

# Water, Soil and Sediment Investigations to Explore the Status and Management Options of Aquatic Ecosystem

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## INTRODUCTION

Aquatic ecosystem quality is of vital concern for living beings as it provides habitats for a variety of flora and fauna, recharges ground water, augments and maintains stream flow, recycles nutrients, purifies water etc. The components of aquatic ecosystem and their working pattern are highly dependent on the catchment structure and the land use pattern in the catchment (Ramachandra and Ahalya, 2001).

Aquatic ecosystems worldwide are being severely altered or destroyed at a rate greater than any other time in human history and faster than they are being restored. Some of these losses occur through intentional exploitation of resources. Other losses occur cumulatively through lack of knowledge or fragmented approach in resource management (UNEP, 1994). The capacity of rivers and their biota to maintain any substantial degree of ecological integrity and to perform ecosystem services, such as pollution dilution and water quality protection, is under immense pressure from large diversions and regulation.

Maintenance and enhancement of economically valuable aquatic ecosystem functions especially floodwater storage and conveyance, pollution control, ground water recharge, and fisheries and wildlife support have all too often been largely ignored in aquatic resource management. The amount of water entering as precipitation that ends up in the stream depends greatly on the

characteristics of the catchment, such as catchment geomorphology, geology, soil type and development and vegetation types and extent of cover (Dodds, 2002). Water falling on the ground may infiltrate the soil or run overland. In catchments with permeable surface, water infiltrating the soil percolates down to the water table. Streams arise where the land surface intersects the water table and groundwater from the water table usually comprises a major part of the stream discharge. Perennial streams are maintained by the ground water flow during times of little or no rainfall (Tideman, 1996). Ecological processes within catchments exert a strong control on the inputs of organic and inorganic chemicals, both particulate and dissolved, into the down slope streams. The disruption of inputs from the catchments is a reliable signal of disturbance. Natural disturbing forces on catchments include fire, cyclones, grazing, defoliation by insects etc., while human-generated/induced disturbances consist of forces such as encroachment, conversion of forest to agricultural land, timber harvesting, livestock grazing and land clearing. It may be due to developmental projects or population pressure on the natural resources (Downes et al., 2002).

Water related developmental projects like hydroelectric power projects have both direct and indirect effect on the river basin and attendant socio-economic condition of the region. Because of their strategic location in the mid-hills (lower contour elevation) and valley bottom, storage reservoirs invariably inundate populated valleys, large forest tracts, and wildlife habitat endowed with rich biodiversity of immense conservation significance (Abbasi, 2000). There are mainly two types of disturbances caused by hydroelectric power projects like submersion and change in basin morphometry and biotic disturbances. Change in catchment practices gives rise to alteration in the physicochemical and biological properties of streams and rivers.

In aquatic ecology, the disturbance is most commonly conceived as being due to physicochemical and biological factors. The alteration in the physicochemical characteristics of aquatic ecosystem is the result of inputs of pollutants from point and non-point sources. The non-point sources of pollution are very difficult to assess and manage. Remediation is also difficult because it usually requires measures to be implemented over a large scale (Gilpin, 1996). In this study the source of pollution was non-point sources like agricultural runoff, bank and catchment soil erosion, diversion of water from rivers for irrigation and poor catchment agricultural practices in the Sharavathi river catchment.

## Objectives

The objectives of the study were:

- To explore the physicochemical status of aquatic ecosystem in the Sharavathi river basin by investigation of the water, soil and sediment and
- To suggest the suitable implementable management options.



## Study Area

Sharavathi river, flowing northwest, originates in the Western Ghats near Ambutirtha in Tirthahalli taluk of Shimoga district. With a length of about 128 km and total drainage of 2771 sq. km., the river with its tributaries flows along the rugged terrain of western ghats of southwest Shimoga and southwest Uttar Kannada districts. The river drops to a vertical fall of about 253 m near Jog and joins the Arabian Sea at Honnavar in Uttar Kannada (Karnataka State Gazetteer Part-1, 1982). This region supports a rich diversity of flora and fauna. Karnataka Power Corporation Limited constructed a dam across the river in 1964 near Linganamakki, which is at present one of the oldest hydroelectric projects in India. The dam has its catchment area of nearly 1991 sq. km. receiving water mainly from rainfall and Chakra and Savahaklu reservoirs, which are linked to dam through a canal. The Linganamakki dam construction has resulted in the submersion of 6,800 acres of land of 62 villages along with loss of biodiversity. The aquatic and soil ecosystems are the major resources under threat. Although different checklists are used to assess the cumulative impact of water related project on the ecosystem, in the present study, water, soil and sediment were characterized to assess the impact. For this purpose continuous monitoring of the Sharavathi and its primary and secondary feeders along with the catchment soil and sediment were carried out for four months. The water soil and sediment sampling sites with their corresponding latitude and longitude are given below in Tables 1 and 2.

**Table 1 Water Sampling Sites**

<i>Sl. No.</i>	<i>Sampling sites</i>	<i>Longitude (Degree)</i>	<i>Latitude (Degree)</i>
1	Sharavathi (Nagara)	75.0601	13.8267
2	Sharavathi (I)	75.065	13.8789
3	Sharmanavathi	75.0822	13.9855
4	Haridravathi	75.1207	14.0384
5	Muppanae	74.7902	14.1083
6	Talakalalae	74.7863	14.1853
7	Dam outlet	74.8268	14.1917
8	Reservoir	74.8977	14.0756
9	Hurlihole	74.8672	13.9914
10	Yennahole	74.759	14.0417
11	Valagare	74.8452	14.0624
12	Nittur	74.9139	13.9371
13	Keshwapura	75.1215	14.0191
14	Nandihole	75.1254	14.0426
15	Sampakai	75.0467	14.048

**Table 2 Soil Sampling Sites**

<i>Sl. No.</i>	<i>Sampling sites</i>	<i>Longitude (Degree)</i>	<i>Latitude (Degree)</i>
1	Agricultural field (Yellodi)	74.8006	14.01117
2	Tumri	74.836	14.018
3	Yennahole-Tailend	74.863	14.0606
4	Hosanagara	75.064	13.9035
5	Haridravathi	75.1058	13.973
6	Agricultural field (Adagalae)	74.8174	13.945
7	To Sagar from Holebagulae	74.963	14.0449
8	Muppanae Forest Area	74.7923	14.1082
9	Evergreen Forest near Dam	74.908	14.0789
10	Island near Holebagulae	74.9031	14.0811
11	Thirumoorthimanai	74.7632	14.043
12	Way to Dam outlet	74.793	14.1787
13	Sharavathi (Nagara)	75.099	14.3795
14	Sharavathi (I)	75.0619	13.8799
15	Sharavathi (II)	75.0619	13.9018
16	Sharmanavathi	75.1028	13.9749
17	Haridravathi	75.1379	14.0046
18	Hurlihole	74.8555	13.9913
19	Yennahole	74.7606	14.0332
20	Valagere	74.8369	14.059
21	Nittur	74.9089	13.9437
22	Nandihole	75.1425	14.0037
23	Keshwapura	75.1425	14.0087
24	Sampakai	75.0373	14.0575

### Sediment Sampling Sites

The sediment sampling sites are (1) Sharavathi (Nagara), (2) Sharavathi-1, (3) Sharmanavathi, (4) Haridravathi, (5) Muppanae, (6) Reservoir, (7) Hurlihole, (8) Yennahole, (9) Valagere, (10) Nittur and (11) Sampakai with corresponding longitude and latitude as given for water sampling sites.

### METHODS ADOPTED

The water samples were characterised using the methods provided by NEERI (National Environmental Engineering Research Institute) and APHA (American Public Health Association). Some variables like turbidity, ammonia, residual chlorine and iron were determined using Tara Water Testing Kit. The soil and sediment samples were analysed by the methods given by the UAS (University of Agricultural Sciences, Bangalore, Karnataka). The organic matter in soil and sediment was determined by a



conservation tillage fact sheet ([http://www.akron.ars.usda.gov/fs\\_field.html](http://www.akron.ars.usda.gov/fs_field.html)). The obtained results of water were compared with Indian Standards for Drinking and Irrigation and standards prescribed by NEERI. The soil and sediment results were compared with the standard from Hand Book of Agriculture.

## ANALYSIS-RESULTS AND DISCUSSIONS

The presence of algae and diatoms in rainy agricultural runoff is the major source of colour of water. The colour of the water of Sharavathi river and its feeders were found to vary from clear (colourless) to brownish green. Natural minerals like ferric hydroxides and organic substances like humic acids give true colour to water along with phyto and zooplankton, which give apparent colour to water bodies. A dark blue green colour is the result of blue-green algae, yellow brown colour is due to diatoms or dinoflagellates and red and purple is due to the presence of zooplankton like *daphnia* sp. or copepods.

Transparency and turbidity are inversely related to each other. Transparency is a characteristic of water that varies with the combined effect of colour and turbidity. Transparency was found in the range of 10 to 284 cm from Valagare or Nandihole to reservoir and the turbidity was found in the range of <5 to 45 NTU. The most threatened sites due to turbidity were Sharavathi-1, Hurlihole, Yennahole and Valagare. The problem is due to siltation and poor agricultural practices in the catchment.

The electrical conductivity was found in the range of 0.014 to 0.1216 ms/cm from Talakalele Dam to Haridravathi and total dissolved solids ranged between 13.77 and 84.3 ppm from Muppene forest area to Haridravathi.

pH is an indicator of acidity and alkalinity of a water body and at a given temperature it indicates the intensity of acidic or basic character of a solution and is controlled by dissolved chemical compounds and biochemical processes in the solution. In unpolluted water the balance between carbon dioxide, carbonate and bicarbonate ions as well as other natural compounds such as humic and fulvic acids controls pH. The most significant environmental effect of pH involves synergistic effect. Synergy involves the combination of two or more substances, which produces greater effect than their sum. The process is important in surface water as this is influenced by runoff from different sources like domestic and agricultural runoff. The pH in this study was found in the range of 6.8 to 8.25 from Muppene forest area to Sharmanavathi. This pH range is suitable for the fish eggs and growth of algae and hence may augment the excessive growth of algae leading to algal bloom (7.5 to 8.4, the best range for algal growth). Acidity ranges from 10 to 40 mg/L from Nittur or Dam outlet or Muppene forest area to Sharmanavathi and alkalinity varied from 8 to 75 mg/L from Muppene forest area or Talakalele Dam or Reservoir to Sharavathi-1. All values of



acidity and alkalinity were found within the limits for drinking and irrigation.

Dissolved oxygen is a measure of gaseous oxygen present in aqueous solution. Oxygen gets into water by diffusion from surrounding air, by aeration (rapid movement) and as a waste product of photosynthesis. The amount of dissolved oxygen is highly dependent on temperature. Atmospheric pressure also has an effect on dissolved oxygen.  $O_2$  concentration increases with increasing water pressure (i.e. depth in water) and decreases with increasing salinity. The amount of oxygen (or any gas) that can dissolve in pure water (saturation point) is inversely proportional to the temperature of water. When water becomes anoxic, the survival of fishes are put under threat. This is the situation when the total respiratory demand exceeds input of photosynthetic and atmospheric oxygen. Higher temperatures often exacerbate the problem because the metabolic rate of heterotrophs is greater and oxygen is lower in warmer water (Varsheny, 1991). The dissolved oxygen concentration was found in the range of 5.8 to 7.8 mg/L, from Keshwapura to Sharavathi-1, indicating the healthy condition of the water bodies.

The hardness of natural water depends mainly on the presence of dissolved calcium and magnesium salts. Hardness may vary widely. Calcium hardness is usually prevalent (upto 70%), although in some cases magnesium hardness can reach 50–60%. Seasonal variation of river water hardness often occurs, reaching the highest values during low flow conditions and the lowest values during floods. Ca and Mg are the major source of hardness in water and for water associated with carbonate rocks, the concentration of calcium ion may vary from 30 to 100 mg/L (salt water have several hundreds mg/L concentration) and in natural condition the Mg concentration in fresh water may range from 1 to >100 mg/L depending on the rock type in the catchment. The total hardness ranged between 20 and 126.44 mg/L from Talakalale Dam to Keshwapura. The Ca concentration was in the range of 12 to 90.26 mg/L from Muppanae forest area to Keshwapura followed by magnesium concentration—8 to 44 mg/L from the Sharavathi-1/TD to Haridravathi.

Chloride is a salt compound resulting from the combination of the gas chlorine and a metal. Chlorides are not usually harmful to people; however, the sodium part of table salt has been linked to heart and kidney disease. Sodium chloride may impart a salty taste at 250 mg/L; however, calcium or magnesium chlorides are not usually detected by taste until levels of 1000 mg/L are reached. Chlorides may get into surface water from several sources including rocks containing chlorides, agricultural runoff, wastewater from industries, oil well wastes, and effluent from wastewater treatment plants. It can corrode metals and affect the taste of food products. Therefore, water that is used in industry or processed for any use has a recommended maximum chloride level. Chlorides can contaminate freshwater streams and lakes. Fish and aquatic communities cannot survive high levels of chlorides. In this study chloride varied from 17.04 to 63.9 mg/L from Sharavathi (Nagara)/



Valagere/Reservoir/Dam outlet to Sharavathi-1, which is within the permissible limit.

Sodium salts are highly water soluble and found in the ionic form and in plant and animal matter. High concentration of sodium can harm the soil permeability. Surface water, which receives wastewaters, has concentrations well below 50 mg/L. In this case the values ranged from 4 to 101.4 mg/L from Valagere to Nandihole. On the other hand, the salts of potassium are highly soluble in water and readily incorporated into mineral structure and accumulated by aquatic biota as it is an essential nutritional element. Concentration in natural water is usually less than 10 mg/L, whereas concentration as high as 100 and 25,000 mg/L can occur in hot springs and brines, respectively. In this case the potassium value was found in the range of 0.077 to 9.5081 mg/L varying from Nittur to Haridravathi. Potassium was found in low concentration in natural water because rocks that contain potassium are relatively resistant to weathering.

Sulphate is naturally present in water as  $\text{SO}_4^{--}$  and arises from the atmospheric deposition of oceanic aerosols and the leaching of sulphur compounds and sulphate minerals such as pyrite from sedimentary rocks. It can be used as oxygen source by bacteria, which convert it into hydrogen sulphide under anaerobic conditions. Sulphate concentrations in natural waters are usually between 2 and 80 mg/L, although they may exceed 1000 mg/L near industrial discharge or in arid regions where sulphate minerals such as gypsum are present. High concentration ( $>400$  mg/L) may make water unpleasant to drink. In the present study sulphate concentration was found in the range of 0.34 to 22.66 mg/L from Dam outlet/Muppanae to Yennahole. The concentration of sulphate was found to decrease from December to March. So according to standard values (for drinking 150 mg/L and 1000 mg/L for irrigation, NEERI) the quality is suitable for irrigation.

Phosphorus is one of the key elements necessary for growth of plants and animals. Phosphorus in elemental form is very toxic and is subject to bioaccumulation. Phosphates  $\text{PO}_4^{---}$  are formed from this element. Phosphates exist in three forms: orthophosphate, metaphosphate (or polyphosphate) and organically bound phosphate. Ortho forms are produced by natural processes and are found in sewage. Poly forms are used for treating boiler waters and in detergents. In water, they change into the ortho form. Organic phosphates are important in nature. Their occurrence may result from the breakdown of organic pesticides, which contain phosphates. They may exist in solution, as particles, loose fragments, or in the bodies of aquatic organisms. Rainfall can cause varying amounts of phosphates to wash from farm soils into nearby waterways. Phosphate will stimulate the growth of plankton and aquatic plants, which provide food for fish. This increased growth may cause an increase in the fish population and improve the overall water quality. However, if an excess of phosphate enters the waterway, algae and aquatic plants will grow wildly, choke up the waterway



and use up large amounts of oxygen. This condition is known as eutrophication or over-fertilisation of receiving waters. The rapid growth of aquatic vegetation can cause the death and decay of vegetation and aquatic life because of the decrease in dissolved oxygen levels. Phosphates are not toxic to people or animals unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphate. In the study area the phosphate concentration was found between 0.0 and 0.0699 mg/L from Hurlihole/Reservoir/Talakalale Dam to Yennahole.

Nitrogen-containing compounds act as nutrients in streams and rivers. Nitrate reactions [ $\text{NO}_3^-$ ] in fresh water can cause oxygen depletion. Thus, aquatic organisms depending on the supply of oxygen in the stream will die. The major routes of entry of nitrogen into bodies of water are municipal and industrial wastewater, septic tanks, feedlot discharges, animal wastes (including birds and fish) and discharges from car exhausts. Bacteria in water quickly convert nitrites [ $\text{NO}_2^-$ ] to nitrates [ $\text{NO}_3^-$ ]. Nitrites can produce a serious condition in fish called "brown blood disease." Nitrates also react directly with haemoglobin in human blood and other warm-blooded animals to produce methemoglobin. Methemoglobin destroys the ability of red blood cells to transport oxygen. This condition is especially serious in babies under three months of age. It causes a condition known as methemoglobinemia or "blue baby" disease. Water with nitrite levels exceeding 1.0 mg/L should not be used for feeding babies. Nitrite/nitrogen levels below 90 mg/L and nitrate levels below 0.5 mg/L seem to have no effect on warm water fish. In this case the values were found between 0.0 and 1.6226 mg/L and show the water is suitable for irrigation (NEERI, Standard for drinking water—45 mg/L).

Iron in water may be present in varying quantities depending upon the geology of the area and other chemical components of the waterway. Ferrous  $\text{Fe}^{++}$  and ferric  $\text{Fe}^{+++}$  ions are the primary forms of concern in the aquatic environment. Other forms may be in either organic or inorganic wastewater streams. The ferrous form  $\text{Fe}^{++}$  can persist in water void of dissolved oxygen and usually originates from groundwater or mines that are pumped or drained. Iron in domestic water supply systems stains laundry and porcelain. It appears to be more of a nuisance than a potential health hazard. In this case the values were less than 0.3 mg/L at all the sampling sites.

Higher concentration of ammonia is harmful to fish and other biota and even to human beings. The values of ammonia in Sharavathi river catchment was found between  $<0.2$  and 3.0 mg/L in all the cases which indicates that the situation is under control. The residual chlorine intensifies the taste and odour of many other compounds such as phenol etc. It may be harmful to many aquatic organisms in combination with ammonia. The result shows the values always less than 0.2 mg/L (for drinking water max. 0.2 mg/L and for irrigation 1 mg/L).



Total coliform bacteria are a collection of relatively harmless micro-organisms that live in large numbers in the intestines of man and warm- and cold-blooded animals. They aid in the digestion of food. A specific subgroup of this collection is the fecal coliform bacteria, the most common member being *Escherichia coli*. These organisms may be separated from the total coliform group by their ability to grow at elevated temperatures and are associated only with the fecal material of warm-blooded animals. The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with fecal material of man or other animals. At the time this occurred, the source water might have been contaminated by pathogens or disease producing bacteria or viruses, which can also exist in fecal material. Some water-borne pathogenic diseases include typhoid fever, viral and bacterial gastroenteritis and hepatitis A. The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to this water. Fecal coliform bacteria may occur in ambient water as a result of the overflow of domestic sewage or non-point sources of human and animal waste. The presence of coliform is observed in samples collected at Sharmanavathi, Haridravathi, Valagere, Keshwapura, Nandihole and Sampakai. This water used for drinking in these localities raises serious concern from health point of view.

### Soil of Karnataka

Soils are considered as natural bodies covering the part of the earth surface that supports 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. The soil can be represented by a formula i.e.  $S = f(cl, o, p, r, t)$  where  $S$  = soil,  $f$  = function of  $cl$  = climate,  $o$  = organisms,  $p$  = parent materials,  $r$  = relief and  $t$  = time. Karnataka state represents a wide variety of geological, climatic, vegetation and physiographic features, which has its influence on the formation and character of soil. The National Commission on Agriculture has categorised the state soil into nine broad groups. The nine groups are: shallow black soils, medium black soils, deep black soils, red sandy soils, mixed red and black soils, red loamy soils, laterite soils, laterite gravelly soils and coastal soils. In Shimoga district the major soil group is red sandy soils, red loamy soils, laterite and laterite gravelly soils (in the northern part).

The red sandy soil is further categorised as soils of upland, midland and lowland regions. The soils of upland region are shallow to moderately deep, reddish brown to dark reddish brown, gravelly loamy sand to sandy loam on the surface with sandy loam to gravelly sandy clay on the subsurface horizons. They are neutral to slightly acidic and low in cation exchange capacity, base saturation, and water holding capacity. The yield obtained on these lands is very low due to low fertility status of the soil, shallow rooting



depth, lack of adequate storage capacity of soil moisture and uneven distribution of rainfall pattern in this area and their susceptibility to erosion. The soils of midland are deep reddish brown, dark reddish brown, neutral to acidic, and low to medium in cation exchange capacity and base saturation with medium to high water holding capacity. The yields obtained on these lands are generally good when moisture is not a limiting factor. The soils of low region are deep, dark brown, sandy loam to sandy clay loam, neutral to weakly alkaline, non-calcareous to calcareous and have high cation exchange capacity (CEC) and base saturation. The water holding capacity is generally high. The red loamy soils are also divided into three groups like the soils of upper slopes, soils of undulating mid-slopes and soil of valley plains. The soils of upper slopes are shallow to moderately deep, light grey, yellowish red and deep brown with very low acidic character and low cation exchange capacity and base saturation but high moisture content. The soils have low fertility status with shallow rooting depth and low water holding capacity. Soils of undulating mid land are deep, dark brown to dark red weakly acidic, with low CEC, base saturation and medium to high water holding capacity. Soils of valley plains are very deep with dark grey brown colour, dark reddish colour, neutral to weakly alkaline, medium CEC and base saturation. The water holding capacity is generally high. The laterite soils are very deep, yellowish red to dark red, reddish brown to brown, acidic, low in CEC, base saturation and water holding capacity. They respond well to liming irrigation, manuring and other management practices. These soils are formed under heavy rainfall and high temperature conditions resulting in intensive weathering, leaching of bases and silica and accumulation of sesquioxides (iron and alumina). The laterite gravelly soils are shallow to moderately deep and the rest are as laterite soil.

The chemical features of the soils of Shimoga district are divided based on rainfed lands and irrigated lands. In the rainfed lands, the pH of soil is normal in the taluks of Bhadravathi, Channagiri, Honnali and acidic in other taluks. The soluble salt content is normal in all the taluks. The nitrogen content is medium in the taluks of Bhadravathi, Sagar, Shimoga, Thirthahalli, high in Hosanagara, Sorab and low in other taluks. The available  $P_2O_5$  content is low in the taluks of Hosanagara, Shikaripur, Sorab and medium in other taluks. The available  $K_2O$  content is medium in Sagar and high in other taluks. The other type is irrigated lands that have acidic character in all taluks except in Channagiri, where it is normal and normal soluble salt content in all taluks. The nitrogen content is high in the taluks of Sagar, Shikaripur, Thirthahalli and medium in other taluks and the available  $P_2O_5$  is medium in the taluks of Channagiri, Honnali, Thirthahalli and low in other taluks. The available  $K_2O$  is low in Hosnagara, high in Bhadravathi, Channagiri, Sorab and medium in other taluks.



## Soil Analysis-results

Although soil colour has little direct effect on function of soil, it helps in predicting other properties namely the organic matter content, oxides of iron and manganese and their oxidation state and hydration and thereby drainage conditions of the soil. In case of upland and midland profile the soil has darker colour than profiles of lowland. Red colour is due to predominance of iron oxide in these soils. The morphology of the profile shows that with the decrease in gradient of slope, soil colour becomes darker. Soil colour also changes with depth from yellowish brown in uplands to brownish yellow in depth possibly due to oxidation and reduction of iron compounds. In the study area the colour of the soil is brownish yellow, reddish brown, dark earthy grey, and light brown. The dark colour soils are more productive than light yellow colour. The light colour of soil may be due to salt accumulations and the red colour due to the presence of iron in different forms.

The bulk density of soil varies from 1.1 to 1.5 g/cm<sup>3</sup> for fine textured soils and 1.2 to 1.65 g/cm<sup>3</sup> 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 soils having high bulk densities have been found to be inhibitive to root penetration and have low permeability and infiltration. The decrease in bulk densities especially in ultimate horizons may be attributed to decrease in clay content. The bulk densities are slightly reduced at higher elevation due to the higher organic matter content and increase with increasing depth in alfisols (Red soils). The bulk density has been inversely related to pore space of the soil. It was found to vary between 0.7862 and 1.3591 mg/cm<sup>3</sup> from Nittur to Trimurthimannai.

The moisture content of the study area was found in the range of 1.2 to 12.15% from agricultural field at Adagalale to Sampakai. The evapotranspiration exceeds rainfall for eight months from November to June and the moisture deficient period is about 185 days (Jaiswal, 1980). The average rainfall data of all taluks of Shimoga shows that in cold weather period from January to February it was 0 mm, hot weather period from March to May, 93 mm, south west monsoon period from June to September, 2083 mm, north-east monsoon period from October to December, 75 mm, and the overall average is 2251 mm. The average annual rainfall of Sagar is 2528 mm, Bhadravathi 509 mm, Hosnagara 4270 mm, Shikaripur 600 mm, Shimoga 524 mm, Sorab 929 mm and Tirthahalli 3037 mm (Annual rainfall report, 2001). Soil water acts as a solvent, transporting agent and maintains the compactness of soil, thereby making it a habitat for both plants and animals. Water in soil is held as a film on particle surface and in small pores. Large pores allow water to drain by gravitational flow and



small pores retain water by capillary forces. Generally the more clayey the soil and higher humus content the soil will have higher amount of water. Soil with *smectites*, which have additional internal clay surfaces between layers in the clays, hold more water than a soil with similar amount of kaolinite and sesquioxide clays, which do not admit water between clays layers.

The electrical conductivity provides an idea about the exchangeable elements present in the soil matrix. The most common quality of soil measured in terms of electrical conductivity is salinity. The salinity hazard is low at less than 0.75 ms/cm, between 0.75 and 1.5 ms/cm is medium, between 1.5 and 3.0 ms/cm it is high and beyond 3.0 ms/cm it is very high. In the study area the electrical conductivity was found in the range of 0.0176 to 0.1408 ms/cm from Tumri to Sharavathi-1. If electrical conductivity is checked on the basis of tolerance capacities of plants, in the range 0 and 2 ms/cm the salinity effect is tolerable, between 2 and 4 ms/cm very sensitive crops may be restricted, between 4 and 8 ms/cm yield of many crops is restricted, between 8 and 16 ms/cm only tolerant species can yield satisfactory and beyond 16 ms/cm yield of a few very tolerant species are satisfactory.

pH indicates the acidic or alkaline condition of soil and availability of micro and macronutrients to plants. The soils with pH below 5.5 are called strongly acidic, between 5.5 and 5.9 medium acidic, 6.0 to 6.4 slightly acidic, 6.5 to 6.9 very slightly acidic, at 7 it is neutral, between 7.1 and 7.5 very slightly alkaline, between 7.6 and 8.0 slightly alkaline, in the range 8.1 to 8.5 medium alkaline and if the value is beyond 8.5 it is strongly alkaline. Most of the soils have a pH range between 5 and 9. In humid regions, the surface soil usually exhibits a pH range of 5 to 7 because most of the bases are exchanged and leached. Most plants grow best in slightly acidic soils. For example alfalfa, clover and cedar require a soil pH closer to 7.0 for maximum growth whereas pine trees need a soil pH of 5.0. In the pH range 5 to 6 available nutrients are Cu, Zn, B, Mn, Fe, between 6.5 and 7.0 Mo, Ca, S, K, P, N, and between 7.0 and 7.5 Mg. At very strongly acidic condition, phosphate ion concentration is very low because most of the phosphate is precipitated in the form of insoluble  $\text{AlPO}_3$  or  $\text{FePO}_3$ . The concentration of phosphate increases from low pH 3.0 to sufficiently high at pH 6.0 to 7.0. The range of pH for the best crop growth is 6.5 to 7.2. The soil pH ranged from 6.1 to 7.8 (Sharmanavathi to Yellodi) and is interpreted as optimum quality for plant growth. The acidity of soil was found between 1 and 5 mg/gm, from Nagara/Hosanagara to Sharavathi-1 and alkalinity 1 to .5 mg/gm from Sharmanavathi to evergreen forest. It may be due to leaching to base and weathering of rocks due to high rainfall as the study was conducted in post monsoon period.

Calcium is a very important cation in soil and average content of Ca in soil is estimated to be 1.4%. It depends on the parent rocks also. The content of calcium increases depth wise in most of the soil profile and the reason



may be due to heavy leaching of this divalent cation and possible accumulation at deeper depth. The calcium content was found ranging between 1 and 17.2 m.eq./100gm of soil from Yennahole to Island near Holebaugle.

The average magnesium content in soil is approximately 0.5% whereas its concentration in soil water is estimated to be 10 mg/L. It can be found as chlorides, sulphates, bicarbonates etc. The magnesium content in this study ranged between 0.4 and 7.8 m.eq./100 gm of soil from Trimurthimanni to Haridravathi. The reason for low exchangeable magnesium content in these soils may be due to heavy leaching losses of magnesium in well drained soils due to heavy rainfall.

Sodium and Potassium compounds are widely distributed in nature and the content in normal soil on the average is 0.63% and 0.83% respectively. The mineral source for Na and K are albite and silicate respectively. The concentration of these ions in soil water is relatively low as compared to the content in soil. On the average, the K concentration in soil solution is 5 mg/L and that of Na is 10 mg/L or higher. Both ions are stable in soil water and very difficult to precipitate and only by complex formation these can be precipitated. The available potassium in different reaches, decreases from midlands > uplands > lowlands. Potassium in coarse textured soils exhibits less variability with slope position because of its monovalent charge and mobility (Tan, 1994). The variation in the distribution of potassium in red, black, laterite and alluvial soils of Karnataka depended upon the mineral present, particle size and degree of weathering. Loamy-red soils are predominant in the plantation districts like Shimoga, Hassan and Kadur. They are rich in total and available  $K_2O$  (Cairns, 1988). In this study sodium and potassium content were found between 0.004 and 0.182 mg/gm (from Haridravathi to agricultural field at Yellodi) and 0.005 and 0.280 mg/gm (from Sharavathi to Nagara). Hence to meet the requirement of optimum level of sodium and potassium in the soil matrix there should be sustainable use of K-fertilisers.

Sulphur exists in soil and soil water 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 will oxidize in aerobic condition and convert quickly into  $SO_4^{2-}$ . Under anaerobic conditions,  $SO_4^{2-}$ , may be reduced by microorganism into  $SO_3^{2-}$  or  $H_2S$ , because most of the sulfur salt is soluble and sulfate is expected to be lost rapidly by leaching. The anionic nature of the sulfate ion prevents its attraction by clay colloids. However, soils containing hydrous oxide clays or sesquioxide have been reported to absorb considerable amount of sulphate. Most of the sulphur of humid region is present in organic form and is related to the content of organic matter. The available sulphur was greater in soil of humid region than in those of dry region. The sulphate content of soils was found between 0.160 and 1.269 mg/gm from Nagara to agricultural field at Yellodi and the reason for less content may be high



solubility, dry status of soil and leaching of sulphate to lower level as the study was conducted in post monsoon period.

The inorganic phosphorus content in soil is higher than organic P content (Miller and Donahue, 1990). In solution phosphorus is present in the form of  $\text{H}_3\text{PO}_4$  or the secondary  $\text{HPO}_4^{2-}$  orthophosphate ion. The concentration of these ions in the soil solution depends on the pH. In acid soil,  $\text{H}_2\text{PO}_4^-$  will be more dominant than  $\text{HPO}_4^{2-}$ . At pH 6 to 7 both forms are equally represented in the soil solution whereas at pH greater than 7.0,  $\text{HPO}_4^{2-}$  will be dominant together with some  $\text{PO}_4^{3-}$  ions. Maximum availability of these phosphate ions for plant growth occurs within the pH range of 5.5 to 6.5. This is the consequence of the soils being rich in hydrated as well as amorphous oxides of iron and aluminium, which are potent phosphorus fixers in soils. Hence, the phosphate added or the phosphorus released due to weathering of minerals gets fixed by these soils rendering the phosphate less available for plant uptake. The soils of coastal Karnataka like oxisols (laterite), utisols (red), and entisols (alluvial) were low in available  $\text{P}_2\text{O}_5$ . At low pH, it may be fixed as iron and aluminium phosphate, which are not likely to be readily available to plants. Loamy-red soils are predominant in the plantation districts like Shimoga, Hassan and Kadur and the  $\text{P}_2\text{O}_5$  percentage varies from 0.05 to 0.3%. In the study area the content was between 0.00003 and 0.00085 mg/gm from Trimurthimannai to Yennahole. The pH of soil was found favourable (6.1 to 7.8) for the maximum availability (between pH 6.5 and 8.0) of phosphorus, but availability of phosphorus is in two forms—one being adsorbed phosphorus and other in solution and soils with high organic matter content hold less quantities of phosphorus adsorbed and that in solution due to soil erosion and runoff.

The total present soil nitrogen content varies considerably—from 0.05% in the desert soil and in warm humid region soil to 0.3% or higher in the soil of semi-humid regions 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. 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  $\text{NH}_4^+$ ,  $\text{NO}_3^-$  and  $\text{NO}_2^-$ . 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 fertilisers. The nitrogen content is below 0.1% in the soils of Shimoga district. The nitrate content was found in very less concentration ranging between non-detectable to 0.0001 mg/gm. Since the nitrogen fixation is dependent on the water holding capacity or moisture content of soil, the rate of oxygen influx and pH range 6.6 to 8.0 (favourable range for nitrogen fixation). In this case the moisture content is low but the pH range favours. The role of oxygen



is to provide the optimum conditions for nitrifiers to work. The soil water is considered to contain only 50% to 67% of the water holding capacity, so the available water is less to fix nitrogen. Water logging and flooding suppress the nitrification and the  $\text{NH}_4^+$  produced in paddy field tend to get absorbed by the roots and not be nitrified. To meet the nitrogen requirements in the field one should not use much quantity so that the soils become enriched with N for more than five years. According to an estimate there is a great variation in the fate of N-fertiliser, 30% to 70% is removed in harvested crops, 5% to 10% in leaching, 10% to 30% gaseous loss, and 10% to 40% is incorporated in soil organic matter. As a general rule, 50% of fertiliser nitrogen is absorbed by crops, 25% is lost by denitrification, leaching and volatilisation and 25% remains in the soil as mineral nitrogen or is incorporated into new organic matter (Jayan, 2003). The soil erosion is also a major factor for the loss of nutrients in the upper layer of the earth.

Soil organic matter consists of variety of components including varying proportion and many intermediate stages like raw plants residues and microorganisms (1 to 10%), active organic (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 residue predisposes the soil to serious erosion. The active and some of the resistant soil organic matter components together with microorganisms (especially fungi) are involved in binding soil, soil 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 fraction. The amount of soil organic matter characteristic of virgin and cultivated soil in the various zones represent 30 to 50% loss of organic matter in cultivated soil than virgin soil. In this study the organic matter was found between <1 and >4% and organic carbon nil and >2.32% from Sampakai, near Dam outlet, Nittur to Tumari, Yennahole, Island near Holebagulae, Thrumoorthimannai, Sharavathi-1 & 2, Sharamanavathi, Haridravathi and Hurlihole.

### Sediment Quality Analysis

The moisture content of sediment samples was found in the range of 8.802 to 37.702% from Sharavathi-1 to Valagere.

The bulk densities were found between 0.783 and 1.475  $\text{gm/cm}^3$ , from Nittur to Haridravathi showing that the bottom condition is porous to less porous.

The EC values were found between 0.0211  $\text{ms/cm}$  and 0.0403  $\text{ms/cm}$ . These low EC values can result in least nutrient transfer, complexation and exchange of elements.



The pH varied between 6.37 and 7.39 from Yennahole to Nagara (Sharavathi). The pH range indicates the least favourable situation for decomposition. Acidity varied between 2 and 4 mg/gm from Muppanae forest area, Nagara to Reservoir, Valagere, Nittur, Sharavathi-1 and alkalinity varied between 1 and 3 mg/gm from Muppanae, Yennahole to Sampakai, Hurlihole, Haridravathi and Sharmanavathi.

The chloride values were found to be 0.92 to 3.33 mg/gm of sediment from Haridravathi to Sharmanavathi. The calcium and magnesium values ranged between 1.08 and 7.6 mg/gm from Haridravathi to Sharmanavathi and 0.8 to 5 mg/gm from Yennahole to reservoir respectively. It is highly dependent on the parent materials or rocks. The values of Na and K were found ranging between 0.005 and 0.028 mg/gm from Haridravathi to Reservoir and followed by K, 0.013 to 0.89 mg/gm from Sharavathi-1 to Reservoir respectively.

Since the soil has low concentration of these nutrients, consequently, the concentrations of these ions in sediments were found in fewer amounts. Sulphate varied between 0.191 and 0.68 mg/gm from Sharavathi-1 to Reservoir, phosphate 0.00024 to 0.001 mg/gm from Yennahole to Haridravathi and nitrate non-detectable to 0.0007 mg/gm in most of the cases except Muppanae, Valagere, Nittur and Sampakai.

The organic matter was found between 2 and > 4% from Haridravathi to Muppanae forest area. The richness in organic matter is due to the large amount of organic matter in soil. The organic carbon in the sediment was rich ranging from 1.16 to 2.32 % in the same place.

## MANAGEMENT OPTIONS: A WATERSHED APPROACH

In order to ensure the quality and integrity of the river basin, it is necessary to practice watershed approaches taking into account the topography, vegetation and hydrology. This approach in planning ensures the sustainable management of renewable natural resources. Water as well as extent of vegetation and soil are the most important constituents in watershed characterisation. The status of the watershed decides the drainage systems in the catchment as is evident from poor drainage network and seasonal water in degraded ecosystems (eastern parts of the upper basin) and existence of higher order streams with perennial water in good evergreen patches in the western parts of the Sharavathi river basin. Land use changes during the last three decades (especially in the eastern side of the river basin) have contributed to this situation, which is mainly due to conversion of forests to agricultural lands. Eventually these lands have been transformed to unproductive wastelands because of poor agricultural practices (uncontrolled, unplanned, unscientific land and fertiliser use). The deterioration of micro and mini watershed is posing serious threat to the integrity of the river basin and the environmental consequences are:



- low productivity of land (food, fuel, forage, fibre and fruits),
- degradation of forest,
- erosion and denudation within and outside the watershed,
- soil nutrient degradation (desertification),
- quick siltation of streams, reservoir, lakes, ponds etc.,
- poor water quality yield due to heavy sediment,
- decline in aquatic ecosystem productivity,
- frequent flood and droughts and
- poor health of people and cattle.

The conservation and restoration of a watershed involves the management of biotic and abiotic components of the ecosystem involving personnel from diverse backgrounds. The planning is to be done considering the present status of the catchment including infrastructure and socio-economic status.

Integrated watershed management approaches can be employed either by preventive or rehabilitative approaches. In preventive approach, conservation of soil and water resources is achieved by legal regulations and proper use of land according to capability classes. While in rehabilitative approach, technical measures like gully control structures, channel stabilisation and terracing are employed. Rehabilitation and afforestation, erosion and sedimentation and watershed economics can be achieved by participatory approach and through education, awareness and training. This would help in enhancing the quality of biotic and abiotic components of the catchment.

The main threat to Sharavathi river and its tributaries (upstream) is from soil erosion and siltation due to lack of vegetative cover and non point sources of pollution (due to agricultural activities). This is resulting in loss of productive top layer of soil and pollution of ecosystems. The management options of Sharavathi river basin are described hereunder.

Turbidity at sites Keshwapura, Nandihole and Sampakai were high, due to the soil erosion in the catchment and could be minimised by adopting the best management practices listed below:

- The use of contour ploughing, which has the ability of reducing the runoff in rainy season. (26% reduction in runoff in the case of contour ploughed catchment compared to the untreated catchment. Similarly, soil loss was reduced from about 30 tonnes to less than 20 tonnes/ha during the rainy season.
- Leaving unploughed grass strips between ploughed land.
- Maintaining soil cover by vegetative means, so that soil will be rich in humus and organic matter (decaying plant and animal remains). Organic matter acts as chelating agent that binds the soil particles together and plays an important role in preventing erosion. Apart from this, the vegetation cover of soil:
  - slows down runoff and facilitates infiltration,
  - prevents siltation as plant roots hold the soil in position,



- reduces the impact of a raindrop before it hits the soil, thus reducing its ability to erode,
- prevents erosion (due to the presence of plants in wetlands and on the banks of rivers) and
- trees intercept rainfall and reduce its velocity and the force with which the raindrops strike the soil surface. The interception value for *Acacia* is 15 to 20% and for *Shorea robusta* 14%.

Catchment management also involves

- avoiding overgrazing and the over-use of crop lands;
- allowing indigenous plants to grow along the river banks instead of ploughing and planting crops right up to the water edge;
- encouraging biological diversity by practicing polyculture by planting different types of plants together; and
- conservation and sustainable management of wetlands in the Sharavathi river basin which will have a great capacity to recharge the ground water, maintain stream flow and augment the availability of soil water to vegetation.

The biological coliform in water samples at sites—Sharmanavathi, Haridravathi, Valagare, Keshwapura, Nandihole and Sampakai—indicate that water is unfit for human and animal consumption. This necessitates prevention of human and animal waste getting into water bodies.

The soil samples were rich in organic matter and with optimum pH for plant growth and low values for the primary nutrients like Nitrates, Phosphate, Potassium (NPK) and secondary nutrients like sulphates, sodium and calcium at all the sampling sites.

The primary nutrients like nitrogen enhance the plant growth and leaves, seeds, and tubers. Phosphorus stimulates early root and plant growth and hastens maturity. Potassium enhances ability to resist diseases, insect attacks, and adverse weather. It helps in the formation and movement of carbohydrates and oils and improves fruit quality. The secondary nutrients like sulphur, magnesium and calcium are also key nutrients as sulphur is involved in energy producing process and responsible for the flavour and odour of compounds, magnesium is responsible for chlorophyll and seed production and calcium is responsible for root health, growth of new roots, root hair and development of leaves.

Nutrient efficiency is a measure of crop produced per unit of nutrients supplied. Higher the efficiency, more the product per unit of nutrients supplied. The nutrient use efficiency is affected by the quality of soil. The factors affecting nutrients use efficiency are:

1. Erosion and runoff both are detrimental to nutrient management as it is contained in the topsoil along with soil organic matter and these



being washed away with the runoff water and eroding action of wind. Organic matter is transported by water or wind because of its lower specific gravity. Additional nutrients are required to maintain the lost productivity.

2. Deposition of sediments by wind or water in the fields has both positive and negative effect. If the sediment is fine clay particles and contains organic matter, this brings in nutrients and if it is coarser like sand, it does not have high nutrient content, and lacks moisture holding capacity.
3. Compaction: compact soil restricts the movement of roots and the usage of available nutrients by plants. Compaction also restricts the diffusion and flow in soil. The limited roots and nutrient movement results in the stunted growth of plants and retards the air movement and gas exchange in root zone and can lead to denitrification.
4. Soil aggregation favours water and nutrient movement in soil. More aggregation means more surface area of the soil particles has capacity to adsorb the nutrients. Surface aggregation allows pore space for water infiltration, gas exchange, retain organic matter and enhance biological activities for better nutrient cycling.
5. Infiltration: since nutrient transfer takes place in moist soil, soil with good infiltration capacity is capable of making the nutrients available to plant roots. Only those nutrients susceptible to leaching are not carried to the root zone. Percolating water carries the nutrients deeper into the root zone and also removes harmful salt that may accumulate there.
6. Soil crusting seals the soil surface and restricts water infiltration, seed germination, gas exchange etc. Due to crusting, nutrients are susceptible to runoff and wind erosion.
7. Nutrient imbalance: over application of nutrients can lead to plant toxicity, poor pH reactions, excess nutrients available for runoff, leaching and volatilisation, because the whole quantity of nutrients applied are not used by the crops. For example, if phosphorous is applied in large quantity it will restrict the availability of zinc for corn and too much potassium may interfere with the uptake of magnesium by corn and other grasses. Additional application of fertilisers or manure to boost soil nutrient levels into the optimum range not only result in unsatisfactory economic returns, but also can adversely affect plant growth, animal health and environmental quality.
8. Pesticide carryover: pesticides with residual soil activity can stunt growth of subsequent crops. If roots are affected, their ability to absorb nutrients will be lessened. Any effect on plant photosynthesis will reduce the nutrients uptake and metabolism.



9. Organic matter: it is a very important component of the topsoil. Organic matter store nutrients, feed decomposers, return the basic nutrients to the soil, retain soil moisture etc. Hence, maintaining organic matter in soil matrix is helpful in retaining nutrients.
10. Biological activity: a healthy soil system has diverse sets of macro and micro organisms that assure a well functioning soil food web. Microorganisms decompose organic matter, store nutrients in their bodies and on decomposition release nutrients. Some small organisms like insects and crustacea carry organic material and related nutrients into soil and aid in its decomposition. Some microorganisms have symbiotic relationship with plants such as mycorrhiza. Microorganisms live in plant root and help the plants to assimilate water and nutrients.
11. Weeds and pathogens: the efficient utilisation of nutrients means it is converted into harvestable products. If insects or diseases attack crops the efficient utilisation of nutrients are stopped. Hence to overcome this problem weeds and pathogens should be controlled.
12. Extreme soil moisture conditions: soil moisture has a positive response in making the nutrients available to plants but excessive moist condition i.e. waterlogged situation affects the transformation of nutrients. Phosphorus becomes more mobile and less attached to minerals in waterlogged conditions. Nitrate nitrogen is denitrified by changing from liquid to gas and finally lost to atmosphere because gases are transported much more slowly through water (110,000<sup>th</sup> slower) than air. Some gases such as carbon dioxide can accumulate in the soil and are toxic to roots.

Effective nutrient management can be achieved by

- Preventing soil erosion and deposition of coarser sediment in the field
- Reducing soil compaction, soil crusting, nutrient loss or imbalance and augmenting soil aggregation and infiltration
- Increasing organic matter content and biological activity
- Preventing extreme moisture condition (water logging)
- Proper and timely use of fertiliser to prevent volatilisation and leaching
- Selecting proper starter manure which does not cause toxic gas release to affect the seed germination and seedlings growth
- Farm management based on manure production

Hence, management of the watershed at the micro level and integrating the entire aspects helps in achieving ecosystem sustainability.

## CONCLUSION

On the basis of physico-chemical and biological analyses of water, soil and sediment of Sharavathi river catchment the following conclusions were drawn:



- The physico-chemical and biological analyses of water indicate that most of the variables were within the permissible limit but few factors like colour, pH, turbidity and biological coliform were found to adversely affect the water bodies.
- Colour of water samples from Sharmanavathi, Haridravathi, Yennahole and Sampakai were found brownish due to turbidity.
- Turbidity of sites Keshwapura, Handihole and Sampakai were high (more than 10 NTU) showing the increasing trend of dissolved and suspended solids.
- pH (6.8 to 8.25) was found favourable for the fish eggs but simultaneously has a potential to augment the algal growth.
- The faecal coliform in the sites of Sharmanavathi, Haridravathi, Valagare, Keshwapura, Nandihole and Sampakai indicated that it was unfit for the consumption by human and animal.
- The soil samples are rich in organic matter, pH is optimum for the plant growth and low values for the sulphates, phosphate, nitrates, sodium and potassium.
- The sediment also showed similar trends—low level of phosphate, sulphate and nitrate along with high organic matter. The bulk densities indicated that the bottom condition varied from porous to less porous. The elements Na, K, Ca, Mg were found in normal concentration.

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