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Heavy metals accumulation in edible part of vegetables irrigated with untreated municipal wastewater in tropical savannah zone, Nigeria

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In this present study, the quality of municipal wastewater used for irrigation of spinach was investigated for its heavy metal build-up. The municipal wastewater used for irrigation and the irrigated spinach samples were collected and analyzed for their heavy metal concentrations. The results indicate that the municipal wastewater used was contaminated with copper (1.90 mg/l), lead (0.09 mg/l) and iron (25 mg/l) and the municipal-irrigated spinach was contaminated with manganese (95 mg/kg) and cadmium (0.03 mg/kg). The results of these investigations were compared with World Health Organization (WHO) and Food and Agriculture Organization (FAO) heavy metal standards for irrigation water quality and permissible levels of metals in food and water. It revealed that the heavy metal concentrations were above the recommended threshold limits. High concentrations of these metals are very detrimental to the health of the inhabitants and crop consumers. Regular monitoring for safe practice is strongly recommended in order to avert terminal diseases in the area.

Key words: Domestic wastewater, irrigation, heavy metals, soil, vegetables.

INTRODUCTION

Agriculture uses about 70% of water withdrawals, therefore, it is expected that in times and regions of water scarcity, farmers would turn to domestic or urban waste water as a water source (FAO, 2010). In recent times, farmers use wastewater to irrigate their crops. This wastewater contains large amount of organic materials, some inorganic elements and/or substantial amount of toxic heavy metals (Zavadil, 2009; Arora et al., 2008; Lone et al., 2003), non essential heavy metals which when present in large amount could be transferred to animal and human beings through food chain (Lone et al 2003). The presence of these substances are harmful to human health because of the non biodegradable nature of heavy metals and their potential to accumulate in different parts of the body (Lawal and Audu, 2011; Arora et al., 2008). Similarly, toxic metals may be absorbed by vegetables through several processes and finally enter the food chain at high concentrations which are capable

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Table 1. Heavy metals in soil (mg/Kg) at Soje.

Parameter	Mn	Mg	Cu	Zn	Pb	Fe	Cd
Plot average	3.20	6.85	31.00	25.46	10.00	60.96	0.05
Before irrigation	2.01	10.93	26.32	22.00	6.25	33.10	0.04
Control	1.98	10.95	26.85	22.79	8.97	40.00	0.01
Max. limits	-	-	60.50	370.50	2129.0	-	2.25

of causing serious health risks to consumers (Kihampa et al., 2011). Also, accumulation of highly toxic metals (Cd) even at low concentrations in food and water leads to the buildup of cadmium in kidneys and may likely lead to kidney diseases (Latif, 2009). Other effects of metal toxicity may include damage or reduce mental and central nervous function, lower energy levels, and damage to blood composition, lungs, kidneys, liver and other vital organs (Kihampa et al., 2011). Indeed, it was estimated that 10% of the world's population consumes foods irrigated with wastewater (Finley, 2008). However, these factors: climate, atmospheric deposition, the nature of the soil on which the plants are grown and the degree of maturity of the plants at the time of harvesting can influence the concentration of heavy metals on and with plants (Farooq et al., 2008, Muchuweti et al., 2005). Similarly, Nazif et al. (2006) explained that the fate and effects of pollutants discharged into a particular water body will depend not only on the amount of polluting substances emitted but also on the hydrological, physical, chemical and biology conditions characterizing the water body concerned.

Farmers in Soje took advantage of the continuous flow of water at their vicinity, and were unaware of the quality and the implications of using contaminated water for crop cultivation. Thus, this study aimed at quantifying the content and quality of heavy metals in domestic wastewater used for irrigation of vegetables in Soje, in the soil and edible part of spinach.

METHODOLOGY

Study area

The study site selected for this study is the Soje irrigation scheme. Soje irrigation scheme is located in Soje, few kilometers from Minna railway station, Minna, Niger state, Nigeria. Niger state is situated at the North Central part of Nigeria. It lies in the savannah zone of the tropics between latitude 8°10'N and 11°30' N and longitude 3°30' E and 7°30' E. The study area has two main seasons, the rainy and the dry (harmattan). The rainy season begins in April and ends in October while the harmattan starts in November and ends in March. Soje has an average annual rainfall of 103.3 mm, average annual temperature of 22.5°C and average annual relative humidity of 50.3%. The source of water for Soje irrigation scheme is the wastewaters from Minna Township. The water flows through unlined channels. The farmers take advantage of it continuous flow for irrigation. Investigations revealed that the irrigation scheme was set up by farmers in the area and the area is about 7.5 ha.

Collection of samples

Three plots sizes of 1.803 x 2.44 m were marked out for the purpose of this study. Spinach (*Spinacia oleracea*) was planted on the marked out plots during the dry season of 2010. Soil, wastewater and vegetable samples were sampled.

Composite soil samples made up of five soil samples per plots were collected from a depth of 0 to 25 cm before planting and after the growing period from two irrigated plots and a control plot. The soil samples were air-dried, and crushed to pass a 2 mm mesh sieve. 0.5 g of the finely ground soil samples were digested using 2 ml technical grade trioxonitrate (v) (HNO_3) in beakers at 95°C for 1 h after which hydrogen peroxide (H_2O_2) was added. After cooling, the samples were decanted and diluted with MilliQ water to 10 ml mark for analyses.

The plastic bottles for the wastewater collection were thoroughly washed with detergent and rinsed with tap water before taking the bottles to the study site for sample collection. The bottles were rinsed with the waste water samples before collection. Wastewater samples used for the irrigation of the spinach were collected in 2 l plastic bottles from the Soje unlined channel and transported to the laboratory for heavy metal analysis. These samples were collected in three replicates.

The edible part of the spinach were randomly selected and collected from the plots. The collected samples were stored in labeled polythene bags and then transported to the laboratory for preparation and treatment for analysis. A total of 90 samples were collected from the two plots and the control. The samples were washed with distilled water to eliminate suspended particles. The leafy stalks were removed from the samples; they were sliced and dried on a sheet of paper to eliminate excess moisture. The dried samples were weighed and oven dried at 60°C to a constant weight. The oven dried samples were ground in a mortar until it passed through a 60 mm mesh sieve. A mixture of 2 HNO_3 to 1 $HClO_4$ in a conical flask was used for wet digestion for about 2-3 h on a sand bath, 10 ml of HCL was then added after which the digested samples were filtered with a 0.45 µm pore size cellulose nitrate membrane filter paper. The filtered samples were made up to 100 ml with distilled water and stored for analysis using atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

Spinach was cultivated in soil samples with heavy metal as presented on Table 1. Generally, agricultural soils have low background levels of heavy metals; contaminations are mainly through fertilizer application, irrigation with partially treated or untreated sewage. This was reported by Farooq et al. (2008). The result shows that the soil in Soje is not polluted with Mn, Mg, Cu, Zn, Pb, Fe and Cd. There is need to protect the soil from contamination through regular monitoring.

Table 2. Average concentration of elements in domestic wastewater (mg/l).

Parameter	Wastewater	WHO limit
pH	6.40	6.5-8.5
Mn	0.44	-
Mg	0.22	30
Cu	1.90	1.0
B	1.66	-
Zn	1.28	3
Pb	0.09	0.01
Fe	25.0	0.3

Table 3. Heavy metal concentrations in spinach.

Parameter	Mn	Mg	Cu	Cd	Pb	Fe
Irrigated plot 1	1.22	95	1.45	0.033	0.060	3.93
Irrigated plot 2	1.22	95	2.00	0.030	0.030	3.99
Mean concentration	1.22	95	1.73	0.032	0.045	3.96
Control plot	0.64	97	1.09	0.017	0.020	2.21
WHO&FAO*	-	-	40	0.2	0.3	-
USDA*	-	79	-	-	-	2.71
WHO**	6.61		10.00	0.02	2.0	150.0

Permissible levels in food; **Critical level of metal ions in edible portion of vegetables (Lone et al., 2003).

Analysis of waste water

The average concentration of heavy metal content of domestic wastewater used for irrigation purposes at Soje irrigation scheme is shown in Table 2. The pH of the domestic waste water has a low pH, which is not desirable. Low pH value could decrease the solubility of certain essential elements such as selenium and at the same time increase the solubility of many other elements such as Fe, Al, B, Cu, Cd, Hg and Mn (Akan et al., 2008). The concentrations of the heavy metals in the domestic effluent are in the following order of decreasing magnitude Fe > Cu > B > Zn > Mn > Mg > Pb. The concentrations of Fe, Cu, B and Pb were all above the safe limit for WHO standards for domestic wastewater quality for irrigation. Although, Pb is the lowest in concentration of 0.09 mg/l, but it is about the most toxic metals found in aquatic ecosystem. Boron is essential for plant growth in small quantity; the wastewater contained high levels of boron and the toxicity could be observed on older plants by yellowing or drying of the leaf tissue at the tips and edges (Abbott and Hasnip, 1997).

Metal concentration in spinach

The heavy metal concentrations in spinach are shown in Table 3. The concentrations of heavy metals in edible part of spinach vary from metal to metal. The trend of accumulation in the spinach show an order of decreasing magnitude from Mg to Cd (Mg > Fe > Cu > Mn > Pb > Cd). Magnesium had the highest content in spinach sample with cadmium being the lowest of all the metals analyzed. Vegetables are known to naturally accumulate heavy metals from either wastewater or dumpsite (Arora et al., 2008). The Mg content in the spinach far exceeded the permissible levels in food according to the USDA standards. It was also observed that spinach has a good potential for Fe bioaccumulation. Cu, Cd and Pb concentrations were all below the permissible levels allowed in food. Lone et al. (2003) reported that long term exposure to Cd in food and water leads to build up of Cd in kidney causing kidney problems.

Conclusion

Routine monitoring of heavy metal contents of treated, partially treated or untreated domestic wastewater used for irrigation of edible crops are very vital to ensure safe practice, safety to both the health of humans and animals in particular and the environment in general. The quality of soil can also be changed by the application of sewage to farm lands. This study reveals that domestic wastewater depended upon by farmers at Soje for irrigation of their crops is contaminated with lead, copper and iron. Consumption of these food crops can lead to serious health issues such as cancer. The spinach samples were highly contaminated with magnesium. Excess of magnesium is unlikely to inhibit crop growth though it causes deficiency of calcium and potassium which are essential nutrients of plant (Abbott and Hasnip, 1997).

Conflict of Interests

The author(s) have not declared any conflict of interests.

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