Removal of nutrients (N and P) and heavy metals (Fe, Al, Mn and Ni) from industrial wastewaters by phytoremediation using water hyacinth (*Eichhornia crassipes*) under different nutritional conditions

By

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DECLARATION

I certify that this dissertation does not incorporate without acknowledgement of any material previously submitted for a Degree or Diploma in any University and to the best of my knowledge and belief it does not contain any material previously published or written or orally communicated by another person except, where due references is made in the text.

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ABSTRACT

This study was investigated the utilization of phytoremediation strategies to remove nitrogen, phosphorus and heavy metals (Fe, Al, Mn and Ni) from wastewaters by water hyacinth (*Eichhornia crassipes* [Mart.] Solms). Batch studies were conducted for 15 weeks using fiberglass tanks in which healthy young plants were grown for a period of 15 weeks under different nutrient concentrations of 2-fold (56 TN mg/l and 15.4 TP mg/l), 1-fold (28 TN mg/l and 7.7 TP mg/l), 1/2-fold (14 TN mg/l and 3.85 TP mg/l), 1/4-fold (7 TN mg/l and 1.93 TP mg/l), 1/8-fold (3.5 TN mg/l and 0.96 TP mg/l) and control (without nutrients). In each week plants, water and sediments were analysed for TN and TP. The phytoremediation potential of heavy metal removal was determined at above nutrient concentrations with the addition of the constant heavy metal concentrations (Fe-9.27 mg/l, Al-5.62 mg/l, Mn-0.92 mg/l and Ni-0.21 mg/l) in fiberglass tanks. Plant, water and sediment were analyzed for heavy metals during the 15 weeks of culture period. A mass balance was conducted to investigate the phytoremediation efficiencies and to determine the different mechanisms governing nutrient and heavy metal removal from the wastewaters.

Our results manifested that hyacinth could be effectively utilized in constructed wetlands to phytoremediate N rich wastewaters than P. Plant uptake was the major TN and TP removal mechanism during the initial periods. Accumulation of a high content of nitrogen in plant tissues due to plant uptake and denitrification was found to be the key mechanisms involved in the efficient removal of nitrogen at the latter part of the study period. Plant uptake of phosphorus and chemical precipitation together with adsorption on to the detritus are the key mechanisms of phosphorus removal. However the phosphorus removal seems to be not high with that of nitrogen indicating that hyacinth systems are not ideal for phosphorus removal from wastewaters. In conclusion, very young plants having seems to be ideal to commence a constructed wetland after a period of acclimatization and approximately 56-63 days of hydraulic retention time is recommended for optimum phytoremediation of nitrogen as well as phosphorus.

Phytoremediation of Fe largely due to the process of rhizofiltration and the chemical precipitation followed by flocculation and sedimentation were the key Fe removal mechanisms during the first few weeks of the study. Plants grown in the control set-up showed a highest phytoremediation efficiency of 47% during optimum growth at the 6^{th} week with a highest accumulation of 6707 Fe mg/kg dry weight. Root effluxing of Fe to the wastewaters at intermittent periods and with time was a key mechanism of avoiding Fe phytotoxicity in water hyacinth. It can be concluded from this study that water hyacinth is an ideal plant for a batch removal of low polluting Fe rich industrial wastewaters under completely nutrient poor conditions. Very young plants are ideal to commence a constructed wetland after a period of acclimatization and approximately 42 days hydraulic retention time is recommended for optimum phytoremediation. Phytoextraction was the key Mn removal mechanism and root effluxing of Mn was observed intermittently possibly to avoid any phytotoxicity caused by an excessive accumulation of Mn in hyacinths. Hyacinths cultured in the 1/8-fold set-up showed a highest accumulation of 1133 Mn mg/kg dry weight with an optimum removal of 79% at the 9^{th} week. Hence very young plants inhabiting waterbodies containing approximately 3.5 TN mg/l and 0.96 TP mg/l seems to be more ideal for a batch removal of low polluting Mn rich wastewaters in constructed wetlands.

Acclimatization of the plants is necessary for at least 1 week prior to the removal of Mn and then approximately 63 days hydraulic retention time is recommended to optimize phytoremediation. Chemical precipitation followed by flocculation and sedimentation with phytoremediation mainly due to rhizofiltration were the key Al removal mechanisms Control and 1/8-fold set-ups showed higher phytoremediation efficiencies of 63% and 54%, respectively with maximum accumulations of 4278 Al mg/kg dry weight and 4224 Al mg/kg dry weight, respectively. Therefore young plants of completely nutrient starved adult hyacinths seems to be more ideal for a batch removal of low polluting Al rich industrial wastewaters in pilot scale constructed wetlands. A hydraulic retention time of approximately 28 days is recommended for optimum removal after a period of acclimatization of the young plants. The results manifested that hyacinths are essentially Ni excluders since higher levels of Ni were detected in water throughout the study.

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ABBREVIATIONS

AAS	–	Atomic Absorption Spectrophotometer
ACC	–	1-Aminocyclopropane-1-carboxylic acid
AS	–	Aluminosilicate
BAC	–	Bioaccumulation coefficient
BOD	–	Biochemical Oxygen Demand
CEC	–	Cation Exchange Capacity
DNA	–	Deoxyribonucleic Acid
DO	–	Dissolved Oxygen
HRT	–	Hydraulic Retention Time
ITRI	–	Iron Transporter
MAO	–	Monoamine Oxidase Activities
MT	–	Metallothioneins
PAHs	–	Polycyclic Aromatic Hydrocarbons
PC	–	Phytochelatins
PCB	–	Poly Chlorinated Biphenyl
PCP	–	Pentachlorophenol
SD	–	Standard Deviation
SFW	–	Subsurface Flow Wetlands
SOD	–	Sediment oxygen Demand
SRB	–	Sulphate Reducing Bacteria
TCE	–	Trichloroethylene
TN	–	Total Nitrogen
TNT	–	Trinitrotoluene
TP	–	Total Phosphorus
TSS	–	Total Suspended Solids