
Hydrogeochemistry and Environmental Issues of the Wetlands of Kerala, Southwestern India

8

A. Krishnakumar, P. Saranya, and Revathy Das

Abstract

The geomorphic and geologic evolution of coastal lands of Southwest India is influenced by many local and regional factors, including changes in climate, sea level and local and regional tectonics in the late Quaternary period. The wetlands in Kerala State in Southwestern India, forming an interlacing network, act as an integral part of the socio-environmental frame of the state (Kerala) playing vital roles in the hydrological, biological and biogeochemical features of the environment. However, these systems were mismanaged due to lack of scientific data and proper appreciation of the ecosystem functions. During the recent years, there is a growing concern for conservation and management of the wetlands. This chapter provides some baseline data on the geochemical characteristics of the sediments and the water quality of four important wetlands in the state, namely, Vellayani Lake, Sasthamkotta Lake, Pookot Lake (lacustrine wetlands) and Ashtamudi Lake (estuarine wetland), and provides some insights into the need for their conservation.

Keywords

Hydro-geochemistry • Kerala • Pollution load index • Water quality index • Wetlands

A. Krishnakumar (✉) • P. Saranya • R. Das
Natural Resources and Environmental Management Group, ESSO- National Centre for Earth Science Studies (NCESS), Ministry of Earth Sciences (MoES), Government of India, Akkulam, Thiruvananthapuram 695 011, India
e-mail: drakrishnakumar@gmail.com

8.1 Introduction

India is very rich in wetlands and they have assumed considerable significance in recent years in the country with growing interest in them for their productive and retentive uses. But, the country is losing some of its prime wetlands rapidly due to biotic and anthropogenic interferences. In Kerala State, the total estimated wetland area is 160,590 ha, of which 119,714 ha is 'inland wetlands' and 40,876 ha 'coastal wetlands' (SAC 2011). The wetlands in the state in total spread over 4.13% of the state's geographical area (SAC 2011). Kerala State, located in the southwestern part of India, has the imposing Western Ghats as the state's eastern boundary with its western slopes merging with the midland plains and the western seacoast of the state. This provides an ideal topographic setting for development and sustenance of myriad forms of wetlands in this region (Padmalal et al. 2011). The 44 rivers that originate from the Western Ghats create and maintain almost all the major wetlands of the state.

The majority of wetlands of Kerala are brackish, although there are a few freshwater ones believed to have evolved during the Holocene (Padmalal et al. 2011). Considering their importance in sustaining the hydrodynamic regime and overall economic development of the region, three wetlands of Kerala, *viz.* Vembanad Lake, Ashtamudi Lake (brackish water) and Sasthamkotta Lake (freshwater), were designated as Ramsar Sites as per the Ramsar Convention. Ramsar Convention promotes the concept of 'wise use' that stands for 'sustainable utilization' for the benefit of human kind in a way compatible with the maintenance of natural properties of the ecosystem. During the recent decades, the emphasis on exploitation and modification for greater economic returns has caused much damage to many Indian wetlands. The major issues are high silt loads causing shrinkage of the waterbody, threat by agricultural chemicals, toxic effluents, insecticide and pesticide residues, domestic sewages, reduction in waterfowl and growth of water hyacinth, decline in fish production, heavy metal accumulation and so on (Unni 2002).

Not much systematic investigations have been carried out so far in evaluating/ updating information regarding various freshwater environments in Kerala State for their proper maintenance and management or for sustainable utilization. Some geochemical studies of aquatic sediments have been taken up in the last few decades due to the growing awareness of environmental pollution and its impact on the ecosystem and its relation with ecological service delivery potential of wetlands. Surface sediments act both as sink and source for various kinds of environmental pollutants under different geochemical set-ups. Thus, sediments are often considered as indicators of environmental pollution. Lack of baseline information on various parameters that determines the health of these ecosystems is a major problem before the planners and decision makers for chalking out strategies for environmental management and conservation. Geochemical studies of aquatic sediments are of prime requirement for assessing the pollution load in terms of geochemical constituents and impact on the waterbody, since the sediments are in a complex dynamic relation with the overlying water: while the sediments affect the water chemistry, simultaneously being itself affected by that. In this background, this chapter

discusses the hydro-geochemical characteristics of the lacustrine (Vellayani Lake, Sasthamkotta Lake, Pookot Lake) and estuarine (Ashtamudi Lake) wetlands of Kerala in their specific environmental context.

8.2 Lacustrine Wetlands of Kerala

Wetlands are the cradles of civilizations and culture, and they are integral part of the socio-environmental frame of a region. Many of the lacustrine wetlands of the state, such as Sasthamkotta, Vellayani and Pookot (Fig. 8.1), are heading towards degradation due to pollution from various sources and indiscriminate land reclamation. The basic details pertaining to the general profile and geographical delineation of these wetlands are presented in Table 8.1.

Sasthamkotta Lake is listed by the Government of India as a wetland of national importance. It was designated as Ramsar Site in 2002. Its depth varies from 2 to 14 m. A considerable portion of the catchment of the lake and adjacent hillocks are occupied by human settlements (Krishnakumar et al. 2005a) and under a variety of farming practices. This lake serves as source of drinking water to Kollam Municipality and suburbs supplied by the Kerala Water Authority. Recently it is reported that the lake is shrinking at an alarming rate owing to a number of reasons (Das and Krishnakumar 2015). Vellayani Lake, the second largest lacustrine system of Kerala (Table 8.1, Fig. 8.1), is located at the outskirts of Thiruvananthapuram City. The total water spread of the lake is 5.5 km². The lake varies in the depth from 2 to 8 m. The watershed of Vellayani Lake is also used for various agricultural activities (Krishnakumar et al. 2006). Pookot Lake, located at the suburbs of Kalpetta town in Wayanad district, is the third largest freshwater lake in the state (Table 8.1). The surroundings of the lake are dominated with thick vegetation.

Textural studies revealed that predominance of silt and clay with very little quantities of sand in Sasthamkotta Lake sediments (Table 8.2). The overall sediment dispersal pattern observed in the Vellayani Lake and Pookot Lake basin indicates intense siltation to which these freshwater basins are subjected. The relative concentrations of various chemical parameters in sediments are in the order OC > Fe > P > Mn > Pb > Cu > Cd in Sasthamkotta Lake and OC > Fe > P > Mn > Cu > Pb > Cd in Vellayani Lake and in Pookot Lake (Das and Krishnakumar 2015).

The physical, chemical and biological parameters of the water in the three wetlands such as odour, total dissolved solids, pH, nitrates, sulphates, chlorides, hardness, calcium and magnesium fall within the prescribed limits of Bureau of Indian Standards (BIS) (Table 8.3). The turbidity and iron values are slightly higher than prescribed standards for drinking water (BIS 2012). Various anthropogenic activities such as disposal of solid waste, household sewage, fertilizer residues and other chemicals seem to result in higher turbidity as observed in Sasthamkotta and Vellayani Lakes (Krishnakumar et al. 2005a). It is observed that phytoplankton community are growing rapidly in the Pookot Lake thereby depleting the DO (Dissolved Oxygen) content. The average values and ranges observed for different parameters, *viz.* pH, turbidity, nitrate, iron, phosphate and faecal coliform contents

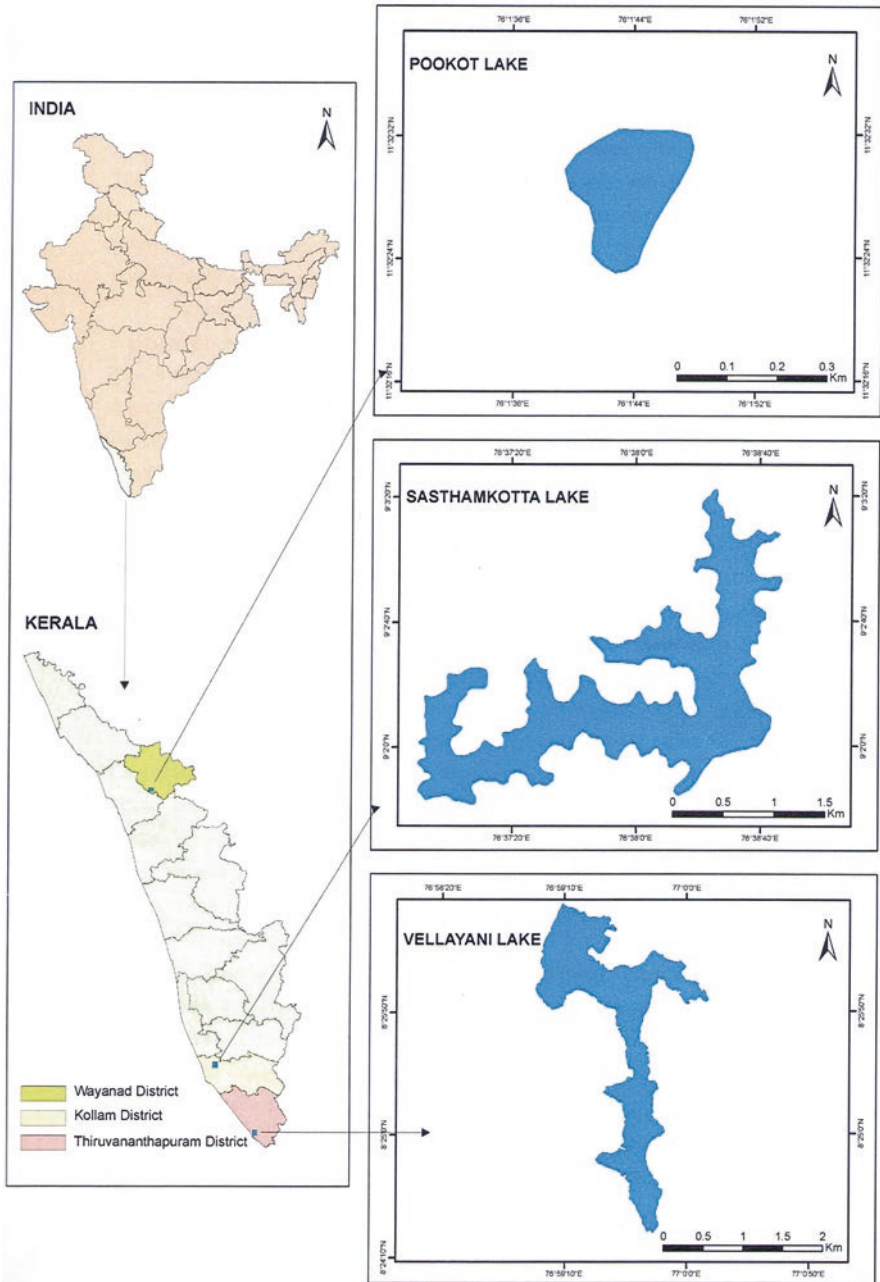


Fig. 8.1 Lacustrine wetlands of Kerala

Table 8.1 Details of Sasthamkotta, Vellayani and Pookot Lakes in Kerala

Particulars	Sasthamkotta Lake	Vellayani Lake	Pookot Lake
District	Kollam	Thiruvananthapuram	Wayanad
Taluk	Kunnathur	Thiruvananthapuram	Vythiri
Block	Sasthamkotta	Nemom, Athiyannur, Thiruvananthapuram Corporation	Kalpetta
Grama panchayats	Sasthamkotta	Kalliyoor, Venganoor, Thiruvananthapuram Corporation	Vythiri
Villages	Sasthamkotta	Kalliyoor, Thiruvallam, Venganoor	Kunnathidavaka
Local name	Sasthamkotta <i>Kayal</i>	Vellayani <i>Kayal</i>	Pookode <i>thadakam</i>
Size (ha)	347.09	230.96	3.70
Location (lat. and long.)	9° 1' 00"-9° 4' 00" N 76° 36' 30" -76° 40' 00"E	8° 24' 09"-8° 26' 33"N 76° 59' 08"- 76° 59' 47"E	11° 30' 20' -11° 32' 36"N 76° 1' 02' -76° 1' 43'E
Existing rights and privileges consistent or not consistent with ecological health of the wetland	Fishing Drinking water Settlements Ramsar site	Fishing Boat race Drinking water	Ecotourism

Table 8.2 Textural and geochemical properties of lacustrine wetland sediments

Parameter	Vellayani		Sasthamkotta		Pookot	
	Range	Average	Range	Average	Range	Average
Sand (%)	0.36–26.5	8.53	0.21–78.63	23.4	0.25–19.8	5.73
Silt (%)	54.4–85.8	79.91	0.065–45.9	28.33	58.9–90.4	81.2
Clay (%)	8.28–41.14	18.54	2.4–76.6	44.35	4.03–69.4	12.58
Mud (silt+clay) (%)	73.5–99.7	91.55	14.99–99.8	72.71	74.7–99.4	92.89
OC (%)	0.84–2.55	1.82	0.6–15.8	8.95	0.88–16.4	8.99
P (%)	0.15–0.36	0.214	0.03–0.203	0.17	0.11–0.39	0.24
Fe (%)	0.392–1.887	1.06	0.69–2.99	1.77	0.49–2.49	1.28
Mn (ppm)	32–96	66	45–103	86	37–110	76
Cu (ppm)	4–184	31.7	6–34	24.07	4–98	26.02
Pb (ppm)	0.8–6.2	1.32	28–86	72.6	19–58	39.8
Cd (ppm)	2–6	0.81	1–5	2	2.2–4.8	1.03

Source: Das and Krishnakumar (2015)

Table 8.3 An overview of the observed hydrochemical values in the lacustrine wetlands

Parameter	Drinking water quality standards		Vellayani	Sasthamkotta	Pookot
	BIS	WHO			
pH	6.5–8.5	6.5–8.5	6.5	6.8	5.60
EC ($\mu\text{S}/\text{cm}$)	–	1,500	111.2	108	40.79
Turbidity (NTU)	5	5	4.66	9.3	7.78
TDS (mg/l)	500	1000	129.6	204.3	86.13
HCO_3^- (mg/l)	–	500	84	85.45	18
Cl^- (mg/l)	250	250	13.6	14.73	4.59
SO_4^{2-} (mg/l)	200	250	12.93	3.24	0.79
NO_3^- (mg/l)	45	50	0.56	0.37	0.16
PO_4^{3-} (mg/l)	–	–	0.36	0.5	0.09
Ca^{2+} (mg/l)	75	50	5.53	7.79	2.94
Mg^{2+} (mg/l)	30	75	2.53	7.09	1.93
Na^+ (mg/l)	–	200	16.83	20.11	17.29
K^+ (mg/l)	–	12	2.08	1.37	2.80
Fe^+ (mg/l)	0.3	0.3	0.3	0.5	0.05
Faecal coliforms (CFU/ml)	Shall not be detectable in any 100 ml sample	–	140	260	90

BIS: Bureau of Indian Standards (2012), *WHO*: World Health Organization (1993)

in the lakes, are presented as box-whisker diagrams (Fig. 8.2). Prevalence of coliforms in all the three lakes was indicative of increasing contamination of the surface water by human excreta. Excessive inputs of organic matter from the surrounding areas as domestic waste, manure and agricultural activities result in profuse growth of the microbes (Krishnakumar et al. 2005b). The risk due to water-borne diseases is directly related to the concentration of waterborne pathogens in surface and drinking water. This assumes significance as Sasthamkotta Lake is the source for water for Kollam and adjacent areas, and Vellayani Lake is the source for water for the urban panchayats in Thiruvananthapuram.

8.2.1 Water Quality Index (WQI)

The water quality index (WQI) is calculated based on the standards prescribed by WHO (1993) for drinking water. The WQI is calculated adopting weighted arithmetical index method, considering 11 water quality parameters (i.e. pH, EC, TDS, HCO_3^- , Ca^{2+} , Mg^{2+} , Na^+ , K^+ , Cl^- , SO_4^{2-} and NO_3^-) in order to assess the degree of contamination and suitability of human use. If the WQI is 50, the water quality is designated as excellent; 50–100 range indicates good water, while WQI in the range 100–200 indicates poor water. The range of 200–300 is indicative of very poor water quality, and >300 indicates that the water is not at all suitable for drinking.

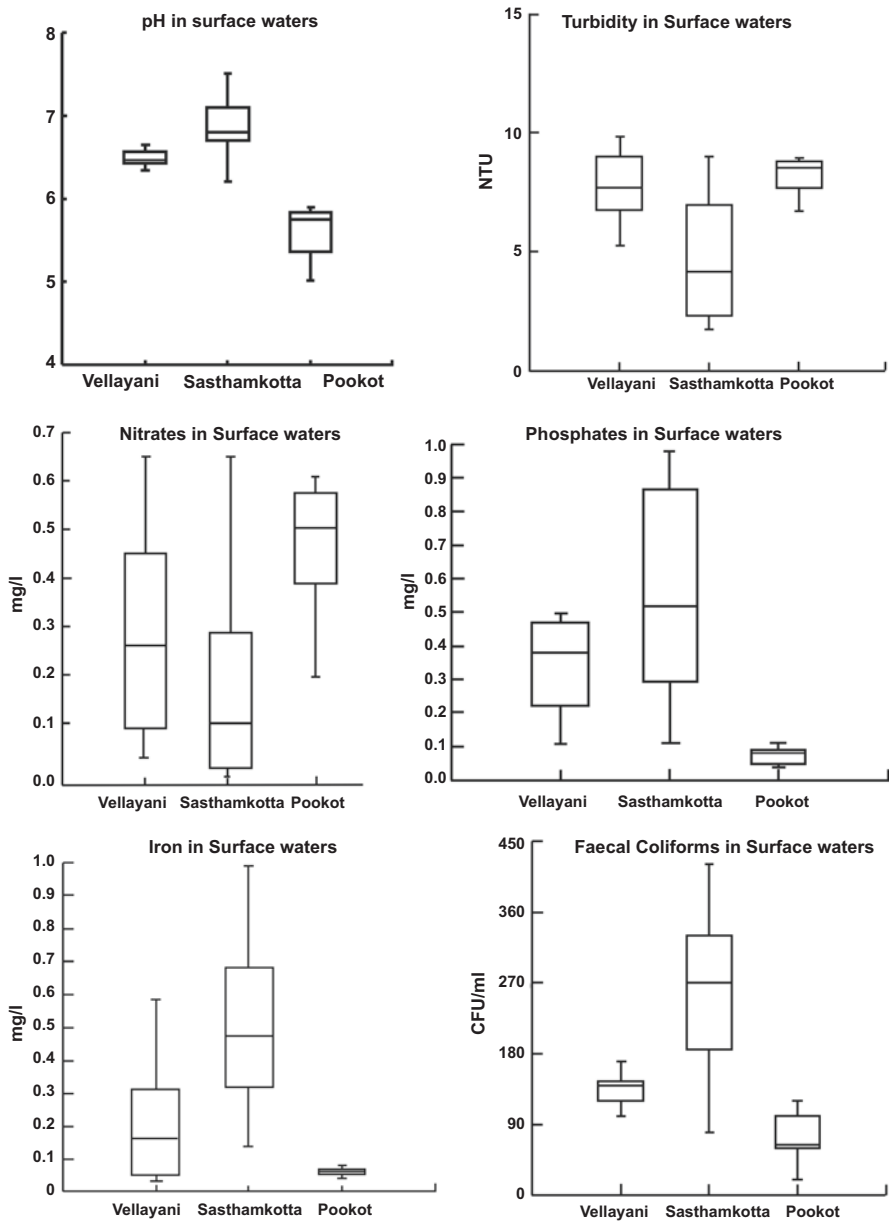


Fig. 8.2 Box-whisker diagrams showing different water quality parameters in the lacustrine wetlands

To calculate the WQI, a weight ranging from 01 to 05 has been assigned for each physico-chemical parameter according to its relative importance in the overall quality of water for drinking purposes. The respective weights assigned are 05 for NO_2 and TDS; 04 for pH, EC, and SO_4 ; 03 for HCO_3 and Cl; 02 for Ca, Na and K; and 01 for Mg (Vasanthavigar et al. 2010). Then the relative weight is computed by the following equation:

$$W_i = w_i / \sum_{i=1}^n w_i \quad (8.1)$$

where W_i is the relative weight, w_i is the weight of each parameter and n is the number of parameters.

The quality rating scale (qi) for each parameter is assigned as per the equation given below:

$$q_i = (C_i / S_i) \times 100 \quad (8.2)$$

where qi is the quality rating, C_i is the concentration of each chemical parameter in each water sample in mg/l and S_i is the WHO standard for each chemical parameter in mg/L.

For computing the final WQI, the SI is first determined for each parameter, which is then used for estimating WQI for each sample:

$$SI_i = W_i \cdot q_i \quad (8.3)$$

$$WQI = \sum SI_i \quad (8.4)$$

where SI_i is the sub-index of i th parameter, qi is the rating based on concentration of i th parameter and n is the number of parameters. Then the computed WQI values were classified into five types, from excellent to water unfit for drinking purposes.

The WQI of the each lake was calculated for assessing the influence of natural and anthropogenic activities (Ramakrishnaiah et al. 2009) based on pH, EC, TDS, HCO_3^- , Cl^- , SO_4^{2-} , NO_3^- , Ca^{2+} , Mg^{2+} , Na^+ and K^+ . In total 20 samples from each of the wetlands (Sasthamkotta, Vellayani and Pookot) were analysed. Based on the WQI (Sasthamkotta 23.67, Vellayani 20.30, Pookot 17.84), majority of the samples in the three wetlands were falling under 'excellent' category with respect to the chemical parameters and suitability for drinking purpose after prior treatments (Table 8.3). But, from the bacteriological point of view, the raw waters of the three lakes are unfit for drinking as they all had high coliform counts. Thus, considering the overall water quality evaluation, it can be concluded that the waters of these wetlands should be thoroughly treated prior to consumption. Treatment processes like aeration (precipitates impurities like iron), coagulation and flocculation (removes turbidity), sedimentation (separates suspended solids) filtration (removes very fine particles of silt, clay and microorganisms including algae, bacteria, viruses, etc.) and disinfection (destroys all disease-producing organisms) are suggested prior to its distribution for drinking purposes (Krishnakumar et al. 2014).

8.2.2 Water Types

The water types in all the three freshwater lakes were determined by constructing Piper trilinear diagrams (Piper 1944) using hydrochemical data (Fig. 8.3). These trilinear diagrams are useful in bringing out chemical relationships among surface water samples in definite terms. In the present study, the Piper plots show predominance of Na-HCO₃ with subordinates of sulphates in Vellayani Lake, Na-HCO₃ type in Pookot Lake and Na-Cl with subordinates of Ca and Mg in Sasthamkotta Lake. Vellayani and Pookot Lakes had excess HCO₃⁻ ions that cause release of alkaline ions, usually Na⁺, into solution by exchange reactions with cation exchangers such as clay and other minerals that form part of the aquifer materials, thereby enriching the waters with Na-HCO₃ as observed elsewhere (Sajilkumar 2013). That indicates that simple mineral dissolution or mixing processes are mainly responsible for the

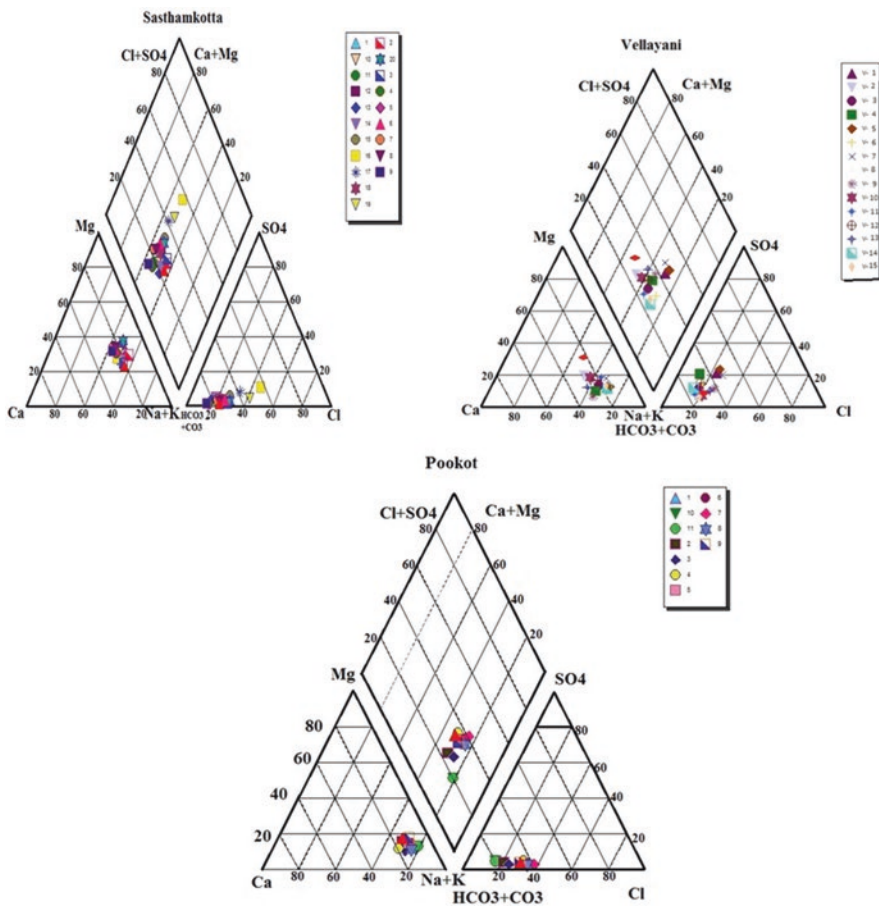


Fig. 8.3 Piper trilinear diagram showing ionic concentration in the lacustrine wetlands

variation of hydro-geochemistry of surface waters in both these lakes. In Sasthamkotta Lake, Piper plots clearly indicate the dominance of Na-Cl species. Due to overextraction of water from the lake, especially in summer, salinity intrusion advances into the lake body, at the same time flushing of the system becoming less effective. The Sasthamkotta Lake is located in the lower stretches of Kallada river basin. Recent studies (Vishnu et al. 2016) reaffirmed that the in-stream and floodplain sand mining in Kallada river basin over the last three to four decades has severely damaged the underground aquifers feeding the lake. Subsequently, seawater intrudes into the coastal aquifers assisted by the overextraction of lake water, as evident from the Piper plot of Sasthamkotta Lake. Earlier studies (Shaji 2013) have also revealed that the rivers of Kerala often experience salinity intrusions into the lower stretches during summer months.

8.2.3 Conservation Implications

The three freshwater lakes (lacustrine wetlands) of Kerala State play vital role in storing rainwater and recharging groundwater. They store large quantities of water during the monsoon and serve as a very useful system in conservation of water, especially in the existing topographical setting of the state. Field investigations reveal degradation of these lakes due to growing problems in and around them. Rapid urbanization is fast shattering the organic structure of the lakes. Fish farming in the lake surroundings is also causing havoc in the ecosystem. Artificial fish feeds and agrochemicals applied in the surrounding agricultural areas of the lakes pollute the lake water. Hence, urgent measures have to be taken to prevent these materials reaching the lakes and for wise use of these precious freshwater resources of the state.

The requirement of water for Thiruvananthapuram City by 2021 is predicted to be around 400 MLD. The existing Aruvikkara and Peppara dams do not have much storage capacity. The Vellayani Lake could be an additional source of drinking water to the capital city and its suburbs. It is inevitable that the Vellayani Lake scheme is undertaken to complement water supply from the existing Aruvikkara scheme. When the scheme materializes, 70 MLD freshwater will be available for distribution in the city, according to the Kerala Water Authority. The future development of Vizhinjam International Seaport is also linked with the better conservation of Vellayani Lake, as it is the prime drinking water source for the same.

8.3 Ashtamudi Lake: An Estuarine Ramsar Site

The Ashtamudi Lake located in Kollam district, a Ramsar Site, is one of the major estuarine wetlands and the second largest backwater system in Kerala (Fig. 8.4). This extensive and deepest wetland of South India, connected to the Arabian Sea, is also important for its hydrological functions and biodiversity. The Ashtamudi

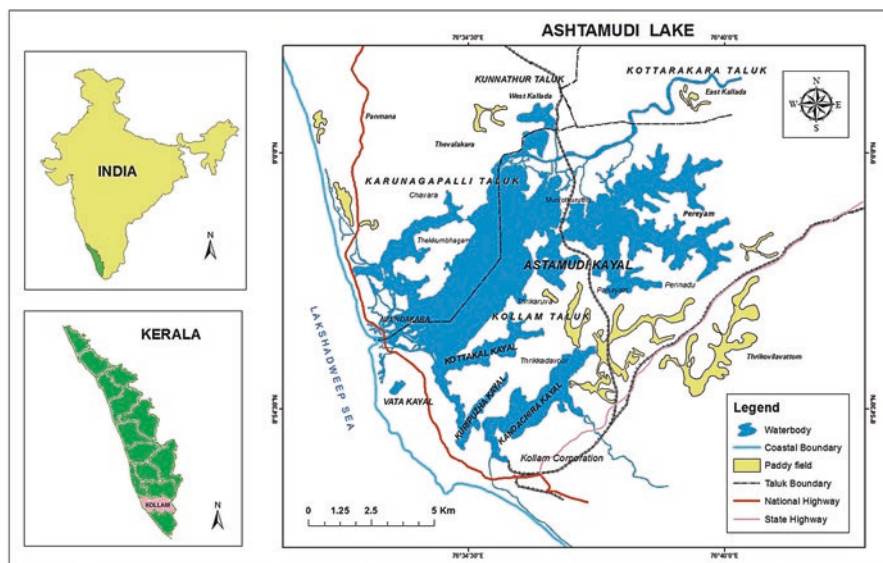


Fig. 8.4 The Ashtamudi Wetland System

Wetland System (AWS) is a palm-shaped waterbody spread over an area of about 32 km². It has many creeks and creeklets, of which eight are prominent ones, all of them together constituting the AWS. The Kallada River originating in the Western Ghats flows westerly and after about 120 km, falls into the AWS.

Population pressure, industrialization and rapid urbanization in and around AWS and the proximity to Kollam town are resulting in degradation of this wetland system. Recent developmental activities brought about elevated levels of heavy metals in the waterbody, and the toxicity and persistency of these pollutants made the system a centre of attention for researchers.

Spatial distribution diagrams related to geochemistry and hydrochemistry of the AWS were prepared in GIS platform using interpolation technique. The spatial variations of organic carbon (OC) and Cr in the sediments of AWS during monsoon and non-monsoon seasons are presented in Figs. 8.5 and 8.6, respectively. The contamination factor (CF: the level of contamination of sediment by metal) of metals indicates that Ashtamudi wetland is moderately contaminated with Cr, Fe, Ni and Cu (Table 8.4). The significant pollution load and spatial variation recorded for some parameters are the reflection of negative impacts of anthropogenic activities. To understand the decadal variation of heavy metal contamination in AWS, a comparison was made with previous data (Table 8.5), and it was found that concentrations of Cr and Cu have considerably increased in the AWS. In contrast to this, Zn level has decreased, which may be due to the leaching of metal from the sediments and the subsequent accumulation in the aquatic biota.

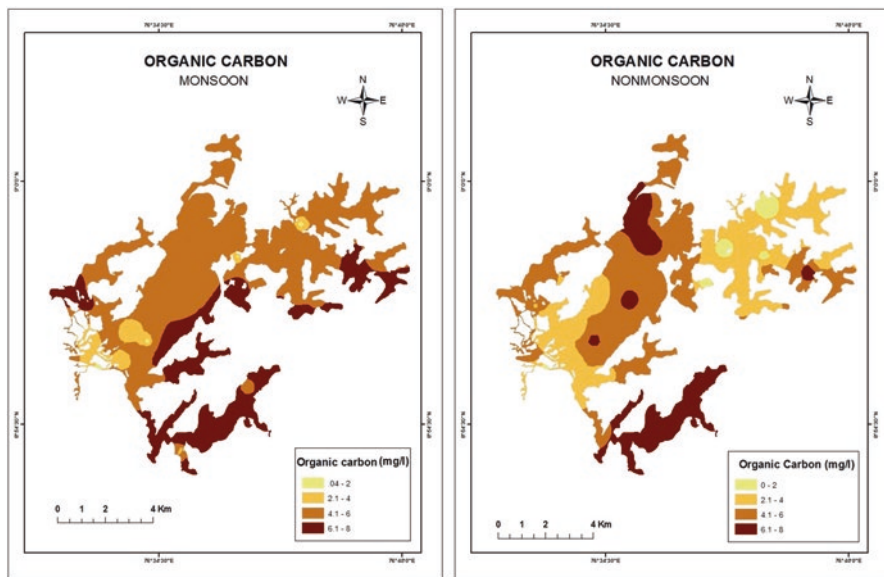


Fig. 8.5 Spatial distribution of Organic Carbon (OC) in surficial sediments of AWS

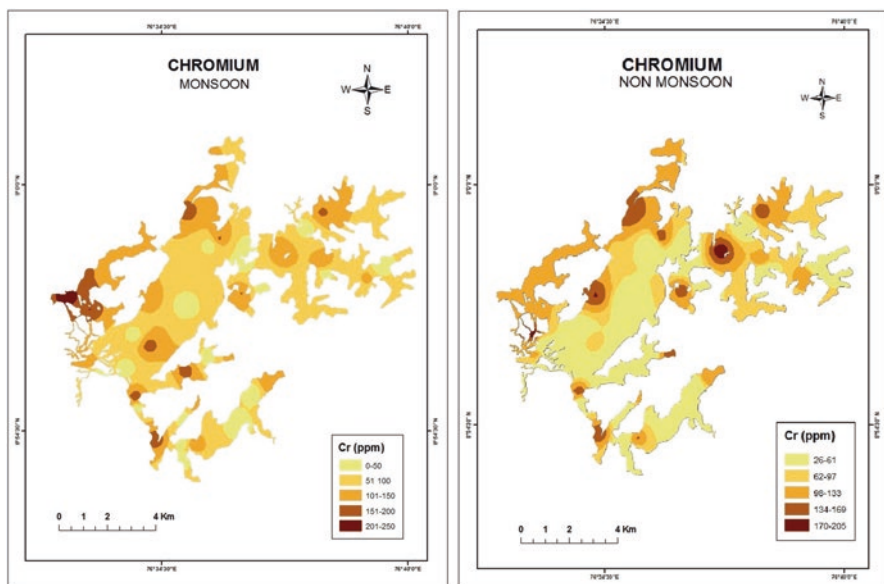


Fig. 8.6 Spatial distribution of chromium in the surficial sediments of AWS

Table 8.4 Observed concentration and contamination factor (CF) of metals in AWS

Sl no.	Elements ^a	Observed ranges of values		World shale average	Contamination factor (CF)		Pollution status
		Monsoon	Non-monsoon		Monsoon	Non-monsoon	
1	Cr	139.4–172.33	126.75–143.66	90	1.55–1.91	1.41–1.60	Moderate
2	Al	0.56–11.58	1.08–10.23	80,000	Negligible	Negligible	NC ^b
3	Mn	0.025–0.08	0.03–0.47	900	Negligible	Negligible	NC ^b
4	Fe	3.72–8.29	3.52–6.88	4.6	0.81–1.80	0.77–1.50	Moderate
5	Co	10–14.2	10–13.2	19	0.53–0.75	0.36–0.77	Low
6	Ni	72.8–99.75	51.4–83.5	68	0.76–1.47	0.76–1.23	Moderate
7	Cu	50.2–70.25	39.4–83.25	45	1.12–1.56	0.88–1.85	Moderate
8	Zn	23.29–73.8	24.7–40	95	0.25–0.78	0.26–0.42	Low
9	Ti	0.56–0.75	0.504–1.08	4,600	Negligible	Negligible	NC ^b

^aAll values are expressed in ppm, except Fe, which is in %

^bNC no Contamination with respect to this element

Table 8.5 Comparative evaluation of heavy metal concentrations in AWS

Elements	Black and Baba 2001 (ppm)	NCESS 2015 (ppm)
Chromium	80–155	136–156
Copper	20–42	59–61
Zinc	57–208	32–49

8.3.1 Water Environment

The nutrient concentration in the AWS is regulated by the freshwater inflow from Kallada River. The nutrient input through the river in non-monsoon season is lesser than that in the monsoon season. However, generally high nutrient inputs from various sources such as coconut husk retting, fish-processing centres, urban sewage and industries located nearby affect the seasonal water quality in the AWS (Table 8.6). In non-monsoon period, reduced freshwater inflow, together with the addition of contaminants in large quantities, depletes the level of DO resulting in subsequent non-oxidation of organic matter. The freshwater inflow into AWS considerably reduces various water quality parameters during monsoon. Earlier studies also have indicated that deterioration in water and sediment quality in AWS is mainly due to input of contaminants through industrial effluents, domestic and municipal sewage, waste disposal and coconut husk retting (Sajan and Damodaran 1981; Narendrababu

Table 8.6 Water quality of AWS

Parameter	Monsoon	Non-monsoon
pH	5.86–8.38	4–8.04
TDS	83–838	464–2,720
TSS	11.7–135.6	53.2–125.6
EC	3.07–32.45	30.9–47.4
Total hardness	96–1,620	4,000–7,400
Calcium	60.12–400.80	320.64–721.44
Magnesium	2.44–299.02	729–1,552.2
Total alkalinity	100–300	500–900
Salinity	18.68–21.25	20.96–72.72
Sodium	123.10–558.6	624–839.7
Potassium	26.20–1,094	114.2–145
DO	5.12–9.07	1.69–6.78
BOD	0.11–5.85	0.089–6.79
Total phosphorus	0.05–0.58	0.07–1.60
PO ₄	0.001–0.08	0.05–0.20
Total nitrogen	0.07–1.75	1.11–2.77
Nitrate, NO ₃ ⁻	0.64–5.20	0.01–1.14
Nitrite, NO ₂ ⁻	0.002–1.30	0.003–0.05
Ammonia	3.03–3.67	0.87–1.72

All values are expressed in mg/l, except EC and salinity, which are in mS/cm and ppt, respectively

et al. 2009). The spatial variations of DO and ammonia in AWS during monsoon and non-monsoon seasons are presented in Figs. 8.7 and 8.8, respectively.

The Centre for Earth Science Studies (CESS) had taken up a study for developing a management plan for Ashtamudi Estuary during 2001. The study reveals that most of the areas surrounding the AWS are used for coconut husk retting, a major occupation of the people in the area, which reduce the pH and DO in the waters (Black and Baba 2001). The recent report of National Centre for Earth Science Studies (NCESS 2015) also revealed that this occupation is continuing in the environments of AWS, resulting in production of hydrogen sulphide from the rotting husk waste. Even though sparingly soluble in water, hydrogen sulphide lowers the pH. Moreover, due to degradation of organic matter by microbial activity, anoxic conditions prevail in this area, and consequent upon the release of organic acids, further reduction in pH is observed. The DO and BOD levels are also adversely affected due to the oxygen demand associated with the decay and breakdown of the coconut husks. This is a testimony of the unscientific use of wetland systems, in spite of its high potential for providing various goods and services.

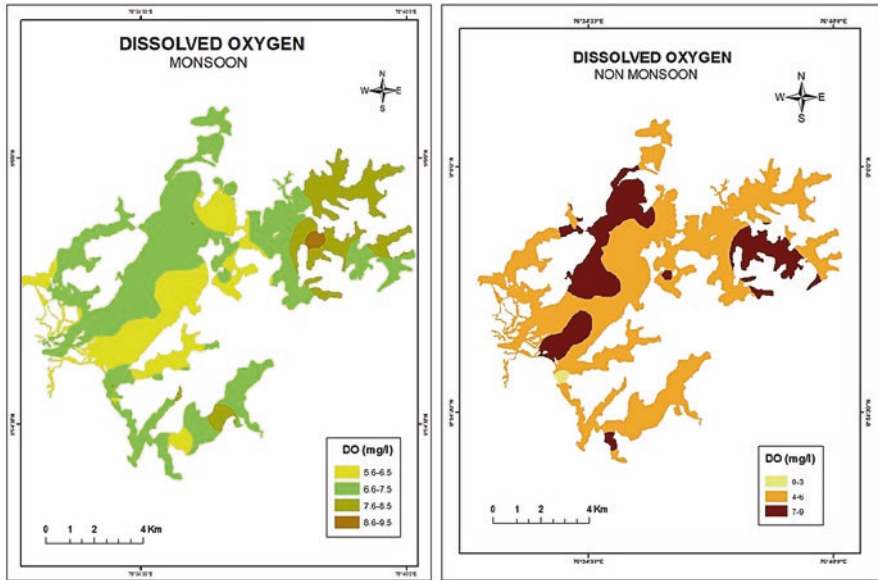


Fig. 8.7 Spatial distribution of Dissolved Oxygen in surface waters of AWS

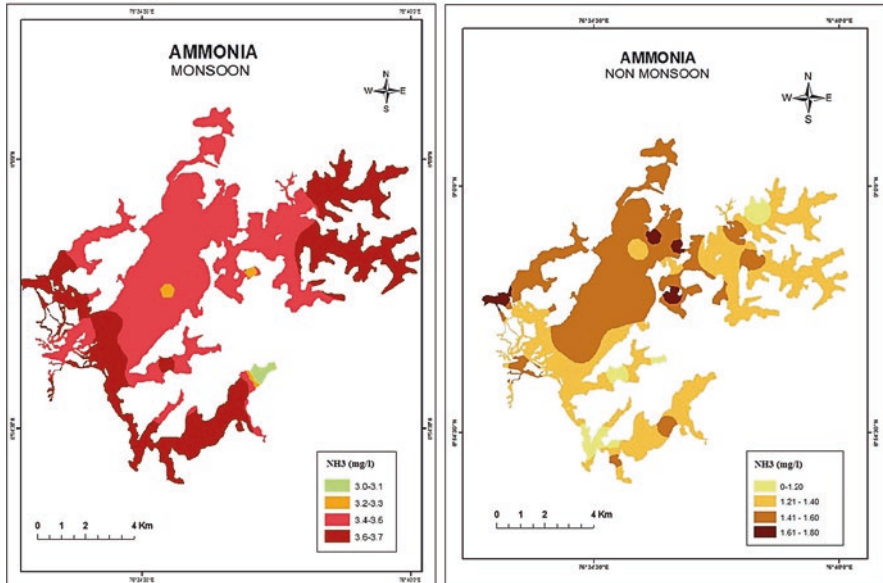


Fig. 8.8 Spatial distribution of ammonia in surface waters of AWS

8.4 Conclusion

Wetlands are the mirrors of nation's ecological wealth and often considered to play a vital role in ensuring social and economic development. The water quality and geochemical characteristics of selected wetlands of Kerala, namely Vellayani Lake, Sasthamkotta Lake and Pookot Lake (three important lacustrine wetlands) and Ashtamudi Wetland System (estuarine wetlands comprising Ashtamudi main lake, Chavara *Kayal*, Kureepuzha-Kandachira *Kayals* and Kumbalathu-Kanjirakottu *Kayals*) in the state have been examined in terms of its hydro-geochemical characteristics and the salient results are highlighted in this chapter. Studies revealed that the pace of urbanization and other anthropogenic activities around the wetlands impose notable changes in the hydro-geochemical characteristics of these natural water bodies, thus deteriorating the health of the ecosystems. Available information emphasizes the need for sustainable management measures for all these wetlands, together with continuous monitoring of sediment and water quality of the different subsystems. Location-specific plans are very much needed for effective conservation and management as well as for sustainable utilization of the important wetland systems in the state.

Acknowledgement The authors wish to express their gratitude to Director T. N. Prakash, NCESS, for the encouragement and support. The help provided by Dr. Anoop Krishnan and Dr. Reji Srinivas during the fieldwork is hereby revered. The financial assistance provided by the Department of Ports and Fisheries, Government of Kerala, for the estuarine wetland studies is gratefully acknowledged.

References

- Black K, Baba M (eds) (2001) Developing a management plan for Ashtamudi Estuary, Kollam, India. ASR Limited, New Zealand and Centre for Earth Science Studies, India
- Bureau of Indian Standards (2012) Drinking water- specification. <http://bis.org.in/>. Accessed 15 Jan 2015
- Das R, Krishnakumar A (2015) Recent hydrochemical characterization of the tropical lacustrine ecosystems of Kerala. In: Siji VL (ed) REACS-2015: recent and emerging advances in chemical sciences, Thiruvananthapuram, India, 8–9 January 2015, ISBN 978–81–930193-0-6
- Krishnakumar A, Baijulal B, Unnikrishnan P, Baiju RS (2005a) Qualitative hydrogeochemical evaluation of two aquatic bodies of Kerala, India with special reference to environmental management. *Ecol Environ Conserv* 1(3–4):521–526
- Krishnakumar A, Sobha V, Padmalal D (2005b) Status of nutrients and heavy metals in the recently deposited sediments of Vellayani freshwater Lake, Kerala, South West coast of India. *Ecol Environ Conserv* 11(2):235–240
- Krishnakumar A, Sobha V, Padmalal D, Baiju RS, Baijulal B (2006) Hydrogeochemical characterization and socio-environmental implications of Vellayani freshwater Lake, Southern Kerala, India. *J Eco-Chronicle* 1(1):35–46
- Krishnakumar A, Vinduja V, Menon SN (2014) Decadal changes of water quality in Vellayani lake, Kerala – implications of climate change, In: Compendium of the National seminar on Spatial technologies for Watershed Planning, Kerala State Land Use Board, Thiruvananthapuram, India, 8–9 Jan 2014

- NarendraBabu K, Omana PK, Mohan M (2009) Water and sediment quality of Ashtamudi estuary, a Ramsar site, Southwest coast of India-a statistical appraisal. *Environ Monit Assess* 165:307–319
- National Centre for Earth Science Studies (2015) Environmental studies of Kollam-Neendakara wetlands and associated inlands. Project report submitted to the Department of Port and Fisheries. Govt. of Kerala, India
- Padmalal D, Kumaran KPN, Nair KM, Baijulal B, Limaye RB, Vishnu Mohan S (2011) Evolution of the coastal wetland systems of SW India during the Holocene: evidence from marine and terrestrial archives of Kollam coast, Kerala. *Quat Int* 237(1–2):123–139
- Piper AM (1944) A graphic procedure in geochemical interpretation of water analyses. *Trans Am Geophys Union* 25:914–923. doi:[10.1029/TR025i006p00914](https://doi.org/10.1029/TR025i006p00914)
- Ramakrishnaiah CR, Sadashivaiah C, Ranganna G (2009) Assessment of water quality index for the groundwater in Tumkur Taluk, Karnataka State, India. *E-J Chem* 6:523–530. doi:[10.1155/2009/757424](https://doi.org/10.1155/2009/757424)
- SAC (2011) National wetland atlas. Ministry of Environment and Forest, Ahmedabad, p 334
- Sajan K, Damodaran KT (1981) Studies on the distribution of organic matter content in sediments of Ashtamudi lake, Kerala. *Bull Dept Mar Sci Uni Cochin* 12:155–160
- Sajilkumar PK (2013) Interpretation of groundwater chemistry using piper and chadha's diagrams: a comparative study from Perambalur taluk. *Elixir Geosci* 54:12208–12211
- Shaji EJ (2013) Groundwater quality management in Kerala. *Int Inte Res J* 3:63–68
- Unni KS (ed) (2002) Conservation and management of aquatic ecosystems. Daya Publishers, New Delhi
- Vasanthavigar M, Srinivasamoorthy K, Vijayaragavan K, Rajiv Ganthi R, Chidambaram S, Anandhan P, Manivannan R, Vasudevan S (2010) Application of water quality index for groundwater quality assessment: Thirumanimuttar sub-basin, Tamilnadu, India. *Environ Monit Assess* 171:595–609. doi:[10.1007/s10661-009-1302-1](https://doi.org/10.1007/s10661-009-1302-1)
- Vishnu M, John SE, Rajimol TR, Maya K, Sajan K, Padmalal D (2016) Human interventions and consequent environmental degradation of a protected freshwater lake in Kerala, SW India. *Geosci J* 20(3):391–402
- World Health Organization (1993) Guidelines for drinking water quality. www.who.in/. Accessed 15 Jan 2015