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Research Article

TREATMENT OF HOSPITAL WASTEWATER BY VETIVER AND TYPICAL REED PLANTS AT WETLAND METHOD

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ABSTRACT

In recent years, the lack of water crisis has been considered as a big problem in many countries. In this vein, using the naturally or artificially refined wastewaters in agriculture and other similar applications has been offered as an important and practical solution to solve the problem. The natural method of refining has been a suitable method in comparison to other refinery methods. This method is applied naturally by means of artificial reed. This method has good advantages such as low cost, easy management, low technology required, and finally yet importantly, low energy consumption. Enhancing the reeds' refinement efficiency, different kinds of plants have been used, among which vetiver has unique morphological, genetic, and physiological features. Regarding to the limited information about this plant in refinement of industrial wastewaters, in this research, a comparison between the refinability of hospital wastewater by vetiver and usual reed plants was made in tropical regions.

This is an experimental study which was done during the summer of 1391. In this research, two glass pilot were designed in $60\times50\times100$ cm^3 dimensions. The soil was a mixture of sand, gravel, and typical clay. In this study, the subsurface and continuous system of irrigation was applied. At first, as the primary sedimentation, hospital wastewater was kept in a 220-liter tank for two hours, then, it was led to the reed bed with the hydrological retention time of 4 days and flow rate of 0.85 liters per hour. The chemical parameters such as PH, COD, TP, TN, TSS, BODS were measured based on standard methods in order to analyzing the efficiency of each plant in refinement of the hospital wastewater. Analyzing the gathered data, t-test and Mann Whitney test were administered in SPSS 16.

Based on the findings obtained from this research the removal rate of TN and BOD_5 parameters for vetiver plant were 88.46% and 88.54% respectively, and 75.03% and 82.52% for the reed.

Vetiver plant has unique features such as high resistance to unsuitable environmental conditions and it has a better efficiency in comparison to the reed plant, therefore, it is recommended to be used in refinement of hospital wastewater.

***Keywords**: Hospital Wastewater, Vetiver Plant, Reed Plant, Wastewater Treatment*

INTRODUCTION

Wastewater refinement is of utmost important in the world and it imposes huge expenses on cities and countries. Hence, applying an appropriate technology with regard to the climate condition and social and economic features of the region is very important (Ghaderi, 2004). Generally, wastewaters are divided into two broad categories: urban and industrial. Industrial wastewaters are very important because of its complexity in quality and quantity features. The hospital wastewater is a kind of industrial wastewater. Hospital waste due to a variety of toxic and hazardous substances such as chlorinated organic compounds, heavy metals, cytotoxic compounds, radioactive elements, and chemical solvents, detergents, pharmaceuticals, etc., are of particular importance (Amooyi *et al.,* 2010). Wastewater refinement is done by a variety of natural and artificial methods, each of which has its own advantages and disadvantages. The main problems for mechanical systems are the high cost of construction, high-energy consumption, the need for efficiency, and refinement and disposal of the sludge (Yoosofi *et al.,* 2001). Therefore, experts have always been concerned about accessing to an appropriate and cost-effective natural method of refinement (Ehram *et al.,* 2004).

The natural method of refinement by means of wetlands is a suitable refining method in comparison to other refining methods because of low cost, easy management, low technology required and low energy consumption. In addition, this method improves the environment (Ghaderi, 2004).

The refining systems in constructed wetlands (CWs) are classified in 3 groups: wetlands with a surface water flow (FWS), wetlands with a sub-surface flow (SSF), and wetlands with a mixed flow. The flow direction in the second type can be vertical subsurface (VSSF) or horizontal subsurface (HSSF). In FW systems, the refining process is performed by some complex interactions between the vegetation and the existing biofilm in the water phase located in shallow ponds in which water is flown on the surface. In this system, the layer near the surface is aerobic. In this system the water depth is usually lower than 0.4 meter and the Hydraulic Loading Rates (HLR) is between 0.7 cm/d and 5cm/d. FWs omit the organic materials by microbial methods and the suspended solids by filtration and sedimentation. Generally, in these systems, the removal efficiency of TSS, BOD, COD and pathogens are above 70 percent. In SSF systems which have horizontal and vertical sub-surface currents, the currents are passed through a permeable environment usually consisted of sand, gravel, and rubbles. Nowadays, systems with horizontal sub-surface currents are used more than before.

In these systems, the water flow crosses through a granular bed and gets in touch with a network of aerobic condition, anoxic and anaerobic areas (Zhang *et al.,* 2014).

Generally, the artificial reed is filled with sand and gravel with a certain uniformity coefficient. Then they are covered with various plant species. The vegetation cover

Vegetation cover, because of its supply of oxygen to the bed, accumulation of microorganisms on the roots, absorption of wastewater nutrients, and aide for removing the suspended solids wastewater is important (Sundaravadivel and Vigneswaran, 2001). Furthermore, planting will provide a suitable and dense environment for rhizospheres to activate microbes and release carbon compounds from roots (Zhang *et al.,* 2014).

Consequently, choosing an appropriate plant in the bed helps a lot to improve the system efficiency. One of the plants, which is a particular concern for experts, is vetiver.

Due the specific morphological and ecological characteristics of the plant, vetiver has high tolerance to the climate change, long drought, flood, temperature tension between -14 and 55 $^{\circ}c$, good PH tolerance between 3.3 to 12.5, and high resistance to heavy metals and pesticides (Truong *et al.,* 2008; Barakati *et al.,* 2011).

Of other unique features of this plant are having long, branched, and bulky root which go down for 2-4 meters depth in soil and this leads to soil and soil preservation (Barakati *et al.,* 2011). As the plant roots play the main role in refining the wastewater in wetland method, therefore, with regard to its root and stem, it can be very practical in refining the wastewaters. In a study by Kanokporn *et al.,* entitled as "Refining domestic wastewater by planting vetiver in floating beds" the removal efficiency of TP, TN, and BOD_5 for high dense domestic wastewater in this method are 5.5 - 91.5, 61 - 62.90, and 17.8 – 35.9 respectively (Boonsong and Chansiri, 2008).

In Hadi pourdar *et al.,* study about the use of hospital wastewater in irrigation of green spaces by means of active sludge and through continuous aeration; removal amount of COD, BOD_5, suspended materials, and MPN were reported as 83.7, 86.4, 78/6, and 99.15 percent, respectively (Poordar *et al.,* 2004). Moreover, in some study which is entitled as "hospital wastewater refinement by means of aerobic and anaerobic bioreactors of fixed film the decreasing amount of BOD and COD was reported from 270 to 30 Mg/Li and from 450 to 80 Mg/Li, respectively (Rezaee *et al.,* 2005).

Conclusively, regarding to the fact that not enough research has been done on hospital wastewater natural refinement in Iran, this research was done to compare the effectiveness of refinement through vetiver and reed plants in wetland system.

MATERIALS AND METHODS

The present research was carried out to compare the refinement of hospital wastewater by two plants of vetiver and reed in tropical regions. This experimental research was done in the dessert pilot of public health faculty of Sabzevar university of medical sciences during the summer of 1391.

The Used Pilots: Two glass pilots in $60\times50\times100$ cm^3 dimensions were made in this research (figure1).

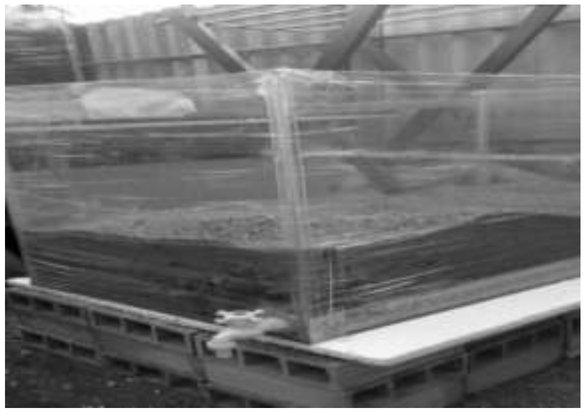


Figure 1: the glass pilots, ready to plant sprouts

The pilots were put in fresh air to improve the precision of the results and to provide natural conditions. The reason of using glass pilots was to observe the root length and the plant growth during the exploiting period. The used soil for plants' growth was a combination of sand (60% because of high penetrating factor of the plant root in the bed) gravel (20% for using in the entrance and exit of the bed and the cover on wastewater collection pipes) and clay (20% to make a better and stronger system of roots in the bed at the beginning stages of growth). At the height of 5 cm above the bottom, a drain valve was provided and some big rubbles were put on it to avoid being clogged.

How to Plant the Plants

According to the previous studies, the suitable temperature for planting the plants is 25°c. therefore, with regard to regional temperature condition, planting was done during the spring (Rahmani *et al.*, 2011). In order to for a better growth in the bed, the Vetiveria Zizanioides (the reason behind this choice is that these species are not productive and as a result, they shall not be considered as weeds) and Phragmites species were used. The sprouts were planted in a 20 cm distance from each other on the surface layer of the soil. Adapting the plant to the bed, the first irrigation was done by urban wastewater. The irrigation method was subsurface and continuous system irrigation method.

The produced wastewater in Shahid Mobini hospital, before leading to the pilot, was kept in a 220-liter tank for two hours, then it was led to the beds through a drain valve with a flow rate of 0.85 liters per hour.

The chemical parameters such as PH, COD, TP, TN, TSS, BODS were measured based on standard methods in order to analyzing the efficiency of each plant in refinement of the hospital wastewater. Sampling was done in a four – hour compound method, twice a week, and during 3 months from entrance and exit part of the pilot. With regard to the faculty facilities, the experiments on BOD_5 and TN were done routinely and twice a week, the experiments on COD were done once a month to investigate its relationship with BOD, last but not the least, the experiments on TP and TN were done twice a month.

It should be mentioned that TP and TN tests were done twice a week because of the same reason. Analyzing the gathered data, parametric and nonparametric t-test and Mann Whitney test were administered in SPSS 11.5. The features of the raw wastewater are listed in table 1 based on the experiments done on the raw wastewater entered into the pilots.

RESULTS AND DISCUSSION

The features of the raw wastewater are listed in table 1 based on the experiments done on the raw wastewater entered into the pilots.

Table 1: The values of different parameters of entered raw wastewater into the pilot

The Exiting Standard for Agricultural Use	Raw Wastewater Values	Parameter
mg/li 100	mg/li 1090.9	BOD5
mg/li 100	mg/li 610	TSS
mg/li 200	mg/li 2694.52	COD
-	mg/li 5.056	TP
-	mg/li 135.478	TN
6-8.5	6.89	pH

As the utility of the irrigation water is conformed based on the amount of minerals it contain, therefore, the low-quality of irrigation water may cause some problems for the soil and plants. Of these problems we can cite salinity, permeability, and toxicity (Poordar *et al.*, 2004).

The results of this study showed that the parameters' values for raw wastewater are all above the standards for being discharged into the environment and agricultural use, except for pH (Ehrampoush *et al.*, 2013). As a result, with regard to the fact that during the recent decades wetlands have become a popular option in wastewater refinement, this method can be approaches as an alternative method because of its high efficiency in contaminant removal, easy installation and maintenance, low energy consumption, high rate of water recycling, and environmental preservation. The comparison of removal rate of BOD_5 between vetiver and reed is shown in.

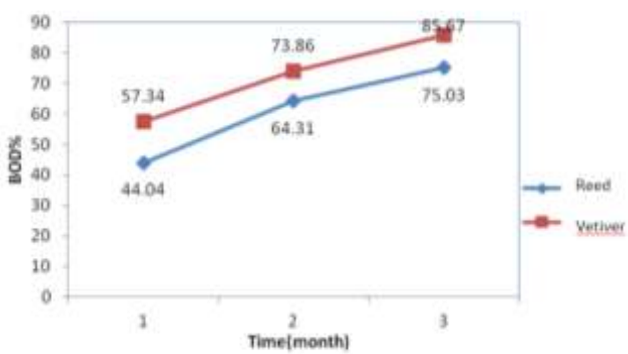


Diagram 1: The comparison of removal rate of BOD_5 between vetiver and reed

The contaminant removal efficiency depends mostly on contaminant loading, hydraulic diet, vegetation cover type, and the temperature. Overally, because of high temperature and direct sunlight exposure of the wetlands, the required time for microbial decomposition decreases and this leads into high efficiency in contaminants refinement and removal (Zhang *et al.*, 2014). BOD reduction in wetlands is due to the aerobic bacteria, which are attached to the bed and plant root. Overally, BOD and COD values indicate the settleable solids, which are settled by a sedimentation process, then are removed from the bed through the metabolic processes of microorganisms and chemical and physical interactions in the root zone.

The results of this research showed that the removal efficiency of BOD_5 for both plants increased over time. However, this increase was more remarkable for vetiver pilot than for reed pilot, during the first week. The results of Mann Whitney statistical test showed a meaningful difference in removal value (P-value = 0.001). In similar studies, the removal efficiency of BOD was reported to be 75.10% for wetlands with horizontal sub-surface flows (Zhang *et al.*, 2014). In addition, in some similar studies, the removal efficiency was reported to be higher for vetiver than reed (Barakati *et al.*, 2011). In an investigation, in

which the removal efficiency for BOD by use of vetiver plant was investigated on three kinds of wastewater, namely, auto repair (w1), spray color manufacturing factory (w2), and agricultural wastewater (w3), the results showed that this plant, in all three types of wastewater, was able to remove BOD for 80%. The results in the present study was in line with the results in the above-mentioned study. Among the reasons behind this higher efficiency in vetiver pilot in comparison with reed pilot may be its faster growth of the plant and its bulkier roots, which leads to better and more accumulation of micro-organisms, and therefore, a better BOD removal. Moreover, bulkier vetiver leaves compared to reed, leads to a better and more oxygen transfer to the roots and stems; this also helps removing the BODs.
The comparison of removal rate of TN between vetiver and reed is depicted in diagram 2 below.

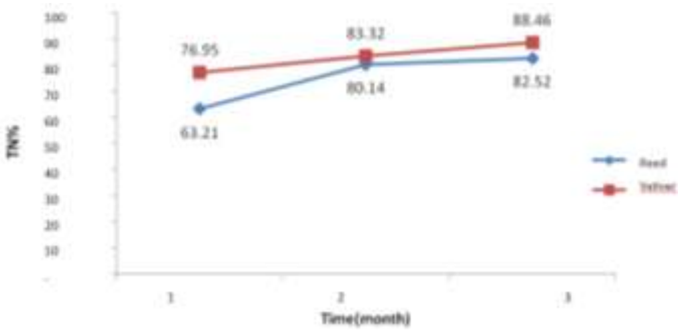
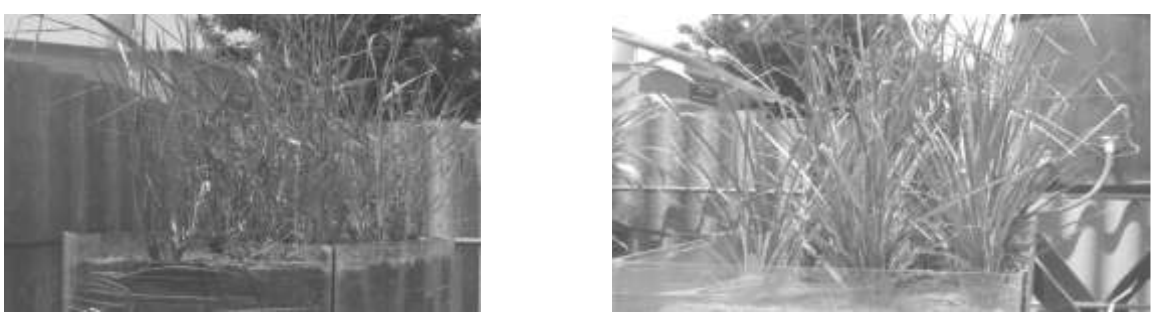


Diagram 2: The comparison of removal rate of TN between vetiver and reed

Nitrogen removal in artificial reeds is due to microbial activities; nitrification and denitrification; evaporation; and plant and bacterial uptake phenomenons. These mechanisms are taken into consideration as the key processes to remove nitrogen in wetlands (Dhanya and Jaya, 2013). In this research, the comparison of removal percent for TN between the two pilots showed a better performance for vetiver plant. However, no statistical significant difference was observed (p-value = 0.082).The results a study showed that NO_3-N concentration decreases by use of vetiver. This plant is also able to remove 100% of NO_2-N from wastewater.
The removal of this factor depends on the current concentration, Nitrogen chemical form, temperature, season, access to organic carbon, and the concentration of dissolved oxygen. Since the microbial conditions were the same for both plants, the plant absorption can be the reason for better efficiency of vetiver in plant uptake, because this plant is classified as C4 (gramineous plants) and it has the highest photosynthesis efficiency (15). Nitrogen uptake by the plant is the dominant mechanism for nitrogen removal (Dhanya and Jaya, 2013). In addition, the accumulation of oxygen around roots leads into more nitrification in this zone that makes the nitrogen removal more probable.
Figure 2 shows a better growth for vetiver. In this figure you can see that vetiver has more leaves and it is more green.



A) Reed **B) Vetiver**

Figure 2: The growth comparison between the two plants after 3 months of being watered with hospital wastewater

Different plant species have different capacity of nutrition uptakes and also different potential of accumulating heavy metals. Results show that the efficiency of contaminant removal is related to the season and growth pattern of the plant (Zhang *et al.*, 2014) and in different conditions they may result differently.

Using vetiver is a new phyto technology. It is a plant with strong structure and high tolerance for variation in wastewater loads. This plant can refine the wastewater without pre-dilution of the wastewater (Truong and Barbara, 2001). Thus, we can consider constructing wetlands (CWs) as the best method for the tropical places. Because hot weather during the year could lead to the plant growth and increase the microbial activities which increases the positive effects on the refinement efficiency (Zhang *et al.*, 2014). Being sterilized, this type of vetiver stops turning it into weeds. As a result, we can use this plant as a good buffer in wetlands. Choosing the continuous flow of water for this study was a suitable option because vetiver consumed more water in wetland than other types of plants.

Based on the experiments, the average of PH variation in the outcome wastewater was 7.07 and 7.09, respectively, for vetiver and reed. Based on the results, the removal efficiency for TP was measured to be 98.06% for vetiver and higher than reed (90.6%). However, this variation in efficiency faded out over time.

However, no meaningful difference was observed based on Mann Whitney statistical test, generally speaking, the removal efficiency for TP by vetiver (99.80%) was more than reed (99.80%).

In similar studies, the removal percentage of phosphor was between 76-91 percent after the second weak and after 3-4 weeks it exceeds 98% (Dhanya and Jaya, 2013). Generally, the removal mechanism of phosphor in wetland is done through microbial plant, chopping, washing, burrying, absorbing in sail in long term because of the contact between wastewater and filtration bed (Zhang *et al.*, 2014) and processes of surface absorption and chemical precipitation.

As the soil quality and its materials, the reason for better efficiency of vetiver in this research was its unique efficiency features in absorption of dissolved nutrients, namely, phosphor (Shooshtaryan and Tehrani, 2010). The use of clay as media materials in pilots has increases the phosphorus uptake (Badaliyans, 2002).

The research has also shown that vetiver has the ability to remove the dissolved nutrients and it decreases the algae (Truong and Barbara, 2001).

Results also indicated that the removal value for TSS for vetiver has a better increasing trend than reed during a period of 3 months. However, no meaningful difference was observed based on the statistical t-test (P-value $\geq$0.05).

Contaminant removal process in wetlands is consisted of biological, microbial changes, and physical and chemical processes such as absorption and sedimentation (Dhanya and Jaya, 2013).

Moreover, while passing materials along bed, other mechanisms such as adhesion, chemical and physical absorption, and clotting process with regard to the materials' and bed's features may affect removal. Generally, solid materials removal is done through a number of complicated processes such as transmitting the solid particles by alive creatures in wetlands, low water speed, the plant cover, bed, and filtration. However, the physical removal of the TSS is usually done by media and the roots (Dhanya and Jaya, 2013; Mofayezi, 2009) (15).

With regard to the stability of media and the type of granulation in both pilot, the faster rate of removal of TSS in vetiver pilot in this 3-months period may be attributed to its morphological and physiological features. Features such as its root which is so bulky with delicate structure, very fast growth rate, and high penetrating power in soil depth. This plant by means of its bulky root and by creating porosity, like a powerful filter traps the coarse sediments and uptakes the nutrients, and provides a good condition for microbiological processes (Truong and Barbara, 2001; Shooshtaryan and Tehrani, 2010).

In this study, regarding to the low-depth of the pilot, the plant root could not penetrate more and it provided a very powerful filter of root mass at the floor of the pilot. This reason was effective in the high removal efficiency of vetiver. In the study done by Barakati *et al.*, the removal percentage of this parameter was reported as 82% and 96.5% for reed and vetiver respectively. This amount was reported to be 98% for reed in the study done by Ghaderi *et al.*, (Ghaderi, 2004; Barakati *et al.*, 2011). In another study, the removal percentage of TDS in wetland which were produced auto repair (w1), spray color manufacturing factory (w2), and agricultural wastewater (w3) were reported as 97.44%, 81,51%, and 80% (Dhanya and Jaya, 2013), respectively. Based on the results obtained from statistical t-test, the removal value of COD (p-value= 0/065) was not meaningful, however, as a whole, the efficiency of vetiver in removing this parameter was more than reed (Vetiver, 90.72% and reed, 81/44%).

Conclusion

Regarding to the fact that the cost for making wetlands is almost one third of the cost for constructing a typical system based on activated sludge process (20), and the results obtained from this research that showed a high efficiency of vetiver in removing BOD; it could be an appropriate plant to establish a green atmosphere for these regions (Dhanya and Jaya, 2013).

Among other reasons for using this plant are the facts that removing the organic materials is more important than other parameters in refining the wastewater because of getting the wastewater free in nature. As the plant of vetiver has the potential and because of its special features, the application of vetiver system (VS) in order to refine the wastewater is a new technology to refine the wastewater by plants which has an extraordinary potential.

We can take vetiver as a natural, green, simple, and economical solution. This plant could grow in dry and hot climate so it is good for making green places because vetiver has very beautiful light-purple leaves and flowers.

Its unique morphological, physiological, economical, and genetic features makes its introduction, identification, and use more important in our country, of course, like any other method, the method of artificial reed with sub-surface flows can be problematic if it is not correctly installed and maintained. In order to prevent these problems in the case of installment we should take into account some topics such as temperature, the wastewater compounds, the bed humidity, and its bottom's penetration. Moreover, some ideas such as pre-refinement, loading shock, reaping the reeds, washing the wastewater distributing network, blocking the holes, etc. should be considered for its maintenance.

Furthermore, one of the other important or main problems or hardness of wetland systems especially in highly-populated regions is that this method needs a lot of lands. If there is enough land, this method could be economical, however, in recent studies we can decrease the land need by baffling the wetlands (Amooyi *et al.,* 2010). Overally, based on the results of the research, the vetiver has an appropriate and high efficiency and using this system in urban and industrial wastewater refinement can be a good option.

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