ABSTRACT

The indiscriminate exploitation of wetlands beyond its supportive capacity, and input of residues exceeding its assimilative capacity, pollutes the wetland system of Kerala state of India, the magnitude of which is very alarming. The Vembanad wetland system is a complex aquatic system of coastal backwaters, lagoons, marshes, mangroves and reclaimed lands with an intricate network of natural and man made channels and its associated drainage basins are situated in the humid tropical region on the south west coast of the Indian peninsula. Numerous studies have demonstrated that wetlands in general are sinks for various pollutants. Pollution in the wetland is attributed to industrial, urban and agricultural effluents from the city of Kochi and adjoining areas. The environmental status of this wetland including the water and sediment quality had been carried out in the present study. The wetland is an important water body formed by backwaters, estuaries, lagoons and canals, spreading over 196Km in the north-south direction and 29Km in the east-west direction, play an important role in hydrologic functions. Hence the study also focuses on the distribution of various natural isotopes in the wetland system and its use in identifying the source of pollution.

The study on the spatial and temporal variation in water quality of Vembanad Lake indicated that the physico-chemical and microbiological status of the wetland system had been worsened by pollutants. The source of major cations and anions in the system is mainly from the saline contribution of Cochin estuary. Nutrient level in water is as high to cause eutrophication in the system, which is reflected by hypereutrophic stage in many parts of the water body. The sewage running through the open canals of Alappuzha contributed high amount of inorganic and organic components to the water body. The dewatering from the agricultural areas also causes damage to physical and chemical quality of water. The improper management of Thanneermukkom bund flushes high concentrations of ions to the fresh water region which poses threat to the paddy fields. Absence of dissolved oxygen in some sites in the southern part of Thanneermukkom bund is a major threat to the aquatic organisms. The microbiological contamination of the lake is caused by domestic sewage, tourist boats and other anthropogenic activities. In monsoon no stations were free of Escherichia coli. The uncontrolled playing of house boats discharges organic wastes, which is threatening the system with very high amount of oil and grease. With respect to the drinking water guidelines, most of the groundwater samples in the basins of Vembanad Lake were not found to be good for drinking.

Chemical classification of wetland system based on Wilcox and USSL diagrams were carried out. The different chemical characteristics such as sodium absorption ratio, sodium percentage, soluble sodium percentage, Kelly’s ratio, magnesium hazard ratio, residual sodium carbonate, chloro-alkaline index and permeability index of the surface and groundwater samples were calculated. Hydrochemical facies showed sodium-calcium-chloride-bicarbonate type for most of the groundwater and sodium-chloride for most of the surface water. Indices of Base Exchange indicated cation exchange in groundwater samples.
The geochemical analyses of different core sediments collected from Vembanad Lake revealed that the lake is blanketed with highly nutrient rich sediments, which are polluted by heavy metals like manganese, nickel, copper, zinc, cadmium, lead, mercury and chromium. Determination of the texture of the sediment indicated various proportion of silt and sand in different regions of the wetland system. There was high accumulation of organic matter. The variation of C/N ratios in the sediment core indicated maximum contribution of terrestrial sources and a few aquatic sources towards organic matter. Determination of nutrient concentrations revealed a hypereutrophic stage of the lake with vertical increase in the deposition of major anions. The relative concentration of major exchangeable cations indicated the variability in ion exchange capacity of sediments in different regions of wetland system. Phosphorous fractionation study revealed more contribution of organic phosphorous in the region close to Alappuzha town and more inorganic phosphorous near the agricultural area. Examination of pesticides in sediments revealed high concentration of chlorinated pesticides in the wetland system.

Most of the heavy metals reported enrichment towards the surface of the core sediment and its concentration is very alarming in the Cochin side. Quality of the sediments were evaluated based on Sediment Quality Guidelines, Pollution Load Index, sum of Toxic Units and with Effect Range Low/Effect Range Median and Threshold Effect Level/Probable Effect Level values of Environmental Protection Agency guidelines. The degree of contamination for each station was determined. The concentrations of different heavy metals were compared with world average concentration of shale values. Statistical analysis showed correlation among different parameters. The analysis of the core collected from the estuarine region of the wetland confirmed the role of Cochin industrial belt in determining the pollution status of the southern region of the wetland system. The concentration of heavy metals in some stations exceeded the effect range median levels, which represents a probable effect range with in which adverse biological effects frequently occur. The spatial variation of heavy metals showed more contamination in the downstream at Pathalam industrial site. The present study highlighted severe heavy metal contamination of wetland system with increased rate of deposition.

The heavy metals (iron, manganese, nickel, cadmium, copper, zinc, mercury, lead and chromium) were quantified in certain native aquatic macrophytes (*Eichornia crassipes, Sacciolepis interrpta, Alternanthera philoxeroides, Salvenia molesta and Pistia stratiotes*) of Vembanad wetland system. The results indicated that the concentration of all the heavy metals were high with maximum concentration in the roots of *Alternanthera philoxeroides* except mercury which is high in leaves, and minimum value in the stem of *Sacciolepis interrpta*. Comparison of the heavy metals with the background concentration of sediment showed more chromium and mercury in *Alternanthera philoxeroides*. The species *Sacciolepis interrpta* and *Pistia stratiotes* reported minimum uptake of heavy metals. The concentration factor calculated showed the comparative suitability of different macrophytes among the selected plants as biomonitor for specific heavy metal. *Eichornia crassipes* is the suitable biomonitor for iron, *Alternanthera philoxeroides* for manganese, nickel, lead, cadmium, chromium and mercury and *Salvinia molesta* for copper and zinc.
Seasonal and spatial variations in the stable isotopic composition of natural water were investigated in Vembanad wetland system. The precipitation samples of the area follow the equation $\delta D = 5.32\delta^{18}O + 9.0$. The stable isotopic composition of precipitation showed seasonal and amount effect. The lake water has the most enriched values of $\delta^{18}O$ and $\delta^2H$ in the pre-monsoon season. But in the monsoon season the water samples were relatively depleted in isotopic composition. The spatial variation of $\delta^{18}O$ showed most enriched value at the station Thanneermukkom north, through which saline water enters to the fresh water region. The highest enriched value of $\delta^2H$ was observed at the station Kanavattinkara, where the lake is stagnant with high rate of evaporation. The slope of the best fit line to all groundwater data in $\delta^{18}O$-$\delta D$ plot is 6.5 with a $d$-excess of 7.3‰. The study to understand interconnection between surface and subsurface water identified three groups of samples. The $\delta^{34}S$ value of sulphate showed a disparity from +10.5‰ to +23.9‰. A plot of sulphate concentration against $\delta^{34}S$ revealed that, the station Thanneermukkom has marine contribution whereas the station Cherukarakayal has marked difference from the range of other stations. Recent sedimentation rate of the lake determined using $^{137}$Cs dating technique was found to be 0.51 cm/year.

**Key words:** Vembanad wetland system, Aquatic macrophytes, Heavy metals, Delta values, Precipitation, Sedimentation rate.