WATER, SOIL, AND SEDIMENT CHARACTERISATION: SHARAVATHI RIVER BASIN, WESTERN GHATS

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1.0 SUMMARY

Aquatic ecosystems perform valuable environmental functions like nutrient recycle, ground water recharge, stream flow maintenance, habitat for flora and fauna and provide recreation for people. Structural changes in these complex and dynamic ecosystems will have significant effect on its functioning. These structural changes take place due to unplanned developmental activities without holistic approach on watershed basis. These effects could be cumulative and its assessment is required for remedial measures. To assess these impacts due to river valley projects, the present study was undertaken in Sharavathi river basin. This is done through water, soil and sediment quality analyses by analytical methods. The water quality is impaired due to non-point source of pollution. This includes soil erosion and biological coliform at few sites. Soils under study are deficient in nutrients like nitrates, phosphate and sulphates but rich in organic matter. Since the character of sediment is highly dependent on the basin character, the soils of catchment having less amount of above-mentioned nutrients is consequently reflected in sediment also. The management options suggested are effective in soil erosion control based on soil type and appropriate catchment treatment.

2.0 INTRODUCTION

Integrated planning and management based on a comprehensive ecosystem assessment is necessary for environmentally sound, sustainable management of natural resources. In the development of the power sector in a country, the role of hydropower generation stands well recognised. However, in the interest of sustainable development, it is necessary that environmental concerns are identified and duly addressed as early as possible in the project. Planned development with an integrated approach is necessary to raise the living standards of the people, revive economy and alleviate poverty. Poorly planned projects can result in disastrous impacts on basic life-support systems such as clean air and water, productive soil and rich biotic diversity. Development of water resource projects such as dams and reservoirs, canalisation and dredging activities, irrigation schemes and others such as the creation of new lands via filling operations can represent large scale engineering works which can cause significant impact on physico-chemical, biological, cultural, sustainable development and socio-economic components of the environment. Development of river valley projects involves change in land use pattern and corresponding hydrological regimes. These developmental projects often result in unanticipated and undesirable consequences, which may be drastic so as to reduce or even nullify the socio-economic benefits for which the projects were planned.

Large dams in India and elsewhere have been accompanied by significant alterations in the upstream and downstream physical and biological environment. In India, there is no comprehensive audit of these impacts, but some available facts and figures indicate the magnitude and severity of such developments. They are:

- The creation of reservoirs in more than 1,500 major river valley projects has flooded over 500,000 ha. (5,000 sq. km.) of forest land;

- Water logging and/or salinisation perhaps affect half of the canal irrigated land in the country, with varying degrees of severity;
- Malaria has seen a resurgence in the last decade or so, especially in the command areas of irrigation projects and around reservoirs;
- Several species of wild animals and plants (such as the River dolphin *Platanista gangetica* and the fish *Hilsa ilisha*) have been threatened by dams and their associated impacts;
- Salt-water ingress in the coastal areas of states with a major dam-building history (in the states of Kerala and Karnataka) is severely affecting drinking water and agricultural lands for several kilometres inland.

The associated environmental problems of water related projects are erosion, flooding, sedimentation, landslide, torrents, roadside erosion and shifting cultivation areas. In order to minimise these impacts, there is a need to adopt comprehensive, integrated watershed approach in the development of hydro-projects for electricity generation and irrigation. Water and soil ecosystems play a vital role in sustaining all life forms performing useful functions in the maintenance of the overall balance of nature.

2.1 Characterisation of Water, Soil and Sediments

Water, soil and sediment have their own significance in regulating the biotic system of the universe. Slight alterations in the quality of these will adversely affect the ecosystem. Dam construction uses a large area of land and the mass gathering of labour causes water and soil quality deterioration, and clearing of forest for shelter causes soil erosion, which further results in sedimentation in the river or near-by waterbodies.

Water is essential for life and plays a vital role in the proper functioning of the earth's ecosystem. The pollution of water has serious impact on living creatures and can negatively affect the use of water for drinking, household need, recreation, fishing, transportation and commerce. Many factors affect the chemical, physical and biological characteristics of a waterbody. They may be either natural like geology/ weather or anthropogenic, which contribute to the point and non-point source of pollution. Developmental projects like construction of dams may change the quality of water as it involves blocking the natural flow. It impacts aquatic organisms and changes the nature of the stream itself. As water slows down and backs up behind a dam, various changes in its physico-chemical and biological characteristics take place. Water quality monitoring involves recording data about these various characteristics and usually involves analysing and interpreting these data. Monitoring helps to ensure that a particular waterbody is suitable for its determined use.

Soils are considered natural bodies, covering part of the earth surface that support plant growth and that have properties due to the integrated effect of climate and organisms acting upon the parent materials conditioned by relief over a period of time. This definition of soil shows the dependency of soil on several environmental factors. Hence, soil could be characterised by the formula

$$\mathbf{S = f\ (cl,\ o,\ p,\ r,\ t)}$$

where, s = soil, f = function of, cl = climate, o = organisms, p = parent materials, r=relief and t = time. Any change in these variables will result in change in soil quality.

Nevertheless, the developmental activities in the catchment would certainly change variables and ultimately the fate of soil.

Rivers in the world carry as much as three billion tonnes of material in solution and ten billion tonnes of sediment every year. The characterisation of sediments reflects the quality of the catchment area, through which the rivers flow. Sedimentation of a river, lake or reservoir is associated with its flow and also disturbs the water quality and aquatic ecosystem. Runoff from different sources result in different qualities of sediment and ultimately various changes take place. The sediment content may also vary from month to month depending on the season, while it may be negligible during the winter and summer months, it is greatest during the monsoon months.

Higher sediment delivery ratio (ratio between the amount of sediment yield and the gross erosion in watershed) is associated with smaller catchments. As one moves upstream, the drainage basin area decreases and the topographic factors that promote sediment delivery becomes more intensified resulting in higher sediment - delivery ratio. The actual rate of silting of a reservoir depends on many other factors, in addition to the rate of sediment production in the catchment area. They are, trap efficiency of the reservoir, ratio of reservoir capacity to total runoff, gradation of silt, method of reservoir operation, etc. The trap efficiency of a reservoir is defined as the ratio of sediment retained in the reservoir and sediment brought by the stream. Damming the water also deposits the sediments that they carry. This causes sediment build up behind the dam, often changing the composition of the river.

The following factors affect sedimentation -

a) Extent of catchment area and the friable nature of the different zones.
b) Amount of sediment load in the rivers.
c) Type of rainfall and snowfall in each zone.
d) Mean monthly and annual run-off from catchment or sub-catchment.
e) Slope of each zone of catchment.
f) Vegetation in each zone of catchment.
g) Geological formation of each zone, estimated relative weathering and erosion with due regard to climatic conditions.
h) Presence of upstream reservoirs and extent of trapping of sediment therein.
i) Amount of sediment flushed out through sluices.
j) Degree of consolidation of accumulated sediment depending upon the extent of exposure to air, sun and wind.
k) Operation schedule of reservoir.

2.2 Complexities of Environmental Impacts of River Valley Projects

Assessment of environmental impacts of river valley projects must be taken up with the following considerations:

(i) It is important to identify the positive impacts of a developmental project as well as the negative ones and the constraints they may impose.
(ii) Most of the environmental factors involved in dam construction are interrelated; people displaced from the inundated area of the reservoir, or whose movement is facilitated by the reservoir and dam construction activities may move upstream in the watershed. Use of forests for agricultural activities by them may create additional erosion, leading to increased sedimentation in the reservoirs, thereby reducing storage

capacity. Sediment, in turn affect the water quality and may reduce the capacity for power generation. In general, the dam affects downstream river flow, water quality, associated cultivation, and fisheries. The dam can also affect conditions elsewhere in the river basin through changes in subsurface water levels, resettlement of displaced people and landuse pattern.

(iii) A dam may affect the development of a region and may lead to newer settlements and industrial activity. This impairs the functioning of the ecosystem due to anthropogenic pressure on forest and aquatic ecosystems for land. This facilitates the need to measure cumulative impacts of the projects.

(iv) It is very essential to quantify all the significant impacts of water resource projects through Environmental Impact Assessment (EIA) at different phases of the project.

Thus it is necessary to monitor the impacts of the projects, in order to restore / rehabilitate the ecosystem.

Environmental Assessment is a process used to identify the impacts of a project or activity on the environment. The negative and positive consequences of development projects are assessed to provide decision-makers with a holistic and informed opinion based on sound and objective research and analysis.

Thus Environmental assessments -

- are necessary to guide development, both at the strategic level and at the project level;
- can serve as early warning systems;
- help to identify alternative approaches;
- identify cross-sectoral impacts and enable managers to view project proposals in a local, regional and global perspective; and
- involve dialogue and interaction between various ministries, NGOs, local authorities, municipalities and the private sector.

Cumulative impacts are the additive environmental impacts of a persistent causal agent over time. The term Cumulative Impact Assessment refers to accumulation of human induced changes in valued environmental components including human beings, fauna and flora; soil, water, air, climate and the landscape; the interaction of these factors; and on material assets, and the cultural heritage across space and over time. It reveals the identification, description and assessment of the direct and indirect long-term combined effects of a project.

Cumulative Impacts of river valley projects can be classified into two classes:

1. Cumulative Impacts on environment due to water storage and
2. Cumulative Impacts on ecosystem within and across the reservoir catchment.

Reservoir function is also affected due to these additive impacts, which in turn decreases its actual life. The main impacts are eutrophication, siltation or sedimentation, toxic chemical accumulation, acidification and extinction of natural biota. These are the key effects that start in very acute level and reach to maximum, responsible for quality degradation, reduced recreation and aesthetic values, degraded biodiversity, changes in culture, etc.

On the other hand, the cumulative impacts on surrounding ecosystem include extinction of endemic flora and fauna, succession by alien species, water related diseases affecting both humans and animals, instability of agricultural production, water logging and salinity, etc. The main diseases related to water are malaria, diarrhoea, filariasis,

trachoma, bilharzia, etc. As some of these are additive, it can result in severe damage to the ecosystem and the environment.

This section discusses the water, soil and sediment quality characteristics in the Sharavathi River Basin, by analysing qualitative impacts on water, sediment and soil.

2.3 River Systems and Water Resources of Karnataka

The state has very good water resources in its numerous rivers, lakes and streams and to a certain extent groundwater. Seven river basins drain the whole state (The names and the areas drained are given in Table 1).

Table 1. River basins of Karnataka State.

Name of the Basin	Catchment Area (sq. km)	Total Area of the State (%)	Estimated Average Flow (Million m^3)
Krishna	1,13,271	59.06	27,500
Godavari	4,405	2.30	1,400
Cauvery	34,273	17.87	11,000
West-flowing rivers	26,214	13.68	57,000
North Pennar		3.61	
South Pennar	13,610	1.95	900
Palar		1.54	

The total catchment area of these rivers is 1,91,773 sq. km. and the estimated average flow is 97,800 million m^3 (M cum). The Krishna and Cauvery river basins drain about 77% of geographical area of the state. Sharavathi, Netravathi, Varahi, Bedti (Gangavathi) and Aghanashini are the more important rivers, all of which have considerable hydroelectric potential. They arise in the west of the Ghats and flow into the Arabian Sea. The area of forests and hills has a rugged topography, characterised by deep ravines and steep hills rising to heights of 1,250 to 1,890 m, which are the source of all the east and west-flowing rivers of the state.

3.0 OBJECTIVES

- Assess the status of water, soil and sediment ecosystems by physico-chemical and biological characterisation in Sharavathi River Basin.
- Explore suitable watershed management and conservation strategies for their long-term sustenance.

4.0 STUDY AREA

Sharavathi originates in the Western Ghats near Ambuthirtha in Thirthahalli taluk of Shimoga district (Figure 1.1). Flowing north-west, it is mainly used for generation of hydroelectric power. The river with its tributaries flows along the rugged terrain of Western Ghats of south-west Shimoga and south-east Uttara Kannada districts (Figure 1.2). This region supports a rich diversity of flora and fauna. The Karnataka Power Corporation Limited constructed a dam across the river in 1964 near Linganamakki, which is one of the oldest hydroelectric power projects in India. Linganamakki hydroelectric project has caused submersion of a large area along with loss of biodiversity. The aquatic and soil ecosystems are the major resources under threat. In this

context it would become necessary to assess the cumulative impact of the construction of the dam on the river ecosystem *i.e.*, on the water, soil and sediment status by sampling and analysing the sampled data.

Figure 1.1: Location of Sharavathi River Basin, Karnataka, India

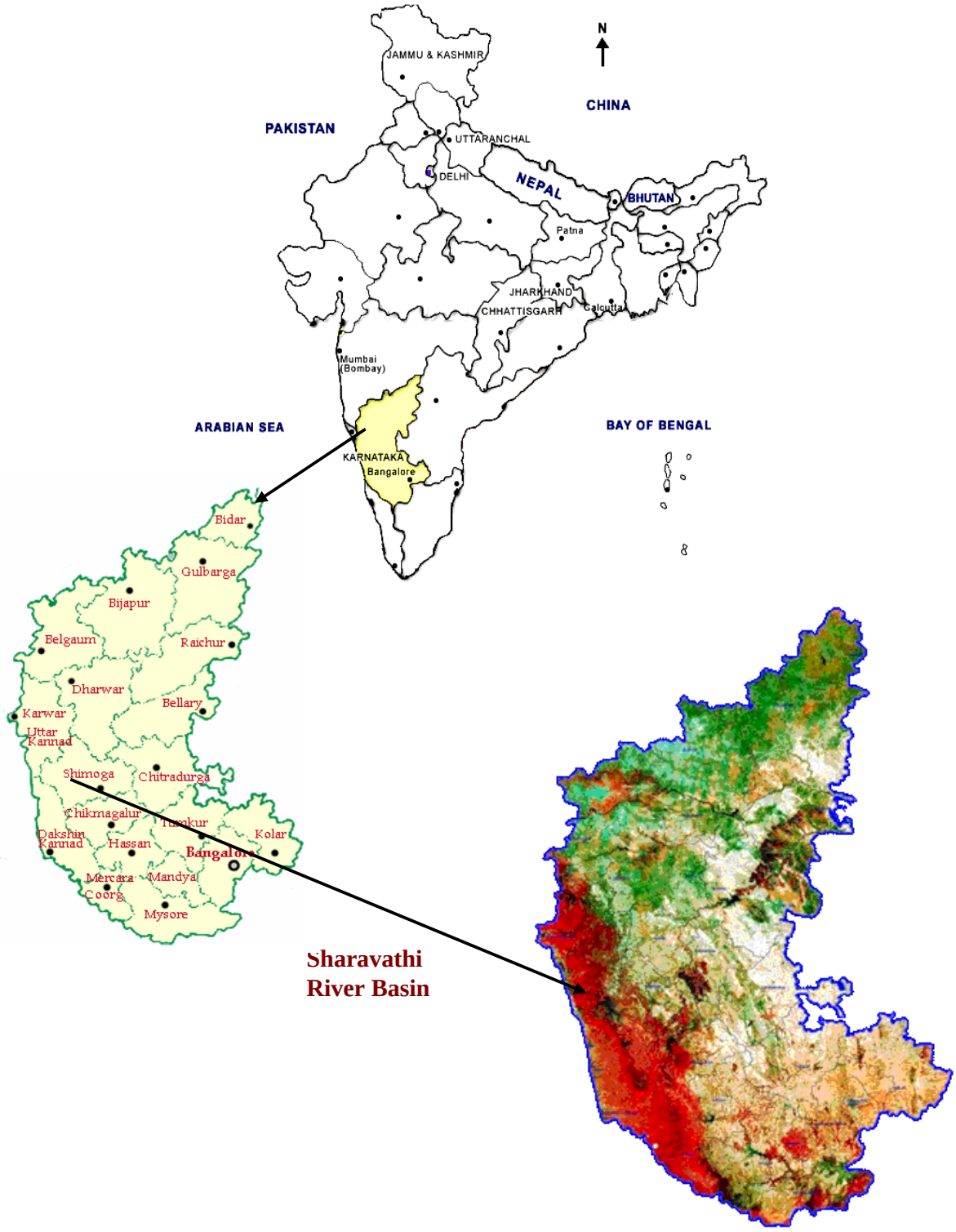
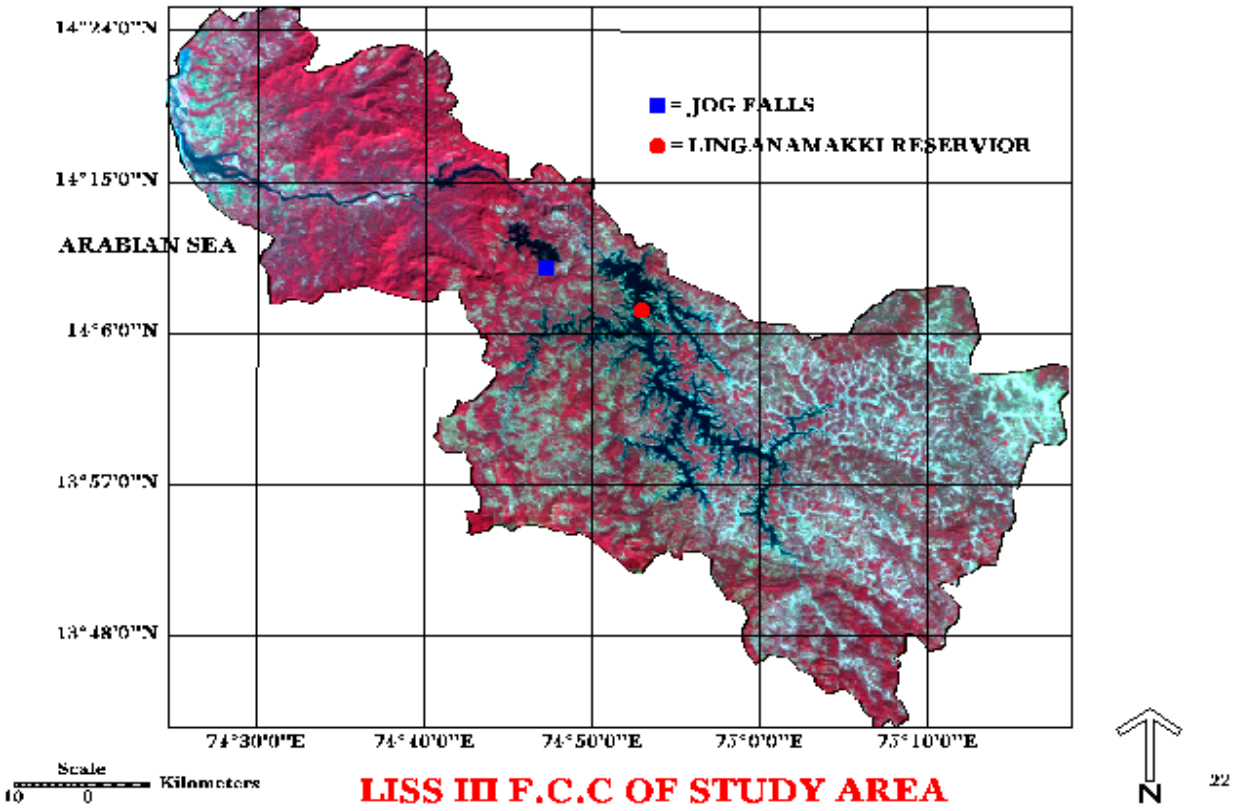


Figure 1.2: Sharavathi River Basin



5.0 SAMPLING AND ANALYSIS OF WATER

Water is a dynamic system and hence its characteristic quality changes with time and place. Water samples were collected at regular intervals to identify their characteristics and the changes in their quality. A total of 40 water samples (16 in the upstream and 24 in the downstream) were collected from various locations encompassing the entire catchment area. Precautions were taken while handling the collected samples to ensure its integrity.

5.1 Sampling Sites

Upper catchment
For physico-chemical and biological characterisation, monthly samples were collected (numbers in the square brackets indicate sampling sites):

- Areas where principal feeder tributaries Sharavathi [1] (Nagara), Sharavathi [2], Sharmanavathi or Mavinaholé [3], Haridravathi [4] and Yenneholé [10] meet the reservoir.
- Central part of reservoir near Holébagilu [8] to get a general quality of the water.
- Outlet [7] from the dam.

- Other minor tributaries like Hurliholé [9] and Keshawapura [14] and Nandiholé [15] (streams near Haridravathi), Valagere [11], Nittur [13] and Sampekai [16].
- At Talakalale dam, a balancing reservoir [6], near Muppane forest area [5] and Madenur dam [12] to get a comparative water quality status over the other sampling sites.

Table 2 gives the water sampling sites and its respective co-ordinates in the upper catchment of Sharavathi river basin.

Table 2. Water sampling representative sites of the Sharavathi upper catchment.

Sub-basin	Sampling Sites	Latitude (°N)	Longitude (°E)
Hilkunji (US8)	Sharavathi (Nagara) [1]	13.8267	75.0601
Sharavathi (US4)	Sharavathi [2]	13.8789	75.065
Mavinaholé (US3)	Sharmanavathi [3]	13.9855	75.0822
Haridravathi (US2)	Haridravathi [4]	14.0384	75.1207
Yenneholé (US5)	Muppane [5]	14.1083	74.7902
Yenneholé (US5)	Talakalale [6]	14.1853	74.7863
Yenneholé (US5)	Dam outlet [7]	14.1917	74.8268
Linganamakki (US9)	Reservoir [8]	14.0756	74.8977
Hurliholé (US6)	Hurliholé [9]	13.9914	74.8672
Yenneholé (US5)	Yenneholé [10]	14.0417	74.759
Linganamakki (US9)	Valagere [11]	14.0624	74.8452
	Madenur Dam [12]		
Linganamakki (US9)	Nittur [13]	13.9371	74.9139
Haridravathi (US2)	Keshawapura [14]	14.0191	75.1215
Nandiholé (US1)	Nandiholé [15]	14.0426	75.1254
Linganamakki (US9)	Sampekai [16]	14.048	75.0467

Note: Numbers in the square brackets indicate sampling sites.

Lower catchment

In the lower catchment among the 7 sub-basins, 20 localities were selected for water sampling (Table 3). Landuse pattern and stream orders of the localities are detailed in Table 4.

Table 3. Water sampling representative sites of the downstream catchment.

Sub Basin	Sampling locations	Latitude (°N)	Longitude (°E)	Altitude (m)
Dabbe falls (DS4)	Hebbankere [2]			
Dabbe falls (DS 4)	Dabbe falls [1]	14.13747	74.74158	567
Magod (DS 3)	Hosagadde [3]	14.17009	74.54848	41
Magod (DS 3)	Dabbod [4]			
Magod (DS 3)	Magodholé [5]	14.22377	74.59595	13
Magod (DS 3)	Gazni/ Hennur [6]	14.21883	74.53471	16
Magod (DS 3)	Heggar [7]	14.23294	74.52602	13
Chandavar (DS 1)	Chandavar [21]			
Chandavar (DS 1)	Gudankateholé [22]	14.38152	74.44321	22
Chandavar (DS 1)	Badagani [23]	14.35294	74.42194	10
Gudankatehole (DS 7)	Bhaskere [8]	14.3027	74.48524	35
Haddinabal (DS 2)	Chandubanu [9]	14.32452	74.58300	27
Haddinabal (DS 2)	Haddinabal [10]	14.28523	74.51153	36
Haddinabal (DS 2)	Mavinaholé [11]	14.24546	74.61644	15

Haddinabal (DS 2)	Mahasati [12]	14.26296	74.68116	76
Haddinabal (DS 2)	Vatahalla [13]	14.27035	74.69153	68
Magod (DS 3)	Upponi location 1 [14]	14.23432	74.60058	26
Magod (DS 3)	Upponi village loc 2 [15]	14.23167	74.58934	31
Kathalekan (DS 6)	Kathalekan [16]	14.27267	74.74788	633
Mavinagundi (DS 5)	Mavinagunde [17]	14.24380	74.81250	577
Mavinagundi (DS 5)	Jog lower [18]	14.22767	74.8120	331
Mavinagundi (DS 5)	Jog upper [19]	14.22973	74.81355	491
Mavinagundi (DS 5)	Joginamuttu [20]	14.23024	74.82361	499

Note: Numbers in the square brackets indicate sampling sites.

Table 4. Sub-basinwise locations, landuse pattern, stream orders in the downstream catchment.

Sub Basin	Sampling locations	Land use pattern	Stream orders
DS 4	Hebbankere	Forest, agriculture	1st
DS 4	Dabbe falls	Forest, agriculture	1st
DS 3	Hossagadde	Agriculture	1st
DS 3	Dabbod	Agriculture	2nd
DS 3	Magodholé	Agriculture	2nd
DS 3	Gazni/ Hennur	Agriculture	2nd
DS 3	Heggar	Human dwelling, Agriculture	3rd
DS 3	Nagarbhastikere	Forest	2nd
DS 1	Chandavar	Agriculture	2nd
DS 1	Gudankateholé	Agriculture	2nd
DS 1	Badagani	Human dwellings and agriculture	2nd
DS 7	Bhaskere	Human dwellings and Agriculture	2nd
DS 2	Chandubanu	Agriculture	2nd
DS 2	Haddinabal	Agriculture	2nd
DS 2	Mavinaholé	Agriculture	2nd
DS 2	Mahasati	Forest	3rd
DS 2	Vatahalla	Forest	2nd
DS 3	Upponi location 1	Agriculture	3rd
DS 3	Upponi village loc 2	Agriculture	3rd
DS 6	Kattlekan	Forest	2nd
DS 5	Mavinagunde	Forest	2nd
DS 5	Jog lower	Forest	3rd
DS 5	Jog upper	Forest	3 rd
DS 5	Joginamuttu	Agriculture	2nd

5.2 Sampling Containers

Polyethylene containers (PEC) were used for collecting and storing the samples in the field.

5.3 Sampling Frequency

The generally adopted frequencies of sampling are hourly, daily, weekly, bi-monthly and monthly. Monthly samplings were adopted to get samples at these representative points.

5.4 Preservation and Handling Methods

The samples were preserved in the dark and the temperature was lowered to $4^{o}C$

5.5 Sampling Procedure

The following procedure was followed while sampling.

- The container was rinsed with HCl followed by distilled water.
- Before being filled with the sample, the container was first rinsed with the sample.

- The samples were collected by directly immersing the container in the water, and it was closed properly using appropriate stoppers.
- A number of parameters like pH, temperature, colour, and dissolved oxygen were measured at the sampling sites immediately after collection of the sample.
- After the addition of preservatives like Toluene (to check microbial action) the samples were transported to the laboratory for further analysis (physico-chemical and biological).

5.6 Physico-Chemical and Biological Analysis

Physico-chemical and biological parameters for monthly samples were analysed according to the standard methods provided by National Environmental Engineering Research Institute NEERI and American Public Health Association (APHA) and the values were compared with World Health Organization and Indian Standard Specifications (IS: 1050-1983; IS: 2490 –1982).
The following physico-chemical and biological parameters were measured at various representative sites within the Sharavathi catchment area at one-month intervals. Table 5 gives physico-chemical and biological parameters and its respective method of analysis.

Table 5. Water quality parameters and its method of analysis.

Physical Parameter	**Method of Analysis**
Temperature (°C)	Mercury Thermometer
Transparency (cm)	Secchi Disk
Total Dissolved Solids (mg/L)	Electrometric
Total Suspended Solids (mg/L)	Gravimetric
Turbidity (NTU)	Jal Tara Water Testing Kit
Colour	Visual Comparison
Odour	Olfactory sensing
Chemical Parameter	
pH	Electrometric
Conductivity (mS/cm)	Electrometric
Acidity (mg/L)	Titrimetric
Alkalinity (mg/L)	Titrimetric
Chloride (mg/L)	Argentometric
Residual chlorine (mg/L)	Visual Colour Comparison
Total Hardness (mg/L)	Titrimetric
Calcium hardness (mg/L)	Titrimetric
Magnesium hardness (mg/L)	Titrimetric
Dissolved oxygen (ppm)	Electrometric
Fluoride (mg/L)	Jal Tara Water Testing Kit
Ammonia (mg/L)	Visual Colour Comparison
Sodium (mg/L)	Flame Photometer
Potassium (mg/L)	Flame Photometer
Sulphates (mg/L)	Spectrophotometer
Iron (mg/L)	Visual Colour Comparison
Nitrates (mg/L)	Phenoldisulphonic Acid
Phosphates (mg/L)	Ammonium molybdate
Biological Parameter	
Coliform	Visual Comparison

Note: Parts per million (ppm) is equivalent to mg/L

Physical Parameters

Temperature

Waterbodies undergo temperature variations that occur seasonally and in some waterbodies diurnally (24 hour period). Rivers also exhibit vertical stratification of temperature within the water column. The rate of chemical and biological processes in surface water, especially oxygen levels, photosynthesis and algal production, are strongly influenced by temperature. Temperature readings are used in the calculations of various forms of alkalinity and salinity. In limnological studies, water temperature is often taken as a function of depth. Increase in temperature over 40°C in natural water tends to accelerate chemical reactions, lower solubility of gases like oxygen, carbon dioxide, nitrogen and methane, amplify taste and odour, and increase metabolic activity of organisms.

Impinging solar radiation and atmospheric temperature brings about spatial and temporal changes in water temperature setting up convection currents and thermal stratification. Temperature plays a very important role in wetland dynamism affecting the various parameters such as alkalinity, salinity, dissolved oxygen, electrical conductivity, etc. In an aquatic system, these parameters affect the chemical and biological reactions such as solubility of oxygen, carbon-dioxide, carbonate-bicarbonate equilibrium, increasing the in metabolic rate and affecting the physiological reactions of organisms, etc. Water temperature is important in relation to fish life. The temperature of drinking water has an influence on its taste.

Apparatus Required: Thermometer- 0.1^{o} C division.

Procedure: Immerse the thermometer directly in the waterbody for a period of time sufficient to permit constant reading. If it is not possible to take reading directly, then collect water in a sampling bottle nearly one L & measure the temperature by dipping the thermometer in the sample. But while collecting the sample, it must not be exposed to heat or direct solar radiation.

Unit: Degrees Celsius (°C)

***Transparency (Light Penetration*)**

The major source of light energy in an aquatic system is solar energy governing the primary productivity. Transparency is a characteristic of water that varies with the combined effect of colour and turbidity. It measures the light penetrating through the waterbody and it is determined using the Secchi disc.

Apparatus Required: Secchi disc; a metallic disc of 20 cm diameter with four quadrats of alternate black and white on the upper surface. The disc with centrally placed weight at the lower surface is suspended with a graduated cord at the centre.

Procedure: Transparency is measured by gradually lowering the Secchi disc at respective sampling points. The depth at which it disappears (X_1) and reappears (X_2) is noted. The transparency of the waterbody is calculated as follows

$$\text{Transparency} = \frac{X1+X2}{2}$$

where, X_1 = Depth at which Secchi disc disappears (cm or m)
X_2 = Depth at which Secchi disc reappears (cm or m)

Total Dissolved Solids

Dissolved solids are in dissolved state in solution (having particle size less than 10^{-9}m). Low concentrations of dissolved substances have no significant influence on the water quality but at high concentrations impair the water quality and suitability of water for various applications such as domestic, industrial and agricultural purposes. It has an overall effect on the living creatures like humans, aquatic and terrestrial organisms. Excessive concentrations increase water turbidity, affects photosynthesis, absorbs more heat, enriches nutrient status of water, etc. It helps in understanding level of turbidity and hardness of water. They cause laxative effects in humans and when present in irrigation water enrich the soil making it saline.

USEPA standard 500 mg/L

Method: Electrometric

Procedure: Take 50 ml of water sample in a 50 ml beaker and insert the TDS probe into it. Record the TDS value from the instrument.

Unit: parts per million or mg/L

Range for total dissolved solids in natural waters:
Freshwater - < 1500 mg/L
Brackish water - 1500 – 5000 mg/L
Saline water - > 5000 mg/L
Sea water - 30000 – 40000 mg/L

Total Suspended Solids

Solids that remain in suspension like silt, sand, clay and phytoplankton etc., form the total suspended solids. Similar to TDS, it interferes in the quality of the water.

Method: Gravimetric

Procedure: Take 50 ml of water sample and filter it using a previously weighed filter paper (Whatman) (W_1). Dry the filter paper in oven at 105°C till it dries. Weigh the dried filter paper (W_2).

Calculations: TSS = ($W_2 – W_1$)/ Sample taken in mL

Unit: parts per million or mg/L

Turbidity

The substances not present in form of true solution can cause turbidity in water. True solution have a particle size of less than 10^{-9} m and any substances having more than this

size will produce turbidity. Suspended solids and colour are the main interference for transparency. The clarity of a natural waterbody is a major determinant of the condition and productivity of the system. Turbidity value above 10 NTU would affect these processes and transparency. It restricts the penetration of light giving rise to reduced photosynthesis and affects the aesthetics. High levels of turbidity can protect microorganisms from the effects of disinfection and can stimulate bacterial growth. The transparency and turbidity are inversely related to each other, if turbidity is more, transparency is less and vice versa.

Turbidity is an expression of optical property; wherein light is scattered by suspended particles present in water (Tyndall effect). Suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton and other microscopic organisms cause turbidity in water. Turbidity affects light penetration, absorption properties and aesthetic appearance of a waterbody. Increase in the intensity of scattered light results in higher values of turbidity.

Increased turbidity associated with reduction in suspended matter and microbial growth makes water unfit for drinking and other purposes. High turbidity levels in natural waters makes water warmer as suspended particles absorb more heat from the sunlight resulting in low dissolved oxygen concentrations. Turbidity also restricts light penetration for photosynthesis and hence a major determinant of the condition and productivity of the natural waterbody.

Method: Turbidity measuring tube

Procedure: Fill the turbidity measuring tube (with a black cross mark at the bottom) till the mark just disappears and note down the range of turbidity marked on the tube.

Unit: NTU [Nephlometric turbidity units]

Colour

In natural water, colour is due to the presence of humic acids, fulvic acids, metallic ions, suspended matter, plankton, weeds and industrial effluents. Colour is removed to make water suitable for general and industrial applications and is determined by visual comparison of the sample with distilled water.

Visual Comparison: About 20 mL of the sample and 20 mL of distilled water are taken in two separate wide mouthed test tubes. The results are noted (as clear, greenish, greyish, brownish, blackish, etc.) by comparing the colour of the sample with distilled water.

Odour

Odour is an *in situ* parameter and temperature dependent. It impairs the water quality creating unhygienic conditions and a pollution indicator. Odour test helps in assessing the suitability of water for the intended applications for process control and wastewater treatment plants. Odour is imparted to water due to the presence of volatile and dissolved organic and inorganic components such as organic matter, phytoplankton, contamination due to domestic sewage and industrial effluents, dissolution and presence of gases in water like NH_3, H_2S, etc.

Method: Sensory method

Units / Range: Odourless, faint, distinct, very strong, odourless, fishy, rotten egg, faecal or any other.

Chemical Parameters

pH

pH has its great influence on the chemical and biological properties of liquids, hence its determination is very important. It is one of the important parameters in water chemistry and is defined as -log $[H^+]$, and measured as intensity of acidity or alkalinity on a logarithmic scale ranging from 0 to 14. If free H^+ are more it is expressed as acidic (i.e. pH < 7) and if OH^- ions are more then it is expressed as alkaline (i.e. pH > 7). pH is important for acid-base neutralisation, water softening, precipitation, coagulation, disinfections and corrosion control. pH less than 7 (acidic) has significance from public health point of view and creates corrosion and interferes in the water softening process. pH greater than 7 (alkaline) is mainly due to carbonates and bicarbonates and hence poses a problem of scale formation, hardness, etc. In natural water, pH is governed by the equilibrium between carbon dioxide / bicarbonate / carbonate ions and ranges between 4.5 and 8.5 although mostly basic. It tends to increase during day largely due to the photosynthetic activity (consumption of carbon dioxide) and decreases during night due to respiratory activity. Wastewater and polluted natural waters have pH values lower or higher than 7 based on the nature of the pollutant.

Apparatus Required:

- Electrometric method: Glass electrode, reference electrode (mercury/calomel or silver/silver chloride) and pH meter.

Principle:

- Electrometric method: pH is determined by measuring the Electro Motive Force (E.M.F) of a cell comprising an indicator electrode (an electrode responsive to hydrogen ions such as a glass electrode) immersed in the test solution and the reference electrode (usually a mercury/calomel electrode). Contact between the test solution and the reference electrode is usually got by means of a liquid junction, which forms a part of reference electrode. EMF of this cell is measured with pH meter, that is, a high impedance voltmeter calibrated in terms of pH. The electrode is allowed to stand for 2 minutes to stabilise before taking reading (at least ±0.1 pH units).

Procedure:

Take 50mL of sample in a beaker and insert the pH probe. Record the readings.

Electrical Conductivity

Conductivity (specific conductance) is the ability of water to conduct an electric current. It is measured in milli-Siemens per cm and depends on the total concentration, mobility, valence of ions and the temperature of the solution. Electrolytes in a solution disassociate into positive (cations) and negative (anions) ions and impart conductivity. Most dissolved

inorganic substances are in the ionised form in water and contribute to conductance. The conductance of the samples gives rapid and practical estimate of the variation in dissolved mineral content of the water supply. Conductance is defined as the reciprocal of the resistance involved and expressed as mho or Siemens (s).

$$G = \frac{1}{R\ (ohm)}$$

where, G – conductance (ohm^{-1} = mho = Siemens)
R – Resistance (ohm)

Apparatus Required: Conductivity meter

Procedure: The electrode of the conductivity meter is dipped into the sample, and the readings are noted for stable value displayed in mS/cm.

Most dissolved inorganic substances in water are in the ionised form and hence contribute to conductance. Conductivity gives a rapid and practical estimate of total dissolved solids. It helps in determining suitability of water for irrigation and domestic applications.

- Pure deionised water : < 1 µS/cm
- Distilled water : 0.5 – 2.0 mS/cm
- Fresh or surface waters – 50 – 500 mS/cm
- Groundwaters > surface waters
- Polluted waters – high conductance
- Rain water: 20 – 40 µS/cm
- Effluent from Effluent Treatment Plants: 300 –1000 µS
- Conductivity µS/cm = 110 – 115 % of TDS [mg/L]

Acidity

Acidity of a liquid is its capacity to denote H^+ ions. Since most of the natural waters and sewage are buffered by carbon dioxide - bicarbonate system, the acidity present due to free CO_2 has no significance from public health point of view. Water containing mineral acidity (due to H_2SO_4, HNO_3 and HCl) is unacceptable. Further, acid waters pose problems of corrosion and interfere with water softening. It is measured by titrimetric method.

Principle: The mineral acids present and contributing mineral acidity can be calculated by titrating or neutralising samples to pH 4.3. The CO_2 and bicarbonate (carbonic acid) present in the sample can be neutralised completely by continuing the titration to pH 8.3.

Reagents:

- Standard sodium hydroxide 0.02N: Dissolve 0.8 g of NaOH and dilute to 1000 mL using CO_2 free distilled water. Store in airtight, rubber stoppered glass bottle to protect from atmospheric CO_2. Standardise against 0.02N potassium biphthalate.
- Phenolphthalein indicator: Dissolve 0.5 g in 500 mL 95% ethyl alcohol. Add 500 mL of distilled water. Add drop wise 0.02N NaOH till faint pink colour appears.
- Methyl orange indicator: Dissolve 0.5 g with CO_2 free distilled water (1000 mL).

Procedure:

- Take 25 or 50 mL of sample in a conical flask add 2 drops of methyl orange and titrate with standard 0.02N NaOH till the colour changes to faint orange, characteristic of pH 4.4 - 4.3.
- Note down the volume of NaOH used.
- Again add 2 or 3 drops of phenolphthalein indicator and continue the titration against the same sodium hydroxide till the pink colour appears.
- Note down the additional volume used.

Calculation:
Each mL of 0.02 N NaOH = 1 mg $CaCO_3$.

Hence, acidity mineral or due to CO_2 as mg/L $CaCO_3$ = $\frac{Vx1000}{mL\ of\ sample}$

If the normality of NaOH is not 0.02, then,
Acidity mineral or due to CO_2 as mg/L, $CaCO_3$ = $\frac{(A\ or\ B)\ x\ N\ x\ 50000}{mL\ of\ sample}$

where, V= volume of NaOH used in final round (vol. 1 + vol. 2)
A = mL of NaOH required for sample to raise pH upto 4.4 -4.3
B = mL NaOH required for sample to raise pH from 4.4 to 8.3.
N = normality of NaOH used.

Alkalinity

The alkalinity of water is the measure of its capacity to neutralise acids. The alkalinity of natural waters is due to the salts of carbonates, bicarbonates, borate, silicates and phosphates along with the hydroxyl ions in the free state. However, hydroxide, carbonate and bicarbonate cause the major portion of the alkalinity in the natural water, which may be ranked in order of their association with high pH values. Alkalinity values provide guidance in applying proper doses of chemicals in water and waste water treatment processes, particularly in coagulation, softening and operational control of anaerobic digestion.

Principle: Alkalinity of a sample can be measured by titrating with standard sulphuric acid. Titration to pH 8.3 or decolourisation of phenolphthalein indicator will indicate complete neutralisation of OH and 1/2 of CO_3 while to pH 4.5 or sharp changes from yellow to orange of methyl orange indicator will indicate total alkalinity.

Reagents:
- Standard H_2SO_4 0.02N: Prepare 0.1N sulphuric acid by diluting 3.0 mL of conc. H_2SO_4 to 1000 mL and standardise it against standard Na_2CO_3 (0.1N). Dilute appropriate volume of H_2SO_4 to get 0.02N H_2SO_4.
- Phenolphthalein indicator: Dissolve 0.5 g in 500 mL 95% ethyl alcohol and add 500 mL distilled water. Add drop-wise 0.02N NaOH till faint pink colour appears.
- Methyl orange: Dissolve 0.5 g and dilute to 1000 mL with CO_2 free distilled water.

Procedure:
- Take 25 or 50 mL sample in a conical flask and add 2 or 3 drops of phenolphthalein indicator.
- If pink colour appears titrate with 0.02N H_2SO_4 till the colour disappears or pH is 8.3. Note the volume of H_2SO_4 used.

- Add 2 or 3 drops methyl orange indicator to the same flask and continue titration till pH comes down to 4.5 or yellow colour changes to orange. Note the sulphuric acid used.

Calculation:
P- alkalinity (mg/L as $CaCO_3$) = (A x 1000) / mL of sample.
Total alkalinity (mg/L as $CaCO_3$) = (B x 1000) / mL of sample.
In case H_2SO_4 is not 0.02N apply the following formula;
Alkalinity mg/L as $CaCO_3$ = {(A or B) x N x 50000}/ mL of sample used.
where, A = mL of H_2SO_4 required to bring the pH to 8.3 (P-alkalinity value)
B = mL of H_2SO_4 required to bring the pH to 4.5 (Total alkalinity)
N = Normality of H_2SO_4 used.

Once the phenolphthalein and total alkalinities are determined then three types of alkalinities *i.e.* hydroxide, carbonate and bicarbonate are easily calculated from the given Table 7.

Table 7. Relation between Hydroxide, Carbonate and Bicarbonate alkalinities

Values of P and T	OH	CO_3	HCO_3
P = 0	0	0	T
P < 1/2 T	0	2P	T-2P
P =1/2 T	0	2P	0
P >1/2 T	2P-T	2(T-P)	0
P =T	T	0	0

Once the values of carbonate and bicarbonate alkalinities are known then their conversion to mg/mL of CO_3^{2-} or HCO_3^- is possible.

mg/L CO_3^{2-} = mg/L carbonate alkalinity x 0.6
mg/L HCO_3^- = mg/L bicarbonate alkalinity x 1.22

Chlorides

The presence of chlorides in natural waters can mainly be attributed to dissolution of salt deposits in the form of ions (Cl^-). Otherwise, high concentrations may indicate pollution by sewage or some industrial wastes or intrusion of seawater or other saline water. It is the major form of inorganic anions in water for aquatic life. High chloride content has a deleterious effect on metallic pipes and structures, as well as agricultural plants. In natural freshwaters, high concentration of chlorides is regarded as an indicator of pollution due to organic wastes of animal origin (animal excreta have higher chlorides along with nitrogenous wastes). Domestic sewage and industrial effluents also bring chlorides into the water. Chloride content above 250 mg/L makes water salty. However, a level up to 1000 mg/L is safe for human consumption. High level results in corrosion and non-palatability. They are calculated by Argentometric method.

Principle: In alkaline or neutral solution, potassium chromate indicates the endpoint of the silver nitrate titration of chlorides. Silver chloride is quantitatively precipitated before the red silver chromate is formed.

Apparatus Required: Lab glassware.

Reagents:

- Potassium chromate indicator solution: 50 g of potassium chromate is dissolved in minimum amount of distilled water and silver nitrate is added drop wise till a red precipitate is formed. The mixture is allowed to stand for about 12 hours and diluted to 1000 mL with distilled water.
- Silver nitrate solution (0.014N): 2.395 g of silver nitrate is dissolved in distilled water and made up to 1000 mL.

Procedure: A known volume of filtered sample (50 mL) is taken in a conical flask, to which about 0.5 mL of potassium chromate indicator is added and titrated against standard silver nitrate till silver dichromate ($AgCrO_4$) starts precipitating.

Calculation:

$$Cl^- (\text{mg/L}) = \frac{(A-B) \times N \times 35.45 \times 1000}{\text{Sample in mL}}$$

where, A - Volume of silver nitrate consumed by the sample
B - Volume of silver nitrate consumed by the blank
N - Normality of silver nitrate

Residual Chlorine

The chlorination of water supplies and polluted waters serves primarily to destroy or deactivate disease-producing microorganisms. A secondary benefit is the overall importance in water quality resulting from the reaction of chlorine with ammonia, iron, manganese, sulphide and some organic substances. Chlorination may produce adverse effects. Taste and odour characteristics of compounds present in a water supply may be intensified. Potentially carcinogenic chloroorganic compounds such as chloroform may be formed. Combined chlorine formed on chlorination of ammonia or amine bearing waters adversely affects some aquatic life. To fulfil the primary purpose of chlorination and to minimise any adverse effect, it is essential that proper testing producers be used with a foreknowledge of the limitation of the analytical determination.

Free chlorine reacts readily with ammonia and certain nitrogenous compounds to form combined chlorine. With ammonia, chlorine reacts to form the chloroamines; monochloroamine, dichloroamines and nitrogen trichloride. The presence and concentrations of these combined forms depend chiefly on pH, temperature, and initial chlorine to nitrogen ratio, absolute chlorine demand and reaction time. Both free and combined chlorine may be present simultaneously. Combined chlorine in water supplies may be formed during the treatment of raw water containing ammonia or ammonium salt. Chlorinated wastewater effluents as well as certain chlorinated industrial effluents, normally contain combined chlorine. In the present study Tara Water Testing Kit was used for the estimation of Residual Chlorine. The permissible level of residual chlorine in drinking water is 0.2mg/L.

Principle: Ortho-toludine forms yellow complex, the intensity of the developed colour is dependent on the amount of residual chlorine present in the sample.

Reagents Used:

1. Ortho-toludine
2. pH paper.

Steps Followed:

1. Take 10 mL sample in a cylinder and find the pH of sample using the pH paper.
2. If the pH is less than 9, add 4 drops of O-toludine and if greater than 9, add 8 or 10 drops.
3. Now compare the colour with standard colour chart given with Tara Water Testing Kit and record the concentration in mg/L.

Total Hardness

Hardness is due to the presence of multivalent metal ions, which come from minerals dissolved in the water. The total hardness is defined as the sum of calcium and magnesium concentrations, expressed as $CaCO_3$ in mg/L and is given in Table 6. Carbonates and bicarbonates of calcium and magnesium cause temporary hardness. Sulphates and chlorides cause permanent hardness. It is based on the ability of these ions to react with soap to form a precipitate or soap scum. In freshwater the primary ions are calcium and magnesium; however iron and manganese may also contribute. Carbonate hardness is equal to alkalinity but a non-carbonate fraction may include nitrates and chlorides. Depending on pH and alkalinity, hardness of about 200 mg/L can result in scale deposition, particularly on heating. Soft waters with a hardness of less than about 100 mg/L have a low buffering capacity and may be more corrosive to water pipes. The taste threshold for the calcium ion is 75 mg/L, depending on the associated anion, and the taste threshold for magnesium is probably less than that for calcium.

Table 6. Water quality on the basis of hardness as ($CaCO_3$).

Soft	0 – 60 mg/L
Medium	60 –120 mg/L
Hard	120 – 180 mg/L
Very Hard	> 180 mg/L

Principle: In alkaline conditions, EDTA (Ethylene-diamine tetra acetic acid) and its sodium salts react with cations forming a soluble chelated complex when added to a solution. If a small amount of dye such as Eriochrome Black-T is added to an aqueous solution containing calcium and magnesium ions at alkaline pH of 10.0 ± 0.1, it forms wine red colour. When EDTA is added as a titrant, all the calcium and magnesium ions in the solution gets complexed resulting in a sharp colour change from wine red to blue, marking the end point of the titration. Hardness of water prevents lather formation with soap rendering the water unsuitable for bathing and washing. It forms scales in boilers, making it unsuitable for industrial usage. At higher pH > 12.0, Mg^{++} ion precipitates with only Ca^{++} in solution. At this pH, Murexide indicator forms a pink colour with Ca^{++} ion. When EDTA is added, Ca^{++} gets complexed resulting in a change from pink to purple indicating end point of the reaction.

Apparatus Required: Lab glassware - burette, pipette, conical flask, beakers, etc.

Reagents:

- Buffer solution: 16.9 g of ammonium chloride, 1.25 g of magnesium salt of EDTA is dissolved in 143 mL of concentrated ammonium hydroxide and diluted to 250 mL with distilled water.

- Eriochrome Black-T indicator: 0.5 g of Eriochrome black-T indicator is dissolved in 100 g of triethanolamine.
- Standard EDTA titrant: 0.01 M or Ng AR grade EDTA is dissolved in distilled water and diluted to 1000 mL and is standardised against standard calcium solution, 1 mL = 1 mg $CaCO_3$.
- Standard Calcium solution: 1.0 g of AR grade $CaCO_3$ is weighed into a 250 mL conical flask, to which 1+1 HCl is added till all $CaCO_3$ is dissolved completely. 200 mL of distilled water is added and boiled to expel carbon-di-oxide. Dilute to 1000 mL. 1 mL = 1 mg $CaCO_3$.

Procedure: Exactly 50 mL of the well-mixed sample is pipetted into a conical flask, to which 1 mL of ammonium buffer and 2-3 drops of Eriochrome black -T indicator is added. The mixture is titrated against standard 0.01M EDTA until the wine red colour of the solution turns pale blue at the end point.

Calculation:

$$\textit{Total Hardness}\ (\text{mg/L}) = \frac{T \times 100}{V}$$

where, T = Volume of titrant, V = Volume of sample

Calcium Hardness

The presence of calcium (fifth most abundant) in water results from passage through or over deposits of limestone, dolomite, gypsum and other calcium bearing rocks. Calcium contributes to the total hardness of water and is an important micronutrient in aquatic environment and is especially needed in large quantities by molluscs and vertebrates. It is measured by EDTA titrimetric method. Small concentration of calcium carbonate prevents corrosion of metal pipes by laying down a protective coating. But increased amount of calcium precipitates on heating to form harmful scales in boilers, pipes and utensils.

Principle: When EDTA (Ethylene-diamine tetra acetic acid) is added to the water containing calcium and magnesium, it combines first with calcium. Calcium can be determined directly with EDTA when pH is made sufficiently high such that the magnesium is largely precipitated as hydroxyl compound (by adding NaOH and iso-propyl alcohol). When murexide indicator is added to the solution containing calcium, all the calcium gets complexed by the EDTA at pH 12-13. The end point is indicated from a colour change from pink to purple.

Apparatus Required: Burettes, pipette, conical flask, beakers and droppers.

Reagents:
- Sodium hydroxide (8%): 8 g of sodium hydroxide is dissolved in 100 mL of distilled water.
- Murexide indicator (ammonium purpurate): 0.2 g of murexide is ground well with 100 g of sodium chloride thoroughly.
- Standard EDTA titrant, 0.01M: 3.723 g of EDTA (disodium salt) is dissolved in distilled water and made up to 100 mL with the same.

Procedure: A known volume (50 mL) of the sample is pipetted into a clean conical flask, to which 1 mL of sodium hydroxide and 1mL of iso-propyl alcohol is added. A pinch of murexide indicator is added to this mixture and titrated against EDTA until the pink colour turns purple.

Calculation:

$$Ca \text{ (mg/L)} = \frac{T \times 400.8 \times A}{V}$$

where, T= volume of titrant, mL
V= volume of sample taken (mL)
A= mg of $CaCO_3$ equivalent to 1mL of EDTA titrant

Calcium as $CaCO_3$

$$CaCO_3 \text{ (mg/L)} = \frac{T \times A \times 1000}{V}$$

Magnesium Hardness

Magnesium is a relatively abundant element in the earth's crust, ranking eighth in abundance among the elements. It is found in all natural waters and its source lies in rocks, generally present in lower concentration than calcium. It is also an important element contributing to hardness and a necessary constituent of chlorophyll. Its concentration greater than 125 mg/L can influence cathartic and diuretic actions.

Principle: Magnesium hardness can be calculated from the determined total hardness and calcium hardness.

Calculation:

$$\text{Magnesium (mg/L)} = (T - C)$$

where, T = Total hardness mg/L as $CaCO_3$
C = Calcium hardness mg/L as $CaCO_3$

High concentration of magnesium proves to be diuretic and laxative, and reduces the utility of water for domestic use while a concentration above 500 mg/L imparts an unpleasant taste to water and renders it unfit for drinking. Chemical softening, reverse osmosis and electro dialysis or ion exchange reduces the magnesium hardness to acceptable levels.

Dissolved Oxygen

Oxygen dissolved in water is a very important parameter in water analysis as it serves as an indicator of the physical, chemical and biological activities of the waterbody. The two main sources of dissolved oxygen are diffusion of oxygen from the air and photosynthetic activity. Diffusion of oxygen from the air into water depends on the solubility of oxygen, and is influenced by many other factors like water movement, temperature, salinity, etc. Photosynthesis, a biological phenomenon carried out by the autotrophs, depends on the plankton population, light condition, gases, etc. Oxygen is considered to be the major limiting factor in waterbodies with organic materials. If its value is less than 3 mg/L, the metabolic processes that produce energy for growth and reproduction get affected.

Oxygen levels that remain below 1-2 mg/L for a few hours can result in large fish kills. In the present study, for analysis of DO, DO meter is used.

Principle: The membrane electrode has a sensing element protected by an oxygen-permeable plastic membrane that serves as a diffusion barrier against impurities. Under steady conditions, the electric current read is directly proportional to the DO concentrations (electric current is directly proportional to the activity of molecular oxygen).

Apparatus and reagents: Oxygen-sensitive membrane electrode, beaker, tissue paper, glass rods, sodium sulphite, sodium sulphate, cobalt chloride, etc.

Method: Instrumental [Systronics DO meter]

Procedure: For calibration, add a pinch of sodium sulphate, sodium sulphite and cobalt chloride to the tap water, dip the probe into it and gently shake the probe till the reading in the DO meter comes to 0.5. For air calibration, wrap the probe with moist tissue paper and keep the probe in the air for 10 minutes. Record the temperature readings of the instrument and refer the table for dissolved oxygen concentrations against temperature. Record the corresponding value and the altitude of location (in feet), refer the table and note the correction factor. Multiply correction factor with the corresponding dissolved oxygen concentration to get the calibration value. Adjust the DO knob to the calibration value calculated and at the same time adjust the salinity knob depending on the source to be monitored. Then dip the DO probe into the sample or waterbody with gentle shaking and record the DO directly from the instrument.

Unit: ppm or mg/L

Range:
5-6 ppm sufficient for most species
<3 ppm stressful to most aquatic species
<2 ppm fatal to most species

Fluoride

Fluorides have dual significance in water supplies. High concentration causes dental fluorosis and lower concentration (< 0.8 mg/L) causes dental caries. A fluoride concentration of approximately 1 mg/L in drinking water is recommended. They are frequently found in certain industrial processes resulting in fluoride rich wastewaters. Significant sources of fluoride are found in coke, glass and ceramic, electronics, pesticide and fertiliser manufacturing, steel and aluminium processing and electroplating industries. For potable water maximum permissible level for fluoride is 1.5mg/L and minimum is 0.6mg/L. In the present, fluoride was estimated using Jal Tara Water Testing Kit.

Principle: The colorimetric method of estimating fluoride is based on the reaction of fluorides (HF) with zirconium dye. Fluoride reacts with the dye dissociating (bleaching) the dye into a colourless complex anion (ZrF_6^{2-}). As the amount of fluoride increases, the colour produced becomes progressively higher or of a different hue.

Apparatus Required: Jal Tara Water Testing Kit and lab glassware.

Reagents: Zirconyl-alizarine reagent

Procedure: Take 50mL of sample in a test tube provided. Add Zirconyl-alizarine till 52.5mL mark on the test tube. Mix the solution well. Allow the solution for an hour till the colour develops. Compare and record the developed colour with the standard chart provided (in mg/L).

Ammonia

Ammonia is produced by the microbial degradation of organic matter. It appears therefore, in many grounds as well as surface waters. Concentrations of ammonia above a certain level in water; polluted either due to sewage or industrial wastes, is toxic to fish. The proportion of two forms of ammonia in surface water depends on pH, which are listed below in Table 8.

Table 8. Availability of ammonia at different pH.

pH	**6**	**7**	**8**	**9**	**10**	**11**
% NH_3	0	1	4	25	78	96
% NH_4^+	100	99	96	75	22	4

For accurate result, it is generally preferable to distil off ammonia from the sample, and absorb in boric acid. It is then determined either by titration of colorimetrically using Nessler reagent. Direct Nesslerization of sample is quicker but subject to considerable interference.

Principle: Ammonia produces a yellow coloured compound when reacted with alkaline Nessler's reagent, provided the sample is clarified properly. Pre-treatment with $ZnSO_4$ and NaOH precipitates Ca, Fe, Mg and sulphide and removes turbidity and apparent colour. Addition of EDTA (before Nessler's reagent) or Rochelle salt solution prevents precipitation of residual Ca and Mg in the presence of alkaline Nessler's reagent.

Interferences: Colour, turbidity Ca, Mg, salts and Fe in the sample constitute the prime sources of interferences.

Method Used: In this study the estimation of ammonia was carried out using Jal Tara Water Testing Kit, following the principle:

When Nessler's reagents is added to a diluted to ammonia solution, the liberated ammonia reacts with the reagent fairly rapid to form an orange-brown product, which remains in colloidal solution but flocculates on long standing.

Reagent Used: Nessler's reagent.

Steps Followed:
1. Take a cylinder and transfer 5 mL sample.
2. Add 2 or 3 drops of Nessler's reagent.

3. Now compare the colour developed with the standard chart given with Tara Water Testing Kit, and find the concentration mg/L

Sodium and Potassium

Sodium is one of the most abundant elements and is a common constituent of natural waters. The sodium concentration of water is of concern primarily when considering their solubility for agricultural uses or boiler feed water. The concentration ranges from very low in the surface waters and relatively high in deep ground waters and highest in the marine waters. At room temperature, the average taste threshold for sodium is about 200 mg/L.

Potassium is found in low concentrations (<10 mg/L) in natural waters since rocks, which contain potassium, are relatively resistant to weathering. It is usually found in ionic form and the salts are highly soluble. Though found in small quantities it plays a vital role in the metabolism of fresh water environment. At room temperature the various threshold values were found to be about 20 mg/L for Na_2CO_3, 150 mg/L for NaCl, 190 mg/L for $NaNO_3$, 220 mg/L for Na_2SO_4 and 400 mg/L for $NaHCO_3$.

Principle: The estimation of sodium and potassium is based on the emission spectroscopy, which deals with the excitation of electrons from ground state to higher energy state and coming back to its original state with the emission of light. An atomiser under controlled conditions sucks the solution. The radiation from the flame enters a dispersing device in order to isolate the desire region of spectrum. The intensity of isolated radiation can be measured by a phototube. After carefully calibrating the photometer with solutions of known strength, it is possible to co-relate the intensity of a given spectral line of unknown with the amount of an element present that emits the particular radiation.

Apparatus Required: Flame photometer (Systronics), lab glassware and Whatman filter paper.

Reagents:

- Deionised distilled water.
- Stock sodium solution: 2.542 g of sodium chloride dried (at 140^o C) is dissolved in 1000 mL distilled water to give 1 mL = 1 mg of sodium.
- Working sodium solution: Dilute 10.0 mL stock solution to 1 L.
- Stock potassium solution: 1.907 g of dried potassium chloride is dissolved in 1000 mL of distilled water, to give 1 mL = 1 mg of potassium.
- Working potassium solution: Dilute 10 mL of the stock solution to 1 L to get 1 mL= 0.01 mg K.

Procedure:

1. Follow the instructions given by the manufacturer.
2. Start the electrical supply and switch on the air supply. Stabilize the air. The needle should be steady at the mark.
3. Switch on the gas and maintain the gas fuel mixture so that the blue flame is seen through viewing window.
4. Aspirate distilled water and adjust the galvanometer reading to zero.
5. Calibrate the instrument by aspirating the standard and adjusting the galvanometric reading to desired mark.

6. Aspired distilled water to bring the reading to zero mark.
7. Aspirate sample and note down the galvanometric reading.
8. Put off the fuel supply first followed by air and then main switch.

From stock solutions working standards are prepared for sodium and potassium as mentioned in the reagents above. From working standards a series of standards of known concentration are prepared. These standards are aspirated into the flame photometer and the emission values are recorded. Then in a similar way the unknown samples are directly aspirated and corresponding emission values are recorded. Then the emission values obtained for unknown samples are multiplied with the slope and the dilution factor. The slope is the sum of the concentrations of the standards prepared divided by sum of their emission values. This gives the concentration of sodium and potassium in mg/L.

Calculation:
The emission of standard solution of sodium and potassium is taken and the sum of concentration is estimated.

$$\text{Sodium or Potassium (mg/L)} = \frac{C}{A} \times \text{emission of sample}$$

The emission setting in flame photometer is as follows

Concentration of Na (mg/L)	Absorbance (Na)	Concentration of K (mg/L)	Absorbance (K)
0.0	0	0.0	0
4	40	10	25
6	60	20	50
8	80	30	75
10	100	40	100

Sulphates

Sulphates are commonly found in all natural waters, particularly those with high salt content. Besides industrial pollution and domestic sewage, biological oxidation of reduced sulphur also adds to sulphate content. It is soluble in water and imparts hardness with other cations. Sulphate causes scaling in industrial water supplies, and odour and corrosion in wastewater treatment processes due to its reduction to H_2S. Its main source is industrial discharge that contains sulphate salts and domestic wastes (heavy use of detergents). When water containing magnesium sulphate at levels about 1000 mg/L acts as a purgative in human adults, lower concentration (below 150 mg/L) may still affect new users and children. Taste threshold concentration for the most prevalent sulphate salts are 200 to 500 mg/L for sodium sulphate, and 400 to 600 mg/L for magnesium sulphate. On the basis of above values, allied to the cathartic effect of sulphate, a guideline value of 400 mg/L is proposed. It can be calculated by turbidometric method.

Principle: Sulphate ions are precipitated as $BaSO_4$ in acidic media (HCl) with barium chloride. The absorption of light by this precipitated suspension is measured by spectrophotometer at 420 nm or scattering of light by Nephelometer.

Apparatus Required: Colorimeter for use at 420 nm, magnetic stirrer, Nessler's tubes and lab glassware.

Reagents:

- Conditioning reagent: 50 mL of glycerol is mixed in a solution containing 30 mL of conc. hydrochloric acid, in 300 mL distilled water (10% HCl), 100 mL of 95% ethyl alcohol or isopropyl alcohol and 75 g NaCl.
- Barium Chloride. Crystals, 20 to 30 mesh.
- Standard sulphate solution: 147.9 mg of AR grade sodium sulphate is dissolved in distilled water and made up to 1000 mL, to give 1 mL = 100 mg sulphate.

Procedure:

1. Take a suitable volume of sample in 250 mL conical flask and dilute to 100 mL.
2. Add 5.0 mL conditioning reagent and mix well.
3. Keep the flask constantly stirred with the help of a stirrer. Add $BaCl_2$ crystals while stirring. Continue stirring for 1 min. after addition of $BaCl_2$.
4. Measure the turbidity developed after the 30 sec. for 4 min. on spectrophotometer at 420 nm. After 2 min. reading will remain constant and use this for calculation.
5. Prepare a standard curve by carrying standard sulphate solution through entire process. Space standard solution at 5 mg/L increment in the 0 to 40 mg/L range.
6. Read the SO_4 present in the sample from the standard curve.

Preparation of standard solutions:

Prepare standards at 5 mg/L increment in the 0 – 40 mg/L range from the reagents above. The absorbance of these standards is recorded from a spectrophotometer at 420 nm. Similarly, absorbance of unknown samples is also recorded. The sum of the concentrations of the various standards divided by the sum of their absorbance values gives the slope. The absorbance of unknown samples is multiplied with the slope and the dilution factor, which gives the concentration of sulphate in mg/L.

Calculation:

$$SO_4 \text{ mg/L} = \frac{C \times \text{absorbance of the sample} \times \text{dilution factor}}{A}$$

Where, C = total concentrations of standards and A = sum of absorbance of all standards.

Iron

Iron is the fourth most abundant element by weight in the earth's crust. In water it occurs mainly in the divalent and trivalent state. Iron in surface water is generally present in the ferric state. The concentration of iron in well-aerated water is seldom high, but under reducing condition, which may exist in some groundwater, lake and reservoir and in the absence of sulphate and carbonate, high concentration of soluble ferrous iron may be found. The presence of iron in natural water can be attributed to the dissolution of rocks and minerals, acid mine drainage, landfill leachates, sewage or engineering industries. Iron is an essential element in human nutrition. It is contained in a number of biologically significant proteins, but ingestion in large quantity results in hemochromatosis where in tissue damage results from iron accumulation. It is determined by colorimeter with an operating range of 400 to 700 nm.

Principle: The ferric form of iron is reduced to ferrous form by boiling with hydrochloric acid and hydroxylamine hydrochloride. Later phenanthroline is added at pH 3.2 to 3.3 to form soluble chelated complex of orange red colour with iron. Three moles of 1, 10 phenanthroline are required to form a complex iron with each Fe^{++}. The colour obeys Beer's law and the intensity of colour is independent of pH from 3 to 9. Total dissolved

and suspended iron can be measured with unfiltered samples. For study of ferrous ferric equilibria it is sometimes desirable to determine the ferrous content of the water sample. For each determination add 10 mL of 1 % 1, 10 phenanthroline and 1 mL of glacial acetic acid to the sample bottle before sample collection for iron. It will complex soluble ferrous iron before it is oxidised to ferric state. The addition of nitrilotriacitic acid to the system further helps to stabilise the ferrous ferric system.

Method Used: Tara Water Testing Kit.

Principle: Iron is brought into ferrous state by boiling with acid and hydroxylamine and treated with 1, 10 phenanthroline at pH 3.2 to 3.3. Three molecules of phenanthroline react with each atom of ferrous iron to form an orange-red colour complex. A pH between 2.9 and 3.5 ensures rapid colour development in the presence of excess of phenanthroline.

Reagents: Hydroxyl amine hydrochloride, Ammonium acetate buffer, 1, 10 phenanthroline, HCl.

Procedure: Take 5 mL of sample, add 0.4 mL of HCl and 4 drops of Hydroxylamine hydrochloride, and heat the sample on a sprit lamp till the liquid reduces to 1/3 of its initial volume. Allow it to cool and add 1mL of Ammonium acetate buffer and 0.4 mL of 1, 10 phenanthroline and wait for 10 or 15 minutes for colour development and compare the colour with the standard colour chart given by Tara Water Testing Kit and record the volume in mg/L.

Nitrates

The nitrate ion is the common form of combined nitrogen found in surface waters. By denitrification process, it may be bio-chemically reduced to nitrite under anaerobic conditions. The significant sources of nitrates are chemical fertilisers from cultivated lands, drainage from livestock feeds, as well as domestic and industrial sources. Natural waters in their unpolluted state contain only minute quantities of nitrates. The stimulation of plant growth by nitrates may result in eutrophication, especially due to algae. The subsequent death and decay of plants produce secondary pollution. Nitrates are most important for biological oxidation of nitrogenous organic matter. Certain nitrogen fixing bacteria and algae have the capacity to fix molecular nitrogen in nitrates. The main source of polluting nitrates is the domestic sewage let into waterbodies. Nitrates may find their way into groundwater through leaching from soil and at times by contamination. Waters with high concentrations (>45mg/L) can represent a significant health risk. Beyond this value methemoglobinemia takes place. They can be measured by the phenoldisulphonic method.

Principle: Nitrates react with phenoldisulphonic acid and produce a nitrate derivative, which in alkaline solution develops yellow colour due to rearrangement of its structure. The colour produced is directly proportional to the concentration of nitrates present in the sample.

Apparatus Required: Nessler's tube, pipettes, beakers, spectrophotometer, Cuvettes, measuring jar and hot water bath.

Reagents:

- Phenol disulphonic acid: 25 g of phenol is dissolved in 150 mL of concentrated sulphuric acid, 85 mL of sulphuric acid is further added and heated for about 90 min on a water bath and stored in dark bottles upon cooling.
- Sodium hydroxide: About 50 g of sodium hydroxide is dissolved in 150-200 mL of water and cooled.
- Conc. Ammonium hydroxide
- Stock nitrate solution: 721.8 mg (0.722 g) of AR potassium nitrate is dissolved in distilled water and made up to 100 mL for stock solution.
- Standard nitrate solution: Standard nitrate solution is prepared by evaporating 50 mL of the stock solution to dryness in the water bath. The obtained residue is dissolved in 2 mL of phenol disulfonic acid and diluted to 500 mL, to give 1 mL = 10 μg. The solution of various strengths ranging from 0.0 (blank) to 1.0 mg/L at intervals of 0.2 mg/L is prepared by diluting stock solution with distilled water.

Procedure: A known volume (50 mL) of the sample is pipetted into a porcelain dish and evaporated to dryness on a hot water bath. 2 mL of phenol disulphonic acid is added to dissolve the residue by constant stirring with a glass rod. Concentrated solution of sodium hydroxide or conc. ammonium hydroxide and distilled water is added with constant stirring to make it alkaline. This is filtered into a Nessler's tube and made upto 50 mL with distilled water. The absorbance is read at 410 nm using a spectrophotometer after the development of colour. Taking concentration along X-axis and the spectrophotometric readings (absorbance) along Y-axis the standard graph is plotted. The value of nitrate is found by comparing absorbance of sample with the standard curve and expressed in mg/L.

Preparation of Standard solutions:
From stock solutions working standards are prepared. From working standards a series of standards of known concentration are prepared and diluted to 50 mL using distilled water. The absorbance of these standards is recorded from spectrophotometer at 410 nm. Similarly, absorbance of unknown samples is also recorded. The sum of the concentrations of the various standards divided by the sum of their absorbance values gives the slope. The absorbance of unknown samples is multiplied with the slope and the dilution factor, which gives the concentration of nitrates in mg/L.

Calculation:

$$\text{Nitrates (mg/L)} = \frac{C \times \text{absorbance of the sample} \times \text{dilution factor}}{A}.$$

where, C = sum of concentrations of the standard nitrate solution used.
A = sum of absorbance of the standard nitrate solution used.

Phosphates

Phosphate's role in promoting plant growth actually makes it a dangerous pollutant when dumped in excessive quantities into aquatic ecosystems. In fact, plants have so much difficulty that the chemical is a limiting nutrient. The rate at which plants can grow and reproduce is limited by the amount of usable phosphate in the soil or water (for aquatic plants). When extra phosphorous was added to water due to anthropogenic activities, it creates a condition called eutrophication that can wipe out aquatic ecosystems. Eutrophication is characterised by a rapid growth in the plant population (an algal bloom). The bacteria that decompose the dead plants use oxygen, and eventually burn up so much

that not enough remains to support fish, insects, mussels, and other animals, leading to a massive die-off. The presence of phosphates in virtually every detergent, including household cleaners and laundry soap, fertiliser run-off from agriculture and landscaping, decomposition of organic matter continues to be a major source of phosphate pollution. Animal wastes can also add significant amounts of phosphate to water. In most surface waters, concentration of phosphorus ranges from 0.005 to 0.020 mg/L PO^4- P.

Principle: In acidic conditions orthophosphate reacts with ammonium molybdate forming Molybdophosphoric acid, reduced further to molybdenum blue by stannous chloride. The intensity of the blue colour is directly proportional to the concentration of phosphate. The absorbance is noted at 690nm using spectrophotometer.

Apparatus Required: Spectrophotometer, lab glassware, hot plate and Nessler's tube.

Reagents:

- Ammonium molybdate reagent: 25 g ammonium molybdate is dissolved in 175 mL distilled water. 280 mL concentrated sulphuric acid is added to 400 mL distilled water and cooled. Molybdate solution is added and the mixture diluted to 1000 mL.
- Stannous chloride reagent: 2.5 g fresh stannous chloride is dissolved in 100 mL glycerol, heated on water bath and stirred with the glass rod to hasten dissolution.
- Standard phosphate solution: 219.5 mg of dried AR potassium hydrogen phosphate is dissolved in distilled water and made up to 1000 mL, where 1 mL = 50.0 μg. of phosphate. 10 mL of the stock solution is made up to 1000 mL to give 1 mL = 0.05 mg. Standards of strength ranging from 0 (blank) to 0.05 mg/L at intervals of 0.01 mg is prepared by diluting the stock with distilled water.

Procedure: To 50 mL of the filtered sample, 4 mL of ammonium molybdate reagent and about 4-5 drops of stannous chloride reagent is added. After about 10 min but before 12 min, the colour developed is measured photometrically at 690 nm and calibration curve is prepared. A reagent blank is always run with same treatment with distilled water as sample. The value of phosphate is obtained by comparing absorbance of sample with the standard curve and expressed as mg/L.

Preparation of standard solutions:
From stock solutions working standards are prepared. From working standards a series of standards of known concentration are prepared and diluted to 50 mL using distilled water. The absorbance of these standards [known concentration] is recorded from spectrophotometer at 690 nm. Similarly absorbance of unknown samples is also recorded. The sum of the concentrations of the various standards divided by the sum of their absorbance values gives the slope. The absorbance of unknown samples is multiplied with the slope and the dilution factor, which gives the concentration of phosphate in mg/L.

Calculation:

$$\text{Phosphate (mg/L)} = \frac{C \times \text{absorbance of the sample} \times \text{dilution factor}}{A}.$$

where, C = sum of concentrations of the standard nitrate solution used.
A = sum of absorbance of the standard nitrate solution used.

High phosphorus content causes increased algal growth till nitrogen becomes limiting, although blue green algae continue to dominate because of its ability to utilise molecular nitrogen. Besides sedimentation, high uptake by phytoplankton is one of the reasons for fast depletion of phosphorus in water.

Biological Parameter

Biological Coliform

Storm water combined with sanitary sewers can flush bacteria laden water into streams. Total coliform bacteria are a collection of relatively harmless microorganisms that live in large number in the intestine of man, and warm and cold blooded animals. They aid in the digestion of food. A specific sub-group of this collection is the faecal coliform bacteria, the most common member being *Escherichia coli* (E. Coli). These organisms may be separated from the total coliform group by their ability to grow at elevated temperatures and are associated with the faecal material of warm-blooded animals. The presence of faecal coliform bacteria in aquatic environment indicates that the water has been contaminated with the faecal material. At the same time the pathogens or diseases producing bacteria or virus that are co-existing with faecal material might also contaminate the water. This results in the outbreak of water born diseases like typhoid, dysentery, diarrhoea, viral and bacterial gastroenteritis and hepatitis A.

The presence of coliform in drinking water is consistently associated with organisms that produce hydrogen sulphide (H_2S). Furthermore, enteric bacteria such as Salmonella, Proteus, Citrobactor and some strain of Klebsiella also produce H_2S. This is a very simple method for the assessment of contamination in drinking water based on the detection of H_2S- producing organisms. It is estimated using the coliform media.

Procedure:

1. Take a coliform media bottle.
2. Fill the bottle with approximately 20 mL sample and place the lid immediately.
3. Allow the bottle to stand at an ambient temperature of 35°C for 48 hours.
4. If the water turns black, it is graded as unfit for consumption due to presence of coliform.
5. Record the presence or absence of faecal pollution due to coliform.

6.0 SAMPLING AND ANALYSIS OF SOIL SAMPLES

6.1 Soil Sampling

Soils are highly heterogeneous, hence it has to be analysed for various physico-chemical and biological variables. This also would help in assessing the amount of nutrients or amendments required for a particular soil to increase its productivity. Hence, a soil test constitutes an important component while developing an efficient soil fertility program, as well as monitoring a field for potential soil and water management problems.

Soil sampling is a technique by which a true representative sample of a given area is collected. Collection of representative samples is most important in an effective soil-testing programme as the entire analysis and recommendation depends on the sample collected.

A one-time sampling of soil representative of the entire catchment area was undertaken and analysed using standard methods.

The soil samples were collected in the Sharavathi River Basin area at the following sampling sites along with their representative habitats given in the Table 9.1, 9.2 and 9.3. Soils were collected and analysed in batches of 24 and 59 samples in upstream and 35 samples in downstream during the study period.

Table 9.1. Sub-basinwise soil sampling sites in upstream catchment (Batch I)

Sub-basin	Habitat	Sampling Sites	Longitude (°E)	Latitude (°N)
Yenneholé	Built up area	Agricultural field [1]	74.8006	14.01117
Hilkunji	MDF	Tumri [2]	74.836	14.018
Sharavathi	MDF	Yenneholé catchment [3]	74.863	14.0606
Linganamakki	Open field	Hosanagara [4]	75.064	13.9035
Sharavathi	Open field	Haridravathi [5]	75.1058	13.973
Hurliholé	MDF	Agricultural field (Adagale) [6]	74.8174	13.945
Linganamakki	MDF	Catchment (near Holébagilu) [7]	74.963	14.0449
Linganamakki	Plantations	Muppane Forest [8]	74.7923	14.1082
Haridravathi	Open field	Evergreen Forest near Dam [9]	74.908	14.0789
Haridravathi	Plantation	Island near Holébagilu [10]	74.9031	14.0811
Linganamakki	SEF	Thirumoorthimane [11]	74.7632	14.043
Linganamakki		Way to Dam outlet [12]	74.793	14.1787
Linganamakki		Sharavathi (Nagara) [13]	75.099	14.3795
Sharavathi	MDF	Sharavathi (I) [14]	75.0619	13.8799
Linganamakki	Built up area	Sharavathi (II) [15]	75.0619	13.9018
Mavinaholé	Open land	Sharmanavathi [16]	75.1028	13.9749
Haridravathi	MDF	Haridravathi [17]	75.1379	14.0046
Hilkunji	SEF	Hurliholé [18]	74.8555	13.9913
Linganamakki	SEF	Yenneholé [19]	74.7606	14.0332
Sharavathi	MDS	Valagere [20]	74.8369	14.059
Linganamakki	Open field	Nittur [21]	74.9089	13.9437
Haridravathi	Open field	Nandiholé [22]	75.1425	14.0037
Haridravathi	Agriculture	Keshawapura [23]	75.1425	14.0087
Linganamakki	E & SEF	Sampekai [24]	75.0373	14.0575

Note: Numbers in the parenthesis denotes the sampling sites.

Table 9.2. Sub-basinwise soil sampling sites in upstream catchment (Batch II)

Sub-basin	Habitat	Longitude (°E)	Latitude (°N)
Nandiholé (US1)	Teak Plantation [1]	75.12023	14.1307
US 1	Moist Deciduous [2]	75.12087	14.13017
US 1	*Acacia* Plantation [3]	75.18827	14.09052
Haridravathi (US 2)	*Acacia* Plantation [4]	75.2407	14.04131
US 2	Barren Land [5]	75.24131	14.04175
US 2	Moist Deciduous [6]	75.23309	13.97649
US 2	Teak Plantation [7]	75.20615	13.96308
US 2	Paddy Field [8]	75.20648	13.96277
Mavinaholé (US 3)	Teak Plantation [9]	75.13208	13.92461
US 3	Moist Deciduous [10]	75.10901	13.97838
Nandiholé (US 1)	Acacia Plantation [11]	75.14449	14.02441
Haridravathi (US 2)	Paddy Field [12]	75.1248	14.039
Linganamakki (US 9)	Moist Deciduous [13]	75.12484	14.04435
US 9	Acacia Plantation [14]	75.11692	14.05869
US 9	Teak Plantation [15]	75.01513	14.09831
US 9	Semievergreen [16]	74.96452	14.03706
US 9	Acacia Plantation [17]	74.9007	14.09993
US 9	Pinus plantation [18]	74.91106	14.09943
US 9	Semievergreen [19]	74.9304	14.07058
US 9	Semievergreen [20]	74.81644	14.15753
Yenneholé (US 5)	Barren Land [21]	74.80147	14.13318
US 5	Semievergreen [23]	74.73947	14.07012
US 5	Grassland [24]	74.72345	14.03604
US 5	Grassland [25]	74.70749	14.01658
US 5	Semievergreen [26]	74.72285	13.97554
US 5	Scrub Land [27]	74.74624	13.94604
US 5	Semievergreen [28]	74.77741	13.94375
Hurliholé (US 6)	Barren Land [29]	74.79629	13.96586
US 6	Barren Land [30]	74.85018	14.02186
Linganamakki (US 9)	Acacia Plantation [35]	74.92303	13.91023
US 9	Semievergreen [36]	74.95604	13.89515
US 9	Semievergreen [37]	74.99492	13.85682
Sharavathi (US 4)	Barren Land [39]	75.0661	13.87612
Linganamakki (US 9)	Pinus plantation [40]	75.07997	13.92404
Mavinaholé (US 3)	Deciduous [41]	75.10078	13.96909
Sharavathi (US 4)	Acacia Plantation [42]	75.08728	13.85926
Sharavathi (US 4)	Pinus plantation [43]	75.12433	13.84291
Haridravathi (US 2)	Deciduous [44]	75.24509	13.90966

Table 9.3. Sub-basinwise soil sampling sites in downstream catchment (Batch III)

Sub basin	Location	Habitat	Longitude (°E)	Latitude (°N)
Haddinabal (DS 2)	Chikoli [1]	Disturbed evergreen	74.57969	14.32705
Magod (DS 3)	Hossagadde [2]	Areca plantation	74.54848	14.17009
Haddinabal (DS 2)	Mahasati [3]	Newly grown acacia	74.6808	14.26329
Dabbe fall (DS 4)	Hebbenkere [4]	Unploughed paddy field	74.67478	14.15489
Dabbe fall (DS 4)	Hallappa [5]	Areca plantation	74.69537	14.14615
Dabbe fall (DS 4)	Hebbenkere [6]	Dist semi to evergreen	74.67298	14.15785
Gudankateholé (DS 3)	Upponi village loc. 2 [7]	Areca plantation	74.58924	14.23176
Dabbe fall (DS 4)	Hebbenkere [8]	Ploughed paddy field	74.67408	14.15559
DS 4	Dabbe [9]	Riparian vegetation		
DS 4	Hebbenkere [10]	Riparian vegetation	74.67298	14.15785
Haddinabal (DS 2)	Chandubanu [11]	Areca plantation	74.58376	14.32563
DS 2	Mavinaholé [12]	Areca plantation	74.61647	14.24541
DS 2	Chikoli [N] [13]	Disturbed evergreen	74.57969	14.32705
Dabbe fall (DS 4)	Hallappa [14]	Mixed areca,pepper	74.6955	14.14596
DS 2	Chandubanu [15]	Teak sloppy terrain	74.58471	14.33088
Kathalekan (DS 6)	Kathalekan [16]	Swamp		
DS 2	Chandubanu route [17]	Teak plain terrain	74.56811	14.31705
Kathalekan (DS 6)	Kathalekan [18]	Disturbed evergreen		
DS 2	Near Chandubanu [19]	Disturbed evergreen		
DS 6	Kathalekan [20]	Swamp		
DS 6	Kathalekan [21]	Swamp		
DS 6	Kathalekan [22]	Disturbed evergreen		
DS 6	Kathalekan [23]	Evergreen		
DS 6	Sharavathi view point [24]	Evergreen		
Haddinbal (DS 2)	Near Chandubanu [25]	Disturbed evergreen		
DS 2	Near Chandubanu [26]	Disturbed evergreen		
DS 6	Sharavathi view point [27]	Evergreen[stony]		
Magod (DS 3)	Near Idagunji [28]	Acacia plantation		
DS 6	Kathalekan [29]	Evergreen		
Dabbe fall (DS 4)	Totaduru [Dabbe falls] [30]	Semi to evergreen	74.7369	14.14993
	Malakanta [Hebbenkere]			
DS 4	[31]	Evergreen	74.68518	14.14994
DS 4	Kanur [swamp][32]	Swamp	74.71044	14.12815
DS 4	Hebbenkere [33]	Evergreen	74.67621	14.15331
Kathalekan (DS 6)	Malemane [34]	Evergreen	74.73668	14.27731
DS 6	Malemane [35]	Evergreen	74.7284	14.27382

6.2 Sample Collection Method

Soil samples were collected using spades, shovels and core sampler of size 15 cm X 9 cm.

6.3 Depth and the Number of Samples

Recommended depths for soil sampling can be in the range of 0-15 cm, 15–30 cm and 30–60 cm. Based on the type of nutrients to be analysed, sampling depths have to be selected. For immobile elements like P, K^{+}, Ca^{2+} and Mg^{2+}, sampling depth is upto 15 cm (tillage depth). But for mobile elements (NO^{-}_{3} and SO^{2-}_{4}), it can be upto a depth of 60 cm. For general characterisation of soil, random samplings can be made at a depth of 15 cm.

The recommended number of samples can be 10–30 cores to make one good composite sample. In this study composite samples were taken randomly over an area having the size, shape and orientation of the prospective plot. Large uniform fields were divided into smaller units, not exceeding 5 ha, and a composite sample was collected from each unit. (Note: Soil samples from near the root of large trees and foundations of civil constructions were avoided, as they do not represent their natural make up).

6.4 Storage Technique

Samples were collected in thick quality polyethylene bags and immediately transported to the laboratory. They were shade dried (except for the analysis of moisture content) and stored. The dried soils were ground using mortar and pestle (taking care to break only the aggregate but not the sand and gravel particles) and sieved through a 2-mm mesh sieve.

6.5 Physico-Chemical Analyses

The main objective of physico-chemical analyses is to assess the general characterisation of soils in the Sharavathi catchment area. The physical parameters analysed were bulk density, moisture content, pH and electrical conductivity. Chemical parameters analysed were alkalinity, acidity, chloride, sulphate, phosphate, nitrate, sodium, potassium, calcium, magnesium, organic matter, organic carbon and lime requirement.

The analyses of the soil qualities were done as per the standard methods provided by Encyclopaedia of Environmental sciences-15 and Methods manual for forest soil and plant analysis.

Table 10. Soil quality parameters and its method of analysis.

Physical Parameter	**Method of Analysis**
Moisture Content (%)	Gravimetric
Bulk Density (g/cm^3)	Gravimetric
Water Holding Capacity (%)	Gravimetric
Colour	Visual Comparison
Chemical Parameter	
pH	Electrometric
EC (mS/cm)	Electrometric
Acidity (mg/g)	Titrimetric
Alkalinity (mg/g)	Titrimetric
Chlorides (mg/g)	Titrimetric
Calcium (M.eq/100g)	Titrimetric
Magnesium (M.eq/100g)	Titrimetric
Sodium (mg/g)	Flame Photometer
Potassium (mg/g)	Flame Photometer
Available Potassium (mg/g)	Flame Photometer
Sulphate (mg/g)	Spectrophotometer
Nitrate (mg/g)	Kjeldahl
Phosphate (mg/g)	Bray's Extractant
Available Phosphorus (mg/g)	Spectrophotometer
Organic Carbon (%)	Wet Digestion
Organic Matter (%)	Wet Digestion
Lime Requirement	Electrometric

Physical Parameters

Moisture Content

Water present in the soil acts as a solvent, transporting agent and maintains the compactness of soil, thereby making it habitable for plant and microorganisms. Soil gets moisture from infiltration of precipitated water and irrigation. It is directly proportional to the water holding capacity. It more or less depends on water holding capacity of soil. However, it drains through percolation, evaporation and uptake by plants and helps in maintaining the soil texture and compactness.

Materials Required: Oven and chemical balance.

Procedure: Weigh a fresh soil sample (X_1) (this is done prior to shade drying of soil samples) allow it to dry in an oven at 105° C until a constant weight is obtained . Cool in a desiccator and record the final weight of the sample (X_2).

Calculation:

$$\text{Moisture Content (\%)} = \frac{(X_1 - X_2)}{X_1} \times 100$$

where, X_1 = Initial weight of sample (g)

X_2 = Final weight of oven dried sample (g).

Bulk Density

It is determined as the oven dry weight of a unit volume of soil, expressed in g/cm^3. Bulk density is inversely proportional to the pore space of the soil i.e., Soils with high bulk density are less porous and hence compact in nature and soils with low bulk density are highly porous and loose in nature. Soils exhibiting high bulk density have low permeability and infiltration and are inhibitive to root penetration. The bulk density of soil generally varies from 1.1 to 1.5 g/cm^3 for fine textured soils and 1.2 to 1.65 g/cm^3 for coarse textured soil. It is slightly higher in case of alkaline saline soil. The bulk density of soil generally increases with depth due to the low organic matter content of the lower layer and due to compaction from the pressure of the upper layer, because of the use of implements and machinery. The soil having high bulk densities are found to be inhibitive to root penetration and have low permeability and infiltration. The bulk density has been inversely related to pore space of soil.

Materials Required: Oven, measuring cylinder, and balance.

Procedure: Collected sample is dried in an oven at 105°C until the constant weight is attained. Place a known amount of this soil (w) in a measuring cylinder and record the volume (v).

Calculation:

$$\text{Bulk Density (g/cm}^3\text{)} = \frac{\text{weight of soil (w) g}}{\text{Volume of soil (v) cm}^3}$$

Water Holding Capacity

Water holding capacity of the soil is defined as the point at which the soil is completely saturated with water with no pore spaces to hold the water. It mainly depends on the physical and chemical nature of the soil. Water holding capacity is influenced by the hydrological cycle and it varies with time and season.

Method: Gravimetric method

Procedure: Weigh the funnel and filter paper [W_1]. Then pipette 10 mL distilled water to moisten the filter paper. Observe till no water drops and then weigh the moist filter paper and funnel [W_2]. Then add 5 g dried soil sample to W_2 and record the weight [W_3]. Pipette 25 mL distilled water to W_3 so that the soil is completely soaked in water and again add 10 mL distilled water subsequently (twice) and observe till no water drops from the funnel and weigh this set up (W_4).

Calculations:
Water Holding Capacity $= [W_4 - W_3] - [W_2 - W_1] / [W_3 - W_2] \times 100 =$ ___ %

Weight of the funnel and filter paper = W_1 g
Weight of the funnel and wet filter paper = W_2 g
Weight of the funnel, wet filter paper and soil = W_3 g
Weight of the funnel, wet filter paper and wet soil = W_4 g

Unit: Percentage [%]

Colour

Based on the dominant colouration, soil colour is determined.

Chemical Parameters

pH of Soil and Sediment

The pH of soil is an important physico-chemical property that influences the suitability of a soil for a crop, availability of nutrients, microbial activity and physical property of soil. It also indicates the need of lime and gypsum application. It also shows the bottom decomposition condition of aquatic ecosystem.

Method: Using pH meter with glass-calomel electrode.

Materials required: pH meter, pH-4, 7.2 and 9.2 solutions.

Procedure: Weigh 10 g of air dried soil or sediment and add 100 mL distilled water to make the suspension of 1:10 w/v dilution. The pH meter is calibrated using the standard solution and the reading of suspension is found out. The categories of soil based on the pH are given in Table 11.

Table 11. Soil categories based on the pH.

pH	Nature	Interpretation
Less than 6.5	Acidic	Requires liming.
6.5 to 8.5	Neutral	No amendment, optimum for crops
Greater than 8.5	Alkaline	Require gypsum for reclamation

Electrical Conductivity

Conductivity is a measure of the current carrying capacity, thus, gives a clear idea of soluble salt present in the soil. Conductivity values depend on the dilution of the soil suspension, and if left for few hours microbial activity can affect the result. Conductivity is determined using conductivity meter which has conductivity cell consisting of two platinum electrodes in the form of rectangular pieces fused on one side and covered with black spongy platinum on the other. Two wire heads connect it to proper terminals on the solute bridge. Cell constant is given with the equipment.

The properties of soil based on the electrical conductivity values are categorised in four classes, which are given in Table 12.

Table 12. Soil properties based on the EC values.

EC (mS/cm)	Nature of soil
< 0.8	Normal.
0.8 to 1.6	Critical for sensitive crops.
1.6 to 2.5	Critical for salt tolerant crops.
> 2.5	Injurious for many crops.

Method: Conductivity meter

Materials Required: Conductivity meter, glassware to prepare soil suspension.

Procedure: Prepare soil suspension using 10 g soil and 25 mL distilled water and dip the electrode of conductivity meter into the soil suspension and record the readings.

Calculation:
Electrical Conductivity = X * Y mS/cm.
where, X = cell constant of the conductivity cell, Y = solute bridge reading

Acidity

Generally, soil becomes acidic in high rainfall areas through the process of leaching (organic acids). Considerable portion of the exchangeable cations in acidic soils are various forms of hydrated aluminium and some lesser amounts of H^+ ions. The sources of H^+ ions, which are the initial source of solution acidity, are as follows;

- Carbon dioxide from humus decomposition and root respiration.
- Oxidation of NH_4^+ from fertilisers.
- Oxidation of added elemental sulphur.
- Excreted H^+ ions by plant root.
- Acid rain (sulphur and nitrogen oxides pollutants).
- Crop removal of the basic cations (Ca, Mg, K, Na) and excretion of H^+ by root.

Method: Titrimetric method.

Reagents used:

(a) Standard sodium hydroxide 0.02N: Dissolve 0.8 g NaOH and dilute to 1000 mL using CO_2 free distilled water. Store in an airtight, rubber stoppered glass bottle to protect from atmospheric CO_2. Standardise against 0.02N potassium biphthalate.
(b) Phenolphthalein indicator: Dissolve 0.5 g in 500 mL 95% ethyl alcohol and add 500 mL distilled water. Add drop-wise 0.02N NaOH till faint colour appears.
(c) Methyl orange indicator: Dissolve 0.5 g methyl orange and dilute to 1000 mL with CO_2 free distilled water.

Procedure:

(a) Weigh 5-10 g of dried soil and make 1:10 w/v suspension and filter the sample using a filter paper Whatman no.44.
(b) Take the 10 or 25mL suspension and add 2 drops of methyl orange and titrate against standard 0.02N NaOH till the colour changes to faint orange and note down the volume of NaOH consumed.

Calculation:

$$\text{Acidity (mg/g)} = \frac{A \times V \times 1}{10 \times X \times (100-M)}$$

Where A= Alkalinity of filtrate (mg/L).
V= Total volume of suspension.
X= Weight of soil (g).
M= Moisture content of soil (%).

Alkalinity

Soils are alkaline due to free calcium and magnesium carbonate. It increases due to irrigation water containing higher quantity of sodium, calcium and magnesium. Theoretically, if sodium is not the factor, even if large quantities of calcium and magnesium carbonate are applied, the soil pH will not increase from 8.2 because at pH 8.2 the soil carbonate reaches equilibrium with atmospheric CO_2.

Method: Titrimetric method.

Reagents Used:

- Standard H_2SO_4 (0.02N): prepare the reagent from the supplied sulphuric acid using the formula $V_1N_1 = V_2N_2$.
- Phenolphthalein indicator: Dissolve 0.5 g phenolphthalein in 50 mL 95% ethyl alcohol. Add 50mL distilled water and add 0.05N CO_2 free NaOH solution drop wise, until the solution turns faintly pink.
- Methyl orange indicator: Dissolve 0.5 g of methyl orange in 100 mL distilled water.

Procedure: Prepare soil suspension of 1:10 ratio and take 5 or 10 mL of this suspension in a conical flask, add 2 or 3 drops of phenolphthalein indicator. If the solution remains colourless, the PA is zero and if the solution turns pink then titrate against 0.02N H_2SO_4 until the colour disappears and note the volume consumed (H_2SO_4). Now add 2 or 3 drops

of methyl orange indicator in the same sample and continue the titration until the yellow changes to pink at the end point. This gives the total alkalinity.

Calculation:

$$\text{Alkalinity (mg/g)} = \frac{A \times V \times 1}{10 \times X \times (100-M)}$$

where, A = alkalinity of filtrate (mg/L)
V = total volume of suspension (mL)
X = weight of soil/ sediment used in suspension (g)
M = moisture content of soil or sediment (%).

Chloride

Most of the chlorides in the soil and sediment are soluble in water and determined directly in soil solution or suspension. Silver nitrate reacts with chloride to form very slightly soluble white precipitate of silver chloride and at the end point when all the chloride gets precipitated, free silver ions react with chromate to form silver chromate of reddish brown colour.

Method: Titrimetric method:

Reagents:

- Silver Nitrate (0.014N) Dissolve 2.395 gof $AgNO_3$ in distilled water and dilute upto 1000 mL, and standardise against NaCl (0.014N).
- Potassium chromate indicator: Dissolve 50 g of K_2CrO_4 in distilled water and add $AgNO_3$ till red precipitate is formed. Allow standing for at least 12 hours.

Procedure: Prepare 1:10 (w/v) soil / sediment suspension and take 5 or 10 mL in conical flask and add 1 mL of potassium chromate. Now titrate against silver nitrate which at the end point colour changes from yellow to brick red.

Calculation:

$$\text{Chlorides (mg/g)} = \frac{A \times V \times 1}{10 \times X \times (100-M)}$$

where, A = chloride estimated in filtrate (mg/g)
V= total volume of suspension (mL)
X= weight of soil or sediment used in suspension (g) and
M = moisture content of soil or sediment (%).

Calcium and Magnesium

Calcium is a very important cation in soil, soil water sediment and waters in lakes and streams. The average Ca content in soil is estimated to be 1.4%. It may vary from soil to soil depending upon the climatic conditions. Soil in desert climate may be high in Ca, often containing $CaCO_3$ in horizons. In humid region, drastic leaching has removed most of the Ca minerals from the soil. The average Mg content in soil is estimated to be approximately 0.5%, whereas its concentration in soil water is estimated to be 10 mg/L.

Method: Titrimetric method:

Principle: In alkaline condition, EDTA reacts with Ca and Mg to form a soluble chelated complex. Ca and Mg, ions develop wine red colour with Eriochrome black-T under alkaline condition, which is the end point of titration.

Reagents used:

- Buffer solution: Dissolve 67.5 g of NH_4Cl in 200 mL of distilled water and add 570 mL conc. NH_4OH further diluted to 1000 mL with distilled water.
- Std. EDTA solution: Dissolve 1.86 g of disodium salt of EDTA in distilled water and make upto 1 L to get 0.01N solution.
- Eriochrome Black - T (EBT) indicator: 0.5 g of Eriochrome black-T indicator is dissolved in 100 g of triethanolamine.
- Murexide indicator: Mix 0.2 g of ammonium purpurate with 40 g of finely grounded potassium sulphate and grind again in agate/glass pestle and mortar.
- 10% NaOH solution: Dissolve 10 g of NaOH in distilled water and make upto 100 mL.
- Buffer complex solution: Mix 50 mL of each of KCN solution, hydroxyl amine hydrochloride solution, potassium ferrocyanide solution and triethanolamine with 800 mL of buffer solution (should not be kept for more than a week).
- Ammonium acetate soil extract: Weigh 5 or 10 g of air dry soil or sediment and add 100 mL ammonium acetate solution to get 1:10 w/v suspension. Now filter it with the filter paper (Whatman No. 44).

Procedure:

1. Calcium and Magnesium: Transfer 5 or 10 mL ammonium acetate extract in to a conical flask and add 5 to 10 mL buffer complex to get pH of about 10, add EBT indicator and titrate the content with std. EDTA till colour changes from pink to blue.
2. Calcium: Transfer 5 or 10 mL of ammonium acetate extract into a conical flask and add sufficient quantity of 10% NaOH solution to attain a pH of 12 or more. Now add a pinch of Murexide indicator and titrate it against std. EDTA solution till the colour changes from pink to violet.

Calculation:

$$\text{M.eq.of (Ca+Mg) per 100g} = \frac{\text{T.V. x N of EDTA x Vol.made x 100}}{\text{Weight of soil x Aliquot taken}}$$

M.eq. of Mg. = M.eq.of (Ca +Mg) - M.eq. of Ca.

Sodium and Potassium

Sodium and Potassium compounds are widely distributed in nature. The sodium content of normal soil is on the average 0.63%, whereas that of potassium is approximately 0.83%. The mineral source of Na and K are sodium aluminium silicate and potassium aluminium silicate. This can also occur in nature as chloride, sulphate and borate. The concentration of Na^+ and K^+ ions in soil water are relatively low if compared with their content in soil. On the average, the K concentration in soil solution is 5 mg/L, whereas that of Na is 10 mg /L or larger. Both ions are stable in soil water and very difficult to precipitate. Only by complex formation can K^+ ion be precipitated. In soil and sediment these ions exist mostly as exchangeable cations.

Method: Flame Photometer

Principle: An atomiser under controlled condition sucks the solution. The radiation from the flame enters a dispersing device in order to isolate the desired region of spectrum. The intensity of isolated radiation can be measured by a phototube. It is possible to co-relate the intensity of given spectral line of the unknown with the amount of element present that emits the particular radiation.

Reagents Used:

- Stock sodium solution: Dissolve 2.254 g (dried at 140°C) sodium chloride in 1000 mL of distilled water (1 mL = 1 mg Na).
- Working sodium solution: Dilute 10 mL of stock solution to 1 litre (1mL= 0.10 mg Na).
- Stock potassium solution: Dissolve 1.907 g (dried at 110°C) KCl in 1000 mL distilled water to get 1 mL = 1 mg K.
- Working potassium solution: Dilute 10.0 mL of the stock solution to 1 litre to get 1mL = 0.10 mg K.
- Soil Extract: Weigh 5 or 10 g soil or sediment sample and add 100 mL ammonium acetate solution to get a suspension of 1:10 w/v ratio. Now, filter the sample using the filter paper Whatman no.44.

Procedure:

1. Calibrate the flame photometer using the standard solution of sodium and potassium.
2. Now feed the soil extract to the flame photometer and write the reading.

Calculation:

$$\text{Sodium and Potassium (mg/L)} = \frac{C}{A} \times (\text{reading displayed for Na or K})$$

where, C = Sum of concentrations of standard solution

A = Sum of the absorbance of the corresponding standard solution

$$\text{Sodium or Potassium (mg/g)} = \frac{X \times V}{W \times 10000}$$

where, X= sodium or potassium content of soil extract (mg/L)

V = total volume of soil extract (mL)

W= weight of air-dry soil/sediment which is taken for extraction.

Available Potassium

Potassium is present in all parts of plants in fairly large amounts. It is more important for the leaves and the growing parts. Potassium helps in the formation of proteins and sugars in the plant and in the transport of these from one part of the plant to the other. It also regulates the water conditions within the plant and helps in the formation of complex substances required for the plant body. In cereals with a mild potassium deficiency, the shoots become very thin and in case of acute deficiency the plants may be thin and stunted, the shoots may die and many tillers may form without any flowering stems. Due to potassium deficiency, the leaves of most plants show a dull bluish green colour with some whitish spots in the beginning. The tips of the older leaves become brown and the margins of the leaves show a scorching effect. In addition, brown spots develop on the

leaves, which are most numerous near the margins. The leaves of many of the broad-leaved plants show a curling effect. The plants become very stunted, internodes of the stems are short, the root development is poor, the production of the grains and fruits is very restricted and the size of the individual grains become small. The available K in soils is generally the sum of water soluble and exchangeable potassium. It gives an idea about the nutrient status of the soils under study.

Range and interpretations

Available K_2O [Kg/ha]	Rating
< 141	Low
141 – 336	Medium
> 336	High

Reagents

- *Neutral N Ammonium acetate solution*: Dissolve 77.09 g of ammonium acetate in distilled water and make up the volume to 1 L. Adjust the solution pH to 7.0 using acetic acid or ammonium hydroxide solution as required.
- *Potassium chloride solution*: Dissolve 1.908 g of AR grade potassium chloride (dried at 60°C for 1 hour) in distilled water, and make up the volume to 1 L. It gives 1000 mg/L K solution and is treated as stock solution of potassium.

Standard curve for K (working K standards): From the stock solution take measured aliquots and dilute with ammonium acetate solution to give 10 – 40 ppm of potassium.

Procedure: Take 5 g of soil and add 25 ml of neutral normal ammonium acetate solution in a conical flask. Shake the contents of the flask on an electric shaker for 5 minutes and filter. Use the filtrate for analysis using flame photometer.
Preparation of standard curve: Dissolve 1.91 g of potassium chloride in distilled water and make up the volume to 1000 mL to give 1000 mg/L solution of potassium. From this prepare the 100 mg/L working solution from which pipette out 10, 15, 20, 30, 40 mg/L of the standard solution in different volumetric flasks and record the absorbance/emission values. From the absorbance/emission values of standards and corresponding concentrations slope is obtained.

$$\text{Slope} = \frac{\text{Sum of Concentrations of the standards prepared}}{\text{Sum of Absorbance values of the standards}}$$

The absorbance/emission values obtained for samples are multiplied with slope and dilution factor which gives concentration of samples in mg/L. To convert mg/L to kg/ha multiply with 2.24.

Sulphate

Sulphur exists in soil and soil water or sediment as SO_4^{2-} ions in combination with the cations, Ca, Mg, K, Na, or NH_4^+. Present in the form of elemental sulphur, it oxidises in aerobic condition and converts quickly into SO_4^{2-}. Under anaerobic conditions, SO_4^{2-}, may be reduced by microorganism into SO_3^{2-} or H_2S. Since, most of the sulphur salt is soluble, sulphate is expected to be lost rapidly by leaching. The anionic nature of the sulphate ion prevents its attraction by clay colloids. However, soils containing hydrous oxide clays or sesquioxide have been reported to absorb considerable amount of sulfate (Tisdale and Nelson, 1975,1993). The positively charged surface of this sesquioxide clay

may cause electrostatic attraction of the negatively charged sulphate ions. Despite the fact that plant absorbs S almost exclusively as SO_4^{2-}, mobility of SO_4^{2-} in soil may not always yield satisfactory results in accordance with the time of sampling, while assessing SO_4^{2-} availability.

Method: Using Spectrophotometer at wavelength 420 nm.

Reagents Used:

- Conditioning reagent: Mix 50 mL glycerol with a solution containing 30 mL concentrated HCl, 300 mL distilled water, 100 mL 95% ethyl alcohol or isopropyl alcohol and 75 g NaCl.
- Barium Chloride: Crystals 20 or 30 mesh.
- Standard sulphate solution: Dissolve 147.9 mg anhydrous Na_2SO_4 and dilute to 1000 mL.(1mL = 100mg SO_4)

Procedure: Weigh 10 g of dry soil or sediment and by adding distilled water (100 mL) prepare the suspension of 1:10 w/v ratio and filter the suspension using filter paper Whatman No. 44. Take 25mL of this suspension in a conical flask and add 2.5 mL conditioning reagent followed by pinch of $BaCl_2$. Now, take the reading on the spectrophotometer at wavelength 420 nm. At the same time take the reading of standard solution of sulphate (1 mL for 2 ppm, 2 mL for 4 ppm, 3mL for 6 ppm, 4 mL for 8 ppm).

Calculation: Find out the value of C/A for the standard solution and then multiply the absorbance and dilution factor with the found value of C/A.

$$SO_4 \text{ mg/L} = \frac{C}{A} \times \text{absorbance of the sample} \times \text{dilution factor}$$

$$\text{Sulphate (mg/g)} = \frac{A \times V \times 1}{10x \times X \times (100-M)}$$

Nitrate

Nitrogen exists in soil in organic and inorganic forms and it is also present in several oxidations states e.g. -3 to +6. The total present soil nitrogen content varies considerably from 0.05% in the desert soil and 0.3% in warm humid region soil or higher in the soil of semi-humid like mollisols. In soil-water the concentration of nitrogen is even lower, constituting only a small fraction of the amount present in soil. Under normal conditions, 2.4 mL nitrogen will dissolve in 100 mL water. Most of the nitrogen in soil (98%) is in the form of organic compound. It is also present in plant residue, barnyard manure and industrial and domestic waste. Some of these organic nitrogen compounds such as amino acids are soluble in soil water. However, most of the nitrogen in soil water is in inorganic form like NH_4^+, NO_3^- and NO_2^-. The latter is released in soil water by decomposition of soil organic matter. Inorganic nitrogen can also be added to soil by the application of fertilizers.

The inorganic nitrogen compounds NO_2^- (nitrite) and NO_3^- (nitrate) are the products of nitrification NH_4^+. Nitrate is used in industry for the manufacture of drugs, plastics, rayon, dyes and for curing meat products. Ham and bacon are cured with $NaNO_3$. Nitrate

is also an important ingredient for the production of explosives like TNT (trinitrotoluene) and gunpowder. In soil-water nitrate is stable in the absence of organic compounds.

Method:
Phenol Disulphonic Acid Method: This method of estimation of nitrates depends on the nitration of 2,4 - disulphonic acid in fuming sulphuric acid.

$$C_6H_3OH(HSO_3)_2 + 2HNO_3 = C_6H_2(OH)(NO_2)_3 + 2H_2SO_4 + H_2O$$

The product trinitrophenol behaves as a nitrophenolic type indicator and is colourless in acid medium and yellow when neutralised or in alkaline solution. A hydroxide such as KOH or NH_4OH is employed to shift the pH to the yellow colour range.

$$C_6H_2(OH)(NO_2)_3 + 2\,KOH = C_6H_2(OK)(NO_2)_3 + H_2O$$

The nitrate solution is dried prior to determination, as the reaction is effected in the presence of water.

Reagents:
- Extractant solution: Mix 20mL of 1N $CuSO_4$ and 100mL of 0.6% Ag_2SO_4 solution and dilute to 1 L.
- Phenol 2,4 disulphonic acid: Dissolve 25g of pure phenol (white in colour) in 150 mL of conc.H_2SO_4. Then add 75 mL fuming H_2SO_4 (15% free SO_3), stir well and heat for 2 hours on water bath. If fuming sulphuric acid is not available, add additional 85mL of conc. H_2SO_4 to the 150 mL H_2SO_4 stir well and heat for 2 hr.
- 6N NH_4OH solution: Mix one part of strong ammonia in one part of water.
- Std. Solution: Dissolve exactly 0.1629 g of pure KNO_3 in water and dilute to 1L to give 100 ppm of NO_3. Prepare a dilute NO_3 standard having 10 ppm concentration.

Extraction of NO_3 from soil:
i. Weigh 50g of soil into a 500 mL conical flask, add 250 mL of extraction reagent and shake for 10 minutes and add 0.5 g of $Ca(OH)_2$. Continue shaking for 5 minutes and add 1 g of $MgCO_3$ (to precipitate Ag and Cu and clarify the solution).
ii. Collect the filtrate by filtering through a dry Whatman No. 42 filter paper.

Estimation:
(a) Take 20 mL of aliquot in a porcelain dish and evaporate to dryness.
(b) Cool and add 3 mL of PDA directly into the centre of the basin.
(c) Swirl the content so that all the residual salts come in contact with PDA and allow the reagent to act for 10 minutes.
(d) Add 15 mL of cold water and stir the solution with a glass rod.
(e) Add 6N NH_4OH slowly till the solution turns yellow (by alkaline condition) and add 3 mL excess (total volume should not exceed 100 mL).
(f) Transfer all the contents of the basin to 100 mL volumetric flask.
(g) Read the intensity of yellow colour at 420 nm using a spectrophotometer.

Preparation of Std. Graph:
1. Pipette out std. Solution to get 1,2,3,4 and 5 ppm of NO_3 into porcelain dish and evaporate to dryness. Follow the same steps (b) to (g) indicated above.
2. Plot the absorbance against concentration and obtain a standard graph.

Calculation:

NO_3 - N (lbs./ac) = $\frac{\text{Gr.ppm x Vol. made up x Vol. of extractant x 2}}{\text{Aliquot taken x Weight of soil.}}$

lbs = pounds, ac = acre

Phosphate

The inorganic phosphorus content in soil is higher than organic P content (Tisdale and Nelson 1975, 1993). In solution the phosphorus is present in the form of H_3PO_4 or the secondary HPO_4^{2-} orthophosphate ion. The concentration of these ions in the soil solution depends on the pH. In acidic soil, $H_2PO_4^-$ will dominate than HPO_4^{2-}. At pH 6 to 7 both forms are equally represented in the soil solution whereas at pH greater than 7.0, HPO_4^{2-} will be dominant together with some PO_4^{3-} ions. Maximum availability of these phosphate ions for plant growth occurs within the pH range of 5.5 to 6.5 (Tisdale and Nelson, 1975, 1993). Large amounts of phosphorus ions are detrimental to the environment. Phosphate reacts readily with metals present in soil. Acid soils contain large amounts of Al, Fe, and Mn, which form complexes or insoluble metal-phosphate compounds. The reaction is phosphate fixation.

Method: Ammonium molybdate method Using Spectrophotometer at 690 nm.

Principle: In acidic condition, orthophosphate reacts with ammonium molybdate to form Molybdophosphoric acid. It is further reduced to molybdenum blue by adding reducing agent stannous chloride. The intensity of the blue coloured complex is measured which is directly proportional to the concentration of phosphate present in the sample.

Reagents Used:

- Stock phosphate solution: It is prepared by dissolving 4.388 g of dried anhydrous potassium hydrogen phosphate in distilled water to make 1000 mL. Now take 10 mL of this solution and prepare 1 litre using distilled water having 1 mg P/L.
- Working phosphate solution: Take different volume from this stock solution to prepare standard working solution like 0.5 mL for 0.01 ppm, 1.0 mL for 0.02 ppm, 1.5 mL for 0.03 ppm, 2.0 mL for 0.04 ppm and so on.
- Ammonium molybdate solution: Dissolve 31.4 g in about 200 mL distilled water. Add carefully 252 mL conc. H_2SO_4 to 400 mL distilled water. Cool and add 3.4 mL conc. HNO_3. To this solution add ammonium molybdate solution and dilute to 1000 mL.
- Sulphuric acid (0.002N): Take 16.66 mL of concentrated sulphuric acid and dilute it to 100mL to get the bench solution of strength 2N. Further, dilute it taking 1mL to 1000 mL to prepare solution of strength 0.002N.

Method: Take 1 g air-dried soil or sediment sample in 500mL flask and add 200mL H_2SO_4 (0.002N). Shake for about half an hour and filter the suspension through the filter paper (Whatman No.50). Now take 5 or 10 mL of this suspension and add 1 mL ammonium molybdate solution followed by 3 drops of stannous chloride to get a blue colour and measure the absorption using a spectrophotometer. At the same time the absorption for the standard is also estimated.

Calculation:

Calculate the C/A and multiply with the absorbance and dilution factor.

Phosphate (mg/L) = $\frac{C}{A}$ x Absorption displayed x dilution factor.

where, C = sum of concentration of all standard solution used.

A = sum of absorption of all standard.

PO_4 - P (mg/g) = $\frac{Ps \times V}{1000 \times Y}$

where, Ps = PO_4 - P estimated in the suspension (mg/L). V = total volume of suspension (mL), Y= weight of air dry soil or sediment taken.

Available Phosphorus

Phosphorous is also one of the most important constituents of all living cells and is very important for the formation of roots, tillers, seeds and fruits. This element also helps in the proper absorption of nitrogen by the plant and helps the crops to mature early. Due to the deficiency of phosphorous, the leaves develop a dull bluish green colour, with shades of purple and sometimes showing brown spots. Apart from this, the effects of phosphorous deficiency are similar to those due to nitrogen deficiency. The maturity of the crops is delayed due to the deficiency of phosphorous. In cereals phosphorous deficiency causes a dark bluish green colour of the leaves and the stems, which later on show a purple colour. Available phosphorus in soils represents a fraction of the total phosphorous which is susceptible to plant uptake during their growth. It gives an idea about the nutrient status of soil under study.

Range and interpretations

Amount of P_2O_5 [kg/ha]	**Rating**
<22.9	Low
22.9 – 56.33	Medium
> 56.33	High

Reagents

- *Bray's extractant No 1 [0.03 N NH_4F in 0.025 N HCL]* : Dissolve 1.11 g NH_4F in 250 ml distilled water and then add 2 ml of concentrated hydrochloric acid and make up the volume to 1 L.
- *1.5 % Ammonium Molybdate* : Dissolve 15 g of ammonium molybdate in 300 ml hot distilled water [50 – 60 ^oC]. Filter if necessary. Cool and add 350 ml 10 N HCl slowly with rapid stirring. Cool and make upto 1 L and store in an amber coloured bottle. If hydrochloric acid is concentrated add calculated amount of hydrochloric acid equivalent to 350 ml of 10 N HCl.
- *Stannous chloride stock solution 40 %* : Dissolve 10 g of stannous chloride in 25 ml of concentrated hydrochloric acid. Add a piece of pure metallic tin and store in an amber coloured glass stopper bottle. Its working solution is prepared by diluting 0.5 ml stock solution to 66 ml distilled water just before use.
- Darco G 60 [P free activated charcoal powder]

Procedure:

Take 5 g and add 50 ml Bray's extractant in a 250 mL conical flask. Mix and shake on end-to-end shaker for 30 minutes and filter. Prepare blank using water instead of sample and adding all other reagents in a similar fashion. Take 5 mL of the filtrate and add 5 mL ammonium molybdate solution in 25 mL volumetric or Nessler's tube. Mix well until the evolution of CO_2 ceases. If more aliquot has to be taken for analysis as in case of low P

soils fluoride interference has to be eliminated by adding 75 mL of boric acid [5% solution] to 5 mL extract. Add about 10 mL of distilled water washing the neck of the flask to remove the adhering molybdate. Add about 1 mL of working stannous chloride solution and make up the volume to the mark with distilled water.

For analysis of various samples, first prepare standard solution of P by dissolving 0.02195 g of KH_2PO_4 in I L of water [5 ppm of P solution]. Pipette out 0.5, 1, 2, 3, 4 and 5 ml of this solution in different volumetric flasks and then proceed to develop colour as done for the test sample and record the absorbance values. From the absorbance values of standards and corresponding concentrations slope is obtained.

$$\text{Slope} = \frac{\text{Sum of Concentrations of the standards prepared}}{\text{Sum of Absorbance values of the standards}}$$

Organic Carbon

Soil organic matter consists of a variety of components including varying proportions and many intermediate stages of raw plant residues and microorganisms (1 to 10 %), active organic traction (10 to 40%) and resistant or stable organic matter or humus (40 to 60 %). The raw plant residues, on surface, help reduce surface wind speed and water runoff. Removal, incorporation or burning of residues predisposes the soil to serious erosion. The active and some of the resistant soil organic component, together with microorganisms (especially fungi) are involved in binding small soil particles into larger aggregates. Aggregation is important for good soil structure, aeration, water, infiltration and resistant to erosion and crusting. The resistant or stable fraction of soil organic matter contributes mainly to nutrient holding capacity (cation exchange capacity) and soil colour. This fraction of organic matter decomposes very slowly and therefore has less influence on soil fertility than the active organic fraction. The amount of soil organic matter characteristic of virgin and cultivated soil in the various zone represent 30 to 50% loss of organic matter in cultivated soil than virgin soil.

The soil organic matter (SOM) includes only those organic materials that accompany soil particles through 2 mm sieve. Its content is an index of the soil productivity. SOM is the source and sink of nutrients (Nitrogen, Phosphorus and Sulphur), it has charge properties which make it a site of ion exchange (generally 1, and OM increase contribute 2 meq).

Method: The Wet Digestion Method

Principle: A known weight of soil or sediment is treated with an excess volume of standard potassium dichromate ($K_2Cr_2O_7$) solution in the presence of concentrated H_2SO_4. The soil is digested by the heat of dilution of H_2SO_4 and organic carbon, which is oxidised to carbon dioxide (CO_2). The excess of potassium dichromate unused in oxidation is titrated back against a standard solution of ferrous ammonium sulphate (FAS, $FeSO_4(NH_4)_2SO_4$) in the presence of sodium fluoride or phosphoric acid (NaF or H_3PO_4)and diphenylamine solution as indicator.

Reagents Used:

- 1N $K_2Cr_2O_7$ solution: Dissolve 49.04 g of potassium dichromate in distilled water and make upto 1000 mL.

- 0.5N FAS (Mohr's Salt): Dissolve 196g of FAS in distilled water, add 50mL conc. H_2SO_4 and make the volume upto 1000 mL.
- Diphenylamine indicator: Dissolve 0.5g of diphenylamine in a mixture of 100mL conc. H_2SO_4 and 20 mL distilled water.
- Concentrated H_2SO_4.
- Sodium fluoride or Orthophosphoric acid (85%).

Apparatus required: 500 mL conical flask, pipettes, burettes and measuring cylinders 25mL.

Procedure:
1. Weigh 5 g of 2 mm sieved soil or sediments into 500 mL conical flask.
2. Add 10 mL 1N $K_2Cr_2O_7$ solution and shake to mix.
3. Add 20 mL conc. H_2S0_4 from side of the flask.
4. Keep the content for 30 minutes undisturbed.
5. Now add 3 g NaF or 10mL H_3PO_4 and 100 mL distilled water and shake vigorously.
6. Add 10 drops of diphenylamine indicator that gives violet colour.
7. Titrate against 0.5N FAS solution till the colour changes from violet to bright green via blue. Note down the volume of the solution used.
8. Carry out a blank titration in a similar manner without soil.

Calculation:
Weight of sample = S g
Vol. of FAS used in blank = X mL.
Vol. of FAS used to oxidize SOC = Y mL.
Normality of FAS = N.
Volume of 1N $K_2Cr_2O_7$ used for the oxidation of carbon = (X-Y)/ 2
1 mL of 1N $K_2Cr_2O_7$ = 0.003g of organic carbon.

$$\text{Organic carbon in the soil (\%)} = \frac{(X-Y) \times 0.003 \times 100}{2 \times S}$$

Organic Matter (%) = soil carbon (%) x 1.724.

Interpretation:

% Organic Carbon	Rating
< 0.40	Low
0.4o to 0.75	Medium
> 0.75	High.

Method Used: Modified Walkley-Black Method

Equipment required: Scoop, Calibrated glass tubes with 25mL mark, Tube rack.
Reagents:
- 1N Potassium dichromate ($K_2Cr_2O_7$, 49.0 g/L)
- Conc. H_2SO_4 (5mL delivery)

Procedure: Place 5 g soil or sediment sample in a tube. Add 2.5 mL of $K_2Cr_2O_7$ and 5mL H_2SO_4. Mix well and allow for 15 minutes to react, now add distilled water to make volume 25 mL. Now compare the colours with the given colour chart.

Lime Requirement of Soils

Acidity in soil is associated with climate and vegetation. Acid soils are formed mainly because of leaching of bases due to high rainfall and quick weathering of acidic rocks. Soil acidity is mainly due to activity of aluminium and hydrogen ions. Aluminium ions on hydrolysis give rise to 3 hydrogen ions. Due to heterogeneous nature of soil, it acts as a buffer. There are two types of acidity in soil viz. Active acidity (pH of the soil solution) and potential acidity (exchangeable).

Liming neutralises the soil acidity and increases base saturation of soil, when a liming material is added to soil the H^+ ion in solution is neutralised, but due to hydrolysis of Al, H^+ will come from exchangeable complex. Hence, to know the lime requirement of soil, the potential acidity of soil should be taken into consideration. For effective liming programme, one should take into consideration (a) lime requirement of the crop to be grown (b) buffering capacity of soil, (c) time and frequency of lime application and (d) type of liming material.

Method: Buffer method

Reagents:

1. Buffer solution: Dissolve 1 to 2g of paranitrophenol, 2.0mL Triethalomine, 3.0g of potassium chromate, 2.0g of calcium acetate and 40g of calcium chloride and approximately 800 mL distilled water. Adjust the pH to 7.5 using dilute HCl or NaOH solution and dilute to 1L.
2. pH buffer solution (pH 4.0 to 7.0).

Procedure:

(a) Weigh 10g of soil into 50mL beaker and add 20 mL buffer solution and shake for 10 minutes.
(b) Determine pH value, after adjusting the pH meter using appropriate buffer.
(c) The Lime requirement (LR) is proportional to the depression in pH of the buffer. From Table 13, the LR of soil can be determined.

Table 13. Lime requirement scale for buffer method

Buffer pH	Lime requirement (Tonnes of $CaCO_3$*/acre)
6.7	1.6
6.6	2.2
6.5	2.8
6.4	3.4
6.3	4.0
6.2	4.5
6.1	5.2
6.0	5.8
5.9	6.4
5.8	7.0
5.7	7.6
5.6	8.2
5.5	8.6
5.4	9.5
5.3	10.1

(* Tonnes of pure $CaCO_3$ per 2 x 10^6 lbs. of soil)

7.0 SAMPLING AND ANALYSIS OF SEDIMENTS

The sediment from waterbodies is usually collected by dredge and scoop and for deeper layer special boring machine is used. In this study samples were collected in polyethylene bags by means of scoop and immediately transported to the laboratory for further physico-chemical analysis. The processing and analysing strategies used were similar to that of soil.

The sediment sampling sites were (1) Sharavathi 1 (Nagara), (2) Sharavathi 2, (3) Sharmanavathi, (4) Haridravathi, (5) Muppane, (6) Linganamakki reservoir, (7) Hurliholé, (8) Yenneholé, (9) Valagere, (10) Nittur, and (11) Sampekai with corresponding longitude and latitude as given for water sampling sites (Table 2).

8.0 RESULTS AND DISCUSSION OF THE WATER ANALYSIS

TEMPERATURE

The temperature of water in upper catchment ranged from 22°C to 34.5°C. In sampling site 8 (Linganamakki Reservoir), water temperature was higher than any other site (Min: 24.0°C Max: 34.5°C). This is a characteristic feature of a lacustrine ecosystem (Table 15).

Table 15. Temperature (°C) in the water samples of the Sharavathi upstream.

Months	**Sampling sites**															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Feb-01	24.5	29.5	29	28			31	34.5		28.9						
Mar-01	30.1	30.5	30.1	31.6	30.6	28	26.5	34	27.9	29.2	29.6	28.3	29.1			
Apr-01	28.1	26.5	26.5	29	29	29.5	31	31.5	28	31	29	30.5	30.5			
May-01	30.1	30.5	30.1	31.6	31	30.5	29.2	34	29	27.5	31	28.9	30			
Jul-01	23.8	24	23.9	24.3	23.3	24.1	24.8	26	24.5	23.4	25.5	24.5		24.1	24.4	25
Aug-01	23.4	27	26	26	25.9	26	25.8	26	24.5	24	26	25		27	26.5	26
Sep-01	26	29	25.5	26.5	27	25.5	27	26.5	27.5	28	27	28	27.5	27.5	27	27
Oct-01	28	31	27	28	27	25	28.5	27	27	28	27.5	27.5	28	29	28	26
Nov-01	26	26	25	29	28	26	28	27	26	29	28	28	28	26	28	28
Dec-01	25.5	24	22	24	26	25	24	25	24	25	25	25.5	26	24	24	27
Jan-02	24	25	23	25	26	25	24	25	25	27	25		25	22	25	29
Feb-02	25	27	29	30	27	25	26	27	27	27	28		28			28
Mar-02	29	29	27	28	26	23	25	24.5	27	26	25		27			
Apr-02	30	29	28	28	27	25	27	26	28	27	26		28			

In downstream, water temperature ranged from 20°C - 36°C (Table 16). Values obtained are well within the limits provided by Indian Standards Specifications (NEERI).

Table 16. Water temperature in downstream localities.

Months	**Sampling sites**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Nov-02			28	29	28	28		27	27	27	26
Dec-02			28	27	28	28		27	27	27	24
Jan-03			28	26	28	28	27	29	27	29	28
Feb-03				30	30	29	28	29	29	31	32
Mar-03				33	33	32	30		31	34	33
April-03				33	34	33	31		31	31	34
May-03				32	32	31	30		35	31	33
Jun-03			29	29	29	29	28	28		28	28

Table 16. Water temperature in downstream localities (cont...).

Months	**Sampling sites**											
	12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Nov-02	29	26	27	28	22	22	22			29	28	30
Dec-02	28	24	28	28	20					27	28	30
Jan-03	29	27	28	30	21	28		27		30	29	26
Feb-03	33	35	30	30	27	28		32	26		30	31
Mar-03	32	30	30		28	28		32	26		29	31
April-03	34	36	32		26	30		32	27		30	32
May-03	32	33	31		26			30	28		30	32
Jun-03	30	28	28		24			25	24		34	27

Transparency and Turbidity

In the upper catchment, transparency varied from 3 cm to 284 cm and turbidity values fluctuated from <5 –125 NTU (Table 17 and 18). Turbidity exceeded NEERI limits, mainly in Hosanagara and some part of Sagar due to agricultural runoff during monsoon.

Table 17. Transparency (cm) in the water samples of the Sharavathi upstream.

Months	**Sampling sites**															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Feb-01	85	80	40	80			27.5	65		76						
Mar-01	80	100	124	74	92	59	73	98	73	93	57	47	56			
Apr-01	64	65	76	56	67	55	60	75	67	67	43	70	45			
May-01	65	43	89	65	92	59	73	70	73	65	67	60	56			
Jul-01	23	16	14	8	50	45	50	43	34	53	45	42		8	8	4
Aug-01	12	12	8	5	30	50	30	37	32	50	42	40		5	3	3
Sep-01	18	15	12	6	25	35	20	75	45	30	45	30	30	7	5	4
Oct-01	53	35	38	3	50	150	65	160	80	80	80	75	32	8	3	35
Nov-01	58	58	38	15	112	166	82	148	70	39	39	39	82	18	15	38
Dec-01	58	38	38	13	97	130	70	280	97	80	148	24	80	10	10	58
Jan-02	80	65	58	23	90	284	82	284	90	35	90		145	20	35	35
Feb-02	82	75	42	12	82	284	80	284	90	35	70		125			15
Mar-02	72	48	15	15	82	284	72	72	58	72	10		130			
Apr-02	75	50	18	15	80	284	70	75	45	70	12		110			

Table 18. Turbidity (NTU) in water samples of the Sharavathi upstream.

Months	Sampling sites															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Feb-01	<10	<10	<10	25			<10			<10						
Mar-01	<10	<10	<10	>50	<10	<10	<10	<10	<10	<10	<10	<10	<10			
Apr-01	<10	<10	<10	>50	<10	<10	<10	<10	<10	<10	<10	<10	<10			
May-01	25	<10	<10	>50	<10	<10	<10	<10	<10	<10	<10	<10	<10			
Jul-01	50	35	30	60	<10	<10	<10	<10	<10	<10	<10	<10		75	75	50
Aug-01	75	50	20	75	<5	<5	12	<5	<10	<10	<10	<10		125	100	50
Sep-01	25	25	20	75	<10	<10	<10	<10	<10	<10	<10	<10	<10	60	75	45
Oct-01	<10	15	20	20	<5	<5	<5	<5	<5	<5	<5	<5	<5	50	70	<10
Nov-01	<10	12	15	20	<5	<5	<10	<5	<5	<5	<5	<5	<5	30	30	15
Dec-01	<10	<10	15	20	<5	<5	<10	<5	<5	<5	<5	<5	20	25	20	15
Jan-02	20	<5	15	30	<10	<10	<10	<10	<10	<10	<10		<10	25	10	20
Feb-02	10	5	20	40	7	<5	5	<10	<5	<10	<10		<10			45
Mar-02	10	5	20	40	7	<5	5	<10	<5	<10	<10		<10			45
Apr-02	10	10	15	25	7	<5	<5	<10	<5	<10	<10		<10			

In lower catchment, turbidity was in the range of 10 - 100 NTU. At Dabbe [DS4], Joginamutt [DS5] and Jog upper [DS5] it was 25-50 NTU, <100 NTU and 10 – 25 NTU respectively and exceeded the standard limit of 10 NTU. It was due to runoff from the catchment area and also due to the obstruction of water for agriculture leading to the increased sediment loads and phyto-productivity in the stream.

Total Dissolved Solids and Total Suspended Solids

In Sharavathi upstream regions, the total suspended solids ranged from 21.3 to 110 mg/L and total dissolved solids 13.77 – 84.03 mg/L (Table 21 and 22). The results showed that TSS concentration exceeds the limits, due to siltation from storm and agricultural runoff (mainly at Hosanagara region) whereas TDS values are within the limits provided by NEERI.

Table 21. Total Suspended Solids (mg/L) in the water samples of the Sharavathi upstream.

Months	Sampling sites															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Feb-01	62	41.3	21.3	52			52	40		38.6						
Mar-01	40	54	30	41	32	50	26	32	40	64	60	35	40			
Apr-01	54	39	68	37	32	37	68	35	46	52	40	52	27.1			
May-01	82	80	74	67	40	26	67	74	32	48	71	57	85			
Jul-01	65	78	76	110	40	35	65	55	65	45	55	55		102	108	58
Aug-01	80	80	82	110	45	40	70	58	68	50	58	60		100	106	55
Sep-01	82	83	80	108	50	50	75	55	70	55	60	65	55	101	105	60
Oct-01	81	83	81	106	49	51	72	51	69	53	62	62	51	101	102	58
Nov-01	85	85	82	108	55	55	75	55	75	55	65	65	55	105	105	65
Dec-01	75	80	80	100	52	50	72	52	72	53	59	60	54	100	98	61

Table 22. Total Dissolved Solids (mg/L) in the water samples of the Sharavathi upstream.

Months	Sampling sites															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Aug-01	26.12	36.76	35.8	46.24	20.99	23.85	27.3	16.32	16.12	17.2	18.59	20		44.3	18.16	18.5
Sep-01	28.14	30.95	37	45.3	14.5	15.95	17.85	17.9	18	15	18.9	18	20	57	36	18.5
Oct-01	28.38	30.69	36.97	46.4	17.5	15.2	20.3	17.65	17.6	14.25	17.5	20.56	22.48	44	42.65	41.71
Nov-01	31.27	32.98	41.38	53.56	15.37	16.63	21.31	18.12	18.38	15.41	18.19	40.72	16.62	60.58	60.93	42.2
Dec-01	33.1	35.1	41.85	56.13	16.11	17.39	18.75	19.09	19.05	21.8	19.1	19.23	17.99	64.03	64.45	42.18
Jan-02	26.95	22.95	42.15	57.1	15.55	16.9	17.8	21.07	21.65	27.5	24.9		20.37	52.95	54.9	45.5
Feb-02	21.85	27.83	41.75	59.94	13.77	14.47	15.07	15.08	21.73	25.5	17.96		16.25			40.13
Mar-02	26.85	33.05	78.34	84.03	19.2	20.34	20.09	22.29	30.51	26.29	24.17		30.25			
Apr-02	27.4	80.8	110	60.83	20.02	21.6	22.52	23.68	32.38	32.38	24.49	26.54	33.96			

In downstream, however, except in the sites in confluence of Sharavathi into Arabian sea (Haddinabal, Gudankateholé and Badagani), all other localities had TDS values in the stipulated USEPA range of 500mg/L (Table 23). In Haddinabal, Gudankateholé and Badagani, TDS ranges between 24.81 – 15,090 mg/L. This indicated the brackish quality of water in the region.

Table 23. Total Dissolved Solids (mg/L) in the water samples of the Sharavathi downstream.

Months	Sampling sites										
	1	2	3	4	5	6	7	8	9	10	11
Nov-02	18.83		22.27	20.26	21.72	20.62		24.31	22.22	24.81	25.95
Dec-02	19.99	30.22	21.78	20.38	21.68	21.22		26.01	23.83	26.34	25.04
Jan-03	24.52	30.9	24.33	29.32	24.26	36.14	23.95	29.53	31.64	1.21*	26.66
Feb-03	29.44			38.29	22	38.89	20.78	41.92	36.86	2.17*	28.53
Mar-03	25.97	36.3		37.26	25.97	39.9	20.93		45.81	1.43*	27.85
April-03	28.11	38.71		36.79	26.89	38.17	21.8		41.26	1.79*	25.7
May-03	29.22	57.95		42.93	23.36	40.44	24.2		77.37	2.20*	26.3
Jun-03	21.24		26.22	25.75	28.23	27.92	30.72	34.91		79.23	32.02

Table 23. Total Dissolved Solids (mg/L) in the water samples of the Sharavathi downstream (cont…).

Months	Sampling sites											
	12	13	14	15	16	17	18	19	20	21	22	23
Nov-02	18.77	27.77	17.71	17.51	19.6	26.36	22.19			19.05	25.24	1.56*
Dec-02	18	30.2	16.2	16.8	21.4					19.71	27.04	6.35*
Jan-03	19.91	41.77	19.49	19.83	27.34	38.42		27.89		21.46	56.5	14.42*
Feb-03	21.14	51.28	20.13	21.45	28.13	43.3		31.95	30.44		95.31	14.32*
Mar-03	20.33	67.82	23.71		36.2	46.21		33.75	32.1		547.2	14.42*
April-03	20.34	72.88	21.23		33.51	46.88		34.07	31.41		1.047 *	15.09*
May-03	21.04	87.98	22.45		33.51			34.83	29.78		11.1 *	14.89*
Jun-03	20.53	39.34	22.32		25.36			31.71	21.45		224.3	5.04*

* expressed as parts per thousand or g/L

Colour

Pure water has no colour, but the presence of soluble or insoluble, organic or inorganic matter will impart greenish blue, green, greenish yellow, yellow or brown colour to water.

Different species of phytoplankton and zooplankton also impart colour. A dark or blue green colour can be caused by blue green algae, yellow-brown by diatoms or dinoflagellates and red and purple by zooplankton such as Daphnia or Copepods. Colour must be removed to make water suitable for general and industrial applications.

In upstream, the water was colourless to brownish green. Brown and brownish green colours were recorded during monsoon due to colloidal suspension of silts from erosion (Table 14). Similar colouration was also observed in the downstream. In streams like Chandubanu, Vatahalla, Hennur, Hossagadde, Bhaskere, it was transparent, colourless and odourless, whereas in Haddinabal it was greenish due to stagnation. In Dabbod, generally water was transparent and colourless, but during agricultural activities it turned slightly turbid and exceeded the permissible limits for turbidity (February, March and April).

Table 14. Coloration of water samples from the Sharavathi upstream.

Months	Sampling sites				
	1	2	3	4	5
Feb-01	Colour less	Colour less	Colour less	Colour less	Colourless
Mar-01	Colour less	Colour less	Colour less	Colour less	Colourless
Apr-01	Colour less	Colour less	Colour less	Colour less	Colourless
May-01	Colour less	Colour less	Colour less	Colour less	Colourless
Jul-01	Brownish	Brownish	Brownish	Brownish	Colourless
Aug-01	Brownish	Brownish	Brownish	Brownish	Colourless
Sep-01	Brownish	Brownish	Brownish	Brownish	Colourless
Oct-01	Colourless	Brownish	Light brown	Brownish	Colourless
Nov-01	Colourless	Colourless	Light green	Brownish green	Colourless
Dec-01	Colourless	Light Brown	Light Brown	Brownish	Colourless
Jan-02	Greenish	Colour less	Light Brown	Brownish green	Colourless
Feb-02	Light Brown	Colour less	Light Brown	Brownish	Colourless
Mar-02	Slight Green	Light Brown	Brownish Green	Slight green	Colourless
Apr-02	Light Brown	Light Brown	Light Brown	Slight green	Colourless

Table 14. Colouration of water samples from the Sharavathi upstream. (Cont...)

Months	Sampling sites				
	6	7	8	9	10
Feb-01	Colour less	Colour less	Colour less	Colour less	Colour less
Mar-01	Colour less	Colour less	Colour less	Colour less	Colour less
Apr-01	Colour less	Colour less	Colour less	Colour less	Colour less
May-01	Colour less	Colour less	Colour less	Colour less	Colour less
Jul-01	Colour less	Light brown	Light brown	Light brown	Colour less
Aug-01	Colour less	Light brown	Light brown	Light brown	Colour less
Sep-01	Colour less	Light brown	Light brown	Light brown	Colour less
Oct-01	Colourless	Colourless	Green	Colourless	Colourless
Nov-01	Colourless	Colourless	Bluish green	Colourless	Colourless
Dec-01	Colourless	Light Green	Light Green	Colourless	Light Green
Jan-02	Slight green	Greenish	Colour less	Colour less	Brownish
Feb-02	Slight green	Light brown	Colour less	Colour less	Brownish
Mar-02	Greenish	Greenish brown	Light Green	Brownish green	Brownish
Apr-02	Slight green	Light brown	Light Green	Brownish green	Light brown

Table 14. Colouration of water samples from the Sharavathi upstream. (Cont...)

Months	Sampling sites					
	11	12	13	14	15	16
Feb-01	Colour less	Colour less	Colour less			
Mar-01	Colour less	Colour less	Colour less			
Apr-01	Colour less	Colour less	Colour less			
May-01	Colour less	Colour less	Colour less			
Jul-01	Light brown	Light Brown		Brownish	Brownish	Brownish
Aug-01	Light brown	Light Brown		Brownish	Brownish	Brownish
Sep-01	Light brown	Light Brown	Light brown	Light Brown	Brownish	Light Brown
Oct-01	Colourless	Colourless	Light brown	Brownish	Brownish	Brownish
Nov-01	Colourless	Colourless	Colourless	Green	Brownish green	Brownish green
Dec-01	Colourless	Colourless	Light brown	Brownish green	Brownish	Light Brown
Jan-02	Light Green		Light brown	Green	Green	Brownish green
Feb-02	Brownish		Colourless			Brownish green
Mar-02	Brownish		Colourless			
Apr-02	Light brown		Colourless			

Electrical conductivity

The electrical conductivity in the upper catchments of Sharavathi River ranged from 0.003 to 0.44 mS/cm (Table 19). Values obtained are well within the limits provided by Indian Standards Specifications (NEERI).

Table 19. Electrical conductivity (mS/cm) in the water samples of the Sharavathi upstream.

Months	Sampling sites							
	1	2	3	4	5	6	7	8
Feb-01	0.042	0.039	0.070	0.077			0.022	0.034
Mar-01	0.064	0.089	0.089	0.089	0.025	0.032	0.025	0.032
Apr-01	0.064	0.096	0.076	0.070	0.057	0.034	0.031	0.283
May-01	0.058	0.040	0.102	0.005	0.096	0.440	0.063	0.003
Jul-01	0.030	0.044	0.040	0.061	0.021	0.027	0.029	0.025
Aug-01	0.027	0.043	0.042	0.055	0.018	0.023	0.027	0.025
Sep-01	0.041	0.042	0.051	0.060	0.202	0.022	0.024	0.026
Oct-01	0.042	0.044	0.052	0.064	0.024	0.022	0.029	0.026
Nov-01	0.042	0.045	0.056	0.070	0.021	0.022	0.028	0.025
Dec-01	0.044	0.048	0.056	0.070	0.058	0.014	0.024	0.025
Jan-02	0.046	0.035	0.064	0.09	0.024	0.025	0.028	0.028
Feb-02	0.035	0.048	0.070	0.09	0.026	0.026	0.025	0.028
Mar-02	0.039	0.051	0.115	0.122	0.031	0.027	0.029	0.032
Apr-02	0.058	0.066	0.22	0.11	0.044	0.041	0.042	0.045

Table 19. Electrical conductivity (mS/cm) in the water samples of the Sharavathi upstream (cont...).

Months	Sampling sites							
	9	10	11	12	13	14	15	16
Feb-01		0.023						
Mar-01	0.03	0.025	0.032	0.032	0.032			
Apr-01	0.03	0.044	0.44	0.096	0.32			
May-01	0.12	0.045	0.064	0.037	0.12			
Jul-01	0.023	0.02	0.025	0.026		0.06	0.067	0.029
Aug-01	0.022	0.02	0.025	0.026		0.028	0.054	0.027
Sep-01	0.026	0.02	0.026	0.023	0.020	0.038	0.064	0.049
Oct-01	0.249	0.02	0.025	0.023	0.021	0.063	0.061	0.059
Nov-01	0.024	0.021	0.024	0.031	0.022	0.077	0.077	0.059
Dec-01	0.023	0.028	0.026	0.024	0.023	0.077	0.09	0.058
Jan-02	0.029	0.033	0.03		0.016	0.083	0.09	0.064
Feb-02	0.038	0.032	0.031		0.028			0.064
Mar-02	0.039	0.037	0.035		0.043			
Apr-02	0.062	0.053	0.048		0.067			

In downstream regions, some localities were recorded with higher electrical conductivity. This is due to the salt-water intrusion by the Arabian Sea in these localities. Table 20 details the electrical conductivity of water samples from the downstream.

Table 20. Electrical conductivity (mS/cm) in the water samples of the Sharavathi downstream

Months	Sampling sites										
	1	2	3	4	5	6	7	8	9	10	11
Nov-02	0.04		0.05	0.04	0.05	0.04		0.05	0.05	0.05	0.05
Dec-02	0.04	0.06	0.04	0.04	0.04	0.04		0.05	0.05	0.05	0.05
Jan-03	0.05	0.06	0.05	0.06	0.05	0.07	0.05	0.06	0.06	2.35	0.05
Feb-03	0.06			0.08	0.04	0.08	0.04	0.08	0.08	4.35	0.06
Mar-03	0.05	0.07		0.08	0.05	0.08	0.04		0.09	2.84	0.06
April-03	0.06	0.08		0.07	0.05	0.08	0.04		0.08	3.56	0.05
May-03	0.06	0.12		0.09	0.05	0.08	0.05		0.16	4.41	0.05
Jun-03	0.04		0.05	0.05	0.06	0.06	0.06	0.07		0.16	0.06

Table 20. Electrical conductivity (mS/cm) in the water samples of the Sharavathi downstream (cont…).

Months	Sampling sites											
	12	13	14	15	16	17	18	19	20	21	22	23
Nov-02	0.04	0.06	0.04	0.04	0.04	0.06	0.05			0.04	0.05	3.28
Dec-02	0.04	0.06	0.03	0.03	0.04					0.04	0.05	12.65
Jan-03	0.04	0.08	0.04	0.04	0.05	0.07		0.05		0.04	0.11	27.91
Feb-03	0.04	0.1	0.04	0.04	0.06	0.09		0.06	0.06		0.19	28.61
Mar-03	0.04	0.13	0.05		0.07	0.09		0.07	0.06		1.1	28.82
April-03	0.04	0.15	0.04		0.07	0.09		0.07	0.06		2.1	30.2
May-03	0.04	0.18	0.05		0.07			0.07	0.06		22.15	29.77
Jun-03	0.04	0.08	0.05		0.05			0.06	0.04		0.44	10.06

pH, Acidity and Alkalinity

In the upstream, pH ranged from 6.53 - 8.25 (Table 24). Acidity 2.5 –40 mg/L (Table 25) and alkalinity value ranged from 8 – 75 mg/L (Table 26), results well within the limits (NEERI and WHO standards).

Table 24. pH in water samples of the Sharavathi upstream.

Months	Sampling sites															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Feb-01	7.4	6.9	7.3	7.5			7.5	6.53		6.7						
Mar-01	6.85	6.53	6.78	7.2	6.85	6.8	6.9	7.4	6.9	6.94	6.75	6.55	6.65			
Apr-01	7	7.2	7	7.4	6.72	6.94	6.94	6.94	6.55	7	7.4	7	6.72			
May-01	7.4	6.9	7.74	7	6.94	6.55	6.72	6.59	6.75	7	7	7.4	6.94			
Jul-01	7.09	6.89	6.97	6.98	6.95	7.22	6.94	6.65	6.6	6.93	6.8	6.99		7.01	6.98	6.85
Aug-01	6.98	7.03	7.15	7.05	7.24	7.07	7.21	7.06	6.69	6.99	6.85	7.03		7.03	6.94	6.83
Sep-01	7.3	7.12	7.17	7.03	7.01	6.64	7.01	7.13	6.75	6.53	6.88	7.27	6.88	7.02	7.53	7.07
Oct-01	7.5	7.43	7.85	7.58	7.12	6.9	7.21	7.38	7.33	7.34	7.33	7.45	7.02	7.9	7.7	7.83
Nov-01	7.35	7.25	7.26	7.55	7.19	7.01	7.27	7.1	7.06	6.99	7.03	6.56	6.96	7.2	7.5	7.34
Dec-01	7.4	7.71	7.59	7.86	6.98	7.76	7.36	7.26	7.01	7.45	7.46	7.43	7.45	7.55	7.81	7.28
Jan-02	7.25	7.2	7.1	7.38	7.08	7.09	7.07	7.01	7.9	7.05	6.69		7.03	7.25	7.48	7.18
Feb-02	7.62	7.7	8.25	7.75	7.7	7.47	7.13	7.38	7.36	7.01	6.93		7.04			7.25
Mar-02	7.27	7.25	7.01	7.73	7.45	7.45	7.58	7.62	7.48	7.38	7.32		7.25			
Apr-02	7.41	8.41	7.05	7.15	6.54	6.55	6.77	7.02	7.76	6.52	6.57		6.63			

Table 25. Acidity (mg/L) in the water samples of the Sharavathi upstream.

Months	Sampling sites															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Feb-01	16	20		8			8	8		12						
Mar-01	8	8	12	12	20	20	12	12	12	16	8	16	12			
Apr-01	6	12	8	12	8	8	8	8	12	8	8	12	12			
May-01	12	16	12	9	12	20	8	12	6	12	20	12	12			
Jul-01	5	5	5	5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5		2.5	2.5	12
Aug-01	10	5	5	10	10	5	10	10	10	5	10	10		10	15	10
Sep-01	15	15	15	20	20	10	15	30	15	10	15	15	10	15	20	20
Oct-01	12	12	10	15	18	8	12	15	12	8	12	12	8	12	18	18
Nov-01	12	12	12	12	15	10	12	12	12	10	15	12	8	12	15	15
Dec-01	17.5	17.5	17.5	17.5	10	12.5	12.5	12.5	12.5	12.5	15	15	12.5	25	30	20
Jan-02	20	17.5	20	20	12.5	15	15	12.5	12.5	15	15		12.5	25	30	25
Feb-02	20	20	20	20	10	20	10	10	20	30	20		10			30
Mar-02	30	30	40	30	20	30	30	20	30	30	30		30			
Apr-02	25	25	35	22	21	25	23	21	32	25	25		27			

Table 26. Alkalinity (mg/L) in the water samples of the Sharavathi upstream.

Months	Sampling sites															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Feb-01	48	40	28	68			24	38		34						
Mar-01	44	56	52	48	32	40	26	44	52	64	60	35	40			
Apr-01	60	40	44	48	36	44	38	32	49	48	36	32	48			
May-01	56	52	48	52	42	50	48	52	52	40	52	48	50			
Jul-01	35	30	35	45	20	20	20	30	20	20	25	25		55	50	32
Aug-01	45	45	50	45	45	45	30	35	20	20	25	24		30	30	30
Sep-01	40	40	45	40	45	35	35	35	20	20	24	28	24	28	30	28
Oct-01	45	40	50	20	20	25	30	30	25	20	25	25	25	55	55	60

Nov-01	45	45	55	25	25	30	30	35	30	25	25	30	30	60	65	55
Dec-01	48	48	59	30	30	30	35	35	32	28	26	32	35	55	68	58
Jan-02	16	12	8	20	8	8	16	8	8	12	8		8	24	8	20
Feb-02	32	16	12	20	16	12	24	20	8	12	8		12			12
Mar-02	75	50	50	50	25	25	50	25	25	25	25		25			
Apr-02	50	45	52	50	33	31	48	28	22	25	30		32			

In the downstream, pH value was generally in circum neutral condition of 6.5 – 7.5 and rarely exceeded 8.0 (Vatahalla: 8.67 in May 2003). Apart from this individual observation, all other localities had pH level within the permissible level of NEERI (Table 27). Tables 28 and 29 show corresponding alkalinity and acidity values of Sharavathi downstream. They were also observed within the permissible level of 100 – 250mg/L.

Table 27. pH in water samples of the Sharavathi downstream.

Months	Sampling sites										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Nov-02	7.26		7	6.98	6.84	6.75		7.14	7.13	6.97	7.01
Dec-02	7.13	7.4	6.72	6.93	7.01	6.98		7.04	7.05	6.95	6.99
Jan-03	7.25	7.59	7.22	7.1	6.94	7.36	6.94	7.31	7.52	7.42	7.35
Feb-03	7.11			6.76	6.78	7.19	6.99	6.91	7.74	7.68	6.93
Mar-03	7.35	7.26		6.36	6.61	6.62	6.9		7.07	7.23	6.37
April-03	7.1	7.28		6.55	6.67	6.76	6.92		6.88	7.17	6.58
May-03	7.29	7.05		6.71	6.68	6.66	6.83		6.92	7.18	6.44
Jun-03	6.66		6.8	6.62	6.51	6.79	6.88	7.13		6.71	7.07

Table 27. pH in water samples of the Sharavathi downstream (cont...).

Months	Sampling sites											
	12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Nov-02	7.5	7.63	7.05	6.94	7.21	7.54	7.27			6.74	6.68	7.07
Dec-02	7.07	7.52	7.06	7.01	7.13					6.78	6.81	7.46
Jan-03	7.07	7.84	6.9	7.23	7.3	7.8		7.3		6.98	7.27	7.38
Feb-03	7.22	7.88	7.21	7.12	7.3	7.6		7.3	6.5		7.16	7.61
Mar-03	6.84	7.85	6.56		7.5	7.4		6.9	6.7		6.84	7.54
April-03	7.16	7.72	6.96		7.2	7.6		7	6.6		6.61	7.51
May-03	7.08	8.67	6.89		7.17			6.84	6.81		6.53	7.54
Jun-03	7.3	7.49	7.5		7.33			6.55	6.68		6.21	7.18

Table 28. Alkalinity (mg/L) in the water samples of the Sharavathi downstream.

Months	Sampling sites										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Nov-02	13.93		16.87	13.2	16.87	16.87		19.8	15.4	19.07	21.27
Dec-02	15.4	24.2	17.6	15.4	16.13	16.5		19.07	18.7	19.8	19.8
Jan-03	15.4	26.4	15.4	19.8	13.2	22	11	17.6	24.2	26.4	17.6
Feb-03	21.6			31.2	16.8	28.8	14.4	26.4	33.6	38.4	21.6
Mar-03	21.6	36		28.8	19.2	31.2	14.4		40.8	45.6	21.6
April-03	24	38.4		28.8	21.6	33.6	19.2		38.4	45.6	19.2
May-03	24	40.8		36	19.2	26.4	16.8		74.4	48	19.2
Jun-03	14.4		14.4	16.8	19.2	16.8	19.2	9.6		19.2	21.6

Table 28. Alkalinity (mg/L) in the water samples of the Sharavathi downstream (cont…).

Months	Sampling sites											
	12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Nov-02	13.2	24.2	12.1	15.4	13.2	22	17.6			13.2	14.67	25.7
Dec-02	15.4	30.8	11	13.2	14.3					13.93	17.6	46.2
Jan-03	13.2	28.6	11	11	17.6	28.6		17.6		11	30.8	73.7
Feb-03	16.8	45.6	14.4	14.4	21.6	38.4		24	24		33.6	76.8
Mar-03	16.8	60	19.2		33.6	40.8		26.4	24		26.4	79.2
April-03	16.8	67.2	16.8		28.8	45.6		28.8	26.4		24	72
May-03	16.8	74.4	19.2		26.4			24	21.6		43.2	74.4
Jun-03	19.2	26.4	19.2		16.8			12	12		9.6	28.8

Table 29. Acidity (mg/L) in the water samples of the Sharavathi downstream.

Months	Sampling sites										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Nov-02	1.8		2.1	2.7	1.8	1.8		1.8	1.8	2.4	3.6
Dec-02	2.7	2.7	2.7	2.25	2.7	2.7		3	1.8	2.4	2.7
Jan-03	1.8	1.8	1.8	1.8	1.8	1.8	1.8	0.9	3.6	1.8	0.9
Feb-03	1.8			5.4	1.8	1.8	1.8	5.4	3.6	3.6	3.6
Mar-03	3.6	3.6		5.4	3.6	3.6	3.6		5.4	3.6	3.6
April-03	4	6		2	2	4	2		2	4	2
May-03	4	4		6	4	8	4		8	6	6
Jun-03	4		2	4	4	4	4	4		4	4

Table 29. Acidity (mg/L) in the water samples of the Sharavathi downstream (cont…).

Months	Sampling sites											
	12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Nov-02	1.8	2.7	1.8	1.8	2.7	2.7	1.8			1.8	2.7	2.7
Dec-02	2.7	2.7	2.7	2.4	2.25					2.7	4.5	1.8
Jan-03	1.8	1.8	1.8	2.7	1.8	1.8		1.8		1.8	1.8	2.7
Feb-03	3.6	5.4	3.6	1.8	1.8	1.8		3.6	3.6		3.6	3.6
Mar-03	3.6	5.4	3.6		3.6	3.6		3.6	3.6		3.6	9
April-03	2	4	2		2	4		4	4		2	4
May-03	4	0	6		4			4	6		12	6
Jun-03	4	4	2		4			4	2		4	8

Dissolved Oxygen

In the upstream region, dissolved oxygen ranged from 5 to 8.0 ppm (Table 30). This is within the range of NEERI standards.

Table 30. Dissolved oxygen (ppm) in water samples of the Sharavathi upstream.

Months	**Sampling sites**															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Feb-01	5	5.4	5.7	5.6			5.2	6		5.9						
Mar-01	6	5.6	5.8	4.8	6.2	5	6.4	5.2	6.4	4.9	5.3	6	5.2			
Apr-01	6.3	5	5.5	5.3	5.8	6	6.3	5.6	5.4	5.8	6.3	6	6.4			
May-01	6.5	4.9	6	6	6.8	6.4	7	7	7	6	7	6.5	7			
Jul-01	7.7	7.5	7.6	7.7	7.7	7.8	7.7	7.7	7.9	8	7.7	7.8		7.3	7.4	7
Aug-01	7.8	8	7.9	7.6	7.8	8	7.7	7.8	7.8	7.9	7.7	7.8		7.7	7.8	7
Sep-01	7.3	7	7.3	7.2	7.4	7.2	7	7.3	7	7.2	7.4	7.1	7.2	7.1	7.3	6.5
Oct-01	7.6	6.9	7.1	6.9	7.3	7.4	6.6	7.3	7	7	7.2	7	7.1	6.4	6.6	6.9
Nov-01	8	7.9	7.7	6.7	7.5	7.5	7.5	7.3	7.5	7.3	6.6	7.5	7	6.8	7.3	7.5
Dec-01	7.8	7.5	7.2	6.5	7.4	7.2	7.5	7	7.1	6.8	7	7.6	7.3	6.5	6.9	7.4
Jan-02	7.2	7.1	6.9	6.3	7	7	7.4	7.3	7.2	7	7.4		7.5	5.8	6.6	6.9
Feb-02	6.7	6.8	6.8	6.5	6.9	7	6.8	7	7.1	7.1	6.7		6.9			6.8
Mar-02	6.1	6.2	6.5	6.4	6.9	7.2	7.1	7.2	6.6	6.5	7.2		6.5			
Apr-02	6	6.3	6.2	6.1	6.3	6.5	6.4	6.5	6.1	6.2	6.5		6.3			

In downstream, DO at Chandavar [16.3 ppm], Gudankateholé [13 ppm], Dabbod [12.2 ppm], Hossagadde [12.2 ppm], Hennur [12.2 ppm] showed comparatively higher values due to high inflow and increased water turbulence in the region. Apart from these extremities, DO range was very much similar to upstream catchment.

Table 31. Dissolved oxygen (ppm) in water samples of the Sharavathi downstream.

Months	**Sampling sites**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Nov-02											
Dec-02	8.1	7.3	12.2	12.2	11.4	12.2		9.7		7.3	6.5
Jan-03			6.5	5.2	6.2	5.9	6.8	8.6	7.9	7.5	6.9
Feb-03	6.3			4.1	6.1	4.5	6.9	5.1	7.7	5.3	6
Mar-03	6.2	6.8		4.2	6.4	5.8	6.9		6.6	6.7	5.5
April-03	6.8	7.1		4.6	5.6	6.7	6.9		6.6	5.9	5.5
May-03	7.4	6.6		4.7	6	6.8	7.1		6.2	6.1	4.9
Jun-03	7.2			6	6.6	6.4	6.7	6.7		6.5	6.6

Table 31. Dissolved oxygen (ppm) in water samples of the Sharavathi downstream (cont…).

Months	**Sampling sites**											
	12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Nov-02												
Dec-02	8.9	8.1	11.4		7.3					16.3	13	7.31
Jan-03	7.1	8	8.2	7.3	9.6	6.4		6.3		7.4	5.6	
Feb-03	7.1	6.8	7.1	8.1	7.4	6.4		5.3	6.7		4	
Mar-03	6.9	6.7	7.9	6.6	7.2	6.3		5.5	6.8		5.7	
April-03	6.5	6.8	6.9		6.4	6.5		6.6	6.9		5.9	
May-03	6.9	9.1	6.9		6.6			6.5	7		6.1	
Jun-03	6.6	8.4	6.7		7.4			7.4	7.6		7.2	

Chloride

The chloride concentration fluctuated from 4.9 to 63.9 mg/L in the upstream region, well within the limits of NEERI (Table 32).

Table 32. Chloride concentration (mg/L) in water samples of the Sharavathi upstream.

Months	Sampling sites															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Feb-01	17.9	12.9	14.9	13.9			10.9	8.9		9.99						
Mar-01	4.9	6.9	12	11	6.9	7.5	6.9	7.9	7.1	5	10.9	8.9	12			
Apr-01	15	9.9	10.9	8.9	9.9	11	8.9	9.9	8.9	11.9	12.9	9.9	12			
May-01	33	23	21.8	23	16	22	18	23	14	18.5	20.8	19.7	21.2			
Jul-01	19.9	14.9	14.9	14.9	14.9	19.9	14.9	14.9	14.9	19.9	14.9	14.9		19.9	24.9	12.99
Aug-01	14.99	19.99	14.99	9.99	14.99	9.99	14.99	14.99	14.9	19.9	14.9	13.9		9.99	14.99	14.99
Sep-01	14.99	14.99	14.99	12.99	12.49	14.99	14.99	14.99	9.99	14.99	9.99	12.9	14.99	12.9	19.99	14.99
Oct-01	24.9	19.99	19.99	24.9	14.99	24.99	14.99	19.99	19.99	19.99	19.99	14.99	19.99	14.99	19.99	19.99
Nov-01	24.99	14.99	14.99	14.99	9.99	14.99	9.99	14.99	14.99	14.99	9.99	14.99	14.99	14.99	14.99	14.99
Dec-01	24.9	24.9	29.99	34.98	34.98	29.99	29.99	29.99	29.99	29.99	29.99	24.9	39.98	34.98	34.98	34.98
Jan-02	17.04	22.72	22.72	25.56	25.56	22.76	25.56	22.72	25.56	25.56	28.4		25.56	28.4	31.24	25.56
Feb-02	19.88	25.56	19.88	22.72	19.88	17.04	17.04	17.04	25.56	31.24	17.04		19.88			19.88
Mar-02	42.6	63.9	63.9	56.8	42.6	56.8	35.5	42.6	49.7	49.7	49.7		42.6			
Apr-02	17.49	42.48	22.47	24.99	14.99	22.49	17.49	19.99	19.99	22.49	19.99		24.99			

In Haddinabal, Gudankateholé and Badagani of downstream, Chloride concentration was comparatively higher (range: 3.19 – 13320.9 mg/L; Table 33) than other sites (both in upstream as well as in downstream). Intrusion of salt-water in the above regions is the main reason for higher chloride concentration.

Table 33. Chloride concentration (mg/L) in Sharavathi downstream water samples.

Months	Sampling sites										
	1	2	3	4	5	6	7	8	9	10	11
Nov-02	1.91		2.87	4.47	3.19	3.51		3.83	2.55	3.19	5.1
Dec-02	2.87	2.39	4.79	4.79	4.15	4.31		4.47	4.31	4.79	2.87
Jan-03	6	6	6	8	6	8	6	16	6	655.8	6
Feb-03	7			11	6	8	6.5	11	7	50.98	7
Mar-03	7	7		8	7	10	6		7	782.75	7
April-03	7	6		9	6	8	6		7	1017.68	7
May-03	7	6		9	6	11	7		31	3049.1	7
Jun-03	5		9	7	8	8	10	9		37.99	8

Table 33. Chloride concentration (mg/L) in Sharavathi downstream water samples (cont…).

Months	Sampling sites											
	12	13	14	15	16	17	18	19	20	21	22	23
Nov-02	2.87	4.15	2.87	1.91	3.19	3.83	3.83			3.19	4.47	871
Dec-02	2.87	3.35	3.83	2.9	3.35					4.79	6.7	5344.1
Jan-03	4	6	6	6	6	6		8		6	16	12371.2
Feb-03	6	8	5	6	7	7		8	7			
Mar-03	6	7	7		7	7		9	9			
April-03	6	8	5		7	7		9	8		570.82	13320.9
May-03	6	9	6		8			10	8		364.89	523.8
Jun-03	5	34.99	5		7			9	6		130	3573.9

Sulphate

The sulphate concentration in the representative samples from the upstream catchment ranged from 0.34 to 32.02 mg/L, within the limits given by NEERI (Table 34).

Table 34. Sulphate concentration (mg/L) in water samples of the Sharavathi upstream.

Months	**Sampling sites**															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Feb-01	19.42	16.05	20.12	32.02			15.28	17.2		16.4						
Mar-01	14.22	16.22	14.89	25.77	13.17	23.35	18.62	14.89	24.81	14.89	20.5	18.29	16.65			
Apr-01	11.3	22.32	24.52	14.65	6.99	12.5	7.15	20.11	14.5	11.87	10.05	10.05	13.79			
May-01	13.27	9.52	15.23	9.24	10.04	15.23	12.4	9.32	12.51	7.39	10.93	12.4	14.21			
Jul-01	4.96	11.28	9.47	22.1	7.44	2.93	4.51	11.28	10.15	7.44	7.66	6.76		21.2	20.07	24.36
Aug-01	13.26	10.38	6.34	15.86	0.86	0.86	0.86	7.86	8.99	6.34	6.53	5.86		19.86	29.9	32
Sep-01	4.76	11.9	9.52	14.86	2.3	4.28	3.33	2.38	3.8	3.33	4.76	3.33	4.76	17.86	15.7	4.76
Oct-01	1.76	4.47	1.76	11.94	1.49	1.19	2.38	2.69	6.86	1.79	1.19	1.49	1.79	9.25	22.3	3.88
Nov-01	7.46	8.06	8.65	9.55	8.06	8.06	9.55	8.36	8.65	10.15	9.85	10.44	11.64	12.53	14.92	13.13
Dec-01	10.46	9.69	11.59	12.56	7.58	9.25	10.25	11.25	12.58	13.01	9.89	11.49	12.59	17.58	18.59	16.48
Jan-02	5.07	1.33	4.53	8	5.87	2.67	2.67	2.13	7.2	22.66	9.33		4.27	7.466	12	13.66
Feb-02	2.99	2.45	4.89	4.89	0.54	3.53	5.17	4.35	2.18	8.16	9.25		5.44			9.25
Mar-02	2	4	9.33	5	0.34	0.67	0.34	0.67	0.67	3.33	0.67		0.67			
Apr-02	2.51	3.24	8.99	6.21	1.24	1.25	1.65	1.22	1.54	2.13	2.01		0.99			

In downstream, apart from Haddinabal, Gudankateholé and Badagani, all other sites had low sulphate concentration, but within NEERI's specification (Table 35).

Table 35. Sulphate concentration (mg/L) in water samples of the Sharavathi downstream.

Months	**Sampling sites**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Nov-02	3.78		3.62	2.5	2.18	2.57		2.07	1.87	3.2	3.43
Dec-02	1.93	1.29	1.47	1.64	1.6	2.52		1.33	2.05	1.68	1.35
Jan-03	4.44	2.46	2.22	4.33	2.57	2.34	3.63	2.46	2.22	79.29	3.51
Feb-03	1.99			2.69	1.64	1.87	1.29	1.87	1.75	117.53	1.29
Mar-03	2.34	2.57		2.69	2.81	3.39	4.56		1.52	84.2	1.52
April-03	1.87	2.11		1.87	1.52	1.99	1.99		1.64	113.21	1.05
May-03	2.22	2.46		1.64	1.52	2.46	2.57		2.34	93.56	1.87
Jun-03	5.61		13.57	1.52	1.99	1.99	1.05	3.51		3.63	2.11

Table 35. Sulphate concentration (mg/L) in the Sharavathi downstream (cont…).

Months	**Sampling sites**											
	12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Nov-02	3.39	2.73	3.12	1.64	3.08	2.69	3.98			2.77	2.49	123.8
Dec-02	1.52	1.82	1.64	1.29	1.41					1.75	2.34	224.2
Jan-03	2.11	2.22	3.74	1.99	2.34	2.69		4.44		3.51	3.16	837.4
Feb-03	1.64	2.22	1.4	1.87	1.75	2.69		1.99	1.99		2.92	
Mar-03	1.4	2.57	1.75		2.22	2.57		2.34	1.29		38.13	456.1
April-03	2.46	3.63	1.52		1.75	2.22		2.69	1.64		48.89	1765.9
May-03	2.11	3.98	1.64		2.11			3.39	2.57		1090.6	1754.3
Jun-03	1.4	3.51	1.4		1.75			5.15	8.07		12.16	321.6

Total Hardness

In the water samples of upstream, total hardness ranged from 27.25 to 148.29 mg/L (Table 36). Except four incidences from Sharamanavathi, Haridravathi, Keshawapura and Sampekai, where total hardness reached beyond 120mg/L, all other sites had very low hardness. The reason for higher concentration could not be substantiated.

Table 36. Total Hardness (mg/L) in water samples of the Sharavathi upstream.

Months	Sampling sites															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Feb-01	59.95	27.25	49.05	27.25			30.12	30.35		32.7						
Mar-01	54.4	49.05	81.7	76.3	49.05	43.6	49.5	76.3	54.5	49.5	38.15	40.9	54.5			
Apr-01	43.6	43.3	39.24	52.32	37.5	49.7	43.6	30.52	50.7	43.6	48.8	39.24	34.48			
May-01	52	43.6	56.6	56.6	50.2	54.3	60.9	65.4	58.2	56.6	58.9	58.2	54.3			
Jul-01	59.5	59.9	76.3	82.2	82.3	49.5	40.9	38.15	54.5	49.5	49.05	43.6		54.5	54.5	40.6
Aug-01	39.24	39.24	43.6	43.6	47.96	34.88	30.52	30.52	46.32	46.35	45.63	40.56		56.68	78.48	39.24
Sep-01	61.04	43.6	56.68	56.6	43.6	52.32	30.52	61.04	39.24	47.96	69.76	78.48	47.9	78.89	122.08	78.48
Oct-01	65.4	49.05	49.05	54.5	43.6	54.5	49.05	49.05	59.95	59.95	43.6	59.95	49.05	70.85	59.95	59.95
Nov-01	78.48	52.32	143.88	122.08	78.48	52.32	87.2	61.04	43.6	39.24	47.96	52.32	56.68	148.24	82.84	65.4
Dec-01	43.6	39.24	47.96	52.32	43.6	30.52	30.52	56.68	65.4	52.32	61.04	43.6	65.4	126.44	95.92	47.96
Jan-02	28	36	68	80	40	32	32	36	32	28	28		32	76	76	44
Feb-02	60	32	52	88	40	20	32	36	44	22	92		32			64
Mar-02	60	50	50	60	50	50	30	30	70	40	30		40			
Apr-02	58	42	55	55	48	50	35	38	68	54	28		38			

Similar to upstream, generally all the sites in downstream exhibited low hardness concentration (Table 37). The reason for higher concentration in Haddinabal, Gudankateholé and Badagani could be due to salt-water intrusion in these regions.

Table 37. Total Hardness (mg/L) in water samples of the Sharavathi downstream.

Months	Sampling sites										
	1	2	3	4	5	6	7	8	9	10	11
Nov-02	16		19.33	14.67	17.33	16.67		18	17.33	21.33	22
Dec-02	17	23	17	15	18.67	19		20	19	18.67	20
Jan-03	16	24	16	20	16	24	12	24	24	232	18
Feb-03	18			24	12	22	12	20	26	400	18
Mar-03	14	24		24	14	20	10		32	272	14
April-03	18	26		24	14	22	10		28	336	14
May-03	18	28		28	12	18	12		64	400	6
Jun-03	12		14	14	18	16	16	20		28	20

Table 37. Total Hardness (mg/L) in water samples of the Sharavathi downstream (cont…).

Months	Sampling sites											
	12	13	14	15	16	17	18	19	20	21	22	23
Nov-02	14	22	16.67	16	16	22	16			14	14.67	1676.7
Dec-02	12	23	16	13.33	16					12.67	18	1866.7
Jan-03	12	26	12	12	22	32		16		16	32	
Feb-03	12	34	10	10	16	30		18	16		32	3800
Mar-03	10	44	10		26	32		16	18		116	4100
April-03	10	52	10		36	36		20	16		196	4300
May-03	6	52	6		8			6	10		3050	4200
Jun-03	12	22	14		16			16	12		52	1250

Calcium Hardness

In downstream sites, Calcium hardness ranged between 4 – 38 mg/L (excluding Haddinabal, Gudankateholé and Badagani). Table 38 details the Calcium hardness in Sharavathi downstream.

Table 38. Calcium hardness (mg/L) in water samples of the Sharavathi downstream.

Months	Sampling sites										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Nov-02	8		8	8	8	8		8	8.67	9.33	10
Dec-02	8	12	8	8	8	8		10	10	10	9
Jan-03	8	12	8	12	8	12	6	12	12	48	8
Feb-03	10			14	6	14	6	10	14	100	8
Mar-03	8	16		14	8	12	6		18	58	10
April-03	10	18		14	10	12	8		16	68	8
May-03	10	18		16	8	12	6		38	100	8
Jun-03	8		8	8	10	8	8	12		12	10

Table 38. Calcium hardness (mg/L) in water samples of the Sharavathi downstream (cont…).

Months	Sampling sites											
	12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Nov-02	8	11.33	8	6	7.33	12	8			6	7.33	66.7
Dec-02	8	12	6	6.67	8					6.67	8	366.7
Jan-03	6	16	6	4	8	14		10		8	14	
Feb-03	6	24	6	6	10	16		10	10		16	600
Mar-03	6	36	6		18	18		10	10		36	700
April-03	8	42	8		20	18		8	10		56	700
May-03	8	50	8		10			8	12		500	700
Jun-03	8	16	10		8			10	8		16	200

MAGNESIUM HARDNESS

In downstream, magnesium hardness was within the permissible level (30 mg/L) in almost all sites (except sampling site 10, 22 and 23). Table 39 shows the magnesium hardness recorded from the downstream localities.

Table 39. Magnesium hardness (mg/L) in water samples of the Sharavathi downstream (cont…).

Months	Sampling sites										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Nov-02	8		11.33	6.67	9.33	8.67		10	8.67	12	12
Dec-02	9	11	9	7	10.67	11		10	9	8.67	11
Jan-03	8	12	8	8	8	12	6	12	12	184	10
Feb-03	8			10	6	8	6	10	12	300	10
Mar-03	6	8		10	6	8	4		14	214	4
April-03	8	8		10	4	10	2		12	268	6
May-03	8	10		12	4	6	6		26	300	
Jun-03	4		6	6	8	8	8	8		16	10

Table 39. Magnesium hardness (mg/L) in water samples of the Sharavathi downstream (cont…).

Months	Sampling sites											
	12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Nov-02	6	10.67	8.67	10	8.67	10	8			8	7.33	1610
Dec-02	4	11	10	6.67	8					6	10	1500
Jan-03	6	10	6	8	14	18		6		8	18	
Feb-03	6	10	4	4	6	14		8	6		16	3200
Mar-03	4	8	4		8	14		6	8		80	3400
April-03	2	10	2		16	18		12	6		140	3600
May-03											2550	3500
Jun-03	4	6	4		8			6	4		36	1050

Sodium and Potassium

Sodium concentration in upstream sites fluctuated between 2.1 to 101.4 mg/L (Table 40) and potassium values ranged between trace amounts to 9.5 mg/L (Table 41). The observed values are well within the limits given by NEERI. Concentration of potassium was much less compared to sodium, as it is not very abundant in natural waters.

Table 40. Sodium concentration (mg/L) in water samples of the Sharavathi upstream.

Months	**Sampling sites**															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Feb-01	16.05	11.74	16.4	16.4			14.28	15.25		17.21						
Mar-01	7.81	9.99	10.44	15.57	12.53	9.8	11.4	12.3	11.5	12.34	12.64	12.97	13.5			
Apr-01	18	18	17	17.4	17.21	14.28	15.25	16.5	13.9	19	32.02	21	16.4			
May-01	12.52	12.64	12.25	11.4	12.3	17.5	15.75	11.5	12.4	9.99	10.53	10.44	7.3			
Jul-01	8.31	13.77	11.33	17.66	4.43	5.63	5.92	5.82	5.24	4.46	5.71	6.04		18.46	29.22	9.23
Aug-01	6.9	11.73	9.27	9.49	2.1	2.61	2.67	2.80	2.53	4.12	5.10	4.03		9.82	9.41	8.24
Sep-01	10.58	12.6	14.07	10.49	3.68	4.22	4.34	4.28	4.38	3.53	4.68	4.7	3.53	10.25	24.5	14.24
Oct-01	9.86	12.36	13.95	15.28	4.15	5.2	4.99	5.69	4.56	4.28	5.1	4.86	4.12	15.6	28.8	20.1
Nov-01	8.63	11.64	14.5	38.08	4.73	5.19	5.73	6.13	5.5	4.61	6.14	6.32	4.64	39.04	40.04	28.04
Dec-01	8.95	10.76	10.54	65.4	4.58	5.15	5.10	5.59	4.96	5.50	5.56	5.48	4.79	85	101.4	34.5
Jan-02	11.23	10.8	15.99	55.36	5.47	6.04	6.46	6.52	5.82	6.68	6.49		5.81	85.27	89.64	35.01
Feb-02	13.33	16.78	12.30	43.54	6.53	7.10	7.31	2.3	9.13	8.53	4		8.07			30.49
Mar-02	9.20	4.36	4.00	49.25	6.68	9.49	9.30	9.39	9.59	8.52	8.91		9.29			
Apr-02	10.21	5.321	3.68	47.86	5.69	10.25	10.25	9.37	9.46	8.65	8.64		10.25			

Table 41. Potassium concentration (mg/L) in water samples of the Sharavathi upstream.

Months	**Sampling sites**															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Feb-01	0.4	0.8	0.7	0.8			ND	ND		ND						
Mar-01	0.039	0.039	0.156	ND	ND	ND	ND	0.078	0.039	ND	0.039	ND	0.039			
Apr-01	0.08	1.4	1.2	0.84	0.43	0.67	0.34	0.43	0.34	1.4	0.91	1.2	0.67			
May-01	0.039	0.56	1.4	0.91	0.22	1.4	0.43	0.1	1.2	1.2	0.84	0.91	0.34			
Jul-01	1.134	2.151	1.564	2.151	0.195	0.743	0.86	0.743	0.391	0.235	0.704	0.899		1.447	2.503	0.169
Aug-01	0.116	0.232	0.116	0.232	ND	0.116	0.116	1.96	0.291	0.203	0.502	0.775		0.155	0.193	0.193
Sep-01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.013	0.03	0.04	0.01
Oct-01	0.95	0.98	0.88	1.1	0.099	0.098	0.15	0.2	0.298	0.258	0.35	0.42	0.199	0.56	0.33	0.99
Nov-01	1.076	1.35	1.35	1.55	0.3	0.478	0.59	0.59	0.478	0.3	0.59	0.59	0.398	1.435	1.91	1.395
Dec-01	0.3	0.348	0.503	0.465	0.077	0.116	0.116	0.15	0.116	0.116	0.15	0.15	0.077	0.54	0.69	0.348
Jan-02	2.7	2.156	4.156	4.274	0.919	1.216	2.039	1.647	1.176	1.294	1.686		0.941	2.94	4.039	3.25
Feb-02	0.883	0.803	1.225	3.214	0.281	0.361	0.401	0.401	0.321	0.562	0.321		1.285			4.416
Mar-02	3.518	2.345	7.818	9.508	5.863	1.564	4.691	1.173	0.782	0.782	0.782		1.564			
Apr-02	1.025	1.365	4.256	8.25	4.35	2.317	3.214	2.154	1.255	1.256	2.351		2.155			

In downstream localities, the lowest concentration of 0.1 mg/L of sodium was recorded at Dabbe falls and Joginamutt and was highest with 36.60 mg/L at Chandubanu (Table 42). High sodium concentrations were attributed to seawater intrusion. The permissible range of sodium concentration for surface water is <1 - > 300 mg/L. Similarly, potassium concentration in the downstream sub-basins ranged between 0.09 – 6.4mg/L (0.7 – 1.80 mg/L [DS 4], 0.09– 2.50 mg/L [DS 3], 0.09 – 6.4 mg/L [DS 2], 0.46 – 2.6 mg/L [DS 5]).

Table 42. Sodium concentration (mg/L) in water samples of the Sharavathi downstream.

Months	Sampling sites										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Nov-02	5.46		6.57	6.53	6.38	6.52		7.08	6.73	6.92	6.98
Dec-02											
Jan-03											
Feb-03	17.79			17.59	17.88	15.75	17.88	5.73	17.5		17.3
Mar-03	17.88	16.52			17.69	11.86	17.79		17.4		17.3
April-03	17.59	17.01		16.33	17.3	14	17.88		17.3		17.5
May-03				5.03	3	11.9	3.8		36.6	5356.8	3.87
Jun-03	0.1		0.6	0.7	0.8	0.7	2.29	1.6		20.54	1.1

Table 42. Sodium concentration (mg/L) in water samples of the Sharavathi downstream (cont…).

Months	Sampling sites											
	12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Nov-02	5.8	7.38	6.07	5.57	6.19	6.38	6.95			7.16	8.53	1339.8
Dec-02										7.16		1339.8
Jan-03												1339.8
Feb-03	17.69	10.11	17.69	17.79	17.5	17.2		14.29	17.3		53.36	
Mar-03	17.79	6.12	17.59		16.72	17.2		12.44	15.75			
April-03	17.79	3.6	17.88		16.33	16.62		7.78	15.84			
May-03	2.42	13.6	2.5		4.5			12.08	4.06			
Jun-03	0.02	2.19	0.4		0.8			1.2	0.1		70.58	1908

Table 43. Potassium concentration (mg/L) in water samples of the Sharavathi downstream.

Months	Sampling sites										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Nov-02	0.51		0.07	0.24	0.13	0.44		0.31	0.33	0.24	0.4
Dec-02											
Jan-03											
Feb-03	1.8			1	0.9	1.5	0.9	2.2	1		0.7
Mar-03	0.9	0.7			0.9	1.6	0.8		1		0.9
April-03	1	1.3		1.2	1.3	2.5	0.8		1.2		0.9
May-03				0.09	0.09	0.09	0.09		0.09	0	0.09
Jun-03	1.29			0.89	1.09	0.8	0.89	1.49		1.89	0.89

Table 43. Potassium concentration (mg/L) in water samples of the Sharavathi downstream (cont…).

Months	Sampling sites											
	12	13	14	15	16	17	18	19	20	21	22	23
Nov-02	0.4	0.84	0.81	0.79	0.31	0.46	0.4			0.04	0.22	186.9
Dec-02										0.04		186.9
Jan-03												186.9
Feb-03	1.1	4.5	0.8	0.8	1	2.2		1.7	2.3		4.7	
Mar-03	0.9	5.8	1.2		1.3	2.6		2	1.7			
April-03	0.9	6.4	1		1.3	2.6		2.4	1.7			
May-03	0.09	1.74	0.09									
Jun-03	0.6	2.09	0.6		0.8			1.79	1.69		3.18	82

Nitrate Nitrogen

In Sharavathi upstream, Nitrate nitrogen concentration in water samples ranged from trace to 1.622 mg/L (Table 44).

Table 44. Nitrate concentration (mg/L) in the water samples of the Sharavathi upstream.

Months	Sampling sites															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Feb-01	0.161	0.167	0.12	0.154			0.147	0.141		0.134						
Mar-01	0.004	0.024	0.007	0.014	0.012	0.01	ND	ND	0.024	0.028	ND	ND	0.012			
Apr-01	0.013	0.073	0.213	0.34	0.01	0.04	0.06	0.006	0.067	0.033	0.053	0.06	0.006			
May-01	0.1	0.14	0.02	0.42	0.012	0.01	ND	0.14	0.024	0.16	0.13	0.4	0.14			
Jul-01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND	ND	0.099
Aug-01	0.015	0.05	0.01	0.01	0.015	0.075	0.01	0.095	0.1	0.015	0.075	0.074		0.11	0.12	0.095
Sep-01	0.045	0.075	0.15	0.15	0.022	0.15	0.12	0.15	0.15	0.03	0.105	0.095	0.095	0.14	0.157	0.105
Oct-01	0.052	0.079	0.155	0.168	0.066	0.099	0.085	0.13	0.056	0.098	0.256	0.099	0.101	0.169	0.561	0.589
Nov-01	0.055	0.086	0.162	0.199	0.092	0.087	0.098	0.092	0.105	0.159	0.361	0.134	0.198	0.235	0.942	0.789
Dec-01	0.061	0.101	0.188	0.254	0.15	0.025	0.056	0.075	0.213	0.312	0.587	0.857	0.534	0.654	1.023	0.954
Jan-02	0.083	0.139	0.251	0.307	0.279	ND	ND	0.008	0.335	0.587	0.979	0.712	0.979	0.979	1.259	1.623
Feb-02	0.042	0.063	0.021	ND	ND	ND	0.056	ND	ND	0.416	0.071		ND			ND
Mar-02	0.09	0.128	0.308	0.142	0.160	0.038	0.257	0.039	0.071	0.192	0.769		0.026			
Apr-02	0.076	0.099	0.125	0.125	0.099	0.036	0.354	0.047	0.075	0.231	0.564		0.055			

In downstream sites, nitrate concentration was higher at Hossagadde, Bhaskere and Mavinaholé with 1.011 mg/L, 1.208 mg/L and 1.114 mg/l respectively (Table 45). Comparatively, downstream sites had low nitrate concentration than upstream sites.

Table 45. Nitrate concentration (mg/L) in the water samples of the Sharavathi downstream.

Months	Sampling sites										
	1	2	3	4	5	6	7	8	9	10	11
Nov-02	0.149		0.203	0.146	0.134	0.173		0.094	0.113	0.153	0.097
Dec-02	0.144	0.146	0.12	0.178	0.15	0.142		0.153	0.165	0.12	0.142
Jan-03	0.231	0.231	0.206	0.343	0.253	0.793	0.326	0.253	0.279	0.206	0.214
Feb-03	0.317			0.308	0.214	0.27	0.24	0.249	0.219	0.206	0.236
Mar-03	0.27	0.279		0.176	0.21	0.227	0.244		0.223	0.249	0.219
April-03	0.047	0.099		0.06	0.064	0.06	0.051		0.039	0.06	0.021
May-03											
Jun-03	0.63		1.011	0.716	0.908	0.951	0.176	1.208		0.788	1.114

Table 45. Nitrate concentration (mg/L) in the Sharavathi downstream (cont…).

Months	Sampling sites											
	12	13	14	15	16	17	18	19	20	21	22	23
Nov-02	0.103	0.103	0.21	0.2	0.13	0.1				0.12	0.32	0.13
Dec-02	0.13	0.12	0.17	0.183	0.155					0.13	0.18	0.11
Jan-03	0.27	0.3	0.39	0.43	0.24	0.26		0.3		0.21	0.29	0.25
Feb-03	0.29	0.21	0.27	0.21	0.27	0.24		0.27	0.28		0.24	0.19
Mar-03	0.2	0.2	0.19		0.24	0.21		0.23	0.24		0.27	0.19
April-03	0.05	0.04	0.12		0.13	0.09		0.09	0.06		0.14	0.04
May-03												
Jun-03	0.154	0.24	0.206		0.163			0.514	0.65		0.48	0.18

Phosphate

The values ranged from non-detectable (ND) to 0.0929 mg/L (Table 46). The occasional rise in concentration can be attributed to the agricultural runoff getting into that water.

Table 46. Phosphate concentration (mg/L) in the water samples of the Sharavathi upstream.

Months	Sampling sites															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Feb-01	0.007	0.009	0.009	0.008			0.006	0.018		0.007						
Mar-01	0.008	ND	0.012	0.009	0.004	ND	0.002	ND	ND	0.005	ND	0.012	0.004			
Apr-01	0.004	0.01	ND	0.004	0.004	ND	0.002	0.005	0.002	0.003	0.003	0.001	ND			
May-01	0.002	0.003	0.001	0.01	ND	0.004	0.004	0.004	0.002	ND	0.004	0.014	ND			
Jul-01	0.014	0.014	0.014	0.02	0.005	0.01	0.011	0.019	0.01	0.015	0.01	0.02		0.018	0.032	0.003
Aug-01	0.017	0.008	0.012	0.018	0.012	0.009	0.02	0.005	0.012	0.015	0.010	0.02		0.013	0.017	0.002
Sep-01	0.004	0.007	0.004	0.005	0.003	0.002	0.01	0.001	0.004	0.007	0.005	0.01	0.005	0.005	0.005	0.004
Oct-01	0.022	0.015	0.053	0.012	0.025	0.008	0.008	0.032	0.008	0.028	0.023	0.011	0.007	0.092	0.003	0.036
Nov-01	0.009	0.005	0.008	0.007	0.012	0.011	0.014	0.008	0.016	0.014	0.010	0.01	0.011	0.014	0.013	0.014
Dec-01	0.014	0.010	0.017	0.005	0.004	0.003	0.014	0.038	0.022	0.07	0.014	0.017	0.007	0.048	0.051	0.021
Jan-02	0.001	0.005	ND	0.009	0.008	0.003	0.007	0.004	0.003	0.004	ND		ND	0.004	0.001	0.002
Feb-02	ND	0.046	ND	0.057	ND	ND	0.009	ND	ND	ND	ND		ND			ND
Mar-02	0.003	0.002	0.006	0.018	0.006	0.017	0.017	0.014	0.005	0.001	0.004		0.001			
Apr-02	0.002	0.002	0.004	0.026	0.005	0.021	0.015	0.015	0.005	0.002	0.004		0.002			

Contrasting to upstream, the downstream localities generally had low phosphate concentration (trace to 0.025 mg/L) and fluctuations were also very less (Table 47).

Table 47. Phosphate concentration (mg/L) in the water samples of the Sharavathi upstream.

Months	Sampling sites										
	1	2	3	4	5	6	7	8	9	10	11
Nov-02	0.01		0.01	0.01	0.01	0.02		0.01	0.01	0.01	0.01
Dec-02	0.01	0.01	0.01	0.01	0.01	0.01		0.01	0.01	0.01	0.01
Jan-03	0.017	0.014	0.016	0.016	0.016	0.016	0.015	0.015	0.017	0.014	0.016
Feb-03	0.016			0.014	0.013	0.012	0.014	0.012	0.016	0.009	0.014
Mar-03	0.017	0.02		0.025	0.015	0.018	0.022		0.017	0.016	0.015
April-03	0.003	0.004		0.003	0.003	0.006	0.003		0.003	0.003	0.003
May-03	0.004	0.004		0.003	0.003	0.006	0.003		0.003	0.003	0.003
Jun-03	0.014		0.016	0.013	0.015	0.015	0.016	0.012		0.014	0.014

Table 47. Phosphate concentration (mg/L) in the Sharavathi upstream (cont…).

Months	Sampling sites											
	12	13	14	15	16	17	18	19	20	21	22	23
Nov-02	0.01	0.01	0.01	0.01	0.01	0.01	0.01			0.01	0.01	0.01
Dec-02	0.01	0.01	0.01	0.01	0.01					0.01	0.01	0.01
Jan-03	0.016	0.017	0.015	0.012	0.016	0.016		0.016		0.01	0.02	0.01
Feb-03	0.014	0.018	0.013	0.013	0.013	0.021		0.014	0.014		0.013	0.01
Mar-03	0.01	0.02	0.03		0.01	0.02		0.02	0.02		0.02	0.01
April-03	0.003	0.003	0.003		0.003	0.004		0.003	0.003		0	0
May-03	0.003	0.003	0.003		0.003			0.004	0.003		0.003	0
Jun-03	0.009	0.013	0.01		0.014			0.012	0.015		0.013	0.013

Iron

Iron concentration in all upstream sampling points was <0.3 mg/L, within the limits of NEERI and APHA (drinking water 0.3mg/L and freshwater bodies 1.0mg/L).

Ammonia

In upstream sites, concentration of ammonia ranged between <0.2 to 3 mg/L.

Fluoride

In downstream, fluoride concentrations in all sub-basins were 0.6 mg/L which falls within the standard limit of 0.6 – 1.2 mg/L for drinking water.

Coliform Bacteria

In upstream, water samples taken during monsoon had coliform bacteria at Sharavathi 1 and 2, Sharmanavathi, Haridravathi and its nearby streams (Keshawapura and Nandiholé). This is due to human or animal interference with the waterbodies of the region. Other sampling sites showed occasional presence of coliform bacteria.

In downstream localities, coliform bacteria were found in almost all the samples. This could be due to human faecal matter or due to aquatic or terrestrial animal wastes. As per the permissible limits for drinking water, there should not be any coliform bacteria in the water.

8.1 Comparison with NEERI and WHO Standards

Table 48 details the comparison of the study with NEERI and WHO standards. Only those parameters having permissible levels according to NEERI are considered here. A few parameters have exceeded the stipulated limits, but they require continued monitoring.

Table 48. Obtained values vs. standard values of NEERI and WHO

Variables	Permissible Limits	Upstream	Downstream
Turbidity (NTU)	Not more than 10	<5 – 125	10 – 100
Total Dissolved Solids (mg/L)	100	13.77 – 110	16.2 – 15,090 mg/L
Colour	Colourless	Colourless – Brownish green	Colourless – Brownish green
pH	6.5-8.5	6.52-8.41	6.21-8.67

Conductivity (mS/cm)	0.05-1.5	0.003-0.44	0.03-30.20
Alkalinity (mg/L)	200	8 -75	9.6-79.2
Dissolved oxygen (ppm)	Not less than 3.0	4.8-8	4.0-16.3
Total Hardness (mg/L)	300	27.25 - 148.29	6-4300
Sulphate (mg/L)	150	0.34-32.02	1.05-1765.3
Chloride (mg/L)	250	4.9-63.9	1.91-13320.9
Sodium (mg/L)	200	2.1 - 101.4	0.1-1908
Potassium (mg/L)	-	Trace - 9.508	0.09-186.9
Nitrates (mg/L)	45	Trace - 1.623	0.021-1.114
Phosphates (mg/L)	0.03	Trace - 0.092	Trace – 0.025
Coliform Bacteria	Should be nil	Nil - Present	Nil – Present

8.2 Comparison between Sampling Sites in Upstream

The upper catchment area was divided into three categories based on the their disturbance level. Group A was classified under most disturbed area (agricultural activities, siltation process, etc), whereas Group B and Group C come under comparatively less disturbed area. Table 49 gives the classification of groups based on their disturbance level.

Table 49. Classification of study area (upstream)

Group A	Group B	Group C
Sharavathi [1] and [2]	Muppane [5]	Linganamakki Reservoir [8]
Sharmanavathi [3]	Talakalale dam [6]	Valagere [9]
Haridravathi [4]	Dam outlet [7]	Yenneholé [10]
Nandiholé [14]		Hurliholé [11]
Keshavapura [15]		Nittur [12]
Sampekai [16]		Madenur [13]

Table 50 gives the comparison of water quality variables between sampling sites under each group.

Table 50. Comparison between sampling sites.

Variables	Group A	Group B	Group C
Transparency (cm)	3 – 124	20 – 284	24 - 284
Turbidity (NTU)	10 – 125	<5 – 12	5 - 20
Colour	Light Brown - Brownish green	Colourless - Brownish green	Colourless - Brownish
Total Dissolved Solids (mg/L)	18.16 – 84	13.77 - 27.3	14.25 - 40.72
Total Suspended Solids (mg/L)	21.3 – 110	26 – 75	26 - 85
pH	6.53 - 8.25	6.54 - 7.757	6.53 - 7.76
Ammonia (mg/L)	<0.2 - >3.0	<0.2 – 3.0	<0.2 - 3.O
Total Hardness (mg/L)	27.25 - 143.88	20 – 87.2	22 - 78.48
Sulphate (mg/L)	1.76 - 32.02	0.34 – 23.35	0.67 - 17.2
Nitrates (mg/L)	ND - 1.6229	ND - 0.279	ND - 0.979
Phosphate (mg/L)	ND - 0.0929	ND - 0.0174	ND - 0.0699
Coliform Bacteria	Almost Present in all sampling sites	ND- Slightly Present	ND-Slightly Present

The results show that the physico-chemical and biological variables under group A is comparatively polluted than group B and group C in terms of transparency, turbidity, suspended solids, phosphate and coliform bacteria.

The tributaries flowing through the sub-basins Nandiholé (US1), Haridravathi (US2), Sharavathi (US4), Mavinaholé (US3) and Hilkunji (US8) (Group A) are relatively more

polluted (in terms of transparency, turbidity, suspended solids, phosphates and coliform) than the tributaries in the sub-basins Yenneholé (US5), Linganamakki (US9), and Hurliholé (US6) (Group B and C) in the Sharavathi upper catchment. The reason for higher pollution in the above said sub-basins is due to agricultural and other anthropogenic activities in the catchment area.

8.3 Comparison between Sampling Sites in Downstream

Stagnant waters especially at Dabbod, Gudankateholé show low DO values in comparison to flowing waters of Vatahalla, Chandubanu. Drastic changes were observed in the water quality during the months of January, February, March and April in the Haddinabal stream due to seawater intrusion as evident by high conductivity and total dissolved solids with corresponding increase in values for all other parameters. Generally, the water is saline only upto Badagani. The seawater intruded backwards upto Hablikapu nearly one and a half km away from Gudankateholé passing through 4 dams/obstructions. Farmers in the nearby areas have noticed crop damage i.e. stunted growth due to saline water usage.

In the coastal belt three locations of a major stream were monitored at Chandavar, Gudankateholé and Badagani. Badagani showed high salinity during all months. Gudankateholé showed freshwater characteristics during November, December, and January. But during the months February, March and April the water turned saline. This has led to the contamination of nearby wells and rendered them unfit for drinking.

Turbidity levels at Dabbod a stream located at the southern end of Sharavathi downstream catchment exceeded the limits during the months of January and April. The reason for this abnormality can be attributed to the damming of this stream where the water was retained for agricultural purposes. Alkalinity levels have also shown substantial increase in the values similar to TDS values. All streams except Chandavar started flowing in June due to rains. There are natural variations and trends in the water quality that the waterbodies are usually bound to experience over a period of time or season. Apart from Haddinabal, Gudankateholé and Badagani, all other sites had the water parameters within the stipulated range of Indian standards for drinking and agriculture except for turbidity and coliform bacteria.

9.0 RESULTS AND DISCUSSION OF THE ANALYSIS OF SOIL

Soils representative of different habitats of entire catchment area like evergreen forests, disturbed evergreen forests, semi evergreen forests, swamps, *Areca* plantations, *Acacia* plantations, paddy fields, teak plantation, *Pinus* plantations, barren lands and riparian habitats were analysed for physical and chemical characteristics.

The results of the upstream (Batch I and II) and downstream (Batch III) soil samples are detailed in Tables 51, 52 and 53 respectively.

The soils of the upper catchment ranged from moderately acidic (pH 5.3 in sub-basin Linganamakki) in a semi-evergreen forest to neutral (7.8 in sub-basin Yenneholé) in the soils obtained from a degraded area (*i.e.,* area with less vegetation cover). The slightly acidic soils found in moist deciduous, deciduous, semi-evergreen patches in sub-basins Nandiholé (US1), Haridravathi (US2), Mavinaholé (US3), Yenneholé (US5),

Linganamakki (US9) would be due to the high organic content in the soils. The soils generally found in these areas are optimal for plant growth and microbial activity.

The bulk densities of *Acacia* plantations, barren lands, teak plantations, moist deciduous forests in all the sub-basins (0.69 – 1.175 g/cm^3) were slightly higher than the evergreen and semi-evergreen patches (0.70 – 0.97 g/cm^3) in the same basins. These results are supported by high moisture content (19.82 – 27.84 %) in the semi-evergreen patches found in sub-basins Yenneholé (US5) and Linganamakki (US9). The increased moisture content in sub-basin 9 would be due to the fact that this is the main reservoir bed. The deciduous, moist deciduous and *Acacia* plantations (6.96 – 22.55%) in sub-basins Nandiholé (US1), Haridravathi (US2), Sharavathi (US4), Linganamakki (US9), Mavinaholé (US3), Nagodiholé (US7) have high moisture content than the barren lands found in Haridravathi (US2), Sharavathi (US4), Yenneholé (US5) and Hurliholé (US6).

The soils in the upper-catchment are generally rich in organic carbon. The relative richness of organic carbon concentrations for various habitats (Tables 51 and 52) are semi-evergreen > deciduous, moist deciduous and *Acacia* plantations > teak plantations. The high organic carbon content in semi-evergreen, deciduous and *Acacia* habitats was due to heavy leaf litter. The organic carbon varied among the similar habitats in different sub-basins: semi evergreen forests [Linganamakki (US9) > Yenneholé (US5)], Moist deciduous forests [Nandiholé (US1) > Mavinaholé (US3) > Haridravathi (US2)], *Pinus* plantation [Linganamakki (US9) > Sharavathi (US4)], Deciduous forests [Mavinaholé (US3) > Haridravathi (US2)], Teak plantation [Nandiholé (US1) > Haridravathi (US2), Mavinaholé (US3), Linganamakki (US9)], *Acacia* plantation [Nandiholé (US1) > Sharavathi (US4) > Linganamakki (US9) > Haridravathi (US2)] and barren land [Hurliholé (US6) > Sharavathi (US4) > Haridravathi (US2)].

The relative concentrations of various elements are as follows Sulphates > Chlorides > Calcium > Magnesium and Nitrates > Phosphates (Table 51).

From the results it can be concluded that soils of the sub-basins Linganamakki (US9), Yenneholé (US5), Nagodiholé (US7), Nandiholé (US1), Haridravathi (US2), Mavinaholé (US3) of the upstream catchment (reflected by high organic content and low bulk density values) were fertile compared to the sub-basins Sharavathi (US4) and Hurliholé (US6).

Table 51. Soil analysis in the Sharavathi upstream (Batch I).

Parameters	Sampling sites											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Physical												
Moisture Content (%)	7.62	5.12	4.1	6.7	11.4	1.2	5.9	5.3	7.64	6.27	7.2	6.16
Bulk Density (g/cm^3)	0.87	1.005	0.944	0.991	1.267	0.876	1.045	0.975	1.09	1.027	1.359	1.037
Colour #	YB	BR	BR	DB	SBY	YB	B	DB	GB	DB	B	RB
Chemical												
pH	7.8	7.65	7.34	7.2	7.1	7.01	7.3	7.45	7.1	7.2	7.28	6.8
EC (mS/cm)	0.026	0.018	0.02	0.042	0.035	0.026	0.022	0.049	0.12	0.06	0.020	0.029
Acidity (mg/g)	3	4	2	1	2	3	2	2	4	4	2	1
Alkalinity (mg/g)	3	3	2	4	3	4	3	5	5	2	2	3
Chloride (mg/g)	0.497	0.426	0.426	0.497	0.426	0.426	0.497	0.568	0.497	0.568	0.781	1.704
Calcium (Meq/100 g)	4	5.4	4	6	3.2	4.1	2.6	14	10.8	17.2	1.8	3.8
Magnesium (Meq/100 g)	2	3.6	2	2	7.8	3.1	0.8	0.8	1.6	1	0.4	1
Sodium (mg/g)	0.182	0.018	0.018	0.024	0.004	0.018	0.026	0.018	0.016	0.02	0.095	0.012
Potassium (mg/g)	0.013	0.027	0.021	0.045	0.066	0.022	0.022	0.082	0.071	0.057	0.017	0.027
Sulphate (mg/g)	0.01	0.073	0.206	0.266	0.222	0.198	0.213	0.259	0.246	0.317	0.246	0.164
Phosphate (10^{-4}mg/g)	4.9	6.2	3.6	4.2	7.4	4.1	5.9	7.0	0.6	3.4	0.4	7.74
Nitrate (mg/g)	ND†	ND	ND	ND	ND	ND	0.0001	ND	ND	ND	ND	ND
Organic Matter (%)	>4	>4	>4	>4	>4	3	3	>4	>4	>4	>4	<1
Organic Carbon (%)	2.32	2.32	2.32	2.32	2.32	1.74	1.74	2.32	2.32	2.32	2.32	ND
Lime Requirement *	7	7	1.6	5.2	1.6	8.2	3.4	7	4	4.5	3.4	1.6

Table 51. Soil analysis in the Sharavathi upstream (Batch I) (cont…).

Parameters	Sampling sites											
	13	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Physical												
Moisture Content (%)	3.214	5.8	5.2	10.4	4.3	5.5	5.6	1.8	9.61	3.85	1.56	1.2
Bulk Density (g/cm^3)	0.971	1.207	1.111	1.209	1.144	1.024	1.174	1.175	0.786	1.125	1.725	0.701
Colour #	YB	GB	GB	DEB	DEB	RB	YB	BY	RB	B	BYE	BYE
Chemical												
pH	7.24	6.62	7.05	6.1	6.68	6.9	6.7	6.45	6.57	6.59	6.82	6.74
EC (mS/cm)	0.027	0.141	0.032	0.026	0.045	0.044	0.020	0.024	0.051	0.05	0.05	0.05
Acidity (mg/g)	1	3	3	5	3	4	2	3	3	3	2	4
Alkalinity (mg/g)	3	2	2	1	2	3	3	2	2	3	2	3
Chloride (mg/g)	0.994	0.914	1.491	2.05	1.42	1.49	0.71	2.62	3.62	1.29	2.01	0.72
Calcium (Meq/100 g)	2	1.2	3.2	4.6	3.4	2.6	1	5.4	7.8	5.4	6.1	1.25
Magnesium (Meq/100 g)	0.8	0.8	1	1.2	0.6	1.6	1	2	2.4	2.2	2.8	0.9
Sodium (mg/g)	0.03	0.012	0.022	0.009	0.014	0.009	0.013	0.014	0.018	0.018	0.016	0.006
Potassium (mg/g)	0.085	0.28	0.005	0.039	0.046	0.015	0.09	0.029	0.035	0.029	0.3	0.012
Sulphate (mg/g)	0.16	0.201	0.17	0.218	0.157	0.232	0.311	0.495	0.847	0.752	0.812	0.355
Phosphate (10^{-4}mg/g)	5.0	1.2	1.5	1.2	7.8	8.0	8.5	4.3	4.4	7.1	4.8	2.2
Nitrate (mg/g)	ND†	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Organic Matter (%)	2	>4	>4	>4	>4	>4	>4	3	<1	3	3	<1
Organic Carbon (%)	1.16	2.32	2.32	2.32	2.32	2.32	2.32	1.74	Nil	1.74	1.74	Nil
Lime Requirement *	7.6	4.5	2.2	3.4	4	6.4	4.5	2.8	2.2	8.2	4	8.2

Note: **#** Colour abbreviation used YB: Yellowish brown, BR: Brownish red, DB: Dark brown, SBY: Slightly brownish yellow, RB: Reddish brown, B: Brown, GB: Grayish brown, DEB: Dark earthy brown, BY: Bright yellow, BYE: Brownish yellow.

***** in Tonnes of $CaCO_3$/acre; **†** Not detectable

Table 52. Soil analysis in the Sharavathi upstream (Batch II).

Parameters	***Sampling sites***									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Physical										
Moisture Content (%)	12.8	15.4	8.8	6.96	8.15	10.64	14.08	16.98	6.41	14.59
Bulk Density (g/cm^3)	1.01	1.02	0.99	1.07	1.13	1.11	0.98	1.03	1.11	0.98
Chemical										
pH	6.58	6.28	6.1	6.63	6.07	6.44	6.43	6.18	5.97	6.12
Conductivity (mS/cm)	0.048	0.045	0.055	0.03	0.046	0.055	0.033	0.114	0.038	0.032
Acidity (mg/g)	0.022	0.02	0.044	0.005	0.006	0.014	0.014	0.013	0.006	0.007
Alkalinity (mg/g)	0.014	0.029	0.013	0.01	0.008	0.018	0.01	0.009	0.006	0.01
Chloride (mg/g)	0.021	0.059	0.077	0.017	-	0.049	0.079	0.08	0.016	0.046
Calcium (M.eq/100g)	0.002	0.002	0.0022	0.0002	-	0.0007	0.0015	0.0013	-	0.0032
Magnesium (M.eq/100g)	0.0002	0.0002	0.0044	0.0001	-	0.0001	0.0002	0.0005	-	0.001
Nitrates (10^{-4}mg/g)	8.2	9.2	12.2	8.2	7.1	1.3	-	20.3	7.6	10.8
Sulphates (mg/g)	0.24	0.12	0.11	0.22	0.21	0.13	0.24	0.27	0.001	0.24
Phosphate (10^{-4}mg/g)	2.5	0.1	0.4	1.1	0.5	0.8	1.2	1.5	1.1	0.8
Organic matter (%)	5.16	5.59	6.44	2.44	1.21	3.53	3.22	3.83	3.16	4.89
Organic carbon (%)	2.99	3.24	3.73	1.42	0.7	2.05	1.87	2.22	1.83	2.83

Table 52. Soil analysis in the Sharavathi upstream (Batch II) (cont…).

Parameters	***Sampling sites***									
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Physical										
Moisture Content (%)	14.75	9.16	13.31	11.66	10.53	19.82	13.18	16.67	20.42	27.84
Bulk Density (g/cm^3)	0.98	1.11	1.08	1.03	1.04	0.97	0.99	0.93	0.87	0.73
Chemical										
pH	6.16	5.69	6.42	5.69	5.68	6.36	6.36	6.01	5.87	6.88
Conductivity (mS/cm)	0.044	0.04	0.051	0.045	0.032	0.066	0.056	0.047	0.056	0.049
Acidity (mg/g)	0.01	0.01	0.011	0.02	0.007	0.027	0.017	0.016	-	0.05
Alkalinity (mg/g)	0.014	0.007	0.014	0.009	0.007	0.032	0.014	0.024	-	0.03
Chloride (mg/g)	0.03	0.038	0.019	0.068	0.011	0.053	0.031	0.046	0.032	0.053
Calcium (M.eq/100g)	0.0007	0.0003	0.0024	0.0003	-	0.0014	-	0.0011	0.001	0.1027
Magnesium (M.eq/100g)	0.0006	0.0002	0.0002	0.0001	-	0.0002	-	0.0011	0.0001	-
Nitrates (10^{-4}mg/g)	12.7	44.8	15.4	14.3	7.4	8.9	16.5	12	7.5	32.1
Sulphates (mg/g)	0.163	0.045	0.129	0.159	0.026	0.199	0.051	0.153	0.095	1.319
Phosphate (10^{-4}mg/g)	0.4	0.4	0.5	0.8	2.2	0.4	1.6	1.7	1.2	4.7
Organic matter (%)	6.38	0.86	4.58	3.84	3.28	5.02	3.6	3.98	6.99	7.89
Organic carbon (%)	3.7	0.5	2.66	2.23	1.9	2.91	2.09	2.31	4.06	4.58

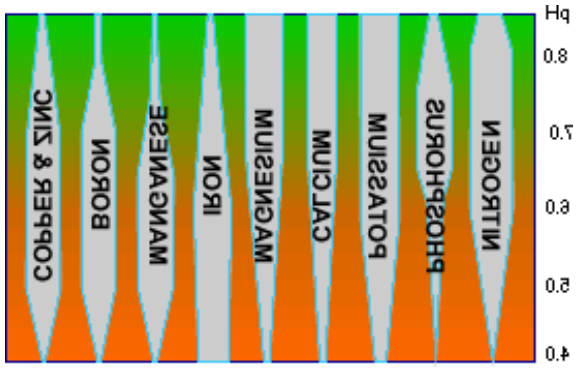
Table 52. Soil analysis in the Sharavathi upstream (Batch II) (cont…).

Parameters	***Sampling sites***									
	21	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**35**
Physical										
Moisture Content (%)	14.97	27.96	18.46	18.01	25.56	22.31	27.42	25.62	27.93	22.55
Bulk Density (g/cm^3)	0.97	0.7	-	0.88	0.77	0.76	0.71	0.69	0.7	0.75
Chemical										
pH	6.01	6.38	5.94	5.94	6.09	5.81	6.25	5.66	6.25	5.92
Conductivity (mS/cm)	0.024	0.012	0.01	0.011	0.017	0.01	0.023	0.013	0.03	0.014
Acidity (mg/g)	0.011	0.025	0.022	0.015	0.016	0.036	0.03	0.024	0.026	0.093
Alkalinity (mg/g)	0.026	0.013	0.027	0.036	0.039	0.028	0.039	0.025	0.028	0.022
Chloride (mg/g)	0.032	0.026	0.038	0.017	0.036	0.027	0.041	0.019	0.007	0.047
Calcium (M.eq/100g)	-	0.0324	-	0.0091	0.0023	-	0.0321	-	-	0.0148
Magnesium (M.eq/100g)	-	-	-	-	-	-	-	-	-	-
Nitrates (10^{-4}mg/g)	47.2	48.5	104.5	16.9	40	28.1	110.4	16.4	20.4	29.6
Sulphates (mg/g)	-	0.62557	0.59652	0.70255	0.87482	0.94383	1.11732	0.71729	0.9555	0.70155
Phosphate (10^{-4}mg/g)	3.6	2.1	4.8	4.7	4.6	2.5	4.7	-	-	2.2
Organic matter (%)	5.27	3.4	1.46	3.04	2.64	4.11	3.88	5.3	8.28	3.95
Organic carbon (%)	3.05	1.97	0.85	1.77	1.53	2.38	2.25	3.08	4.8	2.29

Table 52. Soil analysis in the Sharavathi upstream (Batch II) (cont…).

Parameters	***Sampling sites***							
	36	**37**	**39**	**40**	**41**	**42**	**43**	**44**
Physical								
Moisture Content (%)	26.81	24.7	13.18	12.19	18.88	19	13.82	17.26
Bulk Density (g/cm^3)	-	0.73	0.88	0.77	0.81	0.76	0.78	0.74
Chemical								
pH	6.13	5.43	5.52	5.88	6.02	5.93	5.99	5.8
Conductivity (mS/cm)	0.02	0.022	0.017	0.016	0.032	0.029	0.014	0.009
Acidity (mg/g)	0.024	0.012	0.021	0.04	0.033	0.022	0.039	0.015
Alkalinity (mg/g)	0.02	0.007	0.017	0.025	0.014	-	0.021	0.017
Chloride (mg/g)	0.027	0.021	0.02	0.018	0.022	0.028	0.027	0.006
Calcium (M.eq/100g)	0.0451	-	-	-	0.0175	0.0343	0.0201	0.0168
Magnesium (M.eq/100g)	-	-	-	-	-	-	-	-
Nitrates (10^{-4}mg/g)	44.4	48.1	60.1	21.4	88.6	195.6	22.7	10.5
Sulphates (mg/g)	0.572	0.172	0.589	0.798	0.234	0.877	0.692	1.335
Phosphate (10^{-4}mg/g)	1.7	2.9	2.3	3.2	4.5	3.3	4.8	1.7
Organic matter (%)	8.68	4.52	2.41	2.18	9.2	3.88	2.28	4.48
Organic carbon (%)	5.04	2.62	1.4	1.27	5.34	2.25	1.32	2.6

The soil analysis for the Sharavathi downstream catchment reveals that the soils from all the habitats analysed are moderate to slightly acidic in nature (4.9 to 6.07), which is shown in the Table 53. Most of the plants grow optimally in this pH range, as the nutrients are available for their growth (as shown below) and the microbial activity is also optimum at this range.



(http://www.pda.org.uk/leaflets/24/leaflet24-6.html)

Conductivity values for all habitats were within permissible limits for good quality soil. Bulk density (2.02 – 2.25 g/cm^3) was high in the areca plantations in the sub-basins Dabbe falls (DS4), Magod (DS3) and Haddinabal (DS2), which could be attributed to the compactness and nonporous nature of the soil. The mulching of soil would be the reason for higher moisture content in these plantations (20.44 –23.68%). Riparian habitat at Dabbe showed a high value of bulk density 2.05 g/cm^3, due to clayey skeletal nature of the soil, which is generally compact. These results are supported by low water holding capacity (9.76 – 39.24%) and moderate concentrations of organic carbon (0.44 to 0.84%).

The evergreen patches in Dabbe falls (DS4), Haddinabal (DS2) and Kathalekan (DS6) have lower bulk densities (1.29 – 1.94 g/cm^3, Table 53) than Areca and other plantations. Consequently, these patches have high water holding capacity (13.48 -55.31%) and organic carbon (0.66 – 2.59%).

At Idagunji (Magod DS3), Acacia plantations showed organic carbon concentrations of 1.55 % and at Mahasati (Haddinabal DS2) it was 0.20 %. Due to older plantations, in Idagunji leaf litter was high.

Areca plantations near Hossagadde and Mavinaholé in Magod (DS3) and Haddinabal (DS2) respectively are deficient in phosphorous levels with 7.88 and 9.46 kg/ha whereas Chandubanu (Haddinabal DS2) is rich in available phosphorous [165.55 kg/ha], which is due to fertiliser applications. Ploughed paddy field at Hebbenkere (Dabbe fall DS4) is deficient in phosphorous with 7.88 kg/ha compared to moderate concentrations of 25.23 kg/ha in unploughed paddy field (DS4) This is probably due to the disturbances to the topsoil (which is rich in phosphorous) while ploughing.

Compared to paddy fields, the riparian vegetation soils in sub-basin 4 have moderate phosphorous levels (28.38 kg/ha). The teak plantations (Haddinabal DS2) grown on slopes is deficient in phosphorous (12.61 kg/ha) when compared to plantations (34.69 kg/ha) in flat terrain. The low phosphorous levels would be due to soil erosion on the slopes. The evergreen patches in certain areas like Kathalekan (sub-basin 6), Chikoli

(sub-basin 2), and Chandubanu (sub-basin 2) are deficient in phosphorous levels - 14.19, 1.58 and 15.77 kg/ha respectively. This can be attributed to the disturbance of the soil surface.

The Areca plantations in Dabbe falls (DS4), Magod (DS3) and Haddinabal (DS2) have low available potassium (69.5 – 142.9 kg/ha) whereas in other habitats like evergreen and semi-evergreen patches in the same sub-basins, it was higher.

Thus, from the results, it can be concluded that the soils in the Areca, Acacia and teak plantations in Dabbe falls (DS4), Magod (DS3) and Haddinabal (DS2) have a low nutrient status (as shown by low water holding capacity, low organic content and high bulk density values) than the soils in the evergreen and semi-evergreen patches in the same sub-basins.

The evergreen patches of sub-basin Haddinabal (DS2) and Kathalekan (DS6) have high available potassium and phosphorous values compared to other habitats and sub-basins.

The soils of Haddinabal (DS2) and Kathalekan (DS6) of the downstream catchment of the Sharavathi river basin are relatively fertile compared to Dabbe falls (DS4) and Magod (DS3). Most of the areas in the DS4 and DS3 come under different plantations and have the maximum anthropogenic activity compared to the other two sub-basins.

Table 53. Soil analysis in the Sharavathi downstream (Batch III).

Parameters	***Sampling Sites***									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Moisture content (%)	18.5	20.54	14.69	20.84	23.68	20.72	21.06	13	21.67	12.7
Bulk density (g/cm^3)	1.69	2.25	1.65	1.62	2.12	1.29	2.02	1.65	2.09	1.53
Water holding capacity (%)	13.48	9.76	20.73	46.23	13.8	25.9	26.68	47.21	31.29	37.62
PH	5.49	5.8	5.6	5.4	5.8	4.9	5.55	5.2	5.8	5.6
Conductivity (mS/cm)	0.031	0.016	0.013	0.017	0.022	0.02	0.025	0.023	0.014	0.023
Available Phosphorus (kg/ha)	-	7.88	23.65	25.23	-	93.03	29.96	7.88	28.38	14.19
Organic carbon (%)	1.68	0.44	0.2	1.13	0.84	1.76	0.57	0.91	0.66	1.24
Available Potassium (kg/ha)	230.5	113.3	252.4	76	101.7	140.3	69.5	106.9	91.4	188
Lime requirement *	7.6	3.4	2.2	7.6	5.2	10.1	4.5	6.4	4	6.4

Table 53. Soil analysis in the Sharavathi downstream (Batch III) (cont…).

Parameters	***Sampling Sites***									
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Moisture content (%)	20.66	20.44	20.88	22.78	7.19	12.9	5.79	15.56	17.89	18.69
Bulk density (g/cm^3)	2.19	2.05	1.33	2.35	1.65	1.49	1.56	1.48	1.52	1.72
Water holding capacity (%)	34.94	39.24	45.03	29.82	24.01	34.91	24.15	44.75	54.71	44.98
pH	6	5.8	6.07	5.4	5.4	5.1	5.7	5.2	5.8	5.2
Conductivity (mS/cm)	0.018	0.031	0.101	0.015	0.039	0.016	0.062	0.02	0.035	0.031
Available Phosphorus (kg/ha)	165.55	9.46	1.58	-	12.61	4.73	34.69	47.3	15.77	50.45
Organic carbon (%)	0.6	0.6	2.59	0.7	1.01	0.78	0.82	1.18	2.2	0.78
Available Potassium (kg/ha)	123.6	142.9	419.7	91.4	164.8	114.6	177.7	292.3	243.3	128.8
Lime requirement *	5.2	4	5.8	4.5	4	6.4	5.8	7.6	6.4	5.2

Table 53. Soil analysis in the Sharavathi downstream (Batch III) (cont…).

Parameters	*Sampling Sites*									
	21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Moisture content (%)	19.02	11.46	29.84	10.83	17.38	16.33	8.88	10.74	28.09	20.79
Bulk density (g/cm^3)	1.69	1.37	1.74	1.49	1.53	1.52	1.94	1.84	1.58	1.43
Water holding capacity (%)	37.92	42.45	53.17	36.94	55.31	41.67	36.85	52.09	46.11	43.41
pH	5.2	5.8	4.9	5.6	5.9	5.8	5.4	5.3	5.1	5.3
Conductivity (mS/cm)	0.026	0.027	0.079	0.026	0.033	0.028	0.024	0.011	0.019	0.105
Available Phosphorus (kg/ha)	47.3	93.03	52.03	126.14	77.26	63.07	69.38	3.15	14.19	-
Organic carbon (%)	0.54	0.89	1.14	0.66	2.23	1.8	0.77	1.55	0.77	-
Available Potassium (kg/ha)	108.2	136.5	164.8	181.5	372.1	244.6	236.9	70.8	145.5	-
Lime requirement *	4.5	4	-	4.5	-	6.4	5.2	10.1	-	-

Table 53. Soil analysis in the Sharavathi downstream (Batch III) (cont…).

Parameters	*Sampling Sites*				
	31	**32**	**33**	**34**	**35**
Moisture content (%)	26.79	20.31	20.72	16.14	20.04
Bulk density (g/cm^3)	1.63	1.63	1.29	1.76	1.56
Water holding capacity (%)	33.13	42.38	44.05	40.11	52.4
pH	5.6	5.5	5.5	5.8	5.5
Conductivity (mS/cm)	0.1049	0.0794	0.099	0.041	0.17
Available Phosphorus (kg/ha)	-	-	-	-	-
Organic carbon (%)	-	-	-	-	-
Available Potassium (kg/ha)	-	-	-	-	-
Lime requirement *	-	-	-	-	-

***** in Tonnes of $CaCO_3$/acre

10.0 RESULTS OF SEDIMENT ANALYSIS

The results of the sediment analysis at various sampling sites of Sharavathi catchment are listed in Table 54.

Moisture Content

The moisture content of sediment samples ranged between 8.8021 and 37.702%.

Bulk Density

Bulk Density ranged from 0.783 to 1.475 g/cm^3, from Nittur to Haridravathi.

Electrical Conductivity (EC)

The EC values varied from 0.0211 to 0.0403 mS/cm.

pH, Acidity and Alkalinity

The pH fluctuated from 6.37 to 7.39, from Yenneholé to Sharavathi 1 (Nagara). Acidity varied from 2 to 4 mg/g from Muppane forest area and Sharavathi 1 (Nagara) to Reservoir, Valagere, Nittur and Sharavathi 2; and alkalinity varied between 1 to 3 mg/g

from Muppane forest area and Yenneholé to Sampekai, Hurliholé, Haridravathi and Sharmanavathi.

Chloride

The chloride concentration ranged from 0.92 to 3.33 mg/g from Haridravathi to Sharmanavathi.

Calcium and Magnesium

The calcium and magnesium values ranged between 1.08 to 7.6 mg/g from Haridravathi to Sharmanavathi and 0.8 to 5 mg/g from Yenneholé to reservoir respectively. It is highly dependent on the parent materials or rocks.

Sodium and Potassium

The values of sodium were found ranging from 0.005 to 0.028 mg/g from Haridravathi to Reservoir and potassium between 0.013 and 0.89 mg/g from Sharavathi-2 to Reservoir.

Sulphate, Phosphate and Nitrate

Since the soil has low concentrations of these nutrients, consequently, the concentrations of these ions were found in lesser amounts. Sulphate varied from 0.191 to 0.68 mg/g from Sharavathi-2 to Reservoir, phosphate 0.00024 to 0.001 mg/g from Yenneholé to Haridravathi and nitrate was in a non-detectable limit to 0.0007 mg/g in most of the cases except Muppane, Valagere, Nittur and Sampekai.

Organic Matter and Organic Carbon

The organic matter was found to be varying from 2 to > 4% from Haridravathi to Muppane forest area. The richness in organic matter is due to the large amount of organic matter in soil. The organic carbon ranged from 1.16 to 2.32 %.

Table 54. Results of sediment analysis of Sharavathi.

Variables	Sampling sites					
	1	**2**	**3**	**4**	**5**	**6**
Physical						
Moisture Content (%)	11.3077	8.8021	12.8672	9.052	20.669	28.845
Bulk Density (g/cm^3)	1.362	1.312	1.26	1.475	1.105	1.029
Chemical						
pH	7.39	7.37	7.1	6.88	6.8	6.63
EC (mS/cm)	0.0403	0.0403	0.0313	0.0236	0.0211	0.0268
Acidity (mg/g)	2	4	3	3	2	4
Alkalinity (mg/g)	2	2	3	3	1	2
Chlorides (mg/g)	1.42	1.2	3.4	0.92	2.41	3.33
Calcium (M eq./100 g)	1.4	1.6	7.6	1.08	5	4.4
Magnesium (M eq./100 g)	2.6	1.8	2	1.52	1.8	5
Sodium (mg/g)	0.006	0.007	0.016	0.005	0.014	0.028
Potassium (mg/g)	0.021	0.013	0.019	0.047	0.026	0.025
Sulphate (mg/g)	0.376	0.191	0.273	0.208	0.352	0.68

Phosphate (10^{-4}mg/g)	3.1	7.0	3.5	10	7.2	3.3
Nitrate (mg/g)	ND	ND	ND	ND	0.0005	ND
Organic Matter (%)	3	3	3	2	>4	2.5
Organic Carbon (%)	1.74	1.74	1.74	1.16	2.32	1.45

Table 54. Results of sediment analysis of Sharavathi

Variables	Sampling sites				
	7	8	9	10	11
Physical					
Moisture Content (%)	35.1156	25.1939	37.702	21.934	14.203
Bulk Density (g/cm^3)	1.102	0.988	0.987	0.783	1.293
Chemical					
pH	6.6	6.37	6.59	6.57	6.9
EC (mS/cm)	0.0278	0.0243	0.0248	0.0249	0.0224
Acidity (mg/g)	3	3	4	3	4
Alkalinity (mg/g)	3	1	2	2	3
Chlorides (mg/g)	2.51	1.95	2.13	1.77	1.34
Calcium (M eq./100 g)	4.8	4.8	3.9	4	1.6
Magnesium (M eq./100 g)	3.4	0.8	1	1	2.2
Sodium (mg/g)	0.026	0.027	0.019	0.015	0.009
Potassium (mg/g)	0.031	0.027	0.029	0.089	0.017
Sulphate (mg/g)	0.512	0.328	0.312	0.266	0.461
Phosphate (10^{-4} mg/g)	2.8	2.4	2.9	7.54	4.0
Nitrate (mg/g)	ND	ND	0.005	0.00004	0.0007
Organic Matter (%)	3	3	3	3	3
Organic Carbon (%)	1.74	1.74	1.74	1.74	1.74

11.0 CONCLUSION

The water, soil and sediments of Sharavathi downstream and upstream catchments were analysed for their physico-chemical and biological parameters. The upstream and downstream catchments were divided into various sub-basins and their quality in terms of water, soil and sediment was evaluated.

- Field and laboratory investigations of the water quality of the Sharavathi upstream catchment reveal that the tributaries flowing through the sub–basins of Nandiholé (US1), Haridravathi (US2), Sharavathi (US4), Mavinaholé (US3) and Hilkunji (US8) (Group A) are relatively more polluted as evident from transparency, turbidity, suspended solids, phosphates and coliform than the tributaries in the sub-basins of Yenneholé (US5), Linganamakki (US9), and Hurliholé (US6) (Group B and C). The reasons for pollutions in these sub-basins are due to the agricultural and other anthropogenic activities in the catchment area.

- The Sharavathi downstream catchment shows that the streams flowing through the sub-basins of Magod (DS3), Dabbefall (DS4), Mavinagundi (DS5), Kathalekan (DS6) and Gudankateholé (DS7) are fresh and unpolluted. But streams like Dabbod in sub-basin 3 (Magod) showed variations in the physico-chemical characteristics like turbidity because of the increased run-off from the nearby agricultural fields. In certain months, the water is dammed for agricultural purposes and during the months of February, March and April, the water is highly turbid. The tributaries flowing through Chandavar (DS1) and Haddinabal (DS2) of

the downstream catchment are prone to salinity (high values of sodium, chlorides, sulphates, hardness, conductivity, TDS, alkalinity, etc.,) as there is seawater intrusion.

- The analysis of the soil samples collected from representative sites in the Sharavathi upstream catchment revealed that the soils of the sub-basins of Linganamakki (US9), Yenneholé (US5), Nagodiholé (7), Nandiholé (1), Haridravathi (US2), Mavinaholé (3) were fertile compared to the sub-basins Sharavathi (4) and Hurliholé (6) (indicated by high organic content and low bulk density values).

- The analysis of downstream catchment soil samples showed that the soils of Haddinabal (DS2) and Kathalekan (DS6) sub-basins are relatively fertile compared to the sub-basins Dabbe falls (DS4) and Magod (DS3). Most of the areas in the sub-basins DS4 and DS3 come under different plantations and have maximum anthropogenic activities in the catchment area compared to the other two sub-basins.

- The sediment samples collected from the Sharavathi upstream area revealed that the sediments were rich in organic carbon but were poor in other nutrients.

12.0 ACTION PLANS

- Introduction of any local grass species like *Dichanthium annulatum*, *Panicum antidotale*, *Sehima nervosum*, *Cenchrus ciliaris*, *Csetigerous* and *Chrysopogon fulvus* along the edges in agricultural fields or along the streams near Gudankateholé, Dabbod, Hennur, and Hebbankere. This conservation measure will prevent runoff and preserve soil and vegetation, improve soil moisture, prevent direct contamination of the streams and provide fodder for livestock. Preferably this conservation strategy should be strongly adopted at all agricultural fields near riparian habitats. This can be implemented by bringing awareness among the farmers and adopting the above method to conserve the natural resources like soil and water in the Sharavathi downstream catchment.

- Afforestation or plantation of hardy evergreen tree species like *Olea dioica*, *Aporosa lindleyana* along with grass species that slow down and retain water, which prevent excess nutrient wash and direct fall of water from the evergreen forests near Vatahalla. This conservation measure preserves the fertility of evergreen forest existing there, prevents soil erosion, reduces excess nutrient flow to the stream and reservoir preventing sedimentation of the reservoir.

- Construction of bunds to prevent seawater intrusion into the stream at Haddinabal as practiced between Badagani and Gudankateholé or permanent embankment as suggested in the subsequent recommendation.

- Back intrusion of seawater into the stream at Gudankateholé can be overcome by constructing a permanent embankment or dam wall near Badagani with provision for regulating the flow of water from the upstream to downstream from period to period.

- Afforestation programme to be undertaken extensively in the catchments of major tributaries like Nandiholé, Haridravathi, Mavinaholé, Sharavathi and central part of the Sharavathi upper catchment.

- Stream bank afforestation to be undertaken near major tributaries like Nandiholé, Haridravathi, Mavinaholé, Sharavathi, Hilkunji and other lower order streams in eastern part of the Sharavathi upper catchment.

- Utilisation of excessive inorganic fertilisers for cultivation of crops has affected the water quality and soil in the eastern parts like Haridravathi, Nandiholé, areas surrounding Hosanagara in the Sharavathi upper catchment and streams near Gudankateholé, Haddinabal, Dabbod, Magod in the downstream. Therefore, it is recommended to practice organic farming and utilise bio-pesticides. Utilisation of excessive inorganic fertilisers for cultivation of crops has affected the water quality and soil in the eastern parts like Haridravathi, Nandiholé, areas surrounding Hosanagara in the Sharavathi upper catchment and streams near Gudankateholé, Haddinabal, Dabbod, and Magod in the downstream. Therefore, It is recommended to promote organic agriculture, vermiculture etc. in these regions. Local farmers should be educated about the significance of aquatic habitats and possible impacts of unplanned agricultural activity, use of excessive fertilisers/pesticides and discharge of excessive agricultural contaminants directly into the aquatic bodies and its consequences, etc.

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