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Suspended particulate matter dynamics act as a driving force for single pond sewage stabilization system

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ABSTRACT

Suspended particulate matter (SPM) in aquatic system often causes negative impact on water quality and hence its removal is the prerequisite in sewage stabilization process to avoid the consequences of pollution. The conventional wastewater treatment technology based on highly optimized physical, chemical and microbial processes is cost effective where ecologically sustainable technology would be the best alternative. Present study is an endeavor to give a new insight into the beneficiary roles of SPM during its mass movement in single pond sewage stabilization system. The SPM undergo a dynamic movement in different layers of water column in wetland's single pond (East Kolkata Wetland) during wastewater purification process. Compositional analysis of SPM reveals that inorganic fraction was abundant (80%) at initial stage, was removed (70–82%) under gravity (0–3 days) in association with Fecal coliform (FC) bacteria and permitted sunlight to ingress resulting in increased temperature ($p < 0.05$). This condition initiated algal production increasing SPM burden in the system and developed stratification ($p < 0.05$) of temperature, pH and dissolved oxygen (DO) for 3–5 days. Thereafter, de-stratification occurred due to mass movement of these components ($p > 0.05$) throughout the water column. This phenomenon favored the activity of aerobic microbial population contributing a lot for oxidation of organic matter (7–10 days). SPM in stabilization pond thus shows pioneering role through its dynamics which ingress other subsidiary natural processes may serve for designing, optimizing or improving treatment technology.

1. Introduction

Suspended particulate matter (SPM) are usually termed as particles of inorganic and organic matter having a diameter of less than 63 μm (Waters, 1995), which exists in aquatic medium in suspension under the influence of turbulence. Since aquatic system is in close contact with biosphere, lithosphere and atmosphere, it must contain some ingredients of other spheres under natural condition. SPM is a good example of one of those ingredients and thus becomes an integral part of the ecosystem (Ryan, 1991). The source of SPM could be either autochthonous or allocthonous. Autochthonous particles are derived *in situ* and include planktonic organisms whereas allocthonous particles are derived from land, air or from other draining system (Mutua et al., 2004). An increased concentration of SPM by anthropogenic perturbations can lead to alternations of physical (Lloyd et al., 1987; Ryan, 1991), chemical (Kronvang et al., 2003) and biological properties (Bilotta and Brazier, 2008) of water body. Therefore, SPM has been rightly considered as an extremely important component for monitoring the natural system. The burden of SPM results in water quality deterioration leading to aesthetic issues, increased cost for water treatment, a decline in fishery resource and serious ecological degradation. However, the deterioration of an ecosystem can be attributed to innumerable factors other than SPM. In this context, removal of SPM from a deteriorated aquatic system is prerequisite that usually carried out in sedimentation tank. Consequently, this removal process greatly improves the water quality by welcoming key factors in the system during purification regime. In contrast, the influence of SPM in wastewater stabilization system at East Kolkata Wetland is an important issue to be studied. In conventional sewage treatment (Metacaffe, 1972), usually three different ponds are used in sequential manner: sedimentation (anaerobic), facultative and maturation. Each of these ponds has specific roles in the purification processes. In this treatment technology, the first unit is the sedimentation pond where SPM is removed by gravitational settling (Jamwal et al., 2009). For its rapid and effective

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removal, the ponds are scientifically designed and constructed. Moreover, certain chemicals might also be employed in order to better settling. Although studies on the removal of SPM for treatment purpose are plenty (Andreadakis et al., 2003; Colmenarejo et al., 2006), the beneficiary roles of this constituent through initiating various ecological processes for sewage stabilization are yet to be addressed. Therefore present study is to understand the SPM dynamics and its consequences during sewage purification in natural pond system. Existing literature suggests that studies on this system are sporadic and unable to reveal its highly efficient and sustainable treatment process (Sarkar et al., 2009). Current study is aiming at understanding the dynamics of suspended particulate matter and their role towards sewage purification.

2. Materials and methods

2.1. Study area

East Kolkata Wetland (EKW) area (latitude 22°25′ to 22°40′N and longitude 88°20′ to 88°35′E) in the state West Bengal (India), lies in between Hugli River in the northwest and Bidyadhari river in the east. The entire Kolkata city wastewater (about 50,000 $m^3\ day^{-1}$) including domestic origin flows down through a web of canals passing through EKW towards the final discharge point in Bidyadhari River at Kultigung, nearly 40 km away from Kolkata. This large volume of municipal sewage is naturally treated in fishery ponds by resource recovery practices since last hundred years. This traditional practice produces significant amount of edible components for human consumption (Morrice et al., 1998; Edwards and Pullin, 1990; Furedy and Ghosh, 1984; Saha and Ghosh, 2003). Nowadays, there is no sewage treatment plant for 12 million inhabitants of the city (Dutta et al., 2005; Raychaudhuri et al., 2007). This resource recovery process has a great contribution that it saved the city from the costs of constructing and maintaining sewage treatment plant. For enormous implication of this wetland system, it is included in the list of International Ramsar site as per convention on Wetlands signed at Ramsar, Iran, in 1971. There are 264 fisheries cum sewage treatment ponds that are distributed on both sides of main sewage canal and thus are recognized as the world's largest ensemble of wastewater fisheries.

2.2. Sample collection

Sewage sample was collected from stabilization pond during its treatment as described in our previous paper (Sarkar et al., 2009). The collection of water in sterilized container and ice cool condition was done for Day 0, Day 3, Day 5, Day 7 and Day 10 sequentially. We have taken water samples in middle of the day to forecast the average picture of short term temporal variation. Sampling was carried out from two different ponds of almost equal size. Both the ponds follow very similar method of treatment. Ponds were not receiving any more sewage after onset of treatment till to the end of process. Since, the depth of the stabilization ponds was within 30 cm, sampling from surface (below 5 cm) and depth (below 25 cm) were considered following standard literature (APHA, 1998).

2.3. Physicochemical analysis of water

We have recorded non-conservative physicochemical parameters in the field. These include temperature, pH, dissolved oxygen that were determined using portable instruments (WTW, Model Multi 340i/set). The turbidity was measured by nephelo-meter (Orbeco-Hellige Model 966 Portable) in the laboratory on that day. Other water quality parameters were analyzed in the laboratory by standard methods (APHA, 1998). SPM in sewage was determined by filtering known volume through 0.45 μm pore Whatman® GF/C filters. The filters were then dried at 105 °C for 24 h in the hot air oven and cooled in desiccators before weighing. Difference in weight corrected for filter paper weight was taken to represent SPM greater than 0.45 μm. The fraction of particulate organic matter (POM) was determined by weight loss on ignition at 450 °C for 3 h in muffle furnace (Dean, 1974) and the fraction of particulate inorganic matter (PIM) was calculated from the weight of the remaining matter on the crucible (Paul Wassmann, 1983)

The extent of thermal stratification (Chemey et al., 2006) was evaluated by comparing the relative thermal resistance to mixing (RTRM) between the surface and the bottom. RTRM values were calculated following Wetzel (2001).

$$\psi = \frac{(\rho z_2 - \rho z_1)}{(\rho_4 - \rho_5)}$$

In the above equation, ψ is the RTRM (dimensionless), ρz_2 and ρz_1 are the water densities at depths of z_2 (depth) and z_1 (surface) respectively ($kg\ m^{-3}$). ρ_4 and ρ_5 are water densities at 4 °C and 5 °C respectively ($kg\ m^{-3}$). Water densities at a given temperature can be calculated using the formula by Henderson-Sellers (1984).

$$\rho_t = 999.9726[1 - 9.297173 \times 10^{-6}|t - 277.029323|1.894816]$$

While, ρ_t is the water density at the ambient temperature t (°C). The thermal stratification is directly proportional to magnitude of RTRM. Extinction co-efficient η (m^{-1}) was calculated according to the following formula $\eta = 1.7/z$ (Wetzel, 2001), where z is the Secchi disc transparency of the medium in meter. Secchi disc transparency is measured by immersing Secchi disc, a circular disc of metal of 20 cm in diameter painted alternately black and white with a radial fashion and observing its visual in pond water (Trivedi and Goel, 1986). Turbidity was measured using Nephelometer (Orbeco-Hellige Model 966 Portable) and the data obtained was expressed as Nephelometric Turbidity Unit (NTU).

2.4. Estimation of Faecal coliform

Faecal coliform (FC) bacterial population was enumerated by the standard most probable number technique after inoculating the serially diluted water samples to the EC broth (Hymedia) and following incubating these at 42 °C for 48 h (APHA, 1998).

2.5. Statistical analysis

To validate the experimental results, normal distribution of the data was carried out by Kolmogorov–Smirnov test and thereafter other statistical approaches were followed. One-way analysis of variance (ANOVA) and Pearson's correlation coefficients were then employed for comparison as well as to ascertain interrelationships between and among the results. Pair wise comparison by t-test was considered to assess the degree of stratification across the water column. Results were marked as statistically significant at $p < 0.05$ level. Hochberg's method was employed for multiple comparisons between means of unequal samples (Hochberg, 1974) where significant differences were observed. This outcome provides information to evaluate the degree of changes in physicochemical characters for successive days. All the statistical analysis was performed by SPSS 11 for Windows.

3. Results

3.1. Suspended particulate matter dynamics

The quantity of SPM during the study period varied from 60 to 400 mg/L at surface and from 80 to 510 mg/L at depth (Fig. 1). The extent of SPM variations at surface and depth were quite significant