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An Assessment of Direct and Indirect Emission Reduction Potential of Natural Wetland Systems of Kolkata, India

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Abstract

City effluent management is a critical global issue in recent times as escalating population density across the world cities has amplified waste generation, pollution and green house gas emission. This has led to intensification of climate change and the effects like sea-level rise, increased frequency and intensity of floods, droughts, and tropical storms are being observed across the globe. According to the Intergovernmental Panel on Climate Change Fourth Assessment Report of 2007, reduction of emissions in urban areas over the next two to three decades will be significant in providing long term opportunities to balance levels of atmospheric CO_2 and mitigate impacts of climate change. Wastewater aquaculture and using treated effluent in agriculture as sustainable environment management strategy in urban areas has been tried in several instances by which the waste is transformed to usable resource. Due to the natural process of waste water treatment and carbon sequestration potential of sewage fed fisheries the green house gas emission is reduced. This paper, with the case study of East Kolkata Wetlands, India, analyses its role as "urban kidneys" and also attempts to assess the direct and indirect green house gas emission reduction potential of natural wetland systems of Kolkata by comparing it with the Sewage treatment Plants of the city.

Keywords: Wetlands; waste water treatment; sewage fed fisheries; Green house gas emission; mitigation

1. INTRODUCTION

Urban processes leading to the burning of fossil fuels such as coal, oil, and gas have caused a substantial increase in the concentration of green house gases in the atmosphere which is the prime cause of climate change. Wastewater treatment is a process of intensive use of resources, mainly energy, which accounts for 15 to 40% of the total operating costs in conventional waste water treatment plants (Soares et.al., 2017). With the expected demographic increase the energy consumption tends to increase further leading to rise in Green house gas (GHG) emission.

Recycling of waste water to use for fish and vegetable production is a traditional system in India that produces a large percentage of food. But the urban wetlands which form the core of such sustainable process are under threat due to the pressures of urbanisation. The Secretary General of Ramsar Convention, Martha Rojas Urrego has recently recognized East Kolkata wetlands in the Indian city of Kolkata among two of world's most precious natural resources for its ecosystem services. But in reality, between 2002 and 2017, at least 64 such fish ponds have been filled up and disappeared (Ghosh, 2018). Kolkata has been identified as the third most vulnerable city on the list cities prone to climate disaster, according to the World Bank Report (2011). In such a situation East Kolkata wetlands act as a saviour. It is thus imperative to focus on the ecological service by the wetlands towards mitigation of climate change and mainstream wetland conservation into future planning of city. The study area has been taken as the East Kolkata Wetlands, a Ramsar site, in India.

2. METHODOLOGY

The objective of the paper is examination of wetland based waste water management system in East Kolkata Wetlands by analysing its role as "urban kidney" and quantitative assessment of the ecological benefit the city derives out of it.

The methodology involved the following steps –

I. analysing the geographic and historic context to understand the formation and present configuration of the waste recycling zone of East Kolkata Wetlands (EKW),
II. analysing the processes like hydraulic regime that allows the city sewage to flow through the wetlands and get utilised in the fisheries and the biological process of reduction of Biological oxygen demand (BOD) utilising micro-organisms in presence of sunlight, and
III. assessment of the reduction of direct and indirect green house gas (GHG) emission by the sewage fed fisheries by comparison with sewage treatment plants (STP) of the city.

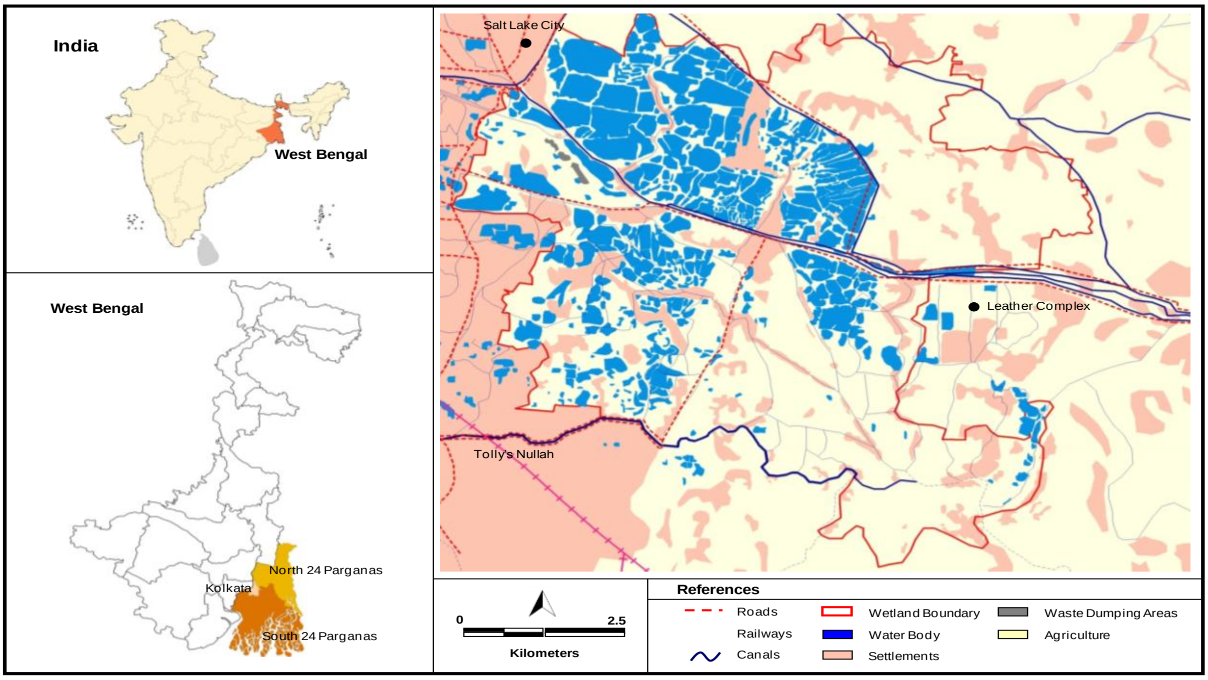
3. EAST KOLKATA WETLANDS

Kolkata is the 3rd largest city in India, with a city population of roughly 4.5 million and an urban area population of about 14 million as per Census-2011. The megacity, Kolkata produces wastewater and sewage almost 750 million litres per day (MLD). Strangely, the core area of the city does not have a single sewage-treatment plant (Ghosh, 2016). There are only five STPs with a total capacity of 162.5 MLD on the outskirts. So how does the city manage so much sewage?

The 12,500 hectare wetlands lie just to the east of the centre city area and act as a natural filter for the city's sewage and other waste—hence, the wetlands have commonly called as the urban kidneys or natural kidneys of Kolkata.

3.1 Geographic context

The East Kolkata Wetlands (EKW) has an area of 12,500 ha, and is located on the eastern fringe of Kolkata city, partly in North 24 Parganas and partly in South 24 Parganas. The region is a part of the Ganga-Brahmaputra Delta on the Bay of Bengal. EKW forms a part of extensive inter-distributory wetland regimes that was transformed into sewage-fed fisheries as far back as in 1928. The wetland comprises of water bodies (used as waste water fed fisheries), land used for vegetable farming and paddy fields using treated effluent. Settlements are interspersed between various land uses. The entire region is criss-crossed by canals which carry sewage water to fisheries and treated effluent to farmlands.



Map i: Location Map of East Kolkata Wetlands (Source: Management plan of EKW, 2010, EKWMA, WISA)

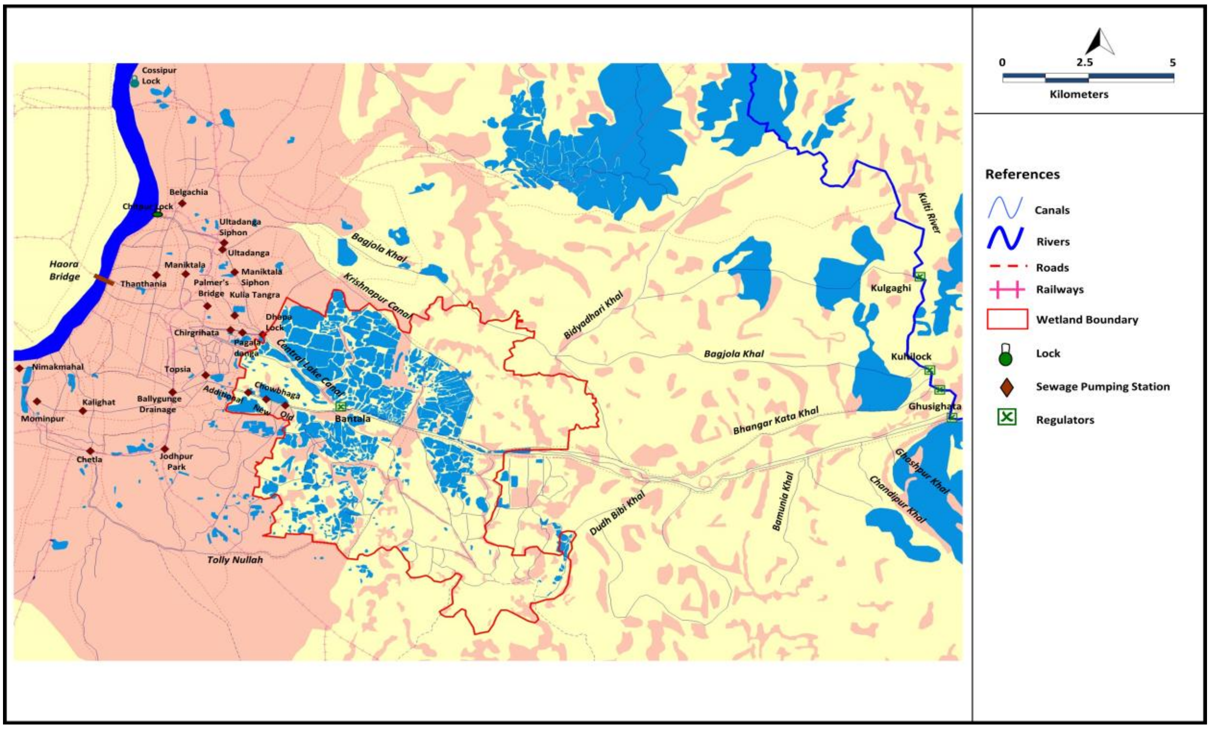
3.2 Historic context

Earliest reference of sewage fed fisheries was found in 1930 when Sri Bibhuti Bhushan Ghosh seems to have innovated a perennial system of urban wastewater fed fisheries to the east of the city. In 1940, the sewage outfall of the city was changed from south-east to east, to the Kulti River. The first stage of organised encroachment and filling up of wetlands happened between 1962-67 when Salt Lake reclamation for the extension of city led to large scale conversion of wetlands. In 1980 started the construction of the Eastern Metropolitan Bypass which further shrunk the wetlands. In 1985 the East Calcutta Wetland and Waste Recycling Region map covering 12500 hectares was released by West Bengal State Planning Board which somewhat marks the present boundary. The importance of wetlands and the need to conserve the system was realised and Institute of Wetland Management and Ecological Design was set up by the Government of West Bengal as an autonomous unit in 1986. In a landmark judgement, Calcutta High Court judgment disallows any change of land use within the 12,500 hectare wetland boundary without the approval of the Calcutta High Court obtained in each case in 1992. In 2002, finally the East Kolkata Wetlands comprising 32 mouzas (a type of administrative district in India) was included in the Ramsar list, covering 12500 hectares. In 2006, East Kolkata Wetland Management Authority (EKWMA) was set up for conserving and managing the threatened ecosystem. On World Water Day 2017, UN declared EKW as one of the most outstanding wetlands in the world where wastewater is being treated (SCOPE, 2017).

The history traces important steps towards conservation and management of EKW, yet it has been ever shrinking due to pressures of urbanisation. The city bound on west side by the river Hooghly is ever expanding eating up the greens and wetlands on the east. Hence, the paper highlights ecological and economic costs of losing the wetlands and the need to integrate the same for resilience planning.

3.3 The Hydraulic Regime

Storm Weather Flow (SWF) & Dry Weather Flow (DWF) are waste channels from the city which are directed to sewage pumping stations located at strategic points in Kolkata (Maiti et al., 2013). Five pumping stations at Topsia, Pamarbazar, Ballygange, Chingrihata or Dhapa lock gate and Chowbaga pump sewage to Dry Weather Flow (DWF) waste channel. DWF start from Topsia pumping station, carries sanitary sewage from the city, flows across the EKW and then releases it to river Bidyadhari near Malancha ghat (Maiti et al., 2012). The SWF channel which runs parallel to the DWF, carries rain water of the city. Both the channels meet before draining into the river.



Map ii: Hydraulic structures within EKW basin (Source: Management plan of EKW, 2010, EKWMA, WISA)

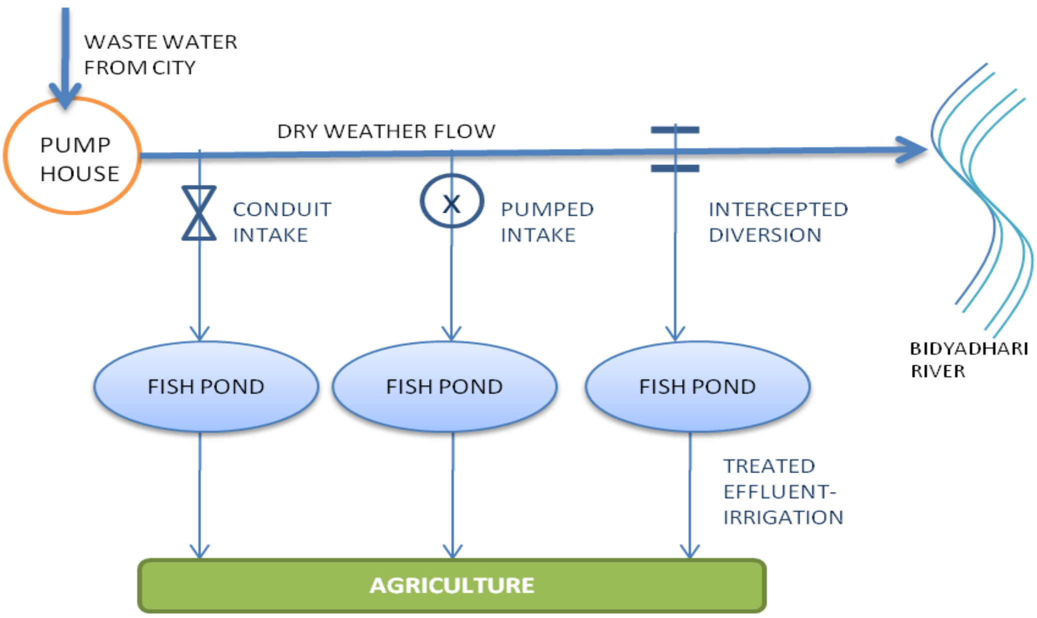
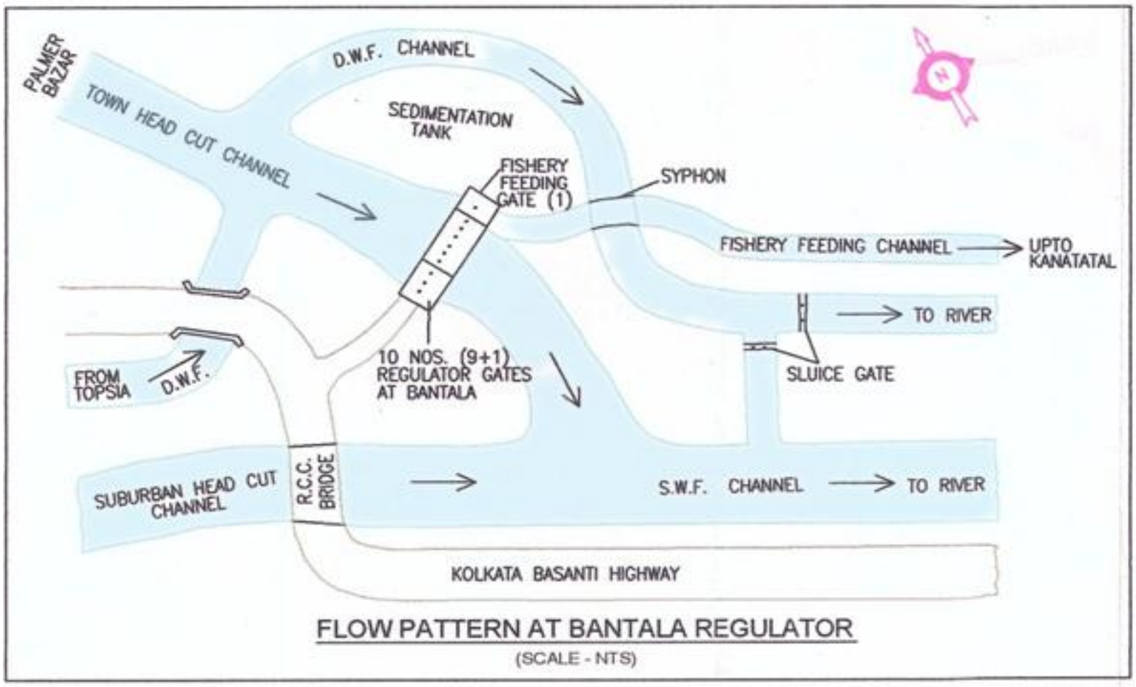


Fig. i: The Hydraulic Regime for Wastewater Utilisation (Source- Author)

The total **DWF generation has been estimated as 993 million litres per day (MLD) within the watersheds draining into the EKW, which is roughly equivalent to 1,000 MLD** (Kolkata Pollution Control Board, 2009). At Bantala lock gate, some fish pond feeder canals start from DWF and carry almost **30% of the sewage** (about 300 MLD) to the fishery pond situated at the both side of DWF (Maiti et al. 2013).



Map iii: The flow pattern at Bantala Regulator (Source- Developed by author over drawing from Kolkata Municipal Corporation)

3.4 The Biological Process In Sewage Fed Fisheries

The biological process facilitated by the fish ponds utilises the Phytoplanktons cleaning waste water in presence of sunlight as well as feeding fish. A unique phenomenon of **algae–bacteria symbiosis** occurs where algal photosynthesis, in the presence of sunlight, releases oxygen resulting in reduction of biochemical oxygen demand (BOD). About 237 kg of (BOD) is removed per day by each hectare of a shallow waterbody (Dey, 2008). This reduces coliform bacteria which even conventional sewage treatment plants may not be able to fully eradicate. The effluents from the fish ponds are then drained through the irrigation canals to be utilised in the agricultural lands.

In another way, the solar energy is trapped by a dense population of phytoplankton (blue-green algae) which in turn are consumed by the fishes. The plankton plays an important role in degrading the organic matter. But the overgrowth of the planktons becomes a problem for pond management since they causes algal bloom. At this stage the fish solves the problem by grazing on the plankton. The two fold role played by the fishes is indeed crucial – they maintain a proper balance of the plankton population in the pond and also convert the available nutrients in the wastewater into readily consumable form (fish) for humans (Ghosh, 1995). Over the years, such resource recovery activities mastered by the fish farmers of EKW yield fish which is 2 to 4 times higher than normal ponds and save huge energy costs required in treating waste water in treatment plants.

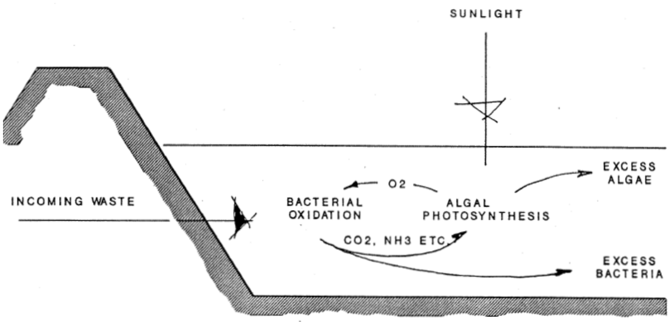


Fig. ii : Algae-Bacteria Symbiosis (Ghosh, 1995)

3.5 Reduction of GHG Emission: A Comparison with Sewage Treatment Plants (STP) of Kolkata

As discussed earlier, Kolkata has five STPs with a total capacity of 162.5 MLD (in aggregate).

Sewage treatment plants are considered as sources of GHG (greenhouse gas) emission; mainly methane, carbon dioxide and nitrous oxide which are produced in two ways-

1. **Direct Emission** - biological sewage treatment processes like aerated lagoon system, activated sludge process and others and

2. **Indirect Emission-** offsite electricity production which is a major source of carbon. (Mrinal et.al., 2016).

The net greenhouse gas release is the sum total of the direct and the indirect emissions because of the generation of power at off-site from the plants. It is found that Keshopur plant in Delhi (72MGD capacity, Activated Sludge Process) has the emission which is 18640 tCO_2/yr out of which from 17413 tCO_2 e/yr, that is, 93.4% is indirect Emissions (as calculated by Mrinal, M. et. al., 2016). Thus we can say that the indirect GHGs emission due to electricity consumption is much more than the direct on-site GHGs emission as a result of sewage treatment in STPs which is negligible.

The most important cause of the day to day increase in the global temperature is increase in the emission of green house gases. Under such situation the treatment of wastewater in fish ponds is an important mitigation and contributor to cities resilience. It not only reduces urban energy consumption but also reduces GHG emissions greatly. This paper attempts to calculate the Tonnes of CO_2 equivalent indirect emission from the STPs of Kolkata and compare it with natural system of EKW to quantify the ecological services rendered by this natural wetland.

3.5.1 Calculation Of Tonnes Of Carbon Dioxide Equivalent Indirect Emission From The STPs

The tonnes of carbon dioxide equivalent indirect emission from the STPs is calculated from respective energy costs. As discussed earlier Kolkata has 5 STPs - Keorapukur STP, Garden Reach STP, Bangur STP, Baghajatin STP and Hatisur STP, out of which only the first three are considered due to availability of data.

The Respective Power Consumption in Megawatt Hour (Mwh/Yr.) has been calculated considering Energy charge for Public Water Works & Sewerage System= Rs. 6.58 /Kilowatt Hour (Kwh) = Rs. 6580 /Megawatt Hour (Mwh) (as per Tariff and Associated Terms and Conditions vide Order dated October 28, 2016 of the Hon'ble West Bengal Electricity Regulatory Commission).

The emission factor is 0.82 t CO_2/Mwh as per Central Electricity Authority, CO2 Baseline Database for Indian Power Sector 2014.

Therefore, Tonnes of carbon dioxide equivalent (tCO2e/yr) = Power Consumption (Mwh/Yr.) X Emission Factor (tCO_2/Mwh) = Power Consumption (Mwh/Yr.) X 0.82 tCO_2/ Mwh (calculation showed in Table i).

Table-i: Calculation of Tonnes of CO_2 Equivalent Indirect Emission from the STPs

Sl.	STP	Capacity MLD*	Technology*	Energy costs /year in lakhs (INR) *	Power Consumption (Mwh/Yr.)	Tonnes of Carbon dioxide Equivalent Emission (tCO_2 e/yr)
1	Keorapukur STP	45	Aerated lagoon	52	790.27	648.02
2	Garden Reach STP	47.5	Activated sludge process	57.36	871.73	714.82
3	Bangur STP	45	Activated sludge process	18.6	282.67	231.79
	Total of 3 STPS of Kolkata	**137.5**		**127.96**	**1944.68**	**1594.64**

NOTE - *Capacities, Technology and Energy costs taken from Report: Details on Water and Sanitation Services maintained by ULBs, Kolkata Municipal Corporation, 2014

Therefore, from the total of 3 STPS of Kolkata, Tonnes of CO_2 Equivalent (t CO_2e/yr) Indirect Emission for 1 MLD capacity can be derived as 11.6 t CO_2 e/yr.

3.5.2 Calculation Of Annual Carbon Sequestration Potential Of The Sewage Fed Fishponds

EKW has 4000 hectares of sewage fed fishponds (Kundu, et. al.). The paper considers only the aquaculture farms which functions a natural wastewater treatment plants, leaving the rest of the vegetable farming area and paddy fields that also considerably contribute to reduction of atmospheric emission by sequestration. Considering aquaculture ponds sequester 1.5 tCO_2/ hectares/ year (Boyd et al, 2010), the finding is a staggering 6000 t CO_2/yr.

3.5.3 A Comparison of the sewage fed fishponds of EKW with the STPs

Now, if we compare EKW with an STP of same capacity, that is, 300 MLD, one can say it is saving the city from emission of 3479 tCO_2 e/yr (Indirect component, considering, 11.6 tCO_2 e/yr per MLD, calculated from table i) due to its natural system utilizing sunlight and 6000 tCO_2 e/yr (Direct component) due to its Carbon sequestration potential. Thus urban wetlands like EKW contribute towards urban environment which is crucial for climate change mitigation and urban sustainability.

Table ii: Comparison of Capacity, Tonnes of CO_2 Equivalent Emission, And Annual Carbon Sequestration Potential of Sewage Fed Fishponds of EKW with the STPs

Sl.		Capacity MLD	Tonnes of CO_2 Equivalent Emission (tCO_2 e/yr)* **INDIRECT COMPONENT**	Annual Carbon sequestration potential (tCO_2 e/yr) ** **DIRECT COMPONENT**
i.	Keorapukur STP	45	648.02*	-
ii.	Garden Reach STP	47.5	714.82*	-
iii.	Bangur STP	45	231.79*	-
iv.	**EKW**	**300**	(-) 3479**	(-) 6000**

Note- **As calculated in Table i, ** As calculated in section 3.5.3, ***As calculated in section 3.5.2.*

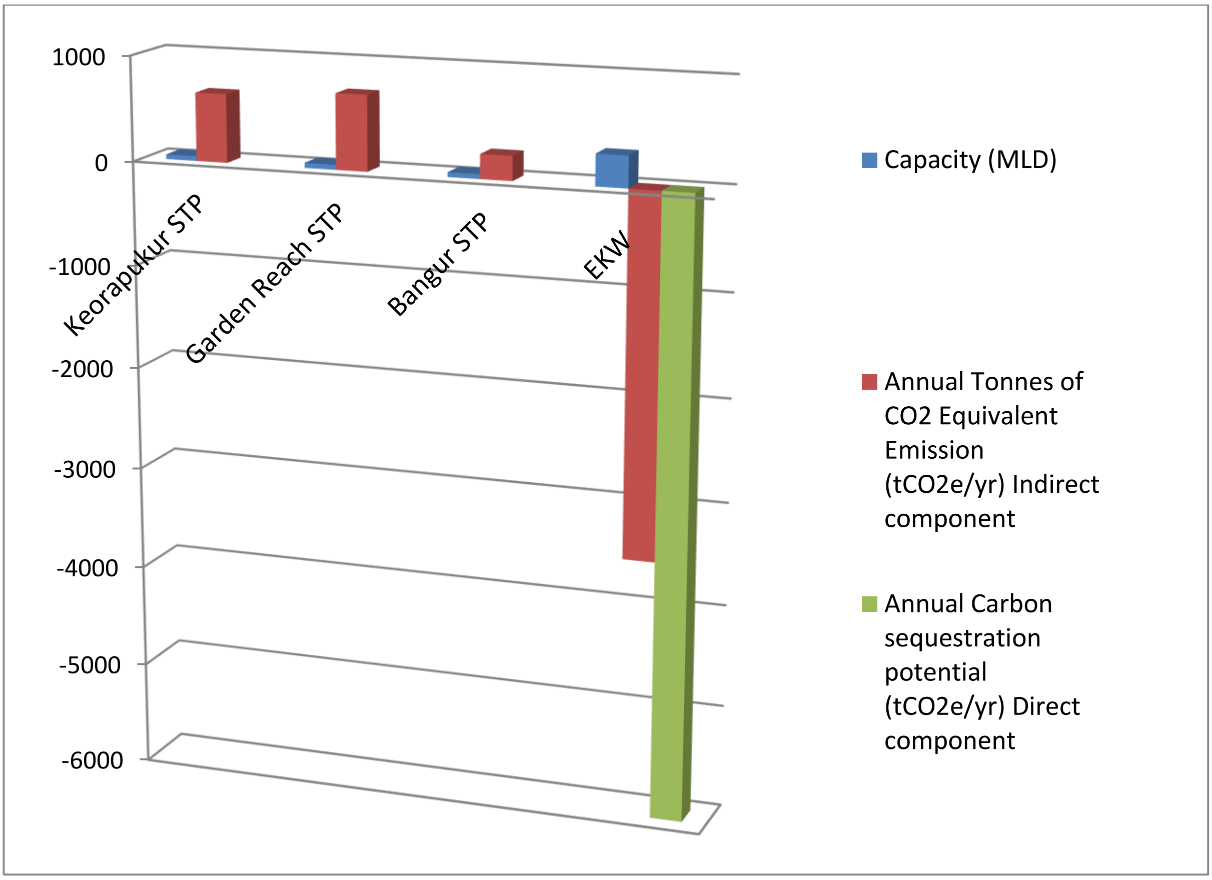


Fig iii: Graph Comparing of Capacity, Tonnes of CO_2 Equivalent Indirect Emission, and Annual Carbon sequestration potential of sewage fed fishponds of EKW with the STPs

This shows a considerable increase in CO_2 emission if EKW is replaced by STPs of same capacity. Hence, one can say, the ecological services provided by the wetlands are irreplaceable.

An STP of 300 MLD would also incur a cost of 279.18 lakhs INR (equivalent to 377,321.26 USD, considering 1USD=73.99 INR, November 1, 2018) per year on electricity only (considering Rs. 127.96 lakhs/year for 137.5 MLD, as in Table1). It is needless to say EKW is responsible for Kolkata being an "ecologically subsidised city" (Ghosh, 2015).

In 2004, Late ecologist Dr. Dhrubajyoti Ghosh had pointed out, "Even by conservative estimates, this has saved the city authorities from spending Rs. 400 crores (4000 million INR or 54.1 million USD as on November 1, 2018) on capital expenditure and incurring a recurring maintenance cost on water treatment plants".

4. CONCLUSION

Globally cities are now recognizing the ecological services of urban wetlands towards urban sustainability and are working to conserve and enhance their potential. Colombo, Sri Lanka aims to be one of the first official 'Wetland Cities' accredited by the Ramsar Convention. In Udon Thani, Thailand, the vision is not only to protect existing wetlands, but also restore lost and create new wetlands, along with other natural infrastructure. The aim is to protect the city by providing green and recreational spaces with "green infrastructure master plan" (Ortinez. Et. al., 2018).

Kolkata has been enjoying a subsidized service of wastewater treatment as well as low-cost supply chain of fresh fish, vegetables, etc., and EKW is enjoying traditional livelihood options through wise-use practices (Dey, et. al, 2018). But the city, on one hand, is setting up urban amenities at the cost of its wetlands and also developing strategies of climate mitigation, on the other. The study is to point at the fact that the two strategies are negating each other and hence a holistic approach is needed. Given the extent of ecological services by EKW towards the city, we must look at a city holistically, understanding the ecological systems that make up the city, the interdependencies and the risks cities may face with loss of the same. Infrastructure planning and environment management has to be integrated and should harmonize each other to fight climate change. An integrated bio system approach of 'constructed wetlands' in the urban fringe can be explored in other cities also while EKW is conserved as an important green infrastructure forming stable urban fringe to an expanding metropolis helping in both resource recovery and environmental protection.

Conflict of Interest Statement- On behalf of all authors, the corresponding author states that there is no conflict of interest.

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