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Verfügbar unter/Available at: https://hdl.handle.net/20.500.11970/109868

Vorgeschlagene Zitierweise/Suggested citation:
Sudha, V.; Ambujam, N. K.; Karunakaran, K. (2010): Environmental Impacts of Sediment Nutrients in Hyper Eutrophic Reservoir in South India. In: Sundar, V.; Srinivasan, K.; Murali, K.; Sudheer, K.P. (Hg.): ICHE 2010. Proceedings of the 9th International Conference on Hydro-Science & Engineering, August 2-5, 2010, Chennai, India. Chennai: Indian Institute of Technology Madras.

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Proceedings of ninth International Conference on Hydro-Science and Engineering (ICHE 2010), IIT Madras, Chennai, India.
2 - 5 August 2010

ENVIRONMENTAL IMPACTS OF SEDIMENT NUTRIENTS IN HYPER EUTROPHIC RESERVOIR IN SOUTH INDIA

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Abstract: Construction of large dams reduces the transport capacity of the stream and consequently the materials scoured and transported by the stream start depositing on the bed progressively. Resulted in the gradual accumulation of the silt and nutrients in the reservoir poses threat not only to the life of reservoirs and but also to the quality of water. Sediment nutrients play a significant role in the environmental state of reservoirs; especially phosphorus plays a major role because of its binding capacity with sediment particles. Krishnagiri reservoir is a hyper eutrophicated reservoir located in Dharmapuri district which is one of the drought prone districts in Tamil Nadu. The reservoir water is being used for various uses such as irrigation, fish rearing, livestock rearing and recreation. Because of the problem of sedimentation the storage capacity of the reservoir was reduced from 66.10 Mm^3 to 39.70 Mm^3. This paper examines the environmental impacts of sediment phosphorus on the quality of sediment and water in the reservoir. Any change in reservoir water quality or quantity will certainly hamper the development of the area. Since there is no an evidence of investigation of impact of sediment phosphorus on water quality in Krishnagiri reservoir and also there is a need to restore the quality of water in the reservoir to meet the demand. So a scientific assessment has been made to assess the environmental impacts of sediment phosphorus on the quality water and sediment. The results were implied that there is an emergency need for the environmental restoration of the reservoir.

Keywords: *Krishnagiri reservoir; sedimentation; sediment nutrients; phosphorus fractions: internal loading; environmental impacts; eutrophication.*

INTRODUCTION

Humans have created artificial reservoirs by damming streams for at least 4000 years. Only in last two centuries, however has this activity become highly significant for the purpose of flood control and provision of power and water for irrigation and urban population. Sedimentation is a major problem that all reservoirs face. Practically the stream borne sediments have their sources from one or the combination of geological erosion, soil erosion and water course erosion.

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Reservoirs and lakes throughout India are experiencing varying degrees of environmental problems, related mainly to encroachments, eutrophication and siltation. Surveys on Indian reservoirs were reported that they receive on an average of about 200 percent more sediment than the design inflow. According to Tejwani 1984, 'misuse and mismanagement' of the catchment area are the causes for higher rates of sedimentation. Reservoirs are effective traps for the incoming sediment loads. Because of this trapping ability they have the unique capacity for recording variations in sediment loading and sediment associated water quality parameters within the drainage basin. These sediment impoundments have proven to be important "environmental archives" of changes in watershed land use, quality of sediment and water in the reservoir and the loading rate of pollutants and nutrients.

Sediments are the most visible pollutants originating from the non-point source pollution, which have two dimensions physical and chemical. Sediment as a physical pollutant affects the receiving water in many ways. The high levels of turbidity limit the light penetration through the water column, there by limiting or reducing growth of algae and rooted aquatic plants. As a chemical pollutant, their finer particles are good carriers of nutrients, organic components, ammonium ions, phosphate, pesticides and other toxic metals. They are transported through the rivers and reach the reservoirs and lakes, and affects humans, animals and agriculture in many ways. Sediments consist of the primary components such as organic matter in various stages of decomposition, nutrients, particulate mineral matter including clays, carbonates and nonclay silicates and inorganic component of biogenic origin.

Nutrients such as phosphorus and nitrogen are the major contributions for non point source pollution. Rivers and streams are the major carriers of nitrogen and phosphorus with in the watershed. In aquatic ecosystems over-enrichment with phosphorus and nitrogen causes a wide range of problems such as increase biomass of phytoplankton and gelatinous zooplankton, increase biomass of benthic and epiphytic algae, changes in macrophyte species composition and biomass, increased turbidity and decrease water transparency, dissolved oxygen depletion and development of anoxic conditions, decrease in species diversity (especially fishes), changes in dominant biota (e.g. Blue-green algae replaced by normal algae), unpleasant odours, slimes & foam formation, toxins produced by some algal species, reduction in harvestable fishes at last decrease in aesthetic value of the water body. Thus nutrient fouling seriously degrades our fresh water and impairs their use for industry, agriculture, recreation, drinking water and other purposes. It has been widely accepted that among phosphorus and nitrogen, phosphorus plays a significant role for the cause of eutrophication in freshwater bodies. Phosphorus is the biogrowth limiting element and it has the binding capacity with sediment particles which nitrogen does not have.

In hyper eutrophic lakes and reservoirs, the role of the sediments comes into focus after a reduction of the external loading of phosphorus. After the reduction of external phosphorus input a process in which the sediment exhibits a net release of phosphorus to the water phase thereby maintaining high in-lake phosphorus concentrations for multiple years. This process is called as ***internal loading of phosphorus*** (Marsden, 1989). So the internal loading of phosphorus will then determine the eutrophication status of the lake and the time lag for recovery. The exchanges of phosphorus between sediments and the overlying water are a major component of the phosphorus cycle in natural water. The phosphorus deposited into the sediments by sedimentation of phosphorus minerals, adsorption of phosphorus with inorganic matter and uptake of it from the water column by algal and other microbial community. Exchange across the sediment-water interface is regulated by mechanisms associated with mineral water equilibria, sorption processes, and redox interaction and physiological and behavioral activities of many biotas associated with sediments.

It was identified that the major environmental impact of sediment nutrients is internal loading of phosphorus and subsequent eutrophication in lakes and reservoirs. When the literature was reviewed it was identified that in tropical and subtropical countries there is a lacuna in the research on contribution of sediment nutrients for eutrophication in lakes and reservoirs. In India especially in Tamil Nadu (Sudha et al 2009) carried out the spatial variation of sediment and porewater characteristics in Krishnagiri reservoir. There is no other evidence of investigation on sediment nutrients dynamics in reservoirs was carried. So the research is being carried out on the role of sediments on nutrients dynamics of hyper eutrophic Krishnagiri reservoir in Tamil Nadu. The present study is focuses on the impacts of sediment nutrients and its potential contribution on the quality of water in the Krishnagiri Reservoir Project (KRP) in South India. The objective of the study was to find out the trophic status of lake sediments, spatial distribution of various phosphorus-binding forms and its impacts on overlying water in KRP.

METHODOLOGY

Study Area

KRP was the first reservoir constructed across the Ponnaiyar river near Periyamuthar village about 10 Km from Krishnagiri town in Krishnagiri district, Tamil Nadu, India (Fig. 1). It is otherwise called as Muthur Dam; find its location between 78^0 and 79^0 East longitude and 12^0 and 13^0 North Latitude. In 1957, KRP dam was opened for irrigation; it irrigates an area of about 3642 ha. The original capacity of the KRP is 68.2 Mm^3 (IHH, 1985). The reservoir has two main canals, one on the left side called Left Main Canal (LMC) and other on the right side Right Main Canal (RMC) running almost parallel to the Ponnaiyar River.

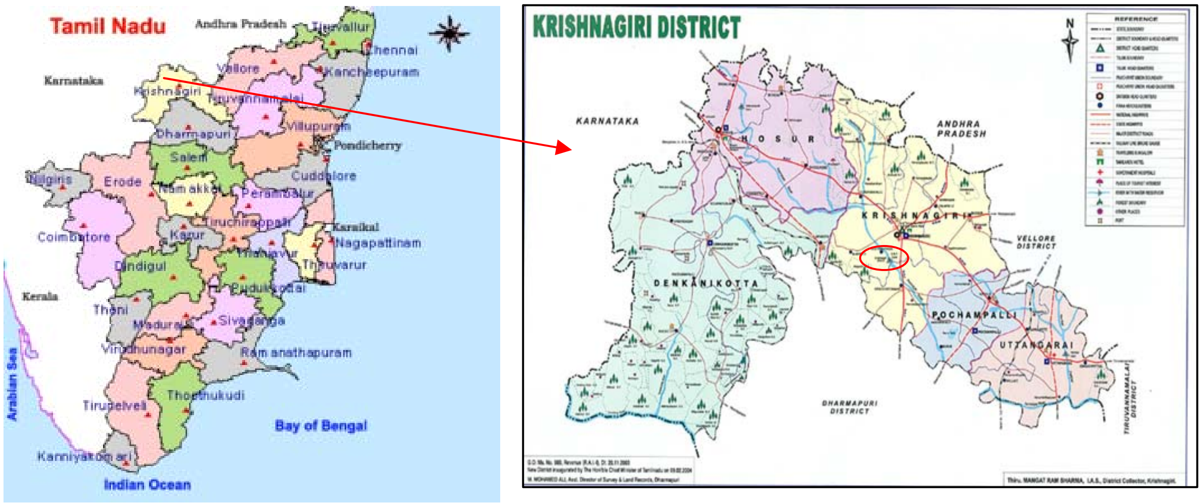


Fig. 1. Location of Krishnagiri Reservoir

There are 16 villages that directly benefit from this reservoir. Physiographically the area of Krishnagiri reservoir project is a pediplain terrain with minor undulation. The general slope of the terrain is towards south. The contour of the plain country varies from 630 m to 650 m above MSL and is confined to the central valley portion of the Ponnaiyar basin. The eastern and western sides of the area are occupied by hills, having altitude ranges from 1080 m to 1220m. The command area is drained by Ponnaiyar River, which flows in the northwest to southeast direction in to the reservoir.

The Ponnaiyar river basin consists of 8 watersheds, among these Vepanapalli, Nachikuppam and the middle and lower parts of the Markandanadhi watersheds contribute high soil erosion rates (Karunakaran 2003). High soil erosion from the catchment may be one of the reasons for sedimentation and nutrient enrichment of the reservoir (Karunakaran, 2004).

Field Work

The field work was carried out during the during the winter season (January) in 2009. Fifteen sampling points were identified at different locations in the KRP (Fig.2). The location L9 is the inflow point and locations L14 and L15 are near the dam wall of the reservoir. Surficial sediment samples were collected with Van Veen grab sampler by traveling on boat in all the 15 sampling locations in the reservoir. The sediment samples were transferred immediately in to zip lock bags to avoid the oxidation of sediment samples. *Insitu* measurement of redox potential (Eh) was measured immediately. The samples were stored at 5^0C in an ice box and carefully transferred to the laboratory.

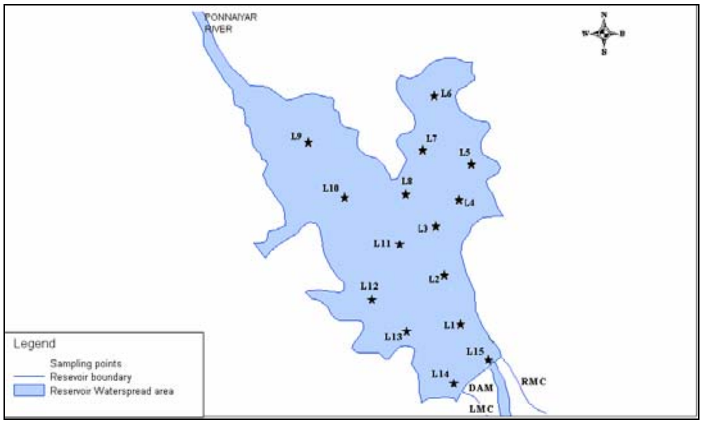


Fig. 2. Sampling locations in KRP

Laboratory analyses

As soon as the samples were being transported to the laboratory, the sediment samples were centrifuged at 3000rpm for 20 minutes to separate the pore water from the sediment. The pH, electrical conductivity, soluble reactive phosphorus (SRP), total phosphorus (TP), nitrate and nitrite were analysed in the porewater samples. TP was determined by digestion with potassium persulphate method as outlined in APHA (1998), SRP was determined on samples filtered through 0.45 µm membrane. Both TP and SRP were determined by UV-Vis spectrophotometer, using molybdenum blue method (Murphy and Riley 1962). Nitrite and nitrate was analysed by spectrophotometer where as nitrate was analysed after reduced in the cadmium reduction column (APHA 1998).

Sediment samples were dried promptly in the room temperature. Water content of the sediment was measured by loss of weight at 105^0C and sediment composition was determined by grinding and wet sieve analysis using 230 ASTM mesh. pH and electrical conductivity were measured in the sediment samples prepared with water in 1:3 ratio. Sediment phosphorus fractionation was determined with the method of Hieltjes and Lijklema (1980), including (i) loosely bound phosphorus ($CO_3 \approx P$) extracted after 2 h with 1 M NH_4Cl (ii) Iron and Aluminium bound phosphorus ($Fe + Al \approx P$) extracted after 17 h with 0.1 N NaOH and (iii) Calcium bound phosphorus ($Ca \approx P$) extracted after 24 h with 0.5 N HCl. Organic – bound phosphorus ($Org \approx P$) was calculated as the difference between TP and the sum of the inorganic fractions. Organic carbon and organic matter were determined by wet oxidation method followed by back titration. Total phosphorus was determined by persulphate and sulphuric acid digestion method. Total Kjeldhal nitrogen was determined by Kjeldhal method.

All the parameters were measured for all sediment samples collected from thirteen locations and reported on dry weight basis. All analyses and extractions were done in triplicate. The study has drawn also from secondary data sources such as Public Works Department, Department of fisheries, Agromet Regional Research Centre.

RESULTS AND DISCUSSION

Table1. shows the loss of storage capacity in KRP for the last 49 years. The very last survey conducted in the year 2006 shows the loss in capacity as 42.48%. According to the fourth capacity survey the storage capacity of the reservoir is 39.7034 Mm^3. If the average annual silting rate with reference to the original capacity is same as that of the fourth capacity survey then at present there is chance of further 2.6% of reduction in the storage capacity.

Table 1. Storage capacity loss in KRP

Capacity Survey	Year	Storage Capacity Mm^3	Loss in Capacity %	Average annual silting rate with reference to original capacity %
1	1976	50.4756	26.05	1.367835
2	1981	47.7886	29.52	1.247031
3	1983	47.1836	30.81	1.185227
4	2006	39.7034	42.48	0.852732

Source: IHH, Poondi (2007, 1985, 1984 &1979)

Physical and Chemical characteristics of Pore water

Table 2 shows the minimum, maximum and average values of physical and chemical characteristics of pore water of 15 sampling locations of the reservoir. The pore water pH was fluctuated between the value of 6.8 and 7.2 with the average of pH 7.01. The minimum pH value was recorded near LMC and the maximum value was recorded near the boat yard. This may be due to eutrophication near the boat area. The minimum EC value was observed near LMC and the maximum in the South western side in the reservoir. Nitrite concentration exhibited the minimum value in L3 and L4 locations and the maximum in the dam zone. Where as nitrate was high near the boat yard and low in the north side in the reservoir.

Tab. 2 Physical and chemical characteristics of pore water

Parameter	Minimum value	Maximum value	Average value
pH	6.8	7.2	7.01
EC (µS/cm)	725	793	763
Nitrite (mgL^{-1})	0.4	1.1	1
Nitrate (mgL^{-1})	5.8	7.4	7

The spatial variation of soluble reactive phosphorus and total phosphorus concentration in the porewater are given in fig. 3a and 3b.

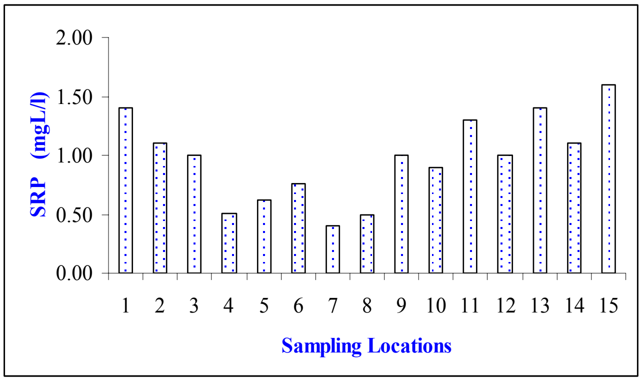


Fig. 3a Spatial variation of pore water Soluble Reactive Phosphorus concentration in KRP

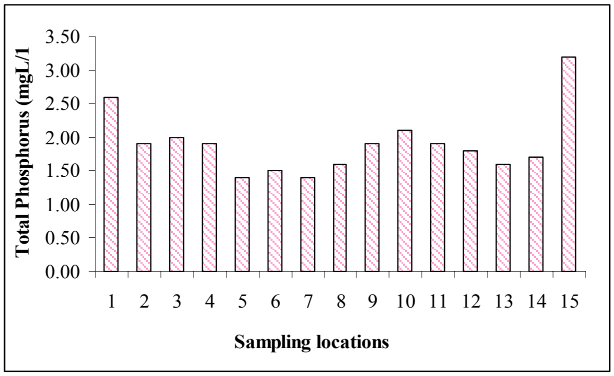


Fig. 3b Spatial variation of Total Phosphorus concentration in KRP

The SRP values are ranged between 0.4 – 1.6 mg/l and the maximum value was recorded in the dam zone area and minimum value was in L7. the high SRP value indicates the hypereutrophic status of the sediments in the dam zone. Highest value of total phosphorus concentration was observed in the dam zone and the average value of total phosphorus was 2 mg/l during the study period. There is a positive correlation ($R^2 = 0.68$) between SRP and TP in the pore water.

General characteristics of Sediments

According to USDA (United States Department of Agriculture) textural classification, the composition of sediment at different locations in KRP is shown in Table.3. When the results were compared with (Sudha et al 2009) there was a variation in the locations such as L3, L4, L8, L9 and L10. They were reported that the sediment texture was loam at the inflow point where as in the present study it is silty loam.

Tab. 3 Sediment composition at different locations of KRP

Sampling locations	Sand %	Clay %	Silt %	USDA texture
L1	2	43	55	Silty clay
L2	1	43	56	Silty clay
L3	1	52	47	Silty clay
L4	1	48	51	Silty clay
L5	5	42	53	Silty clay loam
L6	5	35	60	Silty clay loam
L7	7	27	66	Silty clay loam
L8	10	36	54	Silty clay
L9	2	46	52	Silty loam
L10	56	12	32	Silty caly loam
L11	2	29	69	Silty caly loam
L12	1	42	57	Silty clay
L13	1	42	57	Silty clay
L14	7	45	48	Silty clay
L15	2	48	50	Silty clay

Table. 4 shows the maximum and minimum values of the physico-chemical characteristics of the sediment samples in KRP during the study period. The sediment samples collected from north western side has the maximum pH of 7.61 and sediments in the dam zone has the minimum pH of 6.9. The high EC value was measured in the sediments near the boat area and low EC value in the north side of the reservoir. Positive redox potential values were observed in the all the locations except the sediment sample collected from the center of the reservoir. Maximum redox value was observed in the north side in the reservoir and the negative value was observed at the centre. Dam zone has the high moisture content whereas the eastern side has lower moisture content in the sediment sample. TKN value was measured maximum in the sediment samples collected from the dam zone and minimum in the north side in the reservoir. Highest organic carbon and organic matter content were observed in the dam zone implies that the accumulation of high organic matter may be from the dead cells of algae and the lowest values of the same were recorded in the north western side in the reservoir.

Tab. 4 Minimum and maximum values of general characteristics of sediments in KRP

Parameter	Max	Min
pH	6.9	7.61
EC (µS cm^{-1})	1285	642
Eh	+ 44	- 7
Moisture content (%)	81	40
Organic Carbon (%)	5	2.3
Organic Matter %	8.6	3.9
TKN (gm Kg^{-1} DW)	3.8	0.94

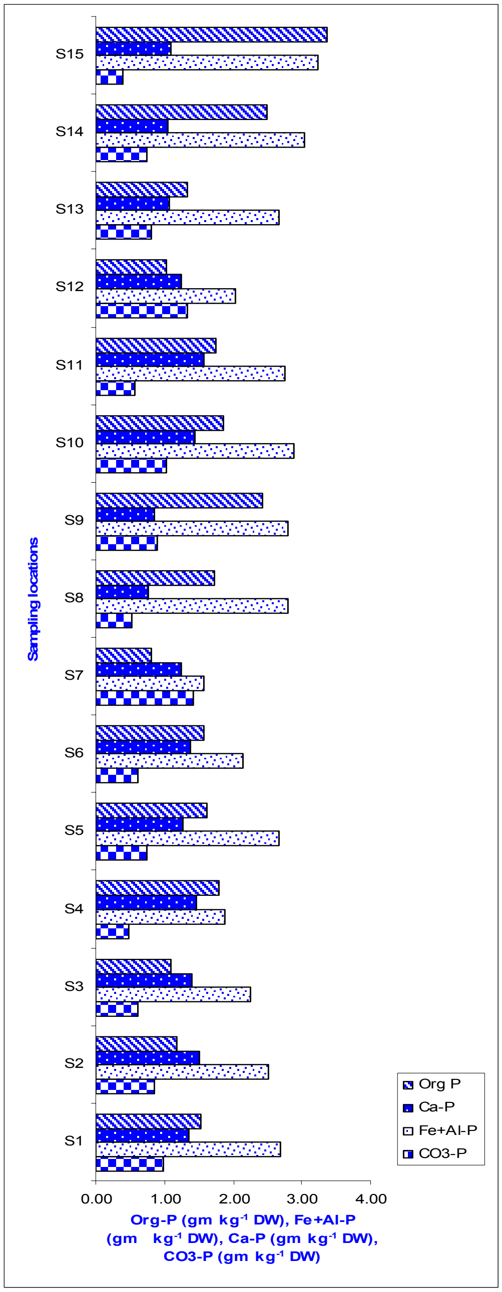
3.2 Trophic Status of Sediments and its impact on water quality

The concentrations of different phosphorus forms in the sediment are shown in fig. 5. The inorganic (inorg-P) form was distributed as follows: 40.44 % Fe+Al-P, 19.87 % Ca-P and 12.7 % CO_3-P. Carbonate –bound phosphorus (CO_3-P) was the smallest of the phosphorus fractions, with a concentration of 0.4-1.41 gm kg^{-1} DW. The most extreme concentration of Fe+Al-P (3.43 gm kg^{-1} DW) detected in the sediment near the dam zone and Ca-P became dominant with the value of 1.58 gm kg^{-1} DW at the center. Organic-bound phosphorus (Org-P) in this study was measured to be 26.94 % of the TP fractions as the second dominated phosphorus fraction. There is a clear correlation (R^2 = 0.77) between the concentrations of organic phosphorus and organic carbon values. This high correlation indicates that both the compounds are in the organic fraction of the sediment and may be from the same origin (Bostan et al 2000 and Sudha et al 2009).

The spatial distribution of TP concentration in sediments were shown in fig.4., the maximum concentration was 8.08 gm kg^{-1} DW in the dam zone and the minimum concentration 5.03 gm kg^{-1} DW was detected in the north western side in the reservoir. About 73.06 % and 26.94 % of the TP content measured in the study were in inorganic and organic forms, respectively.

The present study implies that the concentration of total phosphorus in the pore water as well as in the sediment were significantly higher in the dam zone when compared to other parts of the reservoir. The TP concentrations in the pore water exhibited high range when compared with the results reported by the author (Zhang et al 2006). The high concentration of sediment phosphorus clearly indicates a greater threat of eutrophication in KRP and there is also an evidence of release of phosphorus from the bottom sediments in the damzone during the winter season. There was a high erosion rate varied between 4 to 23 t /ha /y (Ismail and Ravichandran 2007) from the catchment, this may be the main source of nutrients and sediments that are transported to the Krishnagiri reservoir. The sediment phosphorus concentration in the reservoir was less when compared to the values reported in eutrophic Italian lake (Perrone etal 2008).The reservoir sediment phosphorus fractions exhibited a majority of inorg-P fractions, consistent with the results reported by the authors Pulatsu et al (2008) and Sondergaard et al (1996) . Since the Fe+Al-P fraction was the dominant fraction than the other inorg-P fractions such as Ca-P and CO_3-P, shows the significance of retention of Fe+Al-P fraction in the KRP and it is consider to be sensitive to changes in pH and redox potential. The high concentration of sediment Inorg-P was measured in the inflow point of the reservoir. High concentrations of both TP and Inorg-P in sediments at the inflow point and also the nearby location L10 shows that nutrient discharges from the river are the main allochthonous sources in the reservoir. And also the high organic matter in the dam zone implies that the slow process of decomposition and mineralization in the bottom of the reservoir.

The sediment nutrient enrichment problem in KRP clearly warrants the threat of internal loading of phosphorus and its severe impact on the water quality. This issue has to be taken very seriously and the problem has to be managed by framing specific strategies on activities in the watershed and in-lake restoration techniques. The present study revealed that the nutrients especially phosphorus which was entered into the reservoir mainly from allochthonous sources in the reservoir. So appropriate watershed approach has to be implemented for the soil conservation practices and cropping pattern in the Ponnaiyar watersheds. Then only the water quality and ecosystem will be protected from the environmental impacts in Krishnagiri reservoir.



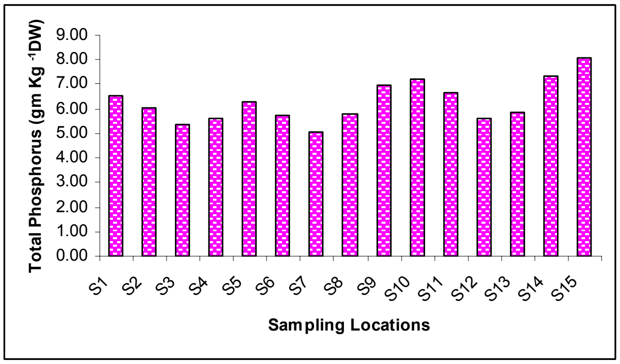


Fig. Phosphorus (P)-fractions concentration in sediments at different locations of KRP

Fig. 4 Spatial distribution of sediment total phosphorus concentration in KRP

Conclusion

In the present study of the Krishnagiri reservoir the trophic status of the sediments in Krishnagiri Reservoir and its environmental were studied during the winter season (January 2009). During the study period it was found the positive retention of phosphorus in the sediments under the favourable environmental conditions like low temperature and low pH values whish are the important factors controlling the internal loading. At the same time the high concentration of SRP values shows that the release of phosphorus from the sediments in the deeper parts of the reservoir. So this may be due to some other factor like bioturbation by bottom feeding fishes. This study concludes that a careful investigation of sediment nutrients in the Krishnagiri Reservoir has to be done to assess the role of sediments in the phosphorus dynamics and its significant effect on eutrophication.

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