AN EXPERIMENTAL STUDY ON SCOPES FOR TRANSFERRING SEWAGE-FED AQUACULTURE (*BHERI*) FROM KOLKATA, INDIA TO BANGLADESH.

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CONTENT

1. BACKGROUND

Literature indicates aquaculture as a commercial activity has been practiced since 500 BC (Bunting, S.W., 2004). Waste water fed aquaculture was initiated in Germany during the late 19th century (Prein, M., 1990). Waste water aquaculture in Asia is more recent, with large-scale systems in countries like China, India, Indonesia and Vietnam arising mostly during the last century. Farmers and local community, mainly contributed to the development of waste water reuse methods like waste water fed aquaculture to increase food productions. Both direct and indirect waste water-fed aquaculture has been practiced throughout the world, including East, South and South-East Asia and other continent (Cointreau, J. S., 1987; Edwards, P., & Pullin, R. S.V., 1990; Edwards, P., 1992; Prein, M., 1996). Waste water fed aquaculture is low technology recycling of the organic residues into a protein rich food source through an eco-friendly balanced system (Jana. B, B., 2005) and is used to put together an economically viable, environmentally sustainable arrangement.

India is the third largest fish producer of the world. Aquaculture production rates are not very significant in Bangladesh. West Bengal tops in terms of aquaculture yields within India (ICAR, India 2013). It was found in the literatures that urban and peri-urban aquaculture around Kolkata, especially in the East Kolkata Wetlands (EKW) has sustained livelihoods of several thousand low income people living in and around the wetlands and makes a significant contribution to food security and income (CRG, 1997; Little D,C.et al., 2002; Punch et al., 2002). The food products generated were found to be safe for consumption (Ray Chaudhuri, S. et al., 2007; Ray Chaudhuri, S. et al., 2008a). The process of waste water fed aquaculture (Bheri) treats 2/3 of Kolkata's soluble waste while suppliers 2/3 of the cities fish demand (Ghosh, D., 2005; Ray, et al., 2004). The scientific mechanism behind the conversion of waste into product (fish, vegetables) has been investigated in detail (Ray Chaudhuri, S. et al., 2008a, Ray Chaudhuri, S. et al., 2008b).

On the contrary, a large proportion of the waste water from Dhaka city discharges into various water bodies in Dhaka resulting in deterioration of water quality. Urban fish farms are growing fast on those water bodies, but with little success as opposed to what is seen at EKW. The high cost of feed is the major constraint to intensive fish production. The increasing cost of fish feed has brought interest in the utilization of waste water in pond fish culture (Bunting, S.W. *et al.*, 2006).

The present study focuses on the system of waste water fed aquaculture in the urban areas of Dhaka, Bangladesh and Kolkata, India. The study compares the water quality in fresh water and waste water bodies involved in aquaculture in the two countries to understand the reason behind the successful fish production in Bheris. This is also a case study of transfer of waste water fed aquaculture technology from EKW, India to Dhaka, Bangladesh.

2. OBJECTIVE

The objective of the study was to understand the criterion of water purification operating at *Bheri* in Kolkata. It was carried out through literature survey followed by physicochemical and biological analysis of water samples from *Bheri* and comparison of that with fresh water ponds in Kolkata. The data was compared with that generated from similar sites at Dhaka to understand further the reason behind the success of the technology at EKW. The final objective of the work was to transfer the technology of waste water fed aquaculture followed at EKW, Kolkata to Dhaka to ensure sustainable waste water fish production with revenue generation at Bangladesh.

3. MATERIALS AND METHODS

i. Study design and sites

The study involved a comparison of physical, chemical and biological parameters of waste water fed and fresh water aquaculture located in and around Kolkata, India and Dhaka, Bangladesh. A quantitative and qualitative survey conducted by direct observation, in-depth interviews of local fishermen; water sample collection and laboratory test for water quality was performed as per standard procedure (CPCB, 1997).

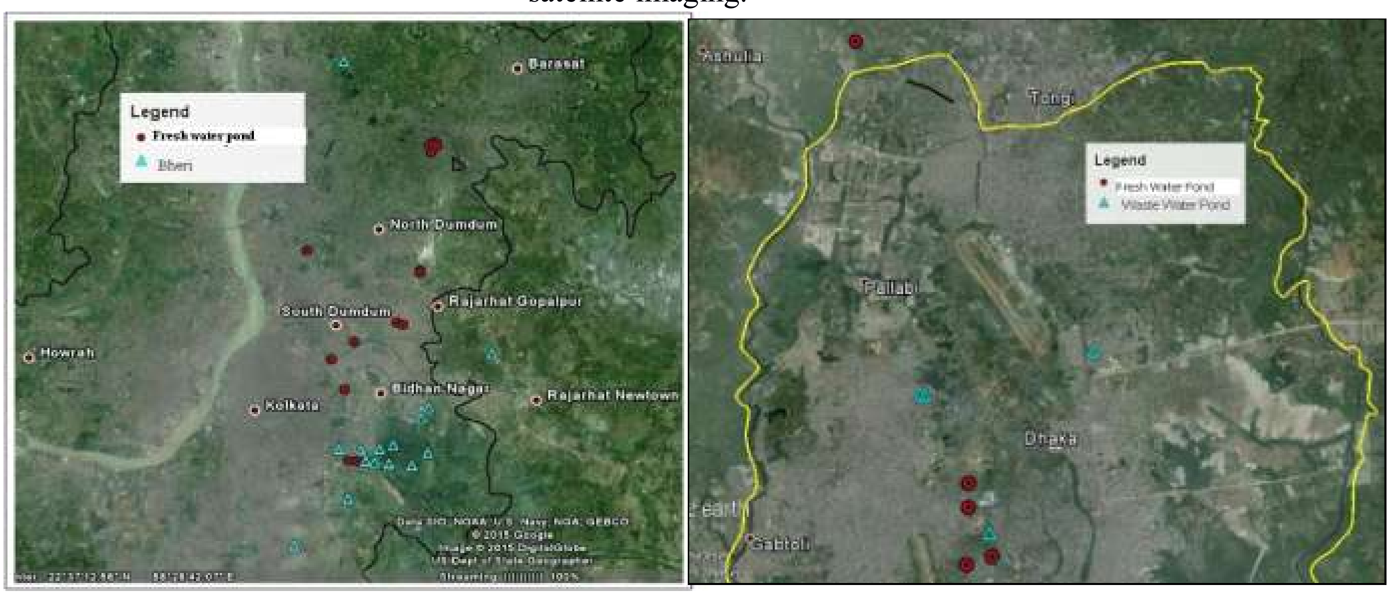
The study was carried out in 15 waste water fed ponds called ‘Bheri’ in local language and 15 fresh water ponds in and around Kolkata. In Bangladesh the study was carried out in 5 waste water fed ponds and 5 fresh water ponds in Dhaka, located in central Bangladesh (Table-1, Fig-1). The sites were selected on the basis of secondary information, mainly based on size, depth, water source, fish production, convenient distance of water sample transportation and active participation of the workers and owners to provide relevant data. The sizes of wastewater fed ponds were between 7.6 to 32.4 Acre (average 18.04 Acre) and that of fresh water ponds were 0.83 to 4.95 Acre (average 1.8 Acre) in Kolkata. Most of the fresh water ponds were used for domestic washing and bathing purpose beside the fish cultivation. The waste water fed and fresh water ponds of Bangladesh were selected in the northern part of Dhaka city. These ponds were around 0.7 to 3.3 Acre and used for fish production, washing and vegetable gardening.

Table 1: Documenting the location of the sample collection spots in Kolkata, India and Dhaka, Bangladesh.

Types	Kolkata, India			Dhaka, Bangladesh		
	Location	Co-ordinates		Location	Co-ordinates	
		(Lat) N	(Lon) E		(Lat) N	(Lon) E
Waste water fed ponds	Captain bheri 1, Bidhannagar	22°33'10"	88°24'43"	Army Quarter pond (North side), Sainik club, Banani	23°47'27"	90°23'49"
	Private bheri , Opposite captain bheri (Chatu lotus)	22°33'19"	88°24'41"	Army Quarter pond (East side), Sainikclub, Banani	23°47'9"	90°23'54"
	Captain bheri 2, behind the captain bheri	22°33'02"	88°24'48"	Khilkhet Kacha bazar, Khilkhet	23°49'51"	90°25'19"
	Noonir bheri , beside the captain bheri	22°33'00"	88°25'02"	Bawniabad slum pond-1, Mirpur	23°49'16"	90°22'47"
	Natar bheri , beside the Noonir bheri	22°32'58"	88°25'25"	Bawniabad slum pond-2, Mirpur	23°49'15"	90°22'51"
	Char (4) no. bheri 1, Boating place	22°33'21"	88°25'10"			
	Char (4) no. bheri 2, beside Char (4) no. bheri 1	22°33'27"	88°25'32"			
	Natar bheri-2, behind Natar bheri	22°32'55"	88°26'02"			
	Nalban bheri , beside Nalban	22°34'10"	88°26'17"			
	Nalban bheri-2, beside Nalban bheri	22°34'26"	88°26'28"			
	Place of Himangini beside Kalyani express highway	22°43'34"	88°24'12"			
	Rajarhatbheri , Rajarhat road bypass	22°35'52"	88°28'09"			
	Char (4) no. bheri 3, behind Char (4) no. bheri-2	22°33'15"	88°26'27"			
	Corakdanga bheri , beside Corakdanga road	22°32'03"	88°24'20"			
	Bonohugli , Bonohugli fisheries cooperative (Mohanagar)	22°30'50"	88°22'54"			
Waste water fed ponds	Koikhali pond-1, Kaikhali road	22°38'03"	88°26'16"	Vacral Pond, Tongi	23°54'7"	90°21'43"
	Koikhali pond-2, beside Koikhali road	22°37'59"	88°26'15"	Bhasantek, Kachukhet	23°48'06"	90°23'31"
	Rail Pukur ,Joramondir	22°36'42"	88°25'38"	Mohakhali DOHS Pond	23°47'03"	90°23'30"
	BoroPukur , Baguihati crossing	22°36'38"	88°25'48"	Post office pond, Cantonment area	23°47'47"	90°23'31"
	Bonohugli pond, (Mohanagar)	22°38'35"	88°23'14"	Army Quarter pond (South side), Sainik club, Banani	23°47'9"	90°23'52"

	Teen(3) number lake, near lake town	22°36'11"	88°24'30"			
	Shipuibari pond , near Ultodanga	22°35'43"	88°23'54"			
	Central pond , near Biddhasagar Nekaton	22°34'56"	88°24'15"			
	Agriculture Runoff spot near ITC Sonar Bangla	22°33'04"	88°24'21"			
	Chatubabur pond, near captain bheri	22°33'03"	88°24'36"			
	Janakalyan pukur , Janakalyan Para, New Barakpur	22°41'22"	88°26'30"			
	ChotoBottala, New Barakpur	22°41'25"	88°26'34"			
	Teen (3) no Jheel , New Barakpur, near police farry	22°41'20"	88°26'43"			
	Mangoli , Near Mangali,New Barakpur	22°41'26"	88°26'41"			
	Oboshar Pukur , New Barakpur, near railway station	22°41'10"	88°26'33"			

Fig 1: Locations of the sampling site in the two cities (Kolkata – A and Dhaka – B) using Google satellite imaging.



B. Kolkata A. Dhaka

ii. Data Collection Method

Physicochemical characteristics

The water samples were collected between December 2012 and September 2013. Different physical, chemical and biological water quality tests were conducted based on the 'Central Pollution Control Board, India guideline (CPCB, 1997). The physical parameters were – Color, Odor, Temperature, Turbidity and Suspended solids. The chemical parameters assessed were - pH, Alkalinity, Total Hardness, Calcium, Fluoride, Ammonia, Phosphate and Dissolved Oxygen (DO) as per the CPCB norms (CPCB, 1997). The sample collection was done as per earlier reports (Ray Chaudhuri, S., 2008b). The biological test was performed at the laboratory following a standard method for water and waste water analysis. The growth of microbes was assessed using HiChrome *E. coli* coliform selective agar base medium (HiMedia M-1294) with overnight incubation at 37°C. Then the coliform counts were taken and the colony forming units per 100 ml of was calculated. The plankton diversity was assessed as per earlier method (Ray Chaudhuri, S., 2008b).

Fish Production & its Economics data

The production and associated revenue generation data was collected from 5 Bheris and 5 fresh water ponds from Kolkata as well as Dhaka. The water qualities of the selected sites were monitored.

iii. Replication of Bheri at Bangladesh

The experiment was carried out in two small ponds. The ponds were located in the northern part of Dhaka city near the Cantonment area where the major land use was for residential purposes with few commercial activities. The co-ordinates of the selected experimental ponds were 23°78′67″N and 90°39′79″E (pond-1) and 23°78′63″N and 90°39′85″E (pond-2). The depths of those ponds were maintained at 2.5 to 3 feet with a flat bottom and sizes were about 1.15 and 1.32 Acre. Waste water drain was close to the ponds (approx. 3 feet far). Most of the waste water came from the residential area, hotels/restaurants and garments industry. The fish cultivation at these waste water fed experimental ponds were carried out as per the literature (Ghosh, D., 2005).

4. RESULTS AND DISCUSSION

i. Physical characteristics

Water quality is the most important factor in fish production and directly affects feed efficiency, growth rates, fish health and survival (Bhatnagar, A. *et al*., 2013). Out of 15 waste water fed and 15 fresh water fed studied ponds in Kolkata, apparently the waste water fed ponds had better quality than fresh water ponds. The deviation from normal condition was more for fresh water than waste water fed ponds (color: 46% and 13%; odor: 53% and 40%; suspended solids: 46% and 0% respectively). About 80% of waste water fed ponds in Kolkata had light green color, an indication of phytoplankton development which is beneficial for fish cultivation (Das, B., 1997). Amongst the five studied waste water fed and fresh water ponds in Dhaka at Bangladesh, about 70% waste water ponds were found to have high concentrations of deep green color, unpleasant odor and high suspended solid detritus because of over manuring through direct inflow of community waste water. The poor water quality of these ponds led to common problems such as excessive algal blooms, overgrowth of plants, noxious smells and dead of fishes (Mokaddes, M. A. A., et al., 2013).

ii. Chemical characteristics

The optimum fish production is dependent on the chemical and biological qualities of water to some extent. The results of the analyzed values were compared with the standard values (based on Santhosh & Singh, 2007; CPCB-ADSORBSI3I 78-79) for different types of water quality parameters essential for fish cultivation. There were significant differences in DO, phosphate and fluoride concentration between the waste water fed and fresh water pond systems in both Kolkata and Dhaka (Table-2).

For aquaculture, maximum permissible limits of pH, alkalinity, and hardness are 8.50, 200 mg/l and 300 mg/l, respectively (Mowka & Edmund., 1988). Usually, the value of alkalinity increases with pH. In some cases it changed because of buffering action (EQS, 2004). However, pH below 5 or above 10 is usually not desirable for growing most of the fishes. The study observed average values of pH, alkalinity and total hardness at Kolkata to be 6.5 ± 0.62, 92 ± 38.8 mg/l, 232.3 ± 80.0 mg/l in the waste water fed pond and 6.1 ± 0.7.3, 101.6 ± 57.0 mg/l and 205 ± 108.2mg/l in the fresh water pond, respectively (Table-2). Variation of pH with respect to both types of ponds was observed to be very small, but the variation in case of alkalinity and total hardness in both types of ponds was visible. The median pH was 6.5 in both types of ponds, but individual values ranged from 5.5 to 7.5 in the waste water fed pond and 5.0 to 7.0 in the fresh water pond. The total value of the alkalinity was from 53 to 180 mg/l and median was 85.0 mg/l in the waste water fed pond; and 32 to 240 mg/l in the fresh water pond. The most favorable value of alkalinity for aquaculture ranges from 50 to 150 mg/l (Santhosh, B. & Singh, N.P., 2007).

According to the result of this investigation, about 80% of the waste water fed pond samples and 67% of the fresh water pond samples met the desirable range of pH and alkalinity for fish cultivation. The total hardness in the present study ranged between 120 mg/l to 400 mg/l and 125 mg/l to 525 mg/l in waste water fed and fresh water ponds respectively. But 3 of the 15 waste water fed ponds expressed high total hardness (above 250 mg/l). The average values of hardness of all the ponds were above 50 mg/l which is significant for fish culture.

The waste water fed and fresh water ponds at Dhaka had mean pH of 6.7 and 6.8, but individual values ranged from 6.4 to 7.0 in the waste water fed ponds and 6.5 to 7.5 in the fresh water ponds. Alkalinity ranged from 48 mg/l to 110 mg/l and 38 mg/l to 140 mg/l for the waste water fed and the fresh water ponds respectively. The mean hardness of the waste water fed and the fresh water ponds were 412 mg/l (280 to 540 mg/l) and 266 mg/l (180 to 360 mg/l) respectively. Both the pH and the Alkalinity were within the desirable range while hardness was much above the acceptable limit.

In aquaculture ponds, turbidity from planktonic organism is desirable to an extent, whereas that caused by suspended particles is undesirable (McCombie, A. M., 1953). However, optimum Secchi-disc visibility for fish ponds is considered to be 20-40 cm. In ponds with Secchi-disc visibility below 10 cm, dissolved oxygen concentration may fall so low at night that fish gets stressed and even killed (Romaire, R.P. et al., 1978). The study observed the turbidity mean to be 19.5cm with a range of 11.1cm to 28.1cm for waste water fed ponds while a mean of 15.2cm with a range of 10.2cm to 21.3cm for fresh water ponds at Kolkata. About 40% waste water fed and 7% fresh water ponds met the desirable range, and most pond samples were within acceptable level for fish cultivation. At Dhaka, the turbidity ranged from 14cm to 20cm and 19cm to 27cm in waste water fed and fresh water ponds respectively. Most of the former are not suitable for aquaculture while the later are within acceptable range.

Dissolved oxygen levels of at least 5 to 6 (mg/l) are typically required for most organisms to grow and engage in activity. Low dissolved oxygen levels are responsible for fish kills, either directly or indirectly. Dissolved oxygen along with the turbidity could provide information about the nature of an ecosystem better than any other chemical parameters (Hutchinson, G. E., 1975). A low level of DO in water indicates the presence of excessive amounts of organic matter (Atlas. R. M., 1995; Zweig, R. D. et al., 1999). From the result of the investigation, the lower levels of DO (2.8 mg/l - 4.0 mg/l) were obtained in 40% (six ponds) fresh water ponds in Kolkata. The main reason of low DO content of the ponds observed may be due to dumping of garbage from the nearest dustbin. About 93% waste water fed pond samples met the desirable range of DO. The obtained mean values of the investigated waste water fed and fresh water ponds at Kolkata were 5.8 ± 1.1 mg/l (4.3 to 8.0 mg/l) and 5.5 ± 1.9 mg/l (2.8 to 8.0 mg/l) respectively (Table-2). The DO at Dhaka ponds (both type) was much lower than acceptable level in majority cases. The levels of DO ranged from 3.2 mg/l to 5.0 mg/l in fresh water ponds and 3.0 mg/l to 6.5 mg/l in waste water fed ponds.

Table -2: Representing the data of different water quality parameters measured as per standard procedure for the different water bodies in Kolkata and Dhaka.

Parameters (Mean value)	Waste water fed pond /Bheri		Fresh water pond		**Parameters Conducive** (Desirable Range)
	Kolkata	Dhaka	Kolkata	Dhaka	
Sample size	*15*	*5*	*15*	*5*	
Turbidity (cm)	19.5 ± 4.3	17.1 ± 2.4	15.2 ± 2.8	22.5 ± 3.5	20-40
pH	6.5 ± 0.62	6.7 ± 0.29	6.1 ± 0.7.3	6.8 ± 0.43	6.0-8.5
Alkalinity (mg/l)	92 ± 38.8	71.8 ± 23.36	101.6 ± 57.0	82.6 ± 44.6	50-150
DO (mg/l)	5.8 ± 1.1	4.3 ± 1.3	5.5 ± 1.9	4.1 ± 0.75	5-10
Total Hardness (mg/l)	232.3 ± 80.0	412 ± 116.3	205 ± 108.2	266 ± 73.3	50-250
Calcium (mg/l)	85.9 ± 28.4	155.6 ± 40.2	78.6 ± 45.8	120.8 ± 25.0	50-150
Fluoride (mg/l)	1.62 ± 0.65	1.6 ± 0.54	2.1 ± 0.77	2.0 ± 0.61	1.0
Phosphate (mg/l)	0.20 ± 0.36	0.16 ± 0.16	0.05 ± 0.05	0.08 ± 0.10	0.05-0.4
Ammonia (mg/l)	1.13 ± 0.85	0.9 ±1.2	1.1± 1.0	0.30 ±0.44	0-2.0

± Standard Deviation

The sampling of waste water fed ponds at Kolkata showed desirable values with 100% calcium, 87% ammonia, 73% phosphate while for fresh water ponds these values were 87% calcium, 87% ammonia, 47% phosphate. About 47% of samples contained less than 50 mg/l optimum level of calcium in fresh water ponds, and calcium content of waste water fed ponds samples were more or less within desirable range in Kolkata. At Dhaka, the ponds where fish cultivation was being carried showed 60% calcium and 40% phosphate for waste water fed while 100% calcium and 40% phosphate for fresh water ponds. The average fluoride concentration was 1.62 mg/l in waste water fed ponds, and 2.1 mg/l in fresh water ponds respectively at Kolkata. The average fluoride concentration was 1.6 mg/l in waste water fed ponds, and 2.0 mg/l in fresh water ponds respectively at Dhaka. In both cases the concentrations of fluoride in both countries were above the acceptable range.

Ammonia measurement help determine the health of water bodies in terms of fish production. Fish are very sensitive to unionised ammonia and the optimum range is 0.02-2.0 mg/l in the pond water. When high levels of ammonia is found in water, it results in either a poor phytoplankton bloom or a nutrient over-load within the pond which the normal bacteria in the pond cannot assimilate (Santhosh, R.P. et al., 2007). According to the present study both types of pond water samples in Kolkata for majority of the cases carry ammonia within the acceptable range (1.13 mg/l in waste water fed and 1.1 mg/l in fresh water ponds). Ammonia concentration ranged between 0 mg/l to 3.0 mg/l in waste water fed and 0 mg/l to 1.5mg/l in fresh water fed ponds in Dhaka, also within the range

iii. Microbial characteristics

Fish, especially young ones has been shown to live and grow better on natural food than on artificial feeds. Microscopic green plants called algae or "Phytoplankton" form the base of the food chain for fish. The planktons play a significant role in degrading the organic matter (Ray Chaudhuri, S. et al. 2008c). The water from different types of water bodies were analyzed for their total plankton count per milliliter of water along with the number of varieties found in each and the total number of useful (from the point of fish growth) varieties of Plankton found per milliliter of water for each (Table-3) sample. The useful varieties were determined from the existing literature (Komarkova, J., 1998; Morabito, G. et al., 1999).

The total phytoplankton count in the present study from Indian samples in wastewater fed ponds varied from 2.4 $x10^5$ to 3.6 $x10^6$ and fresh water ponds from 3.3 $x10^5$ to 1.7 $x10^6$ respectively. It was observed that in waste water fed and fresh water ponds, the mean total phytoplankton value was $1.25x10^6$ and $8.86x10^5$; total variety of phytoplankton observed were 33.8 ± 16.6 and 23.3 ± 6.3 respectively from samples collected from Kolkata. Moreover, obtained mean total phytoplankton values of the investigated waste water fed and fresh water ponds in Dhaka were $4.3x10^5$ and $2.2x10^5$ while the total variety of phytoplankton observed were 22.2 ± 5.5 and 10.2 ± 1.9 respectively (Table-3). The total variety of phytoplankton observed was significantly higher in the waste water fed ponds in both countries.

Table 3: Representing the biological parameters of water samples collected from two types of water bodies within the two countries.

Parameters (Mean value)	Waste water fed pond		Fresh water pond	
	Kolkata	Dhaka	Kolkata	Dhaka
Sample size	*15*	*5*	*15*	*5*
Total Coliform (Cfu//l)	1.8 $x10^5$	1.30 $x10^6$	2.7 $x10^5$	1.31 $x10^6$
Total phytoplankton count	$1.25x10^6$	$4.3x10^5$	$8.86x10^5$	$2.2x10^5$
Total variety of phytoplankton observed	33.8 ± 16.6	22.2 ± 5.5	23.3 ± 6.3	10.2 ± 1.9
Useful plankton count	$4.6x10^5$	$2.46x10^5$	$3.9x10^5$	$1.0x10^5$
Useful plankton Variety	11.7 ± 5.2	11 ± 2.0	10.8 ±6.3	6.8 ±1.3

The bacteriological analyses revealed that the variation in the total viable bacterial counts in the ponds was directly related to the type of diet used in fish nutrition. The mean bacterial counts in the fresh water ponds were 2.7 $x10^5$ cfu/ml while that in waste water fed ponds were 1.8 $x10^5$ cfu/ml. The total bacterial coliform count in the 15 waste water fed and 15 fresh water ponds were 3.4 $x10^4$ to 4.4 $x10^5$ cfu/ml and 4.4 $x10^4$ to 1.7 $x10^6$ cfu/ml respectively. The differences were significant and revealed that 4 fresh water ponds were not suitable for fish cultivation because of high load of coliform count. Total coliform bacteria are principal indicator of the suitability of water for fish culture (APHA, 1995). The population of total coliform was higher in the Dhaka waste water fed ponds (mean 1.3 $x10^6$ cfu/ml) than in the waste water fed pond at Kolkata (mean 1.8 $x10^5$ cfu/ml), because of the lack of architecture based natural microbial waste water treatment that occurs in the Bheri at Kolkata does not occur in absence of the flat bottom shallow depth (Ray Chaudhuri, S. et al., 2012). Hence the direct human excreta discharge allowed into the waste water ponds with the solid waste at Dhaka in absence of natural purification and alkali treatment (as seen in case of Bheri) results in elevated coliform count (Chapman, D., 1992).

According to the guidelines for water quality management for fish cultivation, it is evident that most of the water quality parameters of the 15 waste water fed fish ponds in Kolkata were suitable for fish culture while the transparency and DO level showed variation. In Bangladesh the higher concentration of some parameters in some waste water fed ponds was probably due to heavy pollution load from the nearby domestic, commercial and other point sources. Also waste water fed fish showed higher plankton count (both total as well as useful) and low coliform count from other types of water body.

iv. Fish Production & its Economics

Economic analysis was conducted to determine the economic returns of different types of fish culture pond based on market prices for harvesting fishes and all other items expressed in USD. The economic analysis of fish production from waste water fed (Bheri) and fresh water ponds was given in Table-4. The total income of the ponds described in the table comprises only cash income from fish selling according to the local market price. Income from selling of paddy and other agricultural products; selling of cattle/foul and their products; renting of boats/fishing nets as well as fish used for self-consumption were not taken into consideration. There was no significant difference of the total operational cost in the two types of study pond. In the operational cost, fish fingerlings and feed were expensive components as compared to other variables. The pond preparation, harvesting and marketing costs were more or less same in both countries, but waste water fed pond management cost at Kolkata was lower as compared to other types of ponds considered in this study. The total production cost was significant lower (6%-8%) from other pond system due to the low cost of fish seed & feed. Most of the waste water fed fisheries cooperative produced fish seed and fingerlings inside the farm area using their own existing systems. Survey shows that with minimal investment on growing the fingerlings these waste water fed systems at Kolkata have been sustaining production to a tune of 7.4 tons/Acre/year (Table-4) on a regular basis. On the other hand, the traditional practice of fish culture in fresh water ponds in Kolkata requires supplementary feeding and used of urea like organic matters. In the fresh water pond systems, mean production level was 2.0 tons/Acre/year which is nearly one-fourth of the production from waste water fed ponds after investing 1.8 times more revenue (Ray Chaudhuri, S. et, al., 2008a). At Dhaka, the production from waste water fed and fresh water pond systems were 3.5 and 2.6 ton/Acre/year which is less compared to waste water fed ponds at Kolkata. The fresh water pond areas and culture system was more or less similar in both countries.

Table-4 has shown that the pond preparation cost for the waste water fed ponds of Kolkata varies from 26 to 63 (mean being 47) USD/Acre/year and that in Dhaka from 46 to 245 (mean being 156) USD/Acre/year. It was observed that the pond preparation cost of fresh water fed pond varied between 50 to 148 (mean being 81) USD/Acre/year and 55 to 98 (mean being 76) USD/Acre/year in Kolkata and Dhaka respectively. Pond management cost including seed, feed, fertilizer and labor of the investigated waste water fed and fresh water ponds in Kolkata were between 283 to 384 (mean being 321) USD/Acre/year and 213 to 757 (mean being 528) USD/Acre/year respectively. The same at Dhaka varies from 1222 to 2330 (mean being 1601) USD/Acre/year and 2317 to 3391 (mean being 2655) USD/Acre/year respectively. The pond management cost was significantly higher in both types of ponds at Dhaka. The total fish production cost for waste water fed and fresh water ponds at Kolkata and Dhaka varied between 344 to 523 (mean being 422) and 354 to 1139 (mean being 769) USD/acre/year as well as 1620 to 2453 (mean being 1882) USD/acre/year and 2470 to 3531 (mean being 2865) USD/acre/year respectively. Hence the total production cost of aquaculture in Dhaka, Bangladesh is substantially high mostly due to the cost of fingerlings, inorganic fertilizer as well as supplementary feed (Bunting, S.W. et. al, 2006). The average net income was highest in case of waste water fed ponds at Kolkata (1756 USD /Acre/year), while fresh water fed ponds at Dhaka had the lowest average net income (326 USD /Acre/year) among all kinds of ponds included in this study.

Table-4: Economic status of different types of ponds in Kolkata, India and Dhaka, Bangladesh (USD/Acre/year)

Variable Name (Mean)	Waste Water fed pond		Fresh water pond	
	Kolkata	Dhaka	Kolkata	Dhaka
Pond Size (Acre)	18.0	1.5	1.78	1.6
Fish production (Ton)	7.4	3.5	2.0	2.6
Pond preparation cost	47	156	81	75.5
Pond management cost (including seed, feed, fertilizer and labor)	321	1601	528	2654
Harvest and marketing cost	54	125	112	134.8
Total production cost	422	1882	769	2865
Gross income	2178	2267	1146	3191
Net income	1756	385	377	326

Note: USD 1.00 = BDT 78.00

The estimated gross income from waste water fed ponds in Kolkata was around 1838 to 2562 USD/Acre/year. There were significant differences ($p \leq 0.05$) between the profit level of waste water and fresh water ponds. All these observations showed that the waste water fed ponds in this region has a viable economic proposition and demands much more productive investment (Ghosh, D., 1985a; 1985b; IWMED 1986). Dhaka and Kolkata bearing similar geographic features, this technology of waste water aquaculture with defined pond architecture was tested at Dhaka in two experimental ponds from January 2013 to December 2014.

v. Replication of Bheri at Bangladesh

The experimental ponds were abandoned for four years and overgrown with the hyacinth and dumped garbage. This study was conducted following the guidelines detailed by D. Ghosh for the construction and operation of Bheri (Ghosh. D., 1988; Ghosh, D., 2005; Nandeesha, M.C., 2002). During this study field information was collected and proper design and guidelines for replication of experimental protocols was followed. After pond preparation, sewage water was passed into the pond from the drain through concrete pipe and bamboo sluice. It was left to stabilize for 17 days and water color turns greenish. When the water turns green, the water quality like pH and DO was measured following protocols provided in IWA water test kit. Towards the end of March a stock test of fishes was initially conducted by the fishermen in which a small number of fish were stocked to investigate water quality. After obtaining satisfactory water quality report, proper fish stocking was initiated. Ever year three rounds of stocking were done and this study is the outcome of the data generated in two subsequent years. With an average stocking rate of 5,700 fingerlings per Acre, the annual purchases varied between 20,000 to 22,500 fingerlings per pond. The waste water was put into the ponds throughout the growth cycle. In ponds, the water level was maintained continuously through inflow and outflow pipe. However, during the extreme rain in the 1st year occasionally supplementary feed such as rice, oil cake, breads whose expiry date was over or Bhusi were provided. During latter part of rainy season most of the time, waste water could not be transferred to the fish pond due to dumping of insecticide to prevent mosquito breeding in the waste water canal by city authorities as these are harmful to fish. So, supplementary feed had to be provided during this period. Also sometimes potassium and salt had to be added to remove the insects and *Tara poka.* After completion of one phase (post harvesting), fishes were restocked in the ponds.

Careful pond preparation to ensure penetration of sunlight to the bottom and appropriate alkali treatment of the flat bottom soil of the pond ensured proper coliform removal with plankton growth which was used as fish feed with timely introduction of fingerlings (and hence avoiding algal bloom). The fish production in experimental waste water pond was 4.3 tons/Acre/year while the same in conventional waste water pond was 3.5 tones/Acre/year. The investment on fish cultivation (including pond preparation) in the experimental ponds were 3585 USD/Acre/year for the 1st round while 3200 USD/Acre/year for the subsequent rounds of cultivation (average being 3569 USD/Acre/year). The difference was due to the investment on development of pond architecture during the initiation of the work. The similar costs for conventional waste water fed ponds were 1882 USD/Acre/year. The revenue generated from experimental and conventional waste water ponds were 4493 USD/Acre/year and 2267 USD/Acre/year respectively. The difference was both due to the increase in production and the varieties of fish grown which was higher in case of the former. The net income from experimental and conventional waste water ponds were 924 USD/Acre/year and 385 USD/Acre/year respectively. The adaptation of the waste water aquaculture technology at Dhaka from Kolkata (Bheri) resulted in significant increase in revenue generation from waste water aquaculture. This ensures environmental protection (waste water purification) with edible resource (fish) generation in association with enhanced employability and revenue generation just as seen at EKW (Mukherjee, I., et.al. 2010). It is reported that in Bangladesh approximately 15% income loss occurred due to fish diseases (Guangming Li., 2010; Barua, P. et.al., 2011*)* as a reason of poor water quality. Proper technical knowledge on pond preparation and maintenance is the most important thing for managing the sensitive entrepreneurship like Kolkata waste water fed fish culture. This case study is a successful implementation of technology transfer from India to Bangladesh which has the potential of being further scaled up.

5. CONCLUSION AND FUTURE PROSPECTS

Overall, the study reflects the underlying differences resulting in enhanced fish production in the waste water fed fish (Bheri) ponds as compared to fresh water ponds in Kolkata, India. This study describes the successful transfer of traditional waste water aquaculture (Bheri) technology followed in India at East Kolkata Wetland to Bangladesh. The waste water aquaculture which has been failing for couple of decades in Bangladesh could be revived using the well documented and scientifically explored pond preparation and management technology followed in the Bheri. The shallow, flat bottom architecture of these waste water fed pond ensures penetration of light to the bottom and hence supports growth of planktons. The introduction of fingerlings at the right time of plankton growth ensures consumption of the planktons as fish feed as a result of conversion of the organic matter in waste water into feed. It simultaneously prevents algal bloom which would have resulted in absence of grazing of the planktons by the fish, hence purifying the waste water and minimizing the involved expenditure on procurement of fish feed. The alkaline treatment of the soil during pond preparation results in decrease in coliform count. The integrated technology purifies the waste water while utilizing the nutrients in it for fish production. The treated water is extensively used for cultivation of paddy and vegetables, hence avoiding wastage of potable water for non-potable application like irrigation. Since more than 89% of the potable water is used for irrigation when fresh water scarcity is knocking at the door for most of the countries (with major emphasis on Asian countries), this approach of treated waste water use is a boon. This technology which has been successfully implemented at EKW for over a century results in waste water purification, fish production, employment and revenue generation as well as environmental sustenance. The similarity between Kolkata and Dhaka in terms of the geographical features and the need for sanitation as well as food for both the countries ensured the initiation of this study in 2005 which finally has led to this successful technology transfer in 2015 with enhanced fish production in waste water fed ponds at the experimental pond at Dhaka. The subsequent efforts on reutilization of treated water for agriculture at Dhaka would be the future scope of this joint endeavor.

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