managing natural resources sustainably, which again, is so crucial in designing options for sustainable development. Can we not, therefore, think of setting out independent and self-reliant alternatives to sustainable development for our own countries? Can we take advantage of this 'oriental wisdom' evolved through hundreds of years of experience of living creatively with nature?

There are a number of efforts, both at the national as well as international level to make inventories of traditional practices. These are important and a good beginning but far from being an end in itself. Very little will result from such inventories unless those practices are interpreted ecologically and thereafter re-established or replicated in suitable locations. It is in this bearing, ecology becomes a crucial tool for the changemakers. The present book is an attempt, feeble though, to impress this role of ecology, now well known to the world, in understanding, conserving and mainstreaming a traditional practice, which was lying unnoticed for many decades before the 80s of the last century when the present work was taken up.

Ecology as a subjective tool for the changemakers

Mainly since the 60s of the last century, ecologists have done a good job in exposing the impact of some of the developmental projects on nature and natural resources. The task for them was to bring out the interrelated issues of a development project and their consequential impact. Large dams, for example, were known to control flood, produce hydroelectricity and provide water for irrigation. Ecologists tore open the web of interlinked events and found out that the downstream ecosystem of the river, after the water supply to it has been brought down to nearly no flow, is completely damaged. This has direct impact on the communities living along the side of the river. Compulsory discharge of accumulated water of the reservoir in the late monsoon period causes more intense floods. Waterlogging in the irrigated field results in salt deposition. Not to speak of the fate of the thousands of dam-displaced villagers, who can hardly cope with the new turn in their life. Ecologists did a great job in stopping the construction of big dams. Ecologists were also instrumental in thwarting developmental projects which were indifferent to nature and natural resources and human society at large.

Paul Shepard and Daniel Mckinly wrote a book on ecology that they titled as a 'Subversive Science'. That was in 1969. Unwittingly, or perhaps routinely, the book did not enjoy a particularly long 'shelf life' in the USIS library, Calcutta. Several years later, when I asked Richard Meier, a renowned thinker in ecology from Berkeley, whether he agreed with my understanding of environmental science as an anti-establishment theory, the professor nodded in agreement. Environmentalists all over the world generally share a similar or near similar view. It is true that the findings and activities of environmentalists and ecologists since the sixties shook the foundations of the prevailing economic order and challenged assumptions about nature and natural resources.

The beginning of a new century presents a different challenge for the ecologists in designing implementable options for sustainable development, or the well being of the majority of the earthlings.

If the task of the last century was to obstruct the destructive consequences of development the new challenge is one of constructing the road maps for survival and well-being of the exploited majority.

The areas in need of ecological intervention and interpretation are as follows. We know sustainable development requires honouring the thresholds of nature. Most of our traditional practices, most of the local wisdom is rich in their knowledge in transacting with nature. To come up with implementable ideas from such practices and sacks of wisdom, will require in the first place a holistic understanding of individual practices. This will require an understanding of the social, cultural (including spiritual) and economic context, particularly with reference to studying the feasibility of replication and finally the fusion with modern technology and modifications at the system levels. Contextual fitness may require regional, national and global level policy and regulating provisions along with knowing of the political wind blowing locally, nationally and globally.

Ecology is the science of studying interrelationships between society and nature and it indeed provides the most convenient tool for the new generation changemakers who could ensure sustainable living of the exploited majority.

The originator of Ecology was Ernest Heinrich Haeckel (1884 -1919), one of the foremost scientists and philosophers of Germany. One cannot overstress the contribution of Haeckel in liberating science from the grip of utopian idealism. Not much, however, is discussed by the present day ecologists about the epoch-making contribution of Ernest Haeckel. To be candid, since Haeckel there has not been any theoretical breakthrough, which could create, stir and go against conventional current of epistemology[1]. Recapitulating Haeckel will thus be something more than ritual reference. He states:

> *"By Ecology we mean the body of knowledge concerning the economy of nature – the investigations of the total relations of the animal both to its inorganic and to its organic environment; including above all, its friendly and inimical relation with those animals and plants with which it comes directly or indirectly into contact – in a word, Ecology is the study of all the complex interrelations referred to by Darwin as the conditions of the struggle for existence. The science of ecology, often inaccurately referred to as 'Biology' in a*

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[1] In fact, Haeckel's 'The Riddle of the Universe' was sold in hundreds and thousands of copies and got translated into many languages for its originality in locating the partisan character of philosophy. So much has been the effect of Haeckel's thought that conservatives attempted to kill him (1908) in his study room in Jena.

narrow sense, has thus far formed the principle component of what is commonly referred to as Natural history" (Kormondy, 1974).

It is most unfortunate that even in spite of such bold clarity of Haeckel in bringing out Ecology from the confines of Biology, many of the present day ecologists describe Ecology as a part of Biology (Douglas, 1972). Biology does not investigate the environment as a whole. Environmental resultants are input data in biological investigations. For example, the effect of protein deficiency on living beings is a subject of biological study. But, what are the specific environmental eventualities that cause the protein deficiency lie clearly outside the scope of Biology although essentially within the scope of ecological investigations. The same authors who agree to the spread of ecological investigations in the field of economics, politics, engineering, technology, demography etc. desperately negotiate to describe all these basic problems as biological.

Difference in understanding and interpretation of an event or a phenomenon can be healthy and in fact is an integral part of the history of science. The point however, is to see whether such differences are spontaneous or planted. After all, science is increasingly being pursued within the private domain using corporate funding. Even in the public domain, there are hidden agendas promoting corporate interests. Therefore, the differences in understanding the meaning of Ecology, its scope and role in social reconstructions, may not necessarily be healthy. Introducing confusion and futility in scientific work is indeed a preferred choice of many who fund scientific research. Confusion and futile work helps them in steering clear their views wearing a garb of science. The 1999 World Health Report, for example, observed that "the industry (read tobacco) has played an active role in funding and disseminating research that cast doubt on the links between tobacco and health" Similarly, the conflicting views about the scope and meaning of Ecology may continue for a long time so long science remains a donor's pasture.

CHAPTER 5

What Happens in the East Calcutta Wetlands

The continued uncertainty in this wetland area, which once had thriving resource recovery practices, has flattened the diverse crease of a cultural heritage that is now dying. And this exactly is the challenge of conserving the East Calcutta Wetlands.

Barely five kilometers from the eastern edge of Kolkata, one of the most densely populated mega-cities of India, an amazing spectacle takes a visitor by surprise. One finds very large shallow ponds with sparkling water wrapped in an eerie silence. But the importance of these ponds, locally known as *bheris* goes far beyond their natural beauty.

The interest in the wetland ecosystems at Kolkata's periphery should be understood in the context of the search for development alternatives – for locally adopted appropriate modes of development rather than transplantation of alien models that have been experimented with around the world with no small measure of failure.

In these wetlands, there exists and has existed for more than a hundred years, a lasting tradition of disposal and utilisation of urban waste in agriculture and fisheries. The locals here have employed a remarkable and natural system to help meet the three basic problems of developing countries: shortage of food, shortage of employment opportunities and shortage of funds to treat waste.

Location and climate

Between the levee of the River Hugli on the west and the Kulti Gong on the east lie the East Calcutta Wetlands, distributed nearly equally on the two sides of the Dry Weather Flow Channel that reaches the Kulti Gong to the east. The wetland area lies approximately between latitudes 22º25' to 22º40' north and longitudes 88º20' to 88º35' east. Abundantly endowed with sunshine, the wetlands have a natural resource – solar radiation – treating wastewater and improving wastewater quality. Each hectare of a shallow water body can remove about 237 kgs of Bio-chemical Oxygen Demand (BOD)[1] per day. In winter, the sky clearance factor is satisfactory (about 90 per cent) for carrying out bio-chemical activities in water purification.

[1] Bio-chemical Oxygen Demand (BOD) is the measure of organic load in wastewater

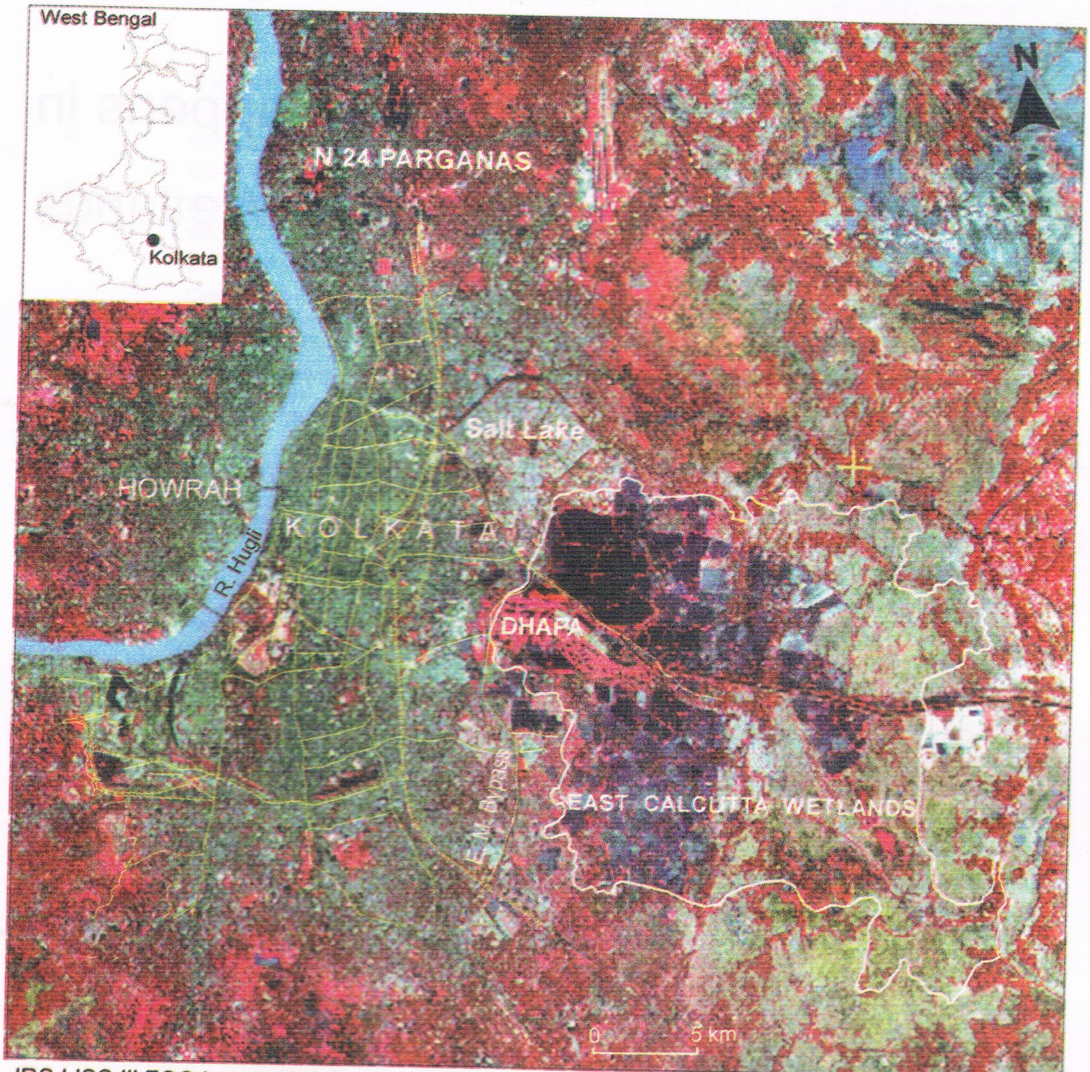

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Fig. 10: Location map of the East Calcutta Wetlands and Waste Recycling Region

The hot, monsoon climate of the East Calcutta Wetlands is largely governed by the Himalayan mountains to the north, the Meghalaya plateau to the north-east and the proximity to the Bay of Bengal. The climate of the East Calcutta Wetlands is broadly similar to that of Kolkata, which, being located almost within a degree of the Tropic of Cancer is at the fringe of the Torrid Zone. With some variations, the mercury is high throughout the year. There are three major seasons.

The cold season or winter sets in from the middle of November and lasts till the end of February. The mean temperatures in December and January are 20.6º C and 20.2º C respectively, with mean monthly minima at 14.2º C and 13.6º C respectively. The total rainfall in four months varies between 75mm and 80mm, the relative humidity remaining around 67 per cent. The average wind speed during this summer remains at about 2.9 kmph.

The hot season or summer starts from March and lasts till mid-June with mean monthly temperatures at 30.65º C, 31.15ºC and 30.4ºC respectively in the months of April, May and June, touching highs of 38ºC to 40.2ºC on some days. The lowest temperature of the season does not fall below 16.4ºC (March). Rainfall, which occurs more frequently towards the end of this season, is associated with thunder and lightning (Nor'westers), with relative humidity varying between 64 per cent in March and 79 per cent in June. The average wind speed rises to about 7 kmph.

The rainy season or the monsoon begins from mid-June and lasts till mid-September, sometimes extending to October. The season is characterised by high average temperature. The average rainy days per month is about 16 but the number decreases to eight days in October. The rainfall in this season comes with the South-West Monsoon that comes from the south and is associated with cyclonic disturbances from the Bay of Bengal. The total rainfall during the monsoons varies between 1200mm and 1300mm. The relative humidity varies between 80 per cent and 85 per cent, while the average wind speed remains at 5 kmph. On the whole, the East Calcutta Wetlands have the features of a tropical region with ample sunshine and a vast water regime.

Lay of the land

The East Calcutta Wetland area falls within the South Bengal ecotone. This region is a part of the mature delta of the river Ganga, the tributaries, distributaries and re-distributaries of which were once active in this area. Since early 15th century, the Ganga changed its main course from the Bhagirathi to the Padma. This eastward shift in the course of the main flow of the river Ganga brought metamorphic changes in the process of delta building in central and south Bengal. A number of distributaries and re-distributaries were cut off from any upland flow, resulting in their decay. However, some of them were still building up land on both sides, but the tract in between, deprived of the annual deposition of silt remained comparatively depressed. The mouths of some of the streams opened directly into the Bay of Bengal and were influenced by tidal action. One such tidal channel was the Bidyadhari River that used to deposit silt in this area.

Extensive saltwater marshes existed between the River Hugli to the west, which is the main distributary of the River Ganga and the Bidyadhari River, to the east, which is now dry. The tidal river fed the marshes, which acted as its spill-reservoir. The salt marshes bear testimony to the processes of incomplete delta building that had occurred in the past in the South Bengal

Basin. Their occurrence, together with other evidences points to both fluvial and marine depositional activities and these saltwater marshes possibly owe their existence to a combination of such processes. The East Calcutta Wetlands now remain as remnants of the vast stretches of the salt lakes, which once extended beyond the present international boundary of Bangladesh (Chakraborty, 1970).

The pattern of delta building has undergone significant changes on account of natural and man-made reasons. In the delta building stage, the rivers had excessive loads of silt, lost their gradient and became sluggish, so that only tidal influx could wash out the silt. Until 1830, the Bidyadhari River was an active delta building tidal channel and was a navigation route from the Bay of Bengal to Calcutta (DECa, 1945). Human interference in the region also contributed to the reduction of the spill area of the tidal channels and their beds heaved up to quicken the process of decay. Thus the Bidyadhari River gradually became defunct and in 1928 it was officially declared dead (Ghosh & Sen, 1987). Since then, the process of natural deposition and raising the level of the spill area stopped and this incomplete process of delta building did not allow the low-lying areas behind the Hugli levee, to the east of Kolkata, to rise higher.

The land to the east of Kolkata in general slopes to the east and south- east, with the natural drainage in those directions. The gradient is, however, practically imperceptible. As obtained from the records of the 19^{th} century, the gradient of the land from the bank of the River Hugli to the Salt Lakes was about 0°2' and the distance of the nearest margin of the Lakes was 3 km from Circular Road, Calcutta (Clarke, 1865).

Transformation of a saline marsh

The earliest known accounts (1748) of the wetland area picture it as marshy Salt Lakes teeming with fish and birds. The Lakes stretch across a vast area, from the vicinity of the River Hugli for about 5 to 6 km to the east (CMG, 1964). According to these early accounts, the circumference of the Lakes was originally much greater than it is at present. In the north, the edge of the Lakes extended up to the foot of a 9 m. high mound known as Dumduma, near which the Burmese and Mug traders, arriving in boats, used to anchor. Within forty years, from the late eighteenth century, the edge of the Lakes receded about one-and-a-half kilometers (Ghosh & Sen, 1987).

The Salt Lakes, as found in old records, were separated into a western and an eastern portion by a ridge, and were connected by a channel. The western portion, which constituted the proper Lake, was traversed by a tidal channel diagonally for 8 km. During high tides, the depth of water used to be between 5 and 6 m. In dry seasons and during low tides, the better-drained adjoining parts of the channel were dry and exposed. The average depth of the Lakes was about half-a-metre of stagnant water, which scarcely drained (Ghosh & Sen, 1987). The tidal channel joined farther down with a deltaic channel of the Sunderbans, through which saltwater flowed into the Lakes (Stewart, 1836).

Initially, when the British settled in this area, the Salt Lakes were left alone. The immediate vicinity of these Lakes was considered inhospitable for settlement, being a breeding-ground of malaria and other diseases (DECa, 1945). In 1803, the city drainage was directed artificially into the River Hugli, against the natural slope. This proved unsatisfactory because of the annual flooding of the city during monsoon rains, and pollution of the river, which provided drinking water to the city.

The then Governor-General of India, Lord Wellesley, appointed a Committee to examine the problems and submit recommendations for improvement (CMG, 1945). After some examination, the Committee approved a scheme of underground drainage for disposal of sewage and storm-water through the same conduit into the Salt Water Lakes, and finally into the Bay of Bengal, following the natural slope of the land towards the south- east through the Bidyadhari and consequently to Matla river (CMG, 1945). The drainage scheme was finally completed in 1884, with construction works such as canals, sluices, bridges, etc., across the wetlands. In the meantime, while the scheme was in progress, several other interferences took place (Ghosh & Sen, 1987).

The natural state of this low-lying area to the east of the ever-expanding city of Kolkata was interfered with for necessities of drainage and waste disposal, with subsequent reclamation for extending the city at different times. One of the major causes of the deterioration of the Bidyadhari River and of the siltation in the Salt Lakes was the discharge of the city's untreated sewage in the area (DECb, 1945). It should be noted here that disposal of solid waste has also resulted in the reclamation of wetlands. Wetlands, when converted to urban land use are lost permanently. However, the loss of wetlands to garbage fill are not of a permanent nature, as this landfill produces an economically viable natural biological system to recycle waste which is inseparably linked with the water bodies of the area. However, there should be a comprehensive planning for disposal of garbage in the area. Together with the changing course of the River Ganges, and consequent changes in the streams of the delta region, human interventions played an important role in shaping the landscape and land use of the region.

In the course of the last hundred or more years, what had been a saline marshy area behind the city of Kolkata thus changed gradually into a waste-recycling region bereft of salinity and of corresponding flora and fauna. The change is remarkable, especially in view of the short span of time in which it took place. A significant output of this change was the opportunity that came with it, to bring out the best of the faculty of the local farmers and entrepreneurs to develop, what may well be the world's largest ensemble of resource-recovery systems incorporating wastewater fisheries and agriculture based on effluents.

Developing successive wastewater utilisation practices

Prior to 1830, the low-lying region with saltwater lakes acting as spill reservoirs for the Bidyadhari were utilized for farming of brackishwater fish such as bhetki (*Lates calcarifer*), parse (*Mugil parsia*), bhangar (*Mugil tade*) and prawns (*Macrobrachium rosenbergii*), etc. (Ghosh and Sen, 1987). The area was gradually rendered derelict on account of the receding Bidyadhari spill channel. Interestingly, these fisheries were responsible for reducing the spill area and this, compounded with the dwindling upland flow from the river Hugli to the spill channel, caused the death of the tidal creek. During the 30s, the river Bidyadhari carried only city sewage and in the process was choked further due to the high silt content of the same. The death of the Bidyadhari and the cessation of tidal flow converted the entire area into a vast derelict swamp.

The diversion of city sewage and storm water into the Salt Lakes along with the deterioration of the Bidyadhari caused a gradual change in the aquatic environment from saline to non-saline. This ultimately led to the changes in the culture of fish in the region, especially in terms of species. In 1929, a leading fish producer of this region successfully experimented with the process of farming fish in sewage-fed ponds. In this process, the sewage-grown fish became prominent with species such as Rohu (*Labeo rohita*), Catla (*Catla catla*), Mrigal (*Cirrhinus mrigala*) and exotic ones such as Silver Carp (*Hypophthalmichthys molitrix*), Grass Carp (*Ctenopharyngodon idella*) and Common Carp (*Cyprinus carpio*) along with Tilapia (*Tilapia mossambica*), Walking Catfish (*Clarius batrachus*), etc. The continual increase in the production of the sewage-fed fisheries can be attributed to more efficient operations through experimentation conducted by the operators using local and indigenous methods and resources. The processes have been proved functional over 40 years and scientific studies undertaken so far corroborate their continuing endurance.

The inadequacies of the drainage system thwarted the immediate spread of wastewater fisheries over the entire wetland region. By the middle of the 40s, with the completion of the late B. N. Dey's drainage outfall scheme up to river Kulti, an adequate water-head could be raised for supplying sewage to most of the fishponds by gravity. This resulted in the extension of wastewater fishponds further east and southeast for about 8,000 hectares. Urban expansion and conversion for agriculture have reduced this area to about 3,500 hectares. During 1969, there was a large-scale conversion of sewage-fed fisheries, when some of these were drained and converted into paddy lands. The entire cultivation in this region is done by irrigation with fishery-effluents. The old practice of growing vegetables on garbage continued in a modified manner in the Dhapa area, the garbage farms providing a low-cost technique of solid waste recycling in agriculture (Ghosh & Sen, 1987).

With the drying up of the tidal flow, what was essentially a tidal wetland became a sewage-fed wetland. The innovation here was the deliberate introduction of city sewage in the fishponds. This saved the livelihood of thousands of fishermen which was threatened by the drying up of brackishwater fisheries. Without this indigenous innovation, the East Calcutta Wetlands would not have existed in the present form. This is why the East Calcutta Wetlands are unquestioningly called a man-made regime. Their uniqueness lies in being the world's largest wastewater ecosystem created to sustain successive resource recovery systems in the form of vegetable farms, fishponds and paddy fields.

In 1980, an assessment of this wetland area and its reuse practices was undertaken, courtesy a research initiated by the Government of West Bengal. By 1983, the first scientific document on this wetland ecosystem was published, and it told the tale of the ecological significance of this outstanding wetland area (Ghosh, 1983). In 1985, the map of the East Calcutta Wetlands and Waste Recycling Region (ECWWRR), which forms the basis of all planning and development activities on this wetland area, was prepared (Fig.11).

In 1992, a case study on the East Calcutta Wetlands was presented in the expert committee meeting of the Ramsar Convention (Ghosh, 1992). This was the only example of "wise use" from India, which was included among 17 other case studies selected from all over the world. This was the beginning of an effort that led to the declaration of the East Calcutta Wetlands as a Ramsar site. The East Calcutta Wetlands are being conserved predominantly as an urban facility. This is a new dimension in wetland conservation strategy.

The wetlands to the east of Kolkata are well known over the world for their multiple uses. The resource-recovery system created and developed by the local innovators through the ages is the largest in the world. It is also the only wetland area by the side of a metropolitan city where the government has introduced development controls to conserve the water bodies and plans to develop it as a unique urban facility for environmental improvement (DOE, 1999, 2001).

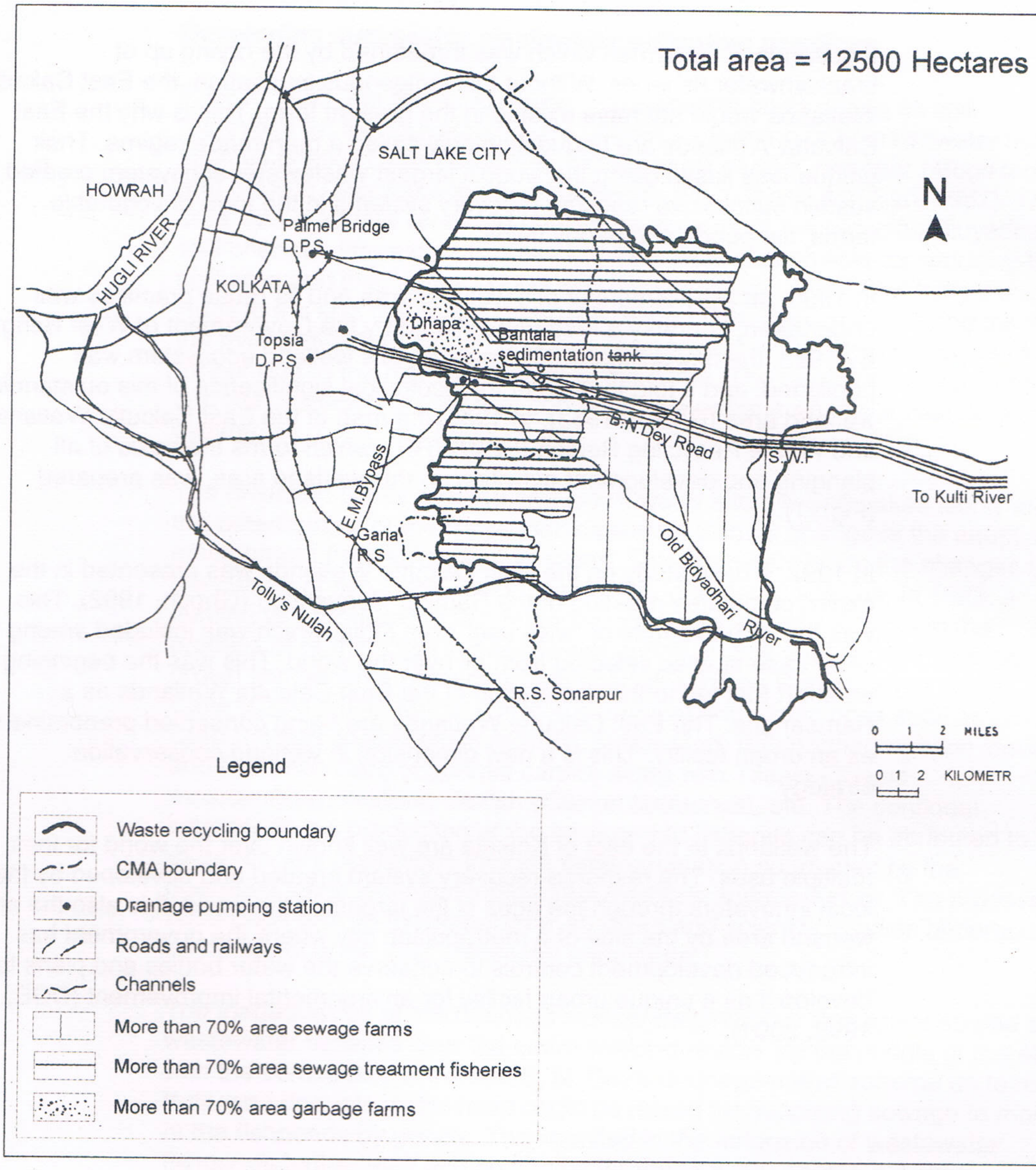


Fig. 11: The East Calcutta Wetlands according to the Ramsar Information Sheet. It has the approval of the relevant departments of the Government of West Bengal and the Ministries of the Government of India.

Toxicity threat: the negative externality

In recent times, a number of studies have pointed towards the chances of heavy metal deposits in fish and vegetables grown in the East Calcutta Wetlands. The local innovators in the East Calcutta Wetlands area did not anticipate that untreated industrial effluents would be used in wastewater ponds. The traditional practice of growing fish and vegetables ensured reasonable protection against bacteriological contamination. In fact a remarkable study in 1987-88 showed that fish from the East Calcutta Wetlands was relatively better than such fish available in the market, which grew in village ponds, without any possibility of wastewater loading (Pal & Dasgupta, 1988).

It is well understood that the toxicity threat to the quality of fish and vegetables comes essentially from the industrial effluents. The storm drainage system set up in the eastern part of the city during late 70s and early 80s made room for unauthorized sewer connections from small and medium industries of these localities. Untreated industrial wastewater began to flow through the outfall canals and in some cases reached the fishponds and agricultural fields.

Zoology department of the University of Calcutta has done preliminary studies in estimating metal ion depositions in five types of fish grown in the East Calcutta Wetlands. Initial results have shown differential deposition of metals in various locations in each of the fish types. Quantitative estimation of heavy metal deposition has revealed that the accumulation essentially takes place in the liver. More importantly, with increasing age of the fish, depletion of metal deposits has been recorded. This phenomenon needs careful examination. It has also been found that biological magnification of heavy metals does not occur here (Banerjee, 1999).

Metals are essential ingredients for carrying out physiological activities. However, for animals living in ecosystems with excessive concentration of metal ion there may be higher dose of metals deposited in their bodies. As the body's natural defence mechanism excess deposition is excreted. Metallothinein, a metal sequestering protein, is produced to drive out excess metal deposited in the body. In the study on fish species this phenomenon of excretion has been observed. A major limitation of the study, however, is the lack of representative nature of the fish samples. Decisive indicators on the subject will require statistically valid sampling procedure.

Toxicity in vegetables has been studied by the Institute of Wetland Management and Ecological Design (IWMED, 1997). The study reveals a high level of deposition of lead (Pb) along with chromium (Cr).A closer analysis of the data can also distinguish between vegetables grown by using direct sewage and those using settled sewage.

A study carried out by Ghosh & Mitra (1997) provides a set of information on the quality of fish and vegetables grown in the East Calcutta Wetlands, contaminated by untreated industrial effluents for about two decades.

The problem of toxicity in fish and vegetables is not a result of any intrinsic failure of the practices in the East Calcutta Wetlands. It is entirely because of inappropriate and offensive acts of a group of industries, which have not installed any pre-treatment facility in their production system and allowed untreated waste to flow through an underground drainage system exclusively created for reducing monsoon flooding.

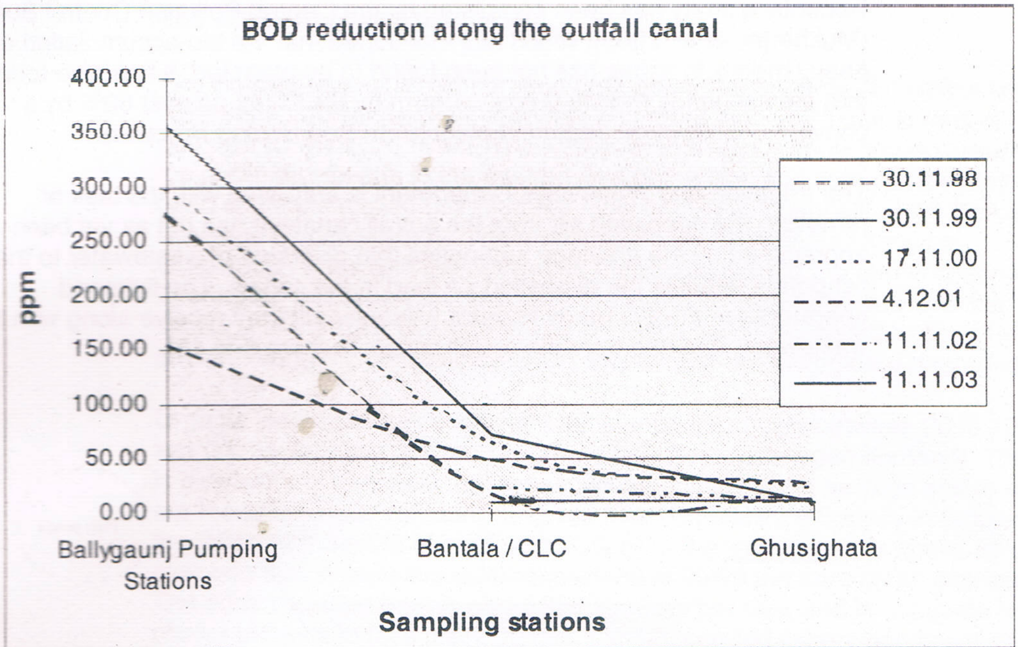
The State Pollution Control Board (WBPCB) has been carrying out routine monitoring work in the outfall canals (Table 2 & Fig.12).

30.11.98	Ballygaunj Pumping Stations	Bantala / CLC	Ghusighata
NH4-N	12.84	6.96	1.86
COD	303.80	166.60	78.40
BOD	155.42	50.00	27.50
Phenol	0.032	BDL	BDL
Cd	0.006	0.006	0.006
Pb	0.101	0.087	0.078
Cr	1.991	0.058	0.075
30.11.99			
NH4-N	15.14	3.11	2.70
COD	355.68	138.82	19.76
BOD	243.33	71.25	8.88
Phenol	0.400	0.080	BDL
Cd	BDL	BDL	BDL
Pb	0.220	0.046	0.034
Cr	0.140	0.090	0.120
17.11.00			
NH4-N	133.33	42.38	7.14
COD	526.40	235.00	103.40
BOD	300.00	66.65	23.75
Phenol	0.25	1.87	BDL
Cd	BDL	0.006	0.002
Pb	0.022	0.030	0.020
Cr	2.680	1.280	0.218

4.12.01	Ballygaunj Pumping Stations	Bantala / CLC	Ghusighata
NH4-N	31.100	19.400	12.300
COD	558.600	117.600	68.600
BOD	275.000	18.750	12.500
Phenol	0.440	0.230	0.090
Cd	BDL	BDL	BDL
Pb	0.300	BDL	0.015
Total Cr	3.200	0.520	BDL
11.11.02			
NH4-N	Data not available	18.40	16.90
COD		105.00	80.00
BOD		23.00	12.28
Phenol		0.09	0.10
Cd		BDL	BDL
Pb		BDL	BDL
Total Cr		BDL	BDL
11.11.03			
NH4-N	Data not available	12.80	11.70
COD		88.75	73.00
BOD		36.13	23.51
Phenol		0.24	0.06
Cd		BDL	BDL
Pb		BDL	BDL
Total Cr		1.06	BDL

Table 2: Wastewater quality along the outfall canals

The wastewater characteristics have been found to change in the normal manner in course of its 28 km travel from Topsia Pumping Station to Ghushighata Tidal Lock.



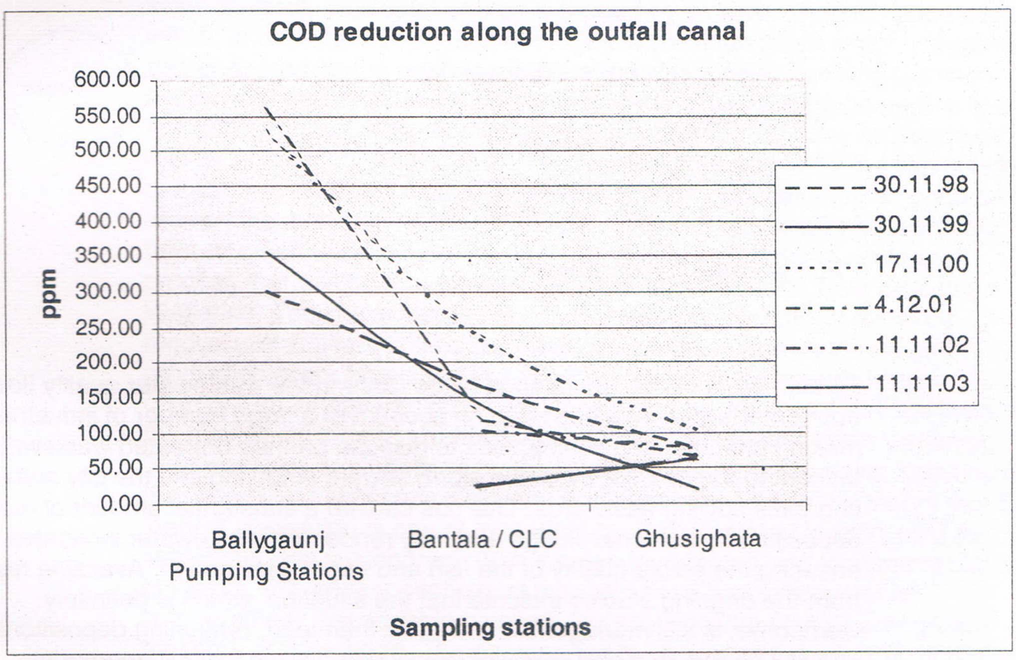


Fig.12: The declining trend of the pollutants in wastewater draining along the outfall canal

Recently a study has been completed by the Central Pollution Control Board (Mukherjee et al, 2005), which has mentioned that the bio-accumulation of heavy metals in fishes has not been found to be alarming. It has also found that the fishponds reduce faecal coliform by 99.7% as against 60% by a conventional sewage treatment plant (Activated Sludge Process).

The Irrigation and Waterways Department is entrusted with the task of removing the deposited silt from the outfall canals. It has not as yet been appreciated by the drainage authorities that diversion of wastewater to the fishponds reduces the deposited silt load in the canals. The fishpond operators are always ready to desilt whatever silt they receive along with the wastewater diverted from the outfall canals to them (Fig.13).

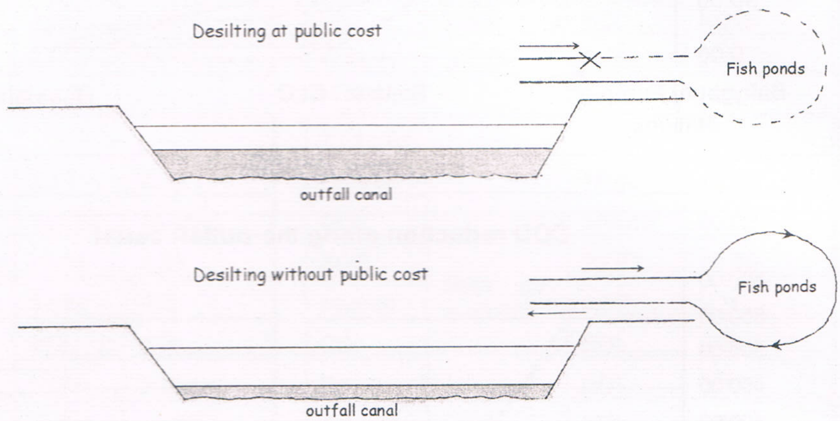


Fig.13: Sharing the cost of desilting

To sum up, a significant change takes place in the wastewater quality flowing out from the city. This has been on account of a large number of industries making unauthorised connections to dispose off their untreated wastewater effluent to the nearest available storm sewers emptying into the city outfall channels flowing eastwards. This has caused a substantial amount of metal deposition in the canal sludge and may render the wastewater incapable of ensuring the edible quality of the fish and vegetables grown. Available results from the ongoing studies indicate that the situation, which is definitely worrisome, is still manageable and other than lead, remaining depositions can still be reduced and kept well below permissible limits if appropriate actions are taken.

The ecosystem and the people

The Kolkata Municipal Corporation area generates roughly 750 million litres of sewage and wastewater everyday and more than 2500 metric tons of garbage (CMW&SA, 1997). The wastewater is led by underground sewers to the pumping stations in the eastern limit of the city, and then pumped into open channels (called Dry Weather Flow or D.W.F. channels of the Kolkata Drainage Outfall system). The responsibility of the Kolkata Municipal Corporation ends with the delivery of the wastewater to the outfall channels. Thereafter, the fishery owners draw the sewage and wastewater into the fisheries of the East Calcutta Wetlands. Here, following detention for a few days, the organic compounds of the wastewater are biologically degraded.

Organic loading rate in these fishponds appears to vary between 20 to 70 kgs per hectare per day (in the form of bio-chemical oxygen demand). There is a network of channels that is used to supply untreated sewage and to drain out the spent water (effluent) (Fig.14). The cumulative efficiency in reducing the BOD. (a measure of organic pollution) of the wastewater is above 80 per cent and that in reducing coliform bacteria is 99.99 per cent on an average. The solar radiation here is about 250 langleys per day, and is adequate for photosynthesis to take place. In fact, the sewage-fed fishery ponds act as solar reactors. This solar energy is tapped by a dense plankton population, which, in turn, the fish consume. While the plankton plays a highly significant role in degrading the organic matter in the wastewater, tackling plankton overgrowth does become a problem in terms of pond management. It is at this critical phase of the ecological process that the fish play an important role by grazing on the plankton. The two-fold role played by the fish is indeed crucial: they maintain a balance of the plankton population in the pond and convert the available nutrients in the wastewater into readily consumable form (viz. fish) for the humans (Fig.15). This is the complex ecological process that has been adopted by the fish farmers of the East Calcutta Wetlands. They have developed such a mastery over these resource recovery activities that they are easily growing fish at a yield rate and production cost unmatched in any other freshwater fishponds of this country.The inhabitants of the wetlands in the backyards of Kolkata lived on the margin, as indeed are most inhabitants of Southeast Asian wetlands. That wetlands are inhabited by the relatively poorer and weaker sections of the "social and economic hierarchy is in consonance with the theory that the story of civilisation is one of man identifying ecologically friendly land for settlement and sustenance. With the rise in numbers and increasing disparity of wealth, the weaker sections of mankind have had to move on to comparatively inhospitable patches. Poverty became starker with greater pressure of population. The poorest had to choose still more difficult regions" (Ghosh, 1999).

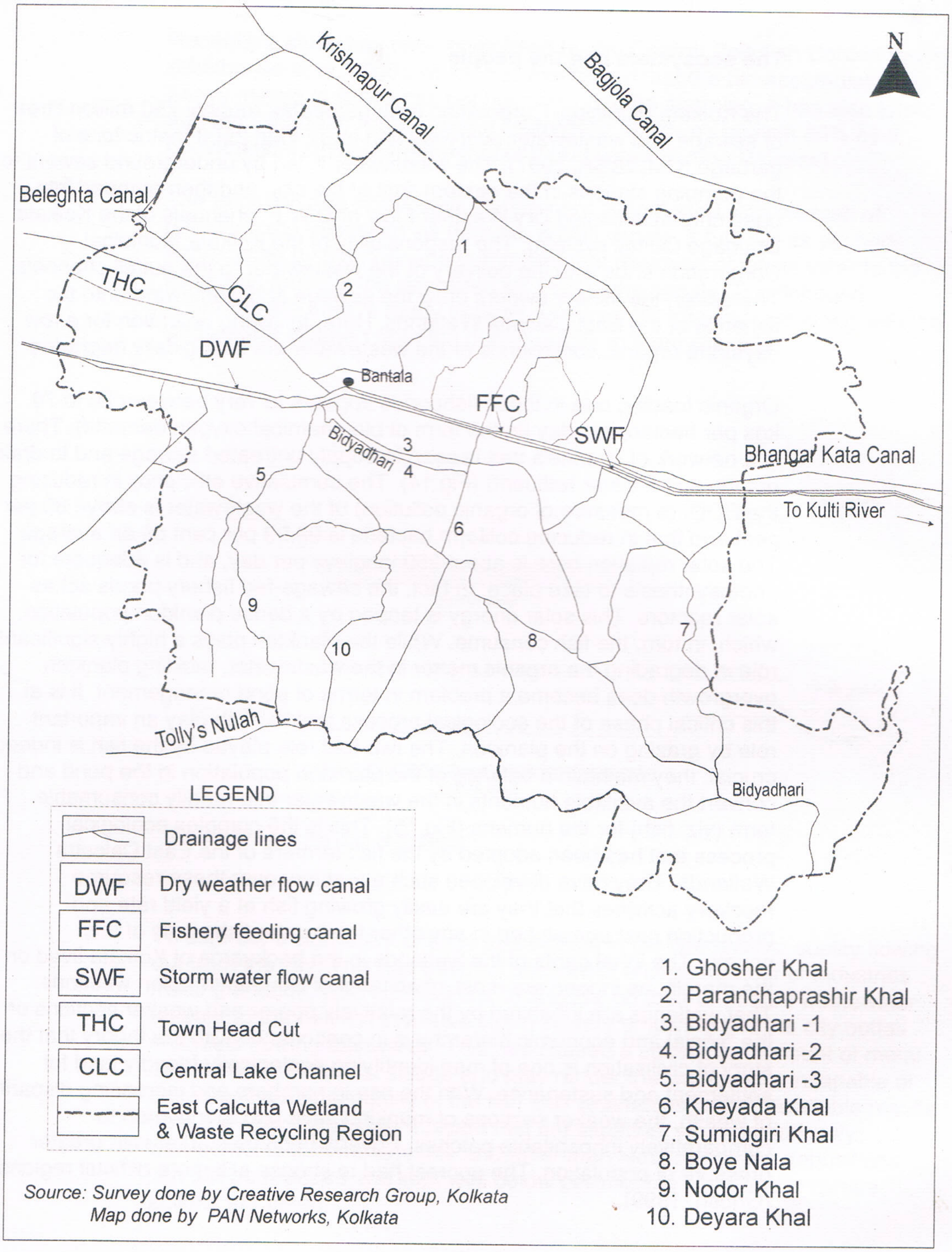


Fig. 14: Drainage network within the East Calcutta Wetlands showing the intensity of the wastewater distributaries.

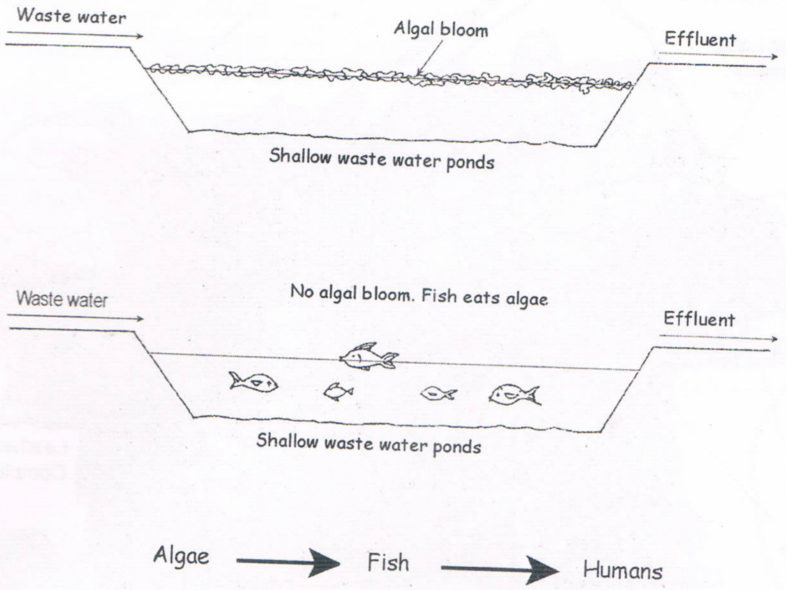


Fig.15: Fish as an ecological manipulator

The uniqueness of the people living in the East Calcutta Wetlands lie in their capacity to convert, through natural resource management, an ecologically disadvantageous situation into one that offers much better livelihood opportunities. When, after the decaying of the Bidyadhari, the brackishwater fishing could not be sustained in the wetlands, a creative fish producer and the local people successfully developed a system to farm fish in a water area using city sewage. Subsequently, they grew a second crop of paddy using pond effluent, a practice that continues, reviving the fortunes of the poorer fish farmers for the next few generations. This population was thus saved from the need to migrate to alien pastures in renewed search for livelihood.

The East Calcutta Wetland area can be divided on the basis of three basic wetland practices: wastewater fisheries, effluent-irrigated paddy cultivation and vegetable farming on garbage substrate (Fig.16). The wetlands and resource recovery area form a good example of productive commercial activities, has a vibrant network of fish auction markets (Fig.17) and support one of the largest clusters of livelihood opportunities for the poorer section of the community. A study carried out in 1997 shows that the fishponds sustain more than 8,500 persons directly of which 90 per cent are from the local villages within the conservation area (CMW&SA, 1997).

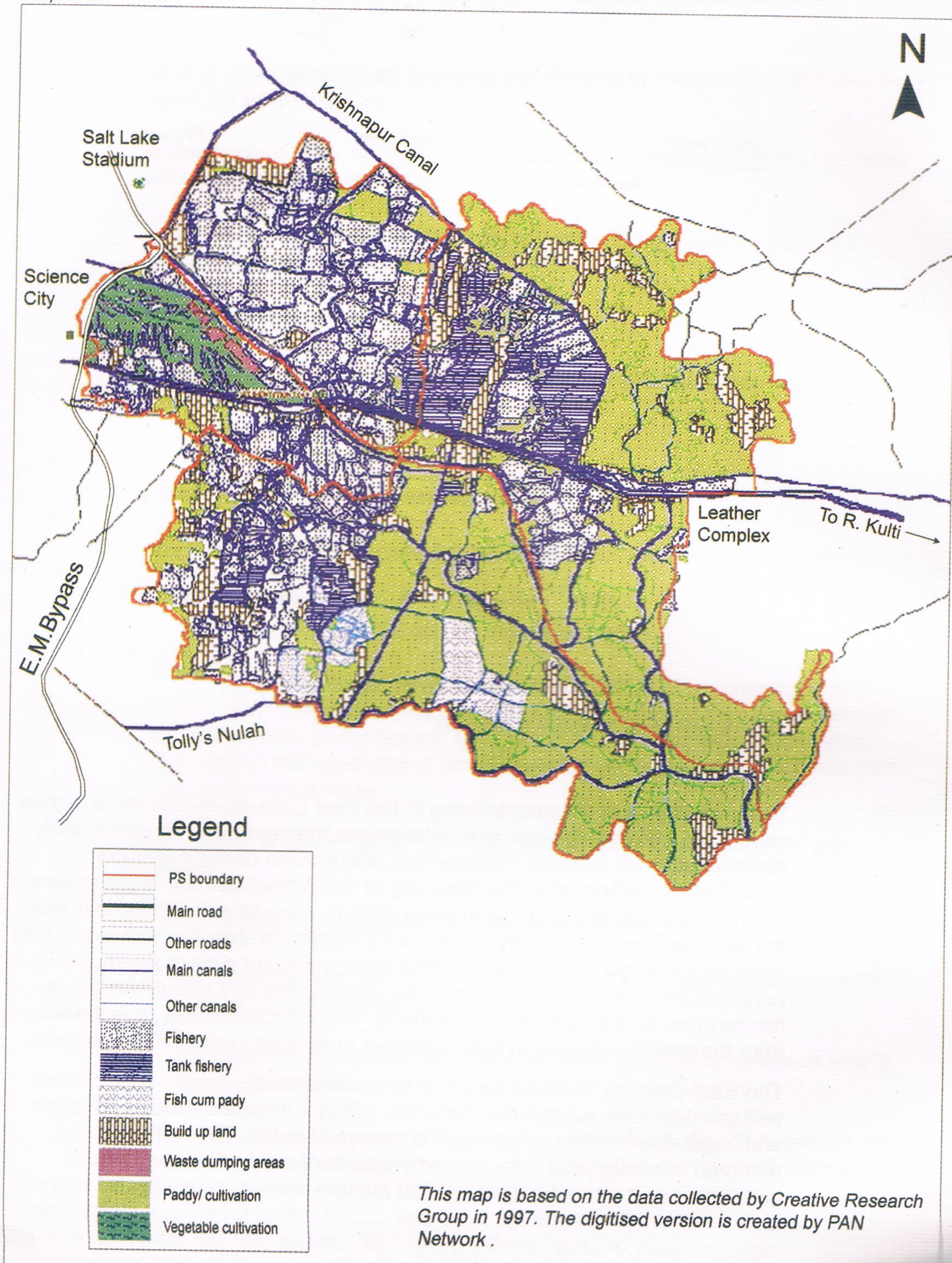


Fig. 16: Land use map of the East Calcutta Wetlands and Waste Recycling Region.

The areas under different land uses have been estimated by the Department of Environment, Government of West Bengal (Table: 3) (DOE, 2004).

Categories of land use	Area in ha.
1.Substantially water body oriented area (primarily sewage-fed fishery activities)	5852.14
2. Agricultural area	4718.56
3. Productive farming areas (Dhapa)	602.78
4. Urban and Rural Settlement	1326.52
TOTAL	12500.00

Table 3: Different categories of land use in the East Calcutta Wetlands

Fig. 17: The fish auction market

A careful study of the baseline document for management action plan as per Ramsar Convention guidelines (CMW&SA, 1997) and the current report of the Committee for Formulation of the Guidelines for Preparation of Management Plan of East Kolkata Wetland (DOE, 2004) reveals that the lack of availability of wastewater in fisheries and agriculture, has become the most crucial determinant in maintaining both the ecosystem quality, for which it has been identified as a Ramsar site, and also the livelihood of the local people. This factor of non-availability of wastewater should be properly brought into focus.

Valuing the East Calcutta Wetlands

The task of evaluating the East Calcutta Wetlands is challenging. A considerable effort has been put up in the department of Business Management, University of Calcutta, and some of the data that have been generated therein has been referred to. The present effort is essentially to provoke an intellectual mind to take up the task of valuing this unique wetlands which will demand a different approach to reach a reasonable guess.

One cannot get tired of repeating that East Calcutta Wetlands is a transformed ecosystem. Here human beings and their institutions are just as integral to its structure and functioning as are water hyacinths, fishes, trees, algae and waterfowls. Accordingly, the value that this wetland derives is from the complex working-together of all these components. Firstly, the channelisation of wastewater to these wetlands through indigenous ecological engineering practices, has led to the growth of fish, proliferation of microbes and increased visits of migratory birds supported by this ecosystem. Secondly, because this wetland ecosystem can act as a pollutant sink as well as a nutrient recovery system, human beings derive benefits not only from its multiple uses, but also by virtue of its very existence.

What is emphasised here is, that while in other wetlands the key role in value generation is played by nature and natural succession alone, in the East Calcutta Wetlands this role is played by a blend of positive human intervention and a favourable ecosystem. It is this synergic interaction between man and nature that provided the stock of capital assets from where flows of services are generated. Such services bestow on this wetland its primary and secondary economic values. Also, these service streams contribute towards the very existence of the East Calcutta Wetlands in its present state. In the former, the considerations of an economist are encompassed while in the latter, the concerns of an ecologist are imbibed.

The endeavour at evaluation of the East Calcutta Wetlands focuses only on those ecosystem services that function as keystones with regard to both the wealth created in these wetlands, as well as to its integrity and survival. The term 'keystone species' is a common parlance in the lexicon of ecology. It refers to those species that have a greater role in maintaining ecosystem structure and/or function than one would think of giving them credit for, on the basis of their relative abundance or biomass. Correspondingly, a keystone ecosystem function is the one whose role in the landscape structure, integrity and biodiversity is indispensable. So much so that, if the proposed keystone service be 'removed' from a particular ecosystem setting, the landscape's response will be in terms of altered disturbance regimes, new patch dynamic equilibria, including loss of integrity and/or dominant species.

In case of the East Calcutta Wetlands such keystone ecosystem service is provided by the interplay of wastewater, sunshine, algae, fishes and the creative intervention of the farmers. As a result of this interplay, the pathogens within the wastewater get destroyed, the nutrients within the wastewater are entrapped by the algae in presence of abundant sunshine and finally, treated water is released to irrigate paddy fields. Our objective will be to find the worth of the wealth thus created from the keystone ecosystem service generated by the synergic interaction of all these key players.

In this regard, no pretensions are made about appreciating the worth of this magnificent ecosystem and the services it provides in its totality. To start with, our information is at best incomplete. So is our understanding of the structure and functioning of these wetland ecosystem boundaries. This makes it all the more difficult to capture all the value components even if they be known. Nevertheless, as our evaluation attempt would reveal, the value streams that we get to appreciate are substantial enough to present a very strong case for wetland conservation. More so because they only give the lower bound of the wetland value.

The act of evaluation itself is not value-neutral. Neither do statements such as 'value reflects social choice' carry much weight. The reasons are as follows: firstly, there are as many choices as there are interest groups; secondly, mere aggregation of individual values held by human members of society cannot derive the social value adequately. For one, in their collective identity human members of a society can (and should) hold values, which transcend those held in their individualist identity. For another, society as a whole may have concerns that do not enter into the considerations of its individual members when they make choices. We must, therefore, at the very outset declare that our evaluation exercise of the East Calcutta Wetlands is aimed at the decision-makers – politicians, bureaucrats and engineers. These are the people who plan and execute policies regarding how best to make use of this ecosystem. Quite naturally, the cost and benefit concerns to be highlighted here may be (and possibly are) different from those of, say a philosopher or a visitor or even a champion-for-wetlands.

Finally, it must be pointed out that, changes of ecosystem structure and functioning are episodic rather than gradual or continuous. In case of our wetland service flows too, threshold limits exist. Once the system flips over this limit, a new regime is initiated. However, we do not as of yet know the irreversible threshold limit of our system. What therefore can be done is to try to find out the streams of value the East Calcutta Wetlands would generate over time if they continue to exist in their present state unaltered. The present evaluation attempt is, therefore, more of a projection exercise than anything else. Such projection is towards reminding the decision makers what is to be gained if we preserve our wetland or conversely, what is to be lost if we let go of it.

In the present case, the wealth created by the keystone ecosystem services will include:

I. Cost of treating with sewage (fishponds act like oxidation ponds for wastewater treatment).

II. Cost of wastewater as fish feed.

III. Cost of irrigation water (effluent from fishponds is used to irrigate downstream paddy fields).

I. Valuation of sewage treatment facility

The cost of averting the sewage treatment plant can be easily worked out as follows:

a) Design flow: 1000 Mld (million litres per day)

b) Cost of sewage treatment plant: Rs 4000 million assuming Rs 3 million / Mld (obtained on the basis of data available for completed sewage treatment plants under Ganga Action Plan phase I) mentioned in table 4, (CMW&SA,1997) and cost of land for setting up the sewage treatment plant at present market rates.

Annualised cost for setting up a 1000 Mld sewage treatment plant will include:

i) interest on capital @ 12.5 per cent per annum

ii) depreciation calculated on the basis of diminishing balance method @ 20 per cent per annum

iii) operation and maintenance cost @ 10 per cent on previous year's expenditure

Average of the aggregated recurring expenditure for first eleven years (assuming complete repayment of principal within that period) comes out to be Rs 1014 million (USD $22.04 million).

Year	Estimated Value (Rs Million)
I	1700.00
II	1580.00
III	1446.00
IV	1342.00
V	1263.30
VI	1206.30
VII	1168.30
VIII	1147.3
IX	1141.6
X	1150.6
XI	1173.4
XII	1210.00

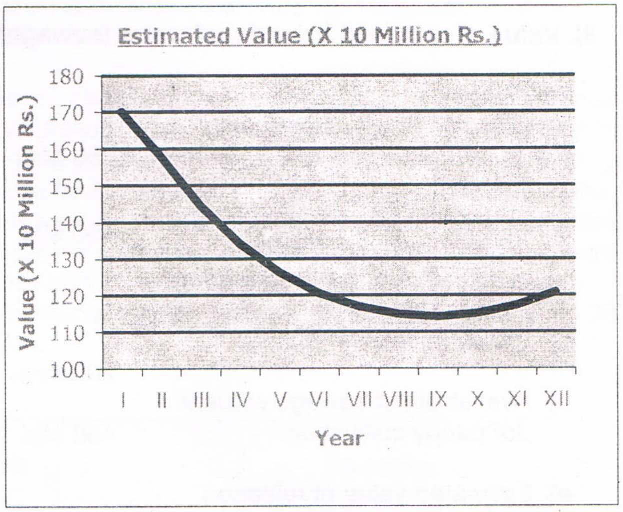


Table 4: Table showing value from Averting Expenditure on Sewage Treatment Plant (STP)

II. Value of wastewater as fish-feed

a) Cost of fish-feed, if purchased from the market : Rs 24, 000 per ha. per year[2]

b) Effective area under fish production in ECW : 2481.15 hectare[3]

c) Total cost of fish-feed for the ECW, if purchased from the open market : 2481.15 x Rs.24,000 = Rs. 5,95,47,600

d) The cost of fish-feed : Rs. 5, 95, 47,600

e) The averted cost for fish feed from the wastewater in East Calcutta Wetlands ~ Rs.60 million (USD $1.304 million)

[2] This value of Rs. 24,000/ ha was obtained by the author from Mr. Santi Das, a knowledgeable fish producer who has fishponds in the same district of North 24 Parganas (2002 value).

[3] CMW&SA 1997.

III. Value of released irrigational water (sewage effluent)

a) Sewage flow released daily to ECW from Kolkata: 750 Mld.

b) Assuming 60 per cent of 750 Mld as sewage effluent available for paddy cultivation: 450 Mld.

c) Paddy cultivation period: 200 days

d) Availability of sewage effluent for paddy cultivation: 450 Mld. X 200 days = $9x10^7$ m^3 per yr.

e) Estimated value of released sewage effluent: $9x10^7 m^3 x1/62.5m^3 xRs.18$
= Rs. 2, 59,20,000
~ Rs.26 Millions (USD $0.56 million).

Note:
(i) 1 acre = 2500 m^2
(ii) 1 inch = 2.5 cm = 0.025 m
(iii) 1 acre-inch = 2500 m^2 x 0.025 m = 62.5 m^3
(iv) Cost of 1 acre-inch irrigational water: Rs 18[4]
(v) Cost of 1 acre-inch = Rs 18
i.e., 62.5 m^3 = Rs 18
or, 1 m^3 = Rs 18 x 1/62.5 m^3

At the fag end of our discussion on how much economic value the keystone ecosystem service of the East Calcutta Wetlands generates, it can be said that the working together of sewage, sunlight, algae, fish and local farmers enables expenditure aversion in course of a number of production and consumption activities. This has been discussed. It has also been pointed out that these, however, are the conservative estimates. The fishpond ecosystems naturally treat the effluent released by the Kolkata municipality and thus save anything around Rs. 1300 million per year (USD $28.26 million).

As for the fish farmers using sewage as a very important input in their production, an expenditure of Rs. 60 million is averted per year. The expenditure averted by the paddy cultivators using the treated sewage to

[4] Data available from West Bengal Comprehensive Area Development Corporation, Kolkata.

water their fields is Rs 26 million. The total expenditure averted through the use of the keystone ecosystem service of the East Calcutta Wetlands in course of diverse economic activities is therefore Rs 1300 + 60 + 26 = Rs.1386 million (USD $30.13million).

Runa Sarkar (2002) derived certain values for the indirect benefits obtained from the East Calcutta Wetlands. The following table gives a summary of her findings. This work was also done primarily on the basis of the CMW&SA report on the East Calcutta Wetlands (1997) to which the author added the results of her own field survey. From this table, it will be practicable to leave out the cost of (a) flood control (because there has not been any flood in that area in the last 100 years) and (b) extensive food chain, because it has already been included as nutrient value. This will give a total value of Rs 387 million (USD $8.41 million).

Description of Benefit or Cost	Annual Contribution (Rs)	Remarks
Flood Control	248 million	Calculated based on damage cost avoided by assessing loss of homes and products
Extensive Food Chain	96 million	Calculated based on a valuation of the change in productivity due to the ecosystem
Livelihood Support Subsistence Use	270 million	Based on direct estimates of wages received
Carbon Sequestration	53 million	Based on estimates from limnologists, but there is a controversy on the contribution from methane generated
Natural Laboratory	18 million	Calculated based on direct economic benefits received from technological breakthroughs achieved due to the ecosystem and its potential as a tutorial ecosystem
Recreation	43 million	Field Survey, using travel cost method and willingness to pay
Open Space	2 million	Field Survey, using travel cost method
Lungs of Calcutta	1 million	Lowest range of monetary value of SPM reduction as estimated by developed countries considered
Restoration of Nitrogen	-	No concrete data available for valuation
Bio – accumulation of toxins	-	No concrete data available for valuation
Heavy Metals	-	No concrete data available for valuation

Table 5: Value of selected benefits from the East Calcutta Wetlands

If all these are added up, the total value of the East Calcutta Wetlands area works out to be about Rs 1773 million (USD $38.54 million).

A team of the Indian Statistical Institute (ISI, 2001) carried out a valuation of the East Calcutta Wetlands using willingness to pay method and arrived at a figure of Rs 72 million per year (USD $1.56 million). The respondents in this survey were hardly informed about the worth of this ecosystem and that has been the reason of arriving at such a low value.

The present attempt of assigning economic values to the ecosystem services of the East Calcutta Wetlands, like all such efforts, was aimed at appreciating the benefit streams generated by these wetlands and the cost that a society would have to bear in case of their disappearance. The result of this elementary exercise, stated simply is: *the East Calcutta Wetlands must be preserved in their present state*. Though only some of the values could be quantified, they are substantial enough to bias our choice in favour of its preservation.

Assigning values does not necessarily ensure social choice. It may not be out of place to discuss the mechanism of social choice in brief. Choices are made about what particular means are to be adopted to realize a desired end. This involves choices about how the resources be allocated among the competing uses. In addition, this also relates to the patterns of resource use over time. In case of any wastewater conservation project (WCP), the desired end for the society under consideration is 'the treatment of so much quantity to so much quality'. The means to this end can be any conventional sewage treatment plant or the traditional ecological engineering practices using pond ecosystem in wastewater conservation project. It is a matter of society's choice which of the alternatives be selected.

Wetland biodiversity

Biodiversity does not just refer to the biological variation of species and protection of the threatened ones but covers the whole spectrum of the natural environment. Biodiversity studies in the East Calcutta Wetlands have dealt with vascular plant diversity, some common ecological indices computed from the quantitative study of the birds, fin-fish and molluscans of the East Calcutta Wetlands and the interrelationship between various physico-chemical variables of the water bodies of the East Calcutta Wetlands (Ghosh & Mitra, 1997).

Wetland plants are very efficient in removing nutrients from polluted waters, minimizing eutrophication of the aquatic habitat that, otherwise, can create oxygen depletion and cause the fish to die. There are at least 12 aquatic vascular hydrophytes in and around the East Calcutta Wetlands that are significant for their bio-filtering potential particularly with respect to BOD, COD, nitrate and phosphate level (Ghosh & Santra, 1997).

The system as a whole, according to the study, (Ghosh & Mitra, 1997) is one of the most biologically productive, taxonomically diverse and aesthetically celebrated, consisting of a series of *bheris* and canal systems. With a floristic resource of about 104 species, it has immense value in terms of global biodiversity. The picture of floristic diversity was different in earlier times. Biswas (1927) identified three zones of vegetation in the Salt Lakes region. Among these, vegetation of embankments and bunds were mostly dominated by *Fimbristylis ferruginea, Sueda maritima, Acanthus ilicifolius, Excoecaria agallocha, Avicennia officinalis*, etc. While Salt Lakes proper was dominated by numerous algal flora, bushes of *Phragmites karka, Aegiceras magus, Typha elephantina* etc., the vegetation of swamps and dry lands, were mostly dominated by oligohaline and mesohaline shrubby species and several halophytic trees like *Sonneratia apetala, Avicenia officinalis* along with quite a good number of bushy shrubs and few filamentous algae like *Enteromorpha intestinalis, E. prolifera* etc. Dasgupta (1973) recorded 97 species belonging to 41 families of which 34 species belong to the wetland habitat. He also mentioned the presence of mangrove flora. In course of time, these mesohaline and oligohaline wetlands have been changed to sewage-fed fisheries and this has resulted in the shifting of aquatic vegetation. Annexure 1 gives a timescale evaluation of biodiversity of flora and fauna of the East Calcutta Wetlands.

The flow of traditional knowledge

Fascinating as the wetland system is, even more fascinating is the story of the flow of traditional knowledge from one generation to the next and how this outstanding practice evolved to what it is today. It also prompts research into the discipline of traditional knowledge vis-à-vis the East Calcutta Wetlands though, admittedly, such a pursuit will be circumscribed by the author's personal experience and conversations with several stalwarts among the fish producers of this area, who are well known for their phenomenal knowledge base in this variety of fish growing. Much of such dialogue has been with one of the leading repositories of such knowledge, the late Ganesh Biswas, who passed away about a decade ago and Premtosh Ghosh, president of the South 24-Parganas Fish Producers' Association, who lost his vision about two decades ago but is blessed by extrasensory perception that gives him vision beyond eyesight. He is perhaps among the last of the Romans reigning over this remarkable traditional knowledge system.

It has been difficult to organize the statements of the local connoisseurs of wastewater fishponds because they have been obtained at various times and in diverse situations and do not lend themselves to logical sequencing. Nevertheless, the evolution of traditional knowledge, flowing down generations, does define a process initiated in the manner fishponds were scientifically managed to meet the ecological challenge of growing fish in untreated municipal wastewater.

The first achievement is in obtaining a water quality that could grow spawns. Fish production begins with procuring eggs and preparing the pond. The second stage is the process of the eggs developing into spawn and daily monitoring of the fish, first in the nursery/rearing pond and then in the stocking pond. The experience and traditional knowledge of pisciculture is of enormous importance here while the fish farmers raise the fish, building on that knowledge base. Indeed, traditional knowledge is the heirloom that remains with the fish farmer as long as he continuously nurtures it.

A familiarization with the fish farmer's calendar, which follows the Bengali calendar, is useful in understanding the traditional practice. However, there is no uniform calendar of activities followed over the entire wetland region. This is because of variations in the size and ordering of the fishponds, availability of wastewater, skill and financial ability of the operators. The following is a generalized activity calendar and may not necessarily hold good for all the farms (Table 6).

Bengali Calendar	Season	English Calendar	Activity
Baishakh	Summer	Mid April – Mid May	Fish growing
Jaishtha	Summer	Mid May – Mid Jun.	Fish growing
Ashadh	Monsoon	Mid Jun. – Mid Jul.	Harvesting begins. Stocking egg in nursery pond begins.
Shravan	Monsoon	Mid Jul. – Mid Aug.	Harvesting continues. In between netting, stock from nursery pond to rearing/stocking pond is transferred.
Bhadra	Autumn	Mid Aug. – Mid Sept.	Harvesting continues. Transfer of stock continues.
Ashwin	Autumn	Mid Sept. – Mid Oct.	Harvesting .Transfer of stock continues.
Kartik	Retreating Autumn	Mid Oct. – Mid Nov.	Harvesting.
Agrahayan	Retreating Autumn	Mid Nov. – Mid Dec.	Harvesting.
Poush	Winter	Mid Dec. – Mid Jan.	Draining out water and preparation for the pond bed begins
Magh	Winter	Mid. Jan. – Mid Feb.	Preparation for the pond bed completed and wastewater intake begins
Phalgun	Spring	Mid Feb. – Mid Mar.	Wastewater intake continues till middle of the month after which stocking begins with early fingerling (up to 75 mm) and fingerling (up to 150 mm).
Chaitra	Spring	Mid Mar. – Mid Apr.	Growing period

Table 6 : Generalised activity calender in the wastewater fish farms.

In the East Calcutta Wetlands, there is no uniformity in the size of the ponds. They range from as small as 5 hectares to as large as 50 hectares. These however exclude nursery ponds, which are much smaller in size. The ponds are shallow, rarely exceeding a depth of 1m. The ordering of the ponds (nursery-rearing and stocking) and sequencing of wastewater intake and drainage also vary. The wide range of variations necessarily have corresponding responses in the cultural practices.

Pisciculture begins with procuring eggs for which there are two markets one each at Howrah and Sealdah. The Sealdah market sells eggs born out of fish that breed in the river and the Howrah market sells eggs from fish bred largely in enclosed places. These eggs, therefore, are either from the river-bred fish or from fish bred by fish farmers, an activity conducted in three main districts: Puruliya, Bankura and Chandrakona of West Medinipur district.

Eggs from here are brought to the markets of Kolkata. At present, decline in the supply of river-bred eggs compel the fishermen to rely on the pond-bred eggs sold at the Howrah market. The fishermen of the East Calcutta Wetlands have succeeded in breeding exotic varieties of carp in wastewater ponds. The eggs are fertilized in a rectangular floating mat of water hyacinth locally known as *hapa*.

Once the seeds are procured, the pond has to be prepared after draining out the sewage. Prior to introducing the eggs, the pond bottom has to be prepared from the end of the month of Poush (mid-January). Should the sludge be too much, the soil has to be dug up 20 to 25 cm. with a plough or spade and brought on top to dry. Both the top and bottom soil of the pond have to be dried to ensure that there is no foul smell and any smell that might be present is got rid of. It is important to note that it is a plough that must be used because there may be small pockets of negligible organic deposits, which host a kind of big-sized snail.

This snail is harmful, as it feeds on the same sewage that serves as food for the fish that grows in the sewage-fed *bheris* and depletes the nutrients, especially those in the soil of the pond bottom as well as in the sewage, which the fish draw upon to grow. The snails must be destroyed. Therefore, the soil needs to be thoroughly ploughed. In fact, one has to dig 3 cm deeper than the depth of the soft topsoil to be able to root out snails and other such other creatures that take away the nutrients meant for the fish (Figs.18 and 19).

Fig. 18: Local women are collecting snails from the pond bottom. Snails are harmful for the fishes

There is a specific plant that helps increase the organic contents of the soil in the bottom of the pond: *dhanche* (*Sesbania sp*). If the soil is good, the plant grows slowly. If it rains, the water has to be drained out so that the root of the plant does not rot. The plant fixes nitrogen in the bottom soil. Thus the deeper the root, the better it is for the soil. The enriched soil can provide nutrients for the fish for three to four years but the problem lies in the time required to prepare the soil, which is about a year and a half - six months to dry the pond bottom and one year to grow the *dhanche*. No fish producer can afford this period of idle labour, which is why such efforts are not common. Fortunately, there are other nutrients such as aquatic weeds that grow at the bottom of the pond and serve as fish food.

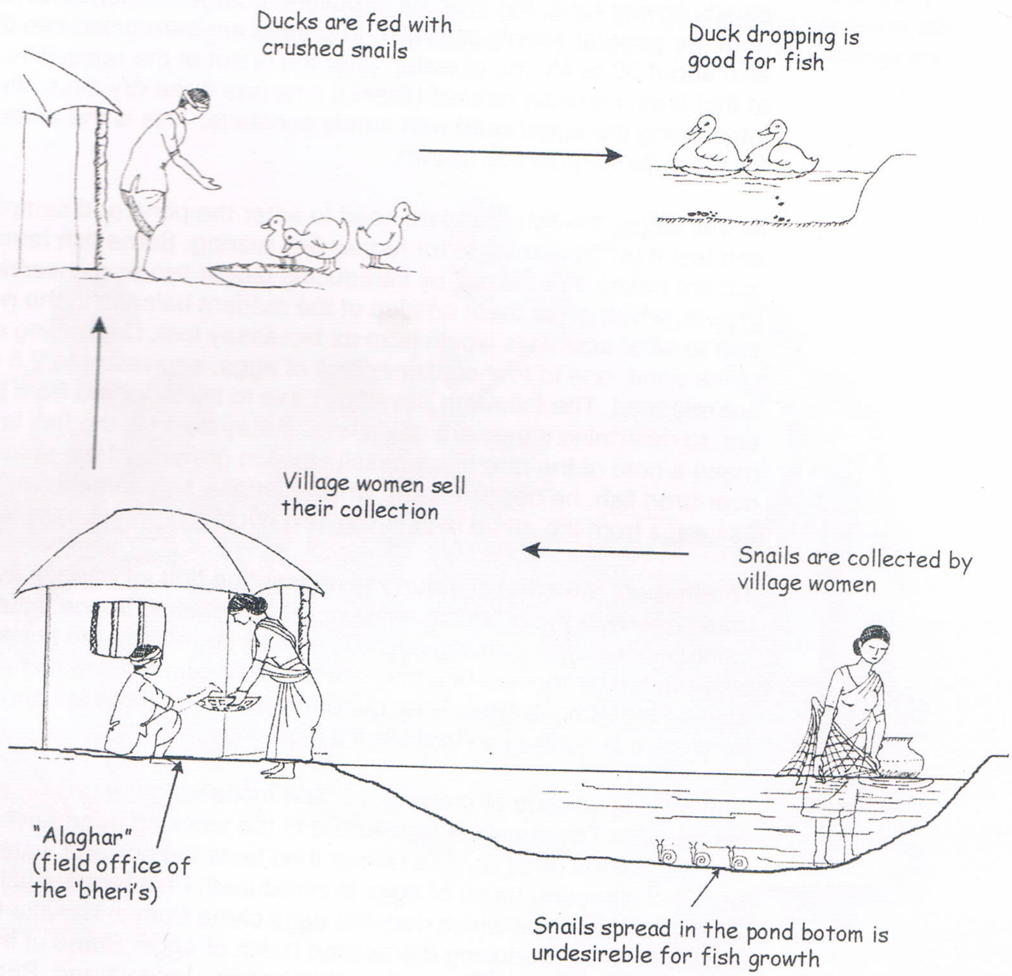


Fig. 19: An excellent example of living creatively with nature. Local innovation converts a problem into a solution using knowledge of natural functions

One of the most important expositions of traditional wisdom in wastewater utilization for growing fish lies in the sequenced feeding of untreated wastewater into the fishponds. The ingenuity of the farmers in using nature creatively has been eminently demonstrated in sequencing the water ingress and drainage. At first they create a stock of treated wastewater (with BOD less than 5 ppm) by detaining untreated wastewater for about 21 days. Incidentally, this detention time is necessary for obtaining the best quality of treated municipal wastewater in tropical areas. The treated water in the pond dilutes the incoming untreated wastewater entering the pond, which, in turn, gets purified after necessary detention, and the process continues.

According to Late Ganesh Biswas, with an adequate managerial skill and a steady flow of fund, the process of culture in large fishponds deviates slightly from the general activity calendar. The eggs are introduced into the ponds with about 30 to 45 cm. of water, after the onset of the rains. The farmer will, at that time, consider himself blessed if he has three dry days after introducing the eggs/ seed with ample sunshine. This is the ambient climate for the eggs to grow into spawn.

At this stage, the fish breeders need to enter the pond and sample the soil and test it for its readiness for further fish rearing. Some fish farmers test the nutrient balance of the soil by introducing bigger fish and observing their growth, which gives them an idea of the nutrient balance in the pond. This is akin to what scientists would term as bio-assay test. Depending on the size of the pond, one to four containers full of eggs, equivalent to 2.5 lakh spawn, are released. The following day, they have to be observed from 5 am to 8 am, to determine if they are doing well. If they do well, the fish farmer must make a note of the rate of successful spawn growing. If the spawn is from river-bred fish, he needs to note which river the egg came from, to be able to use eggs from the same river in the next cycle.

The farmers are often in a hurry to release the first lot of eggs available in the market early in the breeding season, without waiting to see if the nutrient balance is right for growing eggs. This hurry to release the first batch of eggs is prompted by the fact that they are the strongest, having come from the earliest breeding in May. They generally do well without fail and the fish yield from them is quality fish that fetch a high price.

The art and science of growing fish and monitoring the growth is just as fascinating. The spawn is transferred to the stocking pond once it has grown into fingerlings (Fig.20). The farmer then tests the soil and water condition before the second batch of eggs is introduced. Fish farmers using river-bred eggs must also see which river the eggs came from and make the right choice before introducing the second batch of eggs. Some of the eggs are sourced from Assam, Bhagalpur, Darbhanga , Lalgola and Patna, and some from rivers like Churni, Dwarakeswar , Mahanadi and Son. The eggs are often named after the specific places or the rivers where the actual breeding and release of eggs takes place.

The release of the second breed of eggs in a large pond is to be preceded by considerable preparation in terms of drying the pond from Poush to Baisakh or fish farming activities have to be carried out with *shol* (*Ophicaphalus siriatus*) and *laitha* (*Chana puncatatus*) till the middle of Chaitra. Shravan and Bhadra (from peak rainy season to the onset of autumn) are very difficult and challenging periods for fish producers and owners of *bheris*, mainly because climatic changes acutely affect the health of the early fry that grow out of the spawn. The rains follow a regular pattern during these two months. According to Late Ganesh Biswas, rain commencing on a Tuesday is bound to be followed by three days of continuous rain. Rainfall commencing on a

Saturday brings in a seven-day rainy spell. If the stormy easterlies accompany the rain, they could spell havoc and take a toll of the weak early fry (up to 12 mm in size), which would surely perish. The storms generally kill the fry growing out of the eggs because they lack the strength to weather the storm.

Fig.20: Fingerlings are transferred to stocking ponds

The easterlies bring in their own travails. So strong is the fear of flooding in these times that farmers are afraid to let in sewage, even with ample sewage in the storm weather flow channel, lest the waters rush in and the fry flow out of the rearing pond. There is also fear of the fry contracting many a disease. Generally only those fry in ponds that have 32 to 40 cm. of water survive the onslaught of disease in these months.

The easterlies bring such heavy showers along that a continuous downpour over the day and night washes away the pond nutrients. The missing sunshine adds to the farmer's woes. Only those ponds with 32 to 40 cm of water depth have a bit of sunshine. Where the water is deeper, it either becomes white or colourless as the nutrients get washed out leading to the death of a lot of fry. The fish farmer must then rush to fill the pond with *Lankashira* (*Euphorbia pirucalli*) to restore the bluish colour of the rearing pond. These plants rot and restore some of the bluish colour to the water, supplement some of the missing nutrients and possibly save a lot of fry from perishing.

Such stormy winds with heavy rains are typical of the rainy season and not till the period of storms ends completely can the farmers shift the fry from the rearing ponds to the stocking ponds that have been prepared to receive the fry. The easterlies notwithstanding, the stocking ponds do retain some nutrient content and when the fry is put into the pond, they cause a movement in the water, which serves to churn the nutrients in the soil at the pond bottom. This brings back the bluish colour, which is actually a biological indicator of the presence of nutrients, in the water.

Late Ganesh Biswas experienced a serious problem as early as the initial years of the eighties, towards the fag end of his life: an acute shortage of sewage. This meant that fish farmers could not provide adequate nutrients for the fish as most *bheris* had no more than 30 cm to 60 cm of sewage while the need is for 60 cm to 180 cm of sewage. All kinds of fish grow in this depth with a cent per cent success rate while the shallow ponds experience 75 per cent loss of fish – *Catla* (*Catla catla*) does not grow out of the eggs in shallow water and *Rohu* (*Labeo rohita*) becomes prone to a fatal insect attack. This is rife during the winters, when there is inadequate sunshine.

During this time, the water changes colour, indicating a loss of nutrients, signalling the birth of a variety of insects, which suck the blood out of the fish and the *Rohu* and *Catla* fish die. When these fish die, the villagers pick them out of the ponds and, if the fish farmers so wish, they can make fertilizer out of the dead fish. However, this needs the ponds to be emptied first, the fish chopped into pieces, the pond bottom dug up and the fish pieces properly mixed with the soil. The soil has to be dried thereafter. If this is not done and the dead fish is allowed to remain in the water, the insects thrive on them, multiply and affect the rest of the fish. Fish is affected by a variety of disease but if the bluish colour of the water is maintained, the nutrient level stays steady and insects or diseases cannot attack the fish. Maintaining this colour becomes very difficult during the monsoons, when the nutrients tend to get washed away. This can be obviated by advance preparation during the summer to ensure maintenance of the bluish colour and the nutrient level.

Sometimes, the fish producers or *bheri* owners cannot figure out the real cause behind fish disease. Often, they fail to keep in regular touch with the employees/*bheri* labour and remain ignorant about the diseases. The causes of many a fish disease is probably not yet known. Sukumar Biswas, who has followed in the footsteps on his late father Ganesh Biswas, is quite as knowledgeable but Sukumar may not have anyone after him to pass on his knowledge to. And Sukumar is not alone among the surviving custodians of this traditional knowledge system.

Blending ecology, economics & engineering

In its fishponds, paddy fields and co-recycling garbage farms, the East Calcutta Wetlands provide three basic securities critical for human living in the third world country - food, sanitation and livelihood. "The significance of these wetlands in environmental rescue work is manifold" (Ghosh & Furedy, 1984; Ghosh, 1983). They take the city's sewage and garbage and in return provide a significant part of its requirements of fish and vegetables.

Furthermore, these systems provide for the city's spill-basin and excellent biological treatment of wastewater (Ghosh, 1983) – surely most important for a city where no working sewage-treatment plant exists. (Ghosh & Sen, 1987).

This creative and ingenious practice, locally developed and replicated, is a result of traditions of resource conservation and environmental rescue. These wetlands have been preserved and nurtured by local people, mostly villagers belonging to the poorer and weaker sections of the socio-economic rung. What, however, distinguishes the ecologically handicapped population of the East Calcutta Wetlands is their ability to admirably negotiate a critical ecological disorder and raise thereupon a palpable example of natural resource management that many others can emulate. In their attempt to revive their livelihood opportunities (Fig.21) for the next few generations these 'natural ecologists' have automatically brought about a unique blend of ecology, economics and engineering – a feature often lacking in most well thought out development plans.

It is not particularly difficult to visualise how these wetlands host one of the biggest laboratories in the world for sanitary engineers to standardize and develop least-cost alternatives for municipal waste management that would ensure maximum recovery of nutrients available in waste.

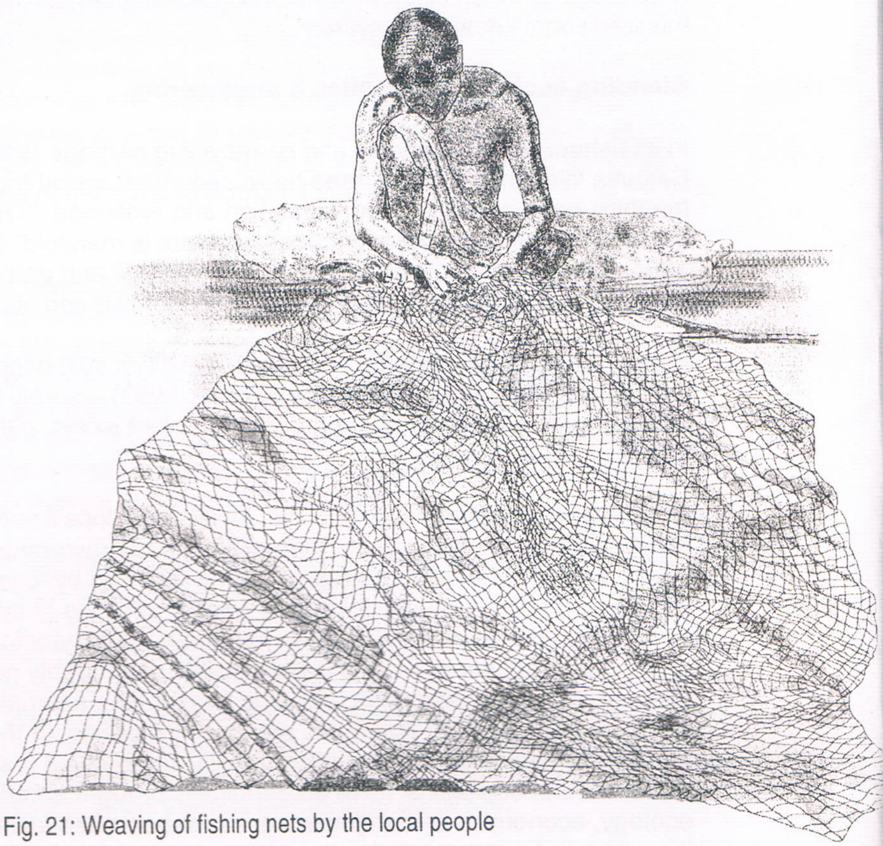


Fig. 21: Weaving of fishing nets by the local people

Sustainable development must rely on technology drawn from traditional practices. "Eco-development entails bringing together creative techniques with the ways in which people perceive and approach the issues of quality of life, through environmental changes that are in the forefront of planning debates. Human and ecologically sound planning requires an integration of such understanding with suitable techniques and procedures" (Ghosh & Sen, 1987).

Subir Ghosh

The wastewater fish ponds in the East Calcutta Wetlands

Subir Ghosh

Fishing in the East Calcutta Wetlands

D. Ghosh

Lock gate at the confluence of Calcutta outfall canals on river Kulti

D. Ghosh

The drainage outfall land carrying Kolkata's wastewater

The East Calcutta Wetlands and Waste Recycling Region
12,500 Hectares

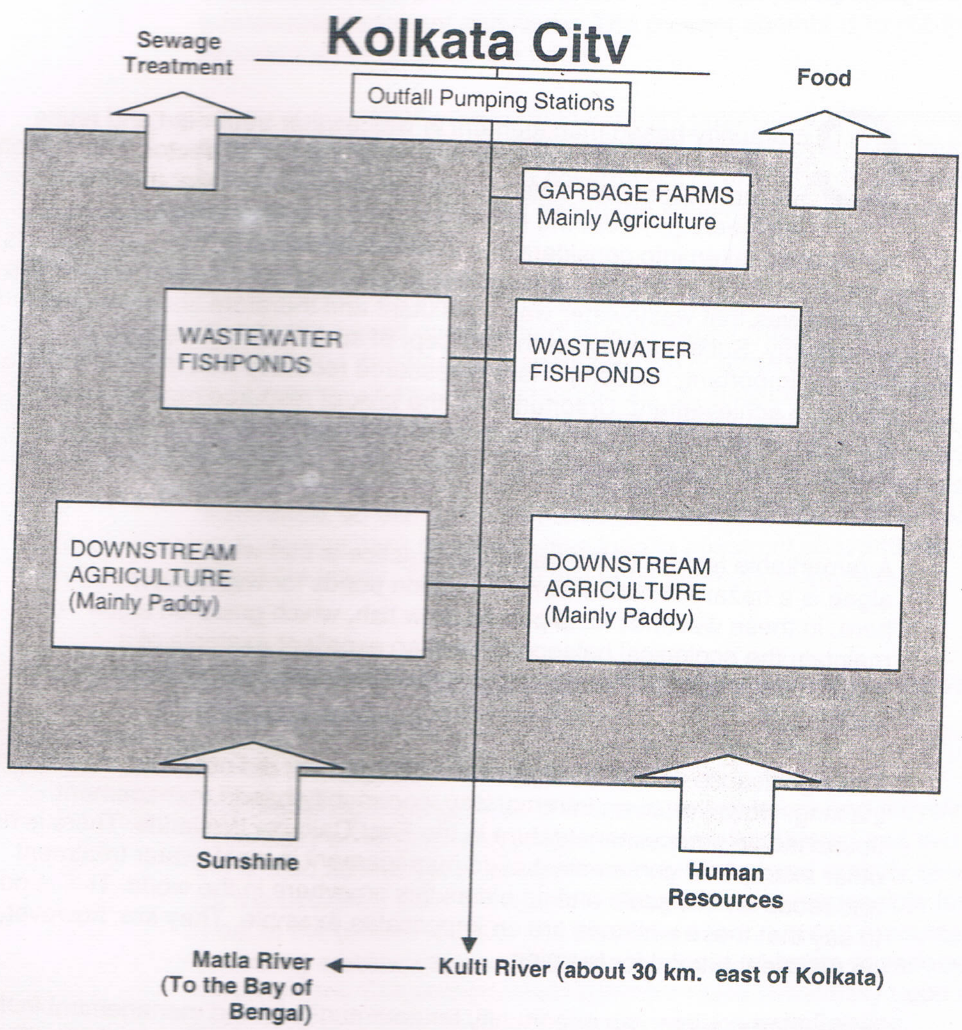


Fig. 22: Process flow diagram for the resource recovery practices in the East Calcutta Wetlands and Waste Recycling Region

CHAPTER 6
Mainstreaming a Local Wisdom

The theory of managing urban waste is undergoing change. Planning for disposal is yielding place to concern for recycling.

Community-based management in wastewater treatment and reuse has not been tried anywhere in India in the formal sector. The reason behind this can be related to the history of wastewater treatment engineering, where the role of the people or their knowledge has hardly been taken into consideration. Wastewater management, the way it is understood today, emerged in response to public health considerations. The thinking was that wastewater was a pollutant and therefore should be treated accordingly. Subsequently, as the concept of sustainable development became important, the component of resource recovery was introduced as a desirable achievement. Unfortunately, the task of resource recovery did not quite get along with the mainstream initiative in wastewater treatment. The reason, to be candid, was the lack of perception and attitudinal limitation of the engineers.

A remarkable feature of the traditional practice is that while overgrowth of algae is a hazard in conventional oxidation ponds for wastewater treatment, here, in these wetlands local people grow fish, which graze on algae and maintain the ecological balance. This is an excellent example of a disadvantage turned into opportunity through community participation and knowledge.

The significance of community-based management did not strike mainstream thinking. However, in an informal way, community-based management flourished as a necessary feature in the East Calcutta Wetlands. There is no other example of community-based management in wastewater treatment and reuse on this scale and as old as this anywhere in the world. This is not to say that these wetlands are an impeccable example. They are, however, an excellent tutorial for learning.

In the formal sector, an opportunity for community-based management in the pond system of wastewater treatment came up under the Ganga Action Plan. This plan was designed to reduce the pollution of the river Ganga, the longest and most important river of India. The basic premise of this plan was to reduce the pollution added by municipal wastewater from the river front cities by setting up sewage treatment plants. These cities contributed about 70 per cent of the pollution load by draining their wastewater into the river. For three municipalities in West Bengal, conventional treatment plants were replaced by the fishpond system options, developed on the basis of the waste recycling practices in the East Calcutta Wetlands. While designing, constructing and running these pond system projects, community-based management as a tool could only be used in fragments. This was because the prevailing framework of planning, design, construction and operation did not allow much of an opportunity to take up community-based management within its fold. Nevertheless, these three fishpond system projects provide substantive lessons for adopting community-based management in wastewater treatment and reuse. The present attempt is to put these experiences in order for the future.

For most community-based management practices in the developing countries, livelihood compulsion acts as a prime mover. This has also been true in the present case. The government or any other formal institutional support did not play any key role in the shaping of this outstanding management practice.

The East Calcutta Wetland practice is amongst the earliest attempts at community-based management in wastewater treatment and recycling. Although the database is inadequate, the practice has a seed that can grow to completely change the fundamentals of municipal wastewater treatment. From being grant-in-aid projects, such public health facilities can be transformed into investment projects. A financial liability will become a revenue earner. Poorer parts of the world would need this transformation to materialise, so that their cash-strapped municipalities need not wait for multinational bank finance to give loan to construct conventional sewage treatment plants. This is what this book attempts to impress.

Understanding community-based management for wastewater treatment and resource recovery

The prevailing management of wastewater treatment and recycling is essentially an engineering programme centrally planned and laid out. It has the limited advantage of being an entirely formal and entirely safe approach for the designer. Safe because the designer is not responsible for negotiating most of the ground realities like insufficient flow, wasted resources, conflicts in sharing wastewater and problems involving interests of various stakeholders. Conventional management relies essentially upon a patron-client relationship between the planner and the beneficiaries.

Community-based management, on the other hand, becomes effective because of meaningful involvement of the people – the stakeholder groups or major beneficiaries. This is an alternative tool for making the task of wastewater treatment economically, ecologically and socially gainful. It liberates the concept of wastewater management from the confines of knowledge owned by a selected few. In community-based management, the local people are no longer passive objects. On the contrary, it is they, who hold the key to the effective functioning of the system.

Community-based management in wastewater treatment and recycling will be a methodology to establish a 'waste-as-resource' approach in place of the conventional 'waste-as-pollutant' projections. Here, the people will be involved throughout in the process of planning, design, construction and system management. These steps will require collection of information, concept articulation, understanding local requirements, skill and priorities and garnering political support.

Where the people know better

The waste recycling practices, developed and managed by the local people for many decades in the East Calcutta Wetlands form the bedrock of developing the community-based management paradigm for wastewater treatment and recycling. This is essentially because it is an altogether different worldview that drives the system where wastewater is considered as a resource rather than a pollutant. Being a special kind of production process, here the most important actors are the entrepreneurs, the local self-government in the form of village *panchayats*, trade unions of fish farm labourers and the irrigation and drainage agency.

For any degree of success achieved by this wastewater-based livelihood and production process, participation of all the major actors for managing matters has been an obligatory criterion. Not that the level and degree of participation have always been satisfactory. In fact, sometimes they have hardly been desirable. But then, lessons in community-based management have been effective. What would happen if a certain decision were reached with or without the participation of one or more actors, how adversely would a failure in participation affect, and such other vital lessons emerge more easily on the basis of real life experiences of both failures and successes.

To a planner, an alternative concept that is less capital intensive than the traditional resource recovery practice of East Kolkata and yet gives the best desired benefits is seldom available. This is particularly true when the search is for an ecologically acceptable choice (Fig.23). The fishpond ecosystem of East Kolkata is one of such none-too-frequent examples in environmental protection and development management that is in harmony with nature, wherein benefits are achieved at a much lower cost. From this we can learn, examine and adopt elsewhere.

What however, is more striking is how easily poor farmers of the wetlands of Kolkata have adopted the complex ecological process. These natural ecologists have developed such a mastery of the resource recovery activities that they easily grow fish at a yield rate and a production cost, unmatched in any other freshwater fishponds of the country. It is always true that the culture of conserving a resource and using it as many times and in as many ways as possible has been seen to thrive among the poor. There is prima facie an inverse relationship between affluence and affinity with recycling. Most of the discoveries in waste reuse, over which scientists in advanced countries congratulate each other, are likely to have been perceived and used much before in the villages of the less developed parts of the world.

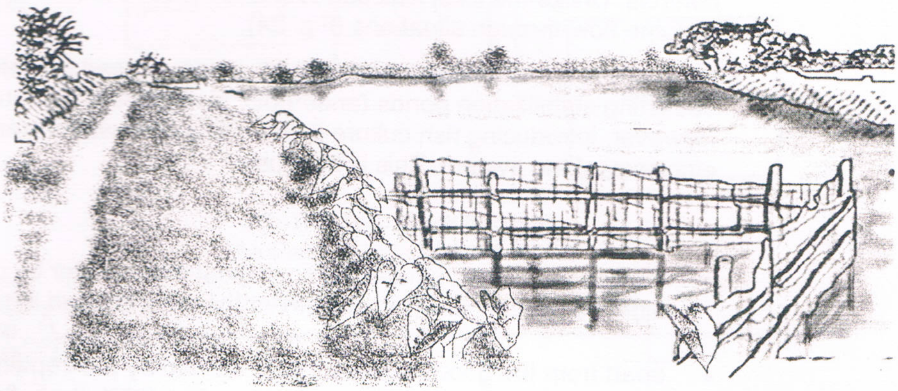


Fig.23: Sieve made of bamboo (*pata*) used for the ingress of wastewater in the fishponds – sharing of a common property resource.

Understanding the East Calcutta Wetland system of resource recovery is far from complete. There is no reason to pretend that the theoretical guidelines for translating the experience of traditional wetland practice into a reliable technology option are foolproof. In fact, the subjective tool of a fishpond system option for treatment and reuse of wastewater is far more crude than conventional hard system choices. Yet, from the standpoint of ecological balance, economic viability and system reliability, the former towers much above the latter in its rustic grace and is destined to shape the future grammar of sanitation technology options for tropical countries, especially the poorer ones.

The fishpond system projects

In India, the launching of the Ganga Action Plan provided the necessary fund and opportunity to experiment with the new generation options in municipal wastewater treatment. The Ganga Action Plan has provision for resource recovery. However, the basic difference between the conventional wastewater treatment plant and the proposed fishpond system option is that resource recovery is suggestive in the former while it is obligatory in the latter. In the latter, it is an integral component of the design, forming the very basis of its community linkage.

The fishpond system project is an outcome of one of the earliest efforts in developing community-based technology for river sanitation. Here, the conventional option in wastewater treatment has been replaced by an ecological design in which the task of reducing pollution and reusing nutrients is linked with enhancement of food security and development of livelihood of the local community using nutrient-enriched effluent in fisheries and agriculture. The actual design is based on a pragmatic manipulation of natural functions within the existing framework of policy and regulatory controls. Unlike the East Calcutta Wetland Practice the fishpond designs assume flow-through situations (Fig. 24).

Pond areas are calculated on the basis of widely used guidelines for designing stabilisation ponds (anaerobic, facultative and maturation). However, introducing fish culture in the admissible water area improves the efficiency of the system. This is because:

- the fish population acts as an ecological manipulator by grazing on the algal population which would have otherwise caused algal bloom and

- apart from the good revenue that is earned by the implementing agency by giving license to use the water area for pisciculture, fish production brings adequate entrepreneurial incentive to operate the system efficiently and productively.

Basic features

Basic features of the pond system projects are:

- Environmentally sound design
- Reliability
- Decentralised management and decision making
- Resource mobilisation and enabling
- Stronger livelihood support

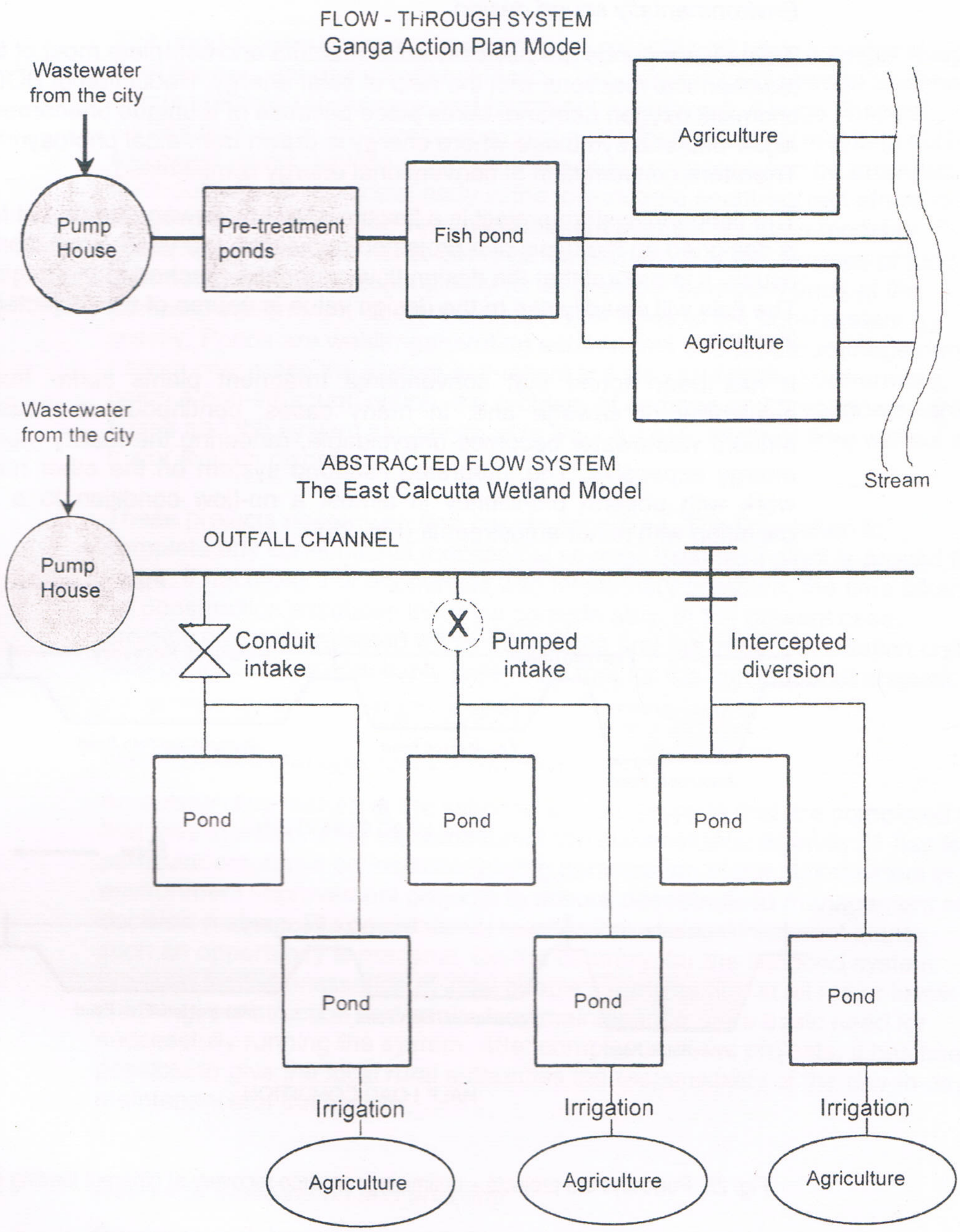


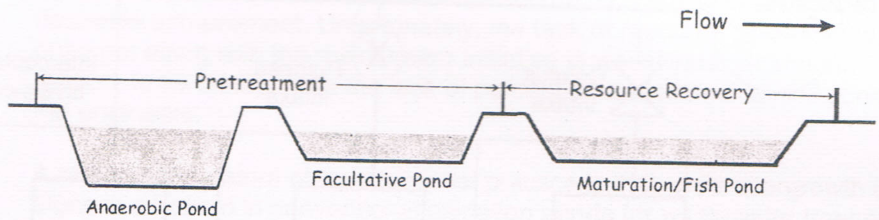
Fig. 24: Different hydraulic regimes for wastewater utilisation and safe disposal

Environmentally sound design

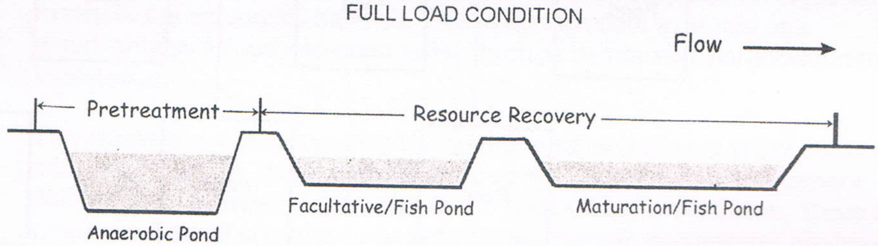
Wastewater ponds are basically solar reactors and complete most of their bio-chemical reactions with the help of solar energy. Reduction of BOD (bio-chemical oxygen demand) takes place because of a unique phenomenon of algae-bacteria symbiosis where energy is drawn from algal photosynthesis. Therefore consumption of conventional energy is minimised.

The fishpond system project is a flexible one. Any sewage treatment facility is designed on the basis of a projected population (20 years projection is usual). It is natural that the design flow cannot be reached at the beginning. The flow will steadily rise to the design value in course of the projected lifespan.

It has been found that conventional treatment plants suffer from non-availability of sewage and, in many cases, continuous re-circulation of effluent wastewater becomes unavoidable, rendering the facility much more energy expensive. The integrated fishpond system on the other hand, can work with uniform proficiency in almost a no-flow condition to a full-flow condition with minor adjustments (Fig. 25).



FULL LOAD CONDITION



HALF LOAD CONDITION

Fig. 25: Pond System projects – optimising resource recovery at different loading conditions

Wastewater ponds can ensure more efficient removal of coliforms. Conventional mechanical sewage treatment plants (trickling filters or activated sludge plants) are largely inefficient in removing coliform bacteria. (Coliform is the indicator species for faecal bacteria, which are likely to be pathogenic).

Reliability

The pond system projects are much more reliable and have a longer lifespan than the conventional treatment facility. The conventional sewage treatment plants are prone to damage and frequent breakdowns. A huge financial liability accrues to the parent municipal authority to properly maintain such treatment plants. Unless continuous financial assistance can be arranged from outside, no municipal body in the low-income countries can afford to run conventional mechanical sewage treatment plants. Resource recovery systems, on the other hand, are revenue earners. For the purpose of fund allotment, municipal responsibility for all practical purposes ends at the pumping station from where the wastewater flows to the pond system by gravity. Ponds are wealth-generating ecosystems and proper management cannot only make the system self-reliant but also profitable. Furthermore, being a non-structural option, the problem of damage and breakdown hardly arises and the system can continue to work for any length of time without any major system disorder.

These projects need much less construction time. The time taken to complete any conventional mechanical sewage treatment plant is around five years, if not more. For economies with inflationary pressure, the time taken for construction escalates the price considerably. In the present case, projects can be completed within 18 months and the impact of inflation on the total project cost is noticeably lower than that for the conventional projects.

Decentralised management and decision-making

An outstanding feature of the fishpond system projects that are completed is that they institutionalise participation of the stakeholders. Agenda 21 has laid particular emphasis on institutionalising participation of the stakeholders in environment improvement projects to ensure decentralised management and decision-making. For conventional mechanical sewage treatment plants, such an opportunity is marginal. On the contrary, for the fishpond system projects, institutionalisation of local people's participation at all major levels of planning, construction and particularly maintenance are a basic need for successfully running the system. After completion of the projects, it has been possible to give the local rural authorities the responsibility of the day-to-day maintenance of the system.

Resource mobilisation and enabling

Resource mobilisation and enabling contributes to rural development. Integrated fishpond system projects have a significant role in rural resource mobilisation. Completion of the projects triggers a chain of economic activities by providing enriched irrigation water in addition to the piscicultural units, which form part of the system. In West Bengal, there are examples of rejuvenation of livelihoods achieved within a short time of completion and commencement of these projects.

Stronger livelihood support

The pond system option compulsorily includes pisciculture, agriculture, horticulture and animal husbandry. All these systems have a common and rich nutrient base that is drawn from municipal wastewater. Unlike in the conventional sewage treatment facility, productivity of these multiple food growing systems goes a long way to render strong support towards the development of livelihood of the farmer families. The conventional sewage treatment plant is invariably considered an externality in the basic social and economic activities of a city and its fringe.

The fishpond system option is least expensive and is estimated to cost about Rs 30 lakh ($100,000) per million litre of wastewater per day (1991 prices). This includes the cost of land. The major cost of the project is that of the land which should preferably be a low-lying area at the fringe of a municipal boundary. These lands are generally the cheapest and in most cases do not raise more than one crop per year. It is possible to engage displaced farmers in the wetland project for providing their continuous source of income that can even be more than the amount earned by them before the implementation of the project. In fact, choosing the fish pond system option will be easier for the cities with a low-lying waterlogged fringe. It is also true that cities in general grow on raised lands and occasionally around a city's fringe there are some low-lying waterlogged areas. Dhaka, Mumbai, Jakarta, Kolkata and Bangkok are a few such cities with marshy backyards.

Conditions for good performance

On the basis of experience in running the pond system projects in West Bengal for several years, it has been possible to enlist the major conditions for good performance as follows:

- Ensuring steady availability of wastewater in the pond system and maintenance of required hydraulic regime.
- Ensuring sufficient reduction of pollutants and appropriate cultural conditions for growth of fish in the admissible water area within the constructed water bodies of the project.
- Ensuring appropriate distribution of nutrient-enriched effluent from the waste system ponds.
- Prevention of any increase of waterlogging in surrounding area during monsoon that may be caused by construction of pond dykes.
- Obstructing natural flow of monsoon runoff.

- Minimising unutilised flow of wastewater.
- Increasing areas of community interface and providing for involvement of stakeholders.
- Ensuring continuous and comprehensive monitoring of selected indicators for appraising the operating conditions and performance level of the fishpond system.
- Cultivation of understanding within the local community, knowledgeable people, village leaders and other groups of stakeholders and individuals.

Measures for initiating community involvement and community-based management

Certain measures taken for initiating community involvement and community-based management are listed below. These measures, understandably, exclude the first step to be taken at the policy level for making participatory approach an obligation for any wastewater treatment project. It will also have to be a policy obligation to recognise wastewater as a resource (a nutrient pool to be more precise) instead of a pollutant.

The measures are:

- Community-based management.
- Institutionalisation of stakeholders' participation.
- Creating entrepreneurial opportunities.
- Basin-wide design for effluent disposal.
- Participatory appraisal.

Community-based management

Non-performance of conventional sewage treatment plants, unlike water treatment plants, does not evoke immediate community response. Neither is there any scope to provide incentive for excellence in performance. In such situations, the task of plant management becomes more difficult and it is hardly surprising that satisfactory management of sewage treatment plants, especially when the work culture is not the best, has been a goal difficult to achieve.

In contrast, if the fishpond system fails to perform properly there may be irregularities in effluent distribution and in such cases the farmers, who are expecting the water, are sure to register their protest. On the other hand, the better the maintenance of the wastewater ponds, the more the yield of fish and resultant profit from sale in addition to other benefits will accrue to the community.