SOLUBILITY AND PHYTOAVAILABILITY OF ZINC AND COPPER IN ABATTOIR WASTEWATER WATER IRRIGATED SOIL AS AFFECTED BY ALKALINE AMENDMENTS

Balaji Seshadri[1,2], Y. Yubo[1,3], N.S. Bolan[1,2] and R. Naidu[1,2]

[1]Global Centre for Environmental Remediation (GCER), University of Newcastle, Newcastle, Australia

[2]Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC CARE), ATC Building, Callaghan NSW 2308, AUSTRALIA

[3]Jiangsu Key Laboratory of Chemical Pollution Control and Resources Reuse, School of Environmental and Biological Engineering, Nanjing University of Science and Technology, Nanjing 210094, China

Balaji.Seshadri@newcastle.edu.au

Keywords: abattoir wastewater, alkaline amendments, phosphorus, copper, zinc

Introduction

Abattoirs are posing enormous problems to the environment by discharging huge volume of wastewater with excessive nutrients (e.g. Phosphorus) and heavy metals. Abattoir wastewater contains blood, urine, other body fluids and animal faeces that contribute to contaminants including phosphorus (P). Metals including zinc (Zn) and copper (Cu) are used as minor feed supplements in cattle and swine production, in the form of zinc oxide and copper sulphate (Jacob et al., 2010). Abattoirs producing beef and pork use these salts extensively as an alternative to antibiotics as they can suppress gut pathogens. Rajasekaran and Santra (2015) claims that higher levels of Cu and Zn in the animal excretory wastes may pose serious threat to the soil microbial diversity and surrounding ecosystem. Hence, the wastewater possess beneficial soil components at undesirable quantities, which needs to be addressed.

Stabilising the heavy metals in the wastewater irrigated soil is being used as an approach to reduce their solubility and bioavailability. Bolan and Duraisamy (2003) showed that phosphates along with organic amendments were effective in stabilising Pb, Cd, Zn, and Cu in contaminated soils and solid wastes, thereby reducing their phytoavailability and mobility in soils. Some solid wastes such as coal fly ash (CFA) and red mud (RM) have also shown to immobilise heavy metals in soil because of their ability to increase soil pH and induce co-precipitation of metals in the soil solution. While Cu can be retained in soil as carbonates and Fe and Al oxy-hydroxides, Zn can be immobilised by P amendments and clays (Kumpiene et al., 2008). Therefore, this research demonstrates the use of CFA and RM as soil amendments, which are rich in calcium carbonates and iron/aluminium oxides, respectively.

Methods

The soil for the study was collected from an abattoir effluent irrigated site at Primos Port Wakefield abattoir, Australia. The soil amendments used in the experiment were CFA (Port Augusta Power Stations, Australia) and RM (Rio Tinto alumina refinery, Gladstone, Australia). The surface characteristics and minerology of CFA and RM were studied using SEM-EDS and XRD, respectively. The influence of soil amendments and P in the wastewater irrigated soil on Cu and Zn stabilisation was studied using water extractability and leaching experiments in amendment incubated soil. The phytoavailability was assessed using the uptake of

Cu and Zn in Napier grass plants grown in abattoir wastewater irrigated soil. Rhizon samplers were used in the greenhouse plant growth experiment for porewater sampling. Soil and plant samples were digested using aqua regia (1:3, HNO_3/HCl), and the concentration of Cu and Zn in the extract was determined using ICP-OES.

Results

The SEM images of the incubated soil samples showed that the alkaline amendments improved the surface binding sites for P to bind with the cationic mineral components. The XRD graph for FA showed Ca-containing minerals (ettringite, wollastonite and merwinite), which suggests that Ca can play an important role in P immobilisation. Among the amendments used, FA was most effective in reducing water soluble P in the incubated soils, which was also supported by the leaching experiment. However, in the plant growth experiment, both FA and RM showed an increase in Olsen P and plant biomass production. There was a decrease in soluble Cu (up to 71 %) and Zn (up to 65 %). Cao et al. (2009) used calcium oxide and observed up to 80 and 69 % reduction in water soluble Cu and Zn, respectively and attributed it to the sorption on calcite and phosphate minerals. However, in the plant study, P did not reduce the phytoavailability of Cu and Zn. The concentration of Cu and Zn in the porewater samples were higher than the incubated samples, indicating the influence of rhizosphere processes on their bioavailability. Seshadri et al. (2014) showed that oxalic acid exudation in the rhizosphere increased Olsen P. However, Cu and Zn uptake at the rates shown in this experiment did not pose threat to the biomass production of the plants.

Conclusion

This study showed that FA and RM can be effective amendments in retaining P components in soil and also increase the biomass yield of Napier grass. Among the amendments, FA showed the highest increase in Olsen P and reduction of water soluble Cu and Zn. The concentration of phytoavailable Cu and Zn in the rhizosphere soil was safe for the increased biomass production of Napier grass.

References

Bolan, N.S., & Duraisamy, V.P. (2003). Role of inorganic and organic soil amendments on immobilisation and phytoavailability of heavy metals. *Soil Res., 41*(3), 533-555.

Cao, X., Wahbi, A., Ma, L., Li, B., & Yang, Y. (2009). Immobilization of Zn, Cu, and Pb in contaminated soils using phosphate rock and phosphoric acid. *J. Hazard. Mater., 164*(2–3), 555-564.

Jacob, M.E., Fox, J.T., Nagaraja, T.G., Drouillard, J.S., Amachawadi, R.G., & Narayanan, S.K. (2010). Effects of Feeding Elevated Concentrations of Copper and Zinc on the Antimicrobial Susceptibilities of Fecal Bacteria in Feedlot Cattle. *Foodborne Pathogens and Disease, 7*(6), 643-648.

Kumpiene, J., Lagerkvist, A., & Maurice, C. (2008). Stabilization of As, Cr, Cu, Pb and Zn in soil using amendments – A review. *Waste Manag., 28*(1), 215-225.

Rajasekaran, P. & Santra, S. (2015). Hydrothermally treated chitosan hydrogel loaded with copper and zinc particles as a potential micronutrient-based antimicrobial feed additive. *Front. Veter. Sci., 2*, 62.

Seshadri, B., Kunhikrishnan, A., Bolan, N.S, & Naidu, R. (2014). Effect of industrial waste products on phosphorus mobilisation and biomass production in abattoir wastewater irrigated soil. *Environ. Sci. Pollut. Res., 21*(17), 10013-10021.