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Water Quality of Treated Wastewater in Integrated Aquaculture System

Mimi Fadzlin Nasruddin[1], Siti Noor Hajjar Md Latip[2*], Khor Bee Chin[3], Siti Nur Aida Damanhuri[3], Nordiana Ibrahim[1], Alijah Mohd Aris[3]

1 Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA Jasin Campus, Melaka, MALAYSIA.

2 Sustainable Crop Protection Research Group, Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA, Shah Alam, Selangor, MALAYSIA.

3 Indah Water Konsortium Sdn Bhd, Jalan Dungun, Damansara Heights, Kuala Lumpur, MALAYSIA.

**Corresponding Author (Tel: +60193099525, Email: noorhajar@ uitm.edu.my).*

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Abstract

Treated wastewater (TWW) constitutes a sustainable water resource that has been used for aquaculture throughout Asia and the Far East. Sewage treatment plant (STP) use can reduce both the demand for freshwater and water costs in existing aquaculture operations, thus rendering fish production more profitable. Wastewater is one of the renewable water supplies that can save potable water. This study aims to evaluate the water quality of treated wastewater used in integrated aquaculture systems and monitor fish growth. For water quality, the physio-chemical characteristics of pH, temperature, chemical oxygen demand (COD), dissolved oxygen (DO), ammonia, nitrate content, and total suspended solids (TSS) were determined according to the procedures outlined in the Standard Method for Water and Wastewater Examination for two-phases. Based on the findings, all parameters for treated wastewater are suitable for fish survival with increased fish growth. The use of treated wastewater in aquaculture will give many benefits to all and can promote sustainable development goals in terms of water reused and cleaning the environment.

Discipline: Water Quality, Treated Wastewater, Aquaculture, Integrated System.

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1 Introduction

Most countries in the world are facing a global water shortage because of rising populations, climate change, and growing demands on water supplies. Water is essential for humans, animals, as well as crops. Given the limited and declining water supply, the competition between water demand in urban areas and the need for agriculture is serious (Mara, 2007). In developed countries, the use of water from treated wastewater has become one of the alternatives for reducing dependency on freshwater resources (Qadir, 2010; Gharbia, 2016). Since the water sources from this treated system are a constant source of water derived from industrial and also private waste, using this can be categorised as a renewable and sustainable water source (Nan, 2007). The usage of treated wastewater can save artificial fertiliser since the content of wastewater has a natural mineral content and it can be used for irrigation in agriculture (Duncan, 2004; Schellenberg, 2020).

Treated wastewater (TWW) constitutes a sustainable water resource that has been used for aquaculture throughout Asia and the Far East. In addition, TWW use can reduce both the demand for freshwater and water costs in existing aquaculture operations, thus rendering fish production more profitable. TWW-fed aquaculture can be applied anywhere near wastewater treatment plants (WWTPs), including in arid and semi-arid climates, independent of natural water resources (Zhou, 1999; Phong, 2007). In nearly all cases, WWTPs are located near urbanised centers, thus offering the advantage of an important food commodity's production being close to the demand centers.

2 Literature Review

1.1 Wastewater Management

Wastewater usage is emerging as a desirable option for conserving and enhancing the supply of available water as freshwater sources grow scarcer. Aquaculture, landscape irrigation, urban and industrial uses, recreation, environmental usage, and groundwater recharge are just a few of the various uses for wastewater. In general, wastewater can be used for any purpose that freshwater is used for, provided the wastewater has passed the proper treatment or there are other safety measures in place. Due to competition for water and climate change, many areas of the world are facing increasing water stress and scarcity, and more of the world's poor are anticipated to be affected by a higher frequency and intensity of droughts (Meehl et al., 2007). According to projections, by 2050, 44 percent of the world's population—up from 7 percent in 1995 (Hinrichsen et al., 1998), will reside in water-stressed areas (Molden, 2007). That being said, there will be an increase in the demand for irrigation water and, in particular, wastewater as a reliable water source, and wastewater will need to be regarded as an essential aspect of local water resources.

1.2 Treated Wastewater in Aquaculture

Aquaculture, in general, refers to the controlled cultivation of aquatic plants and animals by making use of wastewater as a nutrient source for plants and fish. Fish can be grown in ponds where they feed on algae and other organisms that grow in nutrient-rich water. Through feeding, the nutrients from the wastewater are removed, and the fish are eventually harvested for consumption. Three kinds of aquaculture designs for raising fish exist, which are fertilisation of fish ponds with excreta/sludge, fertilisation of fish ponds with effluent (Finley, 2017), and fish grown directly in aerobic ponds (Finley, 2017). When introducing nutrients in the form of effluent or sludge, it is important to limit the additions so that aerobic conditions are maintained. The Food and Agriculture Organization (FAO) stated that aquaculture is the fastest-growing food production sector in recent years, largely due to the expanded consumption of fish as a preferred source of animal protein, alongside a relatively static level of capture fisheries (FAO, 2014) due to declining natural fish stocks (Finley, 2017). In addition, according to the food and agriculture organization's prediction for the early 2020s, aquaculture will cover only 40% of the global fish demand (FAO, 2016; 2018). In order to fill this demand-supply gap. aquaculture would need to globally grow by 9.9% every year. However, the annual growth rate of global aquaculture production is expected to decline (from 5.7% in 2003–2016 to 2.1% in 2017–2030). The availability and accessibility of good quality water are mentioned as the main reasons for this slowdown (FAO, 2016; 2018). Reuse of Treated Wastewater (TWW) for aquaculture applications offers a solution to many of the challenges that global freshwater aquaculture is facing. Indeed, TWW use for food production has been applied successfully and intensively in agriculture through crop irrigation (Valipour & Sigh, 2016). TWW-fed aquaculture can be applied anywhere near wastewater treatment plants (WWTPs), including in arid and semi-arid climates, independent of natural water resources. Recently, a combination of hydroponic plants and bacteria has significantly improved with each component's single application to remove nutrients from wastewater. It has been successfully used in the treatment of wastewater in common pond cultures (Pengju et al., 2022). Hence, this study aims to evaluate the water quality of treated wastewater and monitor fish growth in integrated aquaculture systems.

3 Method

1.3 Integrated Aquaculture System

A canvas pond with a size of 200 x 200 x 50 cm is set up as part of an integrated aquaculture design pond (Figure 1). A filter system and a reserved tank were put in the integrated aquaculture system with a capacity of 1,200 litres, with 2 towers (with 48 holes), 2 units of 1.5 m NFT pipe (with 10 holes), and 1 unit of 1 m NFT pipe (7 holes). A part of it is the three types of filtration systems it encompasses (in an HDPE drum): radial filter, brush filter, and media K1 filter.

Figure 1: Fish pond design for Integrated Aquaculture System.

1.4 Analysis of Wastewater Quality

The study performed an analysis of water quality weekly for 10 weeks in each phase. Phase 1 used African Catfish and water spinach in the integrated aquaculture system, while Phase 2 used Blue Gourami and spinach. A sample of water was gathered from the reserved tank and main pond of the integrated aquaculture system. Subsequently, the physio-chemical characteristics of the data on pH, temperature, chemical oxygen demand (COD), dissolved oxygen (DO), ammonia, nitrate content, and total suspended solids (TSS) were determined according to the procedures outlined in the Standard Method for Water and Wastewater Examination (APHA, 2005). Water quality measurements were taken to determine the quality of treated wastewater used in the integrated aquaculture system. The pH was determined by a pH meter (Jenway 3305) while the temperature and dissolved oxygen (DO) were determined by a DO meter (YSI-model57).

The total suspended solids (TSS) were determined using the gravimetric method, where 0.45 µm filter paper was used to trap the TSS. The filter paper was weighed after drying for one hour at 105 °C. The dried filter paper was then used to filter 100 mL of the water sample. After the filtration process, the filter was then removed and dried at 105 °C for an hour before recording the final weight. The calculation to determine the TSS is as follows:

$$Total\ Suspended\ Solid\ \left(\frac{mg}{L}\right) = \frac{Wfss - Wf}{Vs} \quad (1),$$

where:Wfss: weight of the filter with suspended solids

Wf: weight of the filter

Vs: volume of sample

For the ammonia (NH_3) parameter, the HACH method was used, and a packet of Ammonia Salacylate and a Cynurate Powder Pillow were needed for the water sample. The NH_3 parameter was determined and recorded using a HACH DR 3900 Spectrophotometer. The chemical oxygen demand (COD) of the water sample was also determined using a HACH DR 3900 Spectrophotometer.

Meanwhile, for nitrate (NO_3), the NitrateVer5 Powder Pillow was used. All values were recorded in the form of ± standard deviation average and mean values.

1.5 Data Collection on Fish

Fish was weighed weekly for ten weeks to evaluate growth rates for Phase 1 and Phase 2. A total of 15 samples of fish were weighed and their length was measured weekly.

1.6 Statistical Analysis

The data on water quality and fish growth was expressed using the Statistical Packages for Social Science (SPSS) Version 25 software. The physio-chemical parameters for all studies were explored by calculating Pearson's correlation coefficient (r) value in order to assess the relationship between water quality variables. The correlation for significance was tested by applying a p-value. The variation is significant if $p < 0.05$ and not significant if $p > 0.05$.

4 Result and Discussion

The physio-chemical parameters of treated wastewater for each phase are pH, temperature, chemical oxygen demand (COD), dissolved oxygen (DO), ammonia (NH_3), nitrate (NO_3) content, and total suspended solids (TSS) for Phases 1 and 2 as shown in Table 1. From the physio-chemical analysis for Phase 1, there are significant differences in temperature (31.58 ± 0.58^a), DO (9.61 ± 0.26^a), NH_3 (1.14 ± 0.16^a), NO3 (0.697 ± 0.33^a), and TSS (33.3 ± 6.09^a). In phase 2, there is a significant difference in DO (7.84 ± 0.30^a) and TSS (25.59 ± 5.50^a). The data show that the pH of water is acceptable for fish growth in both phases. For most freshwater fish species, the ideal pH value is reported to be between 6.5 and 9.0 (Boyd, 1990).

Table 1: Mean value and Standard deviation for physio-chemical parameters of treated wastewater in Phase 1 and Phase 2.

Parameter	Unit	Mean Value			
		Phase 1		Phase 2	
		Tank	Pond	Tank	Pond
Temperature	°C	30.75 ± 0.58	31.58 ± 0.58^a	28.78 ± 0.64	29.34 ± 0.89^b
pH	-	7.67 ± 0.18	8.90 ± 0.23^b	8.44 ± 0.30	8.23 ± 0.34^b
Dissolved oxygen (DO)	mg/L	8.70 ± 0.22	9.61 ± 0.26^a	6.55 ± 0.28	7.84 ± 0.30^a
Chemical Oxygen Demand (COD)	mg/L	7.9 ± 1.46	50.5 ± 7.50^b	7.1 ± 0.73	27.5 ± 1.26^b
Ammonia(NH3)	mg/L	2.02 ± 0.36	1.14 ± 0.16^a	1.95 ± 0.33	2.35 ± 0.68^b
Nitrate (NO3)	mg/L	2.18 ± 0.49	0.697 ± 0.33^a	1.57 ± 0.53	1.04 ± 3.6^b
Total Suspended Solid (TSS)	mg/L	5.5 ± 0.93	33.3 ± 6.09^a	3.59 ± 0.87	25.59 ± 5.50^a

*n^a: significant n^b: not significant

Based on Table 2, Phase 1 shows the correlation between pH and temperature, nitrate, and ammonia. Based on this, water pH and temperature influences the other studied parameters. The deviation in water pH from the normal range will adversely affect fish growth, survival, and reproduction and cause high mortality in fish culture ponds (Zweig et al., 1999). The tropical fish species live in open water temperature that ranges from 18 to 28 °C and can survive up to 41 °C.

Phase 2 shows the correlation between pH and temperature, nitrate, and ammonia. Based on this, Priest (2002) stated that *T. trichopterus* can tolerate a wide range of physio-chemical parameters including hardness, water pH, temperature, salinity, and dissolved oxygen condition.

Table 2: Correlation among different parameters of treated wastewater in Phase 1.

Phase 1							
Water Parameter	pH	Temperature	DO	COD	NH3	NO3	TSS
pH	1	0.71	-0.15	-0.44	0.01	0.16	-0.06
Temperature		1	0.26	-0.42	0.18	0.42	-0.02
Dissolved oxygen (DO)			1	0.03	0.04	0.32	0.15
Chemical oxygen demand (COD)				1	-0.67	-0.56	0.67
Ammonia (NH3)					1	0.28	-0.26
Nitrate (NO3)						1	-0.19
Total Dissolve Solid (TSS)							1

Table 3: Correlation among different parameters of treated wastewater in Phase 2.

Phase 2							
Water Parameter	pH	Temperature	DO	COD	NH3	NO3	TSS
pH	1	0.15	0.30	0.16	-0.08	-0.08	0.50
Temperature		1	-0.19	-0.41	0.84	-0.15	0.01
Dissolved oxygen (DO)			1	0.39	-0.20	-0.41	0.78
Chemical oxygen demand (COD)				1	-0.13	0.24	-0.06
Ammonia (NH3)					1	-0.32	-0.19
Nitrate (NO3)						1	-0.51
Total Dissolve Solid (TSS)							1

Fish growth is determined by monitoring its weight (g) and length (cm) from week 1 to week 10. Based on the results in Table 4, the fish growth for both types of fish, African Catfish and Blue Gourami is increasing. Based on the weekly data for the weight (g) and length (cm), both fish show normal growth in the integrated aquaculture system.

Table 4: Fish weight (g) and fish length (cm) in treated wastewater.

Fish Weight (g)	Fish Length (cm)
0.162 ± 0.06	5.6 ± 0.27

5 Conclusion

This study was conducted to assess the interaction between water quality effects on the integrated aquaculture system of African Catfish and Blue Gourami in two phases. Based on the analysis, it was observed that there were fewer dissimilar water quality parameters for both phases. For Phase 1 and Phase 2, the fish grow in an integrated aquaculture system with treated wastewater. Treated wastewater has the potential to be a substitute in integrated aquaculture systems without doing any harm to humans.

6 Availability of Data And Material

Data can be made available by contacting the corresponding author.

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Mimi Fadzlin Nasruddin is a postgraduate student at the Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA, Jasin, Melaka, Malaysia. She has a Bachelor's degree in Agricultural Science from the University College of Agroscience Malaysia. Her research is on sustainable agriculture focusing on the integration of aquaculture and agriculture.

Dr. Siti Noor Hajjar Md Latip is an Associate Professor and Head of Crop Protection at the Faculty of Plantation and Agrotechnology, UiTM Melaka, Jasin Campus. Currently, she is the Head of the Industrial Research Lab – Maz Agriculture Research and Sustainable (MARS) Laboratory. She obtained her Master of Science in Conservation Biology from Universiti Kebangsaan Malaysia (UKM) and her Doctor of Philosophy in Agricultural Entomology from the Faculty of Agriculture, Universiti Putra Malaysia (UPM). Her current research is focusing on Formulating Biopesticides for Controlling Insect Pests, Insect Toxicity, Molecular Entomology and Promoting Integrated Pest Management for Sustainable Agriculture.

Ir. Khor Bee Chin is a Senior Manager at Technology & Innovation Section, Planning and Engineering Department, Indah Water Konsortium Sdn Bhd (IWK). She got a Bachelor's Degree in Chemical Engineering (1st Class Hons) from The Queen's University of Belfast, Northern Ireland, United Kingdom. She obtained her Master of Business Administration from Nottingham Trent University, UK. She is a professional engineer with a practising certificate from the Board of Engineers Malaysia and a member of the Institution of Engineers Malaysia. She is also a Project Management Professional (PMP ®) from Project Management Institute.

Siti Nur Aida Damanhuri is a Research and Development Executive at Technology and Innovation Section, Planning and Engineering Department, Indah Water Konsortium Sdn Bhd (IWK). She got a Bachelor's Degree in Engineering (Agricultural and Biosystem) in Universiti Putra Malaysia (UPM).

Nordiana Ibrahim is a Senior Lecturer at the Faculty of Plantation and Agrotechnology, UiTM Melaka, Jasin Campus. She got her Bachelor Sc. (Hons) in Plantation Technology and Management and her Master's in Plantation Industry Management from Universiti Teknologi MARA (UiTM). Her research area focuses on Agricultural Finance and Plantation Management.

Ts. Alijah Mohd Aris is a Senior Executive and Head of the Unit, Technology and Innovation Section, Planning and Engineering Department, Indah Water Konsortium Sdn Bhd (IWK). She got a Bachelor's Degree in Science Bioindustry (Microbe Technology and Bioprocessing) from Universiti Putra Malaysia (UPM). Currently, she is in the final semester of her postgraduate studies (Master in Philosophy) at Universiti Teknologi Malaysia (UTM). Her area of expertise is in Wastewater, Biotechnology, Green Technology & Resource Recovery.