

WASTEWATER-FED AQUACULTURE: A SOLUTION FOR SUSTAINABLE AQUACULTURE THROUGH WASTEWATER TREATMENT AND MANAGEMENT

Abstract

Wastewater is used for aquaculture in several places of Asia. Nutrient-rich wastewater is introduced into a designed aquatic environment, which consists of one or more water bodies and an integrated food web. Contrary to other biological wastewater treatment techniques that mostly rely on degradation processes, wastewater-fed aquaculture (WFA) is a productive wastewater treatment approach which reuses the wastewater. The system's primary goal is to assimilate dissolved nutrients into biomass. The organic compounds are consumed or mineralised along with the purification of wastewater. Unlike traditional wastewater treatment facilities, WFA places a major focus on the quality of the synthesised biomass and generates a variety of useful products as well as very little sludge. With wastewater fed aquaculture the creation of useful grey water (purification and hygienization of wastewater) and value items (food, animal feed, decorative plants animals, and raw materials) are accomplished concurrently. Along with purification of wastewater reduction in bacterial count, BOD₅, COD and nutrients can also be achieved.

Keywords: Wastewater-fed aquaculture, nightsoil, polishing fishponds, bacterial count, sewage

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I. INTRODUCTION

Wastewater fed aquaculture formally uses discharges from sewage and drainage systems, as well as partially treated effluents, with a certain amount of approval and oversight from governmental authorities. The use of nightsoil or faecal contaminated surface water also has a long history (Dennison, 1989). The use of wastewater for aquaculture is widespread in many parts of Asia, with little practice outside the Asia. Most developing nations, metropolitan areas have inadequate wastewater treatment, and two-thirds of urban wastewater is discharged directly into the nearest surface water source without any kind of treatment. In India, water quality of major rivers has been deteriorated due to the release of partially or completely untreated municipal waste (Kumar et al. 2011). One of the cheap technical solutions that has the potential to provide effective wastewater treatment, as well as economic benefits and job possibilities in rural and peri-urban regions, is sewage-fed aquaculture in combination with pisciculture (Asolekar, 2013; Kumar and Asolekar, 2014). It's considered that wastewater fed aquaculture may have great future potential as it produces low-cost fish for poor people, offers a cost-effective method of treating wastewater, makes the land available for a reasonable price and by treating wastewater. It also helps in reducing environmental pollution which would otherwise be directly discharged into surface waters (Edwards, 2000). Faster urbanisation and decrease in the availability of peri urban area increased pollution from industrial, domestic wastewater and rising living standards of city people who want higher-value fish are the main obstacles to wastewater-fed aquaculture (Howgate et al. 2002; Little & Bunting, 2005).

In Berlin, trials with fish cultivation in sewage effluent fields (wetlands) were started in 1887. An idea for a 3-stage aquaculture system including firstly a microorganism/algal pond, secondly a zooplankton pond and a fish pond was patented in 1897 (Prejr, 1996). The results of trials demonstrated that fish farming could safely and advantageously utilise effluents. Later, this approach was widely adopted in Dortmund, Berlin and Bielefeld. Experiments in Munich (Germany) in 1902, led to implementations of effective fishpond systems that received a range of wastewaters. The majority of ponds featured a sludge settling and mechanical pretreatment facility. It was proposed in 1908 that the wastewater-fishpond system might be used to treat all of Munich's sewage. Munich, which has a population of 500,000, installed the biggest wastewater-fed aquaculture system in Europe in the late 1920s to treat the wastewater. Many towns and cities including Vienna, Amberg and Strasbourg followed the same system, also known as Hofer's wastewater fishpond method (Demoll, 1926; Prejr, 1996). The State of West Bengal, India, has the largest sewage-fed aquaculture system in the worldwide (Kumar and Asolekar, 2014).

Keeping the above stated points there is a necessary to create environmental friendly wastewater treatment methods within developing nations economic and technological capabilities to protect public health (WHO in press). There is also a rising need for low-cost waste stabilisation ponds that are highly effective in removing pathogens. Also, for a comprehensive strategy, it uses renewable energy and minimises costs while reusing nutrients and water naturally to create jobs and affordable food for the underprivileged. This strategy should also include financial incentives to encourage wastewater treatment facilities to operate and maintain themselves efficiently. Urban poverty alleviation initiatives may benefit greatly from wastewater treatment and reuse plans using aquaculture. Due to the increasingly

worsening lack of sustainable water resources, particularly in arid and semi-arid countries, there is also significant interest in the use of treated effluents around the world.

II. TYPES OF WASTEWATER-FED AQUACULTURE SYSTEMS

WFA can be categorised into two types depending on pretreatment methods and types of wastewater used (Schaperclaus, 1961). First, wastewater fishponds i.e these types of ponds receive raw or mechanically treated wastewater. Another type of ponds are polishing fishponds which receive wastewater from complex treatment systems. These wastewaters have significant levels of nutrients but low level of suspended solids. The second type of ponds can be classified further based on those receiving wastewater from and (a) Sewage farms or wetlands and (b) effluents from biological treatment systems e.g trickling filters or activated sludge (Prein, 1988). This classification is widely followed in Germany. Polishing and wastewater fishponds production is about 500 and 400 kg/ha/7 months respectively. It's documented that shallow ponds are highly productive in comparison to deep ponds.

The wastewater fed aquaculture system consists of series of anaerobic pond, facultative pond, maturation pond, macrophyte pond (optional). The wastewater effluent is taken in to the anaerobic or stabilization pond and then it's passed into facultative and maturation ponds in which fishes are reared and then finally to macrophyte pond containing *Pistia*, *Eichhornia*, *Lemna* and *Phragmites* which help in removing the heavy metals, oil, suspended solids (Mondal, 1996).

Up to 90–95% removal of dissolved organic matter and the reduction of pathogens through microbial activity under aerobic and anaerobic conditions in trickling filters, activated sludge processes, etc. make waste stabilisation ponds a successful treatment method. Nutrient removal from wastewater is achieved via interactions among and within carbon, nitrogen, and phosphorus pools in nutrient cycles of wastewater-fed ponds. The microbes play an important role in nutrient recovery by degrading the organic load of wastewater. It has been estimated that near to about 66-67% of N removal occurs in anaerobic ponds (Silva et al., 1995). Sedimentation accounts for the majority (35%) of phosphorus removal in anaerobic ponds, while removal in facultative and maturing systems is just 4% (Mason 1997). Anaerobic and facultative ponds may have a depth of 2 and 1.5 m with retention time of 1 and 5 days respectively.

III. WATER QUALITY

It's crucial to regulate the fishponds environment so that it can produce healthy fish fit for human consumption while also achieving a high degree of water treatment. Wastewater is being loaded into the ponds at a pace of 200 to 2,000 people/ha/day. Wastewater may have a high BOD₅ (about 120-140 mg/l) and organic load so it should be diluted before taking into fish culture ponds. Depending on quality, wastewaters were often diluted with fresh water in a ratio of 1:4 to 1:9. Flow through mechanism was used to operate the ponds. For fish cultivation, both dilution water and wastewater must be of acceptable quality. Due to insufficient amounts and poor-quality dilution the water was acidic and had high iron content which led to failure at Zerzabelshof near Nurnberg. A balance between primary productivity, fish growth and nutrient removal on one side and possibly poor water quality (high ammonia and low dissolved oxygen) can be achieved by loading wastewater at the optimum level.

Depending on the systems design, size, and administration loading rates at various places may change significantly. Wastewater loading similar to 200–300 people/ha/day is utilised for small-scale systems, translating to 1-2 g BOD₅ m²/day. The system in Munich receives a load of 2,000-3,000 people/ha/day, with a maximum of 10-12 g BOD₅ m²/day and this rate is the highest one that has been documented.

Over 20-90% of the nutrients, COD, and BOD₅ were reduced. The number of bacterial counts was decreased by 72 to 99% (Prein, 1990). Natural water is colder than the municipal wastewaters leading to an extension of fish culture time in comparison to the traditional fish ponds. The effectiveness of a wastewater-fed fish culture facility is frequently determined by the quality of water, which varies with input and location. Nutrients are present in excess amount in municipal wastewater. So, no need of any additional fertilization. High pH values must be monitored because of primary productivity as they toxify the un-ionized ammonia.

The literature shows a wide range in treatment efficacy. For a variety of parameters, successful installations have large reduction percentages. For Strasbouig and Munich, the wastewater-fed fishpond system reduced total dry matter by 42% (Prein, 1988). More than 70% reduction in total ammonia is observed when compared to diluted inflow. The ammonia is converted to nitrate in pond. Biological wastewater treatment does not affect some chemicals, such as chloride. Evaporation may potentially cause their levels to rise. These compounds might be utilised to track the ponds flow patterns. Munich is where the only flow-through statistics are available. For an average-sized pond of 7 ha, Liebmann provided a calculated value of 22 hours and an actual determined value of 42 hours. The discrepancy was ascribed to pond shape and growth of algal and macrophytes.

IV. FISH SPECIES FOR WASTEWATER FED SYSTEM

The viability of several fish species in wastewater-fed fish culture has been examined. In 1904, Oesten started experiment with bottom feeding fish common carp, filter feeding fish *Coregonus* sp., carnivorous fish pike-perch, doctor fish, brown trout, rainbow trout and brook trout etc. Results obtained from later studies demonstrated that common carp and tench were the best species because of irregularly high temperatures and a decrease in dissolved oxygen. Rainbow trout can be stocked only if oxygen levels never falls below the critical. But it can tolerate fluctuations in temperature. Polyculture of eel and common carp is also practiced.

Common carp can be stocked at a number of 1000 – 1400, 500-700 and 400/ha for 1-, 2- and 3-year-old fish respectively. If tench is stocked, its density should be 20-25% of carp (Schaperclaus, 1961). This is achieved without any supplementary feeding. Supplementary feeding can also be done to improve the productivity. However, fish in wastewater-fed fishponds often get all of their nutrition from consuming the naturally occurring live organisms. In comparison to fish from traditional pond culture, operations that depended more on supplied feeds, the carp and tench thus produced were described in the literature as being extremely palatable and having firm flesh.

V. DESIGN AND OPERATIONAL SUGGESTIONS FOR WASTEWATER FED FISHPONDS

Sewage fields drainage effluents can be supplied straight into polishing fishponds without dilution, if they are not overloaded. Otherwise, this system is covered by the majority of the rules listed below. In addition, the following guidelines for wastewater fed ponds also applicable to polishing ponds. The following are some of the guidelines:

1. Fishponds supplied by wastewater need to be dug up and well-sealed to prevent seepage.
2. Dykes should be free from plants and trees so that sunlight and breeze may reach the ponds surface without obstruction. If wastewater-fed fishponds are installed in wind-protected places, there is a chance that duckweed will quickly cover the ponds surface.
3. Fishponds that receive wastewater should not be deeper than 60 to 150 cm on average and its construction should be done by following normal accepted guidelines with an outflow-facing harvest trench into which the fish are pushed during harvest.
4. Treatment of wastewater fishponds is only possible after mechanical pretreatment of the raw wastewater which removes at least 50 to 60% of the suspended particles. If not done, ponds become silted up quickly.
5. When entering the fishponds, pretreated wastewater shouldn't be in a decaying state.
6. Municipal wastewaters are ideal for further biological treatment in wastewater-fed fishponds, but they shouldn't include toxic, hazardous industrial wastewater.
7. Depending on the climate, the pretreated wastewater must be diluted three to six times with freshwater in wastewater-fed fishponds. At the fishpond's inflow system, freshwater and wastewater should be mixed. Freshwater should be free from iron and humic acid.
8. After each crop ponds should be dried to deacidify and aerate the sediments. The bottom should be treated with lime for fertilization and also to eliminate cysts, eggs and other infections.
9. Fishponds may be used to treat wastewater and purify it to a level that is on par with effluents from the last stage of current contemporary treatment systems, which removes mineralized organic compounds (nitrate and phosphate).

VI. PUBLIC HEALTH ASPECTS

A properly operated wastewater-fed fish culture system has a high bacterial count reduction value near to 99% (including *coliforms*) compared to the input diluted wastewater. However, there is no published information on the presence of human pathogens in ponds and fish. Fish diseases outbreak does not occur usually in well managed ponds. Demoll stated that “the fish reared in wastewater fed culture are identical to any fish that are raised in ponds at good conditions”. Since some pathogenic organisms (such as those that cause tuberculosis, typhoid fever etc) can survive for longer periods of time in fish guts, without harming the fish itself but extreme care should be taken to maintain cleanliness when eviscerating the recently caught fish. Government laboratories frequently check the fish in Munich, but the only information provided is that all readings are below the thresholds needed to meet German Federal Bureau of Health requirements. Fish flesh has never been discovered to contain human pathogens. Fish are stated to contain levels of heavy metals and aromatic hydrocarbons that are within acceptable government guidelines. It is asserted that as the

heavy metals are bound in pond sediments, fish are not harmed by them. Even if the fish get contaminated with heavy metals and PCB'S they can be decontaminated by culturing in clean water over a period of time.

VII. ECONOMICS OF WASTEWATER FED AQUACULTURE

The amount of money made per unit of area through carp culture in wastewater-fed fishponds at a net yield of 500 kg/ha/yr was discovered to be significantly higher than for agricultural crops (Kisskalt and Ilzhofer, 1937). Carp ponds produce low energy when compared to other systems with about 4 million/ Cal/ha/yr. In comparison with fish production in wastewater-fed fish ponds with agricultural food production on sewage fields, the latter was more productive in terms of kg food produced/ha. Kreuz (1938) stated about 250 g of carp flesh/population equivalent load of wastewater can be produced and in comparison, sewage fields produced a ten-fold output in the form of crops. Miller (1914) examined the economics of sewage fields, fishponds fed by wastewater, trickling filters, and filter beds. Miller discovered that, although having beginning expenditures that were almost twice as high as those of trickling filters and filter beds, wastewater-fed fishponds and sewage fields ended up being the most affordable since they generated an economic return. Additionally, alternative biological techniques like trickling filters are costly, smell awful, and spread fly epidemics. The effectiveness of purification of wastewater in fishponds, which can manage a loading of 2,000–3,000 people/ha/day, is ten times more than that of sewage fields, which can only handle 200–300 people/ha/day.

VIII. SUMMARY

In peri-urban regions of developing nations, wastewater-fed aquaculture has the potential to create employment and affordable fish for the poor. It may offer special promise in arid and semi-arid regions with the urgent need to reuse wastewater for both water and nutrients. The main limiting factors are increasing industrialization, which mixes domestic and industrial wastewater with toxic chemicals, rapid urbanisation, which results in high opportunity costs and limited availability of peri-urban land for relatively land-intensive reuse schemes and rising living standards, which lead to urban consumers favouring higher value carnivorous and pellet-fed freshwater and marine fish over relatively low-value omnivorous and herbivorous fishes from wastewater. Another significant obstacle is that most planners and engineers are unaware of wastewater fed aquaculture as a technically feasible alternative for very inexpensive wastewater treatment and reuse. So, by considering all the above points wastewater fed aquaculture can be a way for sustainable aquaculture and its a cheap tool for wastewater treatment.

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