Peri-Urban Agriculture and Aquaculture

The huge quantities of solid and liquid waste generated by major urban centres have to be effectively managed and disposed. The recycling of this waste to grow food for meeting urban hunger has been done in various parts of the world. East Kolkata wetlands have effectively reused both the solid and liquid waste of the metropolis as a nutrient rich medium for agriculture and aquaculture.

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Waste water has been gainfully utilised for irrigation of food crops, fish production and farming of aquatic plants in different parts of the globe. An estimated 10 per cent of the waste water generated worldwide is used for irrigation, with utilisation as high as 100 per cent in large urban areas like Santiago in Chile and Mexico City. The human excreta present in the waste water used for irrigation acts as a source of plant nutrient, thus reducing the farmers' need to use chemical fertilisers. In several instances, we have seen the organised piped distribution of mechanically and biologically treated waste water to peri-urban farmers where city authorities have consciously planned reuse of waste water (examples being the irrigation of citrus cultivation in Tunis, irrigation of non-food crops, fodder, green belts and golf courses in affluent countries like the US and Saudi Arabia). As a substitute for costly fresh water for irrigation, peri-urban farmers have accessed waste water, legally or illegally, and have also used it in an untreated form. Urban planners have started to include measures for reuse of waste water in sanitation infrastructure planning. Care should be taken not to mix industrial waste water, which contains heavy metals, with domestic waste water used for irrigation and aquaculture. Selected instances of use of waste water for irrigation are given in Table 1.

The inorganic plant nutrients (nitrogen, phosphrous and potassium) in human excreta which are present in domestic waste water, along with the organic substances (not present in chemical fertilisers) which help in conditioning the soil and replenish humus, have also induced farmers to use waste water wherever available, in addition to the use of fresh water for irrigation. The fertilising potential of excreta is enough to meet the basic food requirement of a person as indicated in Table 2 [Martin 2001].

Besides irrigating crops, farming of fish and aquatic plants for human consumption as well as for production of animal feed with the use of waste water and human excreta have been practised in several Asian countries, and parts of Africa and Latin America. In Europe, Germany witnessed experiments with waste water aided aquaculture as early as 1887, and such aquaculture practices continued till about the mid-1900s. The practice declined due to the spread of urbanisation taking up expensive urban land and increased manpower costs resulting from high salaries of urban fish farmers. In comparison, in several emerging Asian economies, fish produced in the waste water fed aquaculture has provided the urban poor with low cost protein. Where human consumption of fish grown in such medium is not socially permissible, the harvest from such waste water fed ponds is used in the "extended food chain" through production of fish meal and livestock feed.

In Bangladesh, urbanisation and high organic loading of the suburban ponds of Dhaka have acted as a constraint on waste water fed aquaculture. However, cultivation of duckweed, to be used for poultry and fish feed has been promoted in Mirzapur and Khulna. In Vietnam, though urban and land use plans for Hanoi have included waste water fed fish and rice cultivation, the area under such land use has declined by about 35 per cent in the face of urbanisation and breakdown of the communal sewage distribution network, over the last 10 years. In China, rapid urbanisation and industrialisation have contaminated waste water (due to petroleum and phenolic compounds), which has constrained the growth of aquaculture based on waste water. However, experiments carried out in Cairo and the treatment system in the Suez, for use of waste water (from secondary treated effluent) in raising tilapia and grey mullet, have yielded products that have been found fit for human consumption from the point of bacterial and heavy metal contamination. Isolated experiments with waste water treatment ponds of Lima have also yielded fish suitable for human consumption [Edwards 2005].

Against this backdrop of peri-urban agricultural and aquacultural practices around the world, it will be interesting to study the unique sustainable model that has been developed in the fringes of the Kolkata metropolis. The practice of urban agriculture, comprising vegetable cultivation and aquaculture, mainly in the eastern fringes of the city (also practised on a limited scale in parts of north and south Kolkata), is of great environmental and economic significance, as on the one hand, it utilises the solid and liquid waste generated by the metropolis in a sustainable manner, while, on the other, it provides a means of livelihood amongst a large number of urban poor and also provides the city residents with a supply of fresh vegetables and fish.

Urban Organic Waste

A city with a population of one million will typically consume 2,000 tonnes (t) of food and 25,000 t of water per day and produce about 2,000 t of solid waste material and 50,000 t of effluent water per day. As against the above estimates, the actual solid waste generated by some representative cities, as of 1995, are Manila (population: 12 million) 4,000 t per day, Jakarta (12 million) 5,000 t per day, Kolkata (10 million) 3,000 t per day, Kano (1.4 million) 450 t per day, Sao Paulo (13 million) 10,000 t per day and Dar es Salaam (3 million) 1,000 t per day. It is a huge task to manage solid and liquid waste, its efficient collection, treatment, segregation and disposal. Solid waste can be composted, a natural process whereby micro-organisms break down organic materials. After manual or mechanical separation of glass, metals, plastics, etc, the compost generation has many advantages in the urban setting. While on the one hand it is of significance from the public health point of view as the high temperature the garbage pile generates (70°C) sanitises the potentially disease ridden materials/pathogens, including highly resistant helminth eggs, on the other, the safe composted material provides an ideal medium for quick growing of high value vegetable crops [Rodrigues et al 1999]. The practice of growing vegetables in the city fringes on solid waste compost exists throughout the world and Kolkata has effectively demonstrated the possibility, more because of the support it has got from the primary treated sewage water, used for irrigation. The sewage water in Kolkata besides providing irrigation, supports another major economic activity, namely, sewage fed aquaculture.

Kolkata Case Study

The peri-urban agricultural activities of Kolkata metropolis can be divided into sewage fed aquaculture and sewage irrigated compost-based horticulture. Rice production is also undertaken on a limited scale, using waste water for irrigation.

The east Kolkata wetlands that lie on the eastern fringe of the city, are part of the delta of the Hooghly. The marshes/lakes were once filled by the tidal flow of the Bidyadhari that flowed into the Bay of Bengal. Subsequent to the drying up of Bidyadhari in the early 1930s, storm water flow channels were dug by the then Calcutta municipal corporation that fed the marshes with sewage water from the city. This was later connected to the Bay of Bengal. Soon, a dry weather flow canal was dug parallel to the storm water flow canals to transport the entire domestic sewage (around 1,395 million litres per day or 283 million gallons per day) to the east Kolkata wetlands [Mukherjee 2002]. It may be noted that the Kolkata municipal corporation does not have any sewage treatment plant and the entire sewage/waste water generated is treated in natural lagoons, and these sewage fed ponds also serve as aquaculture sites.

In the 1950s, the wetland extended over 8,000 hectares, out of which about 4,700 hectares was dedicated to sewage fed aquaculture giving a fish yield of 833 kg/ha/annum. Over the years, the growth of urbanisation has eaten up substantial portions of the natural wetland, and currently about 3,900 hectares (out of which about 700 hectares are seasonal) make up the aquaculture land (ibid). However, the east Kolkata wetlands have been declared a protected zone and currently positive measures are being taken by the authorities for its protection. In spite of the reduction in area, due to improved pisciculture practices, the yield of fish in this pond-based aquaculture system has risen sharply to about 4 tonnes per hectare per year to give a total catch of about 13,000 tonnes per year. Considering a 300-day per year working cycle, this means a production of about 44 tonnes per day, equivalent to about 15 per cent of the Kolkata fish consumption. It is estimated that the yield can be increased to 7 tonnes per hectare [Bunting et al 2002]. The yield comprises a small variety of Indian major carp and tilapia, which is very popular among the economically weaker sections of the city. Though larger sized fish have a higher market value, the operators have chosen to harvest the small fish to avoid the risk of flooding, poaching and poisoning by contaminated water inputs as well as intentionally [Bunting and Little 2002].

Presently, 279 fisheries operate in 3,200 hectares of east Kolkata sewage fed wetland, giving the average fishery a size of 11.46 hectares. On the seasonal area (about 700 hectares), an additional 29 fisheries operate during the season.

Table 1: Waste Water Reuse in Irrigation – Some Examples

Region	Crop/Usage
Africa	
Tunisia	Citrus, fodder
Morocco	Vegetables, fodder
America (North and South)	
US (California)	Vegetables, cereals, fodder, green belts/golf courses
Mexico	Vegetables, fodder, cotton, parks/green belt
Chile	Vegetables, grapes
Argentina	Vegetables, fodder
Peru	Vegetables, fodder, cotton
Asia	
Kuwait	Vegetables, orchard, fodder
Israel	Cotton
Saudi Arabia	Cereals, fodder, green belts
India	Cereals, vegetables

Table 2: Nutrient Availability from Human Excreta

Nutrient	Nutrient Available in Kgs			Nutrient Reqd for 250 Kg of Cereal (Kg)
	In Urine (500 Litres/Year)	In Faeces (50 Litres/Year)	Total	
Nitrogen	4.0	0.5	4.5	5.6
Phosphrous	0.4	0.2	0.6	0.7
Potassium	0.9	0.3	1.2	1.2

Chart: Economics of Waste Water Aquaculture and Garbage-based Waste Water Irrigated Horticulture and Rice Production (Estimates for 2005)

Area covered by fisheries: 3,500 hectares
Area covered by horticulture: 350 hectares
Area covered by rice: 4,800 hectares (4,800 hectares under Aman variety and 2,400 hectare under Boro variety as the second crop)

Estimated yield of:
Fish: 5 tonnes (t) per hectare per year
Vegetables: 128 t per hectare per year
Rice: 2 t per hectare per year for Aman and 2.4 t per hectare per year for Boro variety.

Price realisation for:
Fish : Rs 25 per kg
Vegetables: Rs 6 per kg
Rice: Rs 5 per kg.
(US $ 1 = Rs 46)

Sales proceeds of annual production:			
Fish:	3500 x 5 x 1000 x 25	=	Rs 43.75 crore
Vegetable:	350 x 128 x 1000 x 6	=	Rs 26.88 crore
Rice: Aman	4800 x 2 x 1000 x 10	=	Rs 96 lakh
Boro	2400 x 2.4x1000x 10	=	Rs 57.6 lakh
Total sales		=	Rs 85.99 crore
Production cost at 74 per cent of sales		=	Rs 63.63 crore
Margin		=	Rs 22.36 crore
Farmers/aquaculturists use own labour accounting for 60 per cent of cost of production		=	Rs 38.18 crore
Net income (margin + own labour)		=	Rs 60.54 crore
Employment in aquaculture, vegetable and rice production:			
Aquaculture: Direct manpower in fish production		=	15700
Vegetable & rice (@ 2 persons per hectare)		=	10300
Total direct employment		=	26000
Income per worker= Rs 23,283.44 per year			

Provided adequate sewage water can be channelised to this area, these 700 hectares can be converted to regular fishery from the seasonal and marginal operations. The ownership pattern of these fisheries are diverse. While 43 per cent are managed by the land (fishery) owners, 26 per cent is under partnership (shared ownership) and another 25.8 per cent under informal cooperative arrangement. The balance 5.2 per cent is under formal cooperative, owner-worker participation, incorporated companies and the state government.

The east Kolkata wetlands have for a long time been used as a dumping ground for solid waste. The method followed is to leave a long strip of water body between two dumping grounds giving alternate strips of filled area. The garbage, if present in adequate quantity to exert a self insulating effect, generates the high temperature (up to 70°C), required to form compost. The naturally treated sewage water in between two such garbage strips provides the necessary irrigation for farming. This system of garbage farming has been in existence in the Kolkata wetlands since the beginning of the 20th century and continues today. The area covered under farming stood at about 320 hectares in the early 1990s. The current estimate is of around 400 hectares. About 60 per cent of the farmers surveyed stated that they depended entirely of the adjoining fish pond water for irrigation [Kundu 1994]. The vegetable yield from these garbage farms is estimated at 370 tonnes per hectare per year. In addition to the nutrient rich compost and waste water, the farmers of the present generation are boosting production through use of chemical inputs.

Sewage Irrigated Rice Cultivation

In an estimated 4,888 hectares of land (including the dry bed of the Bidyadhari), rice is cultivated, using the nutrient rich sewage water. Due to problems of land tenure, in the 1960s, about 2,400 hectares of fish ponds were shifted to rice cultivation [Bunting et al 2002]. Two types of rice are grown – Aman and Boro. Aman is sown during the rain and Boro during the winter. While the entire area is suitable for Aman cultivation, Boro is sown over half the area. The yield of Aman is estimated at two tonnes per hectare a year, while that of Boro is 2.471 tonnes per hectare a year. Very little data is available on the number of people engaged in the Kolkata peri-urban interface rice cultivation.

Safety Issues

The use/recycling of solid waste and city sewage for agricultural purposes suggests that this is the most sustainable way to manage the waste generated by the city and at the same time generate some economic activity, which is all the more significant because the main beneficiaries are the poorer cross sections. But any lapse in the management of the process of treatment of the waste may result in severe health hazards for the consumers of the agricultural output. The treatment of both solid and liquid waste is being done in the natural way, without energy-intensive mechanical processes like the use of incinerators or mechanical and electrical powered sewage treatment plants. The contamination of the solid and liquid waste generated in the Kolkata Metropolitan Corporation poses a major constraint to the sustainable character of the recycling of such waste for agriculture and aquaculture.

The waste water, as it flows through the canals gets naturally treated to some extent and then the subsequent treatment in the pre-treatment and facultative ponds helps attain the effluent norms as set by the department of environment and forestry. The WHO recommendations (1989) suggest a minimum retention of raw sewage for eight to ten days, in anaerobic or facultative ponds, before entry into fish ponds. The Kolkata sewage water flows through the channels for a much shorter duration before reaching the fish ponds, resulting in ineffective precipitation of heavy metals. The lack of adequate retention time in stabilising ponds also hampers the attaining of WHO recommended maximum critical density of 10^5 total bacteria/ml, in the waste water fish ponds.

The waste water flowing into the east Kolkata fish ponds is often contaminated with industrial effluents, especially from the tanneries, and other small engineering enterprises like metal working, automobile repair, etc. There is little formal monitoring of the level of contamination from such sources, but the orange appearance of fish ponds suggests a high concentration of chromium. The relocation of about 600 tanneries that discharged an estimated 150 kg of chromium per day into channels carrying municipal waste water, to the east Kolkata wetlands has been a major step taken to eliminate industrial pollutants from contaminating the fish and vegetables. The studies on contamination in fish and vegetables sold in suburban markets of Kolkata show a higher concentration of heavy metals than products available in rural markets [Biswas and Santra 1998]. The soil in Kolkata peri-urban areas, which had been irrigated with waste water for a period of time, was found to have increased levels of iron, copper, lead, zinc, cadmium, nickel and cobalt. Much of these contaminants found their way to the vegetables grown on this soil. The untreated waste water has also contaminated groundwater resources in these areas. It is essential to segregate industrial effluents and also ensure that the city waste water goes through the pre-treatment in stabilisation ponds before its use in fish ponds and irrigation.

Similarly, for solid wastes, there is grave risk of contamination from inadequate composting. In the urge to get quick returns, the urban farmers even bribe the garbage truck drivers to unload the solid waste on their farm and after leaving it only for five to seven days for fermenting, mix it with the soil to sow seeds in it. Neither is the time long enough, nor is the pile structure high enough to allow the pile temperature reach a high enough level to destroy helminth eggs. These farmers do not want to keeps the garbage in a pile for a long time as that would make it obvious that the garbage has been procured illegally, instead of being dumped at designated sites. Neither is there any administrative control, nor is there any extension service provided to educate the farmers on the perils of inadequate composting.

Unless the solid waste and waste water is adequately treated, such sustainable activities like waste water aquaculture, waste water irrigation and garbage fed horticulture will turn into health hazards. Having established the sustainability of these activities, it will be worthwhile to briefly look into their economics (see the Chart).

It is assumed that each family engages two full time employees in aquaculture/horticulture/rice production. This gives an annual family income of around Rs 46,500 per year or Rs 3,875 per month.

As per the Central Statistical Organisation (CSO), government of India, the 2002-2003 per capita income has been estimated at Rs 18,912. For an average family size of 5, this means an average family income of Rs 94,560. The people dependent on Kolkata wetland area for a livelihood are far below the national average in terms of income but are comfortably above the poverty or subsistence level. A lot of inputs can go into organising the aquaculture and farming practices, ensuring proper flow of raw/preliminary treated sewage, strengthening of floriculture and livestock farming and proper training. A large section of the workers are women and special attention should be given to ensure more active economic participation of this group.

All efforts should be made by the city and urban development authorities to conserve and improve the efficiency of the sustainable and economically beneficial waste management and recycling opportunities available in this vast natural setting (the east Kolkata wetland) and assist the farmers in upgrading their farm and aquaculture operations. The vast stretch of green and open space can act as the "lung" for the stifling metropolis and also be developed as a recreational spot for the citizens.

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