Agricultural Water Management 146 (2014) 262–269

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Treatment of wastewater from raw rubber processing industry using water lettuce macrophyte pond and the reuse of its effluent as biofertilizer

H.I. Owamah[a,*], M.A. Enaboifo[b], O.C. Izinyon[c]

[a] Department of Civil Engineering, College of Science and Engineering, Landmark University, P.M.B. 1001, Omu-Aran, Kwara State, Nigeria
[b] Department of Crop Science, University of Benin, Edo State, Nigeria
[c] Department of Civil Engineering, University of Benin, Edo State, Nigeria

ARTICLE INFO

Article history:
Received 7 January 2014
Accepted 19 August 2014
Available online 17 September 2014

Keywords:
Wastewater
Water lettuce
Macrophyte pond
Biofertilizer
Maize plant

ABSTRACT

A 3-year detailed investigation on the use of water lettuce macrophyte pond for the purification of wastewater from rubber processing industries and the reuse of the final effluent as biofertilizer is presented. Baseline wastewater quality information was collected on a monthly basis and analysed for one year before the introduction of water lettuce to 50% pond surface cover. This was done to reliably determine the parameters that exceeded limits and need treatment. These parameters are: phosphate, nitrates, pH, biological oxygen demand, conductivity, turbidity, total dissolved solid and total suspended solid. The effluents from the macrophyte ponds were then monitored mainly on monthly basis for chemical, physical and biological parameters. The treatment and analyses of parameters with exceedance were carried out in the ponds, using the retention periods of 2 weeks, 4 weeks, 8 weeks and 12 weeks for 1st, 2nd and 3rd inoculations. The result of the study showed a progressive reduction in the level of wastewater contaminants fed into the macrophyte pond. Significant reductions within permissible limits were obtained for most of the parameters except TSS and turbidity. Final effluent from the ponds was also found to boast the height, stem girth, leaf area and biomass yield of maize plant. Maximum plant height of 117.5 ± 7.6 cm was obtained using treatment 2 at 63 day after planting. The weight of cob produced from treatment 2 is 46.2 ± 6.1 g while the weight of cob produced by the control experiment is 21.3 ± 6.7 g. The chemical composition of the resulting water lettuce biomass shows it could be utilized as forage for feeding animals.

1. Introduction

Macropytes are known to grow rapidly in wastewater due to the presence of necessary growth requirements (Papadopoulos et al., 2011). They utilize the nutrients in wastewater for growth and other metabolic activities. Water scarcity is usually caused by insufficient local water resources and reduced water quality due to increasing pollution (Jiang, 2009). The release of untreated wastewater into water bodies and land contributes much to this water pollution. It has been estimated that over 40% of the population of the world (representing about 80 countries), are already experiencing water stress, with about 30 of these countries suffering water scarcity in most parts of the year (Kivaisi, 2001). In addition to this natural scarcity of freshwater, the quality of the available freshwater in many developing countries is equally deteriorating as a result of pollution (Kivaisi, 2001). Contaminated drinking water and poor sanitation were reported to rank third in the list of the 20 leading health risk factors in developing nations (Owamah et al., 2013). Furthermore, inadequate energy supply and pollution have been reported as major challenges in Nigeria (Owamah et al., 2014a,b; Dahunsi et al., 2014).

Wastewater pollution from rubber processing industries has been on the increase in Africa and Asia as a result of the increasing number of rubber producing factories due to the presence of virgin forests with large number of mature rubber trees. Rubber producing factories are one of the agro-industries that produce large quantities of wastewater. The practice of indiscriminate discharge of large volumes of wastewater from processing factories to soil and watercourses poses lot of danger to the environment and man. In Nigeria most of the rubber industries discharge their wastes into rivers/streams because they are rarely equipped with

* Corresponding author. Tel.: +234 8035705814.
E-mail addresses: dahilla222@yahoo.com, owamah.hilary@lmu.edu.ng (H.I. Owamah).

http://dx.doi.org/10.1016/j.agwat.2014.08.015
0378-3774/

adequate treatment facilities due to the high cost of conventional treatment technologies. The negative impact of wastewater on the environment calls for the need to develop alternative and economical methods of treatment/utilization. Wastewater reuse is also an important strategy for conserving water resources, particularly in areas suffering from water shortage (Kivaisi, 2001). Constructed wetlands have been reported as cheap technologies and can treat various forms of wastewater of varying strength. They do not need complicated maintenance like other conventional wastewater treatment technologies such as activated sludge system (Stefanakis et al., 2011; Uysal, 2013; Li et al., 2013).

An efficient removal of faecal bacteria from septage in full-scale duckweed-covered pond system was reported by Papadopoulos et al. (2011). Duckweed was equally reported to be efficient for chromium removal from wastewater (Uysal, 2013). Li et al. (2013) reported that the ability of wetland plants to take up nitrogen and phosphorous directly was not affected by the strength of sewage and that total accumulation was governed by the biomass of whole plants. Recent studies have also shown interest in the appropriate selection of macrophyte species for wetlands/stabilization ponds (Li et al., 2013; Brisson and Chazarenc, 2009).

Adsorption through agricultural products such as rice husk, sugarcane bagasse, activated cassava peels, coconut shell, etc. has been extensively studied and found useful and more economical than the conventional treatment system for the removal of toxic metals such as dyes/colour, chromium (Cr), mercury (Hq), copper(Cu), etc. from aqueous solution (Owamah, 2014). Also, the use of microorganisms such as algae, fungi and bacteria for contaminants removal from wastewater has been extensively reported in literature.

Apart from a few reports; Wu (1995), Snow and Ghaly (2008), etc. in literature, information on the use of water lettuce waste stabilization pond for industrial wastewater treatment and the reuse of the resulting effluent as biofertilizer is still scanty. This study was therefore carried out to assess the efficiency of water lettuce based pond for the treatment of wastewater from rubber processing factories. The reuse of the treated effluent as liquid biofertilizer was also investigated. Water lettuce (*Pistia stratiotes* Linn) belongs to the family Araceae. A free-floating aquatic herb with thick, succulent leaves, profuse under water stolons and long, white, unbranched fibrous roots that may sometimes attach to the bottom of shallow waters. It reproduces mainly vegetatively by buds and stolons and rarely produces seeds. They are oblong in shape, 6–12 cm long and 5 cm broad, spongy, strongly inflated and softly hairy on both surfaces, the lower surface has conspicuous veins (nerves) radiating from the base of the leaves. It is a common aquatic weed that occurs in still waters, ponds and pools or in slow flowing rivers and streams throughout West Africa. Aquatic weeds growing in ponds and lakes are beneficial for fish and wildlife. Besides providing food and dissolved oxygen, aquatic weeds can also trap excessive nutrients and detoxify chemicals (Masters, 1991).

2. Methodology

2.1. Sources of effluent, sample collection and analysis

Two rubber factories/sites (Factories A and B) were chosen for this study. The factories were situated along the Ikpoba River which runs across the Eastern end of Benin City, South-South, Nigeria. The entire experiment (baseline wastewater quality monitoring, treatment in the macrophyte pond, and utilization of resulting effluent for growing maize plants) began in November 2003 and ended in March, 2006. The efficiency of water lettuce based macrophyte pond to treat wastewater from rubber processing industries was monitored for three months for each inoculation by varying the retention time. In order to obtain reliable physicochemical and biological parameters of wastewater from the factories prior to treatment in the macrophyte pond, baseline wastewater quality monitoring was performed for one year, starting from November 01, 2003 to November 01, 2004.

2.2. Establishment of water lettuce based pond systems

A batch system of storage ponds was established to compare with a real field macrophyte pond. The ponds were established in plastic pots in the Screen House at the Department of Crop Science, University of Benin, Nigeria. Wastewater quality monitoring was carried out on these pots in order to determine the effectives of a water lettuce based pond for treatment of rubber processing wastewater.

3. Data collection

3.1. Effluent sampling

Effluent samples were collected from November 25, 2004 to September 25, 2005 from the water lettuce based macrophyte ponds. New high-density (polyethylene terephthalate, PET) screw-capped containers of 1.5 L capacity were used to collect the effluent samples. The PET containers and stoppers were thoroughly washed with distilled water for three times before collecting the actual sample. The bottles were immediately stoppered, labelled, ice-cooled and taken to Edo State Environmental Laboratory, Benin, and the Chemistry Department Laboratory of Federal Polytechnic, Ado-Ekiti, all in Nigeria. As was described by Dahunsi et al., 2014 and Owamah et al. (2013), at each site one bottle was filled with effluent having no acid while the other bottle was filled with the effluent from the same point and acidified by adding a few drops of 5% HNO_3 to stop the activities of microorganisms. At the same time, samples for microbial analysis were collected using autoclave-sterilized sample bottles from the same locations. The non-acidified samples and samples for microbial analysis were transported to Edo State Environmental Laboratory, Benin for the analysis of physical parameters, anions and total coliform bacteria while the acidified samples were transported to the Chemistry Department Laboratory of Federal Polytechnic, Ado-Ekiti, for metals analysis. The effluent samples were preserved in a refrigerator at 4 °C to keep the water content intact until analyses were carried out (Owamah et al., 2014a,b; Dahunsi et al., 2014).

3.2. Analytical procedures

The parameters of pH (HI 9024-C, Hanna Instruments, Smithfield, RI, USA), temperature (HI 98517, Hanna Instr.), salinity (HI 19311, Hanna Instr.), electrical conductivity (HI 2315, Hanna Instr.), and total dissolved solids (TDS)(VSI 22, VSI Electronics Private Limited, Punjab, India) were analysed in-situ using the mentioned hand digital meters. Dissolved oxygen of the water samples were analysed using the azide modification of Winkler's method (Owamah et al., 2014a,b). As described in APHA (1992, 2012), chloride was determined by titration. Ultraviolet spectrophotometer screening method was used in the determination of the major anions by strictly following the method described in APHA (1992) using a UV spectrophotometer (DR 2800, HACH, Washington, USA). In order to ensure that the analyses were reliable and reproducible, blank, standard and pre-analysed samples were analysed after every 10 samples (Owamah et al., 2013). Standard methods were used to count the total coli form bacteria as maximum probability number (MPN) in water samples (Owamah et al., 2014a,b). Metals were analysed with atomic absorption spectrophotometer (AAS) (Sens AA 3000, GBC, Australia) following the method in APHA (2012).