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Short communication

Phosphorous dynamics of the aquatic system constitutes an important axis for waste water purification in natural treatment pond(s) in East Kolkata Wetlands

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ABSTRACT

Treatment wetlands provide effective means for sewage purification. Consistently, at East Kolkata Wetlands, a Ramsar site since 2002, the city sewage is purified within 9–12 days and rendered suitable for large scale fish cultivation. But the introduction of the sewage into these wetlands should greatly favour eutrophication event as it contains excess nutrients like phosphorus. Towards understanding the underlying mechanism of prevention of eutrophication, the current study investigated the phosphorus dynamics of the aquatic system during the purification process as phosphorus plays a critical role in regulating the trophic status of a wetland. For this purpose we measured total phosphorous, particulate phosphorous, and soluble phosphorous of the water coloumn at different time points of purification. The result showed that total phosphorous from the water coloumn was removed considerably with time and it can be attributed mainly to the rapid removal of particulate phosphorous during anoxic period of treatment. Besides, trophic status index indicated that wetland maintained a mesotrophic status after the onset of aerobic condition. Alkaline pH of the water column and onset of aerobic condition may also contribute towards maintaining this mesotrophic condition by inhibiting internal loading from sediment-associated phosphorus in the overlying water column. Thus the current study provides an insight into waste water purification wherein phosphorous dynamics plays an important role for the prevention of eutrophication.

1. Introduction

Eutrophication of an aquatic system is a multifaceted and environmentally hazardous phenomenon imposed by excess loading of nutrients, particularly phosphorus. It leads to increased algal productivity and a reduction in the ability of other organisms to survive, which finally results in a major extinction event in aquatic ecosystems (Wetzel, 2001). Ecological importance of phosphorus as a nutrient arises from its major role in biological metabolic processes. It plays an important role in phosphorylation reactions during photosynthesis (Rao, 1997; Wetzel, 2001) and thus its availability is a key determining factor for algal physiology that constitutes an important component of the wetland ecosystem. The lack of availability of phosphorus leads to oligotrophic conditions whereas excess availability of phosphorus causes eutrophication. Therefore, the role of phosphorus is of particular importance in wetland ecosystem.

Wetland ecosystems can receive considerable quantities of phosphorus from domestic sewage through surface runoffs. Sewage is considered to be the single largest form of waste water in the world and typically contains excess nutrients, including phosphorus. Loading of untreated sewage into wetland ecosystems may lead to eutrophication of the wetland and therefore, removal of phosphorus from the water during sewage purification constitutes an important step of sewage purification. But, sewage treatment and removal of phosphorus from the sewage is typically an expensive process.

Treatment wetlands (TWs), which are often engineered systems, provide an effective and inexpensive means for efficient

Abbreviations: BOD, biochemical oxygen demand; DO, dissolved oxygen; EKW, East Kolkata wetlands; PRC, phosphorous retention capacity; TSI(TP), trophic status index (total phosphorus); TW, treatment wetlands.

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sewage purification (Faulwetter et al., 2008). TWs are now successfully employed to remove a diverse array of pollutants originating from almost every plausible contamination source. In this scenario, East Kolkata Wetlands (EKW), a Ramsar site since 2002, presents a natural setting for the treatment of sewage waste by a highly sustainable, extremely efficient and rapid process in a single pond system. EKW is a low lying area consisting of several wetlands where enormous amounts of sewage generated in the city of Kolkata, is efficiently treated through various informal practices adapted by local fish farmers over the past century (Sarkar et al., 2009). Moreover this treated water is utilized for large scale fish cultivation and irrigation, providing economic benefit to the local fish farmers of the area (Raychaudhuri et al., 2007).

The sewage is stored and treated in the ponds by adhering to a set of simple and well-established steps. The first step is the pond preparation process wherein water from a particular pond is removed during the winter months. Then it is completely air dried and ploughed in order to aerate the soil. The soil is also treated with lime and left undisturbed for a few weeks. In the next step, raw untreated sewage from the sewage canals, which feed into EKW, is introduced into the pond and it is filled to a depth of about 60–90 cm. At this time the colour of the sewage is black. At around Day 3–Day 4, the colour turns green due to algal growth. The algal community continues to grow and at around Day 9 the algae are removed by netting and progressively the water turns clear within a few more days. After that the water is utilized for large scale fishery and agricultural purposes.

As mentioned before, the introduction of sewage into these wetlands may greatly favor eutrophication event. Nevertheless, previous studies have shown that the sewage gets purified within a period of 9–12 days and it is also rendered suitable for large scale fish cultivation (Ghosh, 1983; Ghosh and Sen, 1987; Sarkar et al., 2009). Thus, eutrophication event is clearly prevented and the wetland ecosystem proceeds towards a condition suitable for pisciculture. However, the underlying processes through which these events occur remain largely unexplored. To this end, we investigated the processes by which these events are regulated, with respect to phosphorus availability in the water column.

2. Materials and methods

2.1. Study area

East Kolkata Wetland (EKW) area is located along the eastern fringe of Kolkata, West Bengal, India (latitude 22°25′ to 22°40′ N and longitude 88°20′ to 88°35′ E). It is a Ramsar site since 2002. Most of the city sewage (about 50,000 m^3 day^{-1}) flows down through a web of canals towards EKW ponds (Sarkar et al., 2014).

2.2. Sample collection

Water samples were collected in sterilized containers on Day 0, Day 3, Day 6, Day 9, Day 12 and Day 15 from three individual ponds located at EKW region (Supplementary Fig. S1) during the purification process. After the onset of treatment, ponds did not receive any more sewage till the end of process. From each pond, samples were collected at three different sampling sites namely inlet, middle, outlet and at each sampling point, two identical samples were collected. All the ponds followed very similar method of treatment. Since the wetlands are shallow in nature, samples were collected from 5–10 cm below the surface of water, following standard protocols (APHA, 1998). The samples were immediately transported to the laboratory in ice cold condition for further analysis.

2.3. Physicochemical analysis of standard water quality parameters

Standard water quality parameters including biochemical oxygen demand (BOD), dissolved oxygen (DO), pH and fecal coliform content were measured in order to verify the rate and extent of purification. Additionally temperature of the water column was also measured (data not shown). The BOD was measured following standard protocols as prescribed by APHA (1998). The non-conservative parameters namely DO, pH and temperature were measured on site using portable instruments (WTW, Model Multi 340i/set, Germany). Fecal coliform (FC) was enumerated by the standard most probable number (MPN) technique (APHA, 1998).

2.4. Estimation of total phosphorus (TP) content and trophic status index (TSI)

Since eutrophication event is largely regulated by the availability of phosphorus (Wetzel, 2001), TP content of water was determined following standard protocol as described previously (Trivedy and Goel, 1986). The TSI was calculated from TP content using the formula as previously described (Carlson, 1980; Wetzel, 2001):

$$\mathrm{TSI(TP)} = 14.42\ \ln(\mathrm{TP}) + 4.15$$

The phosphorus retention capacity (PRC), an inherent empirical property of the wetland (Wetzel, 2001) was calculated as the percentage of TP that was retained at a particular time point since the pond was filled with sewage.

2.5. Estimation of phosphorous in different fractions of the water column

Since phosphorus is a fundamentally important nutrient and a major cellular constituent, much emphasis has been given the analytical evaluation of its distribution within the environment. A number of operational categories of phosphorus have been recognized, which are differentiated on the basis of reactivity with molybdate, ease of hydrolysis and particle size (Strickland and Parsons, 1972; Wetzel and Likens, 2000). The different operational fractions in which phosphorus exists in the water column can be classified as particulate and soluble phosphorus (Wetzel, 2001). Since particulate matter are usually termed as particles of inorganic and organic matter having a diameter of less than 63 μm (Waters, 1995), the water samples were passed through 45 μm filter paper and the phosphorus content associated with that particulate matter was considered as particulate phosphorus. The phosphorus content associated with the filtered water sample was considered as soluble phosphorus. Reactive phosphorus was considered as the phosphorus that readily reacted with molybdate (Sarkar et al., 2009) and un-reactive phosphorus was considered as the phosphorus that reacted with molybdate after being subjected to acid hydrolysis. The phosphorus content of all these fractions was determined following standard protocol as described previously (Trivedy and Goel, 1986).

2.6. Statistical analysis

Experimental results were subjected to statistical analysis of Pearson's correlation coefficient and one-way analysis of variance (ANOVA). All statistical analyses were performed in Microsoft Office Excel 2007 and SPSS-11.