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Safeguarding Aquatic Ecosystems: Innovative Effluent Treatment Strategies for Sustainable Aquaculture Pond Water Management

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Abstract:

The aquaculture sector is currently witnessing unprecedented demand to meet the growing needs of the populace for fish and its derivatives. In addressing this demand, fish farmers often resort to cultivating fish at exceptionally high densities within confined pond areas with indiscriminate use of chemicals resulting in effluent culture pond water, laden with chemicals, antibiotics, anesthetics, and disinfectants, each leaving its residual trace. This article explores the ramifications of releasing untreated pond water on rivers and fish biodiversity and presents effluent culture pond water treatment ideas and preventive measures aimed at curbing the indiscriminate use of chemicals and antimicrobials in aquaculture practices. The overarching goal is to strike a harmonious balance between meeting the demand for fish and ensuring the sustainability of ecosystems, safeguarding both human and environmental well-being.

Keywords: Effluent treatment; Bioremediation; Wood chip bioreactors; Bio floc technique; Eco-friendly filters

Introduction:

Aquaculture is one of the fastest growing sector of global food producing sectors, contributing 1.1% to the country's gross domestic product (GDP) and over 6.72% contribution to agriculture GDP with 7.98% average annual growth rate in 2022-23 from fish production (Hand book on fisheries statistics 2023, Department of fisheries). As India is 3rd largest fish producer globally, it shares 8.92% fish production, and ranks second in aquaculture production. Inland water resource area like rivers, reservoirs and flood plain wetland were covered under area of 29000 km, 3.15 million ha, and 0.2 million ha respectively. Whereas the total global inland production potential from all of these water bodies are very less which is around 16% (Department of fisheries statistics). So there is a

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need to transformation from capture fisheries to culture fisheries in inland water bodies. Inland fisheries typically employ extensive culture methods. Yet, in response to growing demand for fishery products, farmers are shifting from extensive techniques to semi-intensive and intensive culture systems. In these intensive culture systems, fishes are cultured at high density to very high stocking densities in very limited area. The practice of high stocking density in fish farming can lead to increased stress levels and weakened immune systems, creating conditions conducive to disease caused by bacteria, viruses, parasites, and protozoans to the fish. High-intensity or high stocking density culture is also a contributing factor to the emergence of new varieties of these diseases. In order to prevent these diseases, a wide range of antibiotics, chemicals, drugs, anesthetics, and disinfectants are used in fish ponds, leading to the accumulation of residues in the cultured water.

It is estimated that 30-40% of the feed given to fish in culture ponds becomes solid waste and is converted into biological waste. This waste contains effluents such as nitrogen, phosphorus, organic matter, other nutrients, and carbon, originating from uneaten food and fish excreta. When released into other water bodies, these effluents often cause pollution, requiring significant treatment to mitigate harmful environmental effects. If untreated, they can lead to eutrophication of receiving water bodies, resulting in algal blooms that degrade water quality. Furthermore, this can alter the aquatic environment and promote the development and outbreak of new diseases. The impact of these effluents on the ecosystem underscores the importance of effective waste management and treatment practices in aquaculture to protect water quality and maintain ecological balance.

Impact on human life:

Through soil and groundwater, these chemicals can enter the human body and accumulate in various organs, such as the intestines, brain, liver, and lungs. Long-term exposure to these chemicals increases the risk of malignancies in different parts of the body. Additionally, some fish may also accumulate these harmful substances, which can further contribute to the health risks for humans consuming these fish. The persistence of these chemicals in the environment poses a significant threat to both human health and ecological balance, highlighting the need for stringent regulations and effective mitigation strategies.

Harmful effects on paddy fields and other crops.

The direct release of pond water for secondary use in paddy fields and other small crops leads to the absorption of chemicals, minerals, and water by the plants. These chemicals accumulate in crop products, posing potential health risks to consumers. Additionally, the continuous application of such water degrades soil quality, eventually rendering it infertile. This practice not only impacts crop yield and quality but also undermines long-term agricultural sustainability.

Impacts on environments:

Effluent water from aquaculture farms and processing industries has significant environmental impacts, even though these are often underreported. This effluent, rich in organic matter, can cause pollution, leading to eutrophication and degradation of water quality. Additionally, the chemicals, antimicrobials, and pesticides used in these operations often contain phenolic, alcoholic, and benzene components. High doses of these substances contribute to environmental pollution. Many of these chemicals are volatile, allowing them to mix with atmospheric air and further spread their harmful effects.

Impacts on open water bodies & its biodiversity:

In intensive culture systems, pond water often contains a variety of chemical residues from high loads of antibiotics and pesticides. When this contaminated pond water mixes with nearby open rivers, canals, and creeks, it spreads these chemicals throughout the aquatic ecosystem. Fish living in these waters absorb and accumulate the chemical residues. When humans and other organisms consume these fish, the chemicals enter their bodies and become bio accumulated. This not only poses direct health risks to consumers but also disrupts the balance of the ecosystem, potentially impacting a wide range of species and their habitats. The pervasive spread of these chemicals highlights the need for stringent management practices to protect both environmental and public health.

Antimicrobial resistance in Culture ponds:

The indiscriminate use of antimicrobials, pesticides, and disinfectants in culture ponds significantly impacts microbial populations. Regular and high-dose applications can lead to antimicrobial resistance among harmful microbes. To address this issue, the use of alternatives to antibiotics like biosynthetic nanoparticles and plant based antimicrobial extracts in fish farming is becoming increasingly important.

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Aquaculture effluent water often contains specific pollutants like nitrites, phosphorus, and ammonia. To meet the water quality standards set by the central pollution control board, several innovative aquaculture techniques and effluent treatment methods are employed. These include:

- **Integrated Multi trophic Aquaculture (IMTA):** IMTA is a relatively new technology used in China and Southeast Asia. Similar to polyculture, IMTA involves farming multiple aquatic species from different trophic levels together. This integrated approach improves efficiency, reduces waste, and provides ecosystem services such as bioremediation.

- **Hydroponics:** Hydroponics is a widely used effluent treatment method, particularly in raceway culture systems. This technique involves growing plants in a water medium without soil. The plant roots absorb excess nutrients like nitrogen and phosphorus from fish waste, thereby purifying the water Recently using in RAS, cemented fish farms in India and USA.

- **Biofloc Technology:** Biofloc technology is increasingly popular in aquaculture. In this system, bacterial flocs are introduced to degrade nitrogenous and organic compounds, such as fish excreta and food waste. This process purifies the water, reducing the need for water exchange by 30-40%. The bacteria involved are harmless to the cultured fish This is in use for murrel and pungasious fish farms.

- **Wood Chip Bioreactors:** Wood chip bioreactors are mechanical filtration units where wood chips are used to absorb contaminants from wastewater. These bioreactors store water in tanks, where the wood chips effectively remove pollutants from the effluent discharged from aquaculture ponds often using in Recirculating aquaculture system (RAS), Fish ponds, hatcheries in Countries like USA, Norway, China.
- **Sand Biofiltration:** Sand biofiltration is commonly used in Europe for rainbow trout culture. This method involves a combination of sand and microbes in a filtration chamber,

which degrades organic matter and removes harmful substances like nitrites and ammonia. This eco-friendly technique is known for its effectiveness in maintaining water quality this technique is applying in innovative technologies like RAS and shrimp hatcheries, processing plants etc.

- **Bioremediation:** Bioremediation is a method used to remove nitrogenous compounds such as nitrites, phosphorus, and ammonia from shrimp culture pond water. This technique utilizes specific plants or microbes to treat the effluent water, making it safer for reuse or discharge, it is easy to use and apply for small ornamental fish units and hatcheries.

Mechanical Effluent Treatment Techniques

- **Sedimentation Basins**: These are commonly used for low-intensity production systems. Pond water is collected in basins, where sediments settle at the bottom. The sludge is then removed, and the water can be drained or reused.
- **Micro-screen Effluent Treatment**: This process involves the use of drum filters with mesh sizes of around 63 micrometers, commonly used in Europe. These filters remove up to 20% of effluents and are placed at the outlets of raceways for water reuse.
- **Constructed Wetlands with Halophytes**: Constructed wetlands, often cemented, are used to remove total phosphates, nitrogen, and BOD from effluent water. Halophytic plants, such as water spinach, common reed, and salicornia, absorb nutrients and other pollutants from the water, achieving removal rates of up to 80-90%.

Biological Effluent Treatment Techniques

- **Heterotrophic Bacteria**: Water from ponds is stored in effluent tanks and inoculated with heterotrophic and detritivorous bacteria. These bacteria, including Nitrobacter and Nitrosomonas, reduce harmful ammonia levels, making this method both eco-friendly and cost-effective.
- **Seaweed Utilization:** In enclosed mariculture systems, seaweeds like Gracilaria are cultivated to act as biofilters, absorbing nitrogen, phosphorus, and organic matter from the water, thereby improving water quality by 10-30%.
- **Mangrove Areas**: Mangrove areas, rich in halophilic plants, serve as natural biofilters. Effluent water is drained into these areas, where plants absorb pollutants, making this an effective method for treating aquaculture effluents.

- **Microalgae**: Species like Chlorella and Chaetoceros are used to maintain water quality by absorbing excess organic matter and producing oxygen. While beneficial, monitoring is essential to prevent excessive algal growth.
- **Effluent Treatment Tanks**: Before discharge, effluent water is stored in treatment tanks where chlorine is added and left for 5-7 days. This process purifies the water, making it suitable for reuse. These innovative and eco-friendly techniques are crucial for maintaining water quality in aquaculture systems, ensuring both environmental sustainability and the health of aquatic species.

Preventive measures for reducing the Indiscriminate Use of antimicrobials and Chemicals

To reduce the indiscriminate use of antimicrobials and chemicals in aquaculture, several preventive measures should be implemented. First, strict regulations should be enforced, ensuring that only tested and approved chemicals are used in aquaculture. Best Management Practices (BMPs), including comprehensive health management plans, disease prevention through biosecurity, and fish vaccinations, should be adopted to minimize the need for chemical treatments. Education and training programs should be provided to farmers, teaching them responsible usage and the risks of overuse. Awareness campaigns should inform the public about the consequences of antimicrobial resistance. Alternatives like probiotics, prebiotics, and phytogenic extracts can be promoted to improve fish health without chemicals. Integrated Pest Management (IPM) strategies, such as environmental controls and biological agents, should be used to manage diseases naturally. Regular monitoring, surveillance programs, and responsible use policies like prescription-only antimicrobial use and detailed record-keeping will further help reduce overuse and protect public health and the environment.

Conclusion:

This article highlights the significant potential of aquaculture in meeting the growing demand for fish in the food sector. However, it also emphasizes the need to address the waste and effluent water generated by aquaculture operations. To mitigate environmental and human health impacts, it is crucial to adopt, implement advanced technologies, treatment method and regulations from the Central and State Pollution Control Boards. Moreover, the indiscriminate use of antimicrobials and chemicals in fish culture ponds must be carefully managed to prevent disease development, pest control, and the reduction of harmful microbes by employing effective treatment techniques. The negative impacts of directly releasing pond water into the

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environment can be significantly reduced by raising awareness about these issues through targeted campaigns and training programs is vital. By following a systematic approach, resources can be utilized efficiently, minimizing waste and environmental impacts while ensuring sustainable aquaculture practices.

References

Ahmad, A., Abdullah, S. R. S., Hasan, H. A., Othman, A. R., & Ismail, N. I. (2021). Aquaculture industry: Supply and demand, best practices, effluent and its current issues and treatment technology. *Journal of Environmental Management*, *287*, 112271.

Bondad-Reantaso, M.G., MacKinnon, B., Karunasagar, I., Fridman, S., Alday-Sanz, V., Brun, E., Le Groumellec, M., Li, A., Surachetpong, W., Karunasagar, I. and Hao, B., 2023. Review of alternatives to antibiotic use in aquaculture. *Reviews in Aquaculture*, *15*(4), pp.1421-1451.

Okeke, E. S., Chukwudozie, K. I., Nyaruaba, R., Ita, R. E., Oladipo, A., Ejeromedoghene, O., ... & Okoye, C. O. (2022). Antibiotic resistance in aquaculture and aquatic organisms: a review of current nanotechnology applications for sustainable management. *Environmental Science and Pollution Research*, *29*(46), 69241-69274.

Pathak, S. C., Ghosh, S. K., & Palanisamy, K. (2000). The use of chemicals in aquaculture in India. In J. R. Arthur, C. R. Lavilla-Pitogo, & R. P. Subasinghe (Eds.), Use of Chemicals in Aquaculture in Asia: Proceedings of the Meeting on the Use of Chemicals in Aquaculture in Asia, 20-22 May 1996, Tigbauan, Iloilo, Philippines (pp. 87-112). Tigbauan, Iloilo, Philippines: Aquaculture Department, Southeast Asian Fisheries Development Center.

Sikder, M. N. A., Min, W. W., Ziyad, A. O., Kumar, P. P., & Kumar, R. D. (2016). Sustainable treatment of aquaculture effluents in future-A review. *International Research Journal of Advanced Engineering and Science*, 1(4), 190-193

Turcios, a. E., & papenbrock, j. (2014). Sustainable treatment of aquaculture effluents—what can we learn from the past for the future? Sustainability, 6(2), 836-856.