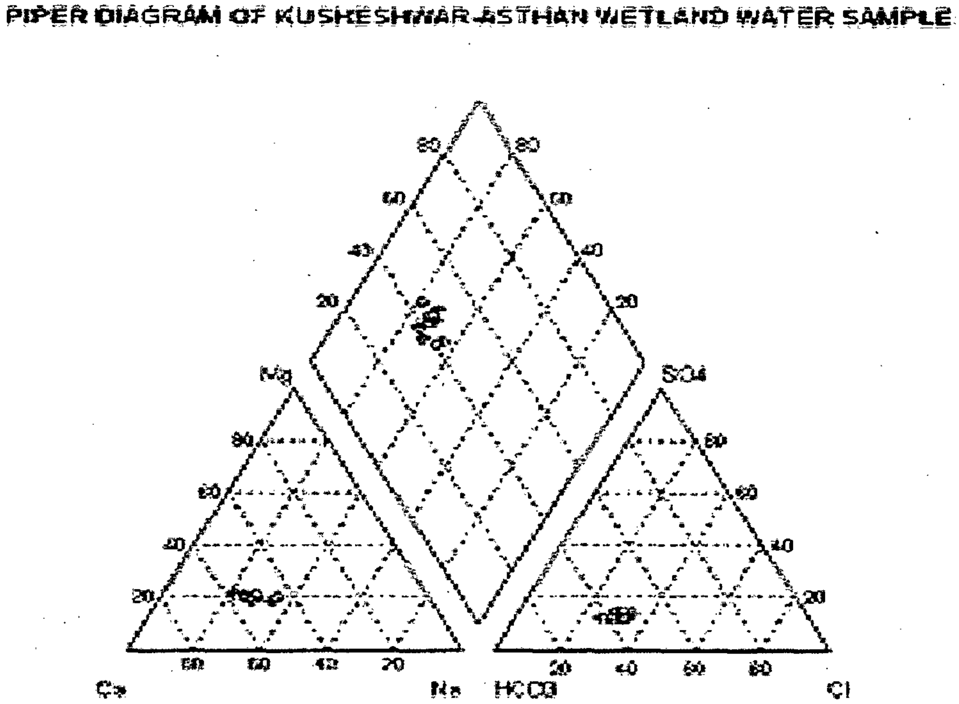

PIPER DIAGRAM OF KUSHESHWAR-ASTHAN WETLAND WATER SAMPLE
80
60
40
20
80
60
40
20
Mg
SO4
80
60
40
20
80
60
40
20
80
60
40
20
20
40
60
80
Ca
Na
HCO3
Cl

Fig. 40

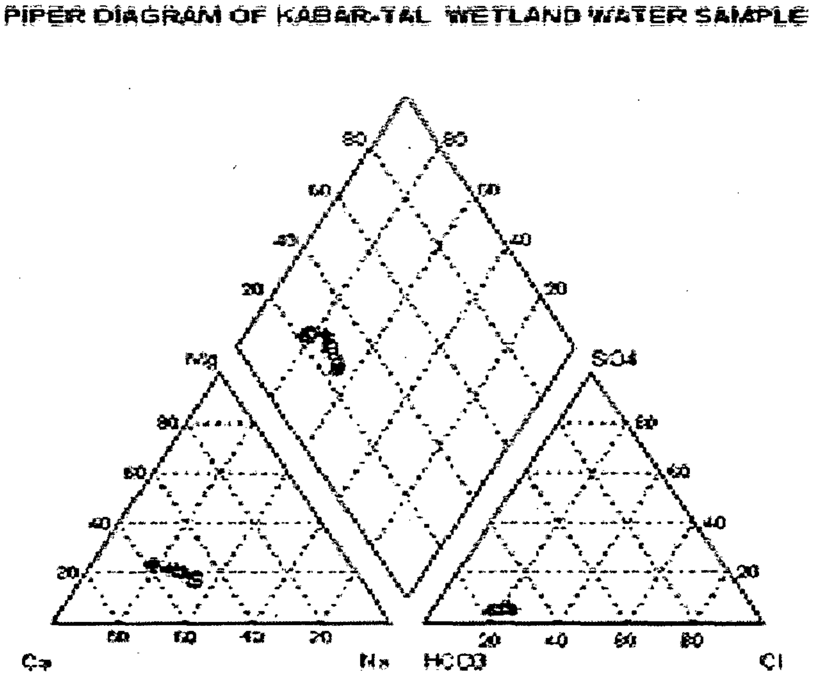

PIPER DIAGRAM OF KABAR-TAL WETLAND WATER SAMPLE
80
60
40
20
80
60
40
20
Mg
SO4
80
60
40
20
80
60
40
20
80
60
40
20
20
40
60
80
Ca
Na
HCO3
Cl

Fig. 41

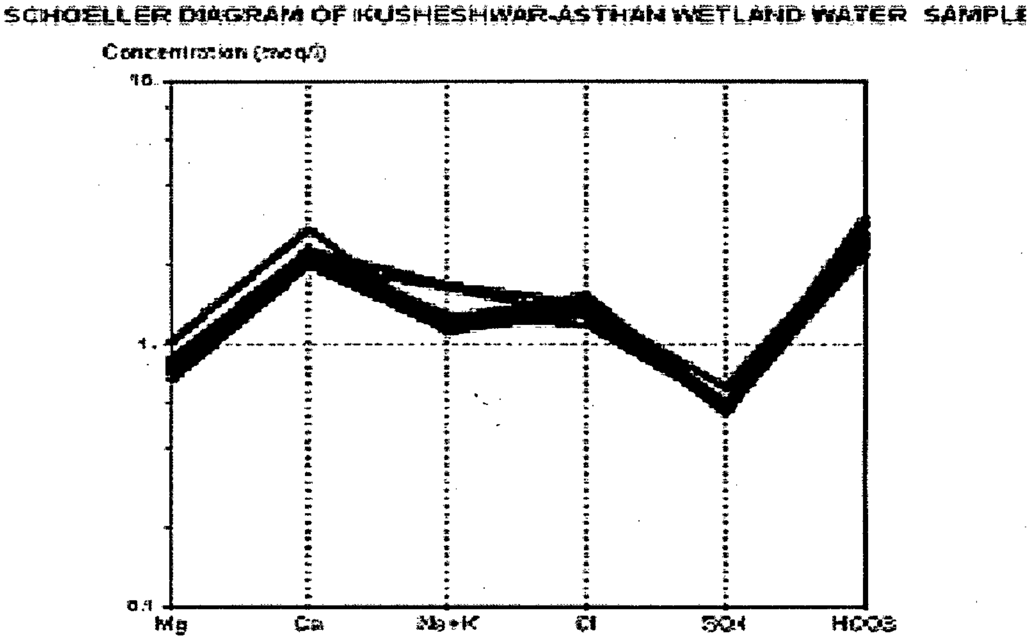

SCHOELLER DIAGRAM OF KUSHESHWAR-ASTHAN WETLAND WATER SAMPL
Concentration (meq/l)
10
1
0.1
Mg
Ca
Na+K
Cl
SO4
HCO3

Fig. 42

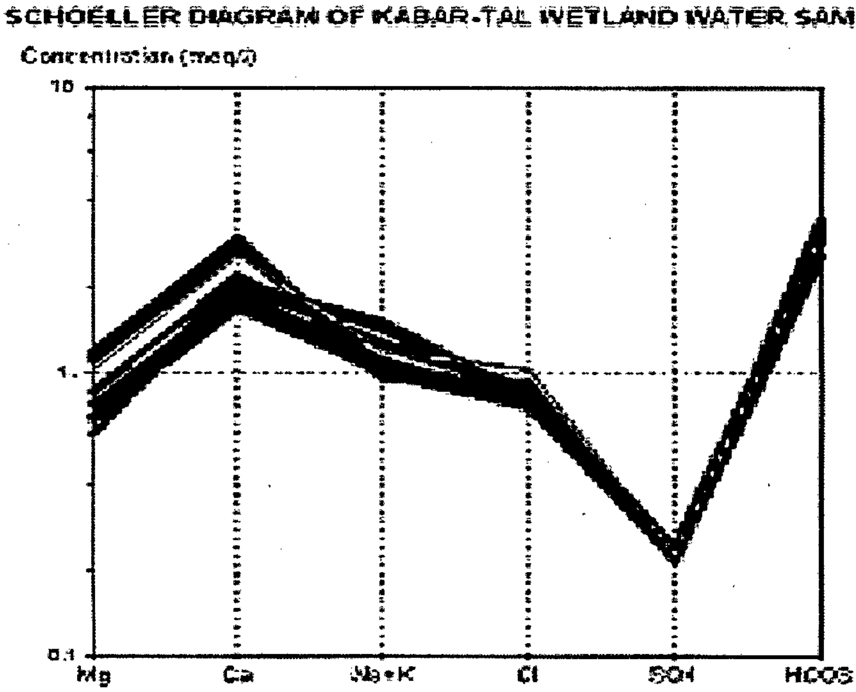

SCHOELLER DIAGRAM OF KABAR-TAL WETLAND WATER SAMPLE
Concentration (meq/l)
10
1
0.1
Mg
Ca
Na+K
Cl
SO4
HCO3

Fig. 43 XRD Analysis of Kabar-Tal Sediment, Sample Station No.2

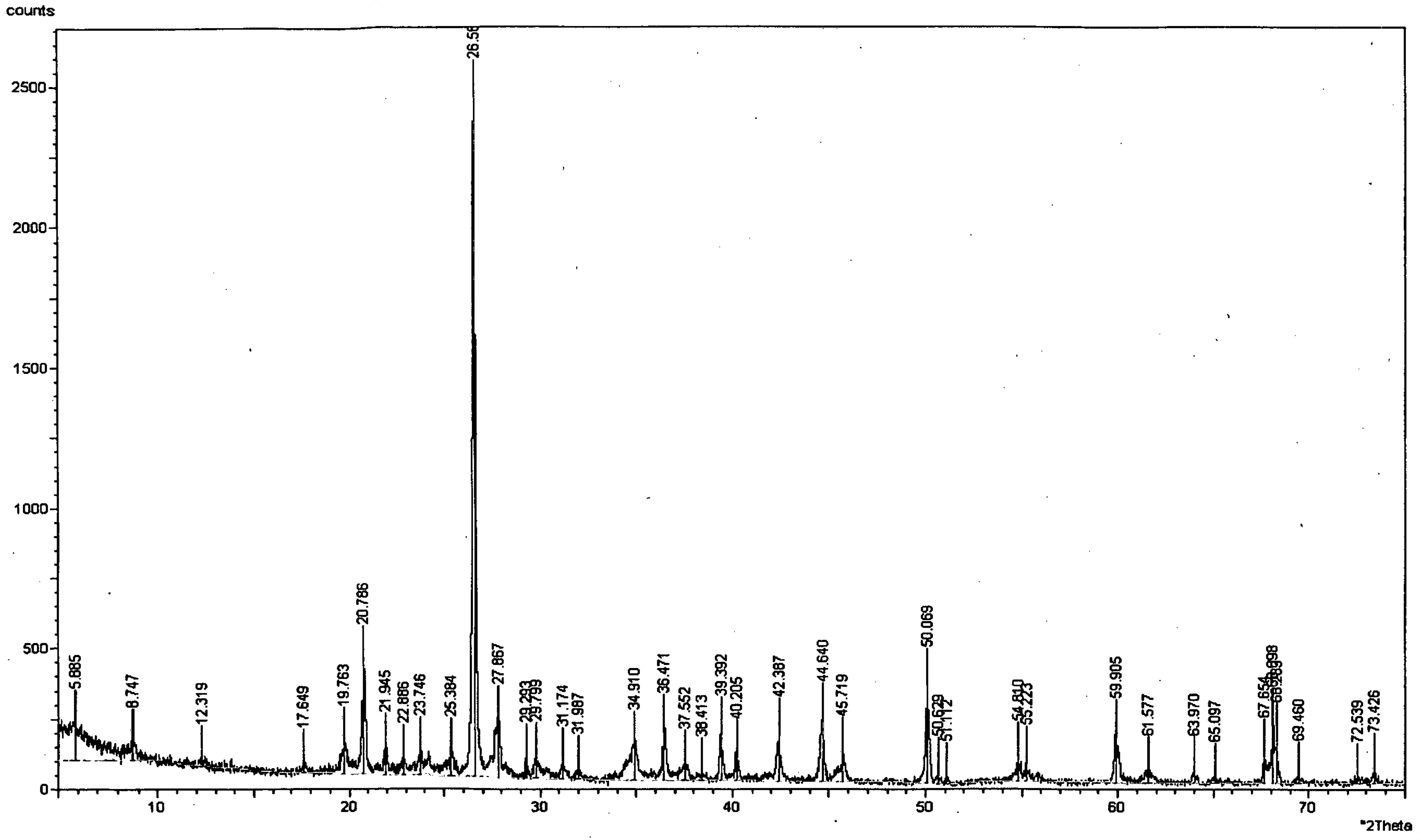


Fig. 44 XRD Analysis of Kusheshwar-Asthan Sediment, Sample Station No.2

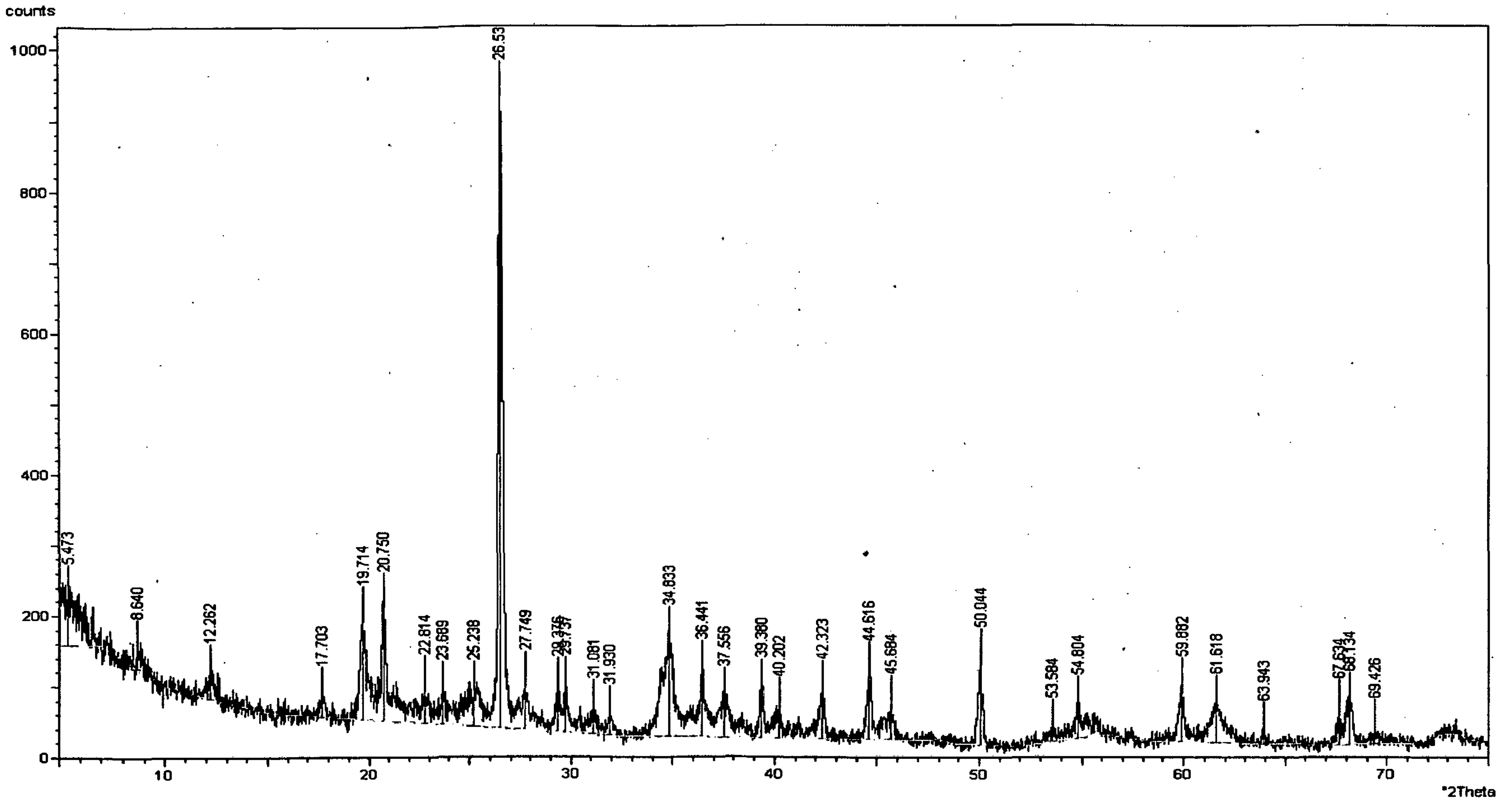
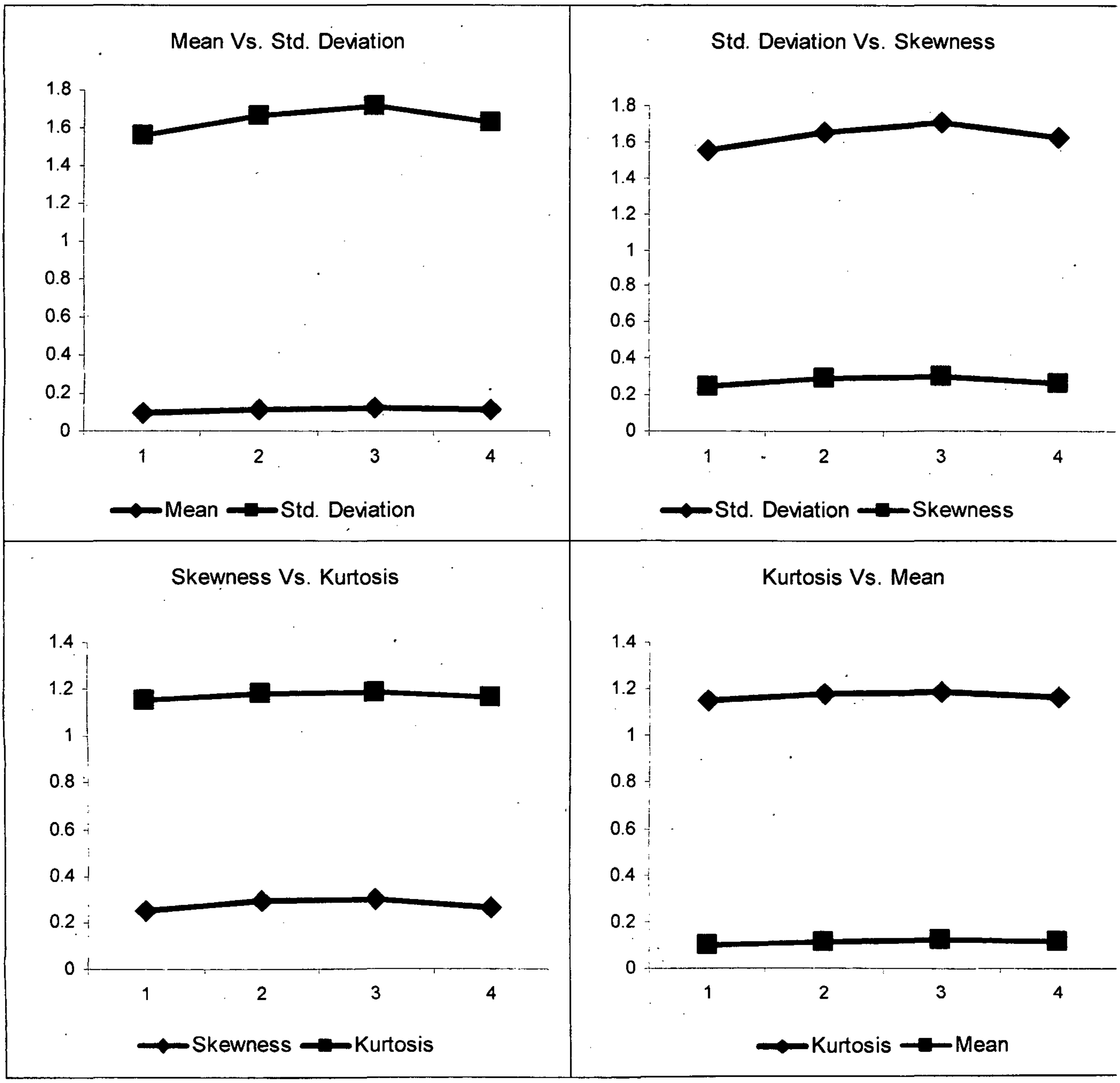


Fig. 45



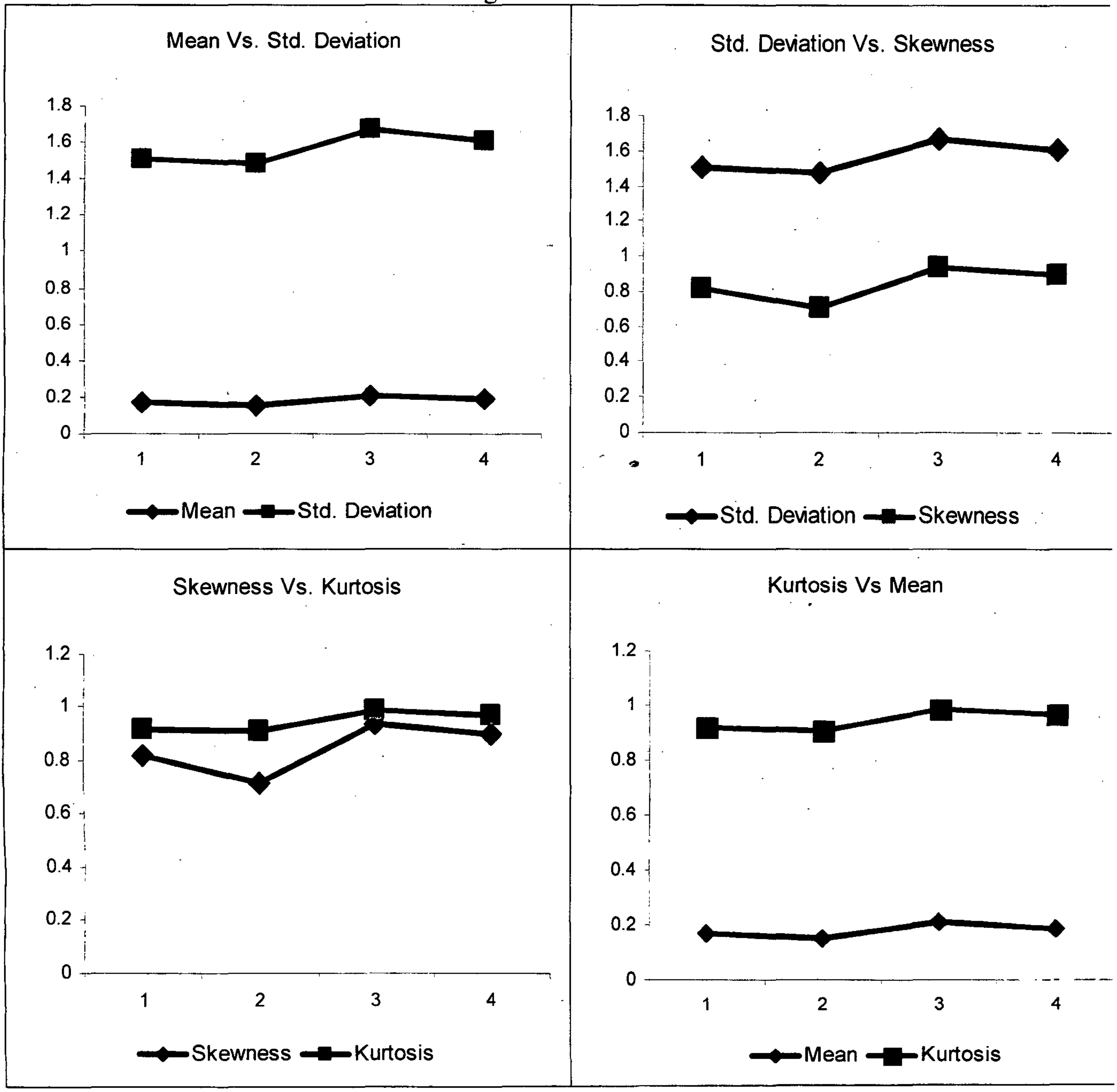
Mean Vs. Std. Deviation

Std. Deviation Vs. Skewness

Skewness Vs. Kurtosis

Kurtosis Vs. Mean

Fig. 46



Mean Vs. Std. Deviation

Std. Deviation Vs. Skewness

Skewness Vs. Kurtosis

Kurtosis Vs Mean

Fig. 47: Kabar-Tal (Sediment Carbon)

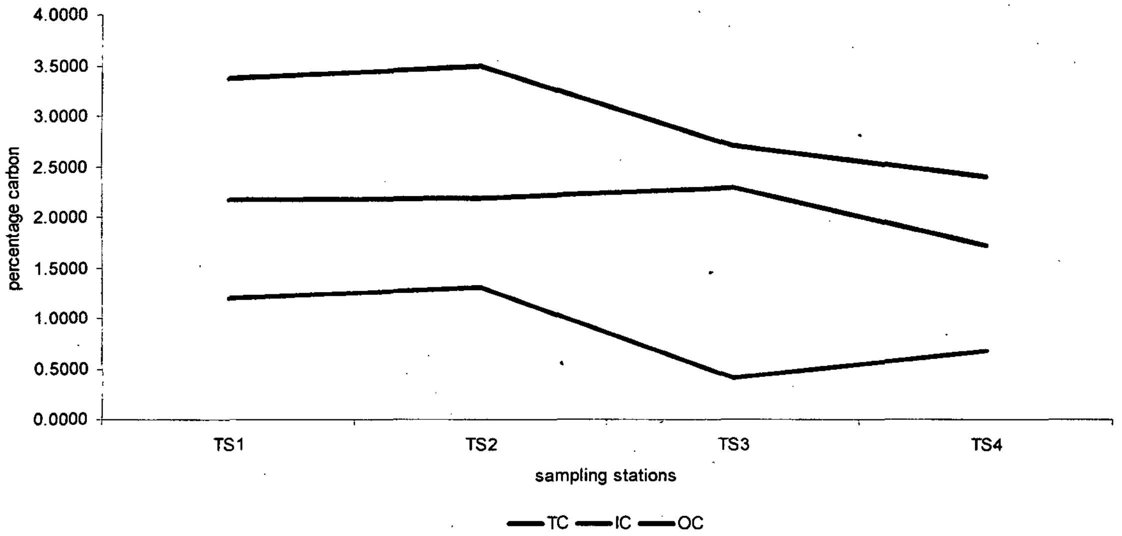


Fig.48 Kusheshwar-Asthan (Sediment Carbon)

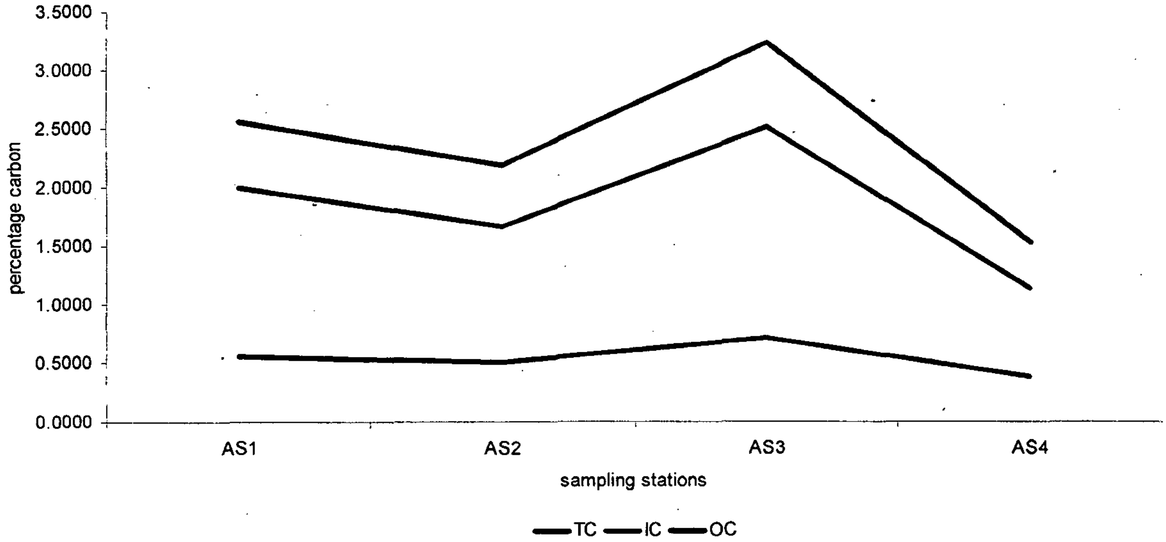


Fig. 49 Kabar-Tal (Sediment Sulfur)

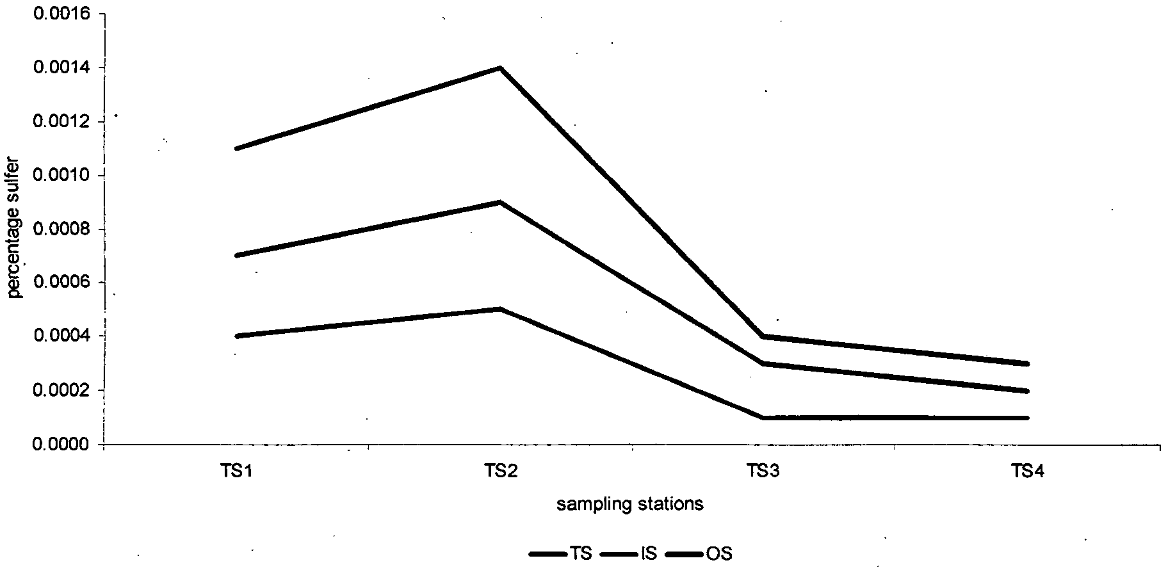


Fig.50 Kusheshwar-Asthan (Sediment Sulfur)

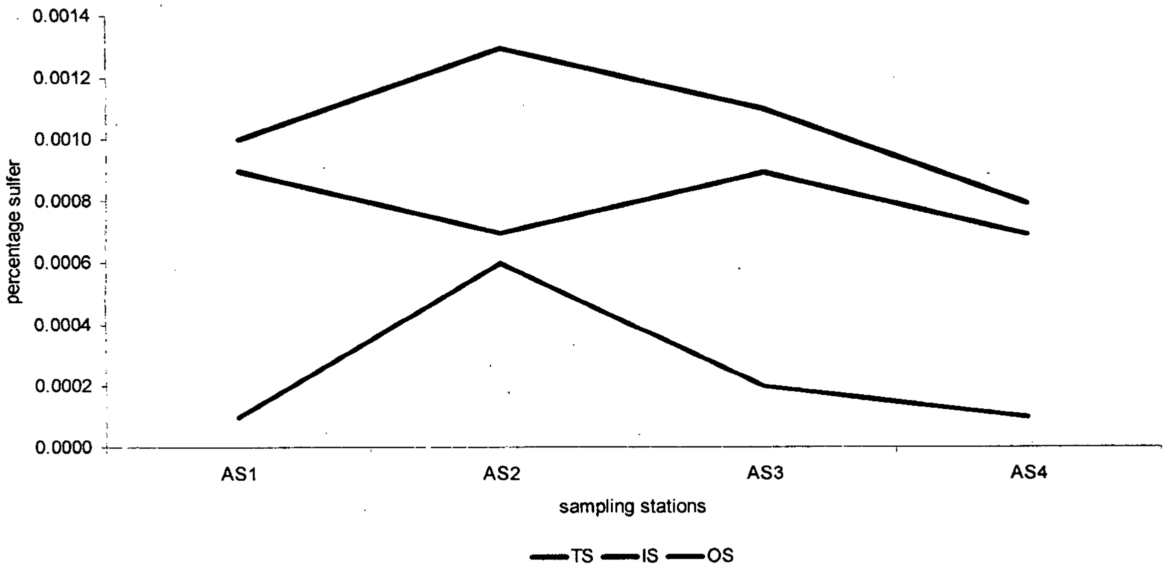


Fig.51 Kabar-Tal (Sediment Nitrogen &Phosphate)

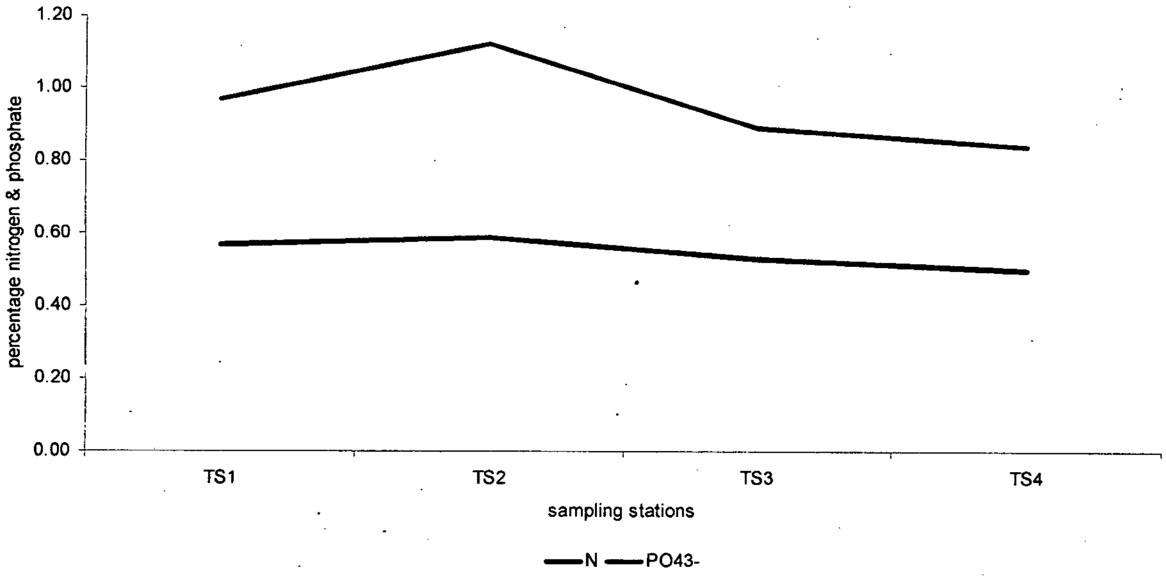


Fig.52 Kusheshwar-Asthan (Sediment Nitrogen &Phosphate)

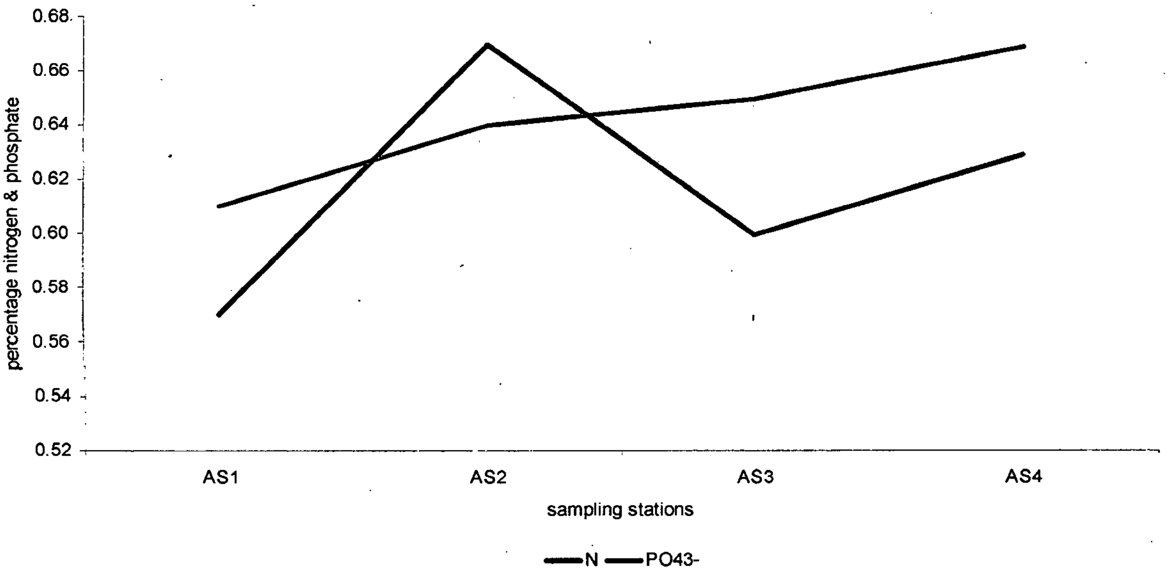


Fig.53 Kabar-Tal (Sediment Si and Al)

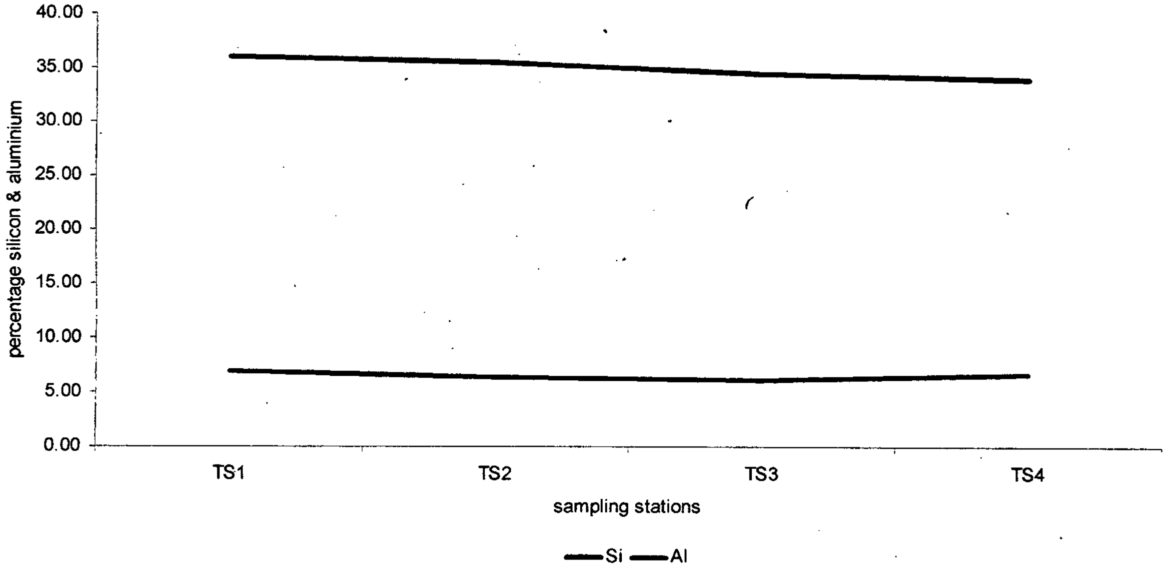


Fig.54 Kusheshwar-Asthan (Sediment Si and Al)

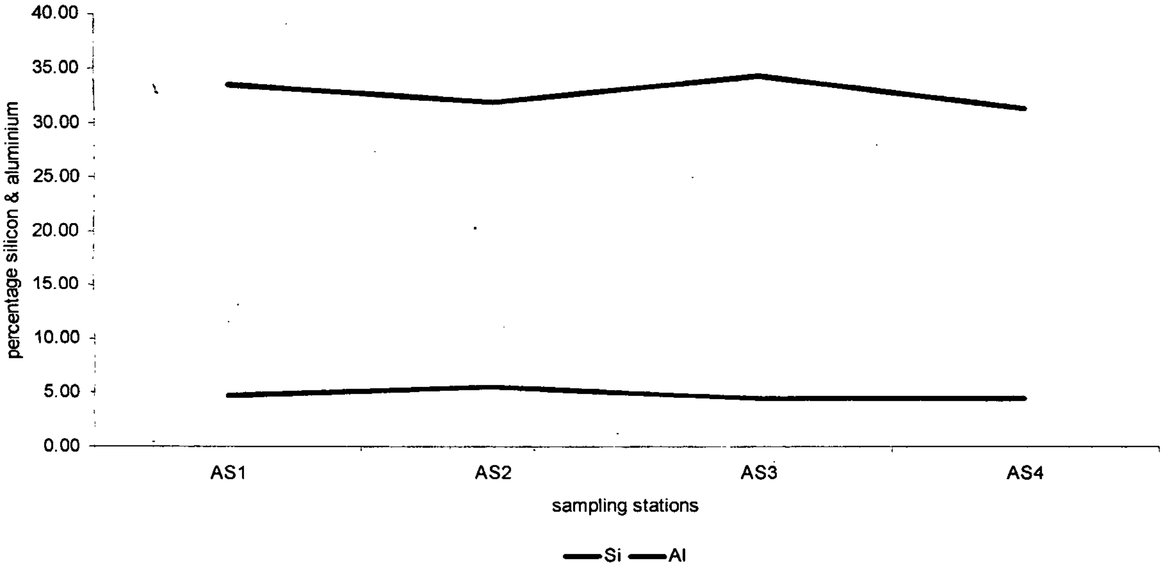


Fig.55 Kabar-Tal (Sediment Total Carbon, Nitrogen and C/N Ratio)

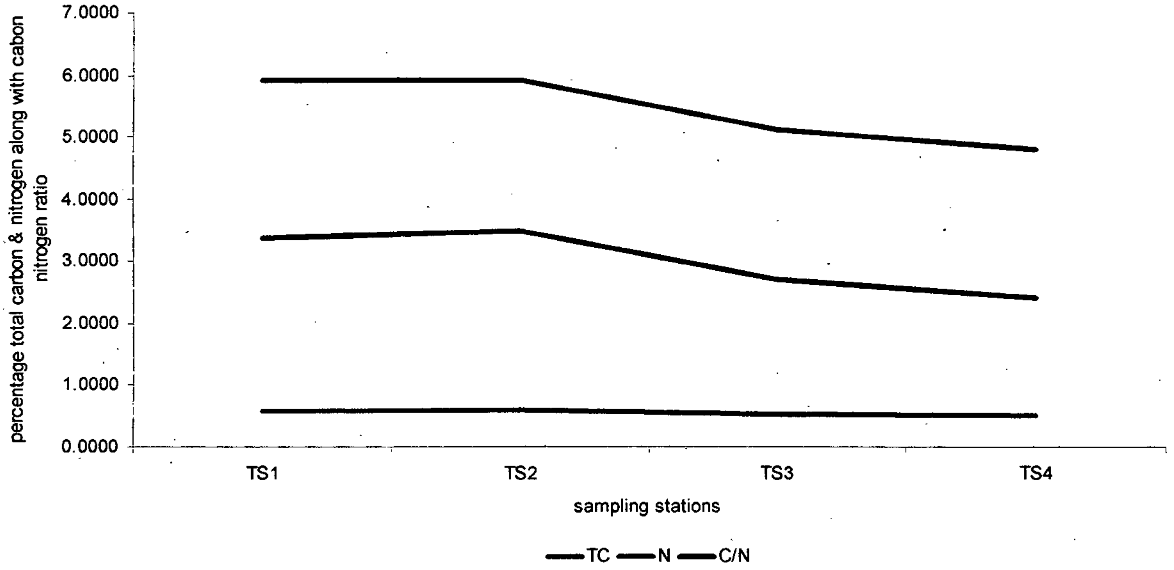
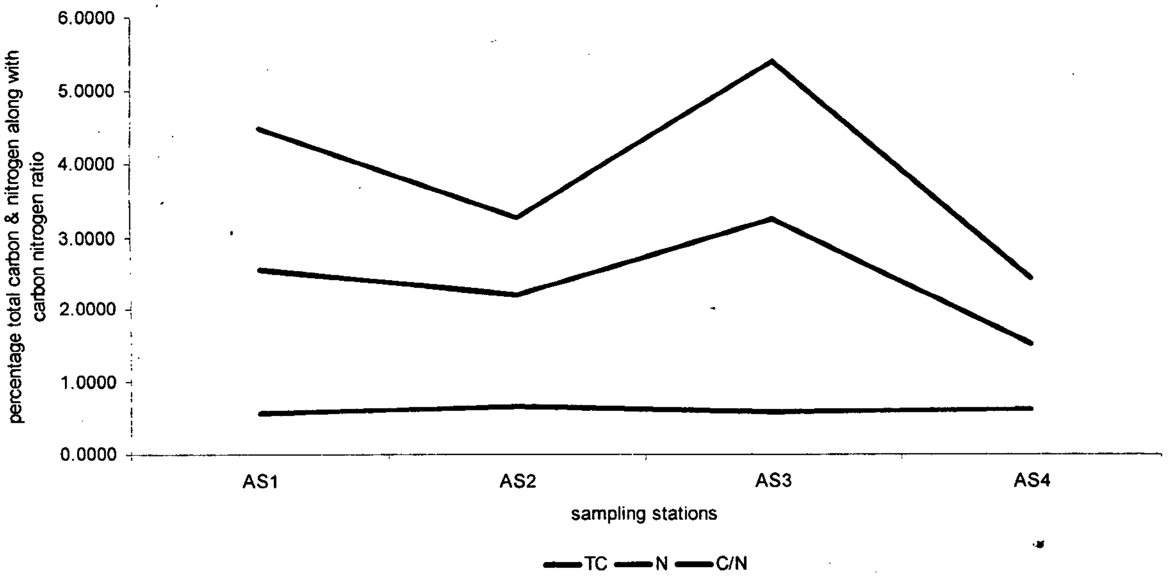


Fig.56 Kusheshwar-Asthan (Sediment Total Carbon, Nitrogen and C/N Ratio)



CHAPTER 7

REFERENCES

7. References

Allan, F.J. (1979). Heavy metals in bottom sediments of Greaz Slave Lake (Canada): A reconnaissance Environ Geol. 3: 305-363.

Anderson, J.M. and Ingram J.S.I. (1993). Tropical soil and fertility: A handbook of methods 2nd Edition.

Andrews, D. and Fritchko, J. (1987). Availability of Zinc to benthic dwelling organisms from sediments fractions (abstr) OME Technology transger. Toronto. Nov 30-Dec 1. 32pp

Annual Report 2002-03, Salim Ali Centre for Ornithology and Natural History; page 5

APHA, AWWA and WPCF, (1995). Standard methods for the examination of water and waste water 19th edition; APHA, Washington D.C.

Asthana, B. (1976). Limnological studies of Chilka Lake, Orissa Project Report, and No.112 of Indian Programme on man and Biosphere. Department of Science and Technology, Government of India.

Barner R.A. and Rao J., (1994). Phosphorus in the sediment of Amezon River and Estuary: Implication for the global flux of phosphorus in the sea. Geochimica Acta. 58(10). 2333-2339.

Beadle, L.C., (1974). The inland waters of Africa: An introduction to Tropical Limnology. Longmans. London. 365 pp.

Biksham, G., Subramanian, V. and Griken, R. V., (1991). Heavy metal distribution the Godavari River Basin. Environ. Geol. Wat. Sci. 17: 117-126.

Biodiversity Profile of India. http://ces.iisc.ernet.in/hpg/cesmg/indiabio.html#Wetlands

Birch, L., Hanselmann K.W. and Bachofen. R., (1996). Heavy metal conservation in Lake Cadagno sediments: Historical records of anthropogenic emissions in a meromictic alpine lake. Water Res. 30: 679-787.

Borovec, Z., (1996). Evolution of the concentration of trace elements in steam sediments by factor and cluster analysis and the sequential extraction procedure. Sci of the Tot Environ. 177: 237-250.

Boyd R., Niskavaara H., Kontas E., Chekushin, V., Pavlo E., Often M., and Reimann C., (1997). Anthropogenic noble metal enrichment of soil in Monchegorsk area, Kola Peninsular north-west Russia. J. of Geochemical Exploration. 58: 283-289.

Carpenter S. R., Bolgerien D., Lathrop R. C., Stowe C. A., Reed T., Wilson M.A., (1997). Ecological and Economic analysis of Lake Eutrophication by non-point pollution, Australia.Tournal of Ecology. 23: 68-79.

Carpenter S. R., Caraco N. F., Correl D. L., Howarth R. W., Sharpley A.N, Smith V.H., (1998). Non-point pollution of surface water with Phosphorus and nitrogen. Ecology Applications. 8: 559-568.

Chakrapani G.J. and Subramanian V., (1990). Preliminary studies of the geochemistry of the Mahanadi river basin. India. Chem Geol. 81: 241-253.

Chakrapani G.J. and Subramanian. V., (1996). Fractionation of heavy metals and phosphorus in suspended sediments of the Yamuna River, India. Environ Monit and Assess. 43: 117-124.

Chakrapani G.J., (2002). Water and sediment geochemistry of major Kamayun Himalayan lakes. India. Environ Geol. 43: 99-107.

Choudri B.S. and Chavadi V.C., (2000). Anthropogenic deposition of trace elements in the sediments of Navalur ponds near Dharuad City, Karnataka, India. Eco Env Cons. 6(3): 351-353.

Clive S., Kaushik N., and Trivedi R. K., (2000). Eutrophication: an introduction, In Detergents and the Environment the Canadian Experience and the Indian Scenario. Tata Mac Graw. 419 pp.

Committee on Earth Observation Satellites.http://www.eohandbook.com /eohb05 /ceos / part2_5.html

Connor J.N.and Martin M R., (1989). An Assessment of phosphorus inactivation, Kezer Lake, New Hampshire. Water Res. Bull. 24(4): 845-853.

Conservation of Wetlands in India. Published by Ministry Of Environment & Forest; (1989).

Copper C. M., (1993). Biological effects of agriculturally derived surface water pollutants on aquatic systems. A review. J. Environ Qual. 23: 403.

Croot P.L. and Hunter K.A., (2000). Labile forms of iron in coastal sea water. Otago Harbour, Newzealand. Mar Fresh Water Resources 51:193-203.

Darling W G., Allen D.J. and Armanson H., (1990). Indirect detection of surface out flow from rift valley Lake. Journal of Hydrology 113: 297-305.

Das B.K. and Singh M., (1996). Water chemistry and control of weathering of Pichola Lake, Udaisagear, Rajasthan, India Environ Geol. 27: 184-190.

Das B.K., (1999). Environmental pollution of Udaisagear Lake and impact of phosphate mine. Udaisagear, Rajasthan, India. Environ Geol. 38(3): 244-248.

Datta D. K. and Subramanian V., (1998). Distribution and fractionation of heavy metals in the surface sediments of Ganges Bramaputra-Meghna River system in the Bengal Basin. Environ Geol. 36: 93-101.

Dewey J.F. and Bird J.M., (1970). Mountain belts and the new global tectonics. Jour. Of Geophys. Res., 75: 2625-2647.

Elampooranan. T., Rajmohan N. and Abrani L., (1999). Hydrochemical studies of artesian Well Waters in Cauvery Deltanic Area, South India. Indian J Envron Hlth. Vol.4. No.2: 107-114.

Elder J.F., (1988). Metal Biogeochemistry in surface water system: A review, Principles and concepts. Denver, Colorado: US Geological Survey, circular 1013. 43 pp.

Elder J.F., (1994). Distribution and grain size partitioning in bottom sediments of an experimentally acidified Winkonsin Lake. Water Res. Bull. 30: 251-259.

Farrah D. and Pickering W. F., (1993). Factors influencing the potential mobility and bio. Availability of metals in dried lake sediments. Chemical Speciation Bioavil. 5: 81-96.

Fernex F., Valle P.Z., Sanchez. R. H., Michaud F., Parron C., Dalmasso J., Genevieve B. F. and Mannuel G. A., (2001). Sedimentation rate in Lake Chapala (wetern Mexico): Possible active tectonic control. Chem Geol. 177: 213-228.

Forstner U. and Muller G., (1974). Schwerme in flussen and see. Berlin: Springer. 255pp.

Forstner U., Wittmann G.T. W., (1981). Metal pollution in the aquatic Environment. 2nd edn. Springer, Berlin. Heidelberg, New York. Springer-Verlag. 481 pp.

Foster I. D. L., (1995). Lake and reservoir bottom sediments as a source of soil erosion and sediment transport data in the UK. , in: Foster IDL. Gurnell AM. Webb BW, editors, sediment and water quality in river catchments Chichester, Willey. Pp 265-283.

Foster I.D.L. and Walling D.E., (1994). Using Reservoir deposits to reconstruct changing sediment yields and sources in catchment of the old Mill Reservoir, South Devon, UK Over past fifty years. Hydrological Sci. J. 39: 347-368.

Foster I.D.L., Lees J.A., Owens P.N. and Walling D.E., (1998). Mineral magnetic characterization of sediments sources from analysis of lake and flood plain sediment in catchment of the old Mill Reservoir and Slapton Lay, South Devon, UK Over past fifty years. Earth Surf Processes Landforms. 23: 685-703.

Gaciri S. J. and Davies T. C., (1993). The occurrence of geochemistry of fluoride some natural waters of Kenya. Journal of Hydrology. 143: 395-412.

Garrel R. M. and Christ C. L.,(1965). Solution Minerals and Equilibrium. Harper and Row, New York. Pp. 450.

Garrel R. M. and Mackenzie F, T., 1967). Origin of the Chemical Composition of some Springs and L:askes. In: (Stumm W., ed) Equilibrium Concepts n Natural Wetlands. Wiley, p 222- 242. Am,erican Chemical Socity, Waghington, D.C.

Gaudet J.J. and Melack J.M., (1981). Major ion chemistry in a tropical African Basin. Fresh Water Biol. 11: 309-333.

Geochemistry and assessment of metal pollution in soil and river components of a monsoon dominated environment near karwar, Southwest coast of India. Envron. Geol. 40: 1462-1470.

Ghosh A.K, Bose N., Singh K.R.P. and Sinha. R.K., (2004). Study of spatio-temporal changes in the weltands of North Bihar through Remote Sensing, July 2004, ISCO-2004, International soil conservation organisation conference Brisbane.

Ghosh A.K., Bose N.K., Singh R.P. and Sinha R.K., (2004). Study of spatio-temporal changes in the wetlands of North Bihar through Remote Sensing, ISCO-2004, International soil conservation organisation conference Brisbane.

Gibbs R.J., (1977). Transport Phase of transition metals in the Amezon and Yukon Rivers. Geol. Sci. Am.Bull.88: 829-943.

Gibbes R. J., (1970). Mechanism Controlling World Water Chemistry. Sciences. 170: 1088-1090.

Goel P.K., Trivedy R.K. and Bhave S.V., (1985). Studies on limnology of a few freshwater bodies in south-western Maharashtra. Indian J. Env Prot. 5(1): 19-25.

Goldman J.C., (1972). The effects of inorganic carbon on Eutrophication. Presented at a seminar on eutrophication and bio stimulation. California Department of Water Resources Proceeding. 3-53.

Golterman H. L., (1995). Wetlands as nutrient buffers between continental and marine.

Goncalves E.P.R., Boaventura R.A.R. and Van Grieken R., (1992). Sediment and aquatic mosses as pollution indicators for heavy metals in the Ave River (Portugal). Sci. Of The Total Env. 114: 7-24.

Goncalves E.P.R., Soares H.M., Boaventura R.A., Michado A.A. and Silva *J.C.*, (1994). Seasonal Variation of heavy metals in sediments and aquatic masses from the Ave River (Portugal). Sci. of the Tot. Env. 142: 143-156.

Gopal B., Hillbri-likowska A., and Wetzel R. G., Waters Some reflections and experiments of research in the Carmague (South France). In Wetland and Ecotones; Studies of land water interactions. National Institute of Ecology New Delhi. 33-49 pp.

Government of India (1985). Research and Reference Division Ministry of Information and Broadcasting

Groombridge B. (ed). (1993). The 1994, IUCN Red List of Threatened Animals. IUCN, Gland, Switzerland and Cambridge, UK. lvi + 286 pp.

Gupta L.P. and Subramanian V., (1994). Environmental geochemistry of the River Gomti a tributary of the Ganga River. Environ Geol. 24: 235-243.

Gupta L.P. and Subramanian V., (1998). Geochemical factors controlling nature of water and sediments in Gomti River, India. Environ Geol. 36(1-2): 102-108.

Gupta P.K. and Pant M. C., (1989). Sediment chemistry of Bhmtal, U.P., India. Int RevHydrobiol. 74: 679-687.

Gupta S.C., Rathore G. S. and Matchthura G.C.D., (2001). Hudrochemistry of Udaipur Lake.

Haque M.A. and Subramanian V., (1982). Cu, Pb and Zn pollution of soil environment

C.R.C. Critic Rev Environ Control. 100: 13-90.

Horowitz A. J., (1991). A primer on sediment trace element chemistry. 2ne ed. Chelsea Michigan. Lewis Publisher. 136pp.

Howarth I. R. W., Billen G., Swaney D., Townsend A., Jowarski N., Lajtha K., Downing J.A., Elmigrean R., Carnaco N., Jordan T., Berndse F., Frenny J., Kudeyovov V., Murdoch P. and Zhao Liang Z., (1996). Regional nitrogen budgets and riverine N and P fluxes for the drainage to the North Atlantic Ocean, natural and human influences. Biogeochemistry 35: 75-139.

Huang W., Campredon R., Abrao J. J., Bernat M. and Latouche C., (1994). Variations of heavy metals in recent sediments form Piratininga Lagoon (Brazil).

Hussain M. A., (1992). Ecology of wetland of Kusheshwar-Asthan PhD thesis L.N. Mithila University, Darbhanga.

Huy N. Q., luyen T.V., Phe T.M. and Mai N.V. (2003). Toxic elements and heavy metals in Than Luong canal, Ho Chi Minh City, Vietnam. Environ Geol.43: 836-841.

I.B.W.L. (1972). Project Tiger. A planning proposal for preservation of tiger (*Panthera tigris tigris Linn.*) in India. Indian Board for Wildlife, Government of India, New Delhi. 114 pp.

I.C.B.P. (1992). Putting biodiversity on the map: priority areas for global conservation. International Council for Bird Preservation, Cambridge, UK. 90 pp.

I.U.C.N. (1986). Review of the Protected Areas System in the Indo-Malayan Realm. IUCN, Gland, Switzerland and Cambridge, U.K. 461 pp.

Indian Metrological Department (I.M.D.)

Indian Water Resource Socity (I.W.R.S.), (1999). Theme Paper on Water: Vision 2050.

Ingram R.L, (1970). Sieve analysis. In Procedures, in the Sedimentology peterology, (Eds.), R.E. Carver, Wiley Interscience, New-York. pp 49-67.

Jenne E., Kennedy V., Burchard J. and Ball R., (1980). Sediment collection and processing for selective extraction and for total metal analysis. In Backer, R. (Eds) Contaminants and sediments vol. 2. Ann Arbor Science Publishers. Ann Arbor, MI. pp 169-189.

Jenne E. A. and Luoma S., (1977). Forms of Trace elements in soil, sediments and associated

Wastes: an overflow of their determination and biological availability. In Biological Implication of Meteals in the environment (RE Wikiling and H. Druken eds.). NTIS, Springfield, Va. pp 110-143.

Jenne F. A., (1968). Controls of Mn, Fe, Co, Ni, Cu and Zn concentrations in soils and Waters: the significance of hydrous Mn and Fe Oxides. Am. Chem. Soc. Adv. Chem. Ser. 73: 337-387.

Jha B.N. (1979) Problems of land utilization –a case study of Kosi region Classical publication, New Delhi. 201 pp

Jha P.K., Subramanian V., Sitasawad R. and Van Grieken R., (1990). Heavy metals in sediments of Yamuna River (a tributary of the Ganges), India. Sci of the Total Environ . 95: 7-27.

Jones B. and Turki A., (1997). Distribution and speciation of heavy metals in surficial sediments of Ganges Estuary. [Ph.D. Thesis]. Jawaharlal Nehru University150 pp.

Karantu K. R. (1989): Groundwater assessment and management. Tata McGraw Hill Publ., New Delhi. 720pp.

Kaul V., Trisal T.L and Handoo T .K., (1978). Distribution and production of macrophytes in some water bodies of Kashmir. In: Glimpses of Ecology (Ed. J.S.Singh & B.Gopal), International Scientific publication, Jaipur, India. 314-334 .

Kaushik S. and Saksena D. N., (1999). Physico-chemical Limnology of certain water bodies of Central India. In Vijayakumar K., (Ed) Fresh water ecosystems of India. Daya Publishing House. I-58 pp.

Khatavkar D., Kulkarni A. Y. and Goel P. K., (1989). Limnological studies on two lentic fresh water bodies at Kolhapur with special reference to pollution. India. J. Environmental protection. Vol. 9, No.3: 198-203.

King D.L, (1970). The role of carbon in eutrophication. J. Water Poll. Cont. Fed. 42: 2035-2051.

Krumbein W. C. and Pettijohn F. J., (1938). Manual of Sedimentology Petrography, Appleton-century crofts, N. Zone.

Kumar S., (2004). Kawar lake wetlands, strategies for conservation.

Lacerda L.D., Fernandez M.A., Calazans C.F. and Tanizanki K.F., (1992). Bio-availability of heavy metals in sediments of two Coastal lagoons in Reo De Jenario, Brazil. Hydrobiologia. 228: 65-75.

Lindholm R. C., (1987). A Practical Approach to Sedimentology.

Lumona S.N. and Jenne E.A. (1977). The availability of sediments bound cobolt, sliver and Zinc to a deposit feeding clam in Biological implication of metals in the Environment (Ed. H. Drucker and R.E. Wildung). E.R.D.A. Symp. Ser. No. 42: 213-230.

Luoma S.N., (1986). A comparison of two methods for determining copper partitioning in oxidized sediments. Mar. Chem. 20: 45-59 [Malavika and Gopal B., (2001)]

Mahadevan T.M., (2002). Geology of Bihar and Jharkhand.

Mahar W.A., (1984). Evaluation of a sequential extraction scheme to study association of a trace elements in estuarian and oceanic sediment. Bull. Env. Contm. Toxicol. 32: 339-344.

Melack J.M., (1979). Temporal variability of phytoplankton in Tropical Lakes. Occologia. 44: 1-7.

Ministry Of Water Resources, Govt. of India.http://wrmin.nic.in/welcome.html.

Mitchel R.L., (1964). In Chemistry of soil (Ed. Bear FE), New York. Reindhold. pp 320-368.

Mitsch W. J. and Gosseling J.G., (1993). Wetlands. Van Nostrand Reinhold, New York.

Munshi J.S.D. and Munshi J.D., (1991). Physiography of Kosi river basin and formation of wetland in north Bihar: A unique fresh water system. J. Freshwater Bio. 3(2): 105-122.

Nagaraju M., Gossmann H. and Lacaze B., (1994). Trace elements geochemistry in the waters of Pulicat Lake, South India. Geo. journal. 34(4): 393-396.

Nagaraju M., Prasad K.S.S. and Narasimhsrso K.L., (1990). Geochemistry of lake waters of Pulicat. India. Geo. Journal. 20(3): 311-318.

Nakanishi M., Tezuke Y., Narita T., Matamura O., Kawabata K. and Nakano S., (1992). Phytoplankton primary production and its fate in a pelagic area of Lake Biwa. Arch Hydrobiol. Beih, Ergebin. Limnol. 35: 535-549.

Navalawala B.N., (1995). Handbook of urban statistics. pp. 91 Water scenario in India. In Bhagirath (a Government of India publication) - Oct-Dec 1995

Niskavaara H., Reimann C., Chekushin V. and Kashulina G., (1997). Seasonal variability of total and easily leach able element content in top soil (0-5 cm) from eight catchments in European Artic (Finland, Norway and Russia).

Njenga J., Ramanathan AL. and Subramaanian V., (2003). Study of Water quality in Lake Naivasha Kenya. In: Recent in hydrogeochemistry (case studies fro surface and sub surface waters of selected countries). Eds. AL. Ramanathan and R. Ramesh. Capital Publishing Company, India. pp 37-42.

Njenga J.W., (2004). Comparative studies of water chemistry of tropical lakes in Kenya and India. Asian J. of Water Environ and Poll. (1, 2): 87-97.

Pande J. and Das S. M., (1980). Metallic contents in water and sediments of Lake Nanital, India. Water Air Soil Poll. 13: 3-7.

Pandey K.N., Prakash V. and Sharma U.P., (1994). Ecology of gastropods in relation to macrophytes of tropical wetlands Kawar-lake, Begusari, Bihar. J. Freshwater Bio. 6(3): 235-238.

Pandey K.N., Prakash V. and Sharma U.P., (1996). Seasonal variation of biomass of molluscus of Kawar-lake, Begusari, Bihar. J. Freshwater Bio. 8(3): 153-157.

Pandey K.N., Prakash V. and Sharma U.P., (1996). Assessment of secondary productivity of insects of Kawar-lake, Begusari, Bihar. J. Freshwater Bio. 8(3): 141-145.

Panigrahy R.C., (2001). The Chilka Lake, A Sensitive coastal Ecosystem of Orissa, east Coast of Indian Ocean. J. of Indian Ocean Studies. 7(2, 3): 223-242.

Parkash B. and Kumar S., 2000. The Indogangetic Basin, Sedimentary burins of India, Tectonic contest.

Paul R. and Varma S., (1999). Hydrobiological studies of a tropical standing water with special reference to nutrient status and primary production. In Vijayakumar K. (Ed). Freshwater Ecosystems of India. 255-286. Daya Publishing House, New Delhi.

Pauling L., (1960). The Nature of the Chemical Bond; Third Edition.

Puente X., Villares R., Caral E. and Carbarreila A., (1996). Nacreous Shell of

Mytilusalloprovincialis

Ramanathan A.L., Subramanian V. and Das B.K., (1996). Biogeochemical studies in the Cauvery estuary, east Coast of India. Indian Journal of Marine Science. Vol. 25: 71-73.

Ramanathan AL., Vaidhyanatahan P., Subramainian, V. and Das B.K., (1996). Sediments and heavy metal accumulation in the Cauvery Basin. Environ. Geol. 27: 164-169.

Ranjana and Siddique E.N., (1995). Systematic survey of cynobacteria from paddy field of Darbhanga. J. Freshwater Bio.7 (4): 231-235.

Rao M.B.R., (1973). The subsurface Geology of the Indo-Gangetic plains.No.3, vol. 14, Journal of Geological Society of India. pp 217-242.

Reimann C., Banks D. and Caritat P., (2000). Impact of airborne contamination on regional soil and water quality: the kola Peninsular Russia. Enviorn Sci and Technol. 34: 2727-2732.

Saekei K., Okazaki O. and Matsumoto S., (1993). The chemical phase changes in heavy metals with drying and oxidation of the sediments. Water Res. 27: 1243 1251.

Sanjer L.R. and Sharma U.P., (1995). Community structure of planktons and their periodicity in Kawar-lake, Begusarai, Bihar. J. Freshwater Biol. 7 (1): 33-36.

Sarana H. M. and Adoni A.D., (1982). Studies on the seasonal variation in pH and dissolved oxygen content in Sugar .lake. Acta Botanica India. 10: 324-326.

Schlesinger W.H., (1991). Biogeochemistry: An analysis of Global Change. Academic Press, San Diego.

Schropp S. J. and Windon H.L., (1988). A guide to the interpretation of metal concentration in estuatine sediments. Florida Department of Environmental Regulation USA.

Scott D.A., (1989). A Directory of Asian Wetlands. IUCN, Gland, Switzerland and Cambridge, UK.

Selinger W.H., Bogg J.A and Biggley W.H., (1985). Catastrophic anoxia in the Chespeak Bay in 1984. Science. 288: 70-73.

Sen Gupta, R., Singhal S. V .S. and Sanjata S., (1978). Atomic Absorption analyses of few trace metals in Arabian Sea Water. Indian Journal Mar. Scie. 7: 295-299.

Seshagiri Rao B. V., (1988). The impact of fisheries on Lake Kolleru, a wetland ecosystem. In: kolleru Environmental status (Past and Present). (Eds.)Y. Anjaneyulu and M.K.Durga Prasad. B.S. Publication. Pp 118-123.

Seshavathranan V., (1992). Ecological Status of Kolleru Lake. A review. Wetlands of India. (K.J.S. Chathran Editor). 172-200.

Shapiro L. and Brannock W. W., (1962). Rapid Analysis of Silicate, carbonate and phosphate rocks. U.S. Geo. Snov. Bull. No. (11): 43- 56 pp.

Sharma U.P., (1995). Conservation management and sustainable development of Kawar-Lake wetland, Begusarai, Bihar for rehabilitation of migratory birds. J. Freshwater Bio. 7 (3): 217-224.

harma U.P., Pandey K.N., and Prakash V., (1994). Ecology of fishes of Kawar lake wetland (Begusarai) Bihar. J. Freshwater Bio. 6(1): 49-55.

Shashtree N.K., Isla M.S., Pathak and Afshan M., (1991). Studies on the physiochemical dimensions of Lentic hydrosphere of Ravindra Sarovar (Gaya). In Current Trends of Limology (N.K. Shastree ed.) Vol. 1: 133 -152. Narendra Publishing House, New Delhi, India.

Shivaji Rao T., (2003). Conflict between development and environment of Kolleru Lake (A case study of environmental impact analysis). In: Lake Kolleru Environmental Status (past and present). (Eds. Y. Anjaneyulu and M.K. Durga Prasad.). B.S. Publication. pp 168-196.

Siddiqui E.N. and Ahmad M.S., (1992). Green algae of Darbhanga N.Bihar. Biojournal. 4 (1, 2): 149-152.

Siddiqui E.N. and Ahmad M.S., (1995). Fresh water diatoms of Darbhanga, N.Bihar. J. Freshwater Bio.7 (1): 37-40.

Singh D. K., Thakur P. K., Singh C. B., and Shalma U. P., (1994). Surface and ground water quality of Kawar Lake area, Begusarai, Bihar (India). Indian J Appl Pure Bio, 19(1): 15-17.

Singh D.K., Sinha A.K., Baruah A. and Sharma U.P. (1994). Fresh water gastropods of Kwar-lake Wetland Begusarai, Bihar, India. J. Freshwater Bio. 6 (1): 41-47.

Singh D.K., Sinha A.K., Baruah A. and Sharma U.P., (1994). Biodiversity and pollution status in relation to physico-chemical factors of Kawar-lake wetland, Begusarai, Bihar. J Freshwater Bio, 6 (4): 309-315.

Singh I. B. and Kumar V. N., (1974). Fluvial Geomorphology of Indian River: an overview. Sedimentology Geology. 12: 53-66.

Singh I. B., (1996). Geological Evolution of Gangaplains an overview. , Journal of Paleontological Society of India. vol.41, pp 99-137.

Singh J.P. and Roy S.P., (1989). Faunistic composition and community structure of the birds of Kawar-lake Begusarai, Bihar. Biological bullatine of Iindia. 11 (1): 1-8.

Singh J.P. and Roy S.P., (1990). Some aspects of ecology of birds of Kawar-lake, Begusarai, Bihar. J. Freshwater Biol., *2* (3): 175-188.

Singh J.P. and Roy S.P., (1991). Interaction between macrophytic biomass and macro-invertebrate abundance in Kanwar Lake, Begusarai (Bihar). (PG Dept Zoo., Bhagalpur University Bhagalpur- 812007). J Freshwater Bio, 8 (3): 229-234.

Singh J.P. and Roy S.P., (1995). Limno-biotic investigation of Kawar Lake, Begusarai, Bihar. (PG Dept Zoo., Bhagalpur Univ, Bhagalpur-812 007). Env. Eco. 13 (2): 330-335.

Singh J.P. and Roy S.P., (1995). Territorial Behavior of Wadar population of Ardeidae: (Iconiforms) of Kawar-lake Begusarai, Bihar. J. Freshwater Biol. 7 (4): 269-272.

Singh M., Ansari A. A., Muller G. And Singh I.B., (1997). Heavy metals in freshly deposited sediments of the Gomti River (a tributary of the Ganga River): Effect of human activities. Environ Geol. 29(3/4): 246-253.

Singh, S.K. and Subramanian, V. (1984). Hydrous Fe and Mn oxides- scavengers of heavy metals in the aquatic environment. C.R.C. Crit. Rev. Environ Control 14(1): 33-90.

Sinha A. K., Barnah A., Singh D. K. and Sharma U.P., (1994). Bio-diversity and pollutional status in relation to physicochemical factors of Kawar lake wetland (Begusarai), North Bihar. J Freshwater Bio 6(4): 309-315.

Sinha A.K. and Sharma U.P., (1996). Interaction of nutrients between abiotic and biotic components of a tropical wetland: macro-nutrients. J Freshwater Bio, 8 (2): 73-76.

Sinha A.K., (1995). Benthic ecology of Kawar-lake Begusari, Bihar. PhD thesis Bagalpur University, Bhagalpur.

Sinha R., (1995). Sedimentology of quaternary alluvial deposits of the Gandak -Kosi interfan, North Bihar plains. J. Geological society of India. 46: 521-532.

Skoulikidis N. T., Bertahas I. and Koussouris T., (1998). The environmental State of freshwater resources in Greece (rivers and Lakes). Environmental Geology. 36: 1-17.

Smith K. A., Chalmers A.G., Chambers B.J. and Chritie P., (1998). Organic manure, phosphorus accumulation, mobility and management. Soil Use and Manage mental. 14: 154-159.

Soares H.M.V.M., Boaventura R.AR., Machado A.A.S.C. and Esteves da Silva J.C.G., (1999). Sediments and overlying water in shallow entropic lakes. A report ENVE 54-76-3 to the Massachusetts Division of water resources department of environmental quality, 244 pp.

Solomons W. and Forster U., (1984). Metals in the Hydrocycle. New York Springe Verlag. 349 pp.

Solomons W., De Rooji N.H., Kerdijk M and Brill J., (1987). Sediment as a source for contaminants Hydrobiologia, 147: 13-30.

Sreenivasa A.R., Ramamohana R. P. and Someswara N.R., (2001). Quality of drinking water from ponds in Villages of kolleru Lake region. Ind. J. Envron. Hlth. 43(1).

Sreenivasa R. A., Ramamohan P.R and Someswara R. (1999). Degradation of water quality of Kolleru Lake. Indian J Environ Hlth. 41(4): 300-311.

Sreenivasa R. A., Ramamohana P. R. and Someswara R., (1999). Degradation of water quality of Kolleru Lake. Indian D J. Environ Hlth. Vol. 41 No 4: 300-311.

Sreenivasa R. and Ramamohan R. P., (2001). Heavy metal concentration in the sediments from Kolleru Lake, India. India J Environ. HLTH 43(4): 148-153.

Srivastava A., (2003). Tectonic Zonation using Multi Criteria Decision Making (MCDM) Techniques: A case study of Kosi - Fan, India. www.gisdevelopment.net/application/geology.

Srivastava M.P., (1989). A new hill stream Sisorid Fish of a genus Hara (Blyth) 1860 from koshi Belt, N.Bihar, India. J. Freshwater Bio. 1(2): 121-125.

Subramanian V. and Mohanachandra G., (1990). Heavy metal distribution in the sedidiment of east coast of India. Marine poll. Bull. 21: 324-330.

Subramanian V., (2000). Transfer of phosphorus from the Indian subcontinent to the adjacent oceans. In: Marine Authigenesis: From global to Microbial SEPM special publication. No.66, pp 77-88.

Subramanian V., Van't D.L. and Grieten R., (1987). Heavy metal distribution in the sediment of Ganges and Brahmaputra River. Env. Geo. water Sci. 9: 93-103.

Sujatha S.D., Sathyanayarnan S., Satish P.N. and Nagaraju D., (2001). Asweage and siudge treated lake and its impact on the environments, Mysouri, India. Environ, Geol. 40: 1209-1213.

Tessier A. and Tuner D., (1995). (Eds). "Metals Specification and bioavability in aquatic systems" PGC Campbell Interaction between trace metals and aquatic organisms: critique of free-ion activity model" John Wiley and Sons Ltd. England. pp 45-102.

Tessier A., Carigan R., Dubreuil B. and Rrapin F., (1989). Partisionig of Zinc between the water column and oxic sediment in lakes. Geochim. Cosmochim Acta. 53: 1511-1522.

Thresh J. J. C., Snikling E. V. and Beale J. F., (1949). The Examination of water and water supplied E.V. Taylor (ed) London.

Thresh J.C., Beale J. F. and Suckling E. V., (1949). The examination of water and water supplies. Ed. 6. By Taylore E. W.

Unni K.S., (1993). Limnology of Central Indian Lakes reservoirs and ponds. A review. In Mishra, P.C. and Trievedy R.K. (EDS). Ecology and pollution of Indian Lakes and Reservoirs, 237-267p. Ashish Publishing House, New Delhi. (Unni 1983)

Verma A.M. (1995). Inland fish culture in Kosi division in north Bihar: problem and prospects. J. Freshwater Bio. 7(3): 207-216.

Villaescusa C.J.A., Gutielez G.E.A. and Flores M.G., (2000). Heavy metals in the fine fraction of coastal sediment from Baja California (Maxico) and California (USA). Env. Poll. 108: 453-462.

Villares R., Puente X. and Calballeira A., (2003). Heavy metals in sandy sediments of the Rias Baixas (NW Spain). Environ Monit and Assess. 83: 129-144.

Vitousek P.M., Aber J., Howarth R. W., Likens G. E., Matson P. A., Schidler P.W., ScheleIsmger W. H., Tilman G. D., (1997). Human alteration of the global nitrogen cycle: Causes and consequences. Ecological Applications. 7: 737-750.

Vitousek P.M., Aber J., Howarth R. W., Likens G. E., Matson P. A., Schidler P.W., ScheleIsmger W. H., Tilman G. D., (1997). Human alteration of the global nitrogen cycle. Causes and consequences. Ecological Applications. 7: 737-750.

Wadia, D.N. 1949. Geology of India. MacMillan Co. Ltd., London.

Wardas M., Budek l. and Rybika E.H. (1996). Variability of heavy metals content in bottom sediments of the Wilga River, a tributary of the Vistula River, Karakov area (Poland). App. Geochem. 11: 197-202.

Wetzel R. G., (1974). The Phosphorus cycle in Limnology, W. B. Saunders Co., Philadelphia. 743 pp

William J. D.H., Syers S.K., Harris R. F. and Armstrong D.E., (1984). Fractionation of Inorganic phosphate in calcareous lake sediments. Soil Sci. Soc. Amer. Proc. 35: 556-561.

WW 2010, The Weather World 2010 Project, October, 1999 http://ww2010.atmos.uiuc.edu/(Gh)/ guides/mtr/hyd/bdgt.rxml

Y. Anjaneyulu and Prasad M.K.D., (2003). Environmental Status (Past and Present). BS Publication. pp 143-157.

Yang H. and Rose L., (2004). Trace element pollution record s in the some UK lake sediments, their history, influence factors and regional differences.

Yu L. and Oldfield F., (1993). Quantitative sediment source ascription using magnetic measurements in a reservoir catchment system near Nijar, SE Spain. Earth Surf. Landforms Processes. 18: 441-454.

Zutshi D.P. and Khan A.U., (1988). Eutrophication gradient in Dal Lake, Kashmir. Indian J. Environ Hlth. 30(4): 348-354.

Zutshi D.P., (1989). Eutrophication of lakes in Khulbe R.D., (Ed). Perspectives in aquatic

Biology Papyrus Publishing House. New Delhi. pp 87-89.

Zutshi D.P., Subla B.A., Khan M.A and Wanganeo A., (1980). Comparative Limnology of nine lakes in Jammu and Kashmir Himalayas. Hydrobiologia. 80: 101-112.