International Journal of Water Resources and Arid Environments 9(2): 107-112, 2020
ISSN 2079-7079

Wastewater Treatment and Reuse in Integrated Irrigation Practice and Aquaculture: An Exploring Concept of Food, Water and Health Nexus

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Abstract: Treated wastewater is considered as important and alternative water resources for productive use in agriculture throughout the world. It is estimated that, approximately 20 million hectares of land is irrigated using treated wastewater worldwide. Reutilization of nutrients and water from treated wastewater to integrated agriculture is often considered as a potential food–water–health nexus strategy. Thus, wastewater treatment plus reuse in integrated farms can enhance nutrients and also directly save groundwater use in farming practice. Integrated aquaculture and irrigation system is one of the attempts for efficient utilization of limited fresh water resource. However, the direct use of wastewater has important health and environmental implications. This is because of particularly in developing countries, the treatment facilities are very less and also involving excessive costs. Hence, proper wastewater treatment system should be adopted to produce treated wastewater which must meet the agricultural water quality criteria. *Tridax procumbens* (Asteraceae) plant leaves were used for the production of biocarbon. As a model trial, Common carp (Cyprinus carpio) and rice cultivation is used in a pilot scale. The results indicate that, the biocarbon technology is highly efficient in removal of various pollutants from wastewater. It is noted that 95.2 – 98.5 percent organic pollution load is removed from the selected industry wastewaters. The integrated aquaculture and rice cultivation system showed significant increase in the production. Further, this study revealedthat the eco-friendly wastewater treatment options that could benefits the food, water and health (FWH) nexus and the potential for recycling wastewater for sustainable agricultural production.

Key words: Wastewater · Reuse · Integrated farming · Food · Health

INTRODUCTION

It is well known that, the large variations in rainfall and limited ground and surface water resources have led to widespread scarcity of the fresh water resources in many regions of the world. Water scarcity is one of the major constraints to socioeconomic development in the arid and semi-arid regions [1]. Climate change is also having adverse impacts on the sustainable water resources management [2]. The contribution of fresh water to the overall water balance is limited and marginal. In this alarming situation, there is a need to search alternative water resources for sustainable development. Water reuse can also help mitigate climate change impacts on crop yields and dwindling water resources [3].

It is also well understood that, the overpopulation pressure, competition with urban and industrial activities and increased frequency of drought are making water a dwindling resource for irrigation [4]. In the modern industrial world, particularly paper and pulp [5], sugar [6] and leather industries [7] are using large volume of fresh water for its various operations. Equally it generates significant amount of wastewater and released into the receiving water bodies [8]. This will create alarming water pollution and environmental hazards. This type of industrial wastewater can be considered as potential resources for sustainable integrated irrigation system [9, 10]. Hence, by using proper wastewater treatment system, treated wastewater can be produced for the selected agricultural activities.

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The treated industrial wastewater is an important resource with reference to environmental and socio-economic perspectives that needs to be managed in an appropriate way [11]. This resource can be utilized in improving the fresh water deficit by reusing the treated wastewater particularly in irrigation systems, industrial unit operations and recharges in aquifers. However, this resource is strictly sensitive and has adverse impacts on the public health [12, 13]. Both negative and positive impacts of the treated wastewater resource should be considered.

Innovative wastewater treatment technologies must be developed to recover renewable resources, such as water, nutrients and also energy, from wastewater [14]. In the current research studies, a novel biocarbon technology is introduced to treat the selected paper and pulp, sugar and leather industries wastewater in continuous mode. The integrated aquaculture and selected crop irrigation system showed significant increase in the production due to higher stocking density of fish thereby increasing the profit margin. The main objective of the present study is to develop an eco-friendly wastewater treatment optionsand to examine the techno-economic feasibility of intensification of fish culture through treated wastewater irrigation system.

MATERIALS AND METHODS

Preparation of Biocarbon: The selected industrial wastewater was treated with a novel biocarbon produced from the leaves of a medicinal plant called "*Tridax procumbens*". The simple preparation process is given below. The biocarbon has unique characters in removing various heavy metals and organic pollutants present in wastewater systems [15]. The black mass generated in the experimental process was washed with distilled water and dried at 110 ± 2°C for 6hrs and stored in airtight glass containers for further applications.

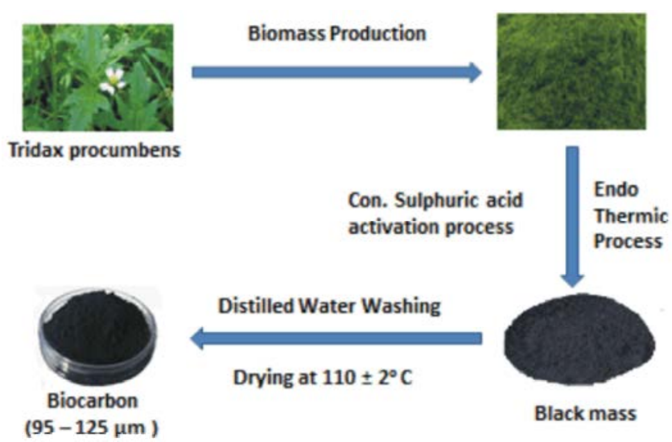

Fig. 1: Process for the preparation of biocarbon

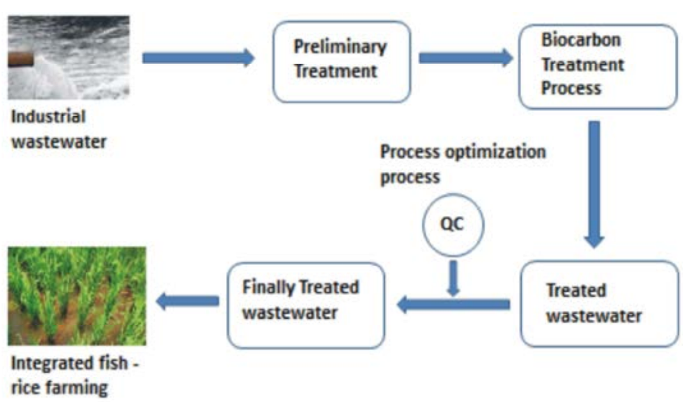

Fig. 2: Industrial wastewater treatment and integrated fish-rice farming.

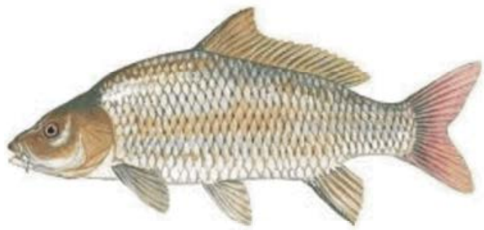

Fig. 3: Common carp (Cyprinus carpio)

Industrial Wastewater Treatment Process and Integrated Irrigation: The industrial wastewater treatment process and the application of treated wastewater in selected integrated fish-rice irrigation system was depicted the Figure 2. The core part of the treatment process mainly depends on the biocarbon treatment process, where the wastewater undergoes continuous treatment steps with clear process optimization and quality control check points. The treated wastewater should meet the agricultural water quality standards.

Common Carp (*Cyprinus carpio*): In the integrated fish-rice farming system, Common carp (*Cyprinus carpio*) species was selected and grown and is shown in the Figure 3. This species can grow well in fresh water with moderate climatic conditions. It is one of the good fish consumed by peoples for their dietary intake. The economic value of the species in the consumer market is good.

RESULTS AND DISCUSSION

The analytical results of physico-chemical characteristics of selected industrial wastewater andtreated wastewater have been evaluated and presented in the Figures 4 – 6. It indicatesthat the industrial wastewater is highly contaminated with heavy metals and organic pollutants. Higher organicload is mainly contributing the rise in biological oxygen demand (BOD) of thewastewater.

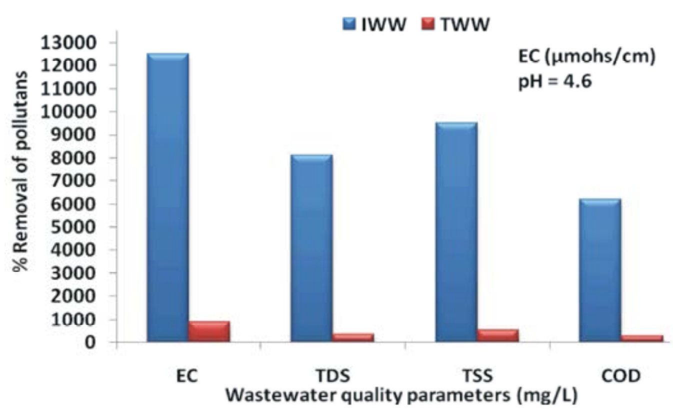

Fig. 4 (a): Selected characteristics of sugar industry wastewater (IWW) and treated wastewater (TWW)

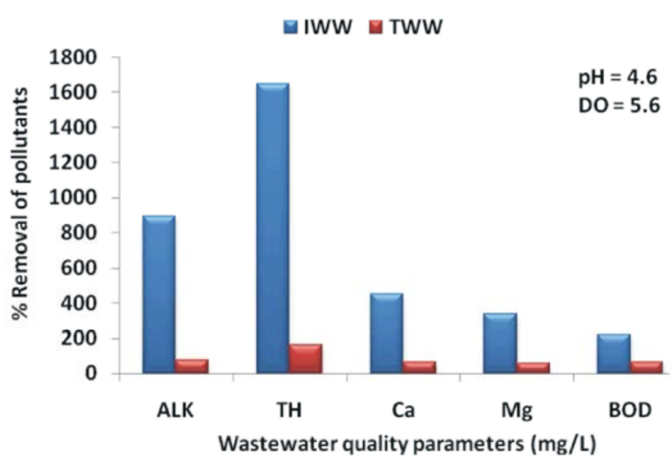

Fig. 4 (b): Selected characteristics of sugar industry wastewater (IWW) and treated wastewater (TWW)

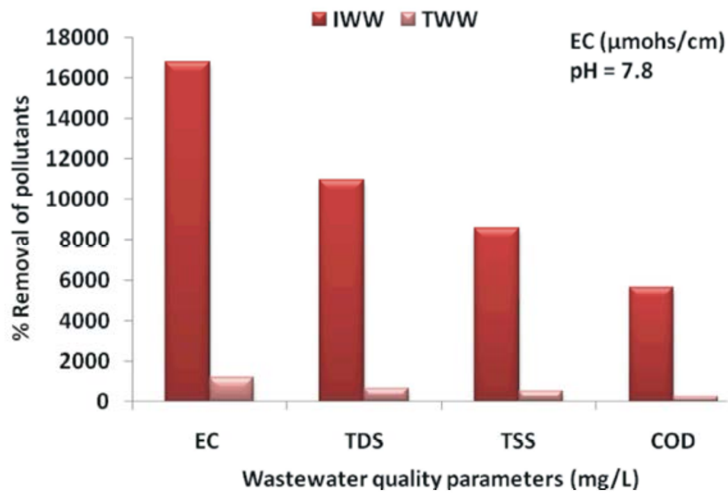

Fig. 5 (a): Selected characteristics of paper and pulp industry wastewater (IWW) and treated wastewater (TWW)

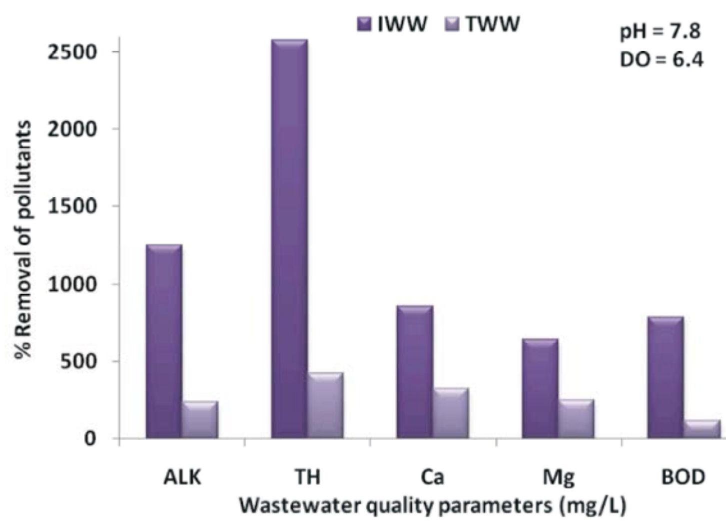

Fig. 5 (b): Selected characteristics of paper and pulp industry wastewater (IWW) and treated wastewater (TWW)

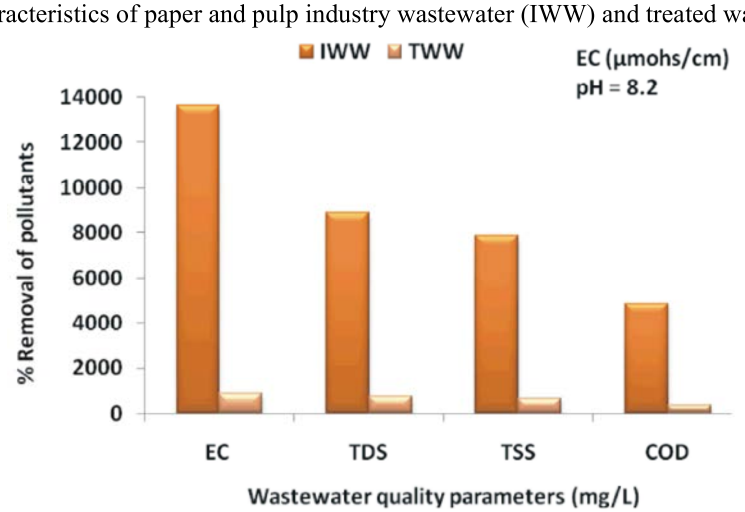

Fig. 6 (a): Selected characteristics of leather industry wastewater (IWW) and treated wastewater (TWW)

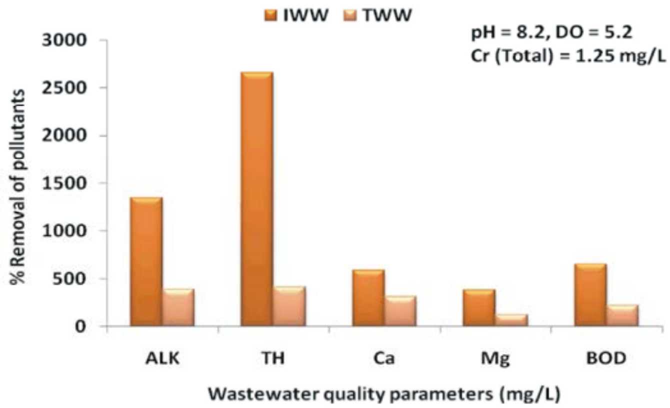

Fig. 6 (b): Selected characteristics of leather industry wastewater (IWW) and treated wastewater (TWW).

In the current research study, the raw sugar industry wastewater and the treated wastewater is represented in the Figures 4 (a) and 4(b) respectively. The results indicate that, the biocarbon treatment is significantly produced good quality wastewater. Notably, 95.2 – 98.5 percent of the orgasmic pollution load is removed in the wastewater.

Paper and pulp industry consumes large amount fresh water in its operations. The volume of wastewater generated in also high. The selected physico-chemical parameters are tested in raw wastewater and the treated wastewater and the analytical results are presented in the Figures 5(a) and 5(b). The results indicated that, around 98.5 percent of organic and inorganic pollutants are removed.

The trend of removal of both, organic and inorganic pollutants from raw and treated leather industry wastewater is presented in the Figures 6(a) and 6(b). The total chromium is one of the important parameter and the results indicated that, 98 percent of chromium is efficiently removed from the wastewater using the biocarbon technology.

All the above observations in the selected industrial wastewater after the treatment can be used for the integrated irrigation system without any health hazards. In the pilot scale integrated irrigation system 600 sq.ft land area is used for the cultivation of rice crop along with Common carp culture. It is well observed that, good quality crop yield was observed.

CONCLUSION

- The biocarbon technology for the treatment of selected industrial effluents is cost effective, simple and economically feasible. It does not produce any major sludge problem.
- The wastewater treatment process also helps to protect the environment from possible cross contamination of water bodies and land system from polluted water discharge.
- The integrated aquaculture and rice cultivation system showed significant increase in the production.
- The results suggest that, this type of irrigation system can be extended in large scale for the development of sustainable agriculture.
- This study revealed the benefits of the food, water and health (FWH) nexus and the potential for recycling wastewater for sustainable agricultural production.

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