Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2014, 6(9):328-333

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Role of sewage fed fisheries for treatment of dry weather flow of Kolkata City maintaining the eco-toxicity balance

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ABSTRACT

A study has been carried out to assess the performance of existing sewage fed fishery under ecologically balanced waste water treatment system. The study also assessed the eco-toxicity of the ecologically balanced waste water system and detail auditing of heavy metals in the fish, sediments and waste water was also carried out. The sewage analysis result of DWF from Topsia point A to Ghushighata reveals that the BOD value of sewage is getting reduced while moving along more than 30 km stretch and also due to utilization of sewage in fish ponds including ecologically balanced treatment in the pond and then getting mixed again in the DWF. The study also indicates that presence of heavy metals in fish is within tolerable limit according to per capita per day consumption basis. In this context, it is to be mentioned that considerable quantum of metal are released out from fish during cutting, dressing and washing.

Keywords: Pisciculture, Dry weather flow, Sewage, Eco-toxicity, Waste water

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INTRODUCTION

Kolkata founded in the year 1690, has grown slowly in an uncontrolled manner along the eastern side of River Ganga and stretching more along the northern and southern direction. The eastern part of Kolkata was chosen by the city managers as a place to receive both liquid and solid waste. Kolkata Municipal Area (KMA) has a combined drainage system. The Dry Weather Flow (DWF) is discharged in a dedicated DWF channel which starts from Topsia Point A and leads to the eastern direction. The dry weather flow comes mainly from Palmer Bridge Pumping Station and Ballygunge pumping station. Separate storm water channels also exist for the city of Kolkata. The dry weather flow and major storm water flow of Kolkata discharge in Kulti-Bidhyadhari river at Ghusighata which is more than 30 km away from the city limit. The storm water channels and dry water flow channel are part of the drainage system of the city. At present dry weather flow leads to DWF channels amounting to approximately 1000 MLD as per Kolkata Municipal Corporation (KMC) [1]. Kolkata is unique as wetlands are situated in the eastern fringe of the city. Local fishermen use sewage conveyed through DWF channels in the wetlands (bheri) for pisciculture. It is the largest sewage fed aquaculture in the world. The sewage fed aquaculture system acts as an ecologically balanced waste water treatment for the city. The production of fish in sewage fed aquaculture system which is considered to be at least 4 times than the production of fish in normal surface water [2-3].

A number of studies have been undertaken of the EKW system [4-10]. These studies highlighted the uniqueness of the system in supporting a large fishery whilst treating large volumes of wastewater from the city of Kolkata, India. Sadhukhan [9] measured the mercury concentration in sediments, water and fish from the East Kolkata wetland. It

was observed that the mercury content of the fish obtained from these water bodies were below the permissible safe dietary level of 0.5 mg/kg while they purify the water and praised the natural system of the wetlands for accommodating the total sewage flow of one of the five most populated cities of the world [1]. The overall objective of this study is to assess the performance of existing sewage fed fishery under ecologically balanced waste water treatment system including detail auditing of heavy metals of East Kolkata Wetland.

EXPERIMENTAL SECTION

Study Area:

The total area of East Kolkata Wetland (EKW) is 12741.30 ha comprising of 364 sewage fed fisheries, several other bodies, agricultural area, garbage disposal site, urban and rural settlement area. Out of this, total water area is about 5852.14 ha. Before 1930, the main source of water for the fisheries was the tidal Bidyadhari River. With the silting up of the river Bidyadhari, entire area became a vast derelict swamp with the elimination of tidal water in these areas. There was a desperate need for an alternate source of water, for thriving the traditional fisheries in this wetland. Thus, at this junction the city sewage was considered for utilization in the fish ponds. With the entry of increasing quantum of sewage from the city into these areas, the salinity went down considerably and the wetlands became ideal for the fresh water pisciculture. Presently 3898.70 ha out of 5852.14 ha water areas are used for sewage fed fish farming. The maximum yield from this sewage fed fisheries is about 30000 MT per year. The average yield of fish from wetland during the last couple of years has been 80% of the maximum yield i.e. 24000 MT/year as per information gathered from the field during the study. EKW was declared as a Ramsar site in 2002. It is an example of wise use of wetlands ecosystem where usage of city sewage for traditional pisciculture and aquaculture are practiced as delineated in figure 1.

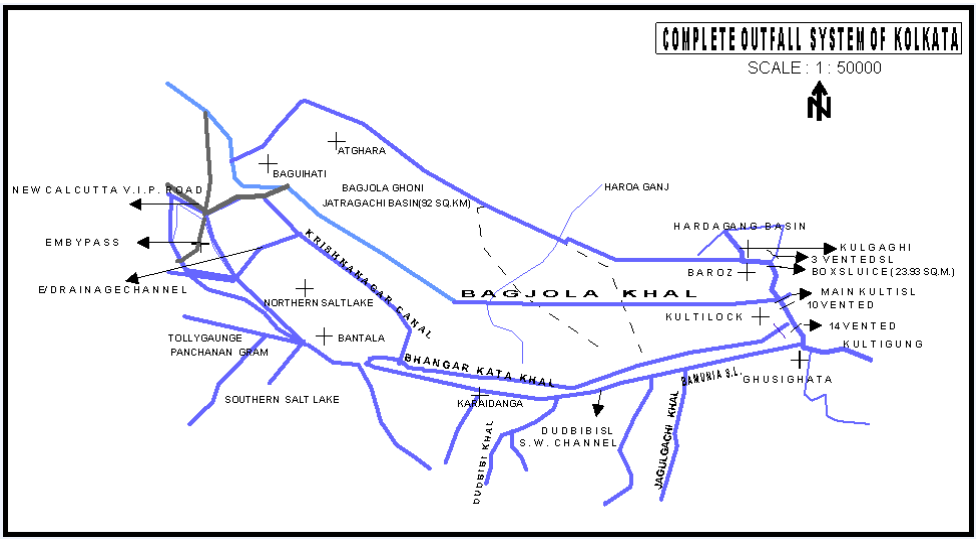


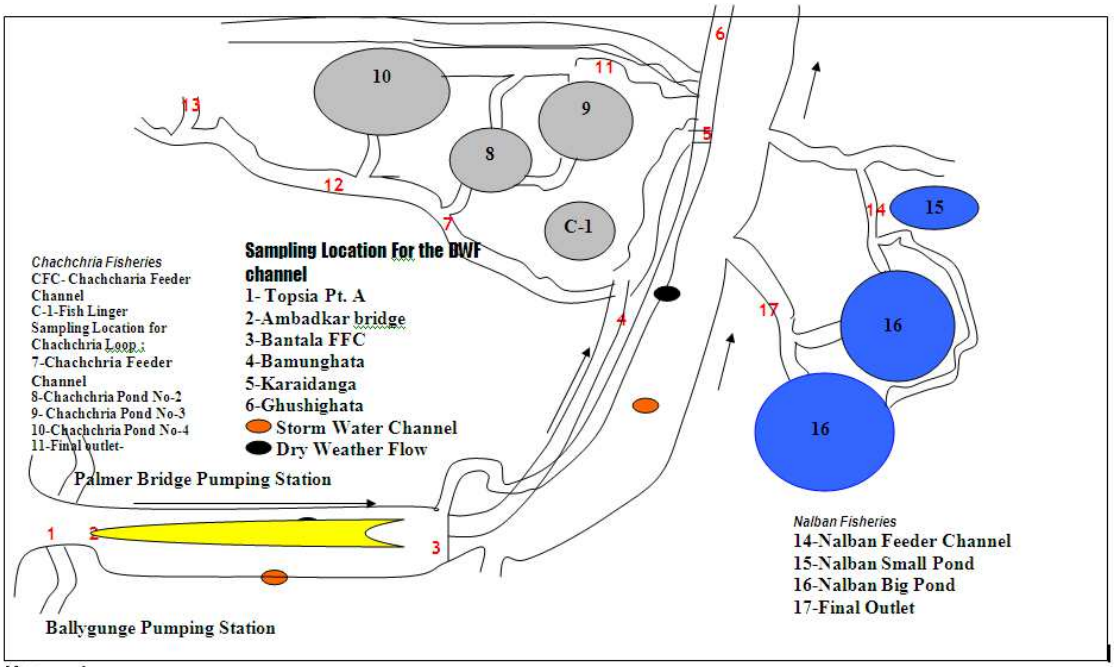
Figure 1. Map Showing complete outfall system of Kolkata, West Bengal, India [3]

The study area extended from Topsia Point A to Ghusighata. DWF channel and sewage-fed fisheries were studied for the model analysis as depicted in figure 2. Monitoring data both primary as well as secondary were considered in the analysis. In the total stretch of DWF, six locations e.g. Tapsia Point A, Ambedkar Bridge, Bantala FFC, Bamanghata, Karaidanga and Ghusighata were selected for water quality and sediment monitoring.

Heavy Metals Analysis of Wastewater:

Concentrations of heavy metals (Zn. Cr, Pb and Cd) from waste water of DWF channel on different dates have been determined and the result is given in Tables 1. Results of analysis bring out that average values of Zn, Cr, Pb and Cd at Topsia Point A of DWF channel are 0.134 mg/L, 0.089 mg/L, 0.074 mg/L and 0.006 mg/L respectively whereas the same at Ghusighata before discharged in Kulti-Bidhyadhari river are 0.07 mg/L, 0.045 mg/L, 0.029 mg/L and 0.002 mg/L respectively as referred in Table 9. Similarly concentrations of such heavy metals in the water of fish-ponds are given in Tables 2 and Table 3. Results of analysis bring out that at the final outlet of fisheries the

concentration of Zn, Cr, Pb and Cd are 0.075 mg/L, <0.01 mg/L, <0.02 mg/L and <0.002 mg/L respectively. Concentration of Zn, Cr, Pb and Cd in flesh, liver and gill of different fish species from the bheries have been analysed and results are given in Table 4 and Table 5. Results of the analysis bring out that maximum quantum of Zn, Cr, Pb and Cd have been found in gill of American Ruhi (179.2 mg/kg), liver of Ruhi (1.91 mg/kg), gill of Mregal (2.67 mg/kg) and gill of Ruhi (0.21 mg/kg) respectively. Heavy metal concentration in Sediments of DWF channel and those of fishery ponds have been determined and are given in Table 6 and 7. Results of analysis bring out that average quantum of Zn, Cr, Pb and Cd in sediment of DWF are 607.5 mg/kg, 291.4 mg/kg, 165.05 mg/kg and 23.05 mg/kg respectively, whereas, the same in the sediments of fish ponds are 215.48 mg/kg, 106.58 mg/kg, 83.74 mg/kg and 11.68 mg/kg respectively.



Not to scale

Figure 2. Sampling location map of East Kolkata Wetland [3]

Table 1. Average values for the DWF Channel of EKW

Sample Name	Zn(mg/L)	Cr(mg/L)	Pb (mg/L)	Cd (mg/L)
Topsia Point A	0.134	0.089	0.074	0.006
Ambedkar Bridge	0.127	0.074	0.05	0.006
Bantala(FFC)	0.051	0.06	0.048	0.006
Banmanghata	0.18	0.05	0.04	-
Karaidanga	0.137	0.05	0.03	-
Ghusighata	0.07	0.045	0.029	0.002

Table 2. Average values for the Chachchria Feeder Channel of EKW

Sample Name	Zn(mg/L)	Cr(mg/L)	Pb(mg/L)	Cd(mg/L)
Chachchria Feeder Channel	0.18	0.04	0.04	0.008
Chachchria 2nd Pond	0.069	<0.01	<0.02	<0.002
Chachchria 3rd Pond	0.045	<0.01	<0.02	<0.002
Chachchria 4th Pond	0.077	0.023	0.02	<0.002
Final Outlet	0.04	< 0.01	<0.02	<0.002

Table 3. Average values for the Nalban Feeder Channel of EKW

Sample Name	Zn(mg/L)	Cr(mg/L)	Pb(mg/L)	Cd(mg/L)
Nalban Feeder Channel	0.18	0.04	0.04	0.004
Nalban Small Pond	0.075	<0.01	<0.02	<0.002
Nalban Big Pond	0.075	<0.01	<0.02	<0.002
Final Outlet	0.075	<0.01	<0.02	<0.002

Table 4. Fish Analysis for Chachchria Co-Operative of EKW

Description	Results mg/kg			
	Zn	Cr	Pb	Cd
American Ruhi-F	19.4	0.13	< 0.1	< 0.1
American Ruhi-L	135.9	0.55	< 0.1	< 0.1
American Ruhi-G	179.2	0.76	0.85	0.13
Telapia-F	8.5	0.26	< 0.1	< 0.1
Telapia-L	21.3	0.66	< 0.1	< 0.1
Telapia-G	20.6	0.81	< 0.1	0.1
Ruhi-F	7.2	0.16	< 0.1	< 0.1
Ruhi-L	65	1.91	< 0.1	< 0.1
Ruhi-G	106.8	0.73	1.01	0.16
Note: F=Flesh, L=Liver & G=Gill.				

Table 5. Fish Analysis for Nalban Co-Operative of EKW

Description	Results mg/kg			
	Zn	Cr	Pb	Cd
Lailentia-F	6.5	0.25	<0.1	<0.1
Lailentia-L	16.6	0.81	< 0.1	< 0.1
Lailentia-G	18	0.87	2.23	0.14
Catla-F	4.6	0.22	< 0.1	< 0.1
Catla-L	123.8	0.89	< 0.1	< 0.1
Catla-G	148	0.99	0.75	0.16
Mregel-F	3.9	0.16	< 0.1	< 0.1
Mregel-L	12	0.36	< 0.1	< 0.1
Mregel-G	23.9	1.28	2.67	0.2
Ruhi-F	5.7	0.23	< 0.1	< 0.1
Ruhi-L	53.1	0.76	< 0.1	< 0.1
Ruhi-G	105.4	1.01	1.77	0.21
Note: F=Flesh, L=Liver & G=Gill.				

Table 6. Sediment Analysis for Heavy Metals (mg/kg) in DWF

Sample Name	Zn	Cr	Pb	Cd
Topsia Point A	681.0	588.0	187.5	56.2
Ambedkar Bridge	668.0	473.0	167.0	37.0
Bantala(FFC)	547.0	309.8	163.1	9.1
Banman Ghata	540.0	195.2	157.9	8.4
Karai Danga	532.0	82.8	142.0	8.0
Ghusighata	677.0	99.6	172.8	19.6
Average	607.5	291.4	165.05	23.05

Table 7. Sediment Analysis for Heavy Metals (mg/kg) in Fish Ponds

Sample Name	Zn	Cr	Pb	Cd
Chachchria 2nd Pond	91.3	13.7	44.3	2.6
Chachchria 3rd Pond	139.5	37.1	67.0	7.0
Chachchria 4th Pond	400.0	285.0	136.3	16.0
Sample Name	Zn	Cr	Pb	Cd
Nalban Big Pond	75.6	5.6	40.0	3.8
Sample Name	Zn	Cr	Pb	Cd
Dhali Bheri	371.0	191.5	131.1	29.0
Average	215.48	106.58	83.74	11.68

RESULTS AND DISCUSSION

Toxicity from heavy metals in the whole eco-system has been worked out and is summarized by metal wise. As per record of pumping (KMC) the dry weather flow is 1000 MLD. It has been observed that certain quantum of DWF enters into the storm water flow channel. Accordingly 800 MLD, DWF has been considered for the eco-toxicity balance calculation. The analysis of zinc-metal balance in wetland has been calculated based on Table 1 and Table 7 by considering the average DWF that entering into the system i.e. 800 MLD. The total quantity of zinc in entering

the East-Kolkata sewage disposal network is 37084 kg. As if, zinc gets deposited mostly in sediments in DWF channel and in fish ponds. Hence the quantity of zinc in pond sediments is 22346 kg. Also the quantity of zinc in fish (Gill, liver and Flesh) per year is 124 kg. Hence quantity of zinc getting discharged in Kulti-Bidyadhari river per year is 10220 kg by considering evaporation and percolation loss as 20 % and 30% utilization in agriculture land. Thus, 3546 kg of zinc is unaccounted for DWF channel. The same analyses have been done for other heavy metals such chromium, lead and zinc as depicted in Table 8.

Table 8. Extent and Magnitude of Heavy Metals (Zinc, Chromium, Lead and Cadmium) in East Kolkata Waste Water Management System (kg/year)

Metal	Quantity entering in Outfall Channel	Quantity deposited in Sediments of Fish Pond	Quantity deposited in Sediments of DWF Channel	Quantity get discharged in Kulti-Bidyadhari River	Quantity get into Fish Bodies	Quantity unaccounted for Zinc
Zinc	37084	22346	848	10220	124	3546 (9.56%)
Chromium	21608	11053	407	6570	1.58	3576.42(16.49%)
Lead	14600	8685	230.5	4234	1.128	1449.372(9.92%)
Cadmium	1752	1212	32.2	292	0.288	215.5(12.3%)

**Unaccounted for metals are deposited in agricultural field and adsorbed by vegetables/crops*

Table 9. General Standard compares with findings data for discharge of Environmental pollutants at Ghushighata

Parameters	Standard for Discharge in Inland Surface Water(mg/L)	Concentration at Ghushighata Discharge Outlet (mg/L)
Zinc	5.0	0.07
Chromium	2.0	0.045
Lead	0.1	0.029
Cadmium	2.0	0.002

(All the above parameters meet the CPCB norms for discharge in Inland Surface Water)

Cadmium

Cadmium Concentration in unpolluted water is usually below 0.001 mg/L. Food is the main source of non-occupational exposure to cadmium, with dietary daily intakes; in the range 10-35 µg [11]. The intake from drinking water is usually less than 2 µg/day [11]. Smoking will increase the daily intake of cadmium. Major effects are desquamation of epithelium, necrosis of the gastric and intestinal mucosa, and dystrophic changes of liver, heart and kidneys. Average cadmium level in fish was reported as 20 µg/kg wet weight i.e. 200 µg/kg dry weights. High levels were found in Shellfish – 200 to 2000 µg/kg. According to the present study, presence of cadmium in fish is 120 µg/kg dry weight. The maximum value of cadmium is found to be 0.21 mg/kg i.e. 210 µg/kg in Gill of fish (dry weight) shown in Tables 4 and 5. Hence the quantum of cadmium in fish has been found within the tolerable limit

Lead

Lead more than 80% of the daily intake of lead is derived from the ingested of food, dirt and dust. Lead intake through food and drink has been reported to be in between 23-90 µg/day [11]. The present study indicated that average lead content in fish is 0.47 mg/kg dry weight i.e. 470 µg/kg. The maximum value of lead is found as 2.67 mg/kg i.e. 2670 µg/kg (267.0 µg/kg as wet weight) as Gill of Mrigal shown in Tables 4 and 5. As per capita consumption per day is not more than 100 gm fish (wet weight), hence daily intake per capita per day is restricted within 26.7 µg/day. Hence the quantum of lead in fish is within tolerable limit.

Chromium

Natural total chromium in surface water is approximately 0.5-2 µg/L. Most surface water contains chromium between 1 to 10 µg/L [11]. Food contains Chromium at Concentration ranging from < 10 to 1300 µg/kg [11]. Highest concentration has been found in meat, fish, fruit and vegetables. The present study has been found average chromium in fish as 0.657 mg/kg dry weight i.e. 657 µg/kg. The maximum value of chromium is found as 1.91 mg/kg i.e. 1910 µg/kg in Liver of Ruhi shown in Tables 4 and 5. Hence the quantum of chromium in fish has been found within the tolerable limit.

Zinc

Protein rich food, such as meat, fish, marine organic contains high concentration of zinc (10-50 mg/kg net weight). Values of 5-22 mg [11] of zinc have been reported in studies on the average daily intake of zinc in different areas. Our study has been found zinc in fish as 51.68 mg/kg dry weight. The maximum value of zinc is found as 179.2

mg/kg i.e. 17920 µg/kg in Gill of American Ruhi shown in Tables 4 and 5. Hence the quantum of zinc in fish has been found within the tolerable limit.

CONCLUSION

The sewage analysis result of DWF from Topsia point A to Ghushighata reveals that the BOD value of sewage is getting reduced while moving along more than 30 km stretch and also due to utilization of sewage in fish ponds including ecologically balanced treatment in the pond and then getting mixed again in the DWF. The BOD at Topsia point A ranges between 150 mg/L to 160 mg/L as measured during end June and early July, 2006. The same during non-monsoon period may be between 170 to 180 mg/L. The BOD at Ghushighata before discharge was found to be around 29 mg/L. The COD at Ghushighata before discharge in Kulti-Bidhyadhari was found to be 80 mg/l. During the waste water analysis, it was observed that the Total Dissolved Solid (TDS) gets increased during high tide period due to the entry of salty water from Kulti-Bidhyadhari river in the DWF as well as storm water channels. During high tide, turbulence is created in DWF at Ghusighata and as a result suspended solid gets increased which often resulted in higher BOD and COD as observed for water sample collected from Ghusighata. The study indicated that presence of Zinc, Chromium, lead and cadmium in fish are within tolerable limit according to per capita per day consumption basis. In this context, it is to be mentioned that considerable quantum of metal are released out from fish during cutting, dressing and washing. The qualitative analysis of waste water of dry weather flow channel at Ghusighata indicated that the discharge of waste water in Kulti-Bidyadhari river conform to the standard.

Acknowledgement
The authors express their sincere thanks to Kolkata Environmental Improvement Project (KEIP) funded by Asian Development Bank (ADB) for providing initial financial support to carry out the initial work.

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