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Wastewater fish culture-way towards water reuse

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Abstract
Earth is the only known planet where life exists. This is possible only due to presence of water and oxygen. Water is the most precious and major requirement for all life on earth. But only a small quantity of clean water is available to be usable by humans. Increase in population growth and development put several pressure in getting access to good quality water resulting in water scarcity. India is one of the countries worldwide facing water stress. In such circumstances, wastewater reclamation and reuse in various fields is the important method to cope up with water scarcity. Annual discharge of domestic sewage in India, contains around 90, 32, 55 Million Tonnes of nitrogen, phosphorous and potassium. Such nutrious water can be made use in aquaculture since aquaculture is an highly water intensive endeavor because large quantity of water is required for the culture year-around and the availability of water is a constrain in the dry months and in rural areas, where there is freshwater scarcity. Hence wastewater fish culture is an economical and helping towards sustainable production. This article deals with importance, scarcity of water and major use of sewage in aquaculture.

Keywords: Fish, waste water, treatment, sewage, water stress

1. Introduction

Earth is known as the "Blue Planet" or “Blue marble” since major part of Earth's crust (nearly 71%) is covered with water. The ocean on earth weight is 1.35×10^{18} metric tonnes, which is 1/4400 the total mass of the earth (Williams, 2014) [35]. Water is the major requirement of any organisms in planet for the body nourishment, sustenance of life. It also act as a instrument of regulating body organs (Khanna *et al*., 2008). Water exists in the air as water vapour, in the land as soil moisture, in rivers, lakes, icecaps, glaciers and aquifers. The circulation of water through the hydro biological cycle involves a biggest flow providing 110,000 km^3 of water to the earth each year as snow and rainfall (Jackson *et al*., 2001) [37]. Although there is abundant of water available, only a little quantity of 0.3% water is usable by humans. The remaining portion of 99.7% is in the oceans, icecaps, soils and floating in the atmosphere (Oves, 2018) [29] as given in Table 1. There are nearly 475 million km^3 of freshwater resources available all over the world in the form of groundwater or surface water to be essentially used by humans (Shiklomanov, 1997) [33].

Table 1: Distribution of water as per National Groundwater Water Association (NGWA)

Source	Percentage of water
Ocean water	97.2%
Glaciers and other ice	2.15%
Groundwater	0.61%
Freshwater lakes	0.0009%
Inland sea	0.008%
Soil moisture	0.005%
Atmosphere	0.001%
Rivers	0.001%

2. Water stress: Water stress is a devasting conflict increasing rapidly when there is stress to meet the demand of people and the quality of water. The common water stress that is being identified globally is drought stress (Oki *et al*., 2006) [27]. There are nearly 65% of people experiences some level of water stress due to the rapid increase in population. Water stress is caused mainly by socioeconomic factors such as population growth and increased wealth.

Chronic water stress may lead to restrictions in the use of freshwater among people (Wiltshire *et al*., 2013) [36]. The main cause of water stress is rise in sea level which results in encroachment of sea water into groundwater present near the coasts and thereby decrease the available groundwater resources (Oki *et al*., 2006) [27]. Table 2 provides the list of countries to face water stress by 2025 according to Jury *et al*. (2007) [18]. World Resources Institute (WRI) stated that there are nearly 167 countries to face water stress by 2030-2040 and 33 countries to face extremely high water stress in 2040 (Maddocks *et al*., 2015) [2]. India faces extremely high water risk holding 13th position in the list of high water risk countries (Table 3) (Dormido, 2019).

Table 2: Population and number of countries to face water stress or scarcity by 2025

Category	Countries	Population (millions)
Water scarce	29	802
Water stressed	19	2027
Water scarce or stressed	47	2826

Table 3: Top 15 water stressed countries (Hannah Dormido, 2019)

Country	Risk level
Qatar	Extremely high
Israel	Extremely high
Lebanon	Extremely high
Iran	Extremely high
Jordan	Extremely high
Libya	Extremely high
Kuwait	Extremely high
Saudi Arabia	Extremely high
Eritrea	Extremely high
UAE	Extremely high
San Marino	Extremely high
Bahrain	Extremely high
India	Extremely high
Pakistan	Extremely high
Turkmenistan	Extremely high

3. Sewerage

Sewerage or wastewater is defined as "utilized water from any mix of residential, mechanical, business or farming exercises, surface overflow or storm water and any sewer inflow or sewer penetration" (Alaa Fahad, 2019). It is also composite of liquid carrying wastes arising from the sanitary conveniences of dwellings, commercial or industrial facilities. It also contains toxic inorganic and organic materials. Its quality is determined by its physical, chemical and biological characteristics (Patro *et al*., 2012) [22].

The characteristics and parameters of municipal sewage are constant whereas, only industrial waste changes (Englande *et al*., 2015) [10]. According to the Central Pollution Control Board (CPCB), 16,000 MLD of wastewater is generated from class 1 cities with population greater than 100,000 no's, and 1600 *MLD* from class 2 cities with the population 50,000-100,00. Of the 45,*000* km length of Indian rivers, 6,000 km have a bio-*oxygen* demand (BOD) above 3mg/l which is not suitable for drinking purpose.

4. Anthropogenic causes of wastewater

The anthropogenic activities include metal finishing and electroplating processes, mining extraction operations, textile industries and nuclear power. The release of heavy metals in water bodies is found to significantly deteriorate the water quality (Akpor *et al*., 2014) [1]. Rapid increase in population and industrialization releases enormous amount of wastewater, which is used as a important asset for water system in urban and pre-urban agribusiness (Fahad *et al*., 2019). In rural areas agriculture practices include use of fertilizers, herbicides and pesticides; river siltation; run-off from degraded forest areas; and animal husbandry are the main cause of pollution. The water qualities in urban areas are affected mainly by increased industrialization, which releases enormous amount of wastewater and other domestic sources (Khatri *et al*., 2015) [20].

5. Implications of wastewater

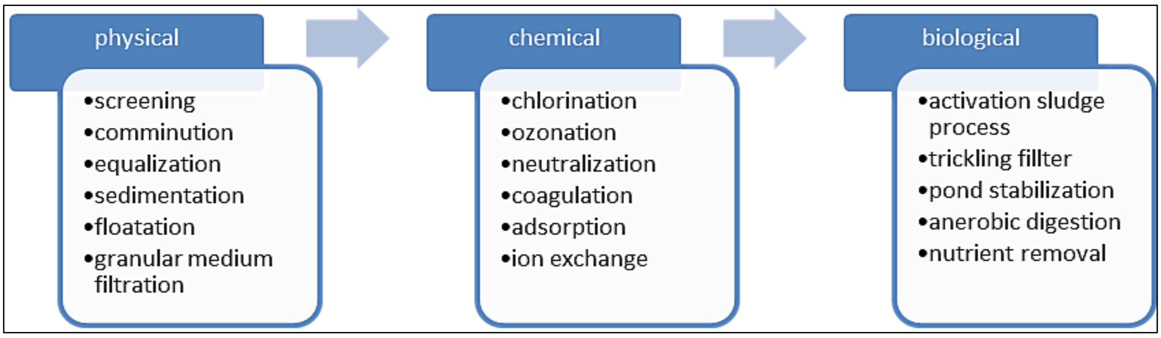
Untreated and improperly treated wastewater contains pathogens which can cause outbreak of numerous diseases and several waterborne diseases like cholera, shigellosis, salmonellosis and diseases associated with *Escherichia coli*. There are some viral diseases like a mild febrile illness and myocarditis. Besides the above, some protozoan disease like cryptosporidiosis, diarrhea encephalitis, giardiasis, amoebiasis and fungal candidiasis, blastomycosis, cryptococcus is, aspergilosis occurs (Olaolu *et al*., 2014) [28]. The fish, plants and anyother organisms living in wastewater will be contaminated with pathogens of human excreta on their body surfaces and visceral organs and hence fishes will be under stressful condition. Untreated sewage is harmful to workers and nearby communities. Wastewater effluents containing heavy metals may be toxic (acute, chronic or sub-chronic), neurotoxic, carcinogenic on humans (Duruibe *et al*., 2007; Akpor *et al*., 2014) [9, 1].

6. Management of wastewater

The goal of wastewater management is to improve the sustainable use of natural resources, with the aim of protection of public health and environment. Sustainable development is essential to meet the needs of society without compromising those for future generations. Hence, objectives for water use, reclamation, and reuse should be consistent with this goal (Englande *et al*., 2015) [10]. Management of this water depends on the various aspects, such as the types of composition of the wastewater like biomedical waste-clinical waste, e-Waste, industrial and municipal waste (Patro *et al*., 2012) [22].

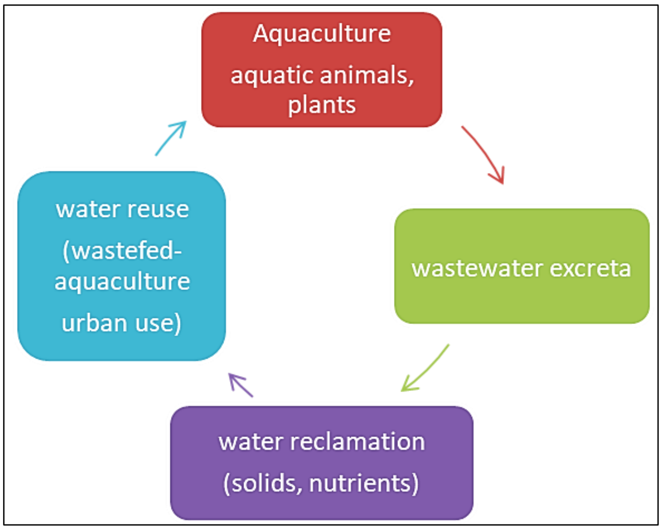
7. Wastewater Treatment Techniques

There are two types of wastewater treatment techniques such as non-conventional and conventional. Conventional treatment includes primary treatment followed by secondary. If necessary, tertiary treatment is included in the steps to separate particular contaminants to very lower levels (Englande *et al*., 2015) [10]. Advanced treatment techniques involves combination of physical, chemical, biological processes which results in removal of suspended, and dissolved solids, organic matter, contaminants, nutrients and pathogens from wastewater (Fahad *et al*., 2019).



8. Wastewater reclamation

Wastewater reclamation is the treatment or processing of wastewater to make it reusable for a beneficial use such as agricultural purposes (Asano, 1998) [3]. Globally, United States of America, Saudi Arabia, Qatar, Israel, and Kuwait are the most remarkable countries based on the per capita wastewater reuse (Jimenez *et al*., 2008) [17]. Effluents with discharge standards could be used for purposes such as aquaculture or for farmland irrigation (Bani, 2011) [4]. Reclamation and reuse plays an efficient role in aquaculture which reduces the usage of freshwater and paves way towards the sustainable environment. Also by using wastewater from aquaculture can be reclaimed and reused again in fish culture (Maharjan *et al*., 2022) [24].



When the water quality is managed through the control of the concentrated input waste, the amount of wastewater treatment is indicated. Water must be reclaimed for aquaculture practices if it contains the waste that will produce abnormal physiological responses in aquatic lives. The untreated water also causes objectionable odour, colour, taste and turbidity. Hence sewage treatment should be flawless and robust. (Rowe *et al*., 1995) [32].

A survey conducted by National Environmental Engineering Research Institute (NEERI) in NAGPUR, India showed that many of the environment and public health problems in wastewater utilization sites are due to the untreated sewage. Hence it is very much important to treat the wastewater (Lyu *et al*., 2016) [23].

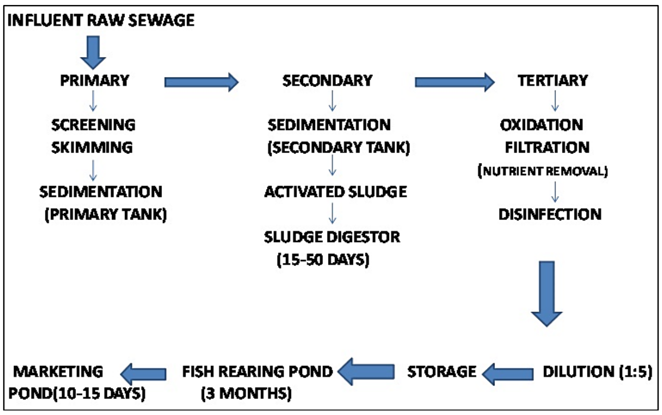
9. Wastewater fish culture

Sewage-fed aquaculture is a unique system and has tremendous advantages. It act as a major source of nutrients for aquaculture. It is economical and helping towards sustainable production and combats environmental pollution. The use of municipal wastewater in the ponds first began in Calcutta in the 1930's (Jana, 1998) [16]. The Rahara Wastewater Aquaculture Farm (CIFA), Captain Bheri, Mudialy Farm and Kalyani Fish Farm are some of the examples of sewage-fed fisheries in and around Kolkata (Lahiri *et al*., 2015) [21].

The first large scale use of sewage fed ponds was at Strasbourg (France). India has the largest area of sewage fed ponds in the world and sewage fish culture occurs in several areas in China followed by Indonesia and Israel. The best is in Munich. Africa, north central and South America also practiced this system (Kaul *et al*., 2002) [19]. At present there are more than 130 wastewater aquaculture units in India covering an area of about 10 000 ha. Almost 80% of these farms are located in West Bengal. Vidyarthi Spill area or Salt Lake is another major sewage irrigated fisheries found in Kolkata (Ganguly *et al*., 2015) [12].

Fish raised in treated sewage are the important source of animal protein. In Kolkata, 3000 ha of fishponds are fed with approximately 550,000 m^3/d of untreated wastewater which produce around 13,000 tonnes of fish (mainly IMC) which are supplied each year to the fish markets of central Kolkata, comprising nearly 16% of the local demand for fish (Mara *et al*., 1993) [25]. Ponds which are extensively used for wastewater fish farming cover an area of 2480 ha, with each fish ponds of area upto 162 ha (Bunting, 2007) [6]. In India, wastewater fish farming system started in four places, Nagpur, Bhilai, Chennai and Bhopal. Due to the enormous growth in this culture system the Indian government permitted growth of some fishes alternative to the carps like *Clarias batrachus, Heteropneustes fossilis, Pangasius sutchi* (FAO 2018).

9.1 Technology of sewage fed fish culture



From the above flow chart, the various phases of sewage treatment can be known (Englande *et al*., 2015) [10]. The influent raw sewage is first sent to the primary treatment for screening, skimming and grit removal process. Further, the water enters at a high velocity to initial sedimentation tank (primary) which is retained for 10-15 days. A considerable reduction on Biochemical oxygen demand levels of wastewater is required before its being transferred to aquaculture facilities, because the Biochemical oxygen demand of raw domestic sewage can be upto the level of 400 mg/l which is toxic to aquatic animals. Therefore, primary method with sedimentation is required to reduce it by 33% and this takes place in initial sedimentation tank (Jana, 1998) [16]. Further, the water is sent to secondary treatment which is abiological process. It removes more than 90% of suspended solids. It includes flocculation, biological filtration and waste stabilization (Cheremisinoff, 2001) [7]. The sludge from primary and secondary treatment tank is sent to the sludge digester to be digested. Oxidation pond is second sedimentation tank in sewage treatment. It contains the algal bacterial culture which oxidizes the organic matter into the CO_2, H_2O, NH_3 that are used as nutrients like nitrite, nitrate, phosphate.

Oxidation or water stabilization ponds are most suitable in India due to the availability of sunshine. In this pond, sewage is retained at the depth of 1-2m for 25-30 days. Algal-bacterial cultures are abundant in this pond which oxidizes the organic matters into other decomposition products (Datta *et al*., 2005) [8]. It is then sent to tertiary treatment which is chemical removal of soluble products which includes chlorination, precipitation, filtration, coagulation etc. for nutrient removal. The disinfection is the final step in tertiary treatment which makes use of chlorine to kill disease causing agents.

It is also recommended to pass the sewage to duckweed pond for 2 days with *Lemna, Wolfia, Eicchornia* etc. which absorbs the heavy metals and increases oxygen by their photosynthetic activity (Datta *et al*., 2005) [8]. Before releasing sewage into fish pond, dilution of treated water with freshwater in the ratio of 1:4.5 or 1:5 is necessary to maintain dissolved oxygen balance (1:1 or 1:2) (Datta *et al*., 2005) [8]. After effective dilution, the concentration of CO_2, H_2S, NH_3 etc. are reduced below the lethal level and sewage is stored for few days along with (duckweeds) to carry out the biological process by micro-organisms, and then the water is sent to the fish rearing pond and used for 3 months. Further, the fish is sent to fish marketing ponds and stored for 10-15 days for the deodoration (Paul *et al*., 2019) [30]. Table 4 shows the water quality parameters of sewage water before and after treatments.

Table 4: Water quality parameters of sewage water before and after treatment (Datta *et al*., 2005) [8]

Water quality parameters of sewage water	Before	After
pH	6.0-8.7	6.5-8.5
Dissolved oxygen	0-3 ppm	3.0-8.0 ppm
Total alkalinity	150-450 ppm	170-490 ppm
Total hardness	240-320 mg caco3/L	340-440 mg caco3/L
Ammonia	12-63 ppm	0.02-0.05 ppm
Nitrite	0-0.092 ppm	nil
Nitrate	0.01-0.06 ppm	25-70 ppm
Phosphate	0.12-15 ppm	0.1-5.5 ppm
Carbon-di-oxide	5-110 ppm	5-47 ppm
Biological oxygen demand	30-200 ppm	6-40 ppm
Chemical oxygen demand	150-180 mg/L	60-100 mg/L
Total suspended solids	160-420 ppm	Trace

10. Conclusion

Increase in population growth and development put several pressure in getting access to good quality water resulting in water scarcity. Thus due to the global water crisis, there is a need to provide water with good sanitation services to a large population in world. In such circumstances, wastewater reclamation acts as a tool to solve the problem. It is a main water-saving measure and results in achieving more sustainable sanitation. Wastewater treatment also helps in various activities like agricultural purposes and aquaculture practices. It also prevents from sewage disposal to water affecting aquatic life. Thus, this article discussed that sewage fed fisheries is an efficient technology which has been recognized as a most economical and eco-friendly method benefitting in both the production and environmental sustainability.

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