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Short Communication

Nitrogen dynamics of the aquatic system is an important driving force for efficient sewage purification in single pond natural treatment wetlands at East Kolkata Wetland

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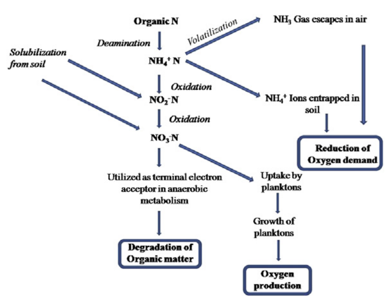
HIGHLIGHTS

- Difference in organic N removal and increased NH_4^+ in water indicates NH_3formation.
- Oxygen demand is greatly reduced by NH_3volatilization at the anoxic phase.
- Wetland soil acts as a vital source of NO_3^- and sink for NH_4^+.
- NO_3^- availability facilitates anaerobic metabolism and planktonic growth.

GRAPHICAL ABSTRACT



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ABSTRACT

At East Kolkata Wetlands, though the domestic city sewage is purified very rapidly, the mechanisms of treatment remains inadequately explored. In this context, the present study investigated nitrogen dynamics of the single pond treatment systems during purification and explored its potential role in sewage treatment. For this purpose the concentrations of different forms of nitrogen present both in water and soil at different time points of purification were measured. The organic nitrogen content decreased sharply, in the early phase, with an increase in ammonium concentration. Notably the reduction in organic nitrogen was significantly higher than the increase in NH_4^+ which can be attributed to the volatilization of NH_4^+ under alkaline pH. This volatilization results in reduced oxygen demand. The nitrate-N concentration decreased sharply from soil with a concomitant increase in water column. However the reduction of nitrate in soil was significantly higher than the increase in water column. It indicated the occurrence of denitrification under anoxic condition wherein nitrate serves as terminal electron acceptor. Additionally a part of the nitrate supported planktonic growth. Thus it describes another mechanism of reducing oxygen demand. The initial NH_4^+-N concentration in the soil was very low and it increased gradually during purification due to increasing soil cation exchange capacity. Thus

Abbreviations: BOD, Biochemical Oxygen Demand; DO, Dissolved Oxygen; EKW, East Kolkata Wetlands; GPP, Gross Primary Productivity; OD, Optical Density; CEC, Cation Exchange Capacity; N, Nitrogen.

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by trapping NH_4^+ ion soil contributes towards preventing contamination of water. Thus at EKW, the cumulative activities in water and soil involved in nitrogen dynamics lead to overall reduction of the oxygen demand and contribute towards efficient sewage purification.

1. Introduction

Liquid wastes such as untreated municipal sewage is a major source of contaminants that frequently pollute aquatic ecosystems due to irresponsible discharge practices, lack of cost effective treatment technologies and surface run offs (Kivaisi, 2001; Denny, 1997). Municipal sewage, the single largest form of wastewater in the world, typically contains excess nutrients including readily biodegradable organic matter, excess nitrogen, phosphorus, some toxic substances and is also associated with high fecal coliform content. Conventional wastewater treatment is typically an expensive and usually involves use of multiple ponds in a sequential manner (Sarkar et al., 2009). In contrast, Treatment Wetlands (TWs) are being successfully employed to remove a wide array of pollutants that originate from a broad range of contamination source (Faulwetter et al., 2009). Compared to conventional treatment systems, treatment wetlands have low operational cost, can be easily operated and maintained efficiently. Moreover treatment wetlands often consist of single pond treatment systems (Mitsch and Gosselink, 2000). In this context, East Kolkata Wetlands (EKW), a collection of low-lying wetlands in the eastern fringe of the city of Kolkata, India, presents a setting for efficient sewage treatment by an exceedingly low cost and rapid process in single pond systems. At EKW, massive amount of domestic city sewage is not only treated in a sustainable manner (Sarkar et al., 2009) but the treated sewage is subsequently used for large scale fish cultivation (Raychaudhuri et al., 2007; Das Gupta et al., 2016). In 2002, EKW was declared a Ramsar site (Sarkar et al., 2009).

The domestic sewage treatment process in single pond systems at EKW was developed by the local indigenous people through empirical observations by applying a “black-box” approach over the preceding century and it involves a number of well-established phases. The fishermen have constructed earthen barriers (with mud and clay) across the wetland area to separate the individual ponds. Inlets and outlets have also been constructed for each wetland for the inflow of untreated sewage (inlet) and outflow of treated water into outlet channels. Inlets and outlets have barriers made up of sustainable materials like bamboo sticks that regulate the flow of water into and out the individual wetlands. The first phase of sewage treatment is known as the pond preparation process. During this process, water from a particular single pond system is completely removed. Subsequently, the pond is air dried and then ploughed which leads to aeration of the soil. After that, the soil is treated with lime and left undisturbed for a span of few weeks. In the next step of treatment, untreated sewage from the city sewage canals is introduced into the single pond system. The pond is completely filled with the untreated sewage up to a depth of about 60–90 cm. At this time (Day 0), the untreated sewage remains black in colour. At around Day 3 to Day 4, the colour turns green due to growth of photoautotrophs like phytoplanktons. These photoautotrophs continue to grow and finally, at around Day 9 they are removed by netting and increasingly the water turn clear within the following days. After that the water is utilized for large scale fishery and irrigation purposes (Sarkar et al., 2009; Das Gupta et al., 2016).

As mentioned earlier, the treatment process applied in these wetlands has been developed by the local indigenous people through a “black box” approach. Moreover, there have been few scientific studies that aimed towards illustrating the underlying mechanisms that govern the various aspects of the treatment process. In this context, it is important to note that the removal of excess nitrogen is considered to be a significant step of sewage purification and the implications of N removal is probably second only to organic carbon removal in domestic wastewater treatment (Faulwetter et al., 2009). The element nitrogen (N) is an essential nutrient for all organisms, and is a fundamental component of proteins and nucleic acids. Within the environment, N exists in multiple oxidation states and chemical forms, and is rapidly converted by the active participation of microorganisms (Francis et al., 2007). Dominant forms of nitrogen in fresh water aquatic ecosystems include ammonium nitrogen, nitrite nitrogen, nitrate nitrogen and organic nitrogen is contained in large number of organic compounds including amino acids, proteins, nucleic acids, amines and recalcitrant humic compounds of low nitrogen content. Moreover, wetland soil rich in organic matter have the ability to adsorb and entrap reduced N in the form of ammonium (Wetzel, 2001). Thus the nitrogen dynamics is a multifaceted process in which nitrogen in various forms is altered by mechanisms that include assimilation, oxidation, reduction, hydrolysis, volatilization, adsorption etc. (Wetzel, 2001). Therefore in this study we investigated the nitrogen dynamics of the ecosystem during sewage treatment and explored its possible role in sewage treatment.

2. Materials and methods

2.1. Study area

EKW (a Ramsar site since 2002) is a low lying wetland area (latitude 22°25′to 22°40′N and longitude 88°20′to 88°35′E) located in the eastern fringe of Kolkata, West Bengal, India. Most of the entire city sewage flows down through a web of canals towards EKW to be subsequently treated in the single pond systems of EKW (Sarkar et al., 2014; Das Gupta et al., 2016).

2.2. Sample collection

For this study, sampling was carried out in three different ponds. From each pond, samples were collected at three different sampling sites, which were the inlet, middle and outlet points and at each sampling point, two identical samples were collected for water and soil respectively. All the three ponds followed identical method of treatment. Ponds did not receive any more sewage after the onset of treatment until the end of process. Water samples were collected from treatment ponds during its treatment as described previously (Das Gupta et al., 2016) in sterilized containers on Day 0, Day 3, Day 6, Day 9, Day 12 and Day 15. Since these ponds are shallow wetlands, samples were collected from 5 cm below the surface of water, following standard protocols (APHA, 1998). Bulk soil samples were also collected from top soil horizon using hand shovel (Alef and Nannipieri, 1995) along with the water samples. The samples were immediately transported to the laboratory in ice cold