APPLICATION OF FLOATING VEGETATIVE PADS (FVP)TO IMPROVE STORM WATER QUALITY – A PILOT SCALE STUDY

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Abstract

Henderson Creek contributes one of the largest load of sediments& heavy metals (e.g. Copper - Cu and Zinc - Zn) into the Central Waitemata Harbour, Auckland. Cu and Zn particles do not decompose so they are persistent, accumulating on sediments, in filter-feeding shellfish and in plants, and therefore, aquatic health is affected by turbidity and that degrades stormwater pond ecosystem. It is the one of the key item of the Auckland City Council agenda to reduce Cu and Zn in urban storm water detention ponds in order to protect & improve the aquatic ecosystems' health of storm water ponds in Auckland Region.

A mesocosm study was conducted at Unitec to investigate the performance of Floating Vegetative Pads (FVP, planted with native plants) in terms of their ability to remove heavy metals, particularly, Cu and Zn and the particulates from the storm water detention pond in Hilwell Drive, Henderson. The eight treatments were compared in this experiment i.e. a floating polystyrene pad on its own (treatment G), a floating polystyrene pad with artificial roots (treatment H), and six floating polystyrene pads with six different native plant species (i.e. *ApodasmiaSimilis* – treatment A, *DeschampsiaCaespitosa* - treatment B, *FiniciaNodosa* - treatment C, *HierocloeRedolens* - treatment D, *LachnagrostisBillardierei* - treatment E, *PoaAnceps Blue* - treatment F*)* in six individual buckets). Storm water samples were collected in the buckets from the studied pond, and then analysed for pH, Cu and Zn. Plant growth of the six native plants used in this experiment were measured by an increase in their wet mass from the start (day 0) until the end of experiment i.e. day 21.

Among all the treatments, B and E treatments removed total Cu (i.e. both dissolved and particulate forms - mg) by 30%. Treatment B and F removed the most total Zn (Zn both in dissolved and particulate forms) by 60% and 50%, respectively. It is not clear why treatment D ended up with more Cu and Zn as compared to the initial values, and this requires further investigation. Although the treatments G and H (i.e. without and with artificial roots) removed Cu and Zn by 20%.

The study showed that treatment E had almost 60% increases in wet mass (i.e. increased from 98.5 to 157.5 g/d). The pH of all treatments except treatment G reduced from 7.35 to 6.45. The drop in pH levels could be due to the bacterial activity happening in the rhizosphere, which releases rhizo deposits and that can drop pH.The treatments E and F had the most area daily Cu-mass removal rates i.e. 0.074 and 0.082 $mg/m^2/d$ (i.e. 7.4 and 8.2 $mg/100\ m^2/d$), respectively. Whereas, treatment B performed well in terms areal daily Zn-mass removal rate of 0.496 $mg/m^2/d$ (i.e. 49.6 $mg/100\ m^2/d$).
Key words: Storm water pond, water quality, floating vegetative pads, Copper & Zinc.

1. AN OVERVIEW OF FLOATING VEGETATIVE PADS (FVP)

A FVP (also called as floating treatment wetland system) basically involves the growth of emergent wetland plants on a structure that floats over a pond. Water receives treatment as it passes through the root mass that develops beneath the floating wetland. Fine particles may potentially be entrapped within roots hanging under the mat and/or be associated with biofilms formed around the roots. Floating wetland systems are just like hydroponic systems, as the plants acquire nutrition directly from the water column in which their roots are suspended, rather than the soil (Headley &Tanner, 2006). A cross-sectional view of a typical floating wetland system is shown below.

Cross-section of a typical floating treatment wetland showing main structural elements in comparison with an open-water pond (Source: Headley and Tanner, 2006).

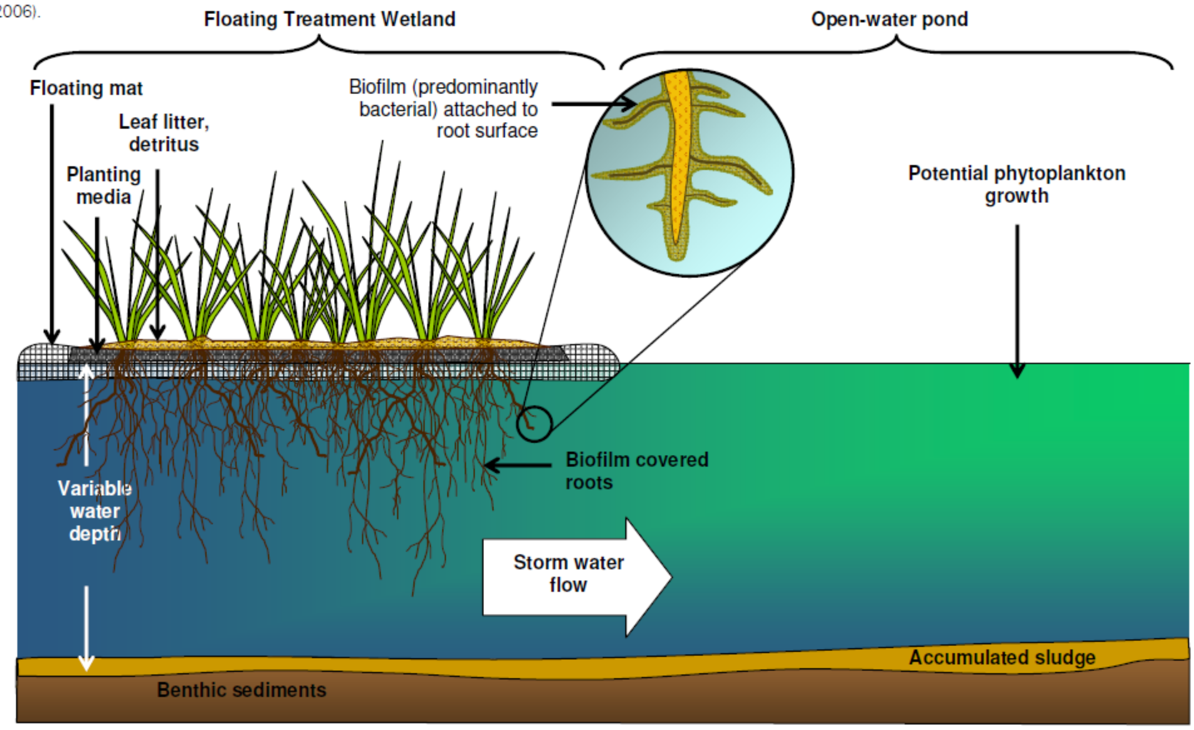

Figure 1: Cross section of a typical wetland showing main structural elements in comparison with an open-water pond (*Sourced:* Headley & Tanner, 2006).

The mechanism to remove metals (such as Cu and Zn) using FVP could be through (i) uptake of pollutant into roots, (ii) sorption on root surfaces, (iii) binding to particles below FVP and then subsequent settlement on the bottom of pond, and (iv) entrapment of pollutants in the roots net and subsequent settlement on the bottom of pond as reported byBorne and Fassman (2011). It has been noted that due to Radial Oxygen Loss (ROL) and the presence of oxidizing bacteria, some heavy metals such as iron or manganese plaques can be formed on the surface of roots (Emerson et al., 1999; Batty et al., 2002). Metals like Cu and Zn can also be sorbed on these plaques (Ye et al., 2001; Batty et al., 2002).

1.1 STUDIED STORM-WATER DETENTION POND

The storm-water detention pond in this pilot scale study was located on Hillwell Drive, Henderson, Auckland. The actual pond size was 1.4 hectares (ha), and it has a catchment area of 124 ha. The pond discharges into WaitemataHarbour via Henderson Creek through an open tidal inlet known as the Huruhuru Creek. Henderson Creek contributes the largest load of sediment, Cu and Zn into the Central

WaitemataHarbour (Green, 2008). The catchment area is fully developed and comprises a mixture of residential and commercial development. The pond is intended to provide a flood peak detention for a variety of storm durations and return periods up to the 1% AEP (i.e. 100 year) storm. The pond has a storage capacity of approximately 4,500m^3. Since 2000, the pond has not been dredged and there is no schedule for one yet (Pers. Comm. Fee Chin, 11 April 2013).

The Technical Publication 237 (2004) of Auckland City Council (ACC) states that although storm water ponds can reduce the rate of contaminant accumulation in receiving waters, but the level of treatment currently attainable will not be adequate to prevent adverse effects in the long term. The research questions we had were: (i) Can we use NZ native plants as in floating pads in order to improve storm water pond quality? (ii) If yes, how effective are they in terms of removing heavy metal from the storm water.Therefore, the aim of this study was to investigate the performance of Floating Vegetative Pads (FVP – planted with NZ native plants) in terms of their ability to remove heavy metals particularly Cu and Zn from stormwater.

2.0 METHODOLOGY

2.1 Experimental Set-up

The experiment was conducted from 26th May to 15th June, 2013. Eight plastic buckets, 10 litre capacity each, were used in this experiment (Fig. 3). Eachbucket was filled with 9 litres of storm-water samples collected from the studied storm water detention pond. The samples were collected from the fore bay at a depth of 300 mm below the water surface from two different sites. The samples were set up in a laboratory under a clear plastic cover wide enough to exclude rain from storm-water buckets while allowing sunshine through for the plants growth.

FVP - The eight treatments were compared in this experiment i.e. a floating polystyrene pad on its own (treatment G), a floating polystyrene pad with artificial roots (treatment H), and six floating polystyrene pads with six different native plant species (i.e. *ApodasmiaSimilis* – treatment A, *DeschampsiaCaespitosa* - treatment B, *FiniciaNodosa* - treatment C, *HierocloeRedolens* - treatment D, *LachnagrostisBillardierei* - treatment E, *PoaAnceps Blue* - treatment F) in six individual buckets (Fig. 3). The polystyrene pad size was 180 mm x 180 mm square by 250 mm thick. The artificial roots for treatment H were created by attaching bundles of branched polyester threads to the under-side of the polystyrene pad (Fig. 2).

Figure 2: Artificial roots created by attaching bundles of polyester threads to the under-side of the polystyrene pad.

Figure 3:Experimental set-up of eight treatments.

Due to the time constraint in growing the native plants, fully grown plants from a native plant nursery were used instead. One fully grown plant per polystyrene pad was used in the experiment. The biomass both above and below the pad plants (roots and shoots included) was taken before they were set in the polystyrene pads and allowed to float on the buckets of stormwater samples.The plants were removed from their original pots and soil was shaken off and rinsed/cleansed with running tap water through them. They were dried with paper towels, hung and air-dried with electric fan. Once dried, each plant was weighed which provided its wet biomass (Fig. 4).

Figure 4: Air-dried plants before weighing to provide their initial wet mass.

2.2 Water Quality Sampling and Analysis

Cu and Zn - The water samples were collected from the six treatments (i.e. from A to F) on day 1 (i.e. 26th May – the starting day), 7, 14 and 21 (i.e. 15th June – the last day of experiment), and then were analysed for total Cu and Zn (i.e. both dissolved and particulate form). The water samples for treatments G and H were only collected and analysed for day 1 and 21 (i.e. at the start and end of the experiment). The water samples were taken from the buckets at 150 mm depth using a plastic syringe after gentle stirrer. Each water sample was taken in a 150 mL plastic bottle. The collected samples were analysed for total Cu and Zn concentrations at the local laboratory using the ICP-MS (Inductively Coupled Plasma – Mass Spectrometry - Talbot & Weiss, 1994) method. Each bucket of storm-water was also weighed on each sampling day in order to monitor evaporation that will affect the concentration of Cu and Zn metals in the bucket.

Turbidityand pH- The turbidity of all collected samples was measured on days 1, 7, 14, and 21 using MICRO TPW field portable turbid meter. The pH of all samples was also measured on days 1, 7, 14 and 21 using the portable pH meter.

Cu and Zn Plant Mass and Areal Mass Removal Rates– The following equations (Headley & Tanner, 2007) were used to estimate the plant mass removal rate for Cu and Zn for 6 treatments.

$$Plant\ Mass\ \mathrm{Re}moval\ Rate(\%) = \frac{M_i - M_t}{P_{mass(t)}} x100 \qquad \text{(Equation 1)}$$

$$Areal\ Mass\ \mathrm{Re}moval\ Rate(mg/m^2/d) = \frac{M_i - M_t}{txA} \qquad \text{(Equation 2)}$$

Where:
M_i= Initial metal mass in storm-water at start of experiment (mg) = concentration (mg/L) x volume of storm-water in the bucket (L).
$M_{(t)}$ = Metal mass in storm-water bucket at time “t” from the start ofexperiment (mg).
$P_{mass(t)}$ = Plant mass at time “t” (mg) = difference in initial and final mass of plant divided by number of days of experiment to obtain daily mass of plant.
t = time since start of experiment (days)
A = surface area of floating pad (m^2)

3. RESULTS AND DISCUSSION

3.1 Copper and Zinc

The measured volume, weight and metal concentrations of all collected storm water samples are shown in Table 1.

The proportion of the total Cu and Zn remaining i.e. (C/C_{in}) in the buckets for all treatments was determined (as shown in Fig. 5 & 6). This was done in order to compare the results between different treatments with slight variations in the starting concentrations of Cu, Zn, and turbidity. The metals concentrations data was normalised by dividing by its initial concentrations (i.e. C/C_{in}).

It is clear from Table 1 that treatments B and E were effective in terms of removing Cu from stormwater by 30%. Whereas, treatments B and F were able to remove Zn by 60% and 50%, respectively. This shows that the pads planted with native bush/plants (i.e. *DeschampsiaCaespitosa* - treatment B, *LachnagrostisBillardierei* - treatment E, and*PoaAnceps Blue* - treatment F*)* had the capacity to remove Cu and Zn between 50 and 70% (overall), and could be used as FVP in order to enhance the performance of storm water detention ponds (*refer* to Table 1, Fig. 5 & 6).

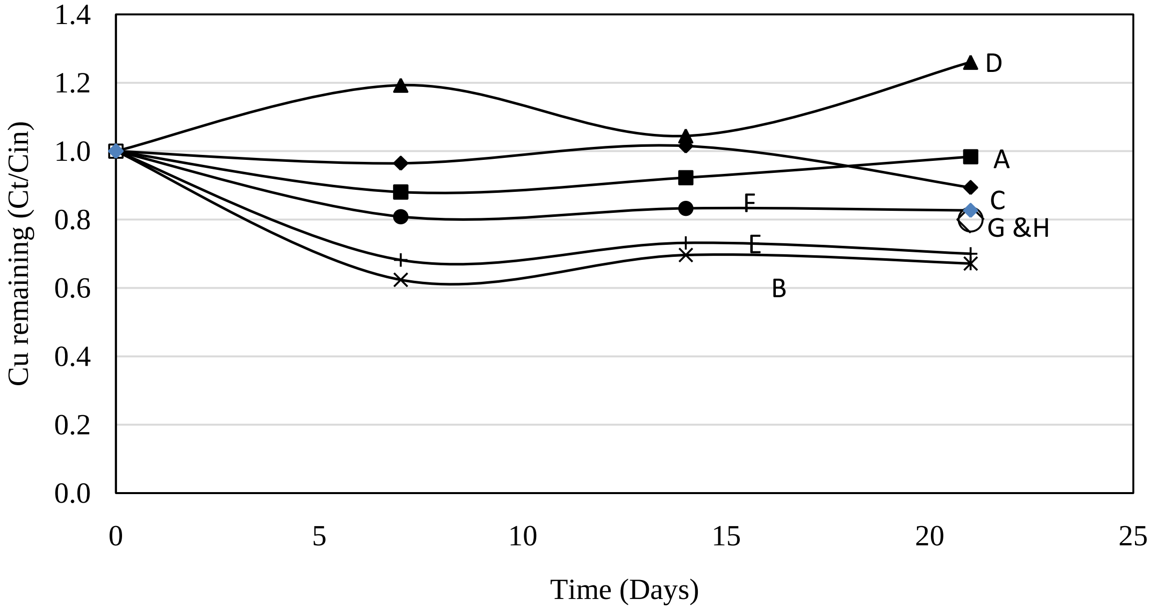

Figure 5: The proportion of total Cu concentration remaining (C/C_{in}) for each treatment throughout the experiment period.

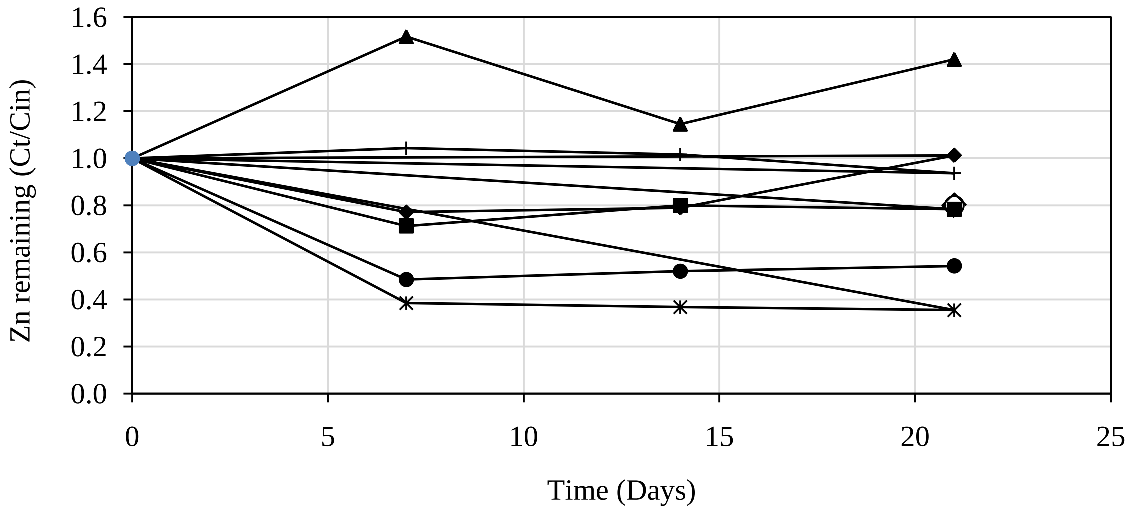

Figure 6: The proportion of total Zn concentration remaining (C/C_{in}) for each treatment throughout the experiment period.

It is not clear why treatment D exhibited a higher Cu & Zn contents at the end of the experiment (than from initial values) as shown Fig. 5 & 6. However, it could possibly be due to the Cu (from fertilizer and pesticide used in the plant nursery) that has been sorbed on to the roots from the soil and has not yet sloughed off during the initial sampling/cleaning, and subsequently settled to the bottom of the bucket while experiment was in progress or due to inconsistency in taking the samples after stirring. In other words, this could be explained by the cycle of entrapment of pollutants in the roots net and sloughing off/settlement to the bottom of the bucket and entrapment into the roots net again after the stirring process when sampling.

Table 1: Table showing storm water samples measured volume & weight, Cu & Zn metal concentrations, and the proportion of CU and Zn remaining in the bucket samples.

Treatments	Day	Cu Conc. (mg/L)	Zn Conc. (mg/L)	Water Volume (V) (L)	Cu weight (mg) = (Conc.*V)	Zn weight (mg) = (Conc.*V)	Cu Remaining = Cu Ct/Cin	Zn Remaining = Zn Ct/Cin
G (Control)	0	0.005	0.03	8.4	0.04	0.25	1.0	1.0
	7			8.3				
	14			8.0				
	21	0.0041	0.025	7.8	0.03	0.20	0.8	0.8
H	0	0.006	0.027	8.8	0.05	0.24	1.0	1.0
	7			8.4				
	14			8.3				
	21	0.006	0.026	7.2	0.04	0.19	0.8	0.8
A	0	0.008	0.048	8.4	0.067	0.40	1.0	1.0
	7	0.007	0.034	8.4	0.06	0.29	0.9	0.7
	14	0.008	0.04	7.7	0.06	0.31	0.9	0.8
	21	0.009	0.043	7.3	0.07	0.31	1.0	0.8
B	0	0.006	0.034	8.5	0.05	0.29	1.0	1.0
	7	0.004	0.014	7.9	0.03	0.11	0.6	0.4
	14	0.005	0.015	7.1	0.04	0.11	0.7	0.4
	21	0.005	0.015	6.8	0.03	0.10	**0.7**	**0.4**
C	0	0.005	0.015	8.4	0.04	0.13	1.0	1.0
	7	0.005	0.012	8.1	0.04	0.10	1.0	0.8
	14	0.006	0.014	7.1	0.04	0.10	1.0	0.8
	21	0.005	0.017	7.5	0.04	0.13	0.9	1.0
D	0	0.005	0.019	8.5	0.04	0.16	1.0	1.0
	7	0.006	0.029	8.4	0.05	0.24	1.2	1.5
	14	0.006	0.025	7.4	0.04	0.18	1.0	1.1
	21	0.007	0.03	7.6	0.05	0.23	1.3	1.4
E	0	0.012	0.048	8.6	0.10	0.41	1.0	1.0
	7	0.008	0.049	8.8	0.07	0.43	0.7	1.0
	14	0.009	0.05	8.4	0.08	0.42	0.7	1.0
	21	0.009	0.049	7.9	0.07	0.39	**0.7**	0.9
F	0	0.006	0.032	8.4	0.05	0.27	1.0	1.0
	7	0.005	0.016	8.1	0.04	0.13	0.8	0.5
	14	0.006	0.02	7.0	0.04	0.14	0.8	0.5
	21	0.006	0.021	6.9	0.04	0.15	0.8	**0.5**

Sample Calculations

Day 21 Cu Remaining Sample Computation for Treatment B:

*Ct/Cin = Cday21/Cday0 = (0.005x6.8)/(0.006x8.5)=
0.666 = 0.7*

Day 21 Zn Remaining Sample Computation for Treatment B:

*Ct/Cin = Cday/Cday0 = (0.015x6.8)/(0,034x8.5) =0.353
= 0.4*

Except treatment D, all the other treatments exhibited a consistent pattern of removing the largest amount of Cu within 7 days and increased gradually until day 14, but decreased a little bit by the end of third week (i.e. day 21).

The treatments G and H (i.e. without and with artificial roots) had a fall in their Cu & Zn levels (as compared to initial levels) by the end of the experiment due to the adsorption functional groups (sulfonates) that polystyrene has, and that is why metals were removed from the storm water (also reported by Park &Na, 2008). The treatment A and C performed the less and were able to just remove Cu and Zn between 10 and 20% (Table 1).

3.2 Plant Growth

Wet mass of the six (6) native plant species used in the water quality improvement trials were measured in the beginning and at the end of the experimentare summarized in Table 1. The figure 7 showed the plant biomass of species used, especially the specie used in treatment E – shown in a circle.

Table 2:Initial and final biomass for six plant species used in this study.

	Species	**Initial Biomass on day 1 (Wet Weight)**	**Final Biomass on day 21 (Wet Weight)**	**Biomass Growth Rate**	
		Initial (I)	**Final (F)**	**[(F-I)/(no. of days)]**	**Biomass Gain (%)**
		(g)	**(g)**	**(g/d)**	**[(F-I)/I]100**
A	*AS*	210	233.5	1.12	11
B	DC	85.2	95.7	0.50	12
C	FN	100.4	97.4	-0.14	-3
D	HR	70.1	70.6	0.02	1
E	LB	98.5	157.5	2.81	60
F	LB	68.3	83.6	0.73	22
G	Polystyrene only				

The plant wet biomass results showed that treatment E and F gained the most biomass i.e. 60% and 22%, respectively (Table 2). There was almost no change in biomass for treatment D before and at the conclusion of the experiment. The treatments A and B biomass increased by 11-12%, whereas, treatment C biomass was reduced by 3%, and this needs further investigation.

Figure 7: Plant roots after the experiment with *L. Billardieri*especie (i.e. treatment E) showing the most root growth (inset, with young roots).

3.3 pH Measurements

Except for day 0 where mean pH for all treatments was alkaline at 7.35, the succeeding means of pH readings on days 7, 14 and 21 became slightly acidic at 6.54, 6.61 and 6.45, respectively. One treatment that remained alkaline for all pH readings was treatment G with very little variation between readings (7.30 – 7.46).

3.4Metal Mass Removal Rates

Table 3: Plant mass and daily areal removal rates for Cu & Zn for six plant species used in this study.

	Treatments	t (day)	Plant Mass Removal Rate =$(M_i - M_t)(100)/(t \times P_t)$ (%)		Areal Daily Removal Rate = $(M_i - M_t)/(t \times A)$ ($mg/m^2/d$)		Areal Daily Removal Rate = $(M_i - M_t)/(t \times A)$ ($mg / 100\ m^2/d$)	
			Cu	**Zn**	**Cu**	**Zn**	**Cu**	**Zn**
Polystyrene only	**G**	0						
		7						
		14						
		21			0.013	0.074	1.3	7.4
	Average							
Artificial roots	**H**	0						
		7						
		14						
		21			0.015	0.074	1.5	7.4
	Average							
AS	**A**	0						
		7	0.0001	0.0014	0.045	0.491	4.5	49.1
		14	0.00006	0.00057	0.022	0.201	2.2	20.1
		21	0.000000	0.00038	0.000	0.134	0.0	13.4
	Average		**6.38E-05**	**0.0008**	**0.022**	**0.275**	**2.2**	**27.5**
DC	**B**	0						
		7	0.00057	0.0051	0.089	0.804	8.9	80.4
		14	0.00014	0.0026	0.022	0.402	2.2	40.2
		21	0.00019	0.0018	0.030	0.283	3.0	28.3
	Average		**0.0003**	**0.0032**	**0.047**	**0.496**	**4.7**	**49.6**
FN	**C**	0						
		7	0.0000	-0.0030	0.000	0.134	0.0	13.4
		14	0.00E+00	-1.50E-03	0.000	0.067	0.0	6.7
		21	0.00000	0.00000	0.000	0.000	0.0	0.0
	Average		**0.00E+00**	**-0.0015**	**0.000**	**0.067**	**0.0**	**6.7**
HR	**D**	0						
		7	-0.0060	-0.048	-0.045	-0.357	-4.5	-35.7
		14	0.00000	-0.0060	0.000	-0.045	0.0	-4.5
		21	-0.0020	-0.014	-0.015	-0.104	-1.5	-10.4
	Average		**-0.0027**	**-0.068**	**-0.020**	**-0.169**	**-2.0**	**-16.9**
LB	**E**	0						
		7	0.00015	-0.00010	0.134	-0.089	13.4	-8.9
		14	5.08E-05	-2.54E-05	0.045	-0.022	4.5	-2.2
		21	5.08E-05	3.39E-05	0.045	0.030	4.5	3.0
	Average		**0.00025**	**-3.11E-05**	**0.074**	**-0.027**	**7.4**	**-2.7**
PA	**F**	0						
		7	0.00019608	0.0027	0.045	0.625	4.5	62.5
		14	9.8039E-05	0.0013	0.022	0.290	2.2	29.0
		21	6.5359E-05	0.0008	0.015	0.1786	1.5	17.9
	Average		**0.0001**	**0.0016**	**0.082**	**0.364583**	**8.2**	**36.5**

Note: Negative sign (-) sign in the above table means an increase in areal daily mass for treatments D and E (i.e. due to increase in Cu and Zn metal concentrations at the end of experiment as shown in Fig 5 & 6).

The daily per unit area and plant mass removal rates are presented in Table 3.

All floating pads planted with native bush were able to remove Zn (from the collected storm water samples) more than Cu. It is clear from Table 3 that treatment B has the most (on average) plant mass removal rate for both Cu and Zn during this experiment (i.e. 21 days). On average, among all species, the areal daily mass removal rate for Cu ranged between 0.013 and 0.082 mg/m^2/d (i.e. 1.3 to 8.2 mg per 100 m^2 per day). The treatment E and F had the biggest areal daily mass removal rate of 7.4 and 8.2 mg/100m^2/d, respectively, for Cu (*refer* to Table 3).

On average, the areal daily mass removal rate for Zn ranged between 0.074 and .496 mg/m^2/d (i.e. 7.4 to 49.6 mg per 100 m^2 per day). The treatment B and F had the biggest areal daily mass removal rate of 49.6 and 36.5 mg/100m^2/d, respectively, for Zn (*refer* to Table 3).

It should be noted here that only one plant was planted per polystyrene pad (i.e. one plant per .032 m^2 pad area). The results could have been better if more plants had been planted per pad.Neither does the data in Table 3 support the findings of Headley & Tanner (2007) that the planted treatments were more effective at removing Cu than the unplanted ones. It is clear (Table 3) that floating pads with artificial roots and without any roots were able to remove Cu (on average) by 0.14 mg/m^2/d and Zn by 0.074 mg/m^2/d, respectively, over 21 days. The treatments D and E had negative values, which means that they were not effective in terms of removing the Zn from the collected storm water samples (as the concentration of the Zn was increased after 7, 14, and 21 days - for treatment E & D).

However both studies (i.e. Headley & Tanner, 2007, and this study) though are in agreement that the role of plants in Zn removal was less clear as both experiments have unplanted treatments removing more Zn than a few of the planted ones. The experiment in Headley and Tanner (2007) had an areal removal rate of Cu and Zn in the order of 3.8 – 6.4 mg/m^2/d and 25 – 88 mg/m^2/d, respectively. In Tanner and Headley (2011) experiment , Cu and Zn had an areal removal rate of 5.6 - 7.7 mg/m^2/d and 25 - 104 mg/m^2/d, respectively which compared favourably with those reported for conventional surface flow constructed wetlands treating urban storm water (Kadlec& Wallace, 2009). It should be noted that there were 44 plant species planted per m^2 in both studies (i.e. Tanner & Headley, 2011).

3.5 Brief General Discussion

A lot of studies have been conducted on the use of floating pads for wastewater in New Zealand. It is reported that FVP could remove 96% of ammonium over 6.7 days, and 85% dissolved reactive phosphorous over 13.6 days (Headley & Tanner, 2007; Stewart, 2007; Li et al., 2010). However, a little amount of work is done on the use of floating vegetative pads to treat storm water. There is only one piece of work that deals with the removal of Cu and Zn from stormwater runoff, and it was not a full field scale study (Tanner & Headley, 2011).

Borne &Fassman(2011) reported a detailed mechanism to remove pollutants from wastewater using the FVP. They reported that (also mentioned above in section 1) that heavy metal could be removed (from storm water using FVP) by different mechanisms such as (i) uptake into the roots, (ii) sorption on root surface and (iii) entrapment in the roots net and subsequent settlement on the bottom of the pond. However, it is not known what proportion of metals removal occurs in each of the above listed mechanisms. Therefore, an assessment of each of the above listed mechanism could provide further answers. The size and design of FVP (in terms of plants age and number of plants per m^2) may have a significant impact on each of the above mentioned mechanisms.

It has also been reported that it could be due to ROL, presence of oxidizing bacteria, and some iron or manganese plaques that can be formed on the surface of roots, and Cu and Zn can be sorbed on these plaques(Borne and Fassman, 2011; Emerson et al., 1999; Batty et al., 2002; Ye et al., 2001& 1998).

4.0 SUMMARY AND CONCLUSIONS

It is well know that the control of Cu and Zn pollutants and suspended solids would mitigate the adverse effects on stormwater quality in terms of both on aquatic life and human environment. The proper control of these pollutants will minimize degradation of the aquatic ecosystem in the receiving waters. Restoring ecological and spiritual integrity of degraded waterways is a very significant principle in local Maori believes. Restorative action including improving water quality is seen as a priority, particularly with respect to resources of high ecological or cultural value. In addition, the fully grown plants floating on the pond will improve the landscape besides providing habitat for wildlife. Keeping in view the aim and research questions of this study, the following conclusions could be drawn from this work.

1. Overall, treatments planted with local species (i.e. treatments A, B, C, E, and F) did perform better in terms of removing Cu and Zn than the unplanted treatments (i.e. G and H), except for treatment D which ended up having more Cu and Zn at the end of the experiment (as compared to initial values). Generally speaking, the results showed that FVPwere capable of removing Cu between 10% and 30% in all treatments (except treatment D), and Zn between 10% and 60%. The treatment B and F removed Cu by 30%, and Zn by 60% and 50%, respectively.
2. Although treatments with polystyrene alone and polystyrene + artificial roots did perform well in the removal of total Cu and Zn (i.e. by 20%) and particularly fine particulates, even better than some planted treatments such as treatment C & D.
3. The results showed that pH was dropped from 7.35 to 6.45 in all treatments (except treatment G), and this could be due to the bacterial activity in the vicinity of plant roots in water (also reported by Borne&Fassman, 2011).
4. The results also showed that the treatment E had the most increase (i.e. 60%) in its wet mass at the conclusion of the experiment, followed by treatment F (i.e. 22%). Plant roots are important in removing Cu and Zn and fine particulates from the storm water samples. They have the ability to uptake Cu and Zn into them as well as sorb these pollutants on to their surfaces (also reported by Borne &Fassman, 2011; Headley & Tanner, 2007). Plant roots also have the ability to entrap fine particulates into their nets and biofilm reduce turbidity.
5. In terms of Cu and Zn mass removal rate per unit area per day, the treatments E and F were able to remove Cu the most i.e. 7.4 and 8.2 mg/100 m^2/d, respectively. Whereas, the treatment B removed the most Zn i.e. 49.6 mg/ 100 m^2/d. Remember, in this study only one plant was planted in each floating pads.

5.0 RECOMMENDATIONS

The findings of this study provide a strong support for experimenting FVP planted with local plant species under more variable field conditions in order to test the long term effects/abilities of using FVP to enhance storm water quality.

Therefore, it is recommended that:

1. FVP planted with native plants should be trialled in storm-water ponds that receives significant loads of metals and sediments (i.e. commercial and industrial catchments areas).
2. A study should be done to determine the optimum ratio of the pond’s open water to the size of the Floating Vegetative Pads collectively as well as the number of plants they require
3. More quantitative type experimental work needs to be done usingother types of native wetland plants to find out if they are even better to remove Cu and Zn and other nutrients from storm water ponds.
4. Determine how to grow and establish the plants successfully from seeds since the plants used in this experiment were already full grown at the start.
5. Determine the most efficient positioning of the FVP on the pond (in a full field scale level study) and how to anchor them safely to prevent them from shifting.

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