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TRANSFORMATION TOWARDS SUSTAINABLE  
AND RESILIENT WASH SERVICES

## Treatment potential of *Typha latifolia* in removal of heavy metals from wastewater using constructed wetlands

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*The objective of the study was to evaluate the phytoremediation potential of the aquatic macrophyte *Typha latifolia* for removal of cadmium, chromium and lead from synthetic wastewaters in constructed wetlands (CW). Four laboratory scale CW units were set up, each containing granite and soil. *Typha latifolia* was planted in the 1<sup>st</sup> unit then intercropped with *Vetiveria zizanioides*, *Phragmites australis* and *Cyperus latifolius* in the 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> unit respectively. The units were treated to wastewaters of different metal concentrations and metal combinations. Wastewater was sampled at different retention periods. Results showed substantial reduction in metal concentrations. Metals were removed in the order Cr>Cd>Pb with maximum removal efficiencies being  $96.36\pm0.52\%$ ,  $95.70\pm1.26\%$  and  $80.59\pm3.58\%$  for Cd, Cr and Pb respectively in the typha only units. The percentage removal of the metals increased with increase in retention time. This study recommends application of *Typha latifolia* in treatment of industrial and mine wastewaters.*

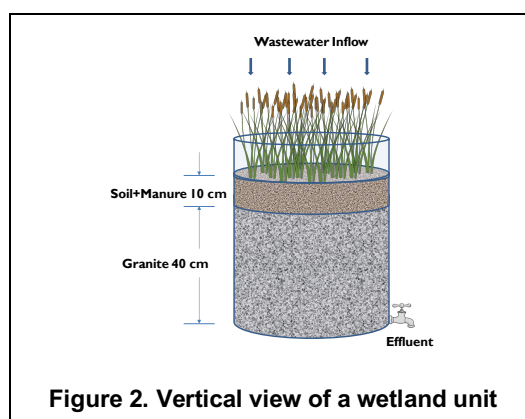
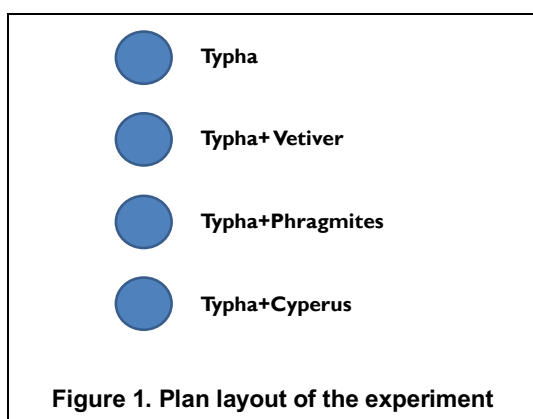
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### Introduction

Environment may become contaminated with heavy metals as a result of natural occurrences as well as through emissions from rapidly expanding industrial and mining and mineral processing activities which release wastewaters that have high concentrations of toxic heavy metals (Sahu, 2014). Once in the environment, these metals are difficult and expensive to remove (Ali et al., 2013). Heavy metals are non biodegradable and therefore persist in the environment for a long time, causing irreversible damage to the environment (Iyengar, 2015). Owing to their toxic nature even at low concentrations (USEPA, 1996), heavy metals are known to cause enormous and irreversible damage to human beings and other living organisms by inducing cancer and damaging body organs (Abas et al., 2013; Iyengar, 2015). Cadmium (Cd), chromium (Cr) and lead (Pb) are heavy metals that are ranked among priority pollutants considered to be of great public health significance and concern (USEPA, 1996). Heavy metals need to be removed from wastewater prior to its disposal into receiving bodies (Abas et al., 2013). Removal technologies that have been in use, based on conventional treatment methods, are expensive and unfriendly to the environment (Odinga et al., 2013). Effective, environmentally friendly and affordable technologies are required in solving the problem of pollution of the environment with heavy metals. Constructed wetland technology has been acknowledged as an affordable and environmentally friendly technology (Sahu, 2014). However, despite its being cost effective and environmentally friendly, field application of constructed wetland technology has only been reported in developed continents such as America, Europe and Asia (Ranieri & Young, 2012). In most developing countries, these are yet to become available probably due to inadequate awareness. In a constructed wetland, plants are known to absorb and accumulate metals in their organs, thereby reducing the concentration of the metals in the wastewater (Abdelhakeem et al., 2016). The plants can be harvested after some growth period and either incinerated or composted to recycle the waste. If the harvested plants are incinerated, the ash produced whose volume is much less than the plant volume is disposed off in a hazardous waste landfill. This study aimed at assessing the performance of constructed wetlands planted with *Typha latifolia* in treating synthetic wastewaters contaminated with Cd, Cr and Pb.

## Methods

This study explored the potential use of *Typha latifolia* in removal of Cd, Cr and Pb from synthetic wastewater. An experiment was set up within Daspoort wastewater treatment plant in Pretoria West (25°44'S, 28°10'E), South Africa, consisting of lab scale wetland units planted with *Typha latifolia* as well as a combination of *typha latifolia* with *Vetiveria zizanioides*, *Phragmites australis* and *Cyperus latifolius*. The constructed wetland experiments consisted of 0.56 m diameter plastic containers that contained a 0.4 m deep layer of granite at the bottom and a 0.1 m layer of soil mixed with manure on top of the granite for plant growth (Figures 1 and 2). Synthetic wastewaters containing heavy metals were prepared by mixing measured quantities of metal salts cadmium nitrate, potassium dichromate and lead nitrate with tap water according to the parameters under study. The solutions were prepared with metal concentrations ranging between 1 and 5 mg/l for single-metal (Cd, Cr and Pb) and multi-metal (Cd+Cr, Cd+Pb, Cr+Pb and Cd+Cr+Pb) wastewaters and between 4 and 21 mg/l for wastewaters of varying initial metal concentrations (5, 10, 15 and 20 mg/l). The pH of the solutions was adjusted using HNO<sub>3</sub> and NaOH. The units were operated in batch flow mode in which each unit received 50 litres of synthetic wastewater which was introduced into each unit from the top and allowed to percolate downwards. Sampling of single- and multi-metal wastewaters was done at 0, 3, 6 and 9 days while wastewaters of varying initial metal concentration was sampled at 0, 0.25, 1, 3, 6, 9, 15, 20 and 24 days after application of the metal solutions. The sampled waters were analysed for Cd, Cr and Pb using inductively coupled plasma (ICP), the concentrations of which were used in the calculation of metal removal efficiencies for the different wastewaters. Height measurements of the tallest typha plants was also done on days 0, 14, 30, 40, 60, 66, 67, 68, 70, 72, 75, 79, 88, 96, 107, 131 and 138.



All statistical analyses were conducted using Statistical Package for Social Science (SPSS). Statistical analysis was carried out by one way ANOVA using student's t-test to test significance of the difference between mean values.

## Results and discussions

### Application of single-metal wastewater

#### *Effect of metals on plant's growth*

The maximum heights reached by typha in the different metal solutions in a period of 150 days of growth, with wastewater being applied at day 60, are shown in Figure 3. Results show that the heights of typha in the different wastewaters increased with time within the experimental period, with a rapid increase at the beginning after application of the metal solutions followed by growth rate reduction. The rapid growth in Cd and Pb wastewaters could be attributed to the nitrates present in the salts that were used to prepare Cd and Pb solutions. In the case of Cr, rapid growth could be as a result of introduction of potassium since Cr solution was prepared from potassium dichromate. This agrees with Suhendrayatna et al. (2009) who reported that Cr, Pb and Cd were found to improve growth of vegetables.

Typha was able to grow well in environments contaminated with heavy metals Cd, Cr and Pb. The growth was however observed to be least in the Cd media with the height in Cd media being lower than the heights in the Cr and Pb media. This implied that, compared with Cr and Pb, Cd had some retarding effect on growth of typha, possibly attributed to the inhibition of mitotic index (tissue growth) as noticed by Vecchia

et al., (2005) in Cd metal treatment. A reduction in growth of other plants as a result of Cd is also supported by other researchers such as Mandakini et al., (2016) and Zhang et al. (2014).

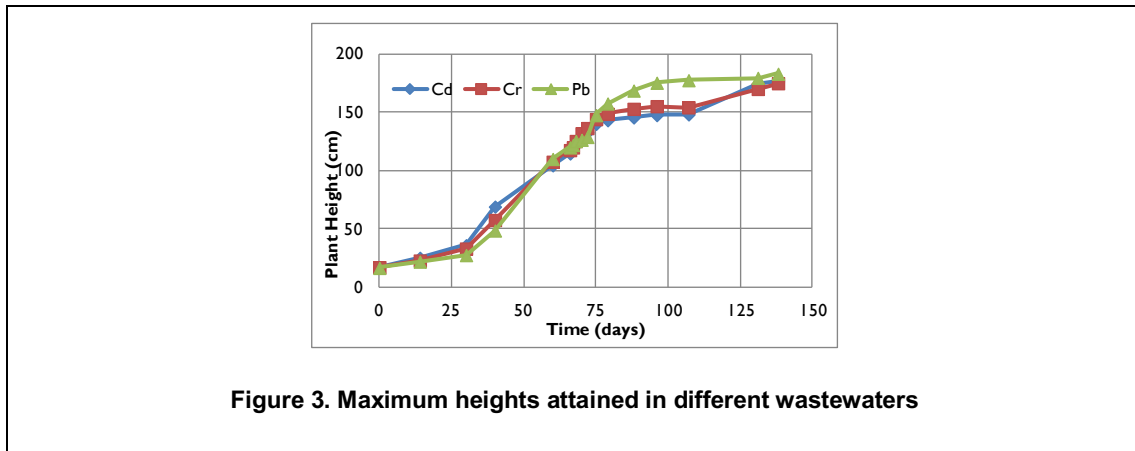


Figure 3. Maximum heights attained in different wastewaters

**Effect of contact time and plant combinations**

The removal efficiencies when typha was grown on its own and when grown in combination with another 3 plant species (vetiver, phragmites and cyperus) are shown in Figures 4 (a), (b), (c) and (d) respectively.

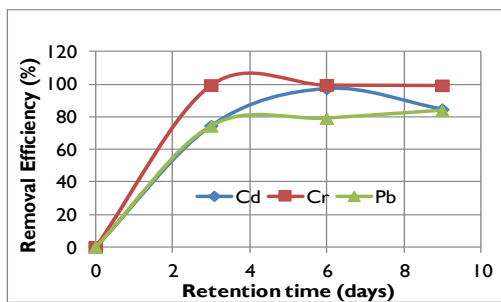


Figure 4(a). Typha

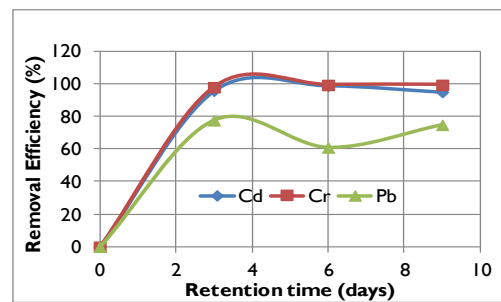


Figure 4(b). Typha+vetiver

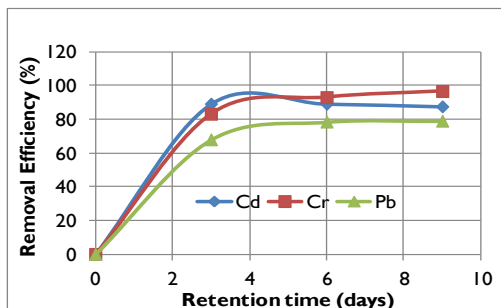


Figure 4(c). Typha+phragmites

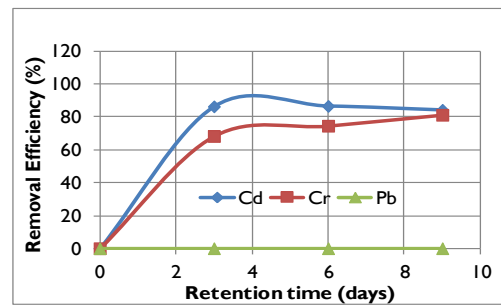


Figure 4(d). Typha+cyperus

Results indicate overall metal removals in the order of Cr > Cd > Pb, in all the plant combinations with Cr and Cd removals being significantly higher than Pb removals. Removal efficiency of all metals increased rapidly with increased time in the initial stage and then levelled off. The optimum time for the metal removal was observed to be 6 days regardless of the plant combinations. In this study, Cr maximum removal values ranged between 81.02 and 99.42% which are a lower than a value of 99.59%, obtained by Suhendrayatna et al., (2009) for typha but higher than 68.1% by Kumari & Tripathi. The maximum Cd removal values in this study ranged between 86.39 and 98.91%, values comparable to 94% by Yang et al. (2006) and 91% by Ye et al., (2001) but higher than 60% by Kumari & Tripathi. The Pb maximum removal values in this study ranged between 66.88 and 83.83%. This was lower than the Pb removal by Lan et al., (1992) and Lim et al.

(2003) but higher than the Pb removal by Kumari & Tripathi (2015). This study showed that typha performed better on its own than when in combination with phragmites or cyperus, contrary to findings by Kumari & Tripathi (2015) and Marchand et al. (2010).

### Effect of combining metals on removal efficiency

Tables 1, 2 and 3 show maximum removal efficiencies of Cd, Cr and Pb respectively in the wetland units.

Plant	Cd only		Cd+Cr		Cd+Pb		Cd+Cr+Pb	
	%	Day	%	Day	%	Day	%	Day
Typha	97.19	6	94.90	6	96.33	9	97.02	6
Typha+Vetiver	98.91	6	96.18	3	96.41	9	96.52	9
Typha+Phragmites	89.12 <sup>abc</sup>	3	96.45 <sup>ad</sup>	6	94.83 <sup>bd</sup>	9	95.61 <sup>c</sup>	6
Typha+ Cyperus	86.39 <sup>abc</sup>	6	97.36 <sup>a</sup>	6	95.96 <sup>b</sup>	9	97.04 <sup>c</sup>	9

Note: Same superscript a, b and c in one row indicates significant difference at p=0.05 level

Plant	Cr only		Cd+Cr		Cr+Pb		Cd+Cr+Pb	
	%	Day	%	Day	%	Day	%	Day
Typha	99.37 <sup>abc</sup>	6	94.07 <sup>a</sup>	6	93.98 <sup>b</sup>	9	95.36 <sup>c</sup>	6
Typha+Vetiver	99.42 <sup>abc</sup>	9	95.33 <sup>ad</sup>	3	93.78 <sup>bd</sup>	6	95.06 <sup>c</sup>	6
Typha+Phragmites	96.61	9	95.25	3	94.74	6	93.70	6
Typha+ Cyperus	81.02 <sup>abc</sup>	3	95.21 <sup>a</sup>	6	89.72 <sup>b</sup>	9	97.13 <sup>c</sup>	9

Note: Same superscript a, b and c in one row indicates significant difference at p=0.05 level

Plant	Pb only		Cd+Pb		Cr+Pb		Cd+Cr+Pb	
	%	Day	%	Day	%	Day	%	Day
Typha	83.83	9	73.97	6	89.12	6	75.43	6
Typha+Vetiver	77.66	3	80.16	6	79.61	6	78.61	6
Typha+Phragmites	79.02	9	82.25	6	79.78	6	73.27	9
Typha+ Cyperus	72.30	6	71.67	6	58.80	9	71.25	9

Overall, the percentage metal removal was observed to increase with the increase in retention time in all units. In single-metal wastewaters, the metal removal order was Cr > Cd > Pb, while in multi-metal wastewaters, the metal removal order was Cd ≈ Cr > Pb, with Cd and Cr removals being significantly higher than Pb removals in both cases.

### Effect of initial metal concentration on removal efficiency

Table 4 shows the maximum Cd, Cr and Pb percentage removals from varying initial metal concentration wastewaters. It was observed that removal efficiency increased with metal concentration from 5 to 20 mg/l, with Cd and Cr removal efficiencies from 5 mg/l wastewater being significantly lower than removal

efficiencies from 20 mg/l wastewater. Pb removal efficiency from 5 mg/l wastewater was significantly lower than removal efficiencies from 15 and 20 mg/l wastewater. Removal of the 3 metals was in the order Cd > Cr > Pb.

**Table 4. Maximum metal removal efficiencies – Varying initial metal concentrations**

Heavy Metal	5 mg/l		10 mg/l		15 mg/l		20 mg/l	
	%	Day	%	Day	%	Day	%	Day
Cadmium	96.90 <sup>a</sup>	15	98.52	9	98.95	24	99.24 <sup>a</sup>	9
Chromium	89.29 <sup>a</sup>	15	95.80	6	96.62	15	97.93 <sup>a</sup>	9
Lead	61.41 <sup>bc</sup>	15	80.58	6	85.21 <sup>b</sup>	1	91.42 <sup>c</sup>	3

Note: Same superscript a, b and c in one row indicates significant difference at p=0.05 level

### Conclusions and recommendations

This study showed that *Typha latifolia* singly, as well as in combination with *Vetiveria zizanioides*, *Phragmites australis* and *Cyperus latifolius*, was able to effectively treat the single- and multi-metal wastewaters. Combining typha with phragmites and cyperus was found to enhance Cd and Cr removals but slightly retard Pb removal. Combining metals retarded Cd and Cr removal but had no defined effect on Pb removal. Removal efficiencies were found to increase with initial metal concentration from 5 to 20 mg/l. Metal removal from single- and multi-metal wastewaters was in the order Cr>Cd>Pb while in wastewater of varying concentration, the removal order was Cd>Cr>Pb. The removals were found to fall within the ranges reported by previous researchers. In all the units, removal efficiency was found to increase with time, reaching its maximum in 6 days in both single- and multi-metal wastewaters. This study shows that typha has a high capacity to reduce concentrations of Cd, Cr and Pb, and can indeed be used in treatment of metal polluted wastewaters, especially from mining and industrial activities.

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