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Compost leachate treatment by a pilot-scale subsurface horizontal flow constructed wetland

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Compost leachate contains high concentrations of pollutants (including organic materials and nitrogen compounds) that are seriously harmful to the environment and human health. The main purpose of this study was to remove organic materials and nitrogen compounds from leachate produced in Isfahan composting facility by a sub-surface horizontal flow constructed wetland (CW). Two horizontal flow wetlands with the dimensions of 1.5m × 0.5m × 0.5m, were constructed, one was planted with Vetiver grass (*Vetiveria zizanioides*), as Vetiver CW and the other one was kept unplanted as control CW. They were operated with a leachate flow rate of 24 L d^{-1} for over five months. Control and Vetiver CW were capable of removing 21.8% and 74.5% of BOD_5, 26.2% and 53.7% of COD, 17.1% and 69.9% of NH_3-N, 34.1% and 73.5% of NO_3-N and 35% and 73.4% of TN, respectively. This study showed that a sub-surface horizontal flow constructed wetland planted with Vetiver has the potential to be used as a leachate pre-treatment or treatment method to treat highly contaminated composting leachate.

1. Introduction

As a result of growing population and increasingly consumptive lifestyles, the amount of municipal solid waste (MSW) produced has drastically increased during the recent decades. Composting as a way to recycle and re-use organic portion of MSW helps decrease the environmental burdens associated with increasing MSW volumes. Leachate produced during the composting process poses a major problem on solid waste facilities. Compost leachate usually contains high concentrations of pollutants and toxic compounds and release of this leachate prior to proper treatment can cause serious threats to the environment and human health.

Constructed wetlands (CW) are engineered systems created to treat anthropogenic discharges by mimicking biological, chemical, and physical processes that occur in natural wetlands. While, in recent years many studies have focused on treating industrial effluents (Vymazal, 2014), mine drainage (Sheoran and Sheoran, 2006), storm water runoff (Choi et al., 2015), domestic wastewater (Ayaz et al., 2015), and MSW leachate (Bakhshoodeh et al., 2016) using CWs, to the knowledge of the authors, literature available on compost leachate treatment is extremely limited. The main concern in treating compost leachate, using CWs, is the high concentration of organic matter in the stream. Previously many studies have been carried out on high strength waste stream treatment using CWs, showing that relatively good contaminant removal efficiencies can be reached. Table 1 shows some of the studies on high strength, waste stream treatment, using constructed wetlands.

Some of the studies on high strength waste stream treatment using CWs, use a pre-treatment stage. These pre-treatment stages depend on the characteristics of the waste stream and include a wide variety of processes, from simpler ones like, using the leachate for watering composting windrows (Vázquez et al., 2013), settling basins (Newman and Clausen, 1997) or stabilization lagoons (Poach et al., 2003) to more advanced processes like sludge digesters (De la Varga et al., 2013), usage of coagulants (del Bubba et al., 2004), or biofilters (Jing et al., 2015).

Some of the studies, suggest waste stream dilution prior to use in CWs in order to decrease inhibiting substances concentrations and to allow plants and wetlands' microorganisms to develop. Shepherd et al. (2001), diluted winery wastewater with tap water to reach desired COD concentrations prior to treating it in a constructed wetland planted with *Typha dominicus*. Del bubba et al. (2004) diluted olive mill wastewater with the waste stream to water ratios

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Table 1
The concentration of BOD_5, COD, NH_3-N, NO_3-N, and TN in influent and effluent and their removal efficiencies in the studies on treatment of high strength waste stream using constructed wetlands.

Type	BOD_5			COD			NH_3-N			NO_3-N			TN			Ref
	In ($mg L^{-1}$)	Out ($mg L^{-1}$)	Removal Eff. (%)	In ($mg L^{-1}$)	Out ($mg L^{-1}$)	Removal Eff. (%)	In ($mg L^{-1}$)	Out ($mg L^{-1}$)	Removal Eff. (%)	In ($mg L^{-1}$)	Out ($mg L^{-1}$)	Removal Eff. (%)	In ($mg L^{-1}$)	Out ($mg L^{-1}$)	Removal Eff. (%)	
Milk house wastewater	3162	2277	28	–	–	–	8.5	8	6	–	–	–	104[a]	76	27	1
Abattoir wastewater	585	137	77	1440	375	74	112	102	9	1.4	1.6	–	124	109	12	2
Sludge treatment of aquaculture facility	–	–		6855	1761	74				0.057	0.38	–	234	32.5	86	3
Winery wastewaters	1833	49	97	3906	131	97	–	–	–	–	–	–	18.9	4.8	75	4
Dairy parlor wastewater	451	28	93.7	1219	98	92	22.4	24.5	–	–	–	–	64.7	33.3	48.5	5
Dairy farm wastewater	920	29	97	2266	109	95	96.5	29	70	–	–	–	135	39.2	71	6
Mill wastewater	29,000	20,000	42	153,000	109,000	29	–	–	–	–	–	–	–	–	–	7
Swine effluent	411	39	92	1160	190	84	185	144	22	3.7	1.7	54	208	158	24	8
Tannery wastewater	898	440	51	2200	778	64	88	79	10	30	27	10	126[a]	94	25	9
Compost-place raw-wastewater	–	–	–	2170	108	84	134	1.3	96	–	–	–	215[a]	–	98	10
Tannery wastewater	728	236	67	1908	412	78	83	37	55	46	27	41	128[a]	51	60	11
High strength organic effluents	580	218	58-61	790	97	80-87	–	–	–	4.1	1.7	47–58	52[a]	4	89-92	12
Olive ill wastewater	–	–	–	6680	1330	80	16.2	7.6	53	3.6	2.2	40	137[a]	30	78	13
Swine slurry composting	1382	13	94	10,640	626	99	212	6.3	95	4.6	112	–	699[a]	37.3	97	14

1. (Newman and Clausen, 1997); 2. (Poggi-Varaldo et al., 1999); 3. (Summerfelt et al., 1999); 4. (Masi et al., 2002); 5. (Mantovi et al., 2003); 6. (Strusevičius and Struseviĉiene, 2003); 7. (del Bubba et al., 2004); 8. (Lee et al., 2004); 9. (Calheiros et al., 2007); 10. (Lindenblatt and Horn, 2007); 11. (Calheiros et al., 2009); 12. (Chuersuwan et al., 2010); 13. (Kapellakis et al., 2012); 14. (Vázquez et al., 2013).

[a] TKN.

of 1:3 and 1:10 and dilution ratio of 1:10 was proved to be the better option, minimizing the plants suffering and maximizing the removal efficiency. In another study, Darajeh et al. (2014) utilized a wetland planted with Vetiver grass to treat waste stream from a palm oil mill, and reported superior contaminant removal when waste stream was diluted nine times with tap water, comparing to when the stream was used undiluted in the wetland.

The main objective of this study was to investigate the feasibility of using a sub-surface horizontal flow constructed wetland to remove organic and nitrogen compounds from leachate produced in Isfahan Composting Facility (ICF) located in central Iran. Two horizontal flow CWs were constructed, one was planted with Vetiver grass as Vetiver CW and the other one was kept unplanted as control CW. Leachate was diluted prior to use and no pre-treatment was performed before CWs. CWs' efficiency in terms of COD, BOD_5, NH_3-N, NO_3-N, TN, and electrical conductivity (EC) removal are compared and removal mechanisms are discussed.

2. Materials and methods

2.1. Study site

ICF is located at the eastern parts of Isfahan city at 32°61′N and 51°81′E, in central Iran. Around, 1000 tons of source-separated organic MSW enters the facility daily. After entering the ICF, waste gets further separated using magnets and manual labor. Separated organic-waste then gets ground into small pieces and then is moved to the composting site for aerated windrow composting. On a daily basis, ICF produces 4000 L of leachate. (Zazouli and Yousefi, 2008). Produced leachate, using concrete aqueducts, gets conveyed to a lagoon system consisting of five consecutive lagoons. The lagoon system consists of pre-sedimentation ponds, a primary waste stabilization pond (WSP), a facultative WSP, and a maturation WSP. Leachate used in this study was collected from the influent of the lagoon system and was then sent to the constructed wetlands on a weekly basis. Fig. 1 shows the satellite view of the ICF and the lagoon system.

Leachate was diluted before being used in the system. Dilutions using different leachate to tap water ratios (1:5, 1:10, and 1:20) were performed and tested on Vetiver plants and the leachate to water ratio of 1:10 proved to minimize the plant loss while maintaining the lowest possible dilution ratio. Similar dilution ratios have been reported in the literature (del Bubba et al., 2004; Darajeh et al., 2014).

2.2. Experimental setup

Constructed wetlands were made from stainless steel, with dimensions of 1.5m × 0.5m × 0.5 m. To provide a uniform flow distribution, CWs were filled with fine gravel with a diameter of 0.5–4 cm and a porosity of 0.25 in the inlet and outlet area of the bed. The remainder part of the bed was filled with fine sand with a diameter of 1–5 mm and a porosity of 0.48. CWs had a 1% bed slope. One of the CWs was used as a control (without plants) and the other one was planted with Vetiver grass with a density of 16 rhizomes (pieces) per m^2 (Fig. 2). Vetiver is well adapted to the Isfahan climate and is wildly growing in the area surrounding the lagoons. To prevent any possible shock to the plants, they were watered with sufficient amounts of tap water and diluted leachate for 60 days prior to the start of the test. During the experiment, diluted leachate was injected to the CWs with a flow rate of $24 L d^{-1}$. Hydraulic retention time was measured to be five days. CWs were placed outside the ICF laboratory and were monitored from March 2013 to August 2013 for a total of 140 days.