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SUMMARY AND CONCLUSION

Estuaries in tropical areas are important receptors of many persistent pollutants, including heavy metals. Reworking and diagenesis of contaminated sediment release heavy metals, which cause continued inputs into the aquatic environment even after cessation of the industrial source. Therefore, sediments contaminated with heavy metals act as both carriers and potential pollution source of metals in aquatic environment. In this study, an attempt has been made to create baseline information on current status of heavy metals, their presence, distribution and the triggering factors such as sulphur chemistry and hydrological characters of Vembanad Lake System (VLS). The hydrology of the system is so peculiar which govern chemical property of the aquatic environment.

The analysis of metals in water samples indicate: the level of mercury is lower than the PEL limit in all the seasons. In northern zone the level of cadmium was found to be more at surface water than that of bottom water, but the value crossed the US EPA Criterion Maximum
Concentration (US EPA CCC-CMC) and within the WHO limit. The Lead concentration was found more in bottom samples. The increased concentration observed at bottom water samples might be due to the mixing of the sedimentary environment to its immediate water column. The higher concentration of metals was observed at post-monsoon season, which might be because the less dilution of the system to the weak flushing and absence of horizontal mixing.

Sediment parameters exhibit distinct pattern of the distribution of metals. The hierarchical cluster diagrams suggest all metals except mercury have a common origin. In terms of contamination, cadmium is the metal with utmost risk in this study area. While considering the region wise distribution of metals in sediment, northern zone of the lake contributes the lion-share of concentration. The concentration for Hg observed in sediments was much lower than the report by Ouseph (1992). The high turn down in Hg concentration in the sediments as observed in the present study may be due to reduction in sediment input in the recent years and re-suspension of contaminated sediment with low Hg content.

Higher concentration of cadmium was observed in industrial outfall regions. The elevated values of cadmium in northern zone attributed to the industrial discharges particularly fertilizer and pesticide manufacturing units located at the bank of Periyar river and its lower reaches. Concentration of lead is found prominent during the dry seasons, due to less flushing and dilution of the lake. During monsoon and post-monsoon season various locations at southern fresh water dominant zone value of lead comes above background concentration, probably by the influence of agricultural and allied activities.

The sediment sulphur chemistry plays a key role in the transformation and mobility of heavy metals. High sulfur pyritisation
was observed in the northern portion of VLS during fractionation. In pre-monsoon the sulphur metal ratio shows a critical value, which is potentially toxic to aquatic organisms. Any dredging operation or natural sediment re-suspension activities can release metal sulfides from sediments to the water column and raise the AVS/SEM ratio to potentially toxic level. During pre-monsoon SEM$_{Hg}$ exceed PEL and TEL limit, while SEM$_{Cd}$ crossed only PEL limit. During pre-monsoon, AVM/SEM ratio approaches to one or near to it for 20% of the locations. Average ratio of all locations showed a critical value above to ‘one’. If molar ratio of SEMs to AVS is >1.0’, the sediment can be considered potentially toxic to aquatic organisms. Accordingly, northern part of Vembanadu lake system has potential for the release of bio-available metals during pre-monsoon season.

While considering the down core variation of elements in the sediment core, average metal concentration was in the following order: Zn>Pb>Cu>Cd. When comparing the core samples with sedimentation rate it is evident that the concentration of metals found higher to background concentration after 1940’s. It is also evident that after 1993 the rate of increase in element concentration becomes fast in core samples. Ecological indices such as PLI, CF and $I_{geo}$ etc revealed that Cadmium was the triggering factor enhancing the contamination level. The PLI value of the core suggests that there is an appreciable level of metal input to the core samples. The level of contamination was most prominent in upper few centimeters suggesting the contribution of recent input in enhancing element concentration in upper few layers. Anthropogenic input and hydrodynamic energy conditions in the northern portion can be considered as the main factor of vertical distribution of metals in these cores. From the results it can be inferred that the serious metal pollution problem in the lake has been increasing over the last few decades.
Summary and conclusion

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Hypsometric analysis infer that Pampa river and Periyar river are at culminating stage. Normally such phenomenons construe the possibility of denudation or mass removal of materials in future. It also signifies the presence of luxuriant forest cover at the higher reaches of these rivers hindering the process of mass wasting. Other rivers Manimala, Meenachil, Muvattupuzha and Achenkovil are found to be at mature to old stage. The concave hypsometric structure indicates more material has been removed from higher elevation through the dominance of alluvial or fluvial process at this system. The basin of the Manimala river is the solitary basin in the Vembanad lake system, where runoff exceeds the water inflow and hence subjected to enormous material removal. From these observations it can be inferred that the hydrology of the system have pronounced effect on the distribution of heavy metals in VLS.

Conclusions

The major conclusions derived from the study are,

- This hydrologic character of the lake is evident from the spatial and temporal variation of physico-chemical properties of the water column.
- Concentration of Cadmium in surface water was crossing US EPA criterion maximum concentration.
- The increased concentration of metals at bottom water samples might be due to the mixing of the sedimentary environment
- During post-monsoon metal concentration found to be higher than the other season because of less dilution and absence of sufficient horizontal mixing.
- Sedimentary environment was contaminated with heavy metals than the water environment.
- The studies suggest all metals have a common origin. In terms of contamination Cadmium is the metal with highest risk in
Vembanad Lake. Concentration of Cadmium was higher in northern zone, the elevated values may be due to the industrial discharges from fertilizer and pesticide manufacturing units in this zone.

- The sediment sulphur chemistry suggests that sediments of VLS are able to trap metals through the production of metal sulfides. AVS/SEM ratio reaches the value ‘1’ during pre-monsoon period. Any sediment re-suspension activity can release the metal sulfides to immediate water column. This can pose toxicity to benthic organisms.

- In core sediment, heavy metal concentration is higher than the background concentration of metals in sediment layers formed approximately after 1940’s. The concentration of metals was more at upper few centimeters suggesting resent input most likely within past 20 year.

- Modifications of landscape and hydrodynamic energy conditions by the embankments and islands in the lake triggered the sedimentation and heavy metal accumulation.

- Regular monitoring of VLS with periodic analysis of water and sediment, development of suitable water and sediment quality criteria for such systems are the suggestion from this study.