Science Arena Publications
Specialty Journal of Engineering and Applied Science
ISSN: 2520-5943
Available online at www.sciarena.com
2019, Vol, 4 (3): 39-47

Studies on the Sediments of Vandiyur Lake, Madurai

Jaffer Ali M[1], Surendran A[2], Joseph Thatheyus A[1]*

[1]PG and Research Department of Zoology, The American College, Madurai, India.
[2] PG Department of Food Science & Nutrition, The American College, Madurai, India.

***Corresponding Author**

Abstract: *The establishment of metal levels in sediments can play a key role in detecting sources of pollution in aquatic systems. During the last three decades sediment analysis has acquired a new dimension by being employed as a tool to trace man- made pollution influences in inland and coastal waters. In the present work, the sediment samples from Vandiyur Lake were collected during premonsoon, monsoon and postmonsoon periods in five locations. Physico-chemical parameters such as pH, electrical conductivity, nitrogen, phosphorous, potassium, iron, manganese, zinc and copper were analysed in sediment samples. Among the metals analysed, iron levels were higher and pH was in the alkaline range. Manganese levels and electrical conductivity values were high during postmonsoon period and the results are discussed.*

Keywords: *Vandiyur Lake, Sediments, Physico-Chemical Parameters, Monsoon*

INTRODUCTION

Sediments found in fresh water and marine ecosystems provide more amount of biodiversity and also help in the biogeochemical events which are essential for existence on Earth (Wall *et al.* 2010). Studies related to the structure of sediments and their role in biogeochemical processes and nutrients are often carried out due to the habitat-centered organization of the research (Wall, 2004).

The sediment reservoir of a lake plays an important role in helping to elucidate many processes occurring within the total lake system, including its surrounding surface and ground water drainage basins (Willliamson *et al.,* 2008). Lake bottoms were recognized as the site of deposition of both mineral and organic matter that is transported as well as matter formed and settled from within the water body proper. Earlier studies on lakes tended to treat the sediments as a repository having little or no additional reaction with the lake once deposited. The sediments were also viewed as a record of the lake history (Wetzel, 2001).

In more recent years, there has been a growing awareness of the role sediments play in the dynamics of lake systems (Scheffer and Vannes, 2007). Recycling of mineralized organic matter, especially the nutrients, in sediments by organic decay and pore fluid transfer processes are now recognized as essential components of models that attempt to describe the nutrient dynamics of lake and reservoir systems (Fennel *et al.,* 2009). In addition, the active role lake sediments play in regulating cycles of trace metals, radionuclides, and synthetic organic chemicals (pesticides, soaps, and industrial effluents) is gaining increasing attention, in culturally developed areas of the world. Thus, the interactive role of sediments and lake water has come to be appreciated as fundamental in lake processes (Downing, 2010).

On the other hand, the mineralogical composition of lake sediments and its importance in helping to understand lake processes is generally not fully appreciated in the field of aquatic chemistry (Leng and Marshall, 2004). The separation of sediments into "organic" and "inorganic" phases is at least conceptually understood in limnology; however, even then, much literature reflects no critical use of such "phase" distinctions. The reasons for neglecting sediment mineralogy are several, but probably are related mostly to two factors. First, mineralogy is a field generally peripheral to the training of many students of lakes. Second, separation and identification of mineral phases and study of their **areal** variations in lake systems is generally difficult and time consuming (Last, 2002). Bulk and extractive chemical techniques have been used in attempts to characterize the "mineral" fraction of sediments without mineralogic separation and identification. Such chemical procedures may be useful for some types of problems, but, in the past, such approaches have met with only limited success. It is important to note that bulk and extractive chemical analyses do not recognize that sediments are complex mixtures of discrete mineral phases and organic compounds, the study of which can provide important insights into lake chemistry and dynamics (Schreiner *et al.,* 2017).

From the above things on lake sediments, it is clear that restriction of the discussion to lake sediment mineralogy alone would not be adequate. To properly elucidate the relationship between the constituent inorganic and organic phases of lake sediments and lake sedimentation processes, the mineralogical and chemical aspects of lake sediments must be discussed (Leeder, 2009). In fact, it is not always possible to separate mineralogical and chemical evidence in lake sediment studies. It must be appreciated that some uses of bulk and extractive chemical analyses represent a valuable technique of "chemical mineralogy." For certain sediments, especially fine-grained and/or organic rich sediments, extractive chemical analyses represent the only way possible with present techniques to distinguish chemically dissimilar "phases" (Bzdusek *et al.,* 2004). It is important to understand, however, that without specific phase characterization of sediments, whether by direct examination (optical microscope, scanning or transmission electron microscopy, X-ray diffraction) or indirectly (by extractive chemical techniques "specific" for certain phases), studies of lake sediment chemistry will lack transfer value. Attempts to extend empirically established interactive relationships between sediments, pore fluids, and overlying lake waters require detailed knowledge of the processes involved, which, in turn, will eventually require characterization of the critical phases within the sediment (Blais and Kalff, 1995; Tao *et al.,* 2012).

One of the prime goals of studying the quantitative mineralogy and chemistry of sediments is the evaluation of the sources of sediment phases and the relative importance of each source. It is useful to distinguish: (1) the minerals brought into the lake by surface water (streams and overland flow), shore erosion, glacial transport, and aeolean processes (allogenic fraction); (2) the minerals originating from processes occurring within the water column (endogenic fraction); and (3) the minerals resulting from processes that occur within the sediments once deposited (authigenic fraction) (Cole and Weihe, 2015). In this context, the present work has been designed to study the physico-chemical parameters of the sediments of Vandiyur Lake which could help in a sustainable restoration plan for the lake.

Materials and Methods

Study area – Vandiyur Lake

Vandiyur Lake is situated on the left bank of Vaigai River near Vandiyur village in Madurai north taluk, Tamil Nadu, India and it has source supply from Sathaiyar channel and upper tanks. This lake is located at 9°56'N latitude, 78°98'E longitudes. The lake belongs to Vandiyur village in Madurai North taluk and Madurai East block. The length of the bund is 2077 meters and it has 10.24 sq.km free catchment area and 96.89 sq.km combined catchment area. It has three sluices, the tank has 107.03mc ft. capacity and its maximum flood discharge is 4059 cusecs.

The Vandiyur Lake has no water supply from the river Vaigai but the surplus water of the tank reaches Vaigai. The lake receives run off from Sathiyar dam which comes from upper catchment area. Surplus from Parasurampatti tank, Sambakulam tank and S.Kodikulam tank flow through Parasurampatti surplus channel. Managiri surplus channel carrying water from Athikulam tank, Kosakulam tank and Thallakulam tank has been closed now. During rainy season flooding affects the encroached residents.

The rainfall data for pre-monsoon (April to July), monsoon (August to November) and post-monsoon (December to March) periods during 2010 -2011 were collected in the present study.

Sediment Sample Collection and Treatment

Sediments samples were collected from five different sampling zones (A, B, C, D and E) in the lake using a stainless steel scoop into polyethylene bags previously soaked with dilute nitric acid for 24 hrs, rinsed with distilled water and dried. The grab samples of surface sediments were taken at a depth of 0-5 cm (Mohinddin *et al.,* 2010). These samples were then transported to Zoology department laboratory, The American College, Madurai, Tamil Nadu, India and air dried for about two weeks at room temperature and ground with mortar and pestle. The ground soil samples were sieved using 0.2mm sieve size and kept in a poly ethylene bottle for further analysis.

Determination of physico-chemical parameters

Sediment samples were tested for different physico-chemical parameters such as Electrical conductivity, pH, Nitrogen, Phosphorus, Potassium, Iron, Manganese, Zinc and Copper based on standard procedures (APHA, 2002; AOAC, 2005).

Results

Rainfall data for premonsoon, monsoon and postmonsoon periods were collected during the period of study. The minimum rainfall for the premonsoon period in Madurai was recorded in April and Sathiyar Dam in June and was maximum in May for Madurai and Sathiar Dam (Fig.1). The minimum rainfall for the monsoon period in Madurai and Sathiyar Dam was in August and maximum in November (Fig.2). The minimum rainfall for the postmonsoon period in Sathiyar Dam was in March (Madurai recorded nil) and the maximum in Madurai and Sathiyar Dam was recorded during December (Fig.3).

The physico-chemical parameters of sediments present in Vandiyur Lake were assessed in five different sampling zones (Table 1, 2 and 3). The maximum Electrical conductivity in the sediments was recorded in the postmonsoon period while the minimum was found in the monsoon period. The pH was the maximum in the lake sediments during premonsoon (8.74) and it was minimum in the postmonsoon period (8.32). The maximum nitrogen content in lake sediments was found in the postmonsoon period while the minimum was noticed in the monsoon period. The phosphorus in the lake sediments was maximum during premonsoon period (0.0299 mg/g) and it was minimum (0.006mg/g) in the postmonsoon period. Maximum potassium in the lake sediments was recorded in the monsoon period while the minimum was observed during postmonsoon period. The iron level in Vandiyur lake sediments was the maximum in the premonsoon period (26.09 ppm) and it was minimum in the postmonsoon period (17.46 ppm). The maximum manganese in the lake sediments was observed in the postmonsoon period while the minimum was recorded in the monsoon period. The maximum zinc level in the lake sediments was recorded in the premonsoon period (2.17 ppm) and the minimum was found in the monsoon period (0.65 ppm). The copper in the lake sediments was the maximum in the monsoon period and the minimum was in the premonsoon period.

Discussion

Madurai exhibits hot and humid summers and pleasant winters which is typical of the Deccan Plateau. As Madurai is located in the central part of India, it receives less amount of rainfall, compared to the coastal cities. The monsoon season in Madurai stretches from September to November. During this period the city of

Madurai is susceptible to heavy rains (Pletcher, 2010). In the present study, the rainfall was the maximum during the monsoon period in 2010 and the minimum during the postmonsoon in 2011.

pH and Electrical conductivity

pH as a measure of the acidity or alkalinity of water is one of the stable measurements. It is a simple parameter but is extremely important, since most of the chemical reactions in aquatic environment are controlled by it. Anything either highly acidic or alkaline would kill life. Aquatic organisms are sensitive to changes in pH and biotreatment requires specific pH. Thus, pH is having primary importance in deciding the quality of water (Langmuir, 1997). The pH of the lake sediments was 8.7, 8.4 and 8.3 in the pre-monsoon, monsoon and post-monsoon respectively. The pH in the sediment was considerably alkaline throughout the seasons. The iron hydroxide and siderite (iron carbonate) probably acted as buffer to prevent the decrease of pH. In the premonsoon period the pH was the highest correspondingly the concentration of iron was also high compared with monsoon and postmonsoon periods. The increase in alkalinity can be due to combination of organic matter, oxidation, hydrolysis, ammonia protonation and absorption, Fe and Mg oxide reduction and carbonate dissolution (Xiong, 2012).

Electrical conductance is a good measure of dissolved solids. Conductivity is used to determine mineralization of water. Physiological activities of plants and animals are often influenced by the number of available ions in water (Mischke et al., 2007). The electrical conductivity was 0.53, 0.2 and 1.28 dsm^{-1} in the pre-monsoon, monsoon and post-monsoon respectively.

Nitrogen, Potassium and Phosphorus

Nitrogen (NO_3, NO_2 and NH_4^-) and silicates contribute significantly in primary productivity. In summer, the plant tissue had higher total nitrogen assimilation. Plants derived nitrogen from nitrogen released from underlying sediments. Water hyacinth plants prefer NH_4^+ - N over NO_3 – N (Rabalais, 2002). Many aquatic plants utilize problem nutrients such as nitrogen and phosphorus present in lakes and streams. Nutrients are discharged into a lake both from external sources (e.g. nutrient discharges from agricultural and urban activities) and from internal sources (e.g. nutrient release from the underlying sediment). Nitrogen uptake rate was found to be higher during the first hundred days of the growing period of water hyacinth and later it decreased. Nitrogen released from the sediment was found to be rapidly taken up by water hyacinth plants. NH_4^+, alkalinity, Fe^{2+} and Mn^{2+} which are produced during organic matter decomposition, increase sharply and regularly with depth below the sediment water interface as reported in many previous studies from both freshwater and saline environments (Thornton et al., 2007). In Vandiyur Lake, nitrogen was found more during the postmonsoon and less during the monsoon period. During summer probably more nitrogen was released from the sediments which were assimilated by the plant tissue. Agricultural and urban activities increase the sedimentation of nitrogen. With organic decomposition more NH_4^+ is found with increase in the depth of the sediments (Sarkar et al., 2012).

Potassium is vital for plant growth. Plants use it, for example, to make proteins (Jonathan *et al.,* 2004). In Vandiyur Lake, potassium was found more during the monsoon and less during the post-monsoon period. Phosphorus is usually found at 2-3 cm depth in the organic rich top layer of the sediments. The amount of phosphorus incorporated in the diatoms is related to available phosphorus levels. High levels can result in a luxury consumption that is several times higher than the amount necessary for growth (Sondergaard et al., 2003). Many aquatic plants utilize nutrients such as nitrogen and phosphorus present in lakes and streams. Nutrients are discharged into a lake from agricultural and urban activities. Certainly photosynthesis within the aquatic system offers the most economical energy pump for recovering phosphorus from the sediments. Sediments often have large phosphorus sorption capacities. Surface adsorption or precipitation by Fe (III) and Al as well as precipitation by Ca are considered important in sediment phosphorus retention. Uptake of phosphorus by non-photosynthetic organisms at the sediment interface has also been cited as an important phosphorus removal mechanism (Lukkari et al., 2009). The maximum phosphorus in the Vandiyur Lake sediments was found during the premonsoon period and the minimum was found during the post monsoon period.

Many aquatic plants utilize the inorganic phosphorus during photosynthesis. Non–photosynthetic organisms also remove phosphorus at the sediment interface. Phosphorus also controls algal biomass. In Vandiyur Lake high sedimentation was observed during the summer. It may be due to urban activities. High sedimentation may enhance high productivity. Iron, clay and aluminium may bind with the phosphorus and remove the phosphorus during sedimentation. Under oxic conditions the sediments are a sink for phosphorus. Under anoxic conditions the phosphorus is released from the sediments (Sondergaard et al., 2003).

Iron and Manganese

Iron and Manganese hydroxides are the main carriers of Cd, Zn and Ni. Sulphates convert iron hydroxides to iron sulphides during methanogenesis. Reducible iron is converted into siderite (iron carbonate). Reducible iron acts as a buffer against the decrease of the pH. The precipitation of manganese is much slower than iron and part of it can escape to the water column (Peng et al., 2009). Precipitating iron oxides scavenge trace metals from the water column and transfer them in particulate form to the sediments. This process is important for copper but less so for zinc (Purushotham and Chkrapani, 2007). Manganese and iron are important micronutrients in aquatic environments and influence the presence or absence of other substances in the water column and sediments. The concentration of zinc was greater in bottom water than at the surface. The concentration increased between spring and summer. Iron was generally greater in the bottom water than in the surface water. Iron as well as the clays and aluminium associated with the inflowing sediments are known to effectively bind phosphorus and remove phosphorus during sedimentation (Davison, 1993).

The concentration of iron in the sediments was more during the premonsoon period and less during the postmonsoon period. The reducible iron acts as a buffer against the decrease in pH and hence high alkalinity was observed again in the premonsoon period. Precipitating iron oxides also scavenge trace metals especially copper from the water column and transfer in particulate form to the sediments. More manganese was observed during postmonsoon period than that of monsoon period. Decomposing plants might have increased the manganese concentration in the sediments. Bottom dwelling Chironomids would have accumulated these manganese (Young and Harvey, 1992).

Zinc and Copper

The area polluted with copper had depressed algal growth. Bacillariophyceae and Chlorococcales were the most affected algae while Chrysophyceae was the only exception. Blue green algae are highly sensitive even at low concentration of copper. The metallic copper ion present in water enters the fish body and gets accumulated in various organs like liver, and kidney. Once surface layers become reduced (as in stagnant basins) zinc release may also occur (Mossop and Davidson, 2003).

In Vandiyur Lake, more zinc was found during premonsoon period while least was found during monsoon period. Besides, more copper was found during the monsoon period and least was found during the premonsoon. Copper affected the growth of Bacillariophyceae, Chlorococcales and blue green algae. Chrysophyceae was the exception and it thrived well when surface layers were oxic and reduced Cu and Zn release was more. In anoxic conditions Cu and Zn were present as sulphides. Clams and May flies accumulated the zinc in their body (Mendil and Uluozlu, 2007).

Conclusion

Vandiyur lake sediments have higher levels of iron and manganese. Efforts must be taken to protect this Lake as it is one of the important aquatic systems of Madurai.

Acknowledgements

The authors thank the authorities of the American College, Madurai, Tamil Nadu, India, for the facilities and encouragement.

Reference

1. AOAC. 2005. Official method of analysis Association of analytical Chemists (18th Ed.), AOAC International Publishers, Maryland, USA.
2. APHA. 2002. Standard Methods for the Examination of Water and Waste Water (21st Ed.), American Water Works Association (AWWA), Water Pollution Control Federation (WPCF) and American Public Health Association (APHA) Washington DC, USA.
3. Blais JM, Kalff, J. 1995. The influence of Lake Morphometry on sediment focusing. Limnology and Oceanography 40(3): 582-588.
4. Bzdusek PA, Christensen ER, Li A, Zou Q. 2004. Source apportionment of sediment PAHs in Lake Calumet, Chicago: application of factor analysis with nonnegative constraints. Environmental science & technology 38(1): 97-103.
5. Cole GA, Weihe PE. 2015. Textbook of limnology. Waveland Press, Illinois, USA
6. Davison W. 1993. Iron and manganese in lakes. Earth-Science Reviews 34(2): 119-163.
7. Downing JA. 2010. Emerging global role of small lakes and ponds: little things mean a lot. Limnetica 29(1): 9-24.
8. Fennel K, Brady D, DiToro D, Fulweiler R.W, Gardner WS, et al. 2009. Modeling denitrification in aquatic sediments. Biogeochemistry 93(1-2): 159-178.
9. Jonathan MP, Ram-Mohan V, Srinivasalu S. 2004. Geochemical variations of major and trace elements in recent sediments, off the Gulf of Mannar, the southeast coast of India. Environl Geol 45: 466-480.
10. Langmuir D. 1997. Aqueous Environmental Chemistry. Prentice-Hall, Inc., New Jersey.
11. Last WM. 2002. Mineralogical analysis of lake sediments. In: Tracking environmental change using lake sediments, Springer, Dordrecht.
12. Leeder MR. 2009. Sedimentology and sedimentary basins: from turbulence to tectonics. John Wiley & Sons, USA.
13. Leng MJ, Marshall JD. 2004. Palaeoclimate interpretation of stable isotope data from lake sediment archives. Quaternary Science Reviews 23(7-8): 811-831.
14. Lukkari K, Leivuori M, Kotilainen A. 2009. The chemical character and behaviour of phosphorus in poorly oxygenated sediments from open sea to organic-rich inner bay in the Baltic Sea. Biogeochemistry 96(1-3): 25-48.
15. Mendil D, Uluozlu OD. 2007. Determination of trace metal levels in sediment and five fish species from lakes in Tokat, Turkey. Food Chemistry 101(2): 739-745.
16. Mischke S, Herzschuh U, Massmann G, Zhang C. 2007. An ostracod-conductivity transfer functions for Tibetan lakes. Journal of Paleolimnology 38(4): 509-524.
17. Mohinddin KM, Zakir HM, Otomo K, Sharmin S, Shikazono N. 2010. Geochemical distribution of trace metal pollutants in water and sediments of downstream of an urban river. Int J Environ Sci Tech 7(1): 17-28.
18. Mossop KF, Davidson CM. 2003. Comparison of original and modified BCR sequential extraction procedures for the fractionation of copper, iron, lead, manganese and zinc in soils and sediments. Analytica Chimica Acta 478(1): 111-118.

19. Peng JF, Song YH, Yuan P, Cui XY, Qiu GL. 2009. The remediation of heavy metals contaminated sediment. Journal of hazardous materials 161(2-3): 633-640.
20. Pletcher K. 2010. The geography of India: sacred and historic places. Britannica educational publishing.
21. Purushothaman P, Chakrapani GJ. 2007. Heavy metals fractionation in Ganga River sediments, India. Environmental monitoring and assessment, 132(1-3): 475-489.
22. Rabalais NN. 2002. Nitrogen in aquatic ecosystems. AMBIO: A Journal of the Human Environment 31(2): 102-113.
23. Sarkar SK, Bhattacharya A, Bhattacharya AK, Satpathy KK, Mohanty AK, Panigrahi S. (2012). Chilika lake. Encyclopedia of lakes and reservoirs 148-156.
24. Scheffer M, Vannes EH. 2007. Shallow lakes theory revisited: various alternative regimes driven by climate, nutrients, depth and lake size. In Shallow lakes in a changing world. Springer, Dordrecht.
25. Schreiner KM, Katsev S, Steinman B, Sterner RW, Williams J, Zak K. 2017. Advancing Graduate Limnology Education through Active Learning and Community Partnerships: A Pilot Program at the Large Lakes Observatory. Limnology and Oceanography Bulletin 26(3): 61-66.
26. Sondergaard M, Jensen JP, Jeppesen E. 2003. Role of sediment and internal loading of phosphorus in shallow lakes. Hydrobiologia 506(1-3): 135-145.
27. Tao Y, Yuan Z, Wei M, Xiaona H. 2012. Characterization of heavy metals in water and sediments in Taihu Lake, China. Environmental Monitoring and Assessment 184(7): 4367-4382.
28. Thornton DC, Dong LF, Underwood GJ, Nedwell DB. 2007. Sediment–water inorganic nutrient exchange and nitrogen budgets in the Colne Estuary, UK. Marine Ecology Progress Series 337: 63-77.
29. Wall DH, Bardgett RD, Kelly E. 2010. Biodiversity in the dark. Nature Geoscience 3: 297–298.
30. Wall DH. 2004. Sustaining Biodiversity and Ecosystem Services in Soils and Sediments. Island Press.
31. Wetzel RG. 2001. Limnology: lake and river ecosystems. Gulf professional publishing.
32. Williamson CE, Dodds W, Kratz TK, Palmer MA. 2008. Lakes and streams as sentinels of environmental change in terrestrial and atmospheric processes. Frontiers in Ecology and the Environment 6(5): 247-254.
33. Xiong J, Liu Y, Lin X, Zhang H, Zeng J, Hou J, et al. 2012. Geographic distance and pH drive bacterial distribution in alkaline lake sediments across Tibetan Plateau. Environmental microbiology 14(9): 2457-2466.
34. Young LB, Harvey HH. 1992. The relative importance of manganese and iron oxides and organic matter in the sorption of trace metals by surficial lake sediments. Geochimica et Cosmochimica Acta 56(3): 1175-1186.

Table 1. Parameters of Vandiyur Lake sediment samples collected during the premonsoon period

Parameters	Sampling Zones					Average
	A	B	C	D	E	
Electrical conductivity (dsm^{-1})	0.50	0.41	0.62	0.46	0.64	0.53
pH	8.7	8.8	8.7	8.8	8.7	8.74
Nitrogen (mg/g)	0.0584	0.0849	0.0860	0.0606	0.0794	0.0739
Phosphorous (mg/g)	0.0216	0.0221	0.0214	0.0221	0.0221	0.0299
Potassium (mg/g)	0.1852	0.2547	0.2007	0.1500	0.2106	0.2024
Iron (ppm)	23.14	28.80	27.62	24.42	26.46	26.09
Manganese (ppm)	8.48	10.56	10.50	9.12	10.16	9.26
Zinc (ppm)	1.78	1.88	1.72	2.46	3	2.17
Copper (ppm)	1.02	1.60	1.26	0.92	1.20	1.20

Table 2. Parameters of Vandiyur Lake sediment samples collected during the monsoon period

Parameters	Sampling Zones					Average
	A	B	C	D	E	
Electrical conductivity (dsm^{-1})	0.21	0.16	0.19	0.17	0.27	0.2
pH	8	8.4	8.4	8.6	8.6	8.4
Nitrogen (mg/g)	0.0761	0.0507	0.0485	0.0529	0.0507	0.0558
Phosphorous (mg/g)	0.0020	0.0221	0.0157	0.0221	0.0221	0.0168
Potassium (mg/g)	0.5360	0.3495	0.3176	0.0165	0.2272	0.2894
Iron (ppm)	25.72	24	25.78	25.98	25.02	25.3
Manganese (ppm)	1.78	14.74	2.08	2.82	2.38	4.76
Zinc (ppm)	0.98	0.46	0.64	0.62	0.54	0.65
Copper (ppm)	2.48	2.32	2	1.86	1.58	2.05

Table 3. Parameters of Vandiyur Lake sediment samples collected during the post-monsoon period

Parameters	Sampling Zones					Average
	A	B	C	D	E	
Electrical conductivity (dsm^{-1})	1.32	1.27	1.31	1.25	1.25	1.28
pH	8.5	8.4	8.2	8.2	8.3	8.32
Nitrogen (mg/g)	0.0684	0.0662	0.0706	0.0684	0.0728	0.6928
Phosphorous (mg/g)	0.0062	0.0055	0.0062	0.0057	0.0064	0.006
Potassium (mg/g)	0.0695	0.1577	0.0960	0.0849	0.1103	0.1037
Iron (ppm)	9.76	26.42	2.32	22.52	26.30	17.46
Manganese (ppm)	20.14	23.08	20.96	8.70	11.54	16.88
Zinc (ppm)	0.76	0.80	0.74	0.82	0.72	0.87
Copper (ppm)	1.24	1.26	1.00	1.26	1.56	1.26

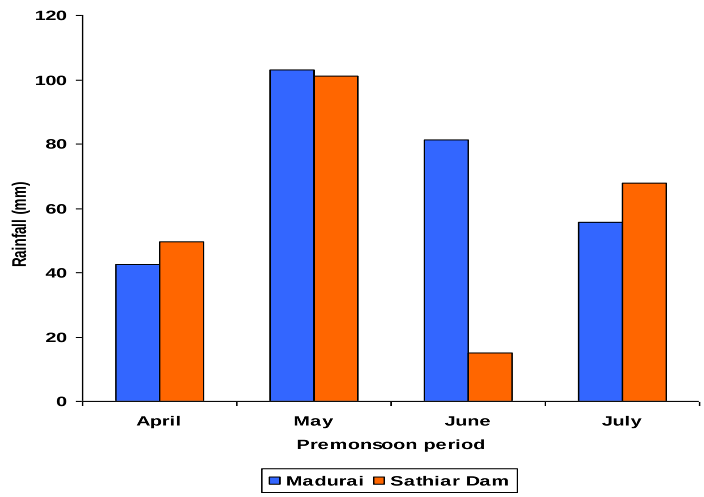

Figure 1. Rainfall data for the premonsoon period 2010

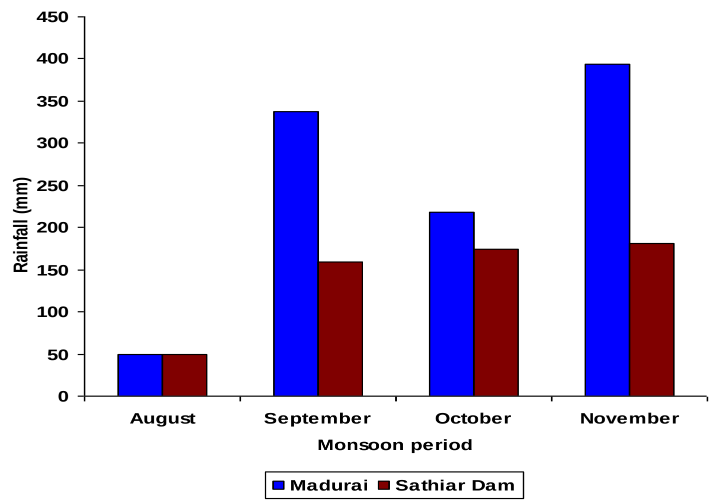

Figure 2. Rainfall data for the monsoon period 2010

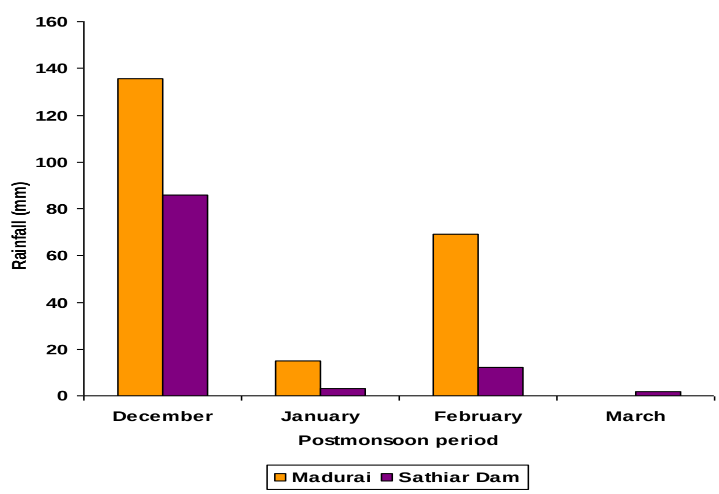

Figure 3. Rainfall data for the Postmonsoon period 2010 – 2011