Ecological Engineering 84 (2015) 551–558

Contents lists available at ScienceDirect

Ecological Engineering

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

Biological treatment of combined industrial wastewater

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ARTICLE INFO

Article history:
Received 29 March 2015
Received in revised form 2 July 2015
Accepted 4 September 2015
Available online 1 October 2015

Keywords:
Constructed wetlands
Natural treatment systems
Water hyacinth
Chelation

ABSTRACT

This study investigated the effect of three integrated constructed wetlands (CW), which have been considered as efficient and cost-effective natural bioremediation systems for the removal of contaminants. Three kind of constructed wetlands were constructed: one was planted with water hyacinth, one with sludge (anaerobic wetland) and the third act as control. The wetland with water hyacinth was efficient in reducing EC (74.9%), turbidity (92.5%), COD (83.7%), TSS (91.8%), TDS (62.3%), TS (80%), nitrates (67.5%), ammonia (71.6%), phosphates (90.2%), Cd (97.5%), Ni (95.1%), Hg (99.9%) and Pb (83.4%). The anaerobic sludge was efficient in reducing EC (61.5%), turbidity (80.0%), COD (76.35%), TSS (91.9%), TDS (78.4%), TS (80%), nitrates (79%), phosphates (59.6%), ammonia (51.7%), Cd (100%), Ni (92.2%), Hg (100%) and Pb (66.75%). CW with water hyacinth was more efficient in reducing EC, turbidity, COD, ammonia, phosphates, Ni and lead than CW with sludge whereas sludge was more efficient in removing nitrates, Cd and Hg as compared to water hyacinth.

1. Introduction

Due to the current economic and energy crisis in many developed and developing nations, there is a need to implement low cost and efficient natural treatment system for the wastewater treatment. Anaerobic digesters, constructed wetlands, oxidation ponds, facultative ponds, lagoons, anaerobic ponds, terrestrial systems and vermicomposting constructed wetlands are the treatment system that requires low energy input, low operational as well as maintenance cost and results in low sludge output (Mahmood et al., 2013). Methods of improving the quality of water sources and dealing with domestic and industrial wastewater in rural areas have been an urgent concern for developing countries. The application of constructed wetlands (CWs) has significantly expanded from traditional tertiary and secondary domestic sewage treatment to the treatment of agricultural effluents, industrial effluents, landfill leachate as well as urban and high way run off (Wu et al., 2013). The natural wetland system uses mostly natural energy, requires low construction and operational costs, and so is energetically sustainable. However, this assumption is not true for constructed wetlands where some energy input from human source is also required (Mahmood et al., 2013). Wetlands occur in a wide range of landscapes and may support permanent shallow (generally < 2 m) or temporary standing water. They have soils, substrates, and biota adapted to flooding and/or water logging and associated conditions of restricted aeration (Vymazal, 2011). Since 1980 the utilization of the CW for the treatment of variety of wastewater has quickly become widespread. The amount of nutrients removed by plants and stored in their tissues is highly relative which depends on the plant type, biomass, and nutrient concentration in tissues (Korboulewsky et al., 2012). Constructed wetlands (CWs) are land based wastewater treatment systems that consist of shallow ponds, beds, or trenches which contain floating or emergent rooted wetland vegetation (Bilgin et al., 2014). Organic compounds are effectively degraded mainly by microbial degradation under anoxic/anaerobic conditions as the concentration of dissolved oxygen in the filtration beds is very limited (Rossmann et al., 2012). Nitrogen is removed primarily through nitrification (in water column) and subsequent denitrification (in the litter layer), and ammonia volatilization under higher pH values caused by algal photosynthesis. Phosphorus retention is usually low because of limited contact of water with soil particles which adsorb and/or precipitate phosphorus (O'Neill et al., 2011). Phosphorus is removed primarily by ligand exchange reactions, where phosphate displaces water or hydroxyls from the surface of iron and aluminum hydrous oxides. Unless special materials are used, removal of P is usually low in HF CWs (Vymazal, 2010) and also the clay substrate was found statistically more efficient in phosphorus removal than the unit containing sand (Kotti et al., 2010). Wetlands are engineered systems that have been designed and constructed to utilize the natural processes involving wetland vegetation, soils, and the

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http://dx.doi.org/10.1016/j.ecoleng.2015.09.014
0925-8574/

associated microbial assemblages to assist in treating wastewaters. It is known as green technology which uses plants for the removal of contaminants from a specified area, and process is known as phytoremediation (Vymazal, 2010). Chronological phytoremediation with a mixture of plants was more effective than that relying only on a single plant species (Farid et al., 2014). Constructed wetlands can effectively remove suspended solids, organic pollutants and nutrients from wastewater (Vymazal, 2013; Kadlec, 2008; Peng et al., 2014). Probably more than 100,000 CWs worldwide currently treat over billion liters of water per day (Turker et al., 2014). CWs provide an inexpensive and reliable method for treating a variety of wastewaters such as sewage, landfill leachate, mine leachate, urban storm-water, agricultural run-off, are very efficient for nutrient removal are comparatively simple to construct, operate, maintain and are suitable for advanced and polishing treatment if water reuse is an option (Białowiec et al., 2014).

Water hyacinth devoid rhizospheric bacteria reduced significantly naphthalene concentration in water, revealing a considerable plant contribution in the biodegradation process of this pollutant. Water hyacinths enhanced the removal of pollutants through their consumption as nutrients and also through microbial activity of their rhizospheric bacteria (Malkovskaya et al., 2012). The importance of the water hyacinth roots as an attachment media, which is extremely biologically active in assisting the organic carbon removal in the water hyacinth constructed wetland (Mayo, 2014). CW systems with Arundo and Sarcocornia were used for polishing high salinity tannery wastewater. CW systems planted with salt tolerant plant species are a promising solution for polishing saline secondary effluent from the tannery industry to levels fulfilling the discharge standards (Calheiros et al., 2012). Hybrid constructed wetlands proved to be robust configurations for wastewater treatment in the Canary Islands (Meliana et al., 2010).

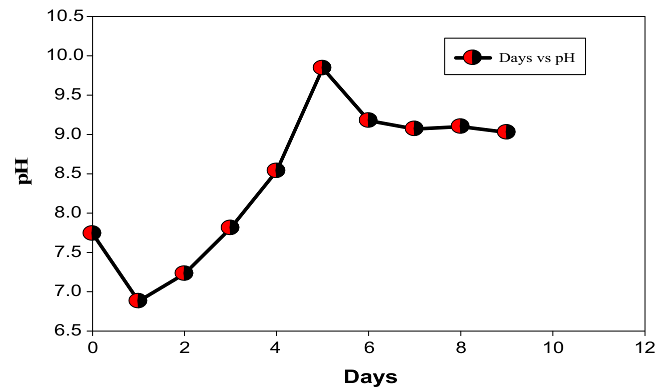

Fig. 3.1. pH dynamics with time in constructed wetland with water hyacinth.

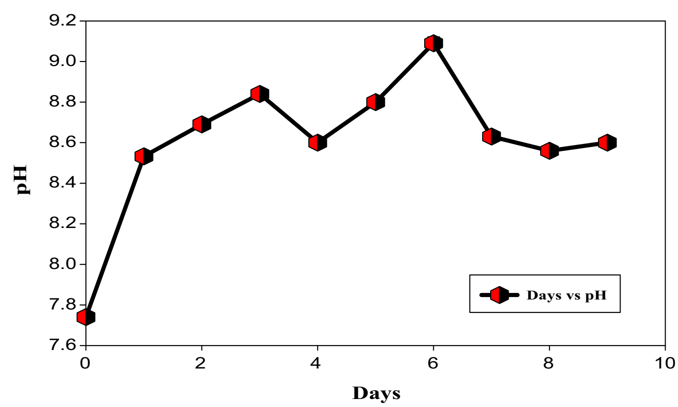

Fig. 3.2. pH dynamics in constructed wetland with sludge.

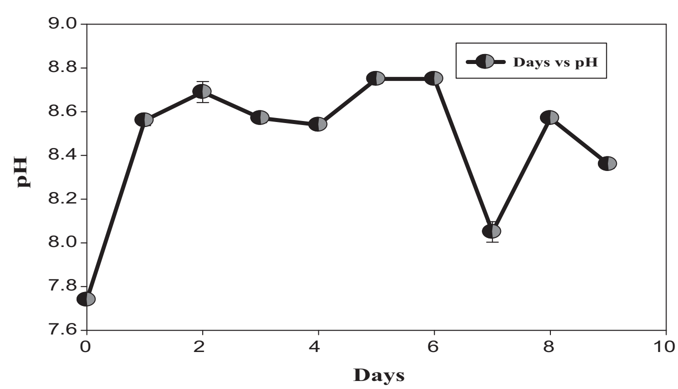

Fig. 3.3. Variation in pH with time in control.

2. Materials and methods

2.1. Collection of wastewater sample, sludge and plants

Grab sampling method was used for collection of industrial wastewater. The industrial wastewater was collected from combined drain at Hattar Industrial Estate, Pakistan. A cleaned cane was pre-rinsed three times and then sample was collected and stored in sampling cane. The physicochemical parameters of water were analyzed in the laboratory within 24 h. The sludge was collected from the municipal committee in a cane and its TS and VS were determined. The plant (water hyacinth) was brought from Swabi, fresh and young plants were collected and were washed properly with distilled water.

2.2. Experimental design

2.2.1. Constructed wetland layering and operation

Three wetlands designed for the treatment of industrial wastewater had length of 120 cm, width of 90 cm and depth of 40 cm, layered with gravel, sand and small crushed gravel, rinsed by HCl solution separately to avoid contamination and then dried in sunlight for 2 days. After drying the wetland was layered. The sand layer was about 5 cm, crushed gravel layer was 3 cm and gravel layer was about 1 cm from bottom to top respectively. Three constructed wetlands were used. In wetland A, aerobic conditions were maintained by growing plants in it, in wetland B, anaerobic

Table 3.1
The effect of treatment on various physico-chemical parameters during one month.

S. no.	Parameter	Initial value	Wetland A (water hyacinth)	Wetland B (sludge)	Wetland C (control)	NEQs
1	pH	7.74	9.026	8.6	8.36	6–9
2	Turbidity (NTU)	31.8	2.38 (92.5%)	6.1 (80.8%)	9.7 (69.4%)	10 NTU
3	TDS (mg/L)	2000	754 (62.3%)	432 (78.4%)	1090 (45.5%)	3500
4	TSS (mg/L)	3000	246 (91.8%)	265 (91.1%)	436 (85.46%)	400
5	TS (mg/L)	5000	1000 (80%)	1000 (80%)	1526 (69%)	
6	EC (μS/cm)	1245	312 (74.9%)	479 (61.5%)	598 (51%)	
7	COD (mg/L)	837.6	136 (83.7%)	198 (76.3%)	587 (29.9%)	150