Available online at www.elixirpublishers.com (Elixir International Journal)

Agriculture

Elixir Agriculture 77 (2014) 29190-29192

ISSN: 2229-712X

Micro nutrient concentration in wastewater used for Peri-Urban irrigation, Ghana

Abagale F. K[1,*], Kyei-Baffour, N[2], Mensah, E[2] and Ofori, E[2]

[1]Faculty of Agriculture, University for Development Studies, Tamale, Ghana.

[2]Department of Agricultural Engineering, College of Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

ARTICLE INFO

Article history:
Received: 15 October 2014;
Received in revised form:
25 November 2014;
Accepted: 16 December 2014;

Keywords
Irrigation,
Adequate,
Safeguards.

ABSTRACT

Wastewater irrigation can pose a variety of potential health risks and also excessive and often imbalanced addition of nutrients to the soil to affect crop production. Thus, its use in agriculture without adequate safeguards has been noted to have serious drawbacks for human health and the environment. This study assessed micro nutrient concentration in wastewater used for peri-urban vegetable crop production in the Tamale Metropolis of Ghana. Aside Fe which was insignificant in both seasons all the others recorded a significant difference in the two seasons. Al, Fe, Mn and Zn on the average recorded higher concentration values in the wet season than the dry season whilst Cu recorded a higher concentration in the dry season than the wet season. Concentrations of most of the micro nutrients were lower than the WHO (2006) recommended standards except Mn which had concentration levels exceeding the recommended standard in the wet season only.

Introduction

Beside pathogens, wastewater and sludge can also be a source of high levels of heavy metals and organic toxic compounds (Abaidoo *et al.,* 2009). Qadir and Scott (2010) reported that when the concentrations of constituents such as heavy metals or organic contaminants are known in the plant tissue, or in food in general, which is eventually consumed by a particular consumer group, it is possible to calculate human exposure (intake). Excessive concentrations of some trace elements may also cause plant toxicity and sometime become a health risk for crop farmers (Jiménez *et al*., 2010). According to Qadir and Scott (2010), wastewater irrigation also adds a range of micronutrients such as iron (Fe), zinc (Zn), manganese (Mn) and copper (Cu).

Hamilton *et al.* (2007) describe increasing total heavy metal concentrations in soils irrigated with sewage for up to a century. The authors found that potentially bio-available forms of the metals have increased and plant tissue showed relatively low concentrations as the metals were strongly absorbed in the soil. Some of these heavy metals are picked up by the roots of plants growing in soils and are stored in different parts of the plants in different concentrations based on the type of plant (Chang *et al.,* 1997; Kulli *et al.,* 1999). Some metals and metalloids are essentially required for adequate plant growth, but are toxic at elevated concentrations e.g. copper (Cu), zinc (Zn), Iron (Fe) Aluminium (Al) and Manganese (Mn) (Qadir and Scott, 2010).

Materials and Methods

Study Area

Tamale Metropolitan area is located at the centre of the Northern Region of Ghana. It occupies 750 km^2 which is 13 % of the total area of the Northern Region. The population of Tamale Metropolis is reported as 371,351 with 185,995 (50.09 %) being males and 185, 356 (49.91 %) being females (GSS, 2012). The Metropolis experiences one rainy season starting from April/May to September/October with a peak season in July/August. The dry season is usually from November to March. The mean annual rainfall is 1100 mm within 95 days of intense rainfall. The mean day temperatures range from 33-39^oC while mean night temperature range from 20-22^oC. The mean annual day sunshine is approximately 7.5 hours.

In the Metropolis there are several sites where wastewater vegetable farming takes place and the crops cultivated include cabbage, lettuce, *Amaranthus* and *Chochorus* etc. The study was undertaken in the Zagyuri community where farmers use a broken down sewer of the Kamina Military Barracks for dry season vegetable crop production.

Water Sampling and Analytical Techniques

Wastewater sampling was done at weekly (7 days) intervals for a period of sixteen (16) weeks that is eight (8) weeks for the rainy season (August and September) and eight (8) weeks for the dry season (January and February) in each sampling year and in the years 2011 and 2012. A total number of ten (10) wastewater samples were collected at each sampling time resulting in 160 wastewater samples per year and 320 samples for the whole study.

Trace metals or micro nutrients were determined using standard methods and the values read with a DR 2800 Spectrophotometer. Zinc was determined using the Zincon method with digestion by ZincoVer 5 reagent powder pillow. Aluminon method used ascorbic acid powder pillow and AluVer 3 Aluminium reagent powder pillow. In the determination of Manganese, the Pan method was used with Ascorbic acid and Alkaline Cyanide as reagents. Copper and Iron were determined using CuVer 1 Copper reagent and FerruVer Iron reagent respectively.

Results and Discussions

Trace Metals Concentration in Wastewater

The results of the mean concentration of Al, Cu, Fe, Mn and Zn in this study for the wet and dry seasons are presented in Table 1. Liu *et al.* (2005) studied the impact of sewage irrigation

Tele:
E-mail addresses: fabagale@yahoo.com

on trace metal contamination in Beijing and reported that the trace metals were enriched in the soil due to sewage irrigation.

Table 1. Trace Metal Concentration in the Wastewater

Trace Metal	Mean Wet Season Levels (mg/l)	Mean Dry Season Levels (mg/l)	Fp > 0.05	EPA Ghana Limits (mg/l)	*RMC (mg/l) (FAO/WHO, 2006)
Al	0.146	0.070	0.024	5.0	5.0
Cu	0.010	0.158	0.037	2.5	0.2
Fe	0.800	0.660	0.588	-	5.0
Mn	0.233	0.101	0.014	2.5	0.2
Zn	0.066	0.015	0.026	5.0	5.0

*RMC – Recommended Maximum Concentration

Concentration of Aluminium (Al)

Aluminium was observed to have a mean concentration level of 0.146 mg/l in the wet season during the study whilst the level recorded in the dry season was 0.070 mg/l. This indicated that wet season recorded relatively higher concentration of aluminium in the wastewater than the dry season. ANOVA at 5 % indicated an F-probability value of 0.024. This means that a significant difference existed between the concentrations of Al in both seasons. According to Jiménez *et al.* (2010) excessive concentrations of some trace elements may cause plant toxicity and sometimes become a health risk for crop consumers. Ayers and Westcot (1985) and Pescod (1992) reported that higher levels of Al can cause non-productivity in acid soils ($pH < 5.5$), but more alkaline soils at $pH > 7.0$ will precipitate the ion and eliminate any toxicity.

DWARF (1996), reported that when soluble aluminium complexes are present, the dissolved aluminium concentration may be significantly high compared to the situation where insoluble aluminium compounds are present in the wastewater.

According to Delhaize and Ryan (1995), the most easily recognized symptom of Al toxicity is the inhibition of root growth, and this has become a widely accepted measure of Al stress in plants. Higher concentration of Al in the soil reduces plant vigour and yield.

The wastewater samples from Zagyuri in both seasons had low Al concentrations and below the limit of 5 mg/l required for irrigation of vegetables. This implies that, the use of wastewater for irrigation in the study area has insignificant effect on Al concentration in the soil, since the mean values recorded were below the recommended maximum concentration levels of WHO (2006).

Concentration of Copper (Cu)

The study results indicated mean Cu concentrations of 0.010 mg/l in the wet season and 0.158 mg/l in the dry season. This implies that the dry season recorded relatively higher concentration of Cu than the wet season. ANOVA on the concentration of Cu at 5 % level of significance for wet and dry seasons gave an Fpr value of 0.037 (Table 1). This indicates a significant difference in the concentration of Cu between the seasons. The higher concentration may be as a result of corrosion of copper pipes used in plumbing works in the barracks.

According to Silva and Uchida (2000) low levels of Cu reduces crop growth, distortion of younger leaves and possible necrosis of the apical meristem. In forage grass, young leaf tips and growing points are affected. First, the plant becomes stunted and chlorotic. Solberg *et al*. (1999) reported that Cu deficient plants are prone to increased disease attack, specifically ergot (a fungus causing reduced yield and grain quantity). Cu at high concentration in plants causes a stress factor triggering physiological responses (Yruela, 2005).

As shown in Table 1 the mean values recorded for both seasons were below the recommended maximum concentrations of 0.20 mg/l by WHO (2006). EPA Ghana have also set a limit of 2.5 mg/l for wastewater to be discharged into water bodies and water courses. This indicates that Cu concentration in wastewater at Zagyuri as used by the farmers have insignificant risks to the soils, vegetable crops and aquatic life in water courses.

Concentration of Iron (Fe)

The mean concentration for Fe was 0.80 mg/l and 0.66 mg/l for the dry and wet seasons respectively (Table 1) and concentration was relatively higher in the wet season as compared to the dry season. A statistical analysis performed at 5 % level of significance resulted in Fpr value of 0.588. This indicated that there is no significant difference in Fe concentrations in both seasons. The lower concentration of Fe in the dry season may be due to the fact that the pH of the wastewater was high as an average pH of 7.52 and 7.33 were recorded for the dry and wet seasons respectively.

Fe is essential in the synthesis and maintenance of chlorophyll in plants and has been strongly associated with protein metabolism. At low concentrations, younger leaves develop interveinal chlorosis (Silva and Uchida, 2000). Wastewater samples in both seasons recorded lower Fe concentrations which was below the limit of 5 mg/l (WHO, 2006) required for irrigation of vegetable crops.

Concentration of Manganese (Mn)

The mean value of Mn was 0.233 mg/l in the wet season whilst the level in the dry season was 0.101 mg/l (Table 1). This implies that the mean concentration in the wet season was relatively higher than the dry season. ANOVA at 5 % level of significance yielded Fpr value of 0.01, which indicated a significant difference in the concentration of Mn between the seasons. Mn is known to function in plants as components of enzymes involved in photosynthesis and other processes. Mn deficiency has very serious effects on non-structural carbohydrates and root carbohydrates especially. Crops quality and quantity decrease due to Mn deficiency and this is due to the low fertility of pollen and low carbohydrates during grain filling (Mousavi *et al*., 2011).

The Mn in the wastewater samples collected in the wet season were observed to be higher in the wet season whilst the dry season was below the recommended maximum concentrations of 0.20 mg/l required for irrigation of vegetables. This implies that the wastewater for vegetable crop irrigation is safe in terms of the Mn concentration. Also, the limit of 2.5 mg/l for release of wastewater into the environment as set by EPA Ghana shows that Mn concentration on the wastewater was very low.

Concentration of Zinc (Zn)

Mean zinc value of 0.066 mg/l in the wet season and 0.015 mg/l in the dry season was observed in the wastewater (Table 1). This implies that the mean concentration in the wet season was relatively higher than the dry season. ANOVA on the concentration of Zn at 5 % level of significance for wet and the dry seasons gave an Fpr value of 0.026. This indicates that the concentration of Zn in both seasons was significant.

According to Alloway (2008) Zn as a micronutrient is an essential element to maintain metabolic functions of living organisms. In plants, Zn plays a key role as a structural constituent or regulatory co-factor of a wide range of different enzymes and proteins in many important biochemical pathways and these are mainly concerned with:

1. Carbohydrate metabolism, both in photosynthesis and in the conversion of sugars to starch,
2. Protein metabolism,
3. Auxin (growth regulator) metabolism,
4. Pollen formation,
5. Maintenance of the integrity of biological membranes and
6. The resistance to infection by certain pathogens.

When the supply of plant-available Zn is inadequate, crop yields are reduced and the quality of crop products is frequently impaired. Zn deficient in leaves display interveinal chlorosis, especially midway between the margin and midrib, producing a striping effect; some mottling may also occur (McCauley *et al.,* 2003). At high levels in the soil, Zn concentration causes phytotoxicity problems to the plants (Pérez-Novo *et al.,* 2008).

As in Table 1, the concentration of Zn in the wastewater samples were below the limit of 5.00 mg/l set by EPA Ghana and WHO (2006) in both seasons.

Conclusions

Except the concentration of Cu in the wastewater which did not record significant difference in levels between the wet and dry seasons, Al, Cu, Mn and Zn were significantly different in concentration between the seasons.

Also, except the mean concentration of Mn (0.233 mg/l) in the wet season, the other micro nutrients where below the recommended maximum concentrations as set by FAO/WHO (2006) and the limits of EPA Ghana for release of wastewater into water courses in the environment. Bioaccumulation of these micro nutrients is therefore possible and can create an imbalance in the nutrient levels of the soils.

References

1. **Abaidoo, R., Keraita, B., Drechsel, P., Dissanayake, P. and Maxwell, A. 2009.** Soil and crop contamination through wastewater irrigation and options for risk reduction in developing countries. In: P. Dion (ed) *Soil Biology and Agriculture in the Tropics*, Springer Verlag, Heidelberg.
2. **Alloway, B. J. 2008.** Zinc in Soils and Crop Nutrition. 2nd Edition. Published by International Zinc Association (IZA) and International Fertilizer Industry Association (IFA), Brussels, Belgium and Paris, France.
3. **Ayers R. S. and Westcot D. W. 1985.** *Water Quality for Agriculture*, Irrigation and Drainage, Paper 29, Rev 1, FAO, Rome
4. **Chang, A.C., Hyun, H-n. and Page, A.L. 1997.** Cadmium uptake for swiss chard grown on composted sewage sludge treated field plots: Plateau or time bomb? J. Environ. Qual. 26:11 – 19.
5. **Delhaize, E., and Ryan R. P. 1995.** Aluminum Toxicity and Tolerance in Plants, Plant Physiol. Vol. 107,Division of Plant Industry, Commonwealth Scientific and Industrial Research Organization, GPO Box 1600, Canberra ACT 2601, Australia.
6. **Department of Water Affairs and Forestry (DWARF), 1996.** South African Water Quality Guidelines (second edition). Volume 4: Agricultural Use: Irrigation.
7. **Hamilton, A. J., Stagnitti, F., Xiong, X., Kreidl, S. L., Benke, K. K. and Maher, P. 2007.** Wastewater irrigation: The state of play', *Vadose Zone Journal*, vol 6, no 4, pp 823–40.
8. **Jiménez, B., Mara, D. Carr, R. and Brissaud, F. 2010.** Wastewater Treatment for Pathogen Removal and Nutrient Conservation: Suitable Systems for Use in Developing Countries. In Drechsel, P., Scott, C. A., Raschid-Sally, L. Redwood, Mark. and Bahri, A. (eds) 2010. Wastewater Irrigation and Health: Assessing and Mitigating Risk in Low-Income Countries. Earthscan Publishers, London.
9. **Kulli, B., Balmer, M., Krebs, R., Lothenbach, B., Geiger, G., Schulin, R. 1999.** The influence of nitrilotriacetate on heavy metal uptake of lettuce and ryegrass. J. Environ. Qual. 28: 1699-1705.
10. **Liu, W.H., Zhao, J. Z., Ouyang, Z.Y., Soderlund, L. and Liu G.H. 2005.** Impacts of sewage irrigation on heavy umetal distribution and contamination in Beijing,China, *Environment International* 31 (2005) 805.
11. **McCauley A., Jones C. and Jacobsen J. 2003.** Plant Nutrient Functions and Deficiency and Toxicity Symptoms Nutrient Management Module No.9
12. **Mousavi, S. R., Shahsavari, M. and Rezaei, M. 2011.** A General Overview On Manganese (Mn) Importance For Crops Production Australian Journal of Basic and Applied Sciences, 5(9): 1799-1803
13. P**érez-Novo, C., Bermúdez-Couso, A., López-Periago, E., Fernández-Calviño, D. and Arias-Estévez, M. 2011**. Zinc adsorption in acid soils Influence of phosphate. Geoderma 162 (2011) 358–364
14. **Pescod, M. 1992.** Wastewater treatment and use in agriculture. Rome, Food and Agriculture Organisation of the United Nations (FAO Irrigation and Drainage paper 47)
15. **Qadir, M. and Scott, C. A. 2010.** Non-Pathogenic Trade-Offs of Wastewater Irrigation: In Drechsel, P., Scott, C. A., Raschid-Sally, L. Redwood, Mark. and Bahri, A. (eds) 2010. Wastewater Iriigation and Health: Assessing and Mitigating Risk in Low-Income Countries. Earthscan Publishers, London.
16. **Silva J. A. and Uchida R., eds 2000.** Plant Nutrient Management in Hawaii's Soils, Approaches for Tropical and Subtropical Agriculture College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa.
17. **Solberg, E., I. Evans, and Penny, D. 1999.** Copper Deficiency: Diagnosis and Correction. Agdex 532-3, September. Alberta Agriculture, Food, and Rural Development.
18. **World Health Organisation (WHO). 2006.** Guidelines for the Safe Use of Wastewater, Excreta and Greywater. Wastewater Use in Agriculture (Volume II).
19. **Yruela I. 2005.** Copper in Plants. Braz. J. Plant Physiol., *17*: 145–156.