Chromium Removal Efficiency by *Vetiveria Zizanioides* and *Vetiveria Nemoralis* in Constructed Wetlands for Tannery Post -Treatment Wastewater

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Abstract The purposes of this study were to investigate the efficiency in chromium removal of two species of vetiver grasses : *Vetiveria zizanioides* (Linn.) Nash [Surat Thani ecotype] and *Vetiveria nemoralis* A.Camus [Prajoub Kirikhan ecotype] in constructed wetlands with Free Water Surface (FWS) of tannery wastewater. Twelve experiments of constructed wetland system were built, nine of them were used to study the efficiency of chromium removal and other three units were used to study on plants growth. Wastewater depths in this study were 0.10 m,0.15m and 0.20m in each three units. FWS with Surat Thani ecotype at water level 0.10 m was the best performance for chromium removal which their efficiency was 89.29 %. While the efficiency of Prajoub Kirikhan ecotype at water level 0.15 m was 86.30 % and the lowest efficiency was found in control unit at 0.10 m was 80.72 %. Their efficiency for chromium removal between vetiver unit and control unit were difference at 8.6 %. Comparing of efficiency for chromium removal at the same wastewater depth, Surat Thani ecotype was better than Prajoub Kirikhan ecotype. It can be concluded that optimum FWS for tannery wastewater post-treatment was with Vetiver grass ; Surat Thani ecotype at 0.10 m wastewater depth

The growth ability; dry weight and height during the experiment period, was found that growth of both species were not affected by the three wastewater depths ($p>0.05$). The height and dry weight of Prajoub Kirikhan ecotype was higher than of Surat Thani ecotype in all of water depth.

Key Word: vetiver, chromium removal, constructed wetland
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1 INTRODUCTION

In the tanning industry wastewater has become the most vital problem because of the high growth rate and its enormous discharge quantity especially chromium to the environment. Now most of tanneries use activated sludge treatment system to treat wastewater before discharging. However chromium has contaminated the effluent that tertiary treatment is needed to treat wastewater. Wetland treatment is becoming important tools for assimilating pollutants in municipal, industrial wastewater and agricultural wastewater. Worldwide designers are recognizing the advantages of using wetlands to treat wastewater. In 1993, North America had more than 200 natural and constructed wetlands treatment systems (US EPA, 2000).

The reason that attracts the public attention is that an appropriate technology with low cost and easy maintenance is needed. Moreover, constructed wetland treatment can be used alone or in series with other appropriate technologies that depends on the required treatment goals. The achievement of constructed wetlands depends on ecological functions that are similar to those of natural wetlands, which are based largely on interactions within plants communities (Guntensper et al. 1989).Vetiver grass is interesting plant because it has been extensively used for soil and water conservation and land stability worldwide. Its massive fibrous roots have the opportunity to contact the high levels of metals in wastewater (World Bank, 1987). The goals of this research, were to study the efficiency for chromium removal of vetiver grass in constructed wetlands at different wastewater depth and to study the growth rate of the grass in constructed wetland system.

3 METHODOLOGY

Constructed wetland was designed to be free water surface (FWS) with the following Criteria.

Factors	Typical value
Aspect ratio (m:m)	5:1
Flow rate (m^3d^{-1})	0.04,0.06,0.08
Water depth (m)	0.10,0.15,0.20
Hydraulic retention time (days)	10

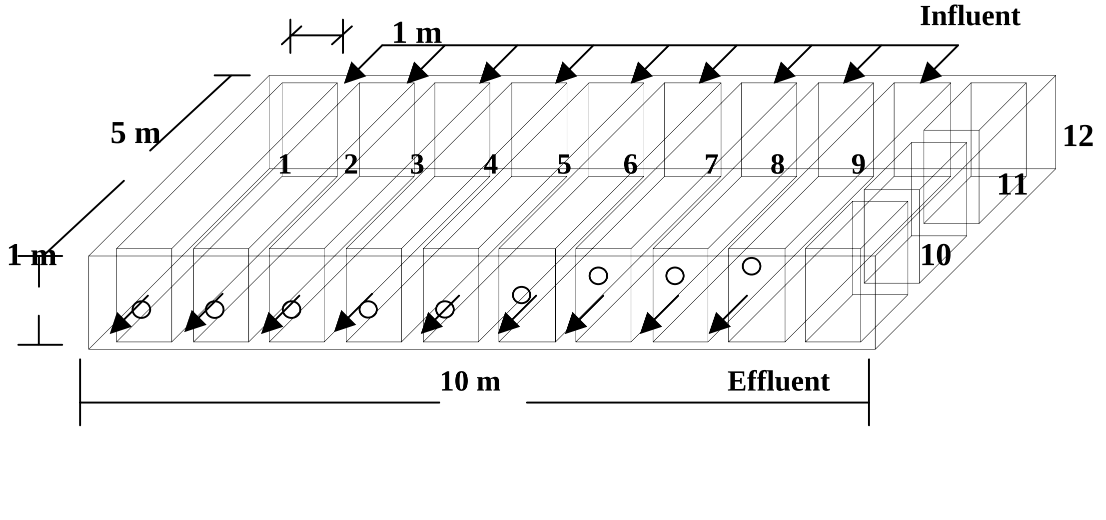
The average flow through the wetland can be calculated by the equation [4]

$$Q = LWdn / t$$

Where
Q = the average flow through the wetland, (m^3d^{-1})
L = length of the wetland cell, (m)
W = width of the wetland cell, (m)
d = depth of water in wetland, (m)
n = the space available for water to flow through the wetland (0.75 for FWS system)
t = hydraulic retention times, (days)

Twelve pilots of constructed wetland systems were made of concrete material. Nine of them with dimension of 1.00 x 5.00 x 1.00 m. (width x length x height) were used to study the efficiency of chromium removal. The others with dimension of 1.00 x 1.60 x 1.00 m were used for studying on plants growth. The experiment was carried out by using two types of the vetiver grass : *Vetiveria zizanioides* (Linn.) Nash (Surat Thani) and *Vetiveria nemoralis* A.Camus (Prajoub Kirikhan), 750 stems of each type were used and all were cut to 0.40 m height. They were planted with 0.20 m intervals in horizontal line and 0.10 m intervals in vertical line. Each experimental unit contained 49 rows (horizontal line) and 5 columns (vertical line) and grown in constructed wetland. The vetiver grass was nourished for 3 weeks to grow-up before the system was operated.

Figure 1. Three-dimension of constructed wetlands pilot scale



S : *Vetiveria zizanioides* (Linn.) Nash   1,2,3 and 10 : water depth = 0.10 m
P : *Vetiveria nemoralis* A.Camus   4,5,6 and 11 : water depth = 0.15 m
N : No plant   7,8,9 and 12 : water depth = 0.20 m

3.1 Wastewater Sample collection

Influent and effluent samples from 9 units were collected every 10 days (retention time) through 100 days experimental period with analysis parameters; pH, temperature, conductivity, salinity, total suspended solid and total chromium amount in soil and plants. All parameters were analyzed according to the methods are pH meter, Thermometer, Conductivity Meter, Salinity Meter, Filtration/Evaporation for analyzed total suspended solid, Mixed Acid Digestion (McBride, 1994) for analyzed chromium in soil and Mix Acid Digestion (Allen, 1989) for analyzed chromium in plants. The growth ability of plant dry weight and height, and total chromium determination in each parts of plant leaves and root.

3.2 Data analysis

1. Comparing the growth rate between experimental unit and controlled unit by using one-way ANOVA at 95% confidence.
2. Comparing the efficiency of two type of vetiver grass in each unit for chromium removal by using one-way ANOVA at 95% confidence

4 RESULTS

4.1 The growth rate of plants

During the experiment, 10 days after planting in all water depths, the growth rate of both types was low. Leaves were narrow and the upper surface had yellow pale color. The growth rate after 10 days was the same as control unit.

4.2 Dry weight

At the end of the experiment, the dry weight of V.*nemoralis* was higher than V.*zizanioides* in all of water depth. Total dry weight was highest at 0.10 m. Statistical analysis by ANOVA demonstrated that water depth had no significant effect on total dry weight.(Table 1)

Table 1. Average dry weight of Vetiver grass at three wastewater depths (g.)

Water Depth (m)	**V.*zizanioides***		**V.*memoralis***	
	Experiment	**Control**	**Experiment**	**Control**
0.10 m	9.776	8.094	13.715	13.711
0.15 m	8.691	7.580	13.297	11.132
0.20 m	8.263	7.916	11.769	11.048
	ns	ns	ns	ns

ns no significant difference at 95%

4.3 Height

Height of two types of vetiver grass in all wastewater depths tended to increase with the experimental period of 100 days. It was found that *V.nemoralis* was higher than V.*zizanioides* in all of water depths. *V.zizanioides* in 0.10m depth was higher than those in 0.15m and 0.20m depths, respectively. Statistical analysis by ANOVA demonstrated that water depth had no significant effect on height (Table 2)

4.4 Wastewater parameter- pH

In all of wastewater depths, the pH value of influent and effluent were the same both in the experiment units and control units. In plants systems the pH effluent of system with plants were much more decreased than with out plant due to the pH was controlled from CO_2 and carbonate. Moreover, dissolution of minerals in soil affected to the increased of pH value. (Table 3)

Table 2. Average height of vetiver grass at three wastewater depths (cm.)

Water Depth (m)	V.*zizanioides*		V.*memoralis*	
	Experiment	Control	Experiment	Control
0.10 m	98.330	106.480	127.892	134.564
0.15 m	93.139	100.307	117.130	120.240
0.20 m	93.259	95.637	110.817	112.230
	ns	ns	ns	ns

ns no significant difference at 95%

4.5 Temperature

Effluent temperature of all experimental units with plant has lower ambient temperature than units with no plant because in experimental units with plant, grass leaves and stems blocked sunlight.(Table 4).

Table 3. pH of influent and effluent wastewater in constructed wetland system

Depth	0.10 m wastewater						0.15 m wastewater						0.20 m wastewater					
Days	V. *zizanioides*		V.*nemoralis*		No plant		V. *zizanioides*		V.*nemoralis*		No plant		V. *zizanioides*		V.*nemoralis*		No plant	
	nf	ff	nf	ff	nf	ff	nf	ff	nf	ff	nf	ff	nf	ff	nf	ff	nf	ff
0	.54	.19	.53	.94	.54	.35	.50	.27	.49	.23	.50	.35	.44	.45	.46	.66	.50	.87
0	.43	.53	.49	.58	.46	.48	.48	.52	.45	.43	.44	.23	.44	.58	.48	.53	.43	.55
0	.49	.16	.64	.01	.51	.39	.49	.08	.47	.02	.49	.28	.47	.36	.46	.26	.49	.53
0	.89	.20	.86	.14	.81	.52	.89	.24	.91	.41	.85	.41	.91	.37	.90	.56	.88	.55
0	.78	.10	.78	.27	.73	.32	.82	.13	.88	.21	.93	.25	.88	.11	.89	.60	.89	.34
0	.76	.02	.79	.05	.88	.65	.90	.08	.90	.13	.94	.67	.95	.09	.96	.79	.96	.29
0	.16	.28	.16	.21	.17	.68	.15	.65	.16	.26	.18	.70	.12	.49	.13	.12	.13	.97
0	.71	.61	.71	.35	.71	.85	.71	.76	.75	.33	.75	.81	.77	.32	.78	.25	.76	.67
0	.64	.18	.62	.11	.62	.51	.62	.21	.62	.18	.61	.71	.65	.15	.62	.83	.65	.05
00	.58	.18	.61	.01	.63	.66	.62	.25	.62	.34	.58	.09	.61	.32	.56	.50	.58	.15

Table 4. Temperature of influent and effluent wastewater in constructed wetland system (c°)

Depth	0.10 m wastewater						0.15 m wastewater						0.20 m wastewater					
Days	V. *zizanioides*		V.*nemoralis*		No plant		V. *zizanioides*		V.*nemoralis*		No plan		V. *zizanioides*		V.*nemoralis*		No plant	
	nf	ff	nf	ff	nf	ff	nf	ff	nf	ff	nf	ff	nf	ff	nf	ff	nf	ff
0	3.0	8.5	3.0	8.4	3.0	8.4	3.0	8.7	3.0	8.6	3.0	8.7	3.0	8.7	3.0	8.8	3.0	8.7
0	0.8	7.3	1.2	6.9	1.4	6.6	0.6	6.7	0.5	6.5	0.4	7.3	1.3	6.4	0.8	7.0	0.6	6.7
0	0.0	8.2	0.7	8.1	0.5	7.8	9.9	8.1	9.9	7.9	9.7	8.3	9.2	8.1	9.3	8.2	9.4	8.1
0	2.5	1.6	2.9	1.1	2.7	1.4	2.1	1.2	1.0	1.3	8.7	0.4	9.9	0.6	0.0	1.3	0.4	0.8
0	0.6	4.5	0.6	4.1	9.7	3.5	9.1	3.4	7.1	3.8	6.2	3.9	4.4	5.0	5.0	4.1	5.9	2.8
0	8.3	5.5	8.9	4.8	8.4	5.1	7.7	4.8	6.9	4.3	6.8	4.8	5.0	4.5	5.7	4.2	5.5	3.8
0	0.0	3.0	1.2	2.6	1.6	2.1	8.7	2.3	7.9	2.3	6.6	1.9	5.3	2.0	7.1	1.8	7.1	2.0

0	0.2	1.0	0.5	1.3	0.0	2.0	8.9	1.5	7.2	1.0	6.0	1.3	3.9	1.5	4.4	1.8	5.2	1.5
0	9.1	1.1	9.4	0.3	9.4	9.7	8.7	0.6	8.6	0.4	8.4	0.7	4.5	0.8	6.0	0.9	7.4	0.9
00	2.2	0.5	9.9	9.7	7.1	9.6	6.9	0.2	7.3	0.1	9.1	0.3	7.0	9.9	8.0	9.8	8.6	0.1

4.6 Conductivity

Conductivity of effluent tended to increase in all of wastewater depth due to the decrease of pH value and temperature (Table 5) . Although with high conductivity, V.*zizanioides* (Linn.) Nash and V.*nemoralis* A.Camus still presented normal growth, because of they are able to grow in various types of pH and soil with high saline (Truong, 1996; truong and Baker, 1998).

Table 5. Conductivity of influent and effluent wastewater in constructed wetland system (ms/cm)

Depth	**0.10 m wastewater**						**0.15 m wastewater**						**0.20 m wastewater**					
Days	**V. *zizanioides***		**V.*nemoralis***		**No plant**		**V. *izanioides***		**V.*nemoralis***		**No plant**		**V. *zizanioides***		**V.*nemoralis***		**No plant**	
	nf	ff	nf	ff	nf	ff	nf	ff	nf	ff	nf	ff	nf	ff	nf	ff	nf	ff
0	1.6	5.3	0.9	4.4	2.5	6.5	1.2	4.4	1.8	2.8	1.3	4.3	2.2	5.8	1.1	2.4	2.4	7.0
0	5.3	6.2	2.0	4.7	2.7	4.1	0.3	2.7	2.4	5.5	0.7	3.8	3.6	3.8	2.3	5.3	4.9	5.0
0	1.6	2.8	2.4	4.3	0.6	3.1	0.8	1.9	2.5	4.8	2.3	4.3	0.7	2.8	0.8	4.1	2.1	4.2
0	0.8	4.2	1.8	2.5	0.5	2.6	2.4	3.6	1.6	3.7	3.0	2.3	1.6	4.3	1.5	3.2	4.3	3.2
0	5.4	4.3	0.8	3.3	3.7	5.5	3.6	3.2	2.3	3.7	3.7	5.8	3.7	4.5	0.6	2.7	3.7	6.2
0	0.8	2.3	2.9	2.8	2.9	2.7	3.0	4.3	2.9	4.0	2.9	7.3	2.9	6.3	2.6	2.8	2.9	7.3
0	2.8	9.6	2.7	8.5	2.5	4.2	2.8	6.2	2.8	5.4	2.8	9.0	2.8	8.9	2.8	4.8	2.8	8.0
0	.40	1.0	1.1	2.5	0.9	1.3	2.9	3.4	1.1	2.7	0.8	1.6	3.1	8.1	2.8	3.1	0.8	1.5
0	1.2	2.6	2.2	4.2	2.2	3.6	2.2	3.2	2.2	4.5	2.7	3.5	3.2	4.2	1.7	2.5	2.2	3.2
00	.89	2.8	3.4	4.8	2.7	3.4	2.8	4.3	3.4	5.3	2.6	4.2	4.5	5.3	2.4	3.6	2.8	4.2

4.7 Salinity

At 0.10m, 0.15 m and 0.20 m in set-up salinity of influent and effluent. Salinity was the same but the end of the experiment, salinity value of effluent tended to decrease because the influent from the factory processes has lower salinity value.(Table 6)

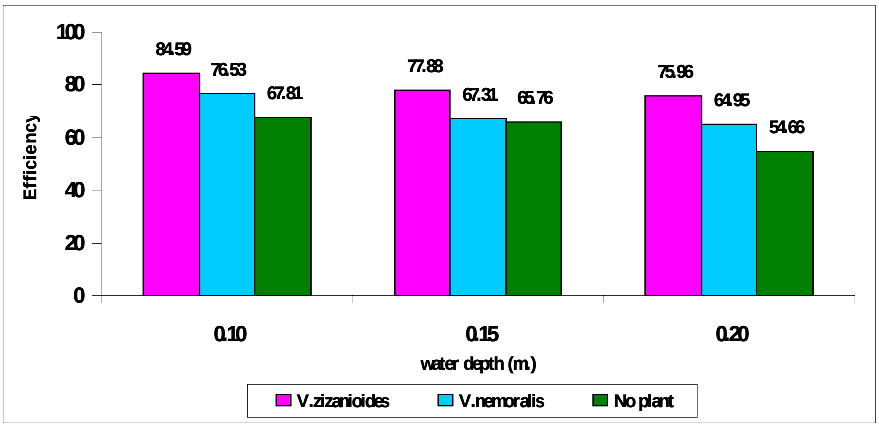
Table 6 Salinity of influent and effluent wastewater in constructed wetland system (ppt)

Depth	**0.10 m wastewater**						**0.15 m wastewater**						**0.20 m wastewater**					
Days	**V. *zizanioides***		**V.*nemoralis***		**No plant**		**V. *izanioides***		**V.*nemoralis***		**No plant**		**V. *zizanioides***		**V.*nemoralis***		**No plant**	
	nf	ff	nf	ff	nf	ff	nf	ff	nf	ff	nf	ff	nf	ff	nf	ff	nf	ff
0	.90	.90	.90	.30	.90	.70	.70	.40	.80	.30	.80	.30	.70	.20	.80	.10	.90	0.00
0	.90	.20	.90	.90	.80	.50	.90	.30	.90	.50	.80	.00	.70	.00	.80	.00	.70	.70
0	.20	.60	.20	.50	.30	.50	.20	.70	.20	.10	.30	.40	.20	.30	.20	.10	.30	.20
0	.20	.10	.30	.10	.20	.30	.30	.00	.30	.50	.50	.00	.30	.60	.30	.50	.30	.60
0	.90	.50	.90	.00	.80	.00	.80	.00	.80	.50	.90	.30	.90	.20	.90	.40	.90	.50
0	.30	.30	.60	.20	.40	.10	.30	.30	.30	.10	.60	0.03	.30	.60	.40	.20	.40	0.02
0	.30	0.16	.30	0.12	.30	.80	.30	.50	.40	.00	.30	0.13	.30	0.12	.30	.30	.30	0.07
0	.00	.20	.10	.90	.10	.20	.10	.40	.00	.40	.00	.50	.00	.20	.00	.10	.00	.50
0	.30	.30	.20	.10	.20	.50	.20	.40	.20	.40	.40	.20	.90	.80	.20	.60	.50	.60
00	.30	.90	.20	.80	.30	.70	.20	.70	.40	.70	.30	.00	.30	.30	.10	.20	.30	.60

The constructed wetland system with V.*zizanioides* had the best efficiency for total suspended solid removal at 0.10 m wastewater depth, 84.59 %, the second and the lowest were the system at 0.15 m and 0.20m, 77.88% and 75.95%, respectively. The Result showed that the efficiency of total suspended solid removal of *V.zizanioides* was higher than *V.nemoralis* in all of wastewater depth due to morphological of *V.zizanioides* had larger clumps from stout rhizomes than *V.nemoralis* and leaves and stems of plants helped to distribute the flow and to filter wastewater solid. The result of the efficiency are shown in Figure 2.

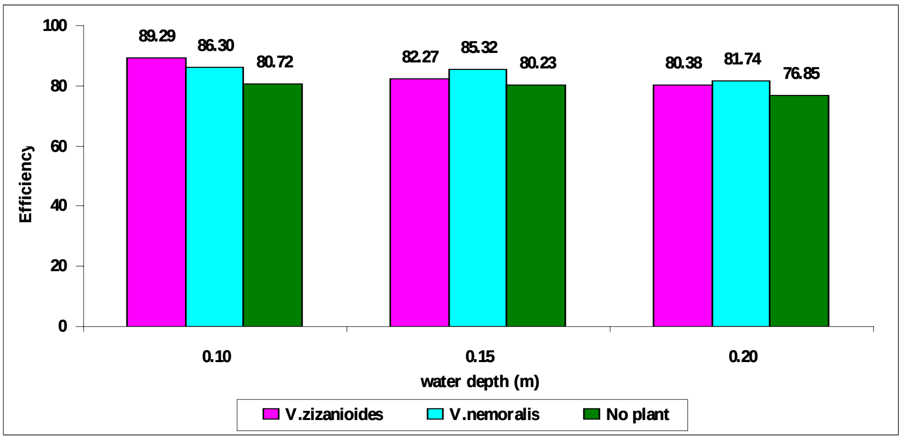
Statistical analysis by ANOVA demonstrated that type of plant and wastewater depth are significant effects on the efficiency of total suspended solid removal. Both type of vetiver grass had the best efficiency for chromium removal at 0.10 m wastewater depth. Moreover, these results showed that constructed wetland system with plant was significantly different from no plant in all of wastewater depths.

Figure 2. Average efficiency of plants for suspended solid at three wastewater depths



The experimental results indicated that the efficiency for chromium removal of the two type of vetiver grass in all wastewater depths had value over 80%. In experiment unit at wastewater depth of 0.10 m *V.zizanioides* had the best efficiency for chromium removal which was 89.29%, while *V.nemoralis* at wastewater depth of 0.10 m was 86.30% and the lowest was the system with no plant at wastewater depth of 0.20m was 76.85 %. The results of the efficiency are shown in Figure 3.

Figure 3. Average efficiency of plants for chromium removal at three wastewater depths



Statistical analysis by ANOVA demonstrated that plant type and wastewater depth had a significant effect on the efficiency for chromium removal. Of the two types of vetiver grass, *V. zizanioides* has a better efficiency in chromium removal than *V. nemoralis*, while the best efficiency was shown at 0.10 m and tended to decrease with increase depth.

4.8 Chromium accumulation in wetland soil beds

In Table 7, showed that the trend of **chromium** accumulation in wetlands soil beds in the entire experiment unit was high along the experimental period. The highest chromium residues in soil were found in all experimental units at 0.20 m wastewater depth. This can be related to the increasing wastewater depth that made higher the sediment.

Table 7 Total chromium accumulation in wetland soil beds of constructed wetland(mg/kg)

Depth	0.10 m wastewater			0.15 m wastewater			0.20 m wastewater		
Days	V. *zizanioides*	V. *nemoralis*	No plant	V. *zizanioides*	V. *nemoralis*	No plant	V. *zizanioides*	V. *nemoralis*	No plant
0	0.175	0.169	0.169	0.179	0.176	0.179	0.178	0.172	0.175
10	0.184	0.173	0.177	0.228	0.215	0.196	0.237	0.214	0.226
20	0.193	0.182	0.184	0.247	0.238	0.219	0.262	0.239	0.238
30	0.206	0.189	0.188	0.265	0.259	0.238	0.281	0.265	0.253
40	0.212	0.196	0.195	0.283	0.275	0.264	0.316	0.298	0.285
50	0.219	0.201	0.204	0.326	0.286	0.285	0.337	0.315	0.317
60	0.227	0.207	0.215	0.330	0.294	0.304	0.358	0.341	0.349
70	0.230	0.218	0.220	0.334	0.327	0.313	0.384	0.366	0.375
80	0.238	0.227	0.225	0.341	0.344	0.322	0.405	0.383	0.398
90	0.247	0.238	0.229	0.357	0.365	0.335	0.427	0.420	0.418
100	0.252	0.245	0.232	0.361	0.371	0.347	0.437	0.432	0.424

4.9 Chromium accumulation in various parts of vetiver grass

For both types of vetiver grass chromium accumulated in root was higher than in leaves. Amount of chromium accumulation in *V.zizanioides* was higher than in *V.nemoralis* in all wastewater depths. *V.zizanioides* at 0.20 m wastewater depth, average chromium accumulation in root and leaves were 0.448 and 0.241 mg/kg (dry weight), respectively. Samilar to *V.nemoralis* at 0.20 m wastewater depth, average chromium accumulation in root and leaves was 0.304 and 0.134 mg/kg (dry weight) , respectively. The result of chromium accumulation in various parts of vetiver grass was shown in Figure 4,5,6 and 7.

Moreover, the accumulation of chromium in roots and leaves of two type of vetiver grass tended to increase in higher wastewater depth. Chromium accumulation in roots was higher than leaves due to the roots had high cation exchange capacity that can absorb chromium when they were contacted directly to wastewater and then transmitted chromium to leaves (Kadlec and and Knight, 1996).

5 CONCLUSION

The efficiency of chromium removal of wetland with *Vetiveria zizanioides* (Linn.) Nash (Surat Thani) at 0.10 m wastewater depth was the best, which is 89.29 %. While the efficiency of *Vetiveria nemoralis* A.Camus (Prajoub Kirikhan) at 0.10 m wastewater depth was 86.30 %. The efficiency for chromium removal between vetiver grass unit and control unit has a difference of 8.6 %. Comparing of efficiency for chromium removal of wastewater at 0.10 m, 0.15 m and 0.20 m was found that the two types vetiver grass had the best efficiency for chromium removal at 0.10 m wastewater depth.

During the experimental period, it was found that the growth of both vetiver grass were not effected by three wastewater depths when compared the experimental unit with the control unit. It was indicated that wastewater depth had no significant effect.

Moreover, the accumulation of chromium in soil and plant tended to increase with passage of time. The highest chromium in soil of *Vetiveria nemoralis* at 0.20 m was 0.432 mgCr/kg soil (dry weight). The accumulation of chromium in plants root was higher than in leaves. Amount of chromium accumulation in *Vetiveria zizanioides* was higher than in *Vetiveria nemoralis* in all of wastewater depths.

Figure 4. Total chromium accumulation in leaves of *Vetiveria zizanioides*

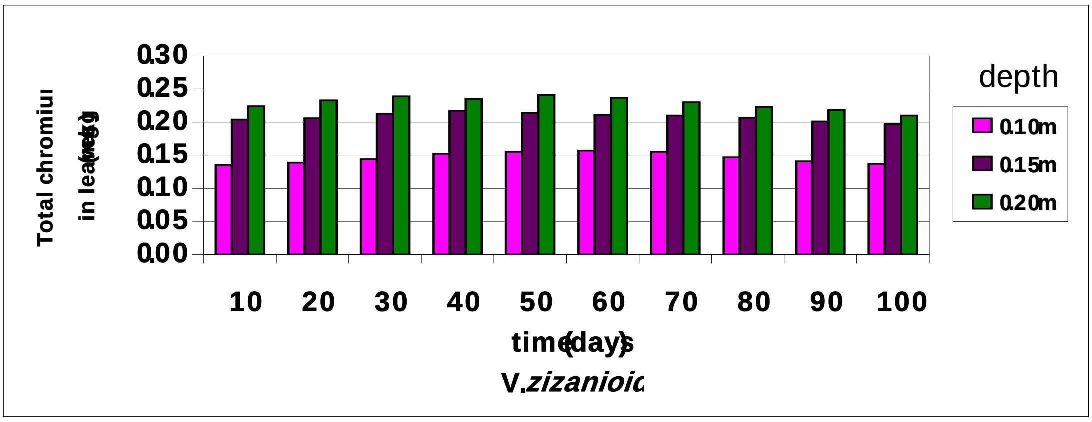


Figure 5. Total chromium accumulation in leaves of *Vetiveria nemoralis*

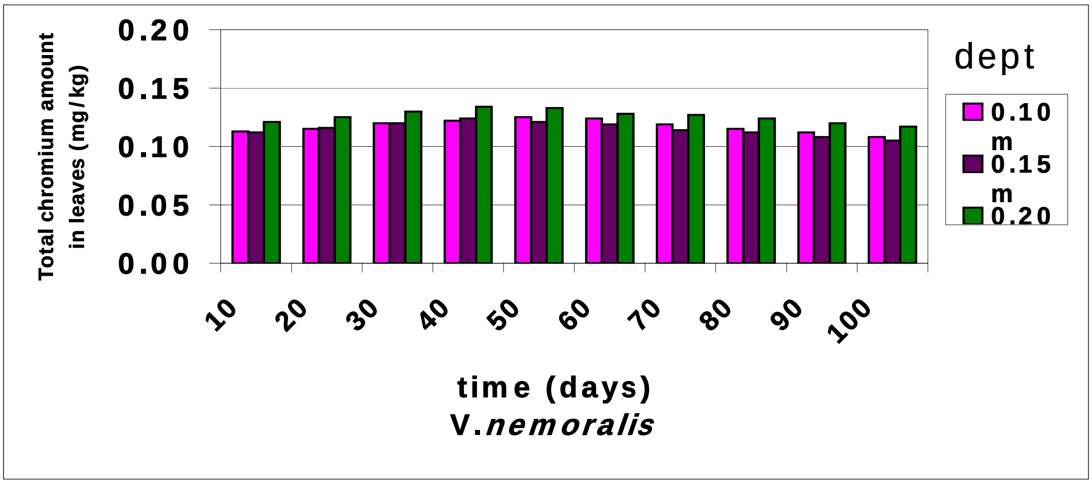


Figure 6. Total chromium accumulation in root of *Vetiveria zizanioides*

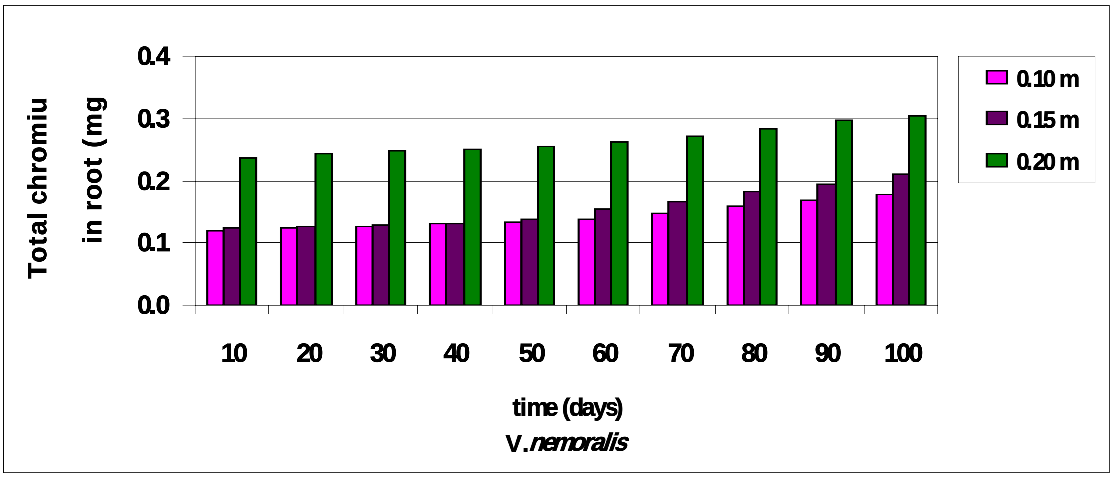
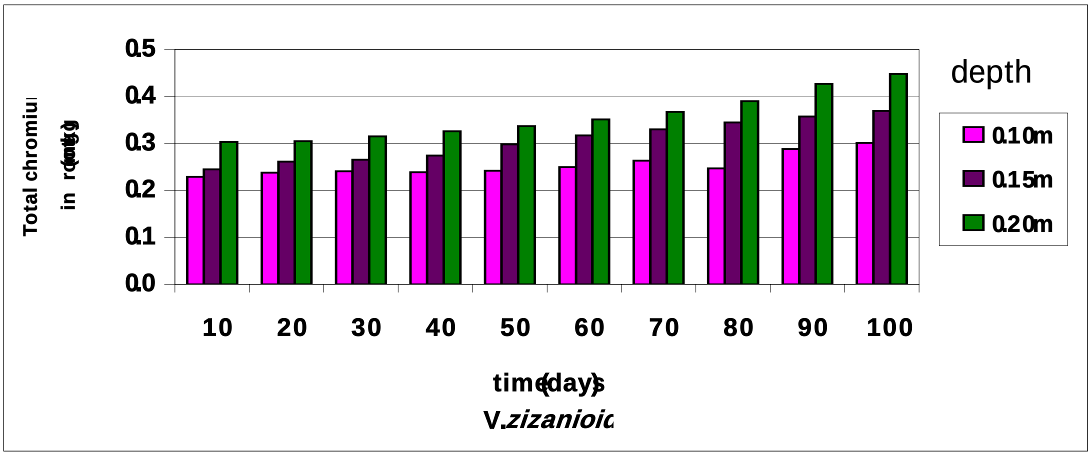


Figure 7. Total chromium accumulation in root of *Vetiveria nemoralis*



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