Sewage Management to Fish Culture - An Age Old Eco-practice at East Kolkata Wetlands

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Abstract Understanding the comprehensive mechanism of sewage decontamination process of East Kolkata Wetlands (EKW) used for the commercial fish production, sustainable development of the area, conservation of local biodiversity and its relation to ecosystem services, needs in-depth research. Sewage-fed aquaculture can contribute to the preservation of high-diversity systems, which may deliver vital ecosystem services such as decreasing environmental pollution, carbon sequestration in the wetlands and keeping balance in different bio-geo-chemical cycles. Scientific knowledge of nutrient recovery from waste, considering relative importance of eco-friendly waste management processes and traditional fish culture methods by reusing sewage might make EKW a replicable model worldwide.

Keywords Carbon cycle, East Kolkata Wetlands, fisheries management, plankton, sewage purification

INTRODUCTION

Controlling urban domestic wastes is a key concern throughout the world, mostly in large emerging nations due to its fast development in these countries (Bassi et al. 2014). In South Asian region like Nepal, Bangladesh and India, surface water pollution has become extensive and life-threatening because of high loads of waste disposal into the river stretches and large water bodies (Karn and Harada 2001; Saha et al. 2016). Sustainable waste management skills are consequently the main focus at this point of time. Reflecting on this global need, the waste-use practices established by the fishermen community in East Kolkata Wetlands (EKW) can be observed as natural and eco-friendly solution for waste treatment and reuse of both sewage and solid waste (Furedy and Ghosh 1984; Mukherjee 1996).

EAST KOLKATA WETLANDS AND ITS UNIQUENESS

EKW is located in the eastern peripheries of metropolitan city of Kolkata, stretching nearly between latitude 22°25’N to 22°40’N and longitude 88°22’E and 88°55’E (Kundu et al. 2008). EKW was nominated as a Ramsar site - a wetland of international importance in 2002 as per the Ramsar convention because of its important role in minimizing load of city sewage along with producing fish out of it (Ghosh 1993). Predominantly it functions as flood control plain along with providing environmental

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profits over value $38.54 million which causes the maintenance of the employment of approximately 1.5 lakh residents directly for last ninety years (Bhattacharyya et al. 2008).

Some occurrences of transforming waste to usable resource by using solid waste in agriculture can be found in various countries including China, Sweden, Hungary and Munich. In China this practice is performed since 1960s (Yan and Zhang 1994), in Sweden sewage-fed aquaculture was experimentally tried out in 1992 as a greenhouse mesocosm in a northern climate (Guterstam 1996), in Hungary (Olah et al. 2003) and secondary sewage for fish culture in Munich (Jena et al. 2010).

Paralleled to these efforts, East Kolkata Wetland (EKW) of India is worlds’ oldest and largest multi-functional resource retrieval model system which is active since 1930 (Ghosh 1999; Raychaudhuri et al. 2008). EKW expands about 12,700 hectares area (Maiti et al. 2012), among which approximately 5,800 hectares of water area (including 3,798 hectares of fisheries area) commercially produce 30,000 metric tons of fish per year (Saha et al. 2014). City sewage is used to produce planktons that act as the main food resource in fish cultivation. The waste to wealth transformation in EKW has made this fisheries a unique aquaculture culture system (Ghosh 2005).

SEWAGE MANAGEMENT TO FISH CULTURE: ENVIRONMENTAL-SOCIO-ECONOMIC IMPACT OF EKW

Since last ninety years, local fishermen, farmers, scavengers and other groups have been generating their livelihood from this area (Edwards and Pullin 1990). Ponds and sewage carrying canals are instrumental in the traditionally developed waste water treatment process in EKW. Approximately 30% of the domestic city sewage of Kolkata is stored in these fishery ponds. The main component of the sewage is organic matter. Microbial population actively take part in degradation of the organic substance of sewage within favorable environmental condition (Sarkar et al. 2009). Thus microbes play significant role in the natural treatment and recycling of wastewater (Sarkar et al. 2014). Within one month of receiving the sewage waste these ponds become ready for fish cultivation. Pond preparation is a crucial step in this water purification process. During pond preparation phase, pond is dried during the period between winters to pre-monsoon seasons (middle of December to early of May). Afterwards, the bottom mud of the pond is ploughed, treated with lime and left for about a month (Sarkar et al. 2011). Subsequently, the raw sewage is let into the pond through the sewage carrying channels (Basu et al. 2016). Sewage is allowed to fill up to a depth of about 60 to 90 cm of the lime treated pond. At the time of sewage entry, the color of the sewage water is deep black and within 3 to 4 days, the water color changes to green due to algal growth. At this time, due to eutrophication, phytoplankton growth reaches its highest and algal bloom takes place. In next 2 to 3 days the algal mat is sieved away by fishermen turning the water crystal clear (Gupta et al. 2016). After netting the algal bloom, the pond with clear water is left for 25 to 30 days before using it for fish cultivation. At the end of the tenure of 30 to 
40 days of natural purification process (Saha et al. 2017) through biological oxidation the pond becomes ready for fish cultivation. The water of the pond at this point of time also become usable for irrigation of the agricultural lands or safely discharged into the surrounding areas (Sarkar et al. 2009; Saha et al. 2014).

The sewage quality can be predictably determined by measuring some key physico-chemical parameters like DO and BOD. However, all the biotic and physico-chemical factors undergo composite and cumulative interactions towards developing an ecosystem (Wetzel 2001). In conventional sewage management, three different pools e.g., sedimentation or anaerobic, facultative and maturation pond are employed consecutively (Sarkar et al. 2009). Each pond has precise activities to add in the purification course. The exclusive feature of this system is that here only one pond is used instead of three sequential ponds, where all the physicochemical activities needed for the purification process, take place (Sarkar et al. 2017; Sarkar et al. 2009).

In the last 25 years numerous studies have been made on the sewage water purification process at EKW ponds. Some studies throw light on the metabolic status and functional diversity of microbial community that is involved in sewage purification process of sewage fed fisheries (Sarkar et al. 2017) and provided an idea about the nature of gradual changes of the physicochemical components during the treatment process (Sarkar et al. 2009). Some of the studies were intended to explore the quality of water after the treatment and the products which were acquired from the treated effluent (Saha and Ghosh 2003; Roy Choudhuri et al. 2007).

Study by Kundu et al. in 2008 put emphasis on the management plans for conservation of the sewage-fed fisheries system as to maintain the livelihood of the local stakeholders as EKW nurtures world’s largest wastewater aquaculture system with 30,000 tons of fish produce each year.

DIVERSITY AND OTHER ECOSYSTEM FUNCTIONS PROVIDED BY EKW

Species diversity help to decrease temporal variability in ecosystem processes in changing environments (Loreau et al. 2001). Anthropogenic impacts on the environment cause general decline in diversity for which many ecosystem functions can be disrupted (Grime et al. 2000) thus detail study of species community diversity is important. Several studies have been carried out on the biodiversity focusing trees, plants, herbs, shrubs, land and aquatic insects, birds, mammals and fishes of EKW (Kundu et al. 2008, Bhattacharyya et al. 2008, Maiti et al. 2012; Saha et al. 2014).

Our previous research concerned the effect of the seasonality on the zooplankton and macroinvertebrate community in the intensive ‘sewage-fed’ fish culture systems and comparing them with control non-fishery ponds showing different trends in their species abundance (Saha et al. 2017). Other than serving as food source for cultivated fish, both plankton and aquatic macroinvertebrate act as indicator of the water quality conditions like pollution or degradation because of their natural ability to

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counter to such changes (Saha 2018; Maiti et al. 2014; Khan and Ghosh 2001). Diversity of plankton is of great concern in the city sewage carrying canals to the Bay of Bengal (Maiti et al. 2013) and during high and low tide at different points over the stretch of river Bidyadhari where the major sewage carrying canals discharge the naturally treated effluent (Sen et al. 2015 (a & b); Maiti et al. 2012). Studies showed the large size wetlands are important for wetland dependent birds and held diverse migratory birds during winter in EKW (Saha et al. 2014). Destruction in the wetland habitat by human activities were indicated by the change in bird diversity and abundance at different habitat patches within these sewage-fed fisheries were observed (Bhattacharyya et al. 2008). Research on the microbial diversity at EKW demonstrate involvement of diverse microbial communities in the sewage purification revealing a significant variation in their metabolic spectrum (Sarkar et al. 2017) and their role as indicator of heavy metal pollution (Sarkar et al. 2011).

THIRST AREAS FOR RESEARCH ON SEWAGE-FED FISHERIES SYSTEM

Since 1930 EKW is functioning as the kidney of the Kolkata metropolis along with generating economy for the local inhabitants but the fruits of research are yet to reach the global scale. Based on the review of research articles and Government reports on EKW, it is felt that the following concepts must be prioritized for future investigation to evolve a wholesome understanding about the dynamics system:

A. Index of biological integrity (IBI) is associated with anthropogenic influences on a water body and is an essential tool to map the integrity of a perturbed aquatic system (Hawkins 2006; Mack 2007). IBI can be formulated using data developed from bio-surveys (Kerans et al. 1992). Biological integrity study of polluted system like the sewage-fed fisheries might reveal the impact of human activities on the biological functions played by the biotic communities within these water-bodies.

B. Since sewage consist mostly of organic matter, the transformation of the nutrient particles present in this organic matter is mainly done by the planktons which are the key driving force in nutrient release and recycling of wastewater (Mukherjee et al. 2012). To unravel the underlying mechanism of wastewater purification at this unique and largest sewage fed fisheries system of EKW, it would be important to know the interactions among the various physicochemical parameters and plankton. The time dependent changes in the plankton community structure parallel to the changes in different physicochemical components of wastewater during the purification regime also need to be evaluated.

C. Plankton are the live food organisms that are foraged by fishes in commercial fisheries (David 2003). In open waters, phytoplankton are the main producer and form the basis of
the food chain (Falkowski 1980). Zooplankton constitutes a major part of the diet for fish larvae in the natural food webs (Das et al. 2012). Investigating the significance of plankton community interplay in relation to physicochemical changes during the pond preparation for fish culture in sewage-fed fisheries might serve as a stepping-stone for future study to reveal the exact mechanism of the waste purification process. This will possibly help the underlying mechanism that can be replicated elsewhere for purifying waste water and reuse it for profitable aquaculture.

D. Recycling of energy-matter or nutrients are fundamental processes which occur in every ecosystem as a buffering mechanism allowing ecosystems to face shortage of nutrient inflows (Allesina and Ulanowicz 2004). Energy cycling through ecological networks acts as homeostatic response to stress (Tollner and Kazanci 2007). To estimate the integrity of the ecosystem, nutrient flow cycle of the system is important to be known. Study should be done to analyze nutrient cycles or bio-geo-chemical cycles like carbon, nitrogen and phosphorus in these fisheries.

E. Research on conceptual and mathematical modeling of the basic nutrients – carbon, nitrogen, phosphorus etc in sewage-fed system will offer vital information leading to enormous understanding of the ecosystem functioning and maintaining ecosystem structure in a sustainable manner. Only a single work was done on phosphorus dynamics (Mandal et al. 2015) on EKW fisheries, while in our previous research, the conceptual model on carbon cycle were proposed and regulatory chemical parameters were identified (Basu et al. 2016; Saha et al. 2016). Such comprehensive study might help to formulate rational and important management approaches that can be included in the conservation strategies of the world’s largest waste to wealth transforming Ramsar site.

**SUSTAINABILITY OF THE EAST KOLKATA WETLANDS**

In developing countries, waste management focuses mostly on chemical treatment (Nasr et al. 2007), yet the potential biological processes of sewage purification and many services which wastes can provide in eco-friendly ways are ignored. EKW is the unique system in the world where both effluent management by the process of biological purification, sewage utilization as fish feed and large scale economy generation through fish cultivation are being taken care of.

Sustainable development emphasize on the balance between three parameters - environment, society and economy (Clune and Zehnder 2018). In sewage-fed fisheries of EKW all these parameters are fulfilled naturally as here the load of city sewage of Kolkata is decreased to one third per day by channelizing it to the surrounding fisheries.
(Sen et al. 2015 (a); Bhattacharyya et al. 2008) which plays an important role in sewage purification thus balancing environmental wellbeing of the area. Providing employment to the local fishermen by the commercial production of huge amount of fish (Sen et al. 2015 (b); Ghosh 2005) and using domestic sewage as nutrients for fish help the practitioners to cut their expenses for externally added marketed fish-feed. Thus accomplish the economic upliftment through sustainability. Fish of EKW serves as an important animal protein resource to the local people and thus might add to the societal health benefit (Hussan 2016; Edwards 2008).

CONCLUSION

Wastewater aquaculture can be a foremost driver of global change and make significant influences in the conservation of the wetlands, while earning benefits from the sustainable management of biodiversity and ecosystem services. These applied potentials of sewage-fed fishery system support the conventional knowledge of biodiversity-driven aquatic ecosystem functioning. More in-depth research addressing both biological and geo-chemical aspects are needed to improve and upscale the view of such eco-practice globally.

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Compliance with Ethical Standards

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