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Quality of Water for Irrigating Urban Vegetable Farms: An assessment of Toxic and Essential Metals in Water from an Urban Lake

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ABSTRACT

In order to advise farmers as to which source of water will be best to draw from for irrigation in order to avoid or minimize the potential of the risk of heavy metal contamination of their vegetables, this study determined the concentrations of selected heavy metals and some physicochemical indicators of the quality of water from along the bank of the Marina Park Lake, which we recollected according to the guidelines of the American Public Health Association. Metals were analysed for with an Atomic Absorption Spectrophotometer and the concentration of the detected metals were within the ranges of 0.628 to 1.816 mg/L for Fe, <0.002 to 0.051 mg/L for Mn, 0.019 to 0.025 mg/L for Zn, 0.024 to 0.033 mg/L for As) and <0.001 to 0.004 mg/L forHg, all of which were less than the FAO recommended maximum concentrations of elements in water[1]for irrigation. Cu, Pd, Cd, Co and Cr were below detection limits. Generally, water from the Marina-Park Lake was suitable, in respect of heavy metal concentrations, for the irrigation of vegetable farms, and specifically Site 2 was the most suitable site to draw water for this purpose.

Keywords: *Toxic metals, essential elements, irrigation, water quality*

Introduction

More than 70% of freshwater bodies in urban areas are irreplaceably used for vegetable growing [1], an activity that has served as a means of livelihood among small scale farmers in most developing countries[2].Urban vegetable cultivation has been fuelled by the increased awareness, positive perception and consumption of "organic vegetables"[3], and the increasing demand of the export markets for vegetables, particularly among West African countries [4, 5]. However, there are concerns in respect of the potential health risk of vegetables from these urban farms, principally those that use water from streams and lakes associated with human activity. Our earlier study (at the same location) had reported data in respect of the microbial safety (bacterial quality) of these vegetables and the water from a lake used for their irrigation[6]. In following with a preventative approach [7, 8],which is supported by the FAO [9], particularly to avert the rejection of the vegetables of these small holder low income farmers on the export markets, we extended our study by evaluating water from this lake, as to whether its toxic metal as well as the essential element contents were less than the FAO maximum recommended concentration for irrigation water; Noting that concentrations of toxic metals such as Pd, Cd and Cr in foods, beyond certain limits, have proven detrimental to human health [1, 10–12].

The findings thereof formed the basis for advising farmers as to which location along the bank of the lake, was best to draw water for irrigation, and the call for regular monitoring of water bodies in urban areas used for agricultural purposes. This is in order to minimize the potential of the risk of heavy metal contamination through food crops.

Methodology

Study Location

The water samples for this study were obtained from the "Marina Park Lake", which is located at 5°41'46.5°N and 0°08'08.7°W and beside the Lakeside Marina Park, in the Greater Accra Region of Ghana. It covers an area of approximately 61,000 m^2. The lake serves as a source of water for a number of human and animal related activities.

Sample Collection and Analysis

Duplicate water samples were collected at five different sites along the banks of the lake(fig.1), with sterile screw-capped plastic bottles (as per standard methods described in the guidelines of the American Public Health Association (APHA) and American Water Works Association (AWWA) [13, 14]. The kind and intensity of consistent (for a few months) human activity were also noted. The water samples collected were labelled and transported to the laboratory for analysis.

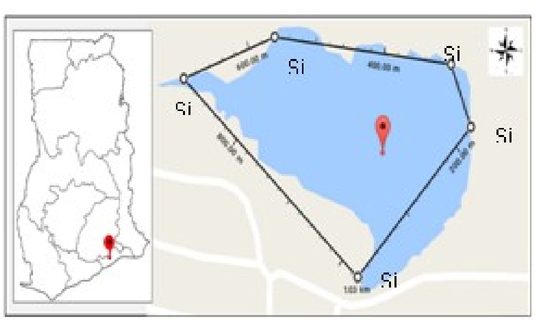

Figure 1: A google map of the "Marina Park Lake" showing the sites of collection of water samples

Sites were chosen based on access and insert is a map of Ghana indicating the location of the lake in the Greater Accra Region.

Digestion Protocol

The milestone Acid Digestion procedure was used, where 5 mL of the each water sample was measured into Teflon beakers, to this, 6 mL of concentrated HNO_3 (65%) and 1 ml H_2O_2 (30%) were added. The Teflon beakers were covered with Teflon cups and loaded onto rotor and tightly secured using a rench or torque. The rotor was then placed in ETHOS 900 microwave oven and digested using a digestion programme [15].

Atomic Absorption Spectrophotometer Determination

Analysis of metals of interest was performed using a Varian model AA 240 FS Atomic Absorption Spectrophotometer with the recommended instrument parameters and detection limits for each metal determined [15].The physicochemical parameters investigated were pH, Electrical Conductivity, hardness ($CaCO_3$) and Alkalinity, The analysis was carried out using the standard methods described by [13, 16].

Results

Study Location

The five sites from where the water samples were collected, were observed to have been associated with the human activities listed in Table 1. The extent of these activates were scored on a scale of 1 to 5, with 5 as the most active.

Table 1: Human interactions and concentration of some chemical indicators of water quality at each sample collection sites.

		Concentration (mg/L)								
Source	**Human Activity (Relative Score*)**	**F**	**Cl**	**$CaCO_3$**	**Nitrate**	**PO_4^{-3}**	**SO_4^{-2}**	**Alkalinity**	**pH***	**Conductivity (µS/cm)**
Site 1	Regular washing of cars and disposal of solid waste. (4)	0.230	84.0	212.0	1.511	0.072	21.9	140	7.0	1134
Site 2	Washing of cloths. (2)	0.210	211.9	228.0	1.520	0.077	23.1	108	7.0	1122
Site 3	Pumping of water for irrigation, washing of cloth, swimming. (3)	0.220	197.9	212.0	1.486	0.069	23.0	110	7.0	1148
rSite 4	Fetching of water by truck with pumps, washing of cloths, washing of cars, cattle drinking sources and main access to the lake. (5)	0.280	203.9	268.0	1.531	0.081	24.2	134	7.0	1146
Site 5	Almost no direct activity (1)	0.210	193.9	232.0	1.508	0.078	23.4	116	7.0	1146
FAO	Minimal human activity	1.000	140	-	< 5.0	2.0	250.0	-	6 – 9	2250

* Relative score of intensity of human activity on a scale of 1 to 5, where 5 is the most intense; *The pH was semi-quantitatively determined with a pH paper

Indicators of Water Quality

Table 1 also presents the levels of the most indicators of the chemical quality of water for each of the study sites. Specifically, the concentration of Fluoride (F) ranged between 0.210 mg/L for sites 2 and 5 and 0.280 mg/L for site 4. Furthermore, while the concentration of Cl was lowest at site 1 (84.0mg/L) and highest at site 2 (211.9 mg/L), the concentration of $CaCO_3$ was lowest at sites 1 and 3 (212.0 mg/L) but highest at site 4 (268 mg/L). The concentration of Nitrate, Phosphate and Sulphate varied within ranges of 1.486 mg/L (site 3) to 1.531 mg/L (site 4); 0.069 mg/L (site 3) to 0.081 mg/L (site 4) and 21.9 mg/L (site 1) to 24.2 mg/L (site 4) respectively. The physicochemical indicators (pH and conductivity) of the water obtained from each of the five sites also varied within a narrow range.

Metal Content

The concentration of Mnin the water ranged between a relatively higher concentrations for three sites; 0.0514 ± 0.001 mg/L for site 1; 0.0450 ± 0.0008 mg/L for site 2 and 0.0491 ± 0.0034 mg/L for site 4 to a relatively moderate concentration of0.0240 ± 0.008 mg/L for site 5 but was not detected in water from site 3 (Figure 2a). On the other hand, the concentrations of Zn were relatively moderate and within a narrower range; varying from 0.0191 ± 0.0004 mg/L for site 2, through 0.0203 ± 0.0008 mg/L for site 5; 0.0229 ± 0.0004 mg/L for sites 1 and 4, to 0.0248 ± 0.0008 mg/L for site 3.Similarly, the concentrations of Aswere also relatively moderate and varied within a narrow range. Mercury was only detected from sites 4 and 5 and its concentrations were relatively very low, compared to the concentrations of the other heavy metals (Fig.2a). The concentration of the following toxic metals Pb, Cd, Cu, Co and Cr in the water from the five sites were below the detection limits of the assays used (data not shown). The concentration of Fe in the water varied from one site to the other within a wider range (Figure 2b); these were 0.4815 ± 0.0128 mg/L and 0.4845 ± 0.0008 for sites 2 and 5 respectively, 0.7901 ± 0.0026 mg/L and 0.7313 ± 0.0045 mg/L for sites 3 and 1 respectively and 1.8161 ± 0.0041 mg/L for site 4. The concentration of magnesium (Mg) in the water from these five sites varied within a very narrow range (Fig. 2b). Specifically, sites 5 and 4 recorded 0.2183 ± 0.0060 mg/L and 0.2194 ± 0.0019 mg/L of Mg respectively, while sites 3, 2 and 1 recorded 0.2348 ± 0.0023 mg/L, 0.2359 ± 0.0026 mg/L and 0.2531 ± 0.004 mg/L in water from respectively.

In respect of the concentration of calcium (Ca) (Fig. 2c), it varied between 49.6 mg/L and 65.6 mg/L. Similarly, the concentration of sodium (Na) ranged from 47.1 mg/L to 56.1 mg/L. On the other hand, the recorded concentrations of potassium (K) were between 6.9 mg/L and 11.7 mg/L. The FAO recommended Maximum Concentration, as reported by Ayers and Westcot, (1985) are presented in the legend to figure 2. A comparison of the concentrations of each heavy metal between the five sites was conducted and the sites were ranged on a scale of 1 to 5, in increasing order.

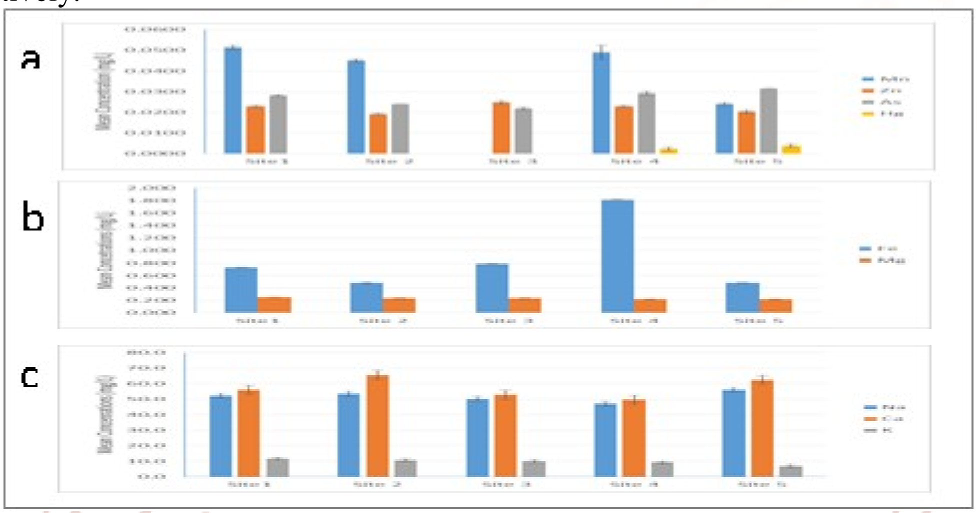

Figure 2: Toxic and essential metals concentrations in water from a Lake in use for irrigations of vegetables. FAO Recommended Maximum Concentration of these elements, in units of mg/L, are as follows; Fe (5.00), Zn (2.00), Mn (0.20), As (0.10), Hg (0.00), Mg (0.20), K (300 ppm*), Na (69.00), Ca (80.00). Adapted from Ayers and Westcot, (1985) and *[17]

DISCUSSION

In pursuit of providing guidance to vegetable farmers regarding the location, along the bank of the Marina Park Lake, from which to draw water for irrigation, we determined whether the concentration of trace and other elements were above the FAO guideline or maximum limits for water used for irrigation (Figure 2). Our findings(Figures 2),indicated that five of the ten major heavy metals of significant health concern (Pb, Cd, Cu, Co and Cr)were below detection limits (data not shown),implies a good indication of a water body potentially uncontaminated with toxic metals and therefore usable for irrigation. Further indications of this potential were that Hg was detected to be present at very low concentration and at only two of the five sites. Furthermore, the favourable usability of water from this lake for irrigation was indicated by the facts that the highest recorded concentrations of Fe, Zn, Mn, and As were extremely lower than the FAO recommended maximum concentrations in water for irrigation [9]. Additionally, the concentration of Na, K and Ca (Figure 2c)were also below their FAO and the USA recommended maximum concentration in water for irrigation[17, 9]. Additionally, the levels of the other indicators of the chemical quality of water, which include F, $CaCO_3$, nitrate, phosphate, sulphate, pH, conductivity and alkalinity were below the FAO recommended maximum levels[9],further indicating a low level of chemical pollution and a high potential usability of water from the Marina Park Lake for irrigation of urban vegetable farms.

These overall or generally very low concentrations of the metals may be due to the facts that the catchment area of this lake have not had, and continues not to have heavy and/or light industrial activity, as well as landfill sites, which are known to contribute significantly to highheavy/toxic metal pollution of water bodies[17–20].

However, in order to identify the most appropriate among these sites, to recommend to the farmers, comparing these findings and how they compare with the FAO recommendations imply that generally, water from the Eastern side of the Marina Park Lake (sites 2 and 3) is most suitable for irrigating vegetable farms. Among these sites, site 2 seems the most preferable location to draw water for irrigating the vegetable farms because it is the only site that did not record the highest relative concentration of any of the heavy metals but only a single second highest for Mg. In addition, Hg was not detected in water from this site and it recorded the lowest relative concentration for Fe and the second lowest relative concentration of As. On the other hand, sites 1 and 3, although less preferable to site 2 are more preferable to site 4 and 5.The variation in the concentrations of the each heavy metal between the sites may have been influenced by the nature and extent of human activity at each site. Therefore, for site 4, which experienced the highest intensity of the human activities, which included automobiles related activity, it is intuitive to expect, as has been observed, that site 4 will record the highest concentrations of the heavy metals. However, the very low extent of human activity at site 5 does not explain the detection of Hg and relative higher concentrations of as at this site, but may partly explain the lower concentration of the other heavy metals. Furthermore, the relative low concentrations of the heavy metals for site 2 intuitively correlate with the low relative intensity and the low number of human activity at that location. Based on the findings, water from the Marina Park Lake generally was usable for the irrigations and drawing water from site 2 will results in the most reduced potential of toxic metal contamination of the vegetables.

Limitations

This study is limited by the lack of a study of data on the geology of the lake and it surrounding land area, which may have contributed to its elemental content[21, 22, 19].Other human activities, which may not have been noted by this study (those that occur at night) and the contribution of vegetation associated with the lake, may have influenced the findings[22, 23]. A furthering of this study analysing oil and vegetables from the farm lands will aid the appropriate identification of the major source contributing to the toxic and/or essential element in such vegetables, and the assessment of the potentially exposure to humans through the consumption of such vegetables, respectively.

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