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Research Article

Evaluation of Selected Wetland Plants for the Removal Efficiency of Pollutants from Waste Water

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Abstract

Wastewater from leather processing industries is very complex and leads to water pollution if discharged untreated, especially due to its high organic loading and chromium content. In Ethiopia industrial wastewater has become one of the most serious problems because of the increase in discharge of untreated effluent to the environment. In this paper the phytoremediation efficiency of selected wetland plant species in subsurface flow constructed wetlands receiving tannery wastewater was investigated. The wastewater analysis showed that Cr in the effluent was reduced up to 99.3 % for an inlet average Cr loading rate of 40 mg/L, COD was reduced by 56-80% for an inlet organic loading varying between 2202 and 8100mg/L and BOD_5 was reduced by 66-77% for an inlet organic loading varying between 650 and 1950 mg/L. Despite the high removal of Cr from the influent wastewater, no significant differences in performance were observed between CW units. Plant analysis showed that Roots accumulate significantly higher Cr in all plant species compared with shoots. Constructed wetlands are cost effective and environmentally friendly treatment methods hence can be used us an alternative treatment method in developing countries.

Introduction

In Ethiopia industrial wastewater has become one of the most serious problems because of the increase in discharge of untreated effluent to the environment. High level of pollutants which are discharged into rivers pose severe problems for plant, animal and human health due to their toxicity and persistence in the environment (Zinabu and Zerihun, 2002). The transformation of raw or semi-pickled skins into commercial products requires high water consumption, roughly 50-150 liters and about 300 kg chemicals are added per ton of hides (Anthony, 1997). The major chemicals used in the various processing stages include chromium salts, sulfate, sodium sulfide, lime powder, ammonium sulfate, sodium chloride, sulfuric acid, sulphonated and sulfated oils, formaldehyde, pigments, dyes and anti-fungal agents. These chemicals in tannery effluents cause the highest toxic intensity per unit of output (Khan, 2001). Chrome tanning is favored by the majority of leather industry than vegetable tanning because of the speed of processing, low cost, flexibility and greater stability of the leather (Hafez *et al.,* 2002).

Constructed wetlands are highly complex systems that separate and transform contaminants by physical, chemical, and biological mechanisms that may occur simultaneously or sequentially as the wastewater flows through the system (Wikipedia, 2007). Phytoremediation is the use of plants to remove, immobilize, and degrade or clean up contaminants. Phytoremediation attracts the public attention, due to its appropriate technology with low cost and easy maintenance**.** Besides, the technology is environmentally sound, socially acceptable and economically feasible. Moreover, constructed wetland treatment technology can be used alone or subsequent to appropriate technologies depending on the required treatment goals and hence selected for this study.

The use of chromium (Cr) in chrome tanning, plating, paints, corrosion inhibitors, reinforced steel, textiles, and fungicides contribute to Cr discharge in the environment. However, the tanning industry is one of the major contributors of Cr pollution in many water resources. Tannery wastewater is characterized by being strongly alkaline with a high salt content, one of which is chromium (Bajza and Vreck, 2001). The present chrome tanning practice only 50 - 60 % of chromium applied is taken by the leather and the balance is discharged as waste (Rajamanickam, 2000). This chromium was produced from the tanning operation. Two forms of chrome associated with the tanning industry are trivalent and hexavalent.

Trivalent chromium is mainly found in waste from the chrome tanning process; it occurs as part of the re-tanning system and is displaced from leathers during re-tanning and dyeing process. This chrome is discharged from processes in soluble form; however, when mixed with tannery wastewaters from other processes, if proteins are present, the reaction is very rapid. Precipitates are formed, mainly protein-chrome, which add to sludge generation. Tannery effluents are unlikely to contain hexavalent chromium (Perk, 2006). Dichromates are toxic to fish life since they swiftly penetrate cell walls. They are mainly absorbed through the gills and the effect is accumulative (Perk, 2006).

In pursuit of a better life, industrialization is growing day by day leaving behind the pollutants in the environment. Since most heavy metals are non-degradable and may lead to toxic end products, their concentrations must be reduced to acceptable levels before discharging them into the environment. Otherwise these could pose threat to public health and affect the quality of natural water bodies. The metals of most immediate concern are chromium, zinc, mercury and lead (Masud *et al.,* 2001).

Chromium has a ‘chronic’ toxic effect upon aquatic life (UNIDO, 2000). Dichromates are toxic to fish life since they rapidly penetrate cell walls. They are mainly absorbed through the gills and the effect is accumulative. Concentration of chromium in natural water that has not been affected by waste disposal is commonly ranges from 0.1-0.6 µg/mL (Perk, 2006). However the consumption of contaminated fish, other foodstuffs and drinking water could increase the daily intake levels far beyond those recommended levels.

Investigations have been performed on fish under conditions of exposure insufficient to cause severe toxicity, yet sufficient to cause visible changes in behaviour at a dosages of 0.2 mg/L. It is understood however, that daphnia are even more susceptible at this dosage, thus posing a potential hazard to the food chain for fish (USPHS, 1997). Treatment of tannery effluent is a challenge because it is a mixture of biogenic matter of hides, inorganic chemicals and a large variety of organic pollutant. Chromium and organic matter removal methods are physicochemical and Biological

Physico-chemical methods include precipitation, coagulation/flocculation, adsorption, membrane filtration, ion exchange, advanced oxidation etc. Mostly, chemical precipitation methods are practiced for the removal of chromium and organic matter, but it has the disadvantage of producing secondary byproducts (USEPA, 1999). Conventional treatment methods for removal of chromium and organic matter are simple in principle; however, they are expensive (high operating and maintenance cost, and consumption of chemicals) and also may produced harmful secondary products such as chrome-bearing solid wastes. Using precipitation method there is 99% Cr removal, 85 - 90% BOD removal and 60 - 70% removal if COD can be achieved (Kornaros and Lyberatos, 2006).

Now a day**,** there is a growing interest in the development of new technologies and methods for the purification of industrial waste. Among these methods, biological methods have been recognized as a viable possibility for the degradation of these wastewaters (Delpozo and Diez, 2003). In biological treatment, microorganisms convert metals and organic wastes into stabilized compounds. Typical biological treatment processes includes trickling filters, activated sludge, Sequencing Batch Reactor (SBR) and Phytoremediation.

The trickling or biological filter system involves a bed, which is formed by a layer of filter medium held within a containing tank or vessel, often cast from concrete, and equipped with a rotating dosing device over which the wastewater is gently sprayed by a rotating arm. The filter is designed to permit good drainage and ventilation. In addition sedimentation and settling tanks are generally associated with the system. The microbial growth occurs on the subsurface of stone or plastic media and the wastewater passes over the media along with air to provide oxygen (Evans and Furlong, 2003). Water needs to be trickled several times over the rock before it is sufficiently cleaned. The wastewater percolates over the biofilm growing on the carrier material to achieve a very high biofilm specific area. Using a trickling filter a removal of 85 - 90% for BOD and 60 - 70% for COD can be achieved (Kornaros and Lyberatos, 2006).

Activated sludge process is a continuous or semi-continuous flow system containing a mass of activated microorganisms that are capable of stabilizing organic matter. This process consists essentially of an aerobic treatment and consortia of microorganisms that oxidizes organic matter to CO_2, H_2O, NH_4, new cell biomass and other end products. It is the most widely used biological treatment process because the recirculation of the biomass allows microorganisms to adapt to changes in the wastewater composition by a relatively short acclimation process (Doan and Lohi, 2001).

Constructed wetland is an artificial marsh or swamp, created for anthropogenic discharge such as industrial wastewater, storm water runoff or sewage treatment, and as habitat for wildlife, or for land reclamation after mining or other disturbance. Natural wetlands act as bio-filter or “Kidney’s of Landscape”, removing sediments and pollutants such as heavy metals from the water, and c onstructed wetlands can be designed to emulate these features (Mitsch and Gosseline, 2000).

Constructed wetlands are wastewater treatment systems composed of one or more treatment cells in a built and partially controlled environment designed and constructed to provide wastewater treatment. It has been used to treat many types of wastewater at various levels of treatment (USEPA, 1999). Hammer (1990) defines constructed wetland as a designed, man-made complex of saturated substrate, emergent and submerged vegetation, animal life and water that simulate wetland for human uses and benefits.

Constructed wetlands can be built with a much greater degree of control, thus allowing the establishment of experimental treatment facilities with a well-defined composition of substrate, type of vegetation and flow pattern. In addition, constructed wetlands offer several additional advantages compared to natural wetlands including site selection, flexibility in sizing and most importantly, control over the hydraulic pathways and retention time (Asaye, 2009). In Ethiopia, some researchers have investigated the wide use of constructed wetland for different type of wastewater, including domestic (Birhanu Genet, 2006) and industrial (Tannery wastewater) (Asaye Ketema, 2009) and have shown significant improvements in water quality in these systems.

In addition, constructed wetland attracts wildlife such as bird, mammals, amphibians and variety of dragon flies and other insects make the wetland home (Martha, 2003). For instance, the recent USEPA (1999) publications indicated that more than 1,400 species of wildlife have been identified from constructed and natural treatment wetlands, of these more than 800 species were reported in constructed wetland alone. Moreover, Constructed Wetland plants provide a more aesthetically pleasing alternative than many other conventional wastewater treatment systems (Richard, 1998).

Constructed wetlands are highly complex systems that separate and transform contaminants by physical, chemical, and biological mechanisms that may occur simultaneously or sequentially as the wastewater flows through the system. Nitrogen transformation involves several biological processes. First the nitrogen contained in the protein (hide and skin) and other sources decompose anaerobically to ammonia nitrogen (NH_4^+ and NH_3). Once NH_4^+ is formed in anaerobic phase, it can take several pathways - absorbed by plants, nitrification, denitrification and NH_3 volatilization. In addition immobilized through ion exchange on negatively charged clay soil particle contribute to nitrogen removal (Mitsch and Gosselink, 2000).

In SSF wetlands, emergent macrophytes grow in a saturated substrate which may be intermittently flooded and drained. One of the most important mechanisms for pollutant removal in wetlands is done by biological means (Debusk, 1999a), in which plants play partial role. Plants can be involved, either directly or indirectly, in the removal of pollutants present in wastewater. When plants directly uptake contaminants into their root structures, this process is called **phytodegradation (phytoextraction),** when plants secret substances that adds to biological degradation, this process is called **rhizodegradation**. The process from where contaminants entered the plant biomass and transpired through the plant leaves is called **phytovolatization** (ITRC, 2003).

Wetland plants take up macro-nutrients (such as N and P) and micro-nutrients through their roots during active plant growth. At the beginning of plant senescence most of the nutrients are translocated to the rhizomes and roots (Mitsch and Gosselink, 1993). Aquatic plants have both structural and physiological adaptations to water logging, which allows them to tolerate anoxia in saturated substrates (Mitsch and Gosselink, 1993). Emergent macrophytes that have been used successfully in surface flow treatment wetlands and subsurface flow treatment wetlands are adapted to cope with anoxia associated with permanent water logging or saturated solids respectively. Plants capacity to supply oxygen to the root zone and nutrient uptake varies among species due to the difference in vascular tissue, metabolism and root distribution (Armstrong, 1999). This also suggests that, if the plant is expected to play a major role, the depth of the bed should not exceed the potential root development for the plant species selected.

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