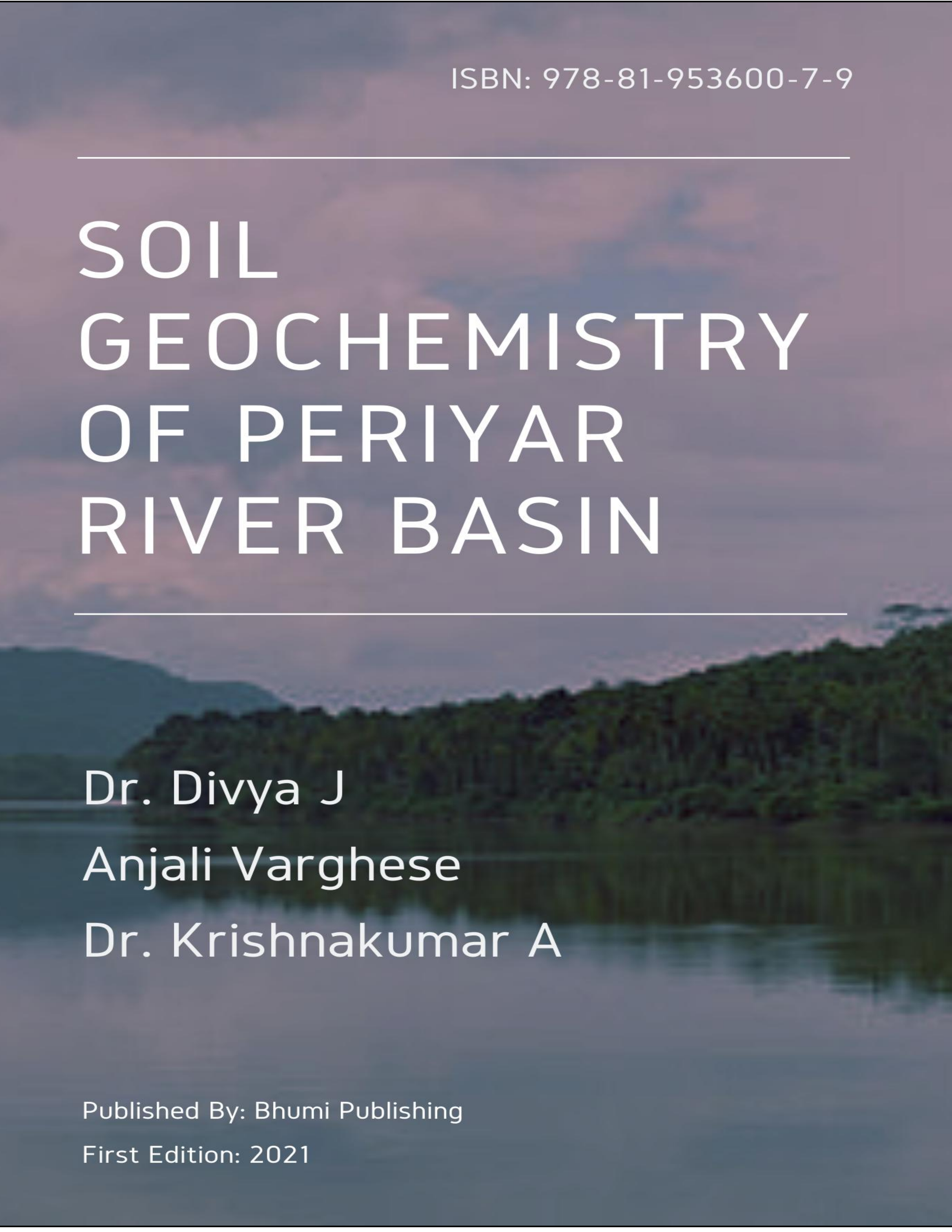

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SOIL GEOCHEMISTRY OF PERIYAR RIVER BASIN

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PREFACE AND ACKNOWLEDGEMENT

The river ecosystem is considered to be one of the complex ecosystemsdue to its dynamic equilibrium. River soils are the type of soils that are carried by the action of rivers. Soils in the river areas are complex in nature due to the materials that river carry from other areas and its deposition. Rivers and streams drain water that falls in upland areas. Moving water dilutes and decomposes pollutants more rapidly than standing water, but many rivers and streams are significantly polluted all around the world. A primary reason for this are the major pollution sources like industry, agriculture and domestic activities that are concentrated along the rivers. Industries and cities have historically been located along the rivers because; the rivers provide transportation and have traditionally been a convenient place to discharge waste products. Agricultural activities have tended to be concentrated near rivers, because river floodplains are exceptionally fertile due to the many nutrients that are deposited in the soil when the river overflows.

The Periyar Riveris considered being very significant in improving the economic status of Kerala. However, as in the case of many inland water bodies, Periyar River is gradually undergoing eco-degradation throughout its course of flow due to supply, irrigation, tourism, industrial production, collection of various inorganic resources, fisheries and due to various anthropogenic stresses, which include indiscriminate deforestation, domestic- agricultural – industrial water pollution, excessive exploitation of resources, large scale sand mining, various interference in the flow of water etc.In this book one can able to understand the development and human activities responsible for river pollution. It gives complete information about the overall geochemical behavior in the Periyar River soils so that, the pollution status can be evaluated.

This book will be very much beneficial for the researchers and students to develop river conservative strategies in future. The authors thank to Bhumi Publishing and their editorial teams for bringing out this book with an appealing get up.

- **Authors**

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ABSTRACT:

Rivers are of immense importance geologically, biologically, historically and culturally. Although rivers account for 0.0001% of the world's total water volume, they are important carriers of water and nutrients throughout the world. The present study was carried out to understand the textural and geochemical constitutions of Periyar River Basin. Form the textural analysis of soil samples, it was found that, the percentage of sand, silt and clay in the soil samples of Periyar River ranges from 17.304 % to 88.18 %, 2.27 % to 58.010 % and 7.22 % to 47.94 % respectively. The textural triangle (Ternary plot) shows that, most of the soil samples falls under sandy clay loam > sandy loam, clay, loam>silt loam, clay loam, sandy clay. The XRF analysis has been carried out to determine the major and heavy metals concentration in the soils of Periyar River basin. Based on the major elemental distribution, it was observed that, the soils are predominantly siliceous type with enrichment of Alumina. The contamination in the soil was assessed on the basis of IGEO and pollution load index. The chemical index of alteration (CIA) helps to find the intensity of weathering. The average value of pollution load index indicates the progressive deterioration of the site. Average value of contamination factor also shows the considerable degree of pollution in the present study area. By analyzing the crustal enrichment factor, it was found that, magnesium and zirconium exhibits moderate enrichment and other elements exhibits minimal enrichment as per soil status, it is clear that, the present study area is moderately contaminated in terms of pollution load index, contamination factor. The presence of magnesium and zirconium is high in the present study area.

Keywords: Soils, River, Texture, Heavy Metals, Pollution.

Chapter 1 Introduction

1.1 General Introduction

Rivers are of immense importance geologically, biologically, historically and culturally. Although rivers account for 0.0001% of the world's total water volume, they are important carriers of water and nutrients throughout the world [1]. Rivers are complex system of flowing waters draining specific land surface which are defined as river basin or water shed. The characteristic of river within the total basin system are related to number of features, which include the size, form and geological characteristics of the basin and the climatic condition which determine the quantities of water to be drained by the river network [2].

Rivers are the dynamic combination of water, sediment, aquatic organisms and riparian vegetation. Water and nutrients are carried by these rivers to the different areas all over the earth. They play a very important part in the water cycle acting as drainage channels for surface water. The shape of rivers and streams changes through time as erosion, deposition and transport of sediment occurs. Rivers and streams maintain a dynamic equilibrium between discharge, slope and sediment load and sediment size. Rivers are a powerful geological agent whose sedimentary records reflect climatic, tectonic and anthropogenic features in combination [3]. Rivers and estuaries constitute the major pathway of natural and anthropogenic materials from land to the sea. Compared to other geological agents such as wind, glaciers, ground water etc., the total amount of materials (dissolved, suspended and bed sediments) carried by rivers is remarkably high. Several attempts have been made to assess the quality and the quantity of river transport materials to the ocean realm [4]. There are 44 rivers in Kerala. The presence of large number of rivers has made Kerala rich in water resources which are being harnessed for power generation and irrigation.

The river ecosystem is a complex mosaic of interaction and interrelationship of the biotic (flora and fauna) and abiotic (hydrologic geomorphic etc.) components in dynamic equilibrium [5]. River soils are type of soils that are carried by the action of rivers. Soils in river areas are complex in nature due to the materials that river bring infrom other areas and deposited.

Generally, soil is the link between air, water, rocks and organisms that are responsiblefor many different functions in the natural world that we call ecosystem services. These soil functions include: air quantity, natural "waste" treatment and recycling andhabitant for the living things and their food. We could not survive without these soil functions, without soil and soil particles, water would be running on bare rocks when it rains, the soil act as sponge, soaking water into the ground. From there a few things can happen to water. The water can be taken up by plants, microbes and other living things or the water moves into the underground aquifers and lakes and flows into stream before eventually making it to the ocean. If the rainfall contains harmful pollutants, the soil act as filters, contaminants are captured by the soil particle sand the water comes out cleaner in the aquifers and rivers. Soils are considered as natural bodies, covering a part of earth surface that support plant growth and have properties due to the integrated effect of climate and organisms acting upon parent material conditioned by relief over a period of time. The formations of soil are influenced by many environmental factors, such as topography, climate, biology, parent materialand time [6].

1 .2 Soils of Kerala

Soil is a dynamic and complex system of air, water, decomposing organic matter, living plants and animals. In addition to this, soil consists of rock fragments, clays, sands and silts organized into definite pattern as dictated by environmental conditions. The major factors involved in the process of soil formation are parent material, climate, time, topography and biota. These factors are influencing the mineralogical, mechanical and chemical properties of soils. The physical properties ofthe soils greatly influence towards the plant growth. This also influences the chemical and biological properties of the soils and it is of utmost importance in relation to plantgrowth as well as soil fertility. Soils typically consist of some mixture of sand, loam and clay [7].

The soils of Kerala have been mainly categorized into ten broad groups based on the physico –chemical properties and morphological features were listed in table 1.1.

Study area

The study area of the present project mainly focused on Periyar River basin, Kerala. The river Periyar is the longest river of the Kerala state (9º to 10º15' North Latitude and 76º to 77º30' East Longitude) is considered to be the life line of central Kerala. It originates from the Sivagiri peaks (1800m MSL) of Sundharamala in Tamil Nadu. The total length is about 300 Kms (244 Kms in Kerala) with a catchment areaof 5396q Kms (5284 Sq.Kms in Kerala).The total annual flow is estimated to be 11607cubic meters. During its journey to Arabian sea at Cochin the river is enriched with water of minor tributaries like Mthayar, Perunt, huraiar, Chinnar, Cheruthony, Kattapanayar and Edamalayar at different junctions.

Table 1.1: Soil types of Kerala

Soil Type	Properties	Location
Red loam soil	Red in color	Southern part Thiruvananthapuram
Laterite soil	Brown color	to yellowish red
Coastal Alluvial soil	Sandy texture	West coast of India
Riverine Alluvial soil	Sandy to clay texture	Banks of rivers in Kerala, Aluva, Kasagode
Onattukara Alluvial Soil	Coarse texture soil	Karunagapally
Brown Soil	Hydromorphic	Brown hydromorphic soil
Saline Soil	Hydromorphic	Variation in texture
Kuttanad Alluvial soil	Water soil	logged soil, Kayal
Black soil	Black in colour	Palakkad
Forest Loam soil	Dark reddish brown color	Kasargode, Kannur

Location

The area selected for the present study, the Periyar River basin, falls within the central part of the Kerala and lies between North latitudes 9°15’50”-10°32’53” and East longitudes 76°07’38”-77°24’32”. The area spreads in the Idukki, Ernakulam and Thrissur districts and comprises 16 taluks- 5 in Thrissur, 7 in Ernakulam and 4 in Idukki. The watershed has a total area 5398 km^2 covering 88 villages spread over 102 panchayats, 21 blocks and 3 districts, maximum width is recorded as 405m [8].

Origin and Tributaries

Periyar originates in the ‘Sivagiri’group of hills in ‘Sundara Malai’ at an elevation of about 1830m. After about 48Km it receives the Mullayar and then turns west to flow into the Periyar Lake at Thekkady. The renowned Periyar Wildlife Sanctuary, famous especially for elephants and Tigers are situated there. From there itflows on and passes Vandiperiyar and after receiving River Perumthurai and River Kattappana, reaches the Idukki catchment. Afterwards, Idamalayar joins Periyar near Neriamangalam. After Neriamangalam the river flows into the Periyar barrage and then on to the Boothathankettu dam. The river then meanders through Malayattoor, Kalady and Aluva, the river bifurcates into the Mangalapuzha branch and the Marthanadavarma branch [8].

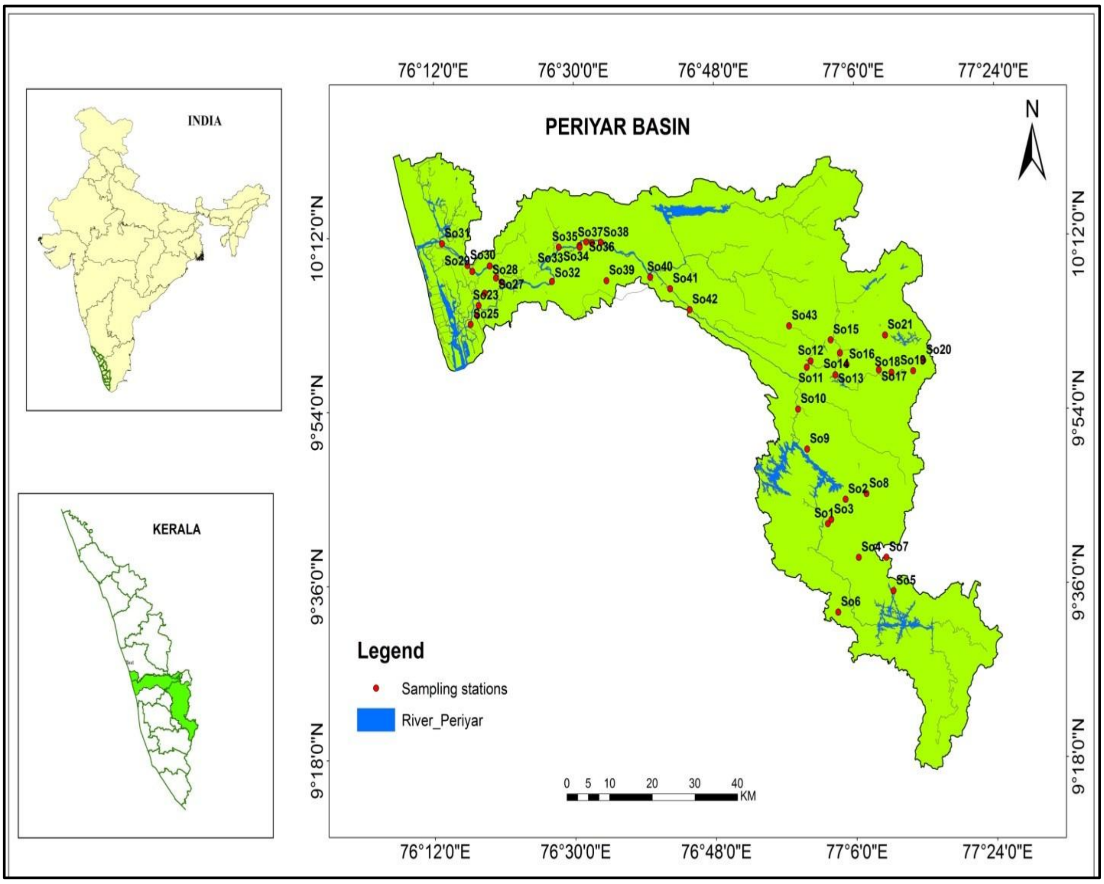

Figure 1.1: The Study area of Periyar River with sampling location

Environmental Pollution in the Study Area

Development and human activities produce large amount of waste that leads to the pollution of the air, water, soil. Improperly treated waste is the major cause of the pollution of the rivers. Air pollution, water pollution and soil pollution will leads to severe environmental pollution. The polluted soil directly affects the water resources. The addition of fertilizers and pesticides from agricultural use will reach soil as run-off. Acid rain and dry deposition of pollutants on the land soil are the impact of pollution.

The Periyar basin spreads over an area of 5,398 square kilometres (2,084 sq mi). The lower area of Periyar is heavily polluted. Greenpeace India describes the lower Periyar as "a cesspool of toxins, which have alarming levels of deadly poisons like DDT, endosulfan, hexa and trivalent chromium, lead, which has dangerous impact towards living things and badly affect the environment. Several studies in the periyar basin pointed out that, the riverbed has deposits of harmful heavy metals like lead, cadmium, mercury, chromium, nickel, cobalt and zinc and the river ecosystem has many dead zones. It directly or indirectly affects the environment adversely.

Sources of pollution of Periyar River can be categorized as

- Sewage and garbage
- Agricultural run-off
- Industrial pollution

Sewage and Garbage

Periyar River directly receives civic effluent from townships like Vandiperiyar, Upputhara, Cheruthony, Munnar, Malayatoor, Kalady, Perumbavoor, Nerimangalam, Aluva and Parur. None of these local bodies possess proper sewage treatment facility. In case of Cochin Corporation, the sewage treatment system is inadequate and untreated organic and inorganic refuses are being discharged into the backwaters [9].

Agricultural Run-off

From the total area of the river basin 39000Ha are available as wet land. Major crops being cultivated in the river basin includes rice, coconut, arecanut, banana, rubber, vegetables etc. The upper reaches of the basin is utilized for plantation crops like tea, coffee, cardamom and rubber. This intensive agricultural practice all alongthe banks and watershed area has been enriching the river water with huge amount of pesticides and fertilizers especially during surface run-off in the rainy season. Loosingof surface soil and the removal of vegetation from catchment area generate problems related to soil erosion and siltation.

Industrial Pollution

Industrial pollution is the most serious threat to the riverine ecosystem in lower reaches of Periyar is about 15 Kms upstream from the backwater of Cochin. Angamaly to Koch is the most industrialized zone of the Periyar River basin. There are over 50 large and medium industries and over 2500 small scale industries in this region. The southern branch of Marthandapuzha which cater to the needs of these industries is estimated to have to learn water flow. The industries located in Edayar- Eloor area consumes about 189343 cum per day and discharge about 75% as used water along with large quantity of effluents and pollutants. The major type of industries are fertilizers, pesticides, chemicals and allied industries, petroleum refining and heavy metal processing, rubber processing units, animal bone processing units, battery manufactures, mercury products, acid manufactures, pigment and latex products etc the wide spectra of pollutants that adversely affect the natural environment quality of water of the river include toxic and hazardous materials such as heavy metals, phenolics, hydrocarbons, pesticides, radionuclide, ammonia,phosphate domestic and untreated waste water.

Geology of Kerala

Physiographic and Stratigraphic description of Kerala are presented as follows:

Physiographic

The Kerala state comprises a narrow strip of land with an area of 38,000 Km^2, extending between latitudes 80°17‟30” and 12°27‟40““ N and Longitude 74°51’’57““and 77°24‟47““ E. The Western Ghats on the east and the Arabian Sea on the westare the natural boundaries of the state. Based on the detailed study of the physiographic and slop maps of Kerala, the state can be classified into 5 physiographic zones.

Mountain Peaks (>1800 m)

Mountains and peaks above 1800 m within the Western Ghats constitute 64 % of the total area of the state. In northern stretch of Ghats within Kerala, peaks rising above 1800 m are limited in number.

Highland (600 m -1800 m)

Highlands that occupy 20.35 % of the state is an important physiographic province. It lies mainly on the eastern edge close to Western Ghats, the peaks ranging in height from 915 to 2695 m. Most of the rivers originate from this region.

Midland (300 m -600 m)

Midland covers nearly 8.44 % of the total area of the state. This region falling between 8m to 80 m above MSL is generally sloping land consisting mainly of lateritefail lands that about at various places along the cost in the form of cliff.

Lowland (10 m -300 m)

The area falling under the altitudinal range of 10 to 300 m and consisting of dissected pene plains constitute the lowlands. Numerous flood plains, alluvial terraces valley fills, colluviums and sedimentary formations are part of lowlands.

Coastal Planes and Lagoons (<10)

The vast low lying area fringing the coast, is not only an important physiographic unit of the state, but also important in terms of economic activity and demographic distribution. It constitutes 16.40% of the area of the state. In central Kerala most of the area shows elevations of 4-6 m above MSL, whereas it is 4-10m in north and south Kerala, except the coastal cliffs, promontories and slopping platforms. Beach dunes, ancient each ridges, barrier flats, coastal alluvial planes,flood plains, river terrains, marshes and lagoons constitute this unit [10].

Stratigraphic

Geologically, Kerala state forms part of peninsular shield bounded by Western Ghats on the east and the Lakshadweep sea on the west. Precambrian formations of Kerala include the Charnockite-Hornblende suits, followed by high grade schist and gneisses. Some metabasic and ultra-basic rocks like granite and syenites are also representative of the Precambrian. The Mesozoic and Tertiary rocks consist of fresh dolerite dykes and gabbro and the Ezhimala stock of granophyres-gabbro correlated tothe Deccan trap activity. The tertiary sedimentary formations of Kerala uncomfortably overlie the Precambrian. The two facies of sediments along the major part of Kerala coast are the continental facies and marine facies. Tertiary rock in the Quilon-Varkala into Quilon beds- consisting of limestone and calcareous clays and Warkalli beds comprising sandstone and clay with lignite. The sub-recent to recent formations include coastal sands, Teris, lagoonal deposits and alluvium [10-11].

Lithology of Kerala

The Precambrian crystalline rocks occupy a considerable area of Kerala. A large part of these crystalline rocks has undergone polymetamorphic and poly deformational activity

Khondalites

Khondalites are essentially garnet sillimanite schist containing with or without graphite, quartz and orthoclase. The age determination of this rock type indicates a range of 670 to 2200M [12].

Charnockites

Charnockite is hypersthene granite, composed of hypersthenes, microclines, quartz and accessory iron ores associated with granulites rocks. They are exposed in Kannur, Kozhikode, Palakkad, Trissur Kottayam and Kollam districts [13].

Acidic and Alkaline Intrusive

The emplacement of acidic and alkaline intrusive along the major lineaments manifests late Proterozoic magmatic activity in the region. Granites and pegmatite and quartz veins are the common acid intrusive observed in Kerala. At several places, the Precambrian crystalline are also traversed by simple and complex pegmatite andquartz.

Basic and Ultra Basic Rocks

They are mainly reported from a number of places in Kerala. Basic gabbrobodies are reported from the Adakkathod and Karrang in Kannur district.

Leptynites

The granitiferous gneisses from a major division called Leptynites. They are found along with Charnockites and are white to grayish in color and this unique color attributed to the alteration of feldspar [14].

Cordierite Gneiss

Quartz, feldspar and cordierite are the essential material in this rock type. The hypersthenes bearing variety, usually seen associated with Charnockites and Khondalites is developed along certain zones in the Achenkovil shear zones [15].

Drainage

The state of Kerala is drained by 44 rivers of which 3 are east flowing. The streams originating from the Western Ghats are short and swift- flowing, showing various stages of gradation. These streams are marked by waterfalls in the upper reaches although in the plains they show evidences of maturity of development. Some of these rivers have steep gradients in their initial reaches. In the case of Periyar and Chalakudi Rivers, this extends for three- fourth of their course, while such gradients are also discernible in the upper reaches of Chaliyar, Valappattanam River, Karamana are suggesting their youthful stage of development.

Rejuvenation of the catchment area closely linked with the west coast faulting and later adjustments may in all probability be the reason for the youthful character of the rivers, while high energy shore line appears to have prevented delta formation in the river mouths [10].

The general drainage pattern of these rivers is dendritic although in places, trellis, sub parallel and radial pattern are also noticeable. Most of the river courses are straight, indicating structural control. General course of the rivers coincides with the prominentlineament directions (NW-SE and NE-SW). Many of the rivers do not have continues flood plain. Backwater-Estuaries and Lagoons, chain of water bodies, locally known as "Kaya" running parallel to the coastline is a characteristic feature of the Kerala coast. These are mostly interconnected by natural or man-made canals, facilitating internal navigation almost for the entire length of the Kerala coast. A Kayal can be generally described as a body of brackish, marine or hyper saline water, impoundedby a sandy barrier and having an inlet connecting it with the open sea. As a rule, numerous perennial rivers discharge into these Kayals. Southern half of the Kerala coast harbors most of these backwaters. The Kayals of the Kerala coast are mostly separated from the sea by elongated sand bars and based on this they can be treated as coastal lagoons. Since perennial rivers touch into the sea through these water bodies making the system compound, these can be considered as lagoon-estuarine systems orpartially mixed estuarine systems.

Climate

As in the case of southwest part of India, climate and hinterland is alsocontrolled by the Western Ghat orography. The respective mean annual minimum - maximum temperature of Kerala are 18.5°C and 28.5°C. Based on the pattern suggested by Indian Meteorological Department, the seasons of Kerala can be demarcated as follows: Hot weather period: March to May. Southwest monsoonseason: June to September Retreating southwest monsoon (northeast monsoon): October to November. Winter (cool weather season): December to February the atmospheric temperature is maximum during pre-monsoon period and from June it gradually comes down due to heavy rainfall. An increasing trend is notices during December to January. Land and sea breezes influence the coastal areas and here, the seasonal and diurnal variations of temperature are almost of the same range.

Rainfall

The annual rainfall varies from less than 100 cm to more than 500 cm with an average of about 300 cm and is precipitated mainly during south west and north east monsoons. Rainfall is also received between the two seasons. The south west monsoon, yielding more than 60% of the total precipitation records high rainfall of more than 300 cm in foot hill zone of Wayanad Plateau and Pyramid – Neriyamanagalam stretch. The north east monsoon yields less rain fall, with maximum (>100cm) recorded in Neriyamangalam. The northern part, generally receives less rain (8% of annual rain fall) in this season, where as in south, it is about 504 mm average (24% of annual rain fall).

Temperature

Temperature data indicates that, the period from March to May is the hottest with temperature reaching more than 32˚C and the lowest temperature are experienced during the months of December and January. Temperature is minimum inthe month of July, when the State receives plenty of rainfall and the sky is cloudy. In the coastal belt the temperature goes up to 30-32˚C while in Palaghat gap region, the temperature often goes beyond 38˚C is experienced in the Munnar – Devikolom area of the Western Ghats.

Wind

Similar to rains, wind velocity is also monsoon dependent. Two distinct patterns are observed for the NE and SW monsoons. The wind directions during the SW monsoon are consistent from the NW quadrant, whereas in the rest of the period the directions are inconsistent. The wind velocity during SW monsoon is from 5 to 25 km/h, whereas, during NE monsoon the speed varies from 5 to 18 km/h.

Aim and Objectives

1. To study the textural characteristics of soils of Periyar River Basin
2. To assess the present status of major elements and heavy metals in the soils of Periyar River Basin
3. To study the quality and extent of pollution in the soils of Periyar River Basin

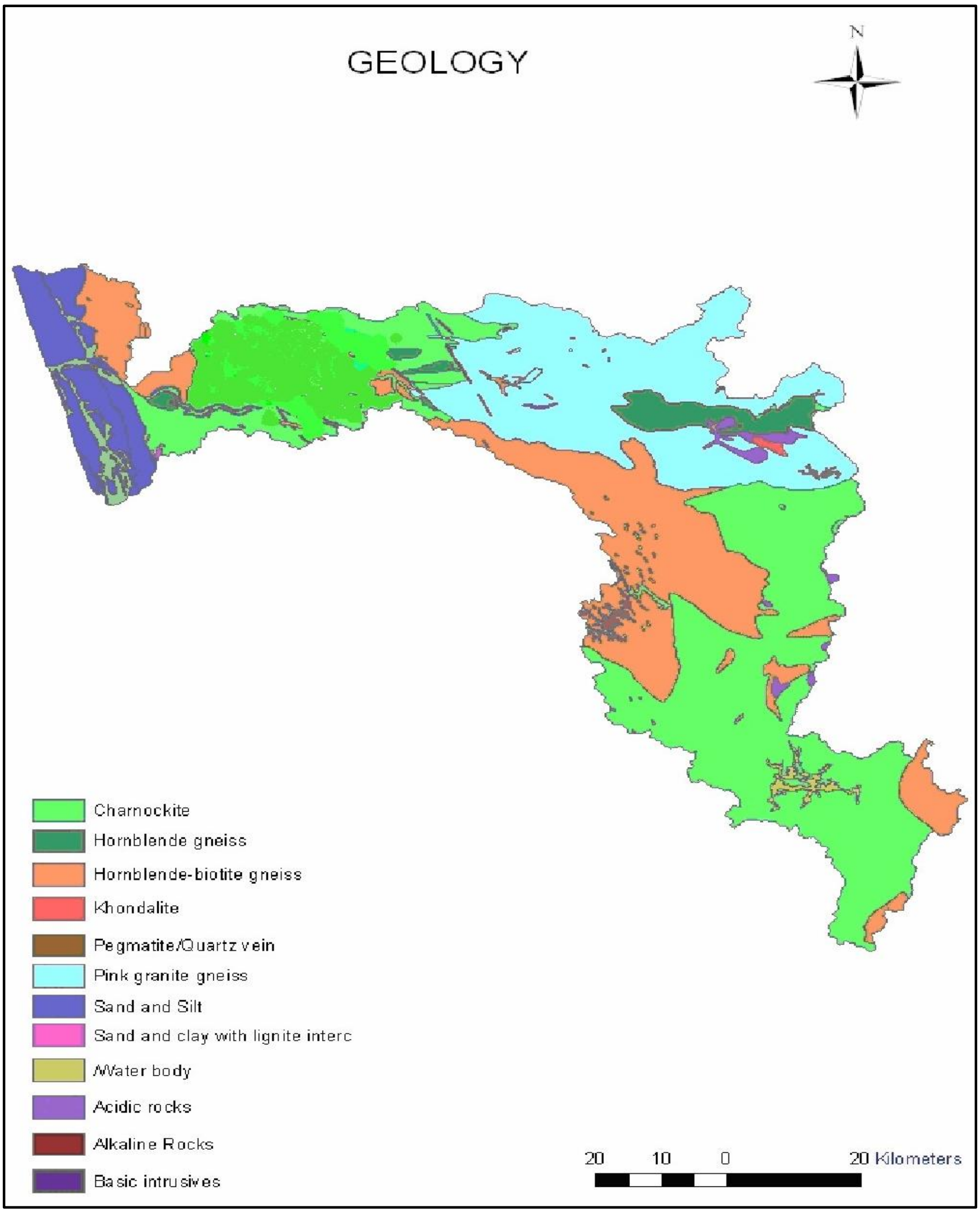

Figure 1.2: Geology map of Periyar River

Chapter 2 Literature Review

Texture

The study on soil water characteristics from texture, examined that, textural ranges within general defined texture classes can cause significant changes of potential and hydraulic conductivities. This study is made to get an idea about important properties and textural characteristics of soil. It took longtime to evaluate the hydrological properties of soils based on their textural characteristics. In thisstudy, they observed higher percentage of sand in association to the percentage of silt and clay suggests good porosity and permeability of soils. The soils of the eastern partof the Lower Subansiri basin are more porous and permeable compared to the western part of the basin. It has been also found that, owing to overall coarseness, better sorting and relatively more uniform grading of constituent grains, the soils of the eastern part of the lower Subansiri basin are relatively more porous and permeable compared to the western part of the basing [17].

Many studies have been carried out to understand the texture of soil for agricultural productivity and it was concluded that, the rate of agricultural production is directly related to the soil texture. The study also showed that, soil texture can give high yield production in agricultural area [18].

An attempt has been made to study the soil texture and it was found that, texture is one of the most important properties of a soil and it greatly affects crop production, land use, and management. Soil texture is directly related to nutrient retention and drainage capabilities. [20].

A study on soil texture determination and sedimentation method of analysishas been carried out, from this study, it was concluded that, the comparison of laser diffraction analysis with the pipette method demonstrated highly significant linear correlation in each of the particle size fraction from clay to coarse silt [21].

A study conducted on effect of texture and tree species on microbial propertiesof mine soil is showed that, the texture of soil substrate is of higher importance for microbial properties of the studied mine soil than the planted vegetables [22].

The study conducted was in sangamner area located in the Ahmednagar district of Maharashtra. The textural and mineralogical characteristics of soils in relation to soil fertility status have been analyzed. From this study, it was concluded that, the textural classification of the soils showed 35.48% samples were clay, 22.58% samples were clay loam, 21% sandy clay, 16% sandy and 5 % sandy clay. This indicates the majority of the soils were found to be clay and clay loam texture [23].

A study on the chemical and physical properties of soil showed that, the particle size distribution will affect water holding capacity of the soil and nutrients. Fine textured soil generally has a higher capacity for water retention, whereas sandy soils contain large pore spaces that allow leaching [24].

The study on the soil bulk density in relation to soil texture showed that, there is no much correlation between the soil properties and the soil bulk density. This study also reveals that, the total macronutrients of the soil increases as the bulkdensity decreases [25].

A study has been made to understand the hydrogeomorphological system of the Katepurna river basin. In this study, it was reported that, utilizing soil texture is one of the qualitative classification tool for both the field and laboratory analysis to determine the classes for agricultural soils based on their physical texture. It was also concluded that, the undulating plains represent potential groundwater horizons due to the availability of aquifer zones [26].

The study conducted in Heihe River basin reveals that, the validation results of the soil texture map achieved an accuracy of 69% for test data from the midstream area of the river basin and it was found that, water resource management at the watershed scale of the Heihe River basin represents much higher accuracy than that of another existing soil map in the Heihe River basin [27].

The study on the properties of soil shows that, the properties of the soil can be estimated using soil texture representation with the standard textural fraction triplet 'sand, slit, clay. These are the commonly used method to estimate soil properties. The 'sand, slit, clay' percentage may give better representation of soil texture for estimating some soil parameter [28].

Geochemistry

A study on Major element oxides such as SiO_2, Al_2O_3, Fe_2O_3 and TiO_2, the major components of soil showing resistant to weathering, while CaO is less resistant to weathering and can be easily eroded. In nature, SiO_2 polymorphs (quartz, tridymite and cristobalite) occur as higher temperature or β-phases, lower temperature or α- phases. In soil the α-phases are usually found Ti and Zr silicate (Zircon), these are the most ubiquitous because of their generally low concentrations in soil, there is little evidence of the effect of Ti and Zr minerals on soil reactivity [31-33].

A study in Musi River and its environs were assessed for heavy metal contamination. The study area was assessed for Zn, Cr, Cu, Ni, Co and Pb in soils, forage grass, milk from cattle leafy and non-leafy vegetables. Partitioning pattern of soil revealed high levels of Zn, Cr and Cu associated with labile fractions, making them more mobile and plant available. Studies show that, the Ganga-Brahmaputra system transports some 118 million tons of dissolved solids annually to the Bay of Bengal and that their water chemistry is dictated by the weathering of carbonates and contributions from soil salts and /or saline ground waters [34].

A pioneer study on pollution aspects of Periyar River provides valuable baseline information towards this direction. This study report Reveals various important parameters like river discharge at different points, influence of tidal influxin the lower reaches, effluent dilution due to discharge of fresh water from unpolluted area, distribution of radioactivity in sediment-water-biota, concentration of other pollutants like heavy metals, organic compounds etc., [35].

A study on geochemical properties of soil shows that, the geochemistry in soil science differs from the classical geochemistry of rock formations, because soil differs fundamentally from weathered rock. One of the important geochemical properties of soils is their content of trace elements [36-37].

An environmental geochemical investigation was carried out in and around the Pali industrial development area of Rajasthan to determine the effect of contamination in that area. This level of metals in soils around the industrial area were found to be significantly higher than their normal distribution in soils such as Pb-293mg/kg, Cr- 240mg/kg, Cu-298mg/kg, Zn-1364mg/kg and V-377mg/kg. High concentration of these toxic elements in soil is responsible for the development of toxicity in agricultural products, which in turn affect human life [38]. Geochemistry is the functional characterization, evaluation of elemental distribution and concentration of chemical elements in the rock, soil and water. The Study further concludes the understanding of chemical processes and reactions that govern .The composition and chemical flux between various states [39].

The geochemical pattern of soil pollution in the environment is a matter of great concern over the last few decades [40]. The pollution with toxic metal has become one of the major environmental problems of our time. The natural and anthropogenic sources and presents a concise and useful review of the characteristics of rocks and soil. Different techniques for the remediation of soils and ground water pollution by heavy metals included physical methods such as, soil washing, encapsulation and electro kinetics, chemical methods such as solidification, precipitation and ion exchange and biological methods which use plants to remove heavy metals [41].

A study carried out on the heavy metals concentration in the European soil, showed that, the database is suitable for geostatistical analysis, the heavy metalconcentration ranges from 2 % (Cr) to 35% (Pb) of variability; it shows special auto correlation [42].

A study on the Geochemistry of trace elements in surface waters of the Arno River Basin, northern Tuscany. Trace elements in the final part of the Arno River are influenced by flocculation processes in addition to mixing. Adsorption phenomena on oxy-hydroxides are denoted by good elemental correlations with Fe and Al. Sporadic anomalous concentration values, possibly related to anthropogenic contributions, mayprevent such correlations. Referring to the quality of waters for potable use and fish life, toxic elements are below the acceptable limits of current European regulations [43].

A study on geochemical Properties of Southern Malaysian organic soil showed that, the geochemical properties, X-ray fluorescence (XRF) and Fourier Transform Infrared (FTIR) were utilized to determine the bulk chemical composition of the soil and its functional group, respectively. The findings of this study are expected to give a better overview of organic soil which enable designer to have a better understanding when dealing with this kind of material [44].

A study has been conducted on heavy metal contents in soil and its special variability in the Duero River Basin and it was found that, heavy metals in soil are visible only at local special scales; in this view natural factors maximize their influence on the distribution of heavy metals when considering larger special scales [46].

A study on heavy metals and metalloids in the soil revealed that, the soils may become contaminated by the accumulation of heavy metals and metalloids' through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals and atmospheric deposition [47].

Chapter 3 Materials and Methods

Field Survey and Sample Collection

A Detailed fieldwork has been carried out in the Periyar River basins for the collection of soil samples, Thiruvananathapuram. As a part of collecting the soil samples, a field work was conducted, thrissur, Ernakulam and idukki districts. A total of 30 soil samples were collected systematically from the different regions of Periyar River basin for detailed textural and geochemical studies. Soil samples were collected using stainless steel spatula and transferred into neatly labeled clean Zip-lock polythene covers and preserved for further analysis. The samples were analyzed for texture, major, heavy, trace metals following standard procedures. Analyses were carried out in the various laboratories of National Centre for Earth Science Studies, Thiruvananthapuram.

Laboratory Procedures

In the laboratory, the samples were mixed thoroughly to make them homogeneous and subjected to pretreatment. From these, a known quantity of soil were subjected to preliminary treatment with dilute 0.2N hydrochloric acid and hydrogen peroxide to remove shell fragments and organic matter, as they interfere in the settling of particles. The sample were then washed and dried at 500°C for further analysis.

Textural studies

Sieving and International Pipette Analysis

Textural studies were carried out by standard sieving and international pipette analysis technique. Known quantities of silt and clay rich soils were dispersed overnight in 0.025N solution of sodium hexametaphosphate. Using a 230 mesh (63µm) the coarse fraction was separated from the dispersed soil by wet sieving for pipette analysis. The filtrate containing the silt and clay fractions were carefullytransferred to a graduated 1 liter measuring jar and volume made up. The solution wasthen stirred thoroughly to obtain a homogenous suspension. A 20 ml of the filtrate was pipette out into previously weighed 50 ml beaker at fixed time intervals from depths. The aliquots were oven dried and weighed accurately after cooling at room temperature. Dry sieving was carried out on sand fraction to complete the analysis.Dry sieving was undertaken at 1/2 ϕ interval using Ro tap sieve shaker for 15 minutes.

Cumulative Frequency Curve

Grain size is plotted on the horizontal axis and cumulative weight is plotted on the vertical axis with a scale running from 0 - 100%. The curve may be drawn usingan arithmetic ordinate scale from this cumulative curve, using Folk‟s formulae. The various size parameters such as mean grain size, standard deviation, skewness and kurtosis have been calculated. From the cumulative frequency curve the values of 5, 16, 25, 50, 75, 84 and 95 percentiles were recorded.

Statistical Parameter

Mainly four-grain size parameters are used to describe the grain size distribution. They are mean grain size, standard deviation, skewness and kurtosis. Median and mode are also used.

Mean Size

Mean is the statistical average expressed in Phi (ϕ) unit.

$$Mz\phi = \frac{\phi 16 + \phi 50 + \phi 84}{3}$$

Standard Deviation

Standard deviation is the measure of sorting. It is the one of the most useful parameter for separating grains.

$$SK = \frac{(\varphi 84 - \varphi 16)}{4.4} + \frac{(\varphi 95 - \varphi 5)}{6.6}$$

According to Folk and Ward the divisional points based on standard deviation are given below:

Standard Deviation (ϕ)	Sorting
<0.35	Very well sorted
0.35 - 0.50	Well sorted
0.50 - 0.71	Moderately well sorted
0.71 - 1	Moderately sorted
1 - 2	Poorly sorted
2 - 4	Very poorly sorted
>4	Extremely poorly sorted

Skewness

The asymmetry of the grain size distribution in a sediment sample is measured by skewness. The skewness index by Folk and Ward is the best skewness measure, as it covers the full curve. The limits of Folk and Ward are,Sign of skewness is related to the environmental energy. Negative skewness is correlated with high energy andwinnowing action (removal of fines) and positive / fines skewness with low energy levels [48]

Skewness value	**Type of skewness**
1 - 0.3	Very fine skewed
0.3 - 0.1	Finely skewed
0.1 - 0.10	Nearly symmetrical
-0.10 - -0.30	Coarse skewed
-0.30 - -1	Very coarse skewed

$$SK = \frac{(\phi16 - \phi84) - 2\,\phi50}{2(\phi84 - \phi15)} + \frac{(\phi5+\phi95) - 2\phi50}{2(\phi95 - \phi5)}$$

Kurtosis

It is the measure of the contrast between sorting observed in the central part ofthe particle size distribution with that of tails. At present the degree to which the particles one concentrated near the centre of the curve. Many curves designated as "normal" by the skewness measure turn out to be markedly non -normal when the kurtosis is computed.

$$\text{Kurtosis} = \frac{\phi95 - \phi5}{2.44(\phi75 - \phi25)}$$

The limits of Folk and Ward are,

Kurtosis value	**Type of Kurtosis**
<0.67	Very platy kurtic
0.67 - 0.90	Platy kurtic
0.90 - 1.11	Meso kurtic
1.11 - 1.50	Lepto kurtic
1.5 - 3	Very Lepto kurtic
<3	Extremely Lepto kurtic

Geochemistry

Laboratory Procedure

The soil samples collected from different stations of Periyar River Basin were brought into the laboratory and they were safely kept for various analysis. Cone and quartering is used to create homogeneity and reduce the sample size. Small stones, roots and other unwanted materials are removed from the sample by handpicking. Then the soil sample was powdered using agate mortar and transferred into a Petridish and dried at 75°C in a hot air oven. After drying, all soil samples were kept in desiccators and then transferred into well labeled air tight covers which in turns used for further geochemical analysis.

XRF Analysis (XRF)

X-ray fluorescence (XRF) spectrometry is an elemental analysis techniquewith broad application in science and industry. Modern XRF instruments are capable of analyzing solid, liquid and thin-film samples of both major and trace (ppm-level) components. The analysis is rapid and sample preparation is minimal XRF is based onthe principle of individual atoms, when exited by an external energy source; emit X- ray photos of characteristics energy of wavelength. By counting the number of photons of energy emitted from a sample. The elements present may be identified andquantifies.

For determining trace metals, around 6 grams of powdered soil samples were taken and sieved in a 230 mesh. It is then taken in a previously weighed cleaned crucible and dried. The weight of crucible with sample was taken before and after drying. And then keep it in a muffle furnace for 900°C and cooled. Again, take the weight and find out loss of ignition values is also given to XRF laboratory for the analysis of trace metals.

Sample Preparation Methods

Pressed pellets are prepared using 40mm aluminium cups filled with boric acid crystals as binder. Finely powdered sample is sprinkled over boric acid and pressed in a 40-ton hydraulic press to produce a circular 40mm disk .the pressed powdered pellets allow trace element determinations with limits of detection up from 1ppm .the elements determined in lab are K,Ca,Ti,V,Cr,Mn,Fe,Ni,Cu,Zn,Rb, Sr,Y,Nb,Ba,Ce,Pb, Th. Light elements like Si,, Al, Mg and Na are less precise by thismethod.

Pollution Load Index (PLI)

The level of contamination of soils by a metal is often expressed in terms of a contamination factor mm calculated as

CF = Metal concentration in the sediment/Background value of the metal

Where Cf< 1 refers to low contamination,

1 ≤ Cf ≤ 3 means moderate contamination,

3 ≤ Cf ≤ 6 indicates considerable contamination, and

Cf > 6 indicates very high contamination.

Pollution load index (PLI),

For particular sites, has been evaluated following the method. This parameter isexpressed as: PLI = (Cf1 x Cf2 x Cf3 x…..x Cfn) Where n is the number of metals and Cf is the contamination factor [50]

Geo Accumulation Index

Geo accumulation index (Igeo), introduced for determining the extent of metal accumulation in soil, and has been used by various workers in their studies. Igeo = log2 Cn/1.5 Bn Cn is the concentration of element in „n‟ and Bn is the geochemical background value. Factor 1.5 is used because of possible variations in background values for a given metal in the environment or a small anthropogenic influence. It consists of seven grades (0-6 ranging from unpolluted to moderately polluted [51-53].Igeo ≤ 0 (grade 0), unpolluted;

0< Igeo ≤1 (grade 1), slightly polluted;

1< Igeo ≤ 2 (grade 2), moderately polluted;

2<Igeo (grade 3), moderately severely polluted

3<Igeo ≤4 (grade 4), severely polluted;

4< Igeo ≤5 (grade 5), severely extremely polluted;

Igeo > 5 (grade 6), extremely polluted.

Chemical Index of Alteration

Nesbitt and Young developed the chemical index of alteration. CIA is interpreted as measure of the extent of conversion of Feldspar to clays such as Koalinite. It has been used in numerous paleosol studies [54-55]. Formula forcalculating CIA as;

$$CIA = \{Al_2O_3 / (Al_2O_3 + CaO^* + Na_2O + K_2O)\} \times 100$$

Crustal Enrichment Factor

The extent of soil contamination was assessed using enrichment factor (EFc) EFc was used in the study to assess the relative contribution of natural and anthropogenic heavy metal inputs to the soil [56-57].

The Crustal Enrichment Factor (EFc) of element can be calculated using the equation

$$EF= \{(Me/Fe\text{-sample}) \} / \{(Me/Fe\text{-background})\}$$

Where sample (Cx/Cal) is the ratio of the concentration of the test element to that of Al and (Cx/CAl) continental crust is the same ratio with respect to reference soil. Taylor and McLennan's continental crust values was used as reference soil and Al was used as the crustal reference soil and Al was used as the crustal reference elements in the EFc calculations. Al can be easily calculated and it is one of thelargest components of the soil, so it was used as the Crustal reference element in the EFc calculations. Five contamination categories are recognized on the basis of the enrichment factor.

EFc<2 deficiency to minimal enrichment

EFc=2-5 moderate enrichment

EFc=5-20 significant enrichment

EFc=20-40 very high enrichment

Table 3.1: Sampling locations of Periyar River basin

Sr. No.	Map code	Location name
1	So1	Ayappan Kovil
2	So2	Kanchiyar
3	So3	Anavilasam
4	So4	Periyar tiger reserve
5	So5	Gramby estate
6	So6	6 mile kumuly
7	So7	Kattapana
8	So8	Narakkakam
9	So9	Manippzra
10	So10	Kallarkutty
11	So11	Audit
12	So12	Mallakanam
13	So13	kattaparachal/kurishadi
14	So14	Alungaljunction, eloor north
15	So15	Cheranellor
16	So16	Kadupadam
17	So17	Thadikadavu palam
18	So18	Parapullikavu regulator bridge
19	So19	Manjali palam
20	So20	Gothuruth
21	So21	Janmamkulangara badrakali temple
22	So22	Neleeswaram
23	So23	Shiva temple,vallam.opp dfo
24	So24	Abhayaranyam ecotourism, kaprikad
25	So25	Alattuchira pumping station
26	So26	Payyal
27	So27	Peninsular woods, Bhoothathankettu
28	So28	Kalakadavu ecopoint
29	So29	Shandhi sadhan, injathotti
30	So30	Dewdrops

Chapter 4 Result and Discussion

Texture

Table 4.1: The sand, silt, clay percentage of Periyar River basin soils

Sample Name	Sand %	Slit %	Clay %
SO 1	17.304	40.016	42.680
SO 2	36.039	16.018	47.944
SO 3	35.381	39.047	25.573
SO 4	30.851	13.259	55.89
SO 5	37.338	44.972	17.690
SO 6	56.718	11.229	32.053
SO 7	54.525	19.596	25.878
SO 8	44.659	12.587	42.755
SO 9	48.027	15.870	36.103
SO 10	43.685	20.915	35.401
SO 11	39.189	36.899	23.913
SO 12	32.785	44.162	23.053
SO 13	60.496	4.867	34.637
SO 14	34.958	9.271	55.770
SO 15	44.481	13.740	41.779
SO 16	57.260	35.240	7.500
SO 17	62.334	14.058	23.608
SO 18	34.643	32.427	32.930
SO 19	27.900	58.010	14.089
SO 20	54.717	15.954	29.329
SO 21	61.691	10.914	27.395
SO 22	34.652	26.446	38.902
SO 23	71.701	9.513	18.786
SO 24	35.663	57.112	7.225
SO 25	79.913	7.531	12.556
SO 26	86.100	2.888	11.013
SO 27	58.381	32.510	9.109
SO 28	30.339	54.917	14.744
SO 29	83.542	2.869	13.589
SO 30	88.182	2.278	9.540

The sand, silt and clay content of the soils of Periyar River vary from 17.304 % to 88.182 %, 2.278 % to 58.010 %, and 7.225 % to 47.944 %, (Table 4.1) respectively. Sandy clay loam is the dominant textural faces of soil. According to the ternary plot of Folk and Ward there are 8 varieties of soils were observed (Fig 4.5), 20 % of sandy clay loam is observed from this diagram, 13.33% of clay, 13.33% of sandy loam, 13.33% of loam, 10% of loamy sand, and 10% of silt loam, 10% of clay loam,10% of sandy clay [48] (Table 4.2).

Sandy loam clay is the dominant textural facies of the bed soil. From the ternary plot of Folk and Ward eight varieties of soils are observed (Fig. 4.5), sandyclay loam is 20%, Based on this textural triangle classification sandy clay loam>sandyloam, loam, clay>loamy sand, silt loam, clay loam, sandy clay. Because of the prevailing energy condition a major part of the finer clay fraction of soil and sediments are washed away and carried in suspension, whereas the entire sand fraction is transported and deposited along the river bed. The bed samples of the upstream part of the river, up to the foot hills part contains a large fraction of gravel [58-63].

Statistical Parameters:

The pattern of variation of the textural parameters along the river is presentedin table 4.1.2

Mean Size (Mz):

The mean size of the studied samples varies from 1.16 – 7.20ϕ with an average value of 4.40ϕ. The average value reflects that, the medium size sand particles are more. The fluctuation in mean value shows that, the variation in energy will affect the soil particle.

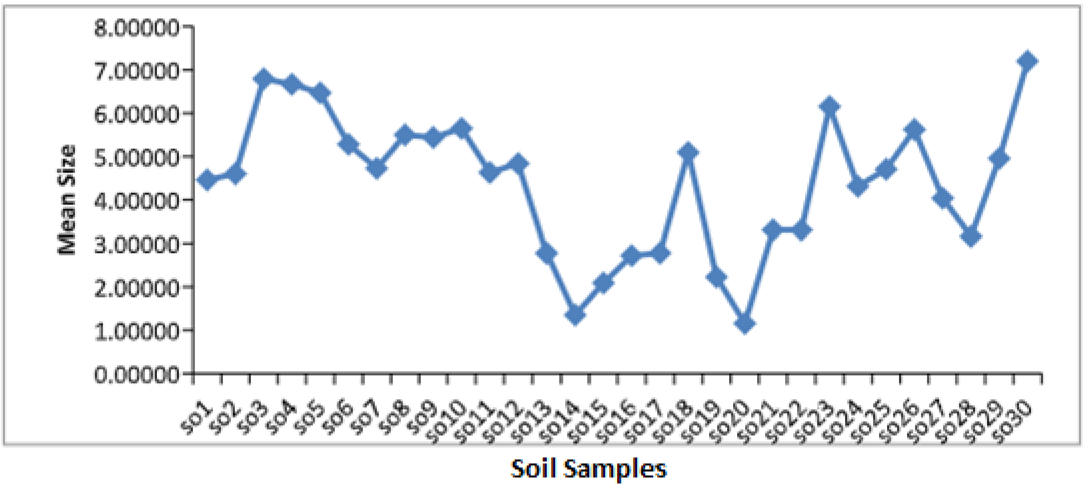

Figure 4.1: Graphical representation of mean size of soil samples for Periyar River basin

Standard Deviation (σ1):

The values of standard deviation in the soil samples range between 2.36% - 4.91%, with an average of 4.03% (Table 4.1). According to the Folks and Wards, the divisional points based on standard deviation in comparison with the obtained results shows that, the soil particles are very poorly sorted.

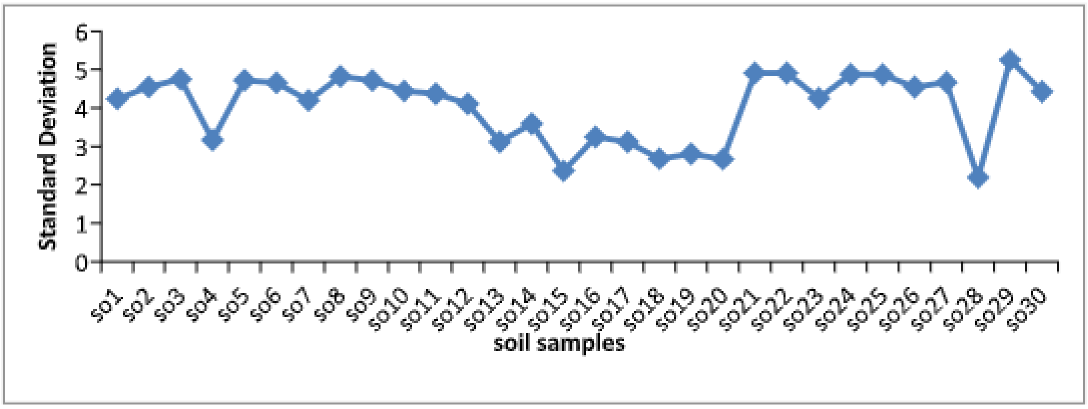

Figure 4.2: Graphical representation of standard deviation of size of soil samples for Periyar River basin

Skewness (SK):

The Skewness value ranges in between -0.63% to 0.57% (very finely skewed to fine skewed) with an average of 0.17%. The presence of fine skewed soil represents excessive riverine deposits. Positive skewed soil shows deposition of soil at lower energy, in the case of negative skewed soils deposition will be at higher energy areas.

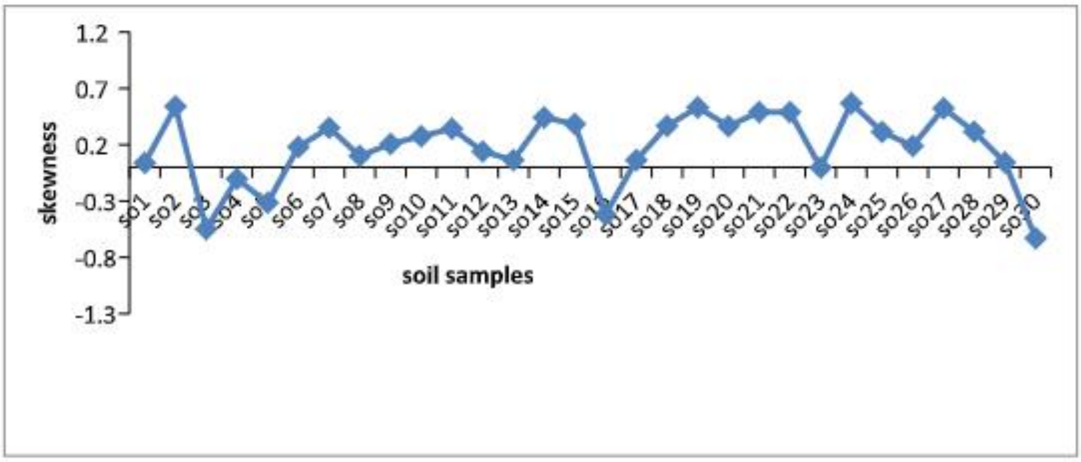

Figure 4.3: Graphical representation of skewness of soil samples from Periyar River basin

Kurtosis (KG):

The value of graphic kurtosis ranges from 0.487% to 1.411%, with an average of 1.008%. During the present study, most of the soil samples will include in very leptokurtic type, which shows that, the soil and sediments are from thesame source.

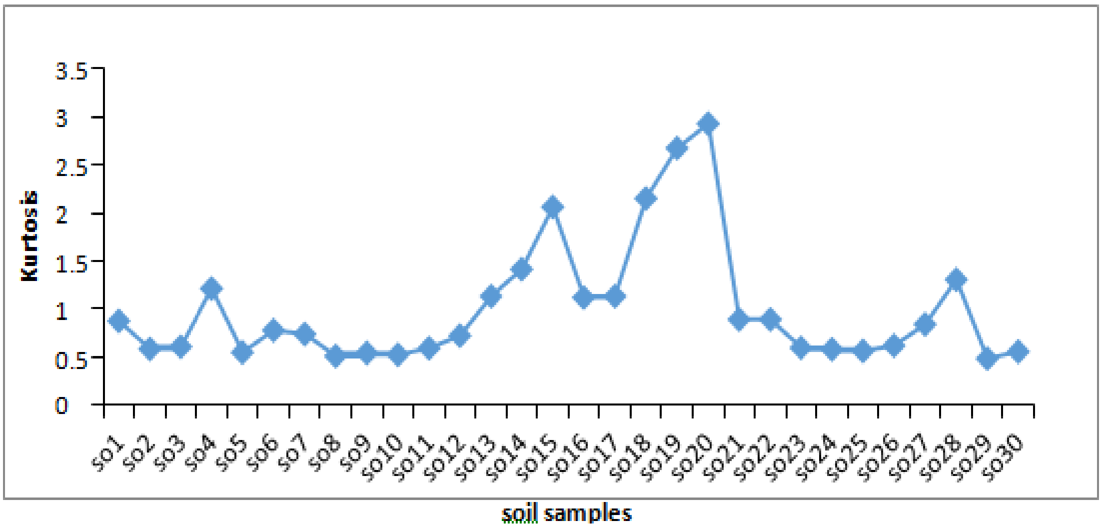

Figure 4.4: Graphical representation of kurtosis of soil samples from Periyar River basin

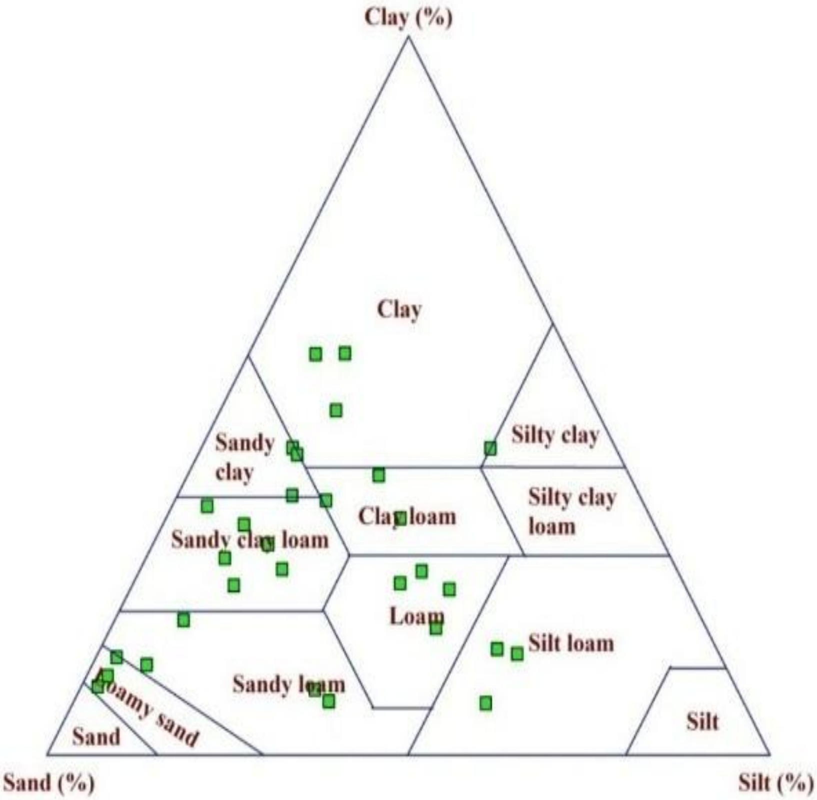

Figure 4.5: Textural Nomenclature of soil samples from Periyar River basin

Table 4.2: Showing the textural parameters of Periyar River basin

Sample Number	Mean		Standard Deviation		Skewness		Kurtosis	
	phi	Description	phi	Description	phi	Description	Phi	Description
So 1	4.46	Very Coarse Silt	4.24	Extremely Poorly Sorted	0.04	Symmetrical	0.879	Platykurtic
So 2	4.60	Very Coarse Silt	4.55	Extremely Poorly Sorted	0.54	Very Fine Skewed	0.588	Very Platykurtic
So 3	6.79	Medium Silt	4.75	Extremely Poorly Sorted	-0.55	Very Coarse Skewed	0.611	Very Platykurtic
So 4	6.67	Medium Silt	3.17	Very Poorly Sorted	- 0.10	Coarse Skewed	1.216	Leptokurtic
So 5	6.47	Medium Silt	4.72	Extremely Poorly Sorted	-0.32	Very Coarse Skewed	0.552	Very Platykurtic
So 6	5.28	Coarse Silt	4.65	Extremely Poorly Sorted	0.18	Fine Skewed	0.781	Platykurtic
So 7	4.73	Very Coarse Silt	4.19	Extremely Poorly Sorted	0.35	Very Fine Skewed	0.742	Platykurtic
So 8	5.50	Coarse Silt	4.82	Extremely Poorly Sorted	0.10	Symmetrical	0.513	Very Platykurtic
So 9	5.44	Coarse Silt	4.71	Extremely Poorly Sorted	0.21	Fine Skewed	0.547	Very Platykurtic
So 10	5.65	Coarse Silt	4.44	Extremely Poorly Sorted	0.28	Fine Skewed	0.528	Very Platykurtic
So 11	4.63	Very Coarse Silt	4.37	Extremely Poorly Sorted	0.34	Very Fine Skewed	0.597	Very Platykurtic
So 12	4.84	Very Coarse Silt	4.11	Extremely Poorly Sorted	0.14	Fine Skewed	0.726	Platykurtic
So 13	2.78	Fine Sand	3.12	Very Poorly Sorted	0.06	Symmetrical	1.135	Leptokurtic
So 14	1.35	Medium Sand	3.59	Very Poorly Sorted	0.44	Very Fine Skewed	1.415	Leptokurtic
So 15	2.09	Fine Sand	2.36	Very Poorly Sorted	0.38	Very Fine Skewed	2.062	Very Leptokurtic

So 16	2.72	Fine Sand	3.25	Very Poorly Sorted	-0.42	Very Coarse Skewed	1.122	Leptokurtic
So 17	2.78	Fine Sand	3.12	Very PoorlySorted	0.06	Symmetrical	1.135	Leptokurtic
So 18	5.09	Coarse Silt	2.68	Very Poorly Sorted	0.37	Very Fine Skewed	2.152	Very Leptokurtic
So 19	2.23	Fine Sand	2.81	Very PoorlySorted	0.53	Very FineSkewed	2.673	Very Leptokurtic
So 20	1.16	Medium Sand	2.67	Very Poorly Sorted	0.37	Very Fine Skewed	2.928	Very Leptokurtic
So 21	3.31	Very FineSand	4.91	Extremely Poorly Sorted	0.49	Very FineSkewed	0.893	Platykurtic
So 22	3.31	Very Fine Sand	4.91	Extremely Poorly Sorted	0.49	Very Fine Skewed	0.893	Platykurtic
So 23	6.16	Medium Silt	4.25	Extremely Poorly Sorted	0.00	Symmetrical	0.600	Very Platykurtic
So 24	4.31	Very Coarse Silt	4.87	Extremely Poorly Sorted	0.57	Very Fine Skewed	0.583	Very Platykurtic
So 25	4.71	Very Coarse Silt	4.87	Extremely Poorly Sorted	0.31	Very Fine Skewed	0.567	Very Platykurtic
So 26	5.62	Coarse Silt	4.54	Extremely Poorly Sorted	0.19	Fine Skewed	0.621	Very Platykurtic
So 27	4.04	Very Coarse Silt	4.67	Extremely Poorly Sorted	0.52	Very Fine Skewed	0.843	Platykurtic
So 28	3.16	Very Fine Sand	2.19	Very Poorly Sorted	0.32	Very Fine Skewed	1.309	Leptokurtic
So 29	4.96	Very Coarse Silt	5.25	Extremely Poorly Sorted	0.04	Symmetrical	0.487	Very Platykurtic
So 30	7.20	Fine Silt	4.42	Extremely Poorly Sorted	-0.63	Very Coarse Skewed	0.560	Very Platykurtic

Table 4.3: Textural terminology of Periyar River Soils

Sample Name	Sample Name	Sand %	Slit %	Clay %	Soil Types
SO 1	mps 8	17.304	40.016	42.680	Clay
SO 2	mps 9	36.039	16.018	47.944	Clay
SO 3	mps 11	35.381	39.047	25.573	Loam
SO 4	mps 6	30.851	13.259	55.89	Clay
SO 5	mps 1	37.338	44.972	17.690	Loam
SO 6	mps 3	56.718	11.229	32.053	sandy clay loam
SO 7	mps 12	54.525	19.596	25.878	sandy clay loam
SO 8	mps 13	44.659	12.587	42.755	sandy clay
SO 9	mps 15	48.027	15.870	36.103	sandy clay
SO 10	mps 16	43.685	20.915	35.401	clay loam
SO 11	mps 22	39.189	36.899	23.913	Loam
SO 12	mps 24	32.785	44.162	23.053	Loam
SO 13	mps 21	60.496	4.867	34.637	sandy clay loam
SO 14	PRA 92	34.958	9.271	55.770	clay
SO 15	PRA 79	44.481	13.740	41.779	sandy clay
SO 16	PRA 76	57.260	35.240	7.500	sandy clay
SO 17	PRA 66	62.334	14.058	23.608	sandy clay loam
SO 18	PRA 63	34.643	32.427	32.930	clay loam
SO 19	PRA 57	27.900	58.010	14.089	silt loam
SO 20	PRA 58	54.717	15.954	29.329	sandy clay loam
SO 21	PRA 56	61.691	10.914	27.395	sandy clay loam
SO 22	PRA 52	34.652	26.446	38.902	clay loam
SO 23	PRA 43	71.701	9.513	18.786	sandy loam
SO 24	PRA 21	35.663	57.112	7.225	silt loam
SO 25	PRA 8	79.913	7.531	12.556	sandy loam
SO 26	PRA 13	86.100	2.888	11.013	loamy sand
SO 27	PRA 24	58.381	32.510	9.109	sandy loam
SO 28	PRA 28	30.339	54.917	14.744	loamy sand
SO 29	PRA 30	83.542	2.869	13.589	silt loam
SO 30	PRA 32	88.182	2.278	9.540	loamy sand

Geochemistry of Major Element

Table 4.4: Major elemental concentration in the soil samples of Periyar River basin

Samples	Na	K	Ca	Mg	Fe	Mn	Si	Ti	Al	P
S0 1	0.282	0.872	0.586	0.464	5.295	0.025	27.051	0.492	10.887	0.074
S0 2	0.156	0.506	0.436	0.271	6.617	0.032	24.700	0.606	11.051	0.127
S0 3	0.527	2.632	0.879	0.724	4.763	0.063	27.944	0.528	8.330	0.166
S0 4	0.126	0.266	0.465	0.271	6.330	0.025	24.868	0.767	10.299	0.074
S0 5	0.185	1.295	0.515	0.615	8.610	0.088	18.791	0.731	12.379	0.118
S0 6	0.178	0.606	0.565	0.271	6.421	0.013	24.008	0.594	11.082	0.105
S0 7	1.016	3.337	1.308	0.905	3.350	0.019	28.808	0.402	9.304	0.118
S0 8	0.423	2.183	0.800	0.736	5.616	0.082	23.199	0.606	10.839	0.170
S0 9	0.608	1.635	0.822	0.887	6.421	0.032	25.111	0.486	11.125	0.109
S0 10	0.675	2.532	1.086	1.894	5.155	0.032	23.746	0.588	10.596	0.113
S0 11	0.675	2.457	0.908	1.110	4.791	0.051	25.728	0.498	9.648	0.135
S0 12	0.134	0.598	0.450	0.428	9.778	0.044	15.556	0.869	14.459	0.113
S0 13	0.104	0.573	0.393	0.344	7.659	0.019	21.362	0.713	13.263	0.096
S0 14	0.942	1.337	1.529	0.416	2.973	0.019	32.940	0.414	6.176	0.144
S0 15	1.402	1.976	2.008	0.495	2.574	0.013	32.305	0.342	6.102	0.166
S0 16	0.527	0.905	0.836	0.259	4.099	0.013	32.445	0.426	6.848	0.109
S0 17	0.972	2.059	1.244	0.796	4.756	0.013	28.509	0.498	9.188	0.105
S0 18	0.979	2.640	1.294	1.502	5.393	0.044	25.256	0.588	10.484	0.144
S0 19	1.335	2.490	1.394	0.712	2.833	0.013	32.207	0.438	7.462	0.105
S0 20	0.987	1.868	1.108	0.314	2.595	0.006	34.483	0.384	6.145	0.083
S0 21	0.668	1.378	0.901	0.495	6.050	0.013	28.364	0.504	8.955	0.105
S0 22	0.727	1.345	0.893	0.398	6.875	0.013	27.668	0.516	8.987	0.166
S0 23	0.890	2.681	1.658	1.037	4.735	0.076	25.027	0.546	10.993	0.170
S0 24	0.326	1.096	0.658	0.495	8.589	0.013	20.731	0.695	13.199	0.166
S0 25	0.527	1.328	0.951	0.784	7.792	0.057	23.241	0.671	10.506	0.135
S0 26	0.371	0.897	0.693	0.428	6.197	0.006	22.708	0.546	12.792	0.205
S0 27	0.490	0.980	1.001	0.482	6.589	0.019	24.054	0.641	12.019	0.131
S0 28	1.291	2.607	1.422	0.965	4.155	0.025	28.383	0.707	8.743	0.087
S0 29	0.237	1.204	0.372	0.476	11.044	0.051	18.889	1.049	12.390	0.118
S0 30	0.111	0.531	0.257	0.247	11.827	0.000	13.934	1.127	16.327	0.170
Avg	0.59	1.56	0.91	0.64	5.99	0.03	25.4	0.59	10.35	3.82

Table 4.5: World average Shale Value for major elements

Elements	Na	K	Ca	Mg	Fe	Mn	Si	Ti	Al	P
Shale Value	0.59	2.66	1.6	1.5	4.72	0.085	27.5	0.46	8.8	0.07

A. Sodium

During the present study, it was found that, the amount of sodium ranges from 0.104 % to 1.402 % with an average of 0.59 % (Table 4.4), which is same when compared with word average shale value. The accumulation of sodium in the soil mayoccur due to different reasons. The spreading of seawater over the arid areas where salts can deposits due to evaporation from the water resource, which generally hold large amount of sodium. The anthropogenic activities also increase the amount of sodium in water. Weathering of rocks is also another major reason of sodium accumulation

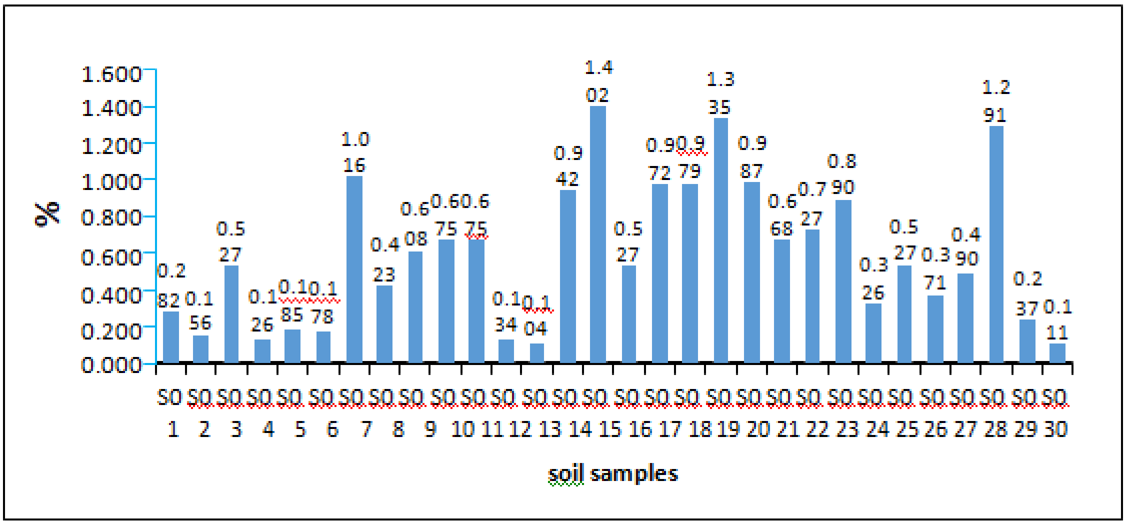

Figure 4.6: Graphical representation of variation of Sodium in the soil samples of Periyar River basin

B. Potassium

During the present study, the potassium value varies from 0.266 % to 2.681% with an average of 0.12% (Table 4.4). In comparison with world average shale value, the amount of potassium is lower in Periyar River basin. Potassium is the most important fertilizer element after nitrogen and phosphorous. The concentration of potassium in the soil solution is very low but it can replenish by diffusion of potassium in between the sheets of the clay minerals [69]. The variation of potassium is represented in the (fig. 4.7).

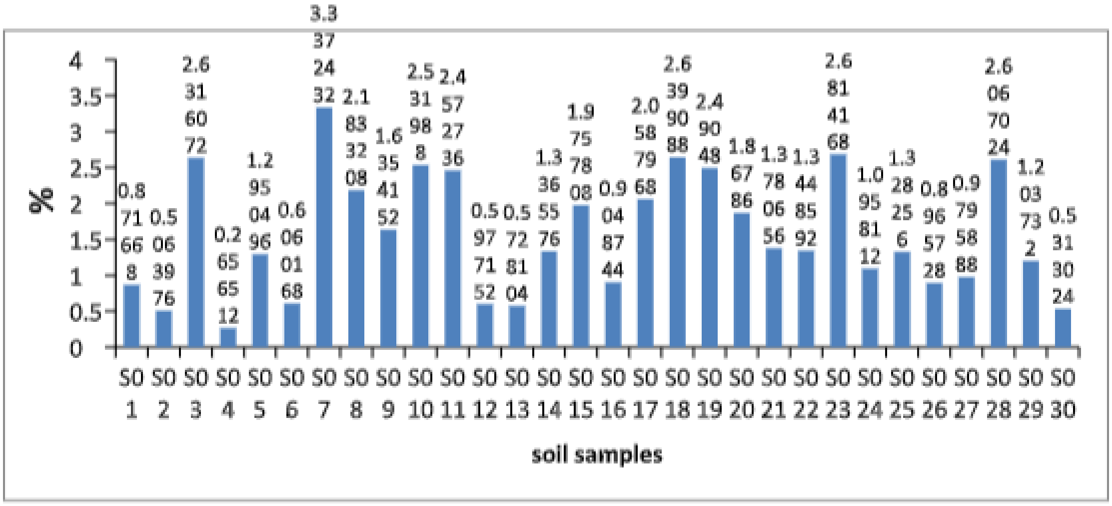

Figure 4.7: Graphical representation of variation of Potassium in the soil samples of Periyar River basin

C. Calcium

In the present study, the concentration of calcium varies from 0.257% to 1.658% with an average of 0.91% (Table 4.4), which is lower concentration in Periyar River basin when compared with world average shale value. High amount of calcium shows a near-neutral pH, it is very important for the most of the living organisms (fig. 4.8).

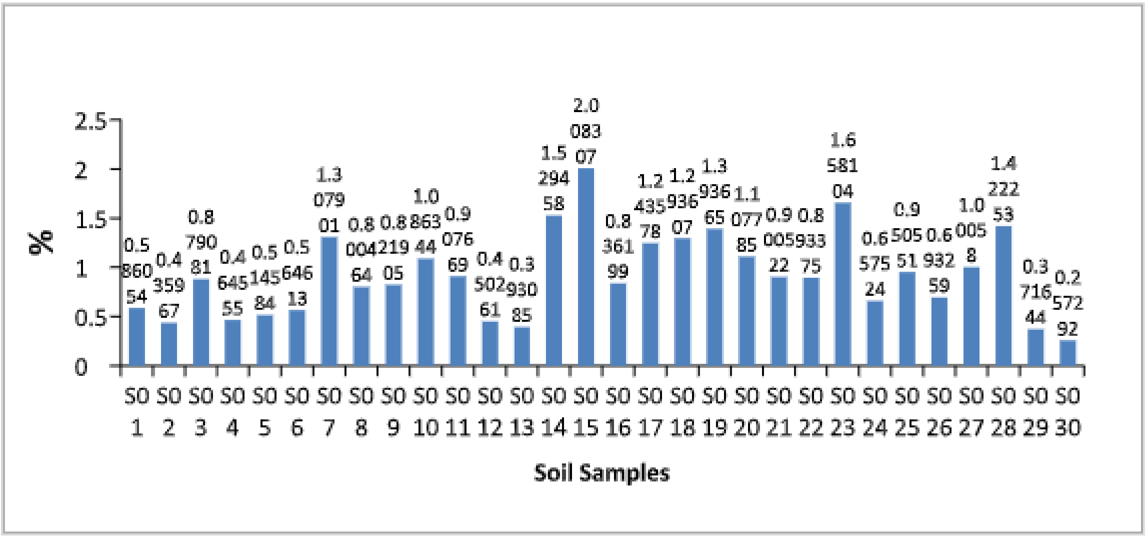

Figure 4.8: Graphical representation of variation of Calcium in the soils of Periyar River basin

D. Magnesium:

The Magnesium value in the present study area varies from 0.247% to 1.894% with an average of 0.64 % (Table 4.4). In comparison with world average shale value, the sample has lower values of Magnesium. The high values may be due to the application of dolomite for maintaining a suitable pH for the crops. Soils with high cation exchange capacity have high Mg concentration [71]. The variation of Magnesium is represented in Fig 4.9.

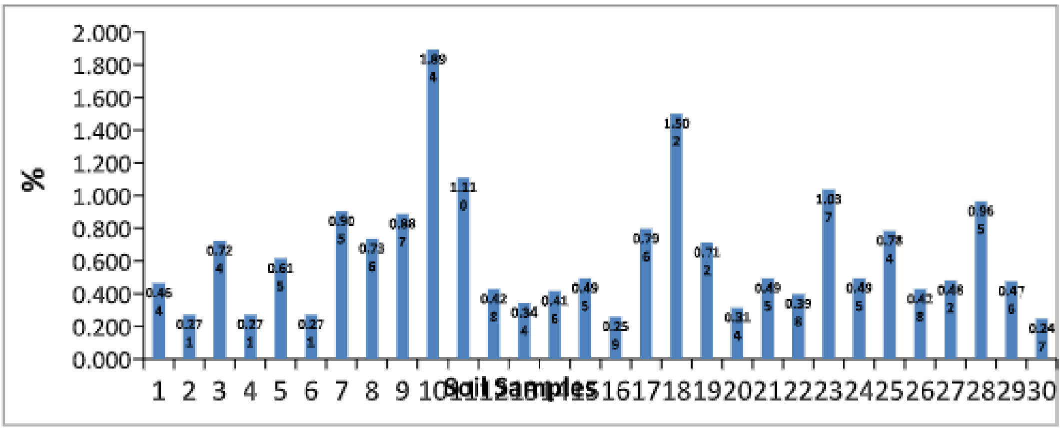

Figure 4.9: Graphical representation of variation of Magnesium in the soil samplesof Periyar River basin

E. Iron:

The distribution of Iron in the soil samples varies from 2.574 % to11.827 % with an average 5.99 % (table 4.4, fig 4.10). Iron contents of the Periyar River basin suggest that, most of the samples have high concentration of iron. The main reason forincreased Iron content in the present study area may be due to the lower temperature, high rainfall and coarse texture of the soil, high pH range, lack of proper nutrients andsalt content. The agrochemical pollution in the catchment area of river and anthropogenic factors leads to the high concentration of Iron [72].

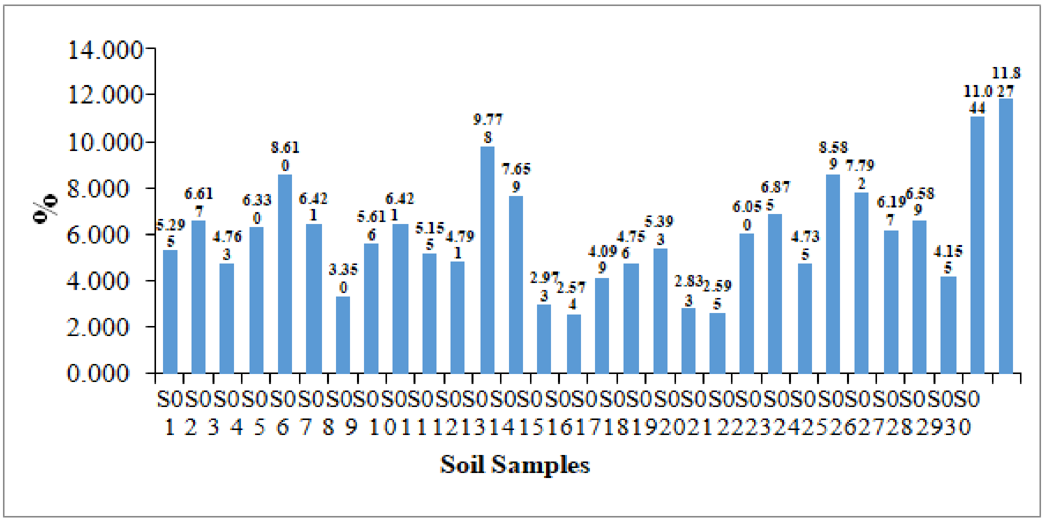

Figure 4.10: Graphical representation of variation of Iron in the study area

F. Mangenese:

In soil samples collected from Periyar River basin, the Mn concentration rangesfrom 0 % to 0.088 % with an average of 0.0305% (Table 4.4, fig 4.11). Only a fewsoil samples show values higher than average shale value. Mn oxides present in the soils perform a wide range of oxidation-reduction and cation–exchange reactions. The dark colour of the soil reflects the presence of manganese in the soil. In plantsManganese activate many enzyme reactions, it also involved in photosynthesis [73].

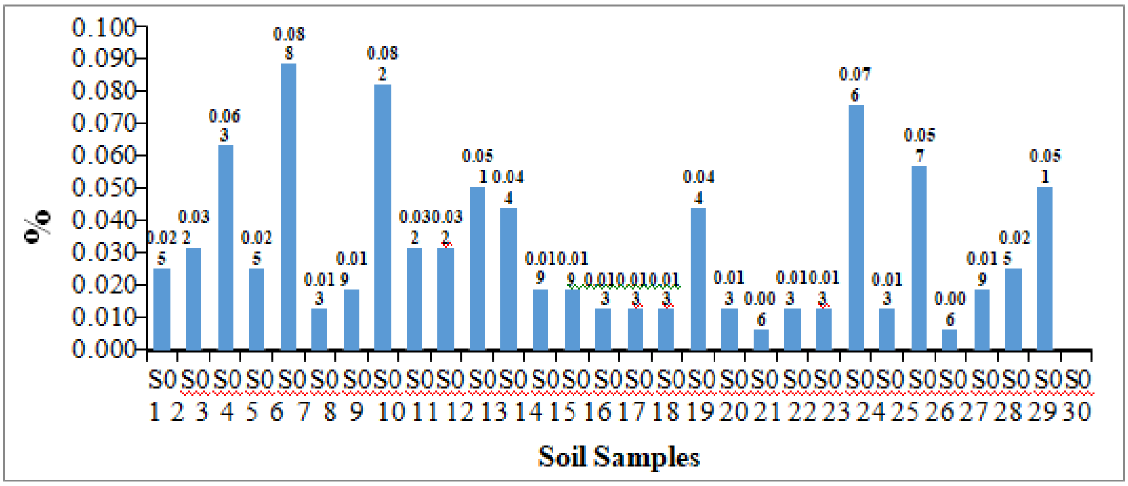

Figure 4.11: Graphical representation of variation of Manganese in the study area

G. Silica:

In the collected soil samples, the silicon value varies from 13.934 % to 34.483 %with an average value of 25.40 % (Table 4.4). The concentration of silicon in the Periyar River basin is within the range when compared with world average shale value [74]. The variation silicon is represented in the fig (4.12).

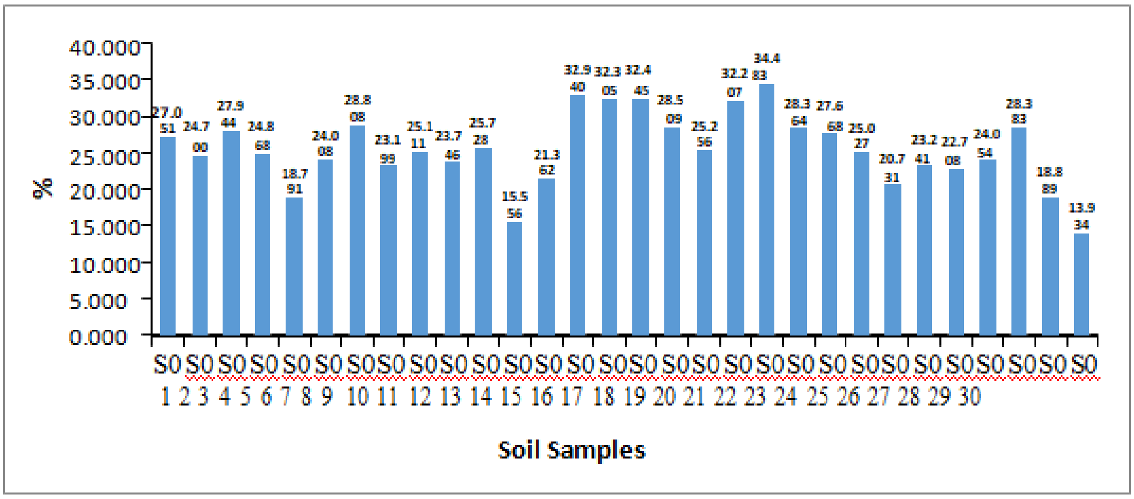

Figure 4.12: Graphical representation of Variation of Silica in the study area

H. Titanium:

The concentration of Titanium in the present study ranges between 0.342 % to 1.127 % with an average of 0.59 %. The Titanium content in the some samples of Periyar River basin were found within the permissible limit, but in most of the places titanium amount was found to be higher than the world average shale value [75]. The variation of Titanium is represented in the figure 4.13.

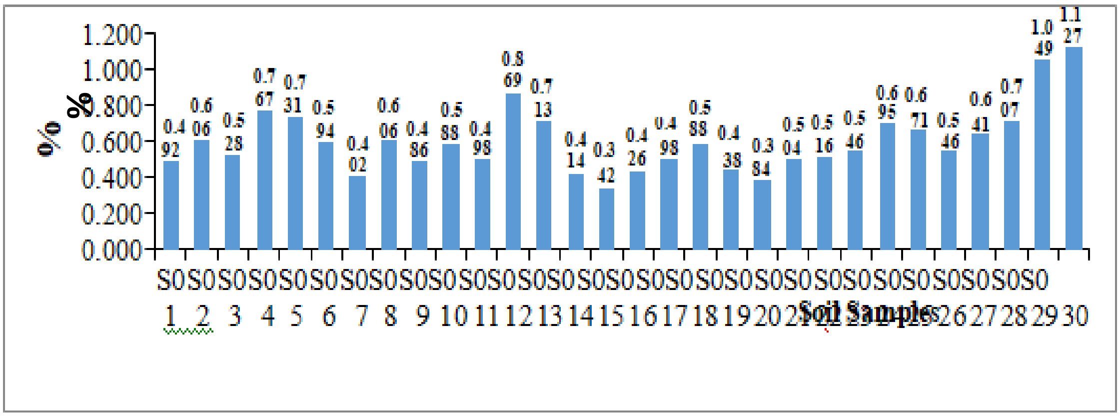

Figure 4.13: Graphical representation of variation of Titanium in the study area

I. Aluminium:

Aluminium concentration in the present study area of Periyar River basin ranges from 6.10 % to 16.32 % with an average of 10.35 % (Table 4.4, fig 4.14). Most of the samples show large deviation when compared with world average shale value. From the present study, it was found that, the majority of the soil samples of the Periyar River basin consists high Aluminium content than normal soils, which occuron up to 40% of the arable lands of the world [73].

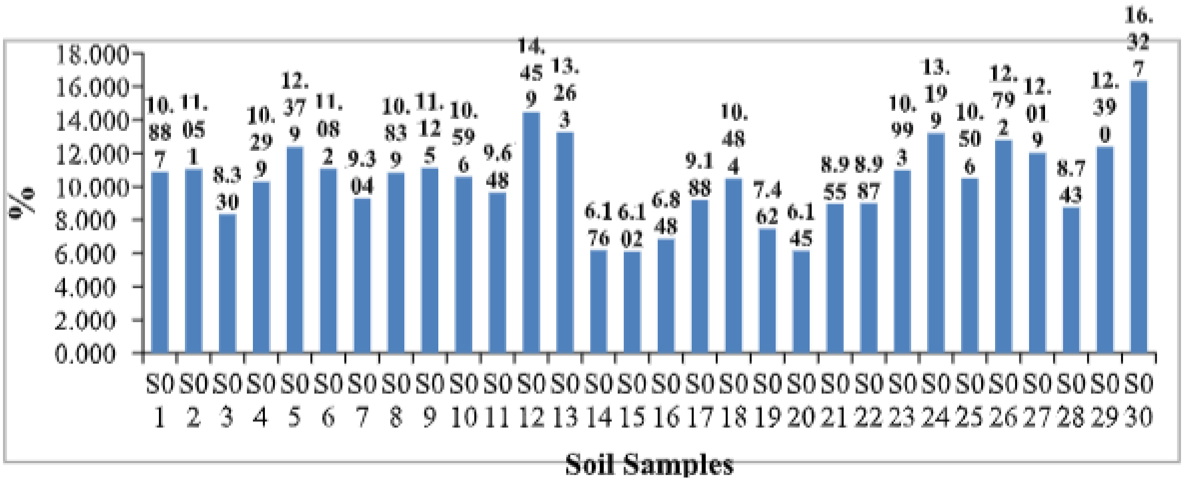

Figure 4.14: Graphical representation of variation of Aluminium in the study area

J. Phosphorous:

Phosphorous content in the present study area varies from 0.074 % to 0.170% with an average value of 0.12758 % (Table 4.4). When compared with the world average shale value, the phosphorous shows higher concentration in the study area Fig. 4.15.

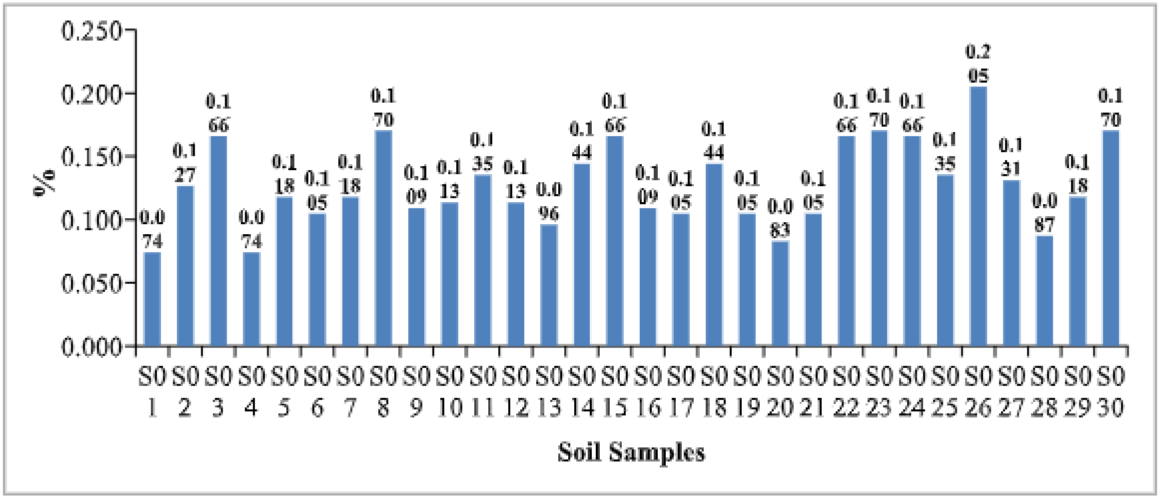

Figure 4.15: Graphical representation of variation of Phosphorus in the study area

Elemental Concentration of Minor Elements

1. Vanadium

Vanadium concentration in Periyar River basin ranges from 66 to 438 ppm with an average of 190.83 ppm (Table 4.6, fig 4.16). Comparing with world average shale value, the Vanadium concentration is higher in the present study area. Soil erosion and leaching from the rocks are the major source of vanadium to water body [76]. The variation of vanadium in the present study area is shown in the figure 4.2.11.

2. Chromium

During the present study, the Chromium values in the soil samples vary from 50 to 313 ppm with an average of 151 ppm (Table 4.6, fig 4.16). The averageconcentration of Cr in Periyar River soil is very high when compare to world average shale value. Chromium is commonly used in the industries as plating, alloying, inhibition of water corrosion, textile dyes, pigments etc. The increased anthropogenic action results in the environmental pollution by the Chromium [77].

Table 4.6: Elemental concentration of minor elements of Periyar River

Samples	V	Cr	Ni	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb	Ba	La	Ce
S0 1	153	203	101	106	98	27	69	101	22	741	9	399	55	110
S0 2	207	156	106	94	88	24	37	55	8	879	10	187	68	131
S0 3	146	108	57	119	97	17	125	226	25	835	9	1414	59	124
S0 4	233	127	94	80	59	22	29	51	10	821	12	251	82	159
S0 5	272	224	126	81	76	31	72	140	54	848	9	676	81	163
S0 6	201	129	78	108	100	27	55	93	16	698	10	320	70	139
S0 7	93	59	29	124	148	21	132	376	26	719	9	1389	43	96
S0 8	182	105	71	139	181	23	94	165	30	829	12	1106	82	149
S0 9	185	201	77	109	101	24	52	272	12	620	9	1070	58	58
S0 10	167	182	97	123	120	25	112	238	26	321	12	1145	53	74
S0 11	146	100	55	94	104	17	89	179	12	351	10	212	73	142
S0 12	334	218	143	74	78	38	45	77	27	709	13	291	102	201
S0 13	252	147	110	61	57	38	57	86	35	737	12	391	101	224
S0 14	87	73	26	51	318	11	46	199	0	998	9	681	0	63
S0 15	66	63	10	47	135	13	58	344	0	890	8	1057	0	38
S0 16	113	112	42	43	88	15	53	173	10	1521	8	500	0	56
S0 17	139	125	52	31	36	24	87	344	24	1223	9	1109	0	92
S0 18	175	131	75	42	93	28	99	320	30	1044	10	1456	0	141
S0 19	89	81	30	30	30	17	95	419	12	1335	10	1251	0	64
S0 20	74	69	23	26	13	11	59	317	0	728	9	1033	0	41
S0 21	171	155	47	31	39	15	48	176	2	1142	8	735	0	99
S0 22	193	284	51	36	63	15	42	148	0	847	8	724	0	114
S0 23	152	109	70	48	88	28	139	387	51	1758	10	1396	0	165
S0 24	267	181	99	58	47	33	50	284	21	1433	11	1171	0	244
S0 25	238	244	89	56	117	26	61	187	24	977	10	947	0	106
S0 26	188	165	71	43	71	28	35	132	0	836	10	464	0	97
S0 27	210	97	50	26	51	29	45	209	8	1262	12	616	0	67
S0 28	164	95	36	54	37	19	87	308	18	3210	11	1185	0	202
S0 29	390	274	104	103	47	25	42	100	22	1211	10	814	0	174
S0 30	438	313	51	22	33	52	34	53	16	1158	14	121	0	183

Table 4.7: World average shale value of minor elements

Elements	V	Cr	Ni	Cu	Ga	Rb	Sr	Y	Zn	Nb	Ba	La	Ca	Ce	Al
ShaleValue	130	90	50	45	39	140	170	26	160	11	580	43	43	82	8.8

3. Nickel

Nickel is commonly present in sulphide and laterite ores. The Nickel concentration in the present study area ranges from 10 to 143 ppm with an average of 69 ppm (Table 4.6, fig 4.16). The presence of Nickel is high in the present study area when compared with the world average shale value. Nickel is the 5th most elements onthe Earth. Nickel is one among metals which is widely distributed in the environment [78]

4. Copper

Copper concentration varies from 22 ppm to 139 ppm with an average content of 68.63 ppm (Table 4.6, Fig. 4.16). The average copper concentration is higher in the present study area when compare to world average shale value. The main reason of increased copper in soil is due to manmade activities, which includes industrial action and mining of the soil.

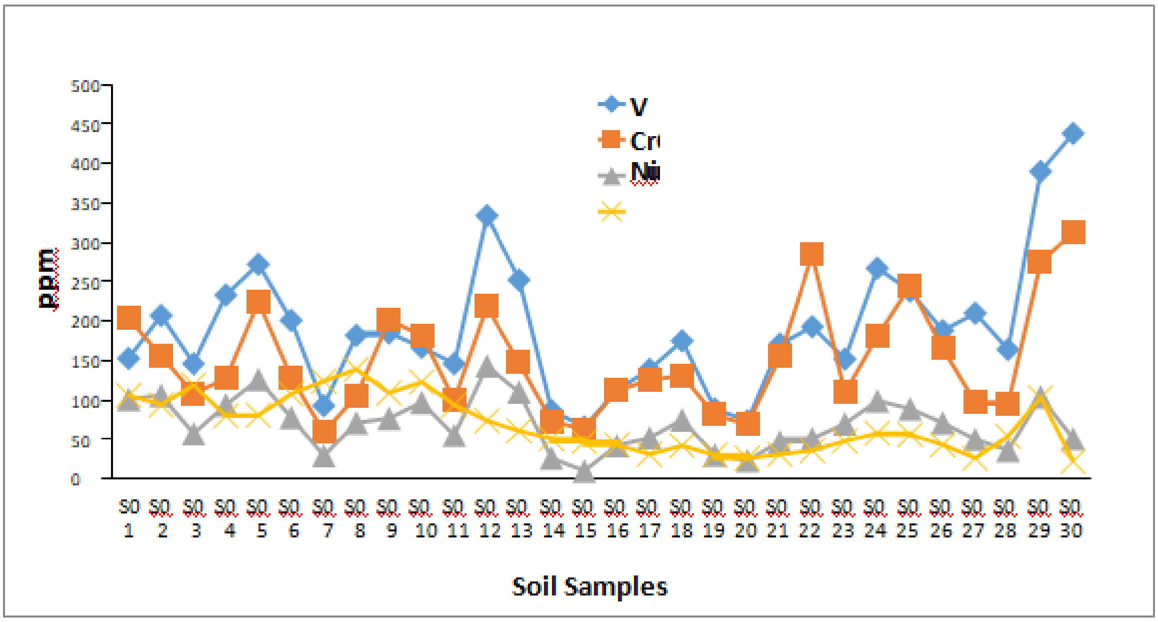

Figure 4.16: Graphical representation of variation of Copper, Nickel, Chromiumand Vanadium from the soils of Periyar River basin

5. Zinc

The Zn concentration varies from 33 to 318 ppm with an average content of 87.1 ppm (Table 4.6, fig 4.17). Comparing with the world average shale value, Zn shows less concentration in Periyar River soils.

6. Gallium

Gallium content in the present study area varies from 11 to 52 ppm with an average of 24.1 ppm (Table 4.6, Fig 4.17). The presence of Gallium in the Periyar River Basin is less when compared with world average shale value. Soils are susceptible to Gallium contamination by the disposal of electronic wastes.

7. Rubidium

Rubidium content in the present study area varies from 34 to 139 ppm with an average of 68.26 ppm (Table 4.6, Fig 4.17). The presence of Rubidium in the Periyar River basin is less when compared with world average shale value. Rubidium is the 25th most abundant elements in the Earth. There are no minerals in which Rb is primary element [80].

8. Strontium

Strontium content in the present study area varies from 53 to 387 ppm with an average of 205.3 ppm (Table 4.6, Fig 4.17). The presence of Rubidium in the Periyar River basin is high when compared with world average shale value.

9. Yttrium

Yttrium content in the present study area varies from 0 to 54 ppm with an average of 18.01 ppm (Table 4.6, Fig 4.18). The presence of Rubidium in the Periyar River basin is less when compared with world average shale value.

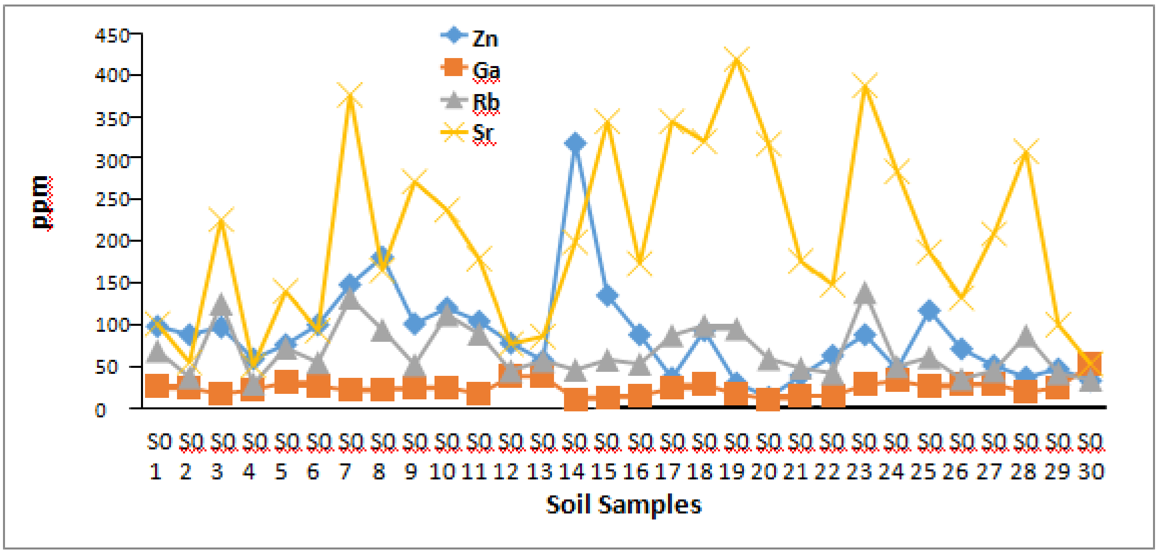

Figure 4.17: Graphical representation of variation of Zinc, Gallium, Rubidium and Strontium

10. Zirconium

Zirconium content in the present study area varies from 321 to 3210 ppm with an average of 1022.7 ppm (Table 4.6, Fig 4.18). The presence of Rubidium in the Periyar River basin is very high when compared with world average shale value.

11. Niobium

During the present study, Niobium content ranges from 8 to 14 ppm with an average of 10 ppm (Table 4.6, Fig 4.18). The presence of Rubidium in the Periyar River basin is less when compared with world average shale value.

12. Barium

Barium content in the present study area varies from 1456 to 121 ppm with an average of 803.7 ppm (Table 4.6, Fig 4.18). The presence of Rubidium in the Periyar River basin is greater when compared with world average shale value.

13. Lanthanum

Lanthanum content in the present study area varies from 0 to 102 ppm with an average of 123.8 ppm (Table 4.6, Fig 4.18). The presence of Lanthanum in the Periyar River basin is greater when compared with world average shale value.

14. Cerium:

Cerium content in the present study area varies from 38 to 244 ppm with an average of123.86 ppm (Table 4.6, Fig 4.18). The presence of Rubidium in the Periyar River basin is greater when compare with world average shale value.

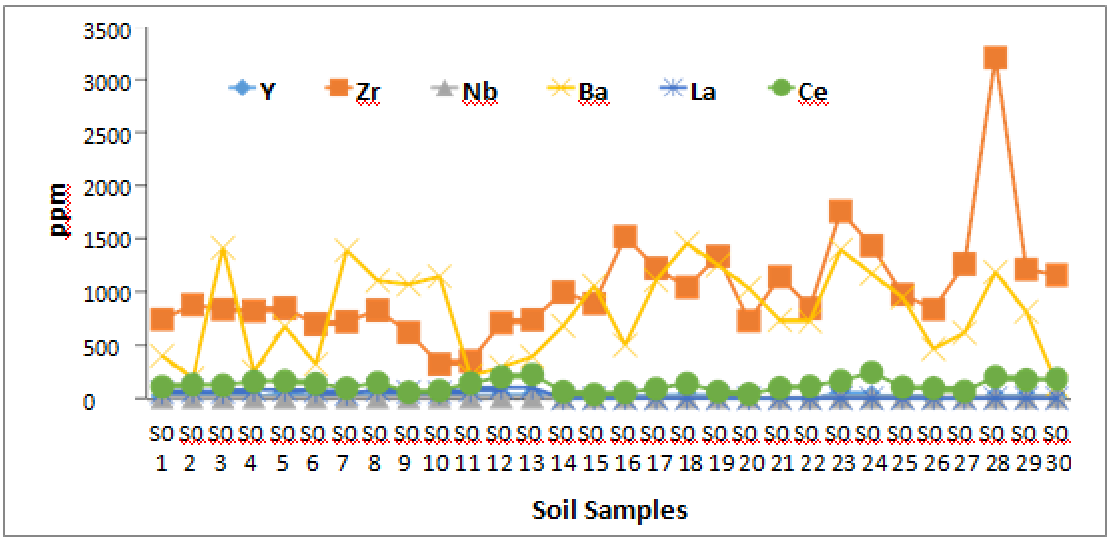

Figure 4.18: Graphical representation of variation of Yttrium, Zirconium, Niobium, Barium and Cerium from the soil samples of Periyar basin

Contamination Factors

The level of contamination of soil by a metal is often expressed in terms of a range CF < 1 Low contamination, CF 1-3 is moderate contamination, range of 3-6 considerable contamination and CF>6 is very high contamination. Metal contamination in the Periyar River soil has been assessed. P (1.82%) > Mn (1.741%)> Ti (1.30%) >Fe (1.27%) >Na (1.01%) > Si (0.924%) >Ca (0.79%) >K (0.58%) > Mg (0.42%) > Al (0.14%). In the case of trace metals contamination of soil assessed Zr (6.3392%). It is observed that, a high Zirconium contamination in the present studyarea of Periyar River basin. Other minor elements shows considerable range of contamination as Cr (1.67%) >Cu (1.52%) >V (1.46%)>Ni (1.38%) >Ba (1.386%)>Sr (1.20%) >Zn (0.914%) > Nb (0.918)>La (0.719%)>Y (0.69%). The metal contamination in the present study area is slightly greater in some parts and other areas it is observed at very low concentration [79-80] (table 4.8, 4.9).

Table 4.8: Contamination factor of major elements in surface soil of Periyar River

Sample	Na	K	Ca	Mg	Fe	Mn	Si	Ti	Al	P
S0 1	0.478	0.328	0.701	0.310	1.122	1.429	0.984	1.069	0.121	1.060
S0 2	0.264	0.190	0.876	0.181	1.402	1.760	0.898	1.316	0.150	1.808
S0 3	0.893	0.989	0.631	0.482	1.009	1.533	1.016	1.147	0.130	2.369
S0 4	0.214	0.100	0.838	0.181	1.341	2.230	0.904	1.668	0.190	1.060
S0 5	0.314	0.487	1.140	0.410	1.824	2.126	0.683	1.590	0.181	1.683
S0 6	0.302	0.228	0.850	0.181	1.360	1.725	0.873	1.290	0.147	1.496
S0 7	1.723	1.255	0.444	0.603	0.710	1.167	1.048	0.873	0.099	1.683
S0 8	0.717	0.821	0.744	0.491	1.190	1.760	0.844	1.316	0.150	2.431
S0 9	1.031	0.615	0.850	0.591	1.360	1.411	0.913	1.056	0.120	1.559
S0 10	1.144	0.952	0.683	1.262	1.092	1.708	0.863	1.277	0.145	1.621
S0 11	1.144	0.924	0.634	0.740	1.015	1.446	0.936	1.082	0.123	1.933
S0 12	0.226	0.225	1.295	0.285	2.072	2.526	0.566	1.890	0.215	1.621
S0 13	0.176	0.215	1.014	0.229	1.623	2.073	0.777	1.551	0.176	1.372
S0 14	1.597	0.502	0.394	0.277	0.630	1.202	1.198	0.899	0.102	2.057
S0 15	2.376	0.743	0.341	0.330	0.545	0.993	1.175	0.743	0.084	2.369
S0 16	0.893	0.340	0.543	0.173	0.868	1.237	1.180	0.925	0.105	1.559
S0 17	1.647	0.774	0.630	0.531	1.008	1.446	1.037	1.082	0.123	1.496
S0 18	1.660	0.992	0.714	1.001	1.143	1.708	0.918	1.277	0.145	2.057
S0 19	2.263	0.936	0.375	0.474	0.600	1.272	1.171	0.951	0.108	1.496
S0 20	1.672	0.702	0.344	0.209	0.550	1.115	1.254	0.834	0.095	1.185
S0 21	1.132	0.518	0.801	0.330	1.282	1.464	1.031	1.095	0.124	1.496
S0 22	1.232	0.506	0.910	0.265	1.457	1.498	1.006	1.121	0.127	2.369
S0 23	1.509	1.008	0.627	0.692	1.003	1.586	0.910	1.186	0.135	2.431
S0 24	0.553	0.412	1.137	0.330	1.820	2.021	0.754	1.512	0.172	2.369
S0 25	0.893	0.499	1.032	0.523	1.651	1.951	0.845	1.460	0.166	1.933
S0 26	0.629	0.337	0.821	0.285	1.313	1.586	0.826	1.186	0.135	2.930
S0 27	0.830	0.368	0.872	0.322	1.396	1.864	0.875	1.395	0.158	1.870
S0 28	2.188	0.980	0.550	0.643	0.880	2.056	1.032	1.538	0.175	1.247
S0 29	0.402	0.453	1.462	0.318	2.340	3.049	0.687	2.281	0.259	1.683
S0 30	0.189	0.200	1.566	0.165	2.506	3.276	0.507	2.450	0.278	2.431
Average Shale values	27.50	0.46	8.80	0.08	4.72	1.60	1.50	0.59	2.66	0.07

Table 4.9: Contamination Factor of minor elements in surface soil of Periyar River basin

Sample	V	Cr	Ni	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb	Ba	La	Ce
S0 1	1.18	2.26	2.02	2.36	1.03	0.69	0.49	0.59	0.85	4.63	0.82	0.69	1.28	1.34
S0 2	1.59	1.73	2.12	2.09	0.93	0.62	0.26	0.32	0.31	5.49	0.91	0.32	1.58	1.60
S0 3	1.12	1.20	1.14	2.64	1.02	0.44	0.89	1.33	0.96	5.22	0.82	2.44	1.37	1.51
S0 4	1.79	1.41	1.88	1.78	0.62	0.56	0.21	0.30	0.38	5.13	1.09	0.43	1.91	1.94
S0 5	2.09	2.49	2.52	1.80	0.80	0.79	0.51	0.82	2.08	5.30	0.82	1.17	1.88	1.99
S0 6	1.55	1.43	1.56	2.40	1.05	0.69	0.39	0.55	0.62	4.36	0.91	0.55	1.63	1.70
S0 7	0.72	0.66	0.58	2.76	1.56	0.54	0.94	2.21	1.00	4.49	0.82	2.39	1.00	1.17
S0 8	1.40	1.17	1.42	3.09	1.91	0.59	0.67	0.97	1.15	5.18	1.09	1.91	1.91	1.82
S0 9	1.42	2.23	1.54	2.42	1.06	0.62	0.37	1.60	0.46	3.88	0.82	1.84	1.35	0.71
S0 10	1.28	2.02	1.94	2.73	1.26	0.64	0.80	1.40	1.00	2.01	1.09	1.97	1.23	0.90
S0 11	1.12	1.11	1.10	2.09	1.09	0.44	0.64	1.05	0.46	2.19	0.91	0.37	1.70	1.73
S0 12	2.57	2.42	2.86	1.64	0.82	0.97	0.32	0.45	1.04	4.43	1.18	0.50	2.37	2.45
S0 13	1.94	1.63	2.20	1.36	0.60	0.97	0.41	0.51	1.35	4.61	1.09	0.67	2.35	2.73
S0 14	0.67	0.81	0.52	1.13	3.35	0.28	0.33	1.17	0.00	6.24	0.82	1.17	0.00	0.77
S0 15	0.51	0.70	0.20	1.04	1.42	0.33	0.41	2.02	0.00	5.56	0.73	1.82	0.00	0.46
S0 16	0.87	1.24	0.84	0.96	0.93	0.38	0.38	1.02	0.38	9.51	0.73	0.86	0.00	0.68
S0 17	1.07	1.39	1.04	0.69	0.38	0.62	0.62	2.02	0.92	7.64	0.82	1.91	0.00	1.12
S0 18	1.35	1.46	1.50	0.93	0.98	0.72	0.71	1.88	1.15	6.53	0.91	2.51	0.00	1.72
S0 19	0.68	0.90	0.60	0.67	0.32	0.44	0.68	2.46	0.46	8.34	0.91	2.16	0.00	0.78
S0 20	0.57	0.77	0.46	0.58	0.14	0.28	0.42	1.86	0.00	4.55	0.82	1.78	0.00	0.50
S0 21	1.32	1.72	0.94	0.69	0.41	0.38	0.34	1.04	0.08	7.14	0.73	1.27	0.00	1.21
S0 22	1.48	3.16	1.02	0.80	0.66	0.38	0.30	0.87	0.00	5.29	0.73	1.25	0.00	1.39
S0 23	1.17	1.21	1.40	1.07	0.93	0.72	0.99	2.28	1.96	10.99	0.91	2.41	0.00	2.01
S0 24	2.05	2.01	1.98	1.29	0.49	0.85	0.36	1.67	0.81	8.96	1.00	2.02	0.00	2.98
S0 25	1.83	2.71	1.78	1.24	1.23	0.67	0.44	1.10	0.92	6.11	0.91	1.63	0.00	1.29
S0 26	1.45	1.83	1.42	0.96	0.75	0.72	0.25	0.78	0.00	5.23	0.91	0.80	0.00	1.18
S0 27	1.62	1.08	1.00	0.58	0.54	0.74	0.32	1.23	0.31	7.89	1.09	1.06	0.00	0.82
S0 28	1.26	1.06	0.72	1.20	0.39	0.49	0.62	1.81	0.69	20.06	1.00	2.04	0.00	2.46
S0 29	3.00	3.04	2.08	2.29	0.49	0.64	0.30	0.59	0.85	7.57	0.91	1.40	0.00	2.12
S0 30	3.37	3.48	1.02	0.49	0.35	1.33	0.24	0.31	0.62	7.24	1.27	0.21	0.00	2.23
Average Shale Value	130	90	50	45	95	19	140	170	26	160	11	580	43	82

Pollution Load Index (PLI)

Pollution load index of present study area are shown in the Table (4.10). The PLI value of the soil samples varies from 0.00 to 0.32 with an average value of 0.033. Degree of contamination values of soil samples of the study region ranges from 7.25 to 11.91 with an average of 9.44. The level of contamination and pollution is moderate in the given study area.

Geo Accumulation Index (IGEO)

IGEO values are calculated based on the world surface rock abundance and presented in (Table 4.11). In the present study, it is evident from the figure that, the IGEO value of all the major and minor elements fall in class 0-1 indicating that, the area is unpolluted to moderate range of contamination. Some of the elements show slightly high pollution content [81].

Chemical Index of Alteration (CIA)

The present study of Periyar River basin soil samples, the CIA values ranges from 61- 96 (Table 4.12) which shows the high rate of chemical weathering. Chemical Index of Alteration uses the whole rock geochemical data of major element oxides. Chemical index of alteration more than hundred shows strong chemical weathering. The varying range of Chemical index of alteration values in the present study indicates the high rate of chemical weathering due to its origin from a high altitude and high energy flowing regime. Also the area is characterized by a lateritic upland with undulating intermittent valley [82].

Crustal Enrichment Factor:

The crustal enrichment factor helps to find the natural and anthropogenic metal deposits in the Periyar River basin. In the present study area Titanium and Magnesium shows moderate enrichment and other elements shows deficiency to minimal enrichment. Among the minor elements, zirconium shows significant enrichment and other shows deficiency to minimal enrichment [83](Table 4.13, 4.14).

Table 4.10: Results of Degree of contamination and pollution load index

Sample	Degree of contamination	PLI
S0 1	7.25	0.001
S0 2	7.96	0.000
S0 3	10.14	0.046
S0 4	7.22	0.000
S0 5	9.76	0.010
S0 6	7.49	0.000
S0 7	9.99	0.027
S0 8	10.50	0.055
S0 9	9.27	0.018
S0 10	10.46	0.082
S0 11	10.03	0.057
S0 12	9.32	0.001
S0 13	7.91	0.000
S0 14	9.04	0.005
S0 15	10.37	0.008
S0 16	7.38	0.000
S0 17	9.54	0.014
S0 18	11.56	0.228
S0 19	9.76	0.011
S0 20	7.87	0.001
S0 21	8.61	0.004
S0 22	9.68	0.005
S0 23	11.91	0.320
S0 24	9.80	0.003
S0 25	10.26	0.044
S0 26	9.46	0.001
S0 27	9.27	0.006
S0 28	10.68	0.063
S0 29	10.39	0.007
S0 30	10.46	0.000
Average value	9.44	0.033

Table 4.11: Geo Accumulation Index of Periyar River soils

Sample	Si	Ti	Al	Mn	Fe	Ca	Mg	Na	K	P
S0 1	149.29	0.05	19.23	0.00	5.02	0.19	0.14	0.03	0.47	0.00
S0 2	136.31	0.06	19.52	0.00	6.27	0.14	0.08	0.02	0.27	0.00
S0 3	154.22	0.05	14.71	0.00	4.51	0.28	0.22	0.06	1.40	0.00
S0 4	137.24	0.07	18.19	0.00	6.00	0.15	0.08	0.01	0.14	0.00
S0 5	103.71	0.07	21.86	0.00	8.16	0.17	0.19	0.02	0.69	0.00
S0 6	132.50	0.05	19.57	0.00	6.08	0.18	0.08	0.02	0.32	0.00
S0 7	158.99	0.04	16.43	0.00	3.17	0.42	0.27	0.12	1.78	0.00
S0 8	128.03	0.06	19.14	0.00	5.32	0.26	0.22	0.05	1.17	0.00
S0 9	138.58	0.04	19.65	0.00	6.08	0.26	0.27	0.07	0.87	0.00
S0 10	131.05	0.05	18.71	0.00	4.88	0.35	0.57	0.08	1.35	0.00
S0 11	141.99	0.05	17.04	0.00	4.54	0.29	0.33	0.08	1.31	0.00
S0 12	85.85	0.08	25.54	0.00	9.26	0.14	0.13	0.02	0.32	0.00
S0 13	117.89	0.07	23.42	0.00	7.25	0.13	0.10	0.01	0.31	0.00
S0 14	181.79	0.04	10.91	0.00	2.82	0.49	0.13	0.11	0.71	0.00
S0 15	178.29	0.03	10.78	0.00	2.44	0.64	0.15	0.17	1.05	0.00
S0 16	179.06	0.04	12.09	0.00	3.88	0.27	0.08	0.06	0.48	0.00
S0 17	157.34	0.05	16.23	0.00	4.51	0.40	0.24	0.12	1.10	0.00
S0 18	139.38	0.05	18.52	0.00	5.11	0.42	0.45	0.12	1.41	0.00
S0 19	177.74	0.04	13.18	0.00	2.68	0.45	0.21	0.16	1.33	0.00
S0 20	190.31	0.04	10.85	0.00	2.46	0.36	0.09	0.12	1.00	0.00
S0 21	156.54	0.05	15.81	0.00	5.73	0.29	0.15	0.08	0.74	0.00
S0 22	152.70	0.05	15.87	0.00	6.51	0.29	0.12	0.09	0.72	0.00
S0 23	138.12	0.05	19.41	0.00	4.49	0.53	0.31	0.11	1.43	0.00
S0 24	114.41	0.06	23.31	0.00	8.14	0.21	0.15	0.04	0.58	0.00
S0 25	128.27	0.06	18.55	0.00	7.38	0.31	0.24	0.06	0.71	0.00
S0 26	125.32	0.05	22.59	0.00	5.87	0.22	0.13	0.04	0.48	0.00
S0 27	132.75	0.06	21.23	0.00	6.24	0.32	0.15	0.06	0.52	0.00
S0 28	156.64	0.07	15.44	0.00	3.94	0.46	0.29	0.15	1.39	0.00
S0 29	104.25	0.10	21.88	0.00	10.46	0.12	0.14	0.03	0.64	0.00
S0 30	76.90	0.10	28.83	0.00	11.20	0.08	0.07	0.01	0.28	0.00

Table 4.12: Chemical Index of Alteration value of Periyar River Basin

Sample	Al_2O_3	Na_2O	K_2O	CaO	CIA
	Percentage				
S0 1	20.57	0.38	1.05	0.82	90.140
S0 2	20.88	0.21	0.61	0.61	93.590
S0 3	15.74	0.71	3.17	1.23	75.492
S0 4	19.46	0.17	0.32	0.65	94.466
S0 5	23.39	0.25	1.56	0.72	90.239
S0 6	20.94	0.24	0.73	0.79	92.247
S0 7	17.58	1.37	4.02	1.83	70.887
S0 8	20.48	0.57	2.63	1.12	82.581
S0 9	21.02	0.82	1.97	1.15	84.215
S0 10	20.02	0.91	3.05	1.52	78.510
S0 11	18.23	0.91	2.96	1.27	78.006
S0 12	27.32	0.18	0.72	0.63	94.697
S0 13	25.06	0.14	0.69	0.55	94.781
S0 14	11.67	1.27	1.61	2.14	69.922
S0 15	11.53	1.89	2.38	2.81	61.956
S0 16	12.94	0.71	1.09	1.17	81.332
S0 17	17.36	1.31	2.48	1.74	75.841
S0 18	19.81	1.32	3.18	1.81	75.842
S0 19	14.1	1.8	3	1.95	67.626
S0 20	11.61	1.33	2.25	1.55	69.355
S0 21	16.92	0.9	1.66	1.26	81.581
S0 22	16.98	0.98	1.62	1.25	81.517
S0 23	20.77	1.2	3.23	2.32	75.472
S0 24	24.94	0.44	1.32	0.92	90.297
S0 25	19.85	0.71	1.6	1.33	84.504
S0 26	24.17	0.5	1.08	0.97	90.457
S0 27	22.71	0.66	1.18	1.4	87.514
S0 28	16.52	1.74	3.14	1.99	70.628
S0 29	23.41	0.32	1.45	0.52	91.089
So 30	30.85	0.15	0.64	0.36	96.406

Table 4.13: Crustal enrichment factor of major elements from the Periyar River basin

Sample	Si	Ti	Mn	Fe	Ca	Mg	Na	K	P
S0 1	0.80	0.86	4.16	0.91	0.30	0.25	0.39	0.26	0.86
S0 2	0.72	1.05	3.38	1.12	0.22	0.14	0.21	0.15	1.44
S0 3	1.07	1.21	1.27	1.07	0.58	0.51	0.94	1.05	2.50
S0 4	0.77	1.43	3.94	1.15	0.25	0.15	0.18	0.09	0.91
S0 5	0.49	1.13	1.35	1.30	0.23	0.29	0.22	0.35	1.20
S0 6	0.69	1.02	8.47	1.08	0.28	0.14	0.24	0.18	1.19
S0 7	0.99	0.83	4.74	0.67	0.77	0.57	1.63	1.19	1.59
S0 8	0.68	1.07	1.27	0.97	0.41	0.40	0.58	0.67	1.97
S0 9	0.72	0.84	3.40	1.08	0.41	0.47	0.82	0.49	1.23
S0 10	0.72	1.06	3.24	0.91	0.56	1.05	0.95	0.79	1.35
S0 11	0.85	0.99	1.84	0.93	0.52	0.67	1.04	0.84	1.76
S0 12	0.34	1.15	3.16	1.26	0.17	0.17	0.14	0.14	0.99
S0 13	0.52	1.03	6.76	1.08	0.16	0.15	0.12	0.14	0.91
S0 14	1.71	1.28	3.15	0.90	1.36	0.40	2.28	0.72	2.93
S0 15	1.69	1.07	4.66	0.79	1.81	0.48	3.43	1.07	3.42
S0 16	1.52	1.19	5.23	1.12	0.67	0.22	1.15	0.44	2.00
S0 17	0.99	1.04	7.02	0.97	0.74	0.51	1.58	0.74	1.43
S0 18	0.77	1.07	2.29	0.96	0.68	0.84	1.39	0.83	1.73
S0 19	1.38	1.12	5.70	0.71	1.03	0.56	2.67	1.10	1.76
S0 20	1.80	1.19	9.39	0.79	0.99	0.30	2.40	1.01	1.70
S0 21	1.01	1.08	6.84	1.26	0.55	0.32	1.11	0.51	1.47
S0 22	0.99	1.10	6.87	1.43	0.55	0.26	1.21	0.50	2.32
S0 23	0.73	0.95	1.40	0.80	0.83	0.55	1.21	0.81	1.95
S0 24	0.50	1.01	10.09	1.21	0.27	0.22	0.37	0.27	1.58
S0 25	0.71	1.22	1.78	1.38	0.50	0.44	0.75	0.42	1.62
S0 26	0.57	0.82	19.55	0.90	0.30	0.20	0.43	0.23	2.02
S0 27	0.64	1.02	6.12	1.02	0.46	0.24	0.61	0.27	1.37
S0 28	1.04	1.55	3.34	0.89	0.89	0.65	2.20	0.99	1.26
S0 29	0.49	1.62	2.37	1.66	0.16	0.23	0.29	0.32	1.20
S0 30	0.27	1.32	0.00	1.35	0.09	0.09	0.10	0.11	1.31
Average	0.872	1.110	4.760	1.054	0.558	0.382	1.021	0.555	1.632

Table 4.14: Crustal enrichment factor minor elements of soils from the Periyar River basin

Sample	V	Cr	Ni	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb	Ba	La	C
S0 1	1.18	2.26	2.02	2.36	1.03	0.69	0.49	0.59	0.85	4.63	0.82	0.69	1.28	1.34
S0 2	1.59	1.73	2.12	2.09	0.93	0.62	0.26	0.32	0.31	5.49	0.91	0.32	1.58	1.60
S0 3	1.12	1.20	1.14	2.64	1.02	0.44	0.89	1.33	0.96	5.22	0.82	2.44	1.37	1.51
S0 4	1.79	1.41	1.88	4.78	0.62	0.56	0.21	0.30	0.38	5.13	1.09	0.43	1.91	1.94
S0 5	2.09	2.49	2.52	1.80	0.80	0.79	0.51	0.82	2.08	5.30	0.82	1.17	1.88	1.99
S0 6	1.55	1.43	1.56	2.40	1.05	0.69	0.39	0.55	0.62	4.36	0.91	0.55	1.63	1.70
S0 7	0.72	0.66	0.58	2.76	1.56	0.54	0.94	2.21	1.00	4.49	0.82	2.39	1.00	1.17
S0 8	1.40	1.17	1.42	3.09	1.91	0.59	0.67	0.97	1.15	5.18	1.09	1.91	1.91	1.82
S0 9	1.42	2.23	1.54	2.42	1.06	0.62	0.37	1.60	0.46	3.88	0.82	1.84	1.35	0.71
S0 10	1.28	2.02	1.94	2.73	1.26	0.64	0.80	1.40	1.00	2.01	1.09	1.97	1.23	0.90
S0 11	1.12	1.11	1.10	2.09	1.09	0.44	0.64	1.05	0.46	2.19	0.91	0.37	1.70	1.73
S0 12	2.57	2.42	2.86	1.64	0.82	0.97	0.32	0.45	1.04	4.43	1.18	0.50	2.37	2.45
S0 13	1.94	1.63	2.20	1.36	0.60	0.97	0.41	0.51	1.35	4.61	1.09	0.67	2.35	2.73
S0 14	0.67	0.81	0.52	1.13	3.35	0.28	0.33	1.17	0.00	6.24	0.82	1.17	0.00	0.77
S0 15	0.51	0.70	0.20	1.04	1.42	0.33	0.41	2.02	0.00	5.56	0.73	1.82	0.00	0.46
S0 16	0.87	1.24	0.84	0.96	0.93	0.38	0.38	1.02	0.38	9.51	0.73	0.86	0.00	0.68

S0 17	1.07	1.39	1.04	0.69	0.38	0.62	0.62	2.02	0.92	7.64	0.82	1.91	0.00	1.12
S0 18	1.35	1.46	1.50	0.93	0.98	0.72	0.71	1.88	1.15	6.53	0.91	2.51	0.00	1.72
S0 19	0.68	0.90	0.60	0.67	0.32	0.44	0.68	2.46	0.46	8.34	0.91	2.16	0.00	0.78
S0 20	0.57	0.77	0.46	0.58	0.14	0.28	0.42	1.86	0.00	4.55	0.82	1.78	0.00	0.50
S0 21	1.32	1.72	0.94	0.69	0.41	0.38	0.34	1.04	0.08	7.14	0.73	1.27	0.00	1.21
S0 22	1.48	3.16	1.02	0.80	0.66	0.38	0.30	0.87	0.00	5.29	0.73	1.25	0.00	1.39
S0 23	1.17	1.21	1.40	1.07	0.93	0.72	0.99	2.28	1.96	10.99	0.91	2.41	0.00	2.01
S0 24	2.05	2.01	1.98	1.29	0.49	0.85	0.36	1.67	0.81	8.96	1.00	2.02	0.00	2.98
S0 25	1.83	2.71	1.78	1.24	1.23	0.67	0.44	1.10	0.92	6.11	0.91	0.80	0.00	1.29
S0 26	1.45	1.83	1.42	0.96	0.75	0.72	0.25	0.78	0.00	5.23	0.91	0.80	0.00	1.18
S0 27	1.62	1.08	1.00	0.58	0.54	0.74	0.32	1.23	0.31	7.89	1.09	1.06	0.00	0.82
S0 28	1.26	1.06	0.72	1.20	0.39	0.49	0.62	1.81	0.69	20.06	1.00	2.04	0.00	2.46
S0 29	3.00	3.04	2.08	2.29	0.49	0.64	0.30	0.59	0.85	7.57	0.91	1.40	0.00	2.12
S0 30	3.37	3.48	1.02	0.49	0.35	1.33	0.24	0.31	0.62	7.24	1.27	0.21	0.00	2.23
Average	1.468	1.678	0.380	1.525	0.917	0.618	0.488	1.208	0.694	6.392	0.918	1.386	0.719	1.511

Chapter 5 Summary and Conclusion

The present study was carried out to understand the textural and geochemical constitutions of Periyar River Basin. The percentage of sand, silt and clay in the soil samples of Periyar River ranges from 17.304 % to 88.18 %, 2.27 % to 58.010 % and 7.22 % to 47.94 % respectively. The textural triangle (Ternary plot) shows that, the most of the soil samples falls under sandy clay loam > sandy loam, clay, loam>silt loam, clay loam, sandy clay. The XRF analysis has been carried out to determine the major and heavy metals concentration in the soils of Periyar River basin.

Based on the major elemental distribution, it was observed that, the soils are predominantly siliceous type with enrichment of Alumina. The contamination in the soil was assessed on the basis of IGEO and pollution load index. The chemical index of alteration (CIA) helps to find the intensity of weathering. The average value of pollution load index indicates the progressive deterioration of the site .Average value of contamination factor also shows the considerable degree of pollution in the present study area. The elemental concentration of the soils from Periyar River was comparatively higher than the permissible limits as prescribed by Taylor and McLennan.

By analyzing the crustal enrichment factor, it was found that, magnesium and zirconium exhibits moderate enrichment and V, Cr, Ni, Cu, Ga, Zn, Ce, Nb, Y, Sr, Rb. Zn exhibits minimal enrichment. More than 50% of the samples sites belong to ‘progressive deterioration sites per pollution load index category. As per soil status, it is clear that, the present study area is moderately contaminated in terms of pollution load index, contamination factor. The presence of magnesium and zirconium is highin the present study area

Periyar basin is the one among the most affected region needing high priority for environmental consideration owing to the various reasons as discussed.Environmental pollution happening in the system may directly affect the people as they govern food safety issues. The degradation and mobilization products of these pollutants in many cases are more toxic than their parent compound. Hence urgent intervention is needed to conserve the soil by adopting suitable location specific management measures for the sustainable utilization of the resources

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SOIL GEOCHEMISTRY OF PERIYAR RIVER BASIN

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