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Original Research Article

Water Quality and Crop Contamination in Peri-Urban Agriculture

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Abstract

The quality of untreated water used by dry season vegetable growers determines the safety of the vegetables produced for human consumption. Traditionally, small scale vegetable farmers site their farms along banks of streams which gradually dry up during the dry season resulting in isolated pockets of ponds at different intervals along the path of the streams which are used by farmers to irrigate. A field experiment was initiated at Ibadan to ascertain the quality of irrigation water used to produce vegetables along Ona-stream during the dry season. Five isolated ponds and one locally dug well were sampled and analysed to ascertain the heavy metals status. Results of soil analysis from five farms (A - E) sited very close to the stream revealed high concentrations of heavy metals ranging from 0.96 to 2.34 mg kg^{-1} for Pb, 0.72 to 2.16 mg kg^{-1} for Cr and 0.30 to 0.92 mg kg^{-1} for Co while farmland F sited about 90m away from the stream was free of Pb, Cr and Co contaminants. Locally dug well F water was free of Cr, Co and Pb while isolated ponds had Cr, Co and Pb in the range of 0.01 to 0.23 mg kg^{-1} which is beyond safe consumption thresholds. There were strong correlations between heavy metals in water and vegetable for Cr (0.992**), Cd (0.599**), Ni (0.614*) and Pb (0.552**) indicating that the hygienic status of dry season vegetables is largely determined by the quality of irrigation water. In addition, all vegetables irrigated with untreated isolated ponds contained Cd, Pb and Ni concentrations above maximum permissible standard which could pose risk to human health. Therefore, farmers should be enlightened on the need to use hygienic water for irrigation. Construction of shallow wells on the farms instead of using contaminated stream water directly could be a better option for healthy and sustainable agriculture.

Key words: water quality; irrigation; heavy metals; soil health; dry season vegetables.

INTRODUCTION

Water quality is a term used to describe the physical, chemical and biological characteristics of water, usually in respect to its suitability for an intended purpose (Diersing, 2009). Water could be used most effectively when it is in its purest form. This purity is, however, threatened by human activities. A variety of human activities such as urban and industrial development, mining and recreation, significantly alter the quality of natural water. Nigeria has about 5,000 registered industrial facilities and some 10,000 small scale industries operating illegally within residential premises (Westcot, 1997). In major cities (e.g Ibadan, Kano, Kaduna, Lagos, and Port-Harcourt), coloured, hot and heavy metal laden effluents especially from the textile, tannery and paint industries are discharged directly into open drains and water channels, constituting direct danger to water users and organisms. All over the world, many human diseases have been traced to pollution. Pollution is defined as the alteration or modification of the environment by the introduction of solid, liquid or gaseous substances at concentrations injurious to plants, animals and humans (Chaudry et al., 1989). The main problem in the residential area of a city is the poor management of garbage which results in pollution of environment (Shu et al., 2000). Stream water can become contaminated by indiscriminate dumping of waste materials from households into it especially during the rainy season. The contaminants such as sewage, sludge, industrial effluents, domestic waste products, oil spillage, pesticides, herbicides, solid industrial wastes and metallurgic waste products are frequently discharged into the stream. Dry season vegetable growers in urban and peri-urban areas make use of the stream water to raise their vegetables regardless of the quality of the water. As the stream gets contaminated with heavy metals, there is the possibility of the vegetables irrigated with this water to accumulate them and have health implications when such vegetables are consumed by humans as food.

In Nigeria, there are two distinct seasons, the rainy season and the dry season. The rainy season is the normal cropping season and this starts from March/April to October/ November, while the dry season starts from November/ December to February/March. Vegetables produced during the dry season usually command higher price than that of rain fed vegetables (Kintomo et al., 1997). This could be as a result of better quality of the dry season vegetables coupled with the low disease incidence compared with vegetables grown under rain fed condition.

Peri-urban vegetable production is an important enterprise in Africa because vegetables are easily cultivated on a small scale. The joint Food and Agriculture Organisation of the United Nations (FAO) and the World Health Organisation (WHO) experts consultation on the diet, nutrition and prevention of chronic diseases, recommended the intake of a minimum of 400 g of fruit and vegetables per day (excluding potatoes and other starchy tubers) for the prevention of chronic diseases such as heart disease, cancer, diabetes and obesity, as well as for the prevention and alleviation of several micronutrient deficiencies, especially in less developed countries (FAO/WHO, 2003). But the average Nigerian vegetable intake per day is below this recommended threshold (Kintomo et al., 1997). This inadequate intake of fresh vegetables may further be worsened during the dry season when scarcity of water limits the area under cultivation and quantity of vegetables that can be grown and supplied to the urban areas (Asiegbu, 1983).

Vegetables usually augment nutritive value of most of our staple food, which are deficient in vitamins, proteins and minerals. A remarkable change in nutritional requirements of an individual is bound to influence his health, skill and productivity. Now that the rural dwellers are finding it difficult to consume enough animal proteins, their dietary needs could be to some appreciable extent, met from the consumption of vegetables (Ellah, 2004). A judicious mixture of different vegetable proteins is enough to meet human daily protein requirements.

As a result of increasing population, irrigated agriculture is growing fast around all major cities in Africa. However, sustainable vegetable cultivation is largely affected by the quantity and quality of water available during the growing season (Van Leeuwen, 2001). It is widely accepted that levels of trace elements and heavy metals in irrigation water are likely to be toxic to plants at concentrations below that at which they pose a significant risk to human health and this provides a degree of natural protection to irrigators and consumers alike, that is, plants fail to thrive and farmers abandon the source well before levels present a risk to human health (Table 1). For example, some leafy vegetables are well-known to accumulate trace metals in the edible parts of vegetables which represent a direct pathway for their incorporation into the human food chain (Florigin, 1993). In addition, a summary of the effects of heavy metals on plants and human health according to FWR (1993), Leita et al. (1995) and Tiller et al. (1994) report is presented in Table 1. However, there is little information as regards the heavy metals status of vegetables raised with untreated stream water by the small scale farmers in Africa. Therefore, an experiment was conducted to access the quality of stream water used by the small scale farmers to irrigate their vegetables and consequently the health implications of consuming such vegetables.

MATERIALS AND METHODS

Site description

The study was conducted at Ajibode near University of Ibadan, Nigeria in January, 2012 at the peak of the dry season. The study area lies approximately between longitude 7^0 27^1N and latitude 3^0 53^1E. The sites have elevation ranging from 171 m -189 m above sea level. The rainfall pattern is bimodal with

Table 1. Heavy metals and their effects on plants and human health

Element	Source	Agronomic effects	Effects on health
Arsenic	Industrial effluents, an impurity in some detergents	Toxicity to plants varies widely	Very harmful, cumulative poison, carcinogenic, skin diseases
Cadmium	Washing powders as an impurity in phosphates, impurity in zinc steel industry, point, plastic	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg l^{-1} in solutions. Risk of accumulation in plants and soils	Very harmful, cumulative poison, food main source of intake
Chromium	Leather tanneries (about 40 mg l^{-1} in surface discharges)	Not generally recognised as an essential growth element. Lack of knowledge on its toxicity to plants	Carcinogenic, dermatitis, painful chrome ulcers. Food main source of intake
Nickel	Industrial effluents	Toxic to a number of crops at 0.5 mg l^{-1} to 1.0 mg l^{-1}	Carcinogenic
Lead	Lead-acid batteries, solder, alloys	Decrease respiration of soil organisms and inhibit plant cell growth at very high concentrations	Accumulate in skeleton, harmful for children and pregnant women

Source: Ghesquire (1999), Data drawn from: FWR (1993), WHO (1993), Tiller et al., 1994, Leita et al., 1995

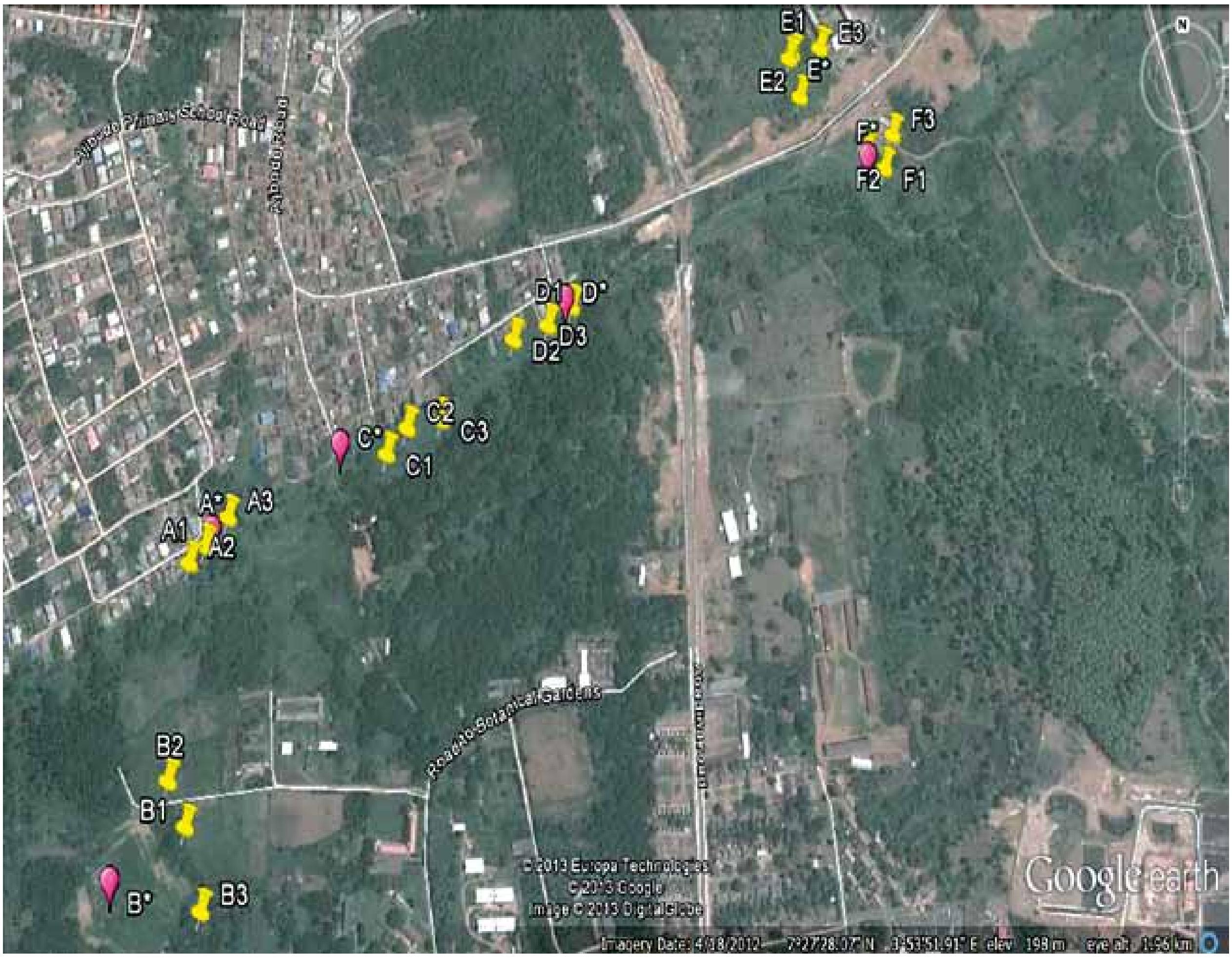

Figure 1. Aerial view of the study location along Ona stream in Ajibode, University of Ibadan

A, B, C, D and E = location of isolated pockets of water while F = location of artificially shallow dug well; (A_1, A_2, A_3), (B_1, B_2, B_3), (C_1, C_2, C_3), (D_1, D_2, D_3), (E_1, E_2, E_3) and (F_1, F_2, F_3) = sampling points on the farms grown to vegetables

an average of 1230 mm *per annum*. Rainfall peaks occur in June and September. There are two vegetative growing cycles during the wet season; an early wet season cycle runs from March to August and late wet cycle, mid-August to October. However, the dry season falls between November and early March. Six farms sited along the Ona stream that cut across the three towns (Orogun-Ajibode-Apete) within Ibadan were chosen and geo-referenced for the study (Fig.1). The selected farmer`s sites (A, B, C, D, E and F) are located at lowland areas with high water table which could only be cultivated during the dry season for vegetable production. These areas of land become inaccessible during the wet season because the land areas are usually flooded when the stream overflows and become uncultivable for vegetables.

Nature of the stream

The stream tributary is from Orogun (urban centre) and cut across Ajibode town. Household refuse were profusely dumped into the stream as a way of getting rid of their wastes. The stream cut across Ajibode town to Apete town. Vegetable growers normally site their farms very close to the bank of stream in order to make use of the raw stream water with minimum effort. During the dry season, the stream gradually dries up leaving only isolated pockets of water at different intervals along the path of the stream. The isolated pockets of water are used by the peasant farmers to irrigate their vegetables grown near the stream (Fig. 2). Crops mostly cultivated and irrigated are *Celosia* spp*., Amaranthus* spp*., Corchorus olitorius* and *Abelmoschus esculentus* as presented in Fig. 3.

Sampling/Data collection

Sampling of isolated pocket of water

The isolated ponds A, B, C, D and E used by vegetable growers to irrigate farms A, B, C, D and E, respectively, were

Figure 2. Pictures of isolated ponds and locally dug shallow well used by the small scale farmers to irrigate leafy vegetables in Ajibode town

sampled (Fig. 2). Locally dug well by farmer F about 90 m away from the stream serving farm F was also sampled (Fig. 2). Farmer F used this well water to irrigate his farm instead of isolated ponds of water used by other farmers. Each water sample was collected in plastic container and analysed within 24 hours. Water samples were analysed for pH, electrical conductivity (EC), biological oxygen demand (BOD), turbidity, sodium (Na) and heavy metals such as cobalt (Co), chromium (Cr), cadmium (Cd), lead (Pb) and nickel (Ni).

Soil sampling and analysis

Three soil core samples at 0-15 cm depth were taken from each farmer`s plot giving rise to 18 samples for six farms used for this study. Undisturbed soil core samples were used to determine bulk density by core method (Grossman and Reinsch, 2002), saturated hydraulic conductivity by the constant head method (Klute, 1986) and field capacity at 0.03 bars on tension table. Soil samples collected were air-dried and passed through a 2-mm sieve. The sieved soil samples were analyzed for pH in a 2:1 soil: water ratio using the Coleman’s pH meter. Particle size distribution was determined by hydrometer method (Gee and Or, 2002). Organic carbon was determined by the Walkley and Black procedure (Nelson and Sommers, 1982). The heavy metals (Ni, Pb, Cr and Cd) were determined by using atomic absorption spectrophotometer (AAS).

Sampling of vegetables from farmers fields

Six plants were randomly sampled from each farmer’s field. The plants were cut at the soil surface level in order to

Figure 3. Harvesting and packing of vegetables irrigated with raw stream water for sales

ascertain heavy metals level of edible portion. Samples were washed, oven dried at 65 ˚C for 72 hours and ground. The 0.5 g of ground sample was weighed into a 100 ml Berzelius beaker and 5 ml of HNO_3 and 2 ml of $HClO_4$ were added and covered with a watch glass. Digestion was carried out in a fume cupboard and the digest solution was filtered through an acid washed filter paper into a 50 ml volumetric flask. The solution was made up to 25 ml. The filtrates were then analysed for heavy metal concentrations (Ni, Pb, Cr and Cd) by using atomic absorption spectrophotometer (Jackson, 1965).

Statistical analysis

The six farmer's fields were regarded as treatments and the number of samples from each field represented the number of replicates. The data set for the soil, water and vegetable samples were analysed using Statistical Analysis Systems (SAS, 2002). The data were subjected to ANOVA using PROC. GLM procedure of the Statistical Analysis Systems (SAS, 2002). Significant differences between individual means were tested using the Least significant Difference (LSD) at p = 0.05. Relationships among the parameters measured were assessed using PROC.CORR. SAS procedure.

RESULTS AND DISCUSSION

Soil physico-chemical properties of the farms

The soil physical and chemical properties of the farmers` fields are presented in Table 1. The farms were significantly different in particle size distribution, bulk density, field capacity, organic carbon and electrical conductivity. In terms of particle size distribution, farms A and B were significantly higher in clay content than other farms. As a result, soils from farms A and B had higher field capacity than soils from farms C, D, E and F. Irrigating all farms with the same quantity of water is misleading as they were different in clay contents resulting to differences in water retention capacity. Farmers need to ascertain the physical conditions of their farms before irrigating in order not to over-rrigate or under-irrigate their farms. The amount of sand particles obtained from farms D, E and F were significantly higher than that of farms A and B indicating that farms D, E and F may have low water retention. Farms A, B and C had soil bulk density values of 1.20 to 1.37 Mg m^{-3} while farms D, E and F had soil bulk density values of 1.42 to 1.63 Mg m^{-3}. These bulk density values showed that farms A, B and C have fine textured soils while D, E and F have coarse textured soils (Hillel, 2004) suggesting that farmlands A, B

Table 2. Selected physical and chemical properties of soil in the farms used for growing dry season vegetables in Ibadan

Parameter	Vegetable Farmlands						LSD value
	A	B	C	D	E	F	
$pH_{2:1}$ (H_2O)	5.9	5.6	5.6	6.9	6.2	6.4	0.6*
Org. C (g kg^{-1})	18.54	36.88	15.13	14.83	35.12	17.05	2.2*
EC (Ns cm^{-1})	555	443	275	197	95	60	41.3*
Sand (gkg^{-1})	752	652	882	885	862	892	65.1*
Silt (g kg^{-1})	127	194	34	80b	54	24	18.4*
Clay (g kg^{-1})	120	154	84	94	84	84	21.6*
BD (Mg m^{-3})	1.36	1.23	1.37	1.63	1.63	1.42	0.2*
FC (m^3m^{-3})	0.53	0.85	0.60	0.63	0.44	0.38	0.2*
SHC (cm hr^{-1})	3.30	12.57	11.34	4.70	8.34	10.89	2.7*

*= significant difference at p = 0.05. Org.C = organic carbon, EC = electrical conductivity, BD = bulk density, FC = field capacity, SHC = saturated hydraulic conductivity

and C have higher ability to retain water and plant nutrients for crop use than farmlands D, E and F. Saturated hydraulic conductivity values from all farms were not significantly different, this could be attributed to the closeness of all the farms to the stream. The soil pH of the six farmlands were significantly different at P= 0.05 (Table 2). Farmlands A, B and C were slightly acidic while farmlands D, E and F were close to neutral. Soils nutrient availability would be higher in farmlands D, E and F with an average pH of 6.5 than farmlands A, B and C with an average pH of 5.7. Soil organic carbon was significantly higher in farms B and E than other farms indicating that the farms were different in nutrient status which would require different farm management practices especially with respect to fertilizer application. Soil electrical conductivity was significantly higher in farmlands A and B followed by farms C and D and least by farms E and F (Table 2). Farm F with 60 Ns cm^{-1} belongs to medium range indicating optimum level for plants while farm E with 95 Ns cm^{-1} belongs to high level indicating that germinating seeds or seedlings are likely to be injured. Farms A, B, C and D had excessive level of EC indicating definite injuries to most plants of all ages (Tony, 2003).

Heavy metals status of the farmlands

The status of heavy metals in the farmlands A, B, C, D, E and F are presented in Table 3. The concentrations of Cd, Pb, Ni, Cr and Co present in the soil are below the contamination level recommended by FAO, 1985 as presented in Table 3. Heavy metals concentration significantly varied from one farm to another. The concentration of Cd from the farm F was significantly lower than that of farms B, C, D and E by 91.8%, 95.0%, 92.3% and 90.1%, respectively. The difference in the concentration of Cd among the farms could be attributed to deposition of contaminants over the years by flooding during the rainy season except farm F. Organic matter can also have the opposite effect, as increasing soil organic matter

Table 3. Soil heavy metal (mg kg^{-1}) status of irrigated farmlands used for growing dry season vegetables at Ajibode village near University of Ibadan

Farm	Na	Cd	Pb	Ni	Cr	Co
	mg kg^{-1}					
A	4.01	0.42	1.40	1.89	1.10	0.30
B	6.14	1.22	2.34	2.13	0.86	0.32
C	2.93	2.03	0.96	3.11	2.16	0.92
D	5.14	1.31	1.57	1.52	1.40	0.40
E	3.00	1.02	1.63	1.45	0.72	0.31
F	2.52	0.10	0.00	0.20	0.00	0.00
LSD value	1.81*	0.02*	0.32*	0.11*	0.23*	0.46*

*= significant different at p = 0.05, Na = Sodium, Co = Cobalt, Cr = Chromium, Cd = Cadmium, Pb = Lead, Ni = Nickel

content increases the cations exchange capacity and thus enhances Cd adsorption (Gray et al., 1999; Rieuwerts et al., 2006). Lead concentration was significantly higher in farm B followed by farms A, D and E and least by C while farm F had none. Farm F did not have Pb concentration possibly because it was located about 90 m away from the stream unlike other farms located very close to the stream. Nickel concentration was significantly lower in farm F than farm A, B, C, D and E by 89.4%, 90.6%, 93.5%, 86.5% and 84.1%, respectively. Chromium concentration ranged from 2.16 mg kg^{-1} in farmland C to 0.72 mg kg^{-1} in farmland E while farmland F had zero concentration. Cobalt concentration was significantly higher in farm C than farm A, B, D, and E by 67.4%, 65.2%, 56.5% and 66.3%, respectively. Farmland F was free of Pb, Cr and Co because farmland F was far away from the reach of flood that contaminates the field during the rainy season. Locating farms away from stream is better than citing farmland nearby the stream for dry season vegetable production where wastes discharged from different sources could reach.

Quality of water used for irrigation

The quality of isolated pockets of stream water used by dry season vegetable growers varied significantly among selected farms as presented in Table 4. The pH of water serving six selected farmlands were not significantly different but ranged from 6.8 to 7.0. These pH values fall within the recommended range of 6.0 to 8.5 for irrigation purpose (FAO, 1985). Electrical conductivity of pockets of stream water used by farmers A, E and F for irrigation were lower than the recommended 300 Ns cm^{-1} by 40.0, 26.0 and 66.0%, respectively. This indicates that the water may not be injurious to any vegetable (FAO, 1985). On the other hand, electrical conductivity of pockets of water used by farmers B, C and D for irrigation was higher than the recommended value by 30.2%, 41.1% and 26.8% indicating that application of such water to vegetables at all ages could be injurious to plants. Biological Oxygen Demand (BOD) of water used for irrigation was significantly lower in artificial dug well used by farmer F than isolated pockets of water along stream course used by farmers A, B, C, D and E as presented in Table 4. This implies that farmlands A to E received water that contained higher quantity of organic wastes than artificially dug well F (FEPA, 1991). Higher quantity of organic waste is likely to contain organisms such as bacteria which could reduce the quality of leafy vegetables such as amaranthus, cochorus and celosia (FEPA, 1991). Increased BOD could also cause pollution in the surface water due to highly suspended solid which micro organisms use as substrate. Zata et al. (2008) reported that pathogenic organisms in irrigation water potentially affect the acceptability of the agricultural produce for safe consumption. Turbidity was significantly different among the isolated pockets of water used by the farmers to irrigate their farms (Table 4). Turbidity of isolated pockets of water serving farms A to E were higher than the recommended value of 5 NTU for irrigation while turbidity of artificially dug well serving farmland F was within the permissible standards (SON, 2007). Turbidity of isolated ponds serving farms A, B, C, D and E were higher than the permissible value by 66.6%, 89.3%, 93.0%, 90.5% and 61.5%, respectively. This could be ascribed to deposition of wastes of different sources into the stream which accumulate at different intervals as the stream gradually dries up at the onset of dry season resulting to the formulation of isolated pockets of water of different concentrations. Eddy and Udoh (2006) and Hashim et al. (2011) reported that the appearance of any water sample depends largely on the amount and types of wastes received or dissolved in it. In terms of the portability of the water, the higher the turbidity level, the higher the risk of contacting gastrointestinal diseases (WHO, 1973).

Table 4. Quality of irrigation water used on irrigated farmlands for growing dry season vegetables compared with safety standards

Farms	pH	EC Ns cm^{-1}	BOD mg c^{-1}	Turbidity NTU	Na	Co	Cr	Cd	Pb	Ni
					Mg l^{-1}					
A	6.8	180	474.2	15	21.2	0.01	0.02	0.10	0.10	0.24
B	7.0	430	796.2	47	73.2	0.01	0.01	0.11	0.21	0.36
C	6.8	510	885.3	72	53.4	0.02	0.21	0.23	0.02	0.42
D	6.9	410	813.4	53	65.4	0.01	0.03	0.10	0.10	0.22
R	6.9	220	467.3	13	31.2	0.01	0.01	0.32	0.10	0.12
F	6.9	100	86.2	5	7.5	0.00	0.00	0.01	0.00	0.01
Maximum permissible levels	6 – 8.5 (FAO)	300 (FA0)	-	5NTU (SON)	920 (FAO)	-	0.05 (SON)	0.03 (SON)	0.01 (SON)	0.02) (SON

EC = Electrical Conductivity, BOD = Biological Oxygen Demand, NTU = Neurometric Turbidity Unit, Na = Sodium, Co = Cobalt, Cr = Chromium, Cd = Cadmium, Pb = Lead, Ni = Nickel, FAO, 1985; SON, 2007

Table 5. Heavy metals content of dry season vegetables obtained from six irrigated farmlands in Ibadan

Farms	Na	Cd	Pb	Ni	Cr	Co
	mg kg^{-1}					
A	7.89	0.02	0.00	0.02	0.01	0.00
B	10.40	0.01	0.02	0.31	0.00	0.00
C	29.30	0.02	0.06	0.53	0.23	0.03
D	30.40	0.02	0.01	0.04	0.04	0.01
E	46.20	0.03	0.02	0.02	0.01	0.00
F	36.70	0.00	0.00	0.00	0.00	0.00
Maximum permissible levels	9.0 (WHO)	0.1 (FAO)	5.0 (FAO)	1.0 (NSC)	-	-

Na = Sodium, Co = Cobalt, Cr = Chromium, Cd = Cadmium, Pb = Lead, Ni = Nickel, NST = National Standard of China (2005)

The sodium concentration of isolated pockets of water and artificially dug well water were all below the recommended values of 920 mg l^{-1} (FAO, 1985). Results suggested that such water could be used to irrigate crops. However, Hudson (1994) reported that poor quality water with high sodicity could reduce the Soil Available Water (SAW) resulting to wilting of crops on the field. Isolated pockets of water serving farms A, B, C, D and E contained some traces of cobalt (Co) and chromium (Cr) while artificially dug well serving farm F contained none suggesting that water from locally made well is more hygienic than isolated pockets of water.

All isolated ponds of water serving farms A, B, C, D and E were higher in Cd than the maximum permitted concentration of 0.003 mg l^{-1} (SON, 2007) by 70.0%, 72.7%, 86.9%, 70.0% and 90.6%, respectively, while artificially dug well was lower in Cd concentration than the maximum permitted value by 66.6%. Result showed that using stream water directly to irrigate vegetables is risky to human health which could result in cancer when such vegetables are consumed (SON, 2007). In the same vein, lead (Pb) concentrations in isolated ponds serving farms A, B, C, D and E were higher than the maximum acceptable standard of 0.01 mg l^{-1} of Pb by 0.09, 0.2, 0.01, 0.09 and 0.09 mg l^{-1} of Pb while artificially dug well was free of Pb. Discharge of solid contaminants such as batteries, domestic wastes and metallurgic waste products could have polluted stream water making the water unsituable for irrigation. Higher concentrations of Pb in water could cause cancer interference with vitamins D metabolism after mental development in infants, toxic to the central and peripheral nervous systems (WHO, 1993; Leita et al., 1995). Again, making a shallow well beside the farm for irrigation is safe and hygienic because artificially shallow well made at about 90 m away from the main stream contained no lead concentration. In terms of Ni concentration, artificially dug well contained 0.01m gl^{-1} which is lower than the acceptable value of 0.02 mg l^{-1}. However, isolated ponds serving farms A, B, C, D and E were higher in Ni than the maximum permissible (0.02 mg l^{-1}) by 91.6%, 94.4%, 95.2%, 90.9% and 83.3%, respectively. According to SON (2007), using such isolated ponds directly could be carcinogenic to humans.

Heavy metals status of the vegetables

The Cd accumulation in the edible portion of vegetable ranged from 0.01 mg kg^{-1} to 0.03 mg kg^{-1} with average concentration of 0.02 mg kg^{-1} among farmlands irrigated with isolated ponds of water. However, vegetables irrigated with well water were free of Cd (Table 5). This could be as a result of higher concentration of Cd in the farms A, B, C, D and E that were irrigated with isolated ponds. The correlation between the Cd concentration in the edible portion of vegetable and the Cd concentration in the water was significant (r = 0.599*) at p = 0.05 as presented in Fig. 4. NIAES (2004) reported a positive correlation between the Cd concentration in the mature cotton seeds and the Cd concentration in the soil. In addition, decreasing the soil Cd concentration led to a decreased Cd concentration in the mature cotton seeds (Maeijima et al., 2007). These previous results suggested that crop Cd uptake depends on the soil Cd concentration. In general, vegetables from farm A, B, C, D and E contained certain amounts of Cd while vegetables from farm F contained none, indicating that Cd-free vegetables could be produced when contaminated stream water is avoided. Vegetables from farmlands A, B, C, D and E contained Pb concentration ranging from 0.01 to 0.06 mg kg^{-1} with average of 0.024 mg kg^{-1} (Table 5), while farm F vegetables were free of Pb. Although Pb concentration in vegetables produced beside the contaminated stream were below the maximum permissible level (6 mg kg^{-1}), it is better and safe to produce Pb-free vegetables as obtained from farm F located a few distance from the path of the stream. Lead-free vegetables obtained from farm F could be linked

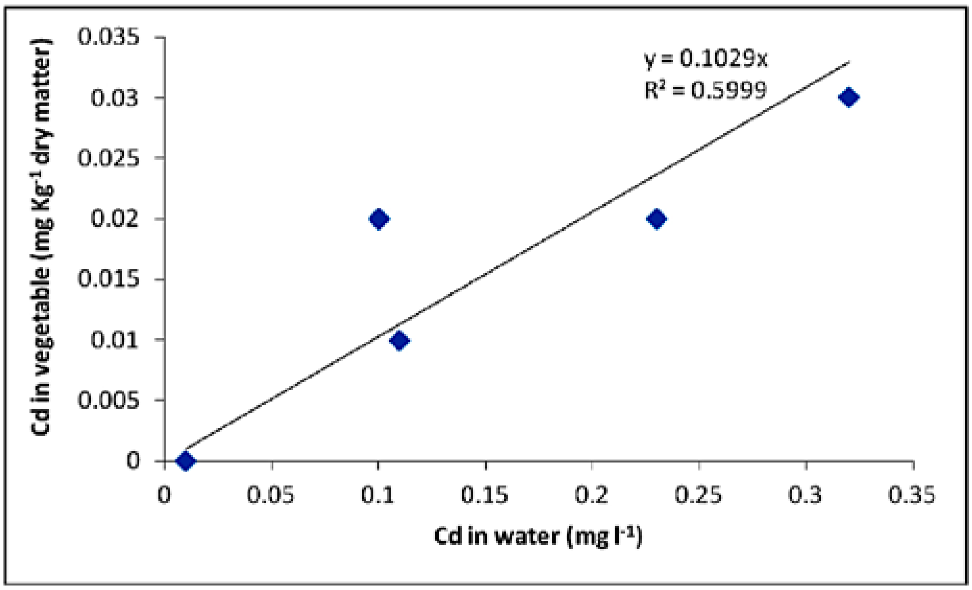

Figure 4. Relationship between the concentration of cadmium in vegetable and the concentration of cadmium in irrigation water

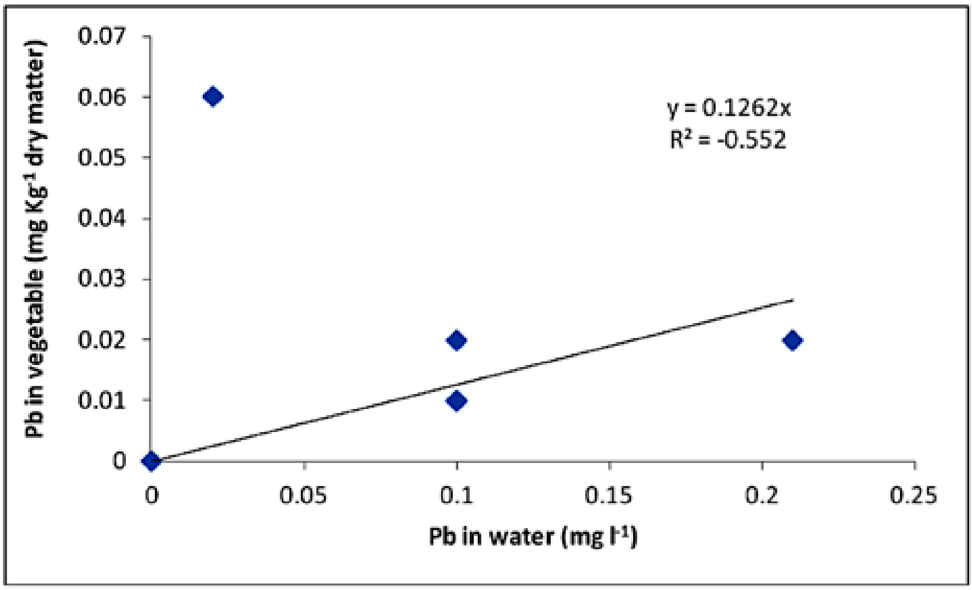

Figure 5. Relationship between the concentration of lead in vegetable and the concentration of lead in irrigation water

to Pb-free water used in irrigating farm F. This is confirmed by the significant (r = 0.552*) correlation between the Pb concentration in the edible portion of vegetable and the Pb concentration in the irrigation water as presented in Fig. 5. Lead contaminated vegetables cause acute and chronic toxicity to humans. Symptoms of acute Pb toxicity are headache, cramps, muscle infirmity, melancholy, coma, and in severe cases, death (Johnson, 1998). The effects of Pb are related to four targeted organ system; the hemopoietic, nervous, gastro-intestinal, and renal systems (Neal et al., 2010). Lead toxicity is more serious in children since the brain is yet to be fully developed and can cause learning disabilities, attention deficit disorders, lowered IQ, and anti-social behaviour (Neal et al., 2010). Vegetables from farm F contained Ni ranging from 0.02 to 0.53 mg kg^{-1} which is lower than maximum acceptable concentration of 30 mg kg^{-1} in vegetables (Li et al., 2010). The relationship between the Ni concentration in the edible portion of vegetable and the Ni concentration in the water was significant (r = 0.614*) at p = 0.05 as presented in Fig. 6. In terms of chromium, the same trend was observed such that vegetables from farms A to E contained 0.01 to 0.23 mg kg^{-1} while vegetables

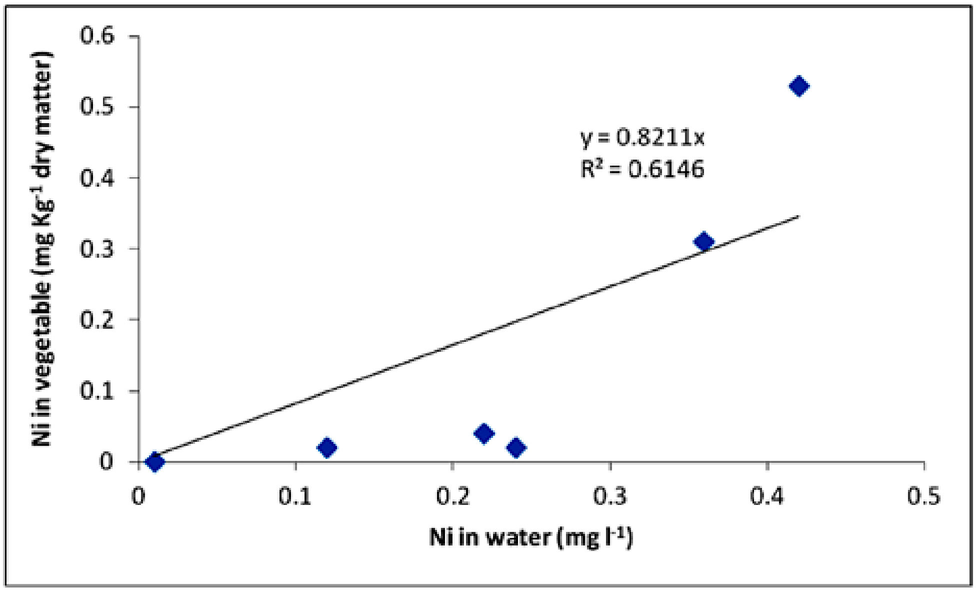

Figure 6. Relationship between the concentration of nickel in vegetable and the concentration of nickel in irrigation water

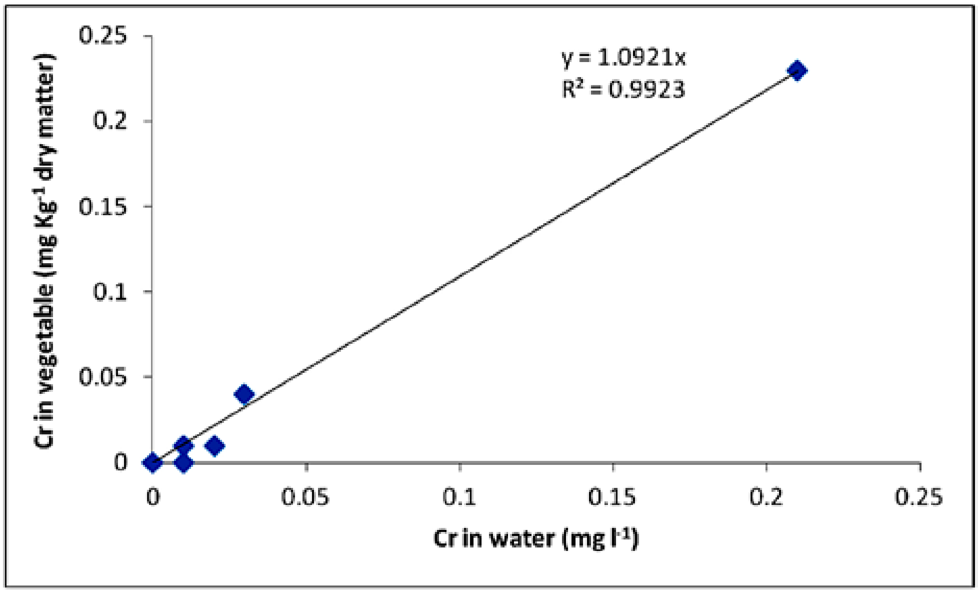

Figure 7. Relationship between the concentration of chromium in vegetable and the concentration of chromium in irrigation water

from farm F did not have chromium. Correlation between the Cr concentration in the edible portion of vegetable and the Cr concentration in the water was highly significant ($r = 0.992^{**}$) at $p = 0.01$ as presented in Fig. 7 suggesting that the quality of vegetable depends largely on the quality of water used. Harvested vegetables from farmlands A, B, E and F were free of cobalt while only vegetables from C and D farms contained 0.03 and 0.01 mg kg^{-1} of cobalt. In general, vegetables harvested from farm F located about 90 m from the contaminated stream were free of Cd, Pb, Ni, Cr and Co. This could be as a result of non-contaminated water and soil used in raising these vegetables.

CONCLUSION

The farmlands were significantly different in soil physical properties most especially field capacity suggesting that irrigating all farms with the same quantity of water is misleading as a result of differences in soil water retention capacity. Farmers need to ascertain the physical conditions of their farmlands before irrigating in order not to over-irrigate or under-irrigate their farmlands. Results also showed that farmlands A, B, C, D and E sited along the stream channel contained certain concentrations of heavy metals; Pb, Cr and Co while soils from the farm F located about 90 m from the path of stream was free of Pb, Cr and Co. Farmland F contained low concentrations of Cd and Ni as against significantly higher concentration of Cd and Ni in the farmlands located near the stream. This could be attributed to the inability of flood carrying contaminants during the rainy season to reach farm F and pollute the site. The quality of naturally isolated pockets of water used in irrigating the dry season vegetables varied in pH, EC, BOD, turbidity and heavy metals concentrations. Locally dug shallow well serving farm F was hygienic for irrigating as its EC, BOD and turbidity were within the acceptable standards recommended by FAO and SON. However, isolated pockets of water serving farms A, B, C, D, and E had EC, BOD and turbidity values above the maximum permissible values indicating that such water is not safe and unhygienic for vegetable cultivation. In general, vegetables harvested from farm F were free of Cd, Pb, Ni, Cr and Co. There were strong correlations between most heavy metals present in water and vegetable indicating that hygienic status of vegetables obtained from farm F could be as a result of non-contaminated soil and water used in raising the vegetables. There is strong indication that the quality of water used for irrigation determine to a very large extent the quality of vegetables produced. Therefore, farmers should be enlightened on the need to use hygienic water for irrigation by making shallow wells on their farms instead of using contaminated stream water directly for healthy and sustainable agriculture.

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