SEWAGE-FED AQUACULTURE

- A Biological Method of Waste Water Treatment

(The Kolkata model)

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Definition of Sewage: Sewage is defined as a cloudy fluid arising out of domestic, municipal and industrial waste, containing mineral and organic matter in solution or having particles of solid matter floating, in suspension, or in colloidal and pseudo-colloidal form in a dispersed state. Sludge differs from sewage in that it is the solid portion of waste and does not include fecal matter urine.

Composition of sewage: Sewage may vary considerably in composition and strength from place to place owing to marked differences in the dietary habit of the people, composition of trade waste and water consumption. The strength of sewage is determined by the amount of O_2 required to oxidize completely the organic matter and ammonia present in it. There is also variation in composition between domestic and industrial sewage, the later containing more pollutants in terms of heavy metals and bacterial load and other toxic ingredients. While the sewage is very rich in anaerobes when it is raw but gradually transforms to an enriched freshwater when it undergoes treatment. Sewage contains living matter especially bacteria and protozoa. The water content of sewage may be 98 – 99.9 %, rest being dry solid matter. Domestic sewage has been reported to contain about 250 – 400 ppm of organic carbon and 80 – 120 ppm of total nitrogen, thus giving the C:N ratio of around 3:1. Industrial sewage may contain more organic carbon and hence may have a higher C: N ratio. Nitrogen in sewage is present partly as organically bound element and partly as ammonical nitrogen.

Following are the common characteristics of Kolkata city (raw) sewage:

pH: 6.8 – 7.8, CO_2: 10 – 140 ppm, Dissolved O_2: almost zero, Total alkalinity: 170 – 490 ppm, Nitrates-N_2: 0.01 – 0.6 ppm, Nitrite- N_2: 0 – 0.08 ppm, Free ammonium- N_2: 12 – 63.6 ppm, Albuminoid ammonium- N_2: 1.1 – 16 ppm, BOD: 100 – 500 ppm, Phosphate (as P_2O_5): 0.12 – 14.5 ppm, Suspended solids: 160 – 420 ppm, Settleable solids: 1.6 – 2.8 ppm, OC: 24 – 88.8 ppm. Gases like CO_2, H_2S, NH_3 etc. are in dissolved state. The raw sewage is detrimental to fish and to make it suitable for aquaculture or for usual disposal to the river, treatment is necessary.

History of sewage fed fish culture

The fish farmer of Kolkata developed a unique technique of utilization of domestic sewage for fish culture long back in 1930s. The early inspiration of utilizing the sewage for fish culture emerged from the waste. Stabilization pond used as water source of vegetable fields. This technique is considered to be the largest operational system in the world to convert the waste in consumable product. The growing fish demand of the metro city Kolkata is widely met by this technique.

Present status of sewage fed fish culture:

In the course of time the area under sewage-fed fish culture reached up to 12,000 ha. But recently due to rapid and indiscriminate urbanization it has come down to 4,000 ha. (approx) resulting in crisis of livelihood of rural people. There are appeals to Government to declare the existing sewage-fed aquaculture area as sanctuaries.

Treatments of sewage:

1. Primary treatment: This is mostly the physical removal of solids by mechanical means. The solid material is removed by screening (for larger coarse particles), skimming (for floating solids) and sedimentation (for suspended particles whose density is greater than that of liquid) techniques.
2. Secondary treatment: Soluble organic and inorganic matter, namely the carbohydrates, proteins, fats, hydrocarbons and other nitrogenous materials which are degraded mostly biologically, using microorganisms into the smaller constituents i.e. CO_2, H_2O, NO_3, NO_2, SO_4, PO_4 etc. which can be easily disposed. Sometimes chemical* and physical removals of substances are combined with this to increase the effectiveness. There are three basic methods for secondary treatments: activated sludge (flocculation), biological filtration and waste stabilization (in oxidation ponds – pl. see page 2). In the activated sludge or flocculation process, the sewage is aerated by diffused air or by mechanical means. The activated sludge (or biological floc) contains the microorganisms that remove the soluble and insoluble organic matter in the sewage by a combination of adsorption and oxidation or assimilation. Aeration supplies the sludge microorganisms with oxygen and keeps the floc in suspension. After a suitable contact time (1 – 20 hrs) the sludge is separated from the sewage effluent in a settling tank. Some of the settled sludge is returned for aeration along with new sewage but most of it is treated separately in a sludge treatment plant.
3. Tertiary treatment: This is biological and chemical removal of soluble products of partial or complete oxidation. For example, removal of NO_3, NO_2, SO_4, PO_4 etc.
4. Quaternary treatment: Physical or chemical removal of refractory organic or other substances which may be unpleasant and even toxic.

Chemical treatment comprises of (a) Coagulation or chemical precipitation (e.g. by alum)

(b) deodorization (by Cl_2, $FeCl_3$) and (c) disinfections or sterilization (by Cl_2, $CuSO_4$, liming etc.).

The process generally adopted for the use of sewage treatment before release in fish ponds are:

(1) Sedimentation (2) Dilution and (3) Storage.

Sedimentation: The function of sedimentation is to remove suspended solids from sewage to the maximum possible extent. It is done by letting sewage into a pond/tank at a high velocity of flow. Sedimentation results due to sudden drop in velocity when sewage enters a large pond from sewage channel. Sedimentation is best carried out by in two successive stages i.e. primary and secondary. The primary stage is intended to settle down most of the heavier solids while the secondary stages serves two purposes: (a). Provision of additional period to help to mix and homogenize variations in the flow and (b). Promotion of natural purification process. It has been estimated that about 33% BOD is got rid of by sedimentation process, which may effect with 90% settlement of suspended solids and about 25% reduction in albuminoid ammonia.

Dilution and storage: Before introduction of sewage into any fishery its dilution by freshwater should be so effected that a positive dissolved oxygen balance (1:1 or 1:2) is maintained and the concentration of unwholesome ingredients such as CO_2, H_2S, NH_3 etc. kept below lethal limit. The oxygen required for biochemical reaction is obtained from fresh water used for dilution and through green algae, and other vegetation in the water body. Sewage is stored here for few days. During storage, the biological processes carried out by microorganisms present in the raw sewage oxidize it.

Use of oxidation ponds (waste stabilization ponds) for sewage-fed fish culture has been suggested by many several workers. The term waste stabilization ponds is applied to a body of water artificial or natural employed with the intention of retaining sewage or organic waters until wastes are rendered inoffensive for discharge into receiving waters or on land through physical, chemical and biological process (self-purification). This pond is suitable in India because of plentiful of sunshine. These are also cheap to construct and easy to operate. Organic matter contained in the waste is stabilized and converted in the pond into more stable matter in the form of algal cell, which find their way into the effluent. These ponds are of three types:

i). Anaerobic ponds: It is pretreatment digester and requires no dissolved oxygen. These are designed to take on higher organic loading so that anaerobic condition prevailed throughout the pond. Such ponds are 2.5 – 3.7 m deep. Ends products are CH_4, H_2S, NH_3.

ii). Aerobic ponds: These are shallow, depth is 0.3m or less, so designed that growth of algae through photosynthetic action is maximized. Waste material is stabilized through microorganisms only and aerobic condition is always maintained. Ends products are CO_2, H_2O, NO_3, SO_4, PO_4 etc.

iii). Facultative ponds: These are 0.9 – 1.5 m deep and are aerobic during day hours as well as for some hours at night. Only for few remaining hours of night, bottom layer become anaerobic. Aerobic, anaerobic and facultative may all be found in a facultative pond. In India, most of the waste stabilization ponds are of facultative type. The village ponds and natural depressions in rural areas are example of waste stabilization ponds.

A conventional oxidation pond retains the settled sewage at a depth of 1 to 2 m (facultative ponds) for a period of 25 to 30 days. This pond contains the algal-bacterial cultures, which oxidizes the organic matter into CO_2, H_2O, H_2S, NH_3 and other decomposition products that are used as nutrients (e.g. NO_3, SO_4, PO_4). If this type of ponds are designed well and operated effectively, well over 90% of the BOD is removed and the micro flora is much reduced.

<u>Conventional methods of fish culture:</u> The fish farmers of Kolkata operating sewage-fed fish fisheries, however generally use raw sewage, relying on intuition and experience for regulating its application. This practice is not only unhygienic but also harmful since the sedimented organic matter besides raising the bed level of pond being highly oxidisable in character may undergo decomposition and cause negative oxygen balance causes mortality.

But sewage partly or fully decomposed contains a high percentage of nitrogen, phosphorus, Ca, K etc. These nutrients together with adequate alkalinity contribute largely to a high productivity in sewage water and for this reason fertilization of fishpond is sometimes carried out with raw sewage. Sewage fed ponds are used for raising seeds of Carps and Tilapia and also culturing them to table size. For raising carp seed, ponds are dewatered completely during summer to remove all the carnivorous and weed fishes. When complete dewatering is not possible treatment with mohua oil cake or other similar fish toxicants is used. Initial fertilization of pond is done with the introduction of fresh sewage effluent, which is taken into the pond up to 90 cm. Following this the ponds show extreme diurnal fluctuation of dissolved oxygen ranging from super saturation stage at day time to serious depletion in night. However, due to dilution and natural putrefaction process, the wide fluctuation of dissolved oxygen is minimized within a month and the pond rendered suitable for stocking and rearing fish seed. The stocking density in such pond varies from 70000 to 150000 per ha. The density is depended mostly on the size of the spawn or fry. An experimental pond of 0.11 ha at Khardah, West Bengal, having a density of 60000 fry/ha with the ratio of

			After 25 days they attained
Catla	40%	72 mm/ 6 gm	133 mm/ 30 g
Rohu	6%	72 mm/ 5 gm	147 mm/ 37 gm
Mrigal	45%	74 mm/ 4 gm	126 mm/ 24 gm
Common Carp	9%	54 mm/ 3 gm	135 mm/ 50 gm

After 25 days when they attained the above-mentioned sizes, were transferred to a bigger stocking pond @ 10000/ha. This pond needed the additional fertilization, which was carried out every month with sewage effluent in small doses. For raising the juveniles, stocking pond was fertilized with raw sewage @ 4500000 lit/ha. Production in stocking pond was recorded 2500 kg to 3000 kg/ha. Ghosh (1974) reported that at a stocking density of 50000 fingerlings/ha at ratio of Rohu, Catla, Mrigal = 1:2:1 gave a production of 7076 Kg/ha in 7 months.

For raising Tilapia seed more or less the same techniques as that of carp seed are adopted. However, instead of Tilapia spawn/fry, adult Tilapia of both sexes are stocked together in the ration of 6 males : 4 females at about 20 000/ha. They bred profusely in the pond. The harvesting of fingerlings is initiated two months after stocking of adults and is continued periodically either fortnightly or monthly depending on the density of harvestable size tilapia. Normally 30 – 40 gms tilapia are harvested. Under this system of culture a production as high as 8 – 10 tons/ha/year were obtained by CICFRI (Ghosh, 1975). Ghosh *et al*. (1979) utilized a sewage-irrigated pond (0.076 ha) for massive tilapia production. Tilapia were not found to be affected even at the highest attained NH_3-N level of 5.43 ppm. He got the production of 9350 kg/ha/yr.

Technologies adopted by farmers:

The sewage fed ponds are locally known as BHERIES. These are the ponds of different sizes, which can be as big as 40 ha. The ponds are shallow with a depth raging from 0.5 to 1.5 m. Generally the culture practice includes five phases:

1. Pond preparation.
2. Primary Fertilization.
3. Fish stocking.
4. Secondary fertilization (Periodic)
5. Harvesting of fish.

Sewage fed fishponds; locally called “Bheries” have a bamboo sluice structure to prevent the entry of wild fishes and escape of the stocked fishes.

Open channel through which sewage is flown. Lush growth of Colocasia is seen on either side of the channel.

Pond Preparation:

Pond preparation is undertaken generally in winter (Nov – Feb) when the fish growth is reported slowest. Ponds are drained, desilted, tilled and dried in sun. The pond dikes are consolidated. Silt traps (perimeter canal along the dikes) 2-3 meter wide and 30-40 cm. deep are dug, as they get filled during regular harvesting of fishes. Aquatic weeds as water hyacinth (*Eichhornia*) is grown along the pond dikes, which save the dikes from wave, and give shelter to fishes against high temperature and poaching and above all it extracts heavy metals from the sewage, supplies oxygen by photosynthetic activity. The bamboo sluice gate is repaired which helps to prevent the entry of unwanted fishes and escape of cultured fishes.

Primary fertilization:

After pond preparation, sewage is passed in to the pond from the feeder canal through bamboo sluice. It is left to stabilize for 15 – 20 days. The self-purification of sewage takes place in presence of atmospheric oxygen and sunlight. When the water turns green due to photosynthetic activity, the pond is considered ready for stocking.

Sewage fed ponds are pumped out to dry.

Drying of ponds is undertaken during winter.

Silt is removed at least once in three years.

Fish stocking:

All the species of Indian major carps e.g. *Labeo rohita* (Rohu), *Catla Catla*, *Cirrhinus mrigala* (Mrigal) and Exotic carps e.g. *Hypophthalmichtys molitrix* (Silver carp), *Ctenopharyngodon idella* (Grass carp), *Cyprinus carpio* (Common carps) are preferred to be stocked but the percentage of Mrigal is kept greater and that of exotic carps is lesser. The popularity of Talapia and fresh water prawn, *Macrobrachium rosenbergii* is increasing these days. *Pangasius hypophthalmus* is also stocked by some farmers to get rid of mollusks.

As the sewage contains high content of nutrient, the farmers keep very high stocking density, i.e. 40,000 to 50,000 fingerlings/ha.

Secondary Fertilization (Periodically):

After stocking, sewage is taken in ponds throughout the culture period at regular intervals @ 1 – 10% of the total water volume of the pond. In bigger ponds, water level is maintained by continuous inflow and out flow. The requirement of sewage is determined by observing the water colour, transparency, temperature and depth.

Feeding of stocked fishes:

Due to high contents of nutrients in sewage, the cultured fishes don’t require at all any supplementary feeding. However, occasionally, especially in rainy season when the potential sewage is lacking, they are fed with supplementary feed.

Dried water hyacinth is kept in heaps in the ponds for decomposition.

Dikes are some times used for the cultivation of horticultural crops

Health care of fishes:

The fishes are most vulnerable to bacterial diseases, but surprisingly the occurrence of bacterial or any other disease is not common in sewage-fed fish farms. Even when EUS was prevailing in recent years in other areas, the sewage-fed ponds were uninfected. However, parasitic infections by *Lernea* (Anchor worm) and *Argulus* (Fish lice) are common but they are not given any proper treatment. There is a need to develope a technique to keep these problems aloof.

Harvesting (in rotational manner with stocking):

The bheri farmers have evolved rotational cropping system to maintain the supply to the market. Fishes are stocked and harvested throughout the culture period leading to periodical stocking and regular harvesting. After completion of one phase, fishes are restocked @ 1 Kg fingerlings per 5 kg harvested fish. Another harvest phase starts after 15 days of restocking. Generally, drag nets are used for harvesting by encircling technique. Some fishes like Tilapia and Common carp require hand picking technique for their harvesting. Specialized fishermen are employed in fishing.

The bulk of the harvested fish consists of Indian major carps and tilapia.

Specialists carry out harvesting of fish in large ponds. Tilapia and common carp are largely harvested through hand picking.

Production:

- Several experiments have been carried out in sewage-fed ponds by different workers and their findings indicate that the production from sewage-fed ponds depend upon:
    a. Quantity of sewage utilized in ponds.
    b. Potentiality of sewage.
    c. Depth of the ponds.
    d. Fish species cultured.
    e. Number of fingerlings stocked (Stocking density)
- There is direct relationship between inflow of sewage and productivity of the ponds.
- The content of dissolved oxygen in the ponds also influences directly the productivity.
- The productivity figure fluctuates from 3 tons to 8 tons/ha/yr.
- The productivity of *Tilapia* ranges 8-10 T/ha/yr when they are stocked @ 20,000 fry/ha (with a male:female ratio 3:2) and harvested after getting the size 40-50 gm. (Ghosh, 1975).
- The average fish productivity of **JAGRASHISHA** sewage fed farm is more than 5T/ha/yr (Nandeesha, 2002).

Marketing of Harvested Fish:

- Harvested fish from sewage-fed ponds are marketed in live condition as they give high market price.
- The harvested fishes are kept in depuration ponds for a few days for their deodouration.
- Based on the market demand different sized fishes are harvested and sold.

❖ Fishes of 100 gm wt. are called 'Hotel Fish' as they are sold hotels.

❖ The fishes are transported to marketing centers on bicycles, tricycles and trucks.

❖ Skilled persons, who get Rs. 40-50 for their 3-4 hours work, transport the fishes on bicycles.

Large plastic containers are used in tricycles transportation of fishes in live condition for the transportation of fish in live condition.

Aluminium vessels, called "hundies", are used to transport seed as well as live fish to market.

Ownership of sewage fed ponds:

❖ Sewage-fed ponds are operated both through individual ownership as well as through cooperatives.

❖ Cooperatives have been largely successful in sewage fed aquaculture and poor people are being benefited by them.

Negative aspect of sewage fed aquaculture – Use of Raw sewage:

❖ The sewage contains high load of organic and inorganic matters, toxic gases but its dissolved oxygen contents is very low.

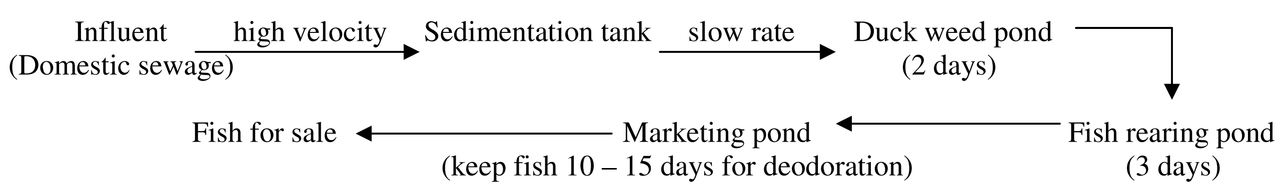
❖ As the raw sewage is used in fish ponds, there is a chance of infection and pollutions to enter into human body through fish. But this risk can be minimized if good managerial practice is followed, e.g.

- Use of treated sewages for fish culture instead of raw sewage.
- Keeping the fish for 3-4 weeks in marketing pond (Clean fresh water pond) before marketing.

- To avoid these harms, a model of sewage fed fish culture techniques is advisable in which the sewages is treated properly.

  a. Ponds should be prepared and categorized as per the treatment techniques.
  b. Screening and Filtration of sewage is done to remove course particles, before taking in to ponds.
  c. Sedimentation of sewage is carried out in large tanks by dropping the sewages with high velocity resulting in settlement of suspended particles at the bottom. Chlorine and $CuSO_4$ further treat the sewages for disinfection.
  d. Oxidation should be done after sedimentation in oxidation/stabilization ponds. Here the sewage is retained for 10-12 days for self-purification in presence of sunlight and atmospheric oxygen. Photosynthetic activity also occurs here. All these result into reduction in CO_2 and increase in oxygen level of sewage.
  e. Now the sewage is passed into duckweed tank where it is let for a few days. The duckweed (*Lemna, Wolfia* etc.) and *Eichhornia* absorb the heavy metals from the sewage and further increase the oxygen level by their photosynthetic activity.
  f. Finally, the sewage is taken in to fishery pond/storage pond where it is diluted with sufficient quantity of fresh water. This results in to reduction in CO_2, H_2S, NH_3 and increase in DO_2 level making the sewages perfect for fish culture.
  g. To avoid the bioaccumulation of pollutants (if any), fish should be harvested within six months of stocking (Datta, S., 2003).
  h. Before marketing, the harvested fishes should be kept in fresh water/marketing pond for 15 days for their deodouration.

CIFA, Bhubaneswar, constructed Aquaculture Sewage Treatment Plant (ASTP) like the outline given below:



<u>Scientific methods of fish culture</u>: For scientific fish culture treated sewage should be used. The hardy fishes i.e. Tilapia, Anabas, Magur, Singhi can be cultured in the primary oxidation tank as these fishes can tolerate a wide range of environmental fluctuations as well as toxicants. Carps should

be cultured in secondary oxidation pond where treated sewage is allowed to enter and diluted at a proper rate.

Before stocking ponds are dried up either by draining out the water through the exit pipe lines or by pumping out. Sludge which accumulates at the bottom of duckweed ponds (25X8X0.6 m^3) and fish ponds (50X20X1.5 m^3) are removed before filling with sewage effluents. The effluent requires stabilization for a few days and after chemical analysis of effluent and assessment of plankton population, the fishes are stocked. Polyculture of IMC and exotic carp is preferable over monoculture in sewage treatment system. The stocking density of fish is 10000/ha. The stocking ratios are given below. 15 – 20 days prior to marketing the fishes are transferred to the marketing pond (40X20X2 m^3).

	Fish ponds (%)	Marketing pond (%)
Catla	25%	10%
Rohu	25%	10%
Mrigal	25%	10%
Silver carp	15%	10%
Grass carp	-	50%
Common carp	10%	10%

Fishes are harvested after 8 – 12 months of stocking, by repeated netting and finally draining the water through the outlet and fish collected in live condition. The mean individual weight of carp species in one year: Catla – 600 gm, rohu - 700 gm, mrigal – 700 gm, silver carp – 800 gm, grass carp – 1800 gm with average production of 3000 kg – 5000 kg/ha. Leguminous crop can be cultivated at the embankment, falling leaves provide supplementary feed to the fish.

Management:

1. Transport and release of fingerlings are carried out during the morning hours.
2. The fish stocked are checked at the monthly intervals for their growth and health through sample netting.
3. Inflow of sewage (2 million lit/ha/day) and dilution should be regulated properly to keep the pond aerobic.
4. Regular monitoring of physico-chemical parameters
5. Regular cleaning of spun pipes interconnecting the treatment pond and fishpond to ensure smooth flow of sewage effluents.

6. Equal splitting of effluent to the fishpond need to be ensured.
7. Wire mesh is to be provided at the entry of sewage effluent to prevent the entry of solid materials into the treatment complex.
8. Proper sloping should be maintained at the entry point to maintain the velocity of influent.

Advantages of sewage-fed Fish culture:

1. No manuring and supplementary feeding is required due to high content of nutrients in sewage.
2. Input cost is very low (only in fish seed) and production is very good.
3. This is the biological method of treating the waste water especially municipal sewages before its final disposal in river.
4. It reduced the pollution load of river and in the aquatic ecosystems.
5. It produces animal proteins i.e. fish at cheaper rate and contributes towards food security.
6. The bherries and ponds in which fishes are cultured act as water harvesting structures.
7. The process recharges the ground water and saves the big city from drying and collapse. The buildings, other establishments & structures above the surface layers of soil may collapse when the underground water column is dried and a vacuum is created below the soil layer.
8. It generates income and lakhs of families manage their livelihood from it.

Conclusion:

The sewage fed fish culture uses the waste recycling process and maintains the good environment around the urban area.

1. Unfortunately, this system is being lost due to urbanization without understanding its ecological, environment and economic benefits.

The sewage fed system is threatened by the increasing urbanization. Note the multistoried commercial complexes behind the fishponds.

2. The quality of fish grown in sewage fed remains as major concern, but the prolonged practice and many scientific studies have discarded it.
3. An international seminar held in 1988 at Kolkata with the support of UNDP, World Bank Water and Sanitation Programme, ESCAP and Govt. of India recognized the uniqueness of this Kolkata system and recommended detailed study on existing practice and quality of fish grown.
4. It is a matter of concern that even after a long journey of these important innovations, it has not spread to the other parts of the country.
5. Perhaps bringing farmers, specialist from the scientific and development community to see this Kolkata practice might help in applying the system elsewhere in country.
6. The CIFA, Bhubaneswar has reported the development of an improved method of sewage fed fish culture avoids direct use of raw sewage.
7. Though there are fears about the safety of the fish grown in sewage fed system, it is general belief in Kolkata that the fish grown in sewage tastes better.

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