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WETLANDS OF KERALA: DEGRADATION, RESTORATION AND FUTURE MANAGEMENT-A CASE STUDY OF KAVVAYI WETLAND-A COASTAL WETLAND IN THE NORTHERN KERALA

P S Harikumar
Senior Principal Scientist
Centre for Water Resources Development and Management
Kozhikode(Calicut) Kerala 673571
E Mail: hps@cwrdm.org, Tel: 04952383736 Mobile:09847781444
Web: http//www.cwrdm.org

Wetlands provide fundamental ecological services and are regulators of water regimes and sources of biodiversity at all levels – species, genetic, and ecosystem. It constitutes a resource of great economic, scientific, cultural, and recreational value for the community. Wetlands play a vital role in climate change adaptation and mitigation. Progressive encroachment on and loss of wetlands can cause serious and sometimes irreparable environmental damage to the provision of ecosystem services. Kerala is located on the southernmost tip of India and embraces the coast of Arabian Sea on the west and is bounded by the Western Ghats in the east extending from 8^0 17' and 12^0 48' north latitude and 74^0 51' and 77^0 20' east longitude with total area of 38, 916 sq km.Studies carried out in recent years have pointed out the unfavorable changes taking place in the physicochemical, biological and geological environment of the wetlands of Kerala. They are facing severe environmental problems including loss of areal extent due to anthropogenic pressure, over exploitation of its resources and reduction of its carrying capacity. A classic example is the Vembanad-kol wetlands which once covered an area of 2033.02 km2 and its river basins spread over 6126.48 km2 area. The area of Vembanad Lake during 1917, 1970 and 1990 had declined to an extend of 290.85 km^2, 227.23 km^2 and 213.28 km^2 respectively (Gopakumarand Takara, 2009). A total of 63.62 km^2area had reclaimed from the lake during the period 1917-1970, was primarily for formation of polders and to enlarge the extent of the Wellington island and Cochin PortThe wetlands of the State are classified into two broad categories namely Inland and Coastal wetlands. The total area under wetlandswas calculated as 127930.07 ha, out of which the inland wetlands cover about 34199.57 ha and the coastal wetlands about 93730.50 ha(MoEF, 1990). Recent areal estimates by various agencies on wetland categories including water-spread area, aquatic vegetation and turbidity show that there are 1762 wetlands in the state. In addition, 2592 wetlands smaller than 2.25 ha had also been identified Thus the total wetland area estimated was 160590 ha. The major wetland types included were River/Stream (65162 ha), Lagoons (38442 ha), Reservoirs (26167 ha) and Waterlogged (20305 ha) areas.The beauty and purity of the wetland is needed to protect it in a wise use concept under Ramsar Convention (Ramsar, 2007).The wise use of wetlands is defined as "the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development". Vembanad-kol, Ashtamudi and Samsthamkotta, are already designated as Ramsar sites in Kerala. In addition to this, two more wetlands - Kottuli in Kozhikode District and Kadalundi in Kozhikode and Malappuram Districts - have been identified by the Ministry of Environment and Forests, Government of India, under National Wetland Conservation Programme. In this paper, we discuss the degradation, conservation steps and management action plans of Kavvayi Lake, a wetland in the Western Ghats of Kerala.

Kavvayi Wetland, a large coastal backwater body spread out in northern Malabar in Kerala,is located in the humid tropical climatic region of the State where rainfall is the predominant climatic factor. The average annual rainfall of the Kavvayi Wetland System is about 3112.3 mm. The south-west monsoon contributes about 86%, north-east monsoon about 8.7% and non-monsoon period during December to May contributes about 5.3% of the annual rainfall. Thus the rainfall is highly seasonal, with heavy dependence on the six month period from June to November. Kavvayi Wetland System consists of the Kavvayi backwater body and five west flowing rivers originate from the Western Ghats and draining to the wetland viz. Nileswar, Kariangode, Kavvayi, Peruvamba and Ramapuram.

The Kavvayi Wetland System (including basin area of five rivers draining to the wetland) has a geographical area of 1264.62sq.km. Out of the five rivers, Kariangode basin is the largest and Ramapuram is the lowest. The annual discharge to the wetland from five rivers is about 4351MCM, of which more than 94% of their annual discharge is during monsoon and remaining 6% only as non-monsoon flows. The flow duration analysis of the rivers indicated that about 50% of the time, these rivers have very negligible flows. The water balance study of all the five river basin draining into the Kavvayi Wetland shows a water surplus on annual basis. Whereas, the basins shows water deficit during the non-monsoon periods in meeting all the water demands. Hence, a system approach is necessary for arriving at an appropriate decision with regard to the optimal utilization of fresh water within the river basins.

The bathymetric survey reveals that the water spread area of Kavvayi Wetland at mean sea level is 9.1 sq.km. The maximum and minimum depth of the Wetland body is 8.9 m and 0.5 m respectively. The maximum depth of the wetland body is observed near to the estuarine. The maximum and minimum width of the Wetland body is 1754.12 m and 155.81 m respectively. The width of the wetland body at estuarine is about 421.31 m. The volume of the Wetland at MSL is estimated at 31.58 MCM. The bathymetric survey reveals that the present lake water spread area is 9.1 sq.km at MSL and corresponding lake volume of 31.58 Mm^3.The water balance study of Kavvayi wetland reveals that the average annual inflow from the total drainage area of the wetland is 4351MCM, which is equivalent to an average annual surface inflow rate (Si) of 138m3/sec. The mean annual precipitation in the wetland and the mean annual evaporation from the wetland is estimated a 3112 mm/year and 1430 mm/year. The average annual outflow from the wetland to the Arabian Sea is about 138.62 m^3/sec or equivalent to an annual volume of 4371.5 MCM. The long term mean water residence time in the Kavvayi lake and turnover rate are estimated as 2.6 days and 139 days/year, respectively. It is seen that, there is a considerable seasonal variability in water residence time within the Kavvayi lake system.

Kavvayi wetland is rich in biodiversity. A sacred grove viz. Edayilakkad island preserves many rare and endemic species. One of the endangered species of bird, White bellied sea eagle and Nervilia species are endemic to Malabar region are also found in this region. The wetland area is rich in mangroves and mangrove associates. Kavvayi wetland acts as fertile ground for many migratory birds.

The physico chemical and biological characteristic of the wetland is directly influenced by the rivers draining into the wetland system. The quality of surface water is interpreted through the Canadian Council of Ministers of the Environment (CCME) Water quality Index. Most of the sampling stations of the Kavvayi Lake show poor water quality according to the Canadian Council of Ministers of the Environment Water quality Index. The various ionic concentration of the river reported comparatively high value in the downstream stations.Similar trend as that of Kavvayi Lake was also observed for the physico chemical parameters of rivers draining into it. The concentrations of physico-chemical parameters of all the five rivers were very low in monsoon season; it may due to the dilution effect.The maximum value of BOD was observed for the surface water sample collected from Kokkinisseri of Peruvamba River. Bacteriological contamination is prevailing in most of the surface and groundwater samples of Kavvayi wetland system.

Heavy metals such as Fe, Mn and Cu were present in almost all the soil samples. According to Canadian Environmental Quality Guidelines for soil quality, some of the samples collected from Kokkal, Thekkekkad and Edayilakkad were found to be contaminated with cadmium and lead. Cation Exchange Capacity of sample collected from Kokkal Island was also high which indicates that heavy metal concentration increases with Cation Exchange Capacity. Soil Texture analysis reveals that most of the soil samples are sandy and maximum clay content was found in samples collected from Kokkal Island. Organochlorine pesticides like Aldrin and Endo- alpha were also detected in the soil samples of Kavvayi Wetland System.

Physico-chemical analysis of surface sediment samples collected from Kavvayi wetland systems indicated that all the samples except one was alkaline. The sample collected from Edayilakkad reported a pH of 3.01. Concentrations of chloride, sulphate, exchangeable sodium, exchangeable potassium, exchangeable calcium and exchangeable magnesium were found to be higher in the sediment samples. Texture analysis indicated that all the samples were sandy type.
Heavy metal analysis of the sediment samples indicated the presence of iron, manganese, copper, lead, cadmium, nickel and zinc in the surface sediments. As per USEPAsediment quality guideline, (KV-6) Ayittikadavu is heavily polluted with lead,

nickel and copper. Mixing Point of Kavvayi River in to lake (KV-2) was heavily polluted with nickel and lead. All the sediment samples except two at stations (KV-9 and KVE-1) were found to be heavily contaminated with lead.

The degree of contamination (Cd) of three stations, KV-2 (mixing point of Kavvayi river into Lake), KV-6 (Ayittikadavu), and KV-11 (mixing point of Nileswar River into Kavvayi Lake) indicated considerable degree of contamination. Sampling stations KV-1, KV-13, KVVP-1 and KVPB-2 were found to be moderately contaminated and all the other stations showed low degree of contamination.

Sediment samples were found to be contaminated with organo chlorine pesticides. Aldrin, Endo-alpha and Endo-beta were detected in sediment samples. Major fraction of sedimentary inorganic phosphorous in surface sediment consisted of NaOH-P (Fe-bound and Al-bound phosphorous) whereas HCl-P (Ca-bound phosphorous) constituted only a minor fraction. Higher concentration of organic phosphorous was also detected. Phosphorous release was from Fe-bound, Al-bound and from organic fractions. Hence in Kavvayi Lake, there can be a choice of considerable release of phosphorous from sediments into surface water.

A study was done to assess the core sediment quality and surface water quality of selected stations of Kavvayi wetland system. Physicochemical characteristics of sediment samples showed that chloride concentration was found to be high which may be due to the salinity intrusion and detected comparatively at a high concentration in Puthiyapuzhakara. A regular trend was observed for cations and anions. Most of the cations were present in the surface sediments and its concentration decreases towards the bottom. Most of the samples from the three stations of Kavvayi wetland system have comparatively high organic matter content. Organic carbon decreases from surface to bottom in all stations. The highest concentration of organic carbon was found in Puthiyapuzhakara. The concentration of inorganic and total phosphorus was found to be high in the bottom portion of the lake. Majority of the sample in the Kavvayi wetland was found to be in sandy (95%) nature. Samples collected from mixing point of Kariyamkode River into Kavvayi Lake had maximum clay content. Heavy metals such as Fe, Mn, Cu, Pb were present in all the samples. Cd was only present only in 24-28cm layer in station (Mixing Point of Kavvayi River into Kavvayi Lake). When compared with USEPA sediment quality guidelines, it was found that mixing point of Kavvayi River into Kavvayi Lake was highly contaminated with Cd and mixing point of Kariyamkode River into Kavvayi Lake and Puthiyapuzhakara was highly contaminated with Ni, and Lead. Statistical analysis was also done to ascertain sources that affect heavy metals distribution in the wetland, inter- elemental Association was evaluated using the Pearson correlation coefficient.

Physicochemical status of the surface water samples indicated that all the surface water samples collected were found to be within the BIS limit. . The high electrical conductivity values may be attributed to the presence of dissolved solids in the water. The maximum EC value of 49800 µs/cm was recorded at site KVL-04. The low value of chloride was recorded at KVL-01 could be due to the fact that the particular site is away from the intrusion of the sea water. Among the seven water samples, chemical parameters such as chloride, calcium, magnesium showed higher values in sample KVL-04 (Puthiyapuzhakara). The highest value of sodium was measured at site KVL-03 it may be due to salinity intrusion. The high potassium level recorded at KVL-03 was an indication of the influence from domestic discharge and agricultural effluents especially from fertilizers containing potassium which can be leached through soil run off into the lake. By measuring dissolved oxygen levels it was found that the wetland supports aquatic life. Bacteriological analysis revealed that all samples were contaminated with Total Coliform and Faecal coliform. Among all these station only KVL-06 (Neeleswaram) showed E.coli contamination. As the spatial and vertical distributions of elements in sediments in creek environment are influenced by so many factors including geochemical and biogeochemical process like sedimentation, precipitation and flocculation particulate substances and hence it is difficult to find the principle one. Present study shows that the vertical concentration of elements is not varying remarkable which indicates that there is a continuous and same source. Pollution load index indicated that the sampling station taken for our present study was not polluted, but it was contaminated with Lead and Cadmium. It is however suggested that heavy metal contamination (pollution) of the wetland should be checked and monitored regularly for environmental pollutions. Due emphasis need to be given to the study of metal distribution, so that contribution of manmade and natural effects may be assessed.

Fed by five rivers and spotted with small islands, Kavvayi wetland is considered as the biggest wetland ecosystem of North Kerala, spreading across an area

of 1264.62 sq km. The wetland body stretches from Kavvayi near Payyannur to Neeleswaram in Kasaragod and is under threat of pollution, land filling, wetland encroachment, destruction of mangrove forests, sand mining, etc. By bringing in strict protective regulations, a long term demand of nature lovers, the illegal mining and reclamation activities could be kept at bay. Kavvayi is an important wetland system and the government should take immediate steps to bring it under nationally important wetland and Ramsar Convention sites. A well functioning wetland provides fish and wildlife habitat, water quality protection, natural floodwater storage and reduction in the erosive potential of surface water. A degraded wetland is not able to effectively perform these functions. Human activities cause wetland degradation and loss by altering water quality, quantity and flow rates. The most important threat to the coastal backwaters is the upstream anthropogenic activities, which exert stress on the downstream area. Increasing pollutant inputs and changing species composition can be the result of the introduction of non-native species. These disturbances can be minimized with strong co-operation between the downstream and upstream population along with the related authorities in restoring the valuable wetlands.

The Kavvayi Wetland system has been facing threat from land reclamation. The environmental problems identified in the catchment area of the wetland include: sand mining, laterite mining, unscientific development of tourism, over exploitation of minerals and resources, aquatic weeds which multiply very quickly and cover the water bodies, destruction of mangroves and unscientific construction of bunds that have been posing a threat to the biodiversity of the wetland which is home to some rare species of hydrophytic plants, birds and fishes, urbanization or anthropogenic pressure and community pressure for fuel, food and fodder. The other major threats include; dumping of wastes, coconut husk retting, sand and shell removal, weed choking, waste disposal by intensive aquaculture, agricultural practices along the catchment area.The impact ofclimate change in the wetland ecosystem has to be undertaken as long measure. This in turn is leading to shallow wetland areas to being swamped and some dwarf species of mangrove trees being submerged and drowned. The primary pollutants causing wet-land degradation are fertilizers, human sewage, animal waste, pesticides, heavy metals etc.

The wetland is located in one of the most populous coastal segments of the Malabar Coastline of India. Most of the people in the Kavvayi islands have adapted to the beneficiaries of this wetland as their livelihood. Fishing and artificial mussel culturing is one of the important income sources of the inhabitants in the Kavvayi wetland islands. Boat services and coir retting also provide earning for common man. Tourism is one of the fast growing sources of revenue. Various activities of tourism development are going on in the various areas of the wetland and are also giving way to gradual sustainable development of economic infrastructure of the wetland.

The goal of management planning for Kavvayi wetland system is to conserve its rich biological diversity and maintain full range of ecosystem services derived from the wetland system in order to sustain livelihoods of dependent communities. The purpose is to put in place effective management practices which enable integration of biological diversity, ecosystem service values in river-basin, ecological and economic security of the people dependent on the wetland resources and coastal zone level conservation and developmental planning. In order to achieve this, management planning has been organized along with the subcomponents, via land and water resources management, biodiversity conservation, ecotourism development, livelihood improvement and institutional development.

Desired stages in the Management Action plan of Kavvayi Wetland System include:

- Create awareness for the inhabitants and the concerned administrative bodies about the need of a MAP for Kavvayi Wetland
- Institutional arrangement for execution of the MAP
- The designated authorities support the institution to help in achieving the goals and objectives proposed in the MAP
- Monitoring and evaluation of the progress in the implementation of MAP objectives
- Achievement of the MAP goals resulting in an improved Kavvayi Wetland System

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