



Heavy Metal and Microbial Contaminants of Some Vegetables Irrigated With Goo Reservoir Water, Navrongo, Ghana

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Authors' contributions

This work was carried out in collaboration between both authors. Author TAA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author CAAW managed the analyses of the study and managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Globally, the safety of vegetables for consumption is becoming an increasing concern to consumers because of the risk associated with eating of vegetables contaminated with heavy metals and microbial organisms. An assessment of the extent of microbial contamination and also levels of heavy metals and the risk associated with the consumption of the vegetables irrigated with polluted Goo reservoir water in the Navrongo municipality was carried out. Site A used the channel flooding irrigation method whilst site B used watering cans for watering during the latter part of the dry season when the pressure of the water is low. A total of 128 vegetables samples were taken for microbial and heavy metals determination each. Samples of leafy vegetable and fruit vegetables were randomly taken from the two sites for microbial and heavy metal analysis. The reservoir was divided to North, South, East and West and water samples taken from each location. The

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concentrations of heavy metals in the reservoir exceeded the Food and Agricultural Organization (FAO) recommended levels of metals in water for irrigation. Site B recorded the highest microbial counts likewise heavy metal contaminants in the sampled vegetables. Levels of cadmium in the vegetables exceeded the World Health Organization/FAO permissible levels. Copper (Cu) had the highest concentration in both sites. Faecal Coliform (FC) levels in the vegetables were above the International Commission on Microbiological Specifications for Food (ICMSF) allowable limits. The high quantities of Total Coliform, Faecal Coliform, *E. coli*, helminthes eggs and salmonella contamination of the vegetables indicate high risk of getting diseases through the consumption of these vegetables. The hazard quotient of all the metals exceeded one in both sites except Zinc (Zn). The hazard index (HI) of heavy metals studied was above one in both sites, indicating they could have adverse health effect to human life. The analysis showed there was significant difference in microbial counts and levels of heavy metals in the vegetables in the two different sites. The consumers of these vegetables were at risk of contracting water-borne diseases like typhoid fever, cholera among others and also a high risk of heavy metal poisoning especially from cadmium.

Keywords: *Parasitic helminthes; pathogen; salmonella SPP; risk assessment; consumption; polluted runoff.*

1. INTRODUCTION

Worldwide, food safety is of great public concern. Currently, the growing demand on food safety has stirred up studies concerning the risks associated with the consumption of vegetables contaminated with heavy metals and pathogenic organisms. Various reports have disclosed that the consumption of vegetables contaminated with pathogens may be injurious to life [1,2]. There is inadequate supply of clean water for vegetable irrigation in urban areas. Therefore, most urban vegetable farmers resort to the use of polluted water for irrigation. This becomes an issue with regards to human health due to the possibility of contaminating the vegetables with pathogens [3]. The practice of using polluted water and fresh poultry droppings for the cultivation of vegetables in developing countries is a big problem causing the contamination of vegetables and hence causes many foodborne diseases [4,5]. The possibility of vegetables becoming contaminated on-farm and during processing becomes a potential source of humans getting infectious diseases [6-8]. Recent studies have shown there are a growing number of food-borne diseases principally due to eating fresh vegetables contaminated with pathogenic organisms [6,9,10]. Vegetables are vital source of nutrients especially vitamins and dietary fiber among others [11]. Heavy metal determination is one of the vital ways of ascertaining the quality assurance of food [12].

Vegetables have the ability to absorb easily and amass heavy metals in their leaves at high levels, irrespective of the quantities of the metals

in the soil due to the bioaccumulation nature of these metals [13]. Continuous consumption of vegetables with unsafe levels of heavy metals over a long period of time is deleterious to human health and is reported to be the cause of many disorders and diseases in humans. [14]. The determinants of the risk related to eating vegetables contaminated with heavy metals by humans are the quantity eaten and the individual's weight. Consumption of vegetables contaminated with low levels of heavy metals over a lengthy period of time has a deleterious effect on human health [15-17].

Goo reservoir is one of the reservoirs in the Kassena Nankana Municipality of Ghana meant for small scale irrigation. Its catchment area covers the entire Navrongo Township which is the capital of the municipality. Along the streams that go to the reservoir, people openly defecate and this is washed into to the reservoir. Farming activities which include chemical control of pest and weeds, fertilizer application and nomadism along the reservoir can affect the quality of water and subsequently have a health challenge for humans, livestock and other aquatic lives. Moreover, the constant use of the reservoir water for irrigation of leafy and fruit vegetables among other food types makes the water susceptible to bioaccumulation of agro-chemicals and other organic matter used in farming along the reservoir. All the storm drains within the township are channeled into the reservoir. Because running water turns to pick up contaminants such as, heavy metals, microbial organisms, trash and other pollutants from its path, eventually all these pollutants are deposited into the reservoir.

The combined effect of this puts the consumers of the vegetables being irrigated at risk of acquiring diseases. The levels of microbial and heavy metal contaminants in vegetables grown using water from Goo reservoir is not known in the present study area. Though similar studies have been done elsewhere, almost all of them were done on vegetables irrigated by sprinkling irrigation method which makes the leafy vegetables tend to accumulate the contaminants more because of their large surface area but in this study the vegetables were irrigated via the channel flooding irrigation method and some via water being sprinkled through watering can. So in this regard, the vegetables that absorb more water would likely accumulate more of the contaminants in the channel flooding method. This study was based on a hypothesis that the polluted runoff has resulted in pollution of the reservoir and hence contamination of the vegetables irrigated. Therefore, the study assessed the levels of microbial and heavy metal contaminants on these vegetables irrigated with polluted water from the reservoir.

The study will contribute to the prevention of likely health risk via the consumption of contaminated vegetables.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The Kassena-Nankana Municipal can be found within the Guinea Savannah vegetation and lies approximately between latitude 11° 10' and 10° 31' North and longitude 10° 11' West. It has a total land area of about 1,674 sq.km and stretch about 55 km North-South and 53 km East-West. The Municipality shares boundaries to the North with Burkina Faso, to the East with Bongo district and Bolgatanga Municipal, West, with the Builsa and Sissala districts and in Southwest with Mamprusi district in the North East region. According to the Ghana Irrigation Development Authority (GIDA), the Goo dam which was created by damming the wurisi stream was originally constructed in 1959 by the then Irrigation, Reclamation and Drainage Authority (IRDA). It has a catchment area of about 544 hectares with a reservoir length of 240 m.

2.2 Sampling and Analysis

Two sampling sites were identified and the selected vegetables were randomly harvested from each. Sixteen samples of the four different types of vegetables were each harvested adding

up to a total of 64 for each site. Viz a total of 128 were taken for microbial analysis and 128 samples for heavy metal determination.

The edible portions of the sampled vegetables were then oven dried at 80°C for about 2–3 days and weighed from time to time up to the time of achieving a constant weight. The oven dried samples were then grounded to get a fine powder and sieved using a 2 mm sieve and stored, until acid digestion.

Multi-element standard solutions of lead (Pb), cadmium (Cd), chromium (Cr), zinc (Zn), and copper (Cu) were prepared by dilution of 1000 mg/L stock solutions with 5% nitric acid (HNO₃) solution. Appropriate amounts of the metal salts were dissolved in purified HNO₃ and then used for the preparation of the calibration curves. The selected vegetable samples were each weighed (0.2 g) in duplicates into digestion flasks and treated with concentrated 10 ml HNO₃ and 5 ml H₂SO₄. A blank sample was equally made using 10 mL of HNO₃ and 5 mL of H₂SO₄ into an empty digestion flask. These flasks were then heated for 2 hrs on an electric hot plate at 80–90°C before the temperature was up to 150°C and the samples were then made to boil. In addition concentrated HNO₃ and H₂SO₄ were added to the sample (3–5 mL of each was added occasionally) and digestion continued until a clear solution was achieved. The solution was then made to cool and then filtered with Whatman's No. 42 filter paper and < 0.45 µm Millipore filter paper. The filtrate was then transferred to a 50 mL volumetric flask and topped up to the mark with deionized water. The digested 50 mL solution was transferred into a sample container which was rinsed with acid and labeled for analysis. Analysis of the sampled metals was done using a Shimadzu model AAS-6300 Atomic Absorption Spectrophotometer.

All quality control and assurance measures were followed, determination of Method Quantification Limits (MQL), and replicate analysis of samples were done. Concentration of heavy metals is presented as the mean value (mg/kg) of dry weight ± SD of four samples from each vegetable.

2.3 Microbial Analysis

A 25 g of each of the selected vegetable samples were blended in 100 mL of sterile saline solution for about 2 minutes under sterile conditions. Disinfection of the bender was cautiously done to prevent likely cross contamination. The

homogenized material were kept in sterile bottles and stored at -20°C until the analysis were done. Aliquots (0.5 mL) of each homogenized material were serially diluted in sterile saline solution. The respective media was then inoculated with the diluent of buffered peptone water. Total coliform and faecal coliform were determined using standard APHA9222A and APHA9222D methods respectively. E. coli was determined using the IDEXX Colilert® and Quanti-Tray® system. Salmonella concentrations were enumerated by the direct isolation method. It was conducted on a selective Difco™ SS Agar. Suitable dilutions of 10-fold, 100-fold and 1000-folds were done and spread in triplicates in selective SS agar and incubated at about 35°C for 2hrs. Positive colonies were then discovered based on their colour and morphology. Helminthes eggs were determined using the concentration method of the United States Environment Protection Agency [18]. The eggs were identified using structural attributes such as shape, colour and size.

2.4 Statistical Analysis

A one-way ANOVA was used to assess the differences among the sampled vegetables. The homogeneities of variances were verified via Levene’s test before the analysis of variance was carried out. Duncan’s test was then used to detect the significant differences amongst the means of the sampled vegetables. The significance in the procedure was set at $p < 0.05$ (significant). Arithmetic means with standard error attached was used to present the data.

2.5 Assessment of the Risk Connected with the Consumption of Vegetables Contaminated with Heavy Metals

Estimation of the possible risks to human life connected with prolong consumption of vegetables contaminated with heavy metals was computed using the average daily dose (ADD) of the selected metals, hazard index (HI), target hazard quotient (THQ), and non-carcinogenic

risk. Table 1 shows the parameters that characterized the ADD.

ADD was estimated using the equation;

$$ADD = C_i \times IR \times EF \times ED / BW \times AT \quad (1)$$

Where;

C_i is the metal concentration in the selected vegetable, IR is the ingestion rate, EF is the exposure frequency, ED is the exposure duration, BW is the body weight of consumer and that of AT is the average time. Estimation of health risk was done in relation to its non-carcinogenic as well as cancer causing effects of the selected metals based on the calculation of ADD estimates and the defined toxicity according to [19,20]. Assessment of non-cancer causing effects of ingestion of the selected metals was done using target hazard quotient values. If the ratio is greater than or equal to one, then consumers are at risk. The non-carcinogenic effect of consuming vegetables contaminated with the selected heavy metals was calculated as:

$$\text{Hazard Quotient (HQ)} = ADD / RfD \quad (2)$$

Where ADD is the average daily dose and RfD is the reference dose. Hazard index is used to assess the possible health risk to consumers when more than one heavy metal is consumed. HI was calculated as the summation of HQs.

$$HI = (THQ_i + THQ_{ii} + THQ_{iii} \dots \dots THQ_n) \sum THQ \quad (3)$$

The metal toxicity responses for the selected metals (dose response) are 5.0×10^{-4} for Cd, 3.0×10^{-3} for Cr, 3.5×10^{-3} for Pb, 3.0×10^{-1} for Zn, and 4.2×10^{-2} for Cu all in mg/kg/day as the Oral Reference Dose (RfD) [19, 20]. In assessing the risk to health of consumers of a mixture of heavy metals, the individual HQs are added to form hazard index (HI). An HI / HQ > 1 means a potential risk of non-carcinogenic effects on health, whilst HI / HQ < 1 means an acceptable level and not risky to consumers health [21].

Table 1. Input parameters used to characterize the ADD value [20]

Exposure parameters	Symbol	Units	Value
concentration	C	mg/kg	-
Ingestion rate	IR	g/day	2.2
Exposure rate	EF	days/year	365
Exposure duration	ED	years	70
Adult B W	BW	kg	70
Child B W	BW	kg	16
Average time	AT	years	25,550

3. RESULTS AND DISCUSSION

3.1 Some Selected Water Quality Parameters of Goo Reservoir

A baseline study was used to establish the levels of microbial and heavy metal contaminants as well as some physicochemical parameters of the reservoir. The results of the study revealed high levels of total coliform (TC), faecal coliform (FC) counts, *E. coli*, Salmonella and Helminthes eggs in the water of the reservoir. The mean coliform counts showed that the level of microbial contamination of the reservoir is far above the maximum permissible limit of 100 coliforms per 100 mL especially for cultivation of vegetables that are to be eaten especially without cooking [22] Table 2.

The south part of the reservoir had the highest mean TC and FC counts. The washing activities of people at this site could be a contributing factor for the high levels of coliform counts. The high TC and FC units, *E. coli*, salmonella and helminthes eggs makes the water unfit for vegetable irrigation without disinfection. The levels of helminthes which were of the *Ascaris lumbricoides* were beyond the maximum allowable limits of less than 1 helminthes egg/l for water meant for irrigation.

The study equally revealed that the reservoir had levels of heavy metal contaminants which exceeded the FAO recommended levels of heavy metals in irrigation water. Mean concentrations of heavy metals are presented in Table 3. Copper (C) recorded the highest mean value. The water was polluted with cadmium. The levels of Lead (Pb) in the reservoir were however below detection limits. Because of the bioaccumulation nature of heavy metals, analyses were conducted to determine if the vegetables irrigated were contaminated. The polluted runoff from the municipality accounted for the levels of microbial and heavy metal contaminants in the water of the reservoir. This undoubtedly had effect on the vegetables being irrigated.

3.2 Microbial Contamination of Vegetables

The selected vegetable samples were analyzed for TC, FC counts, *E. coli*, salmonella and helminthes eggs. Table 4 presents mean coliform forming unit per gramme (CFU/g) for total and faecal coliforms, *E. coli*, salmonella and number

of helminthes eggs. The highest microbial counts were found in the fruit vegetables in Site A except for salmonella and helminthes eggs whilst in Site B the highest microbial counts were found in the leafy vegetables. The channel flooding irrigation method employed by farmers in site A could possibly be the contributory factor for the high levels of microbial contaminants in the fruit vegetables that require more water for their fruiting and hence absorbing more of the polluted water containing the contaminants. The smooth surfaces of tomato and garden eggs could account for the low numbers of helminthes eggs in them because it makes it difficult for attachment by the eggs. On the other hand the leafy vegetables in Site B had the highest microbial counts because they had the largest surface area to accumulate more of the contaminated water which was sprinkled via watering can, hence contain more of the microbial counts. This was so because farms near the water outlet (Site A) used the channel flooding irrigation method throughout the growing season whilst that of farms far away from the outlet (site B) had to use watering cans for watering when the pressure of the water is low during the latter part of the dry season.

Our investigation showed that the vegetables were contaminated with TC, FC, *E. coli*, salmonella and parasitic helminthes. The high quantities of TC, FC, *E. coli*, salmonella and parasitic helminthes contamination of the vegetables indicate a risk of getting diseases via the consumption of these vegetables. The presence of TC, FC and *E. coli* is a suggestion that the vegetables are polluted with faecal matter [24]. The analysis showed that there was significant difference in the microbial counts between the vegetables in site A and B.

Mean values of microbial contaminants in vegetables irrigated with polluted water that are similar to the values recorded in this research were recorded in farms around Adama town in Ethiopia [25]. These coliform bacterial may have several origins some of which could be attributed to the polluted runoff from the municipality that is channeled into the reservoir. It runs off solid surfaces and collects pollutants including bacteria and then deposits them into the water body. Additionally, livestock are allowed to graze and drink freely around and from this water body and in the process indiscriminately contaminate this surface water with their faeces thus contributing to the high incidence of Total and faecal coliform build up.

Table 2. Some selected water quality parameters of Goo reservoir

	Location				Pr > Value
	South	West	East	North	
TC (CFU/100 mL)	7.2 × 10 ^{9b}	6.5 × 10 ^{9ab}	6.2 × 10 ^{9ab}	4.2 × 10 ^{9a}	0.082
FC (CFU/100 mL)	3.3 × 10 ^{9ab}	3.4 × 10 ^{9b}	2.5 × 10 ^{9ab}	2.2 × 10 ^{9a}	0.079
<i>E. coli</i> (CFU/100 mL)	3.4 × 10 ^{9b}	3.3 × 10 ^{9b}	2.9 × 10 ^{9ab}	2.4 × 10 ^{9a}	0.039
Helminthes (egg/L)	3.9 ^b	3.3 ^{ab}	2.6 ^a	2.7 ^a	0.033
Salmonella (CFU/100 mL)	2.5 × 10 ^{7ab}	2.7 × 10 ^{7b}	2.5 × 10 ^{7ab}	2.0 × 10 ^{7a}	0.095
EC (µS/cm)	1056.00 ± 103.6050 ^a	1005.00 ± 9.7639 ^a	1015.00 ± 7.1647 ^a	1012.75 ± 5.4391 ^a	0.532
DO (mg/L)	3.93 ± 0.5909 ^a	3.95 ± 0.4796 ^a	4.08 ± 0.4272 ^a	4.08 ± 0.6021 ^a	0.963
Turbidity (NTU)	888.500 ± 100.3112 ^c	746.750 ± 72.7708 ^b	615.500 ± 54.7814 ^a	707.500 ± 45.3615 ^{ab}	0.001
pH	7.20 ^a	7.22 ^a	7.22 ^a	7.24 ^a	0.900
Temperature (°C)	30.7 ^a	31.1 ^a	31.2 ^a	30.9 ^a	0.838

Table 3. Concentrations (µg/L) of the selected heavy metals in the reservoir water

Location	Heavy Metal (µg/L) ± STD				
	Cd	Cr	Zn	Cu	Pb
South	1.476 ± 0.0905 ^a	4.991 ± 0.1123 ^a	6.563 ± 0.5141 ^a	9.387 ± 0.5661 ^a	BDL
North	1.399 ± 0.0740 ^a	4.686 ± 0.3071 ^a	6.905 ± 0.3583 ^a	9.493 ± 0.5702 ^a	BDL
West	1.373 ± 0.0921 ^a	4.823 ± 0.1558 ^a	6.892 ± 0.7454 ^a	9.373 ± 0.5109 ^a	BDL
East	1.491 ± 0.0583 ^a	4.848 ± 0.2330 ^a	6.801 ± 0.5425 ^a	9.536 ± 0.3852 ^a	BDL
PL[23]	0.01	0.1	2	0.2	
P > value	0.629	0.597	0.819	0.941	N/A

Values are means of four replicates. Means within the same column having no superscript in common are significantly different ($p < 0.05$). Where PL= Permissible level, BDL= Below Detection Limit

Table 4. Mean microbial contamination of on-farm sampled vegetables at Goo irrigation site

SITE	Vegetable Type	Total Coliform (CFU/g) ± STD	Faecal Coliform (CFU/g) ± STD	<i>E. coli</i> (CFU/100 mL) ± STD	Helminth (egg/L± STD)	Salmonella (CFU/100 mL) ± STD
Site A	Tomato	9.0 ×10 ⁷ ±0.53 ^b	3.8×10 ⁷ ±0.60 ^{cd}	3.0×10 ⁷ ±0.42 ^b	1.3±0.13 ^a	1.7×10 ⁵ ±0.21 ^a
	G. Egg	9.1×10 ⁷ ± 0.35 ^b	3.6×10 ⁷ ±1.06 ^{bcd}	3.0×10 ⁷ ±0.3 ^c	1.3±0.17 ^a	1.6×10 ⁵ ±0.25 ^a
	Cabbage	4.6×10 ⁷ ±1.15 ^a	2.6×10 ⁷ ±0.55 ^a	2.3 ×10 ⁷ ±0.34 ^a	2.8±0.40 ^b	2.1 ×10 ⁵ ±0.36 ^b
	Lettuce	3.7×10 ⁷ ±0.60 ^a	2.9×10 ⁷ ±0.40 ^{ab}	2.3 ×10 ⁷ ±0.35 ^{ab}	2.7 ±0.39 ^b	2.2 ×10 ⁵ ±0.16 ^b
Site B	Tomato	8.9 ×10 ⁷ ±0.55 ^b	4.1×10 ⁷ ±0.63 ^d	3.7× 10 ⁷ ±0.41 ^d	1.6±0.15 ^a	2.4×10 ⁵ ±0.23 ^b
	G. Egg	9.1×10 ⁷ ±0.34 ^b	3.6×10 ⁷ ±1.08 ^{bcd}	3.2×10 ⁷ ±0.32 ^c	1.6±0.19 ^a	2.4×10 ⁵ ±0.28 ^b
	Cabbage	4.8×10 ⁸ ±1.13 ^a	3.0×10 ⁸ ±0.54 ^{ab}	2.8×10 ⁸ ±0.24 ^{abc}	3.1±0.43 ^b	2.4 ×10 ⁶ ±0.35 ^b
	Lettuce	4.3×10 ⁸ ±0.64 ^a	3.1×10 ⁸ ±0.45 ^{abc}	2.9 ×10 ⁸ ±0.25 ^{bc}	2.9±0.41 ^b	2.3 ×10 ⁶ ±0.15 ^b
P> Value		< 0.000	0.004	< 0.000	< 0.000	0.002

Values are means of four replicates. Means within the same column having no superscript in common are significantly different ($p<0.05$). Where STD = Standard deviation

Improper sanitary conditions like open defecation in most of the catchment areas also contributed to the high quantities of TC, FC, *E. coli*, salmonella and helminthes eggs counts in the water samples. Ultimately this polluted water used for irrigating the vegetables undoubtedly contributed to the high levels of TC, FC, *E. coli* and helminthes eggs counts in the vegetables sampled. Regardless of the formation of national laws in Ghana, like many other developing nations, the emission of polluted wastes into the environment is still a major challenge [26]. The use of polluted water especially one contaminated with faecal matter for irrigation is one of the vital sources of TC, FC, *E. coli*, salmonella and helminthes eggs contamination of vegetables [27,28]. Based on this that the WHO urged that vegetables to be consumed especially uncooked ought to be irrigated with treated wastewater that has been disinfected to a coliform level of not more than 100 coliforms per 100 mL. Our findings as well as past reports in Ghana [27] intimate that this suggestion has not been complied with. The presence of helminthes eggs in the sampled vegetables suggests that they are leading source of parasitic infections to consumers. This calls for proper washing and disinfection of them before consumption. The incidence of salmonella in the vegetables makes them a potential source of gastroenteritis and typhoid fever for consumers.

These findings indicate that the high levels of TC, FC, *E. coli*, salmonella and parasitic helminthes contamination of the sampled vegetables make them pose potential health risk to consumers. Although, these indicator microorganisms are not pathogenic, they are usually a sign of faecal contamination, leading to the risk of consumers getting exposed to pathogens that could trigger ailments especially diarrhoea and typhoid fever [29]. In order to avert this, the International Commission on Micro Biological Specification for food (ICMSF) established a permissible limit of 1×10^3 100/g fresh weights for FC presence in food and above this the food ought to be regarded unsafe for human consumption. The WHO in this regard also set a guideline value of 1×10^3 per 100 mL as satisfactory levels of faecal coliform presence in food [22]. The present results clearly suggest that the contamination of the vegetables have exceeded the guideline values of both ICMSF and WHO and this may pose risk to consumer's health. Most of the vegetables are eaten raw hence; microbial contamination becomes a leading health risk [30]. It has been reported that when such

contaminated vegetables are consumed especially in their raw state results in diseases such as typhoid, dysentery, diarrhoea and vomiting, cholera and ascariasis [31]. An estimated loss of about 12,000 disability-adjusted life years (DALYs) annually via the consumption of fresh vegetables contaminated with *E. coli* and other harmful pathogens has been reported in Ghana [32]. This estimate is almost 10% of the DALY loss taking place in Ghana as a result of several kinds of water and sanitation related ailments as reported by the WHO [33].

In Ghana, if the quality and safety of urban cultivated vegetables are to be improved, there ought to be the need for ensuring robust observance of on-farm compliance with quality and safety standards. However, just prohibiting the use of polluted wastewater for irrigation might strip several farmers and other vegetable value chain operators their source of livelihood and could also diminish the stock of vegetables in Ghana's urban areas. Therefore, more conscious and combative efforts are needed towards enhancing sanitation within the towns. This especially in the Navrongo municipality would reduce the level of dirt and hence reduce the level of contamination of the reservoir. Also, the Kassena Nankana municipal assembly has to enforce its by-laws to ensure that each house has a toilet facility to eliminate/reduce open defecation which eventually finds its way into the reservoir. Farmers should also be sensitized and encourage to converting poultry droppings into compost before properly applying it to their vegetable farms. This undoubtedly has the possibility of cutting down pathogenic contamination from the use of fresh poultry droppings. Proper public education and sensitization is also needed to ensure proper hygienic practices in handling and preparation of vegetables before consumption. Earlier studies suggest that treating vegetables with ethanol, benzoate, citrate and chlorinated water reduces the microbial loads to a certain degree [32,34,35].

3.3 Heavy Metals Concentrations in Sampled Vegetables

This present results show that there was moderate to high quantities of heavy metals concentrations in the selected vegetables. Table 5 shows the heavy metals mean concentrations of the on-farm sampled vegetables. The concentration of cadmium (Cd) in tomato, cabbage and lettuce was greater than the

WHO/FAO guideline value of 0.02mgkg⁻¹ in site A and that of all the vegetables in site B had Cd levels above the recommended level [36]. The mean values of the rest of the heavy metals in the vegetables were within the guideline values of WHO/FAO. The mean concentrations of Pb in all vegetables selected were below detection limit (BDL). Cu recorded the highest mean values in both sites. The concentration of heavy metals in the vegetables in site B were higher than that of site A and also there was significant difference in the levels of metal contaminants in the vegetables among both sides. This could be attributed to the difference in irrigation methods.

Our findings showed that cadmium concentrations in some of the sampled vegetables were above the WHO/FAO guideline values. Cd values of 0.05 mg/kg in vegetables grown in peri-urban centers were recorded in Tamale Metropolis, Ghana [37]. Previous studies on vegetables grown on contaminated soil in Kumasi revealed high Cd values in the range of 0.68 to 1.78 mg/kg [38]. Equally high mean concentrations of Cd in vegetables that were far above the allowable limits were recorded in Varanasi, India and Addis Ababa, Ethiopia [39,40]. Apparently Cd is becoming a growing health threat in urban vegetable production and is reported to be the cause of several diseases including kidney problems [41]. According to the WHO Cd exposure could lead to a dip in bone calcium concentration which could be fatal to life [41].

Chromium (Cr) concentrations in all the sampled vegetables were far below the WHO/FAO recommended guideline value of 5.0 mg/kg. The findings of this research showed that Cr levels in the vegetables might not be risky to consumer's health. An assessment of different vegetables grown in and around urban areas recorded Cr concentrations in vegetables similar to ours [42]. Chromium is essential for human health and for that matter inadequacy of it in the body could have negative impact on cellular responses to insulin [41].

Zinc (Zn) concentrations in all the sampled vegetables were far below the guideline value of 60 mg/kg. Mean values of Zn below 10 mg/kg in vegetables irrigated with polluted water were recorded in Accra [43]. Equally in Varanasi, India, results similar to our findings were recorded where Zn mean values were within the maximum recommended limit [39]. Zn is required for physiological and metabolic process in humans.

But, higher levels of Zn in diet can be injurious to human life [44].

Copper concentrations in all the selected vegetables were equally far below the guideline value of 40 mg/kg. Therefore, the levels of Cu in the sampled vegetables were safe for consumption. Mean Cu levels that were equally below the guideline values in vegetables irrigated with polluted water were recorded in Ghana [43]. Cu is vital for the proper functioning of the human body. Nonetheless, excessive intake of it could cause a lot of diseases including liver damage [45,46].

Lead (Pb) concentrations in all the vegetables selected were below detection limit. This suggests the vegetables are free from Pb pollution. It is one of the most toxic metals. Exposure to it may have untoward effects on the human body and could cause damage to a lot of the body organs and systems. For instance it could lead to kidney damages and cardiovascular problems [47,48].

In general, the study showed that heavy metal contaminants were present in different amounts in the sampled vegetables irrigated by Goo reservoir. The concentrations of Cd in all except garden egg surpassed the reference limit. The broad differences in metal concentrations in the sampled vegetables could be attributed to variations in how the various vegetables could pick up the metals from the soil/water. Vegetables ability to pick up metals from the soil is dependent on various factors like the soil type, the vegetable species, their stage of growth, and the kind of metal [49, 50]. There are broad variations in how different plant species could take up metals [51]. They reported that Cd, Cu and nickel could be taken up at high levels by plants from soils irrigated with polluted water. In addition, studies showed that plants do not accumulate Pb from the soil because its absorption by roots is passive and low and that the concentration of Pb in plants was due to the levels of Pb in the atmosphere [49,51].

3.4 Health Risk Assessment of Consumption of Vegetables Contaminated with Heavy Metals

There are numerous routes of heavy metals exposure to humans. When vegetables contaminated with substantial amounts of heavy metals are eaten by humans, it could be injurious to their health. The average daily dose was computed using the mean concentrations of Cd,

Cr, Zn, Cu and Pb in the sampled vegetables. Table 6 contains ADD values for both adults and children. These values were then used to determine the hazard quotient (HQ) and overall toxic risk (hazard index, HI) of the various vegetables selected. When the HQ is greater than one, there is fear of possible health effect [52].

The hazard quotient (HQ) and hazard index (HI) values of the sampled vegetables are presented in Table 7. It is clear that for children, the HQ values for all the metals except Zn and Pb exceeded one. Hence, there is the possibility of

health risk in relation to the continuous consumption of these vegetables. Also, for adults Cd and Cr HQ values exceeded one except the Cd value for garden egg which was below one. The findings revealed that the hazard index values of the studied heavy metals varied from 9.76 to 54.21 for site A and that of site B were from 10.69 to 120.20 and were far above one, suggesting the likelihood of adverse health effects on consumers. Therefore, the HI recorded for the sampled on-farm vegetables from the Goo irrigation site indicates that the combined effect of eating the contaminated vegetables could be lethal. The high HI values for the heavy metals

Table 5. Heavy metal concentrations of vegetables sampled from on-farm, Goo irrigation site in (mgkg⁻¹)

SITE	Vegetable Type	Heavy metals (mg/Kg) ± STD				
		Cd	Cr	Zn	Cu	Pb
Site A	Tomato	0.030 ± 0.01 ^a	0.927 ± 0.05 ^c	0.459 ± 0.05 ^{ab}	0.999 ± 0.03 ^{ab}	BDL
	G. Egg	0.015 ± 0.02 ^a	0.831 ± 0.12 ^{abc}	0.275 ± 0.26 ^a	1.056 ± 0.03 ^b	BDL
	Cabbage	0.026 ± 0.05 ^a	0.775 ± 0.05 ^{ab}	0.313 ± 0.17 ^{ab}	0.944 ± 0.06 ^a	BDL
	Lettuce	0.021 ± 0.05 ^a	0.736 ± 0.04 ^a	0.287 ± 0.21 ^{ab}	0.950 ± 0.02 ^a	BDL
Site B	Tomato	0.266 ± 0.07 ^b	0.876 ± 0.03 ^{bc}	0.515 ± 0.06 ^b	1.031 ± 0.04 ^{ab}	BDL
	G. Egg	0.031 ± 0.06 ^a	0.770 ± 0.15 ^{ab}	0.364 ± 0.23 ^{ab}	0.959 ± 0.02 ^a	BDL
	Cabbage	0.055 ± 0.08 ^a	1.871 ± 0.06 ^d	0.732 ± 0.15 ^c	1.489 ± 0.09 ^c	BDL
	Lettuce	0.062 ± 0.03 ^a	2.063 ± 0.09 ^e	0.845 ± 0.27 ^c	2.751 ± 0.05 ^d	BDL
WHO, FAO (2007)		0.02	5	60	40	0.30
P> Value		0.016	< 0.012	< 0.001	< 0.014	

Table 6. Average daily dose (ADD) (mg/kg/day) for sampled vegetables

Metal	Tomato	G.egg	Cabbage	Lettuce
Site A				
Cd adult	0.00094	0.00047	0.0008	0.00066
Cd child	0.0041	0.0021	0.0036	0.0029
Cr adult	0.029	0.026	0.026	0.023
Cr child	0.127	0.114	0.106	0.101
Zn adult	0.014	0.007	0.0098	0.009
Zn child	0.063	0.0038	0.043	0.039
Cu adult	0.031	0.033	0.296	0.299
Cu child	0.139	0.145	0.1298	0.131
Pb adult	-	-	-	-
Pb child	-	-	-	-
Site B				
Cd adult	0.0084	0.00097	0.0017	0.0019
Cd child	0.037	0.0043	0.0076	0.0085
Cr adult	0.028	0.024	0.059	0.065
Cr child	0.12	0.11	0.26	0.28
Zn adult	0.016	0.011	0.023	0.027
Zn child	0.071	0.05	0.1	0.12
Cu adult	0.032	0.03	0.047	0.086
Cu child	0.14	0.13	0.2	0.38
Pb adult	-	-	-	-
Pb child	-	-	-	-

Table 7. Hazard quotient (HQ) and hazard index (HI) of selected on-farm vegetables from Goo irrigation site, Navrongo municipality

Vegetable	Cd	Cr	Zn	Cu	Pb	HI
Site A						
Child						
Tomato	8.20	42.33	0.21	3.47	-	54.21
G.egg	4.20	38.00	0.13	3.63	-	45.92
Cabbage	7.20	35.33	0.14	3.25	-	45.96
Lettuce	5.78	33.66	0.13	3.26	-	42.83
Adult						
Tomato	1.88	9.66	0.04	0.76	-	12.34
G. egg	0.94	8.66	0.02	0.83	-	10.45
Cabbage	1.60	8.00	0.03	0.74	-	10.37
Lettuce	1.32	7.66	0.03	0.75	-	9.76
Site B						
Child						
Tomato	74.00	40.00	0.24	3.50	-	117.74
G.egg	8.60	36.70	0.17	3.30	-	48.77
Cabbage	15.20	86.70	0.30	5.00	-	107.20
Lettuce	17.00	93.30	0.40	9.50	-	120.20
Adult						
Tomato	16.80	9.30	0.05	0.80	-	26.95
G.egg	1.90	8.00	0.04	0.75	-	10.69
Cabbage	3.40	19.70	0.08	1.20	-	24.38
Lettuce	3.80	21.70	0.10	2.20	-	27.80

recorded in tomato, garden egg, cabbage and lettuce present a substantial health risk to the consumer.

The HQ and HI values for children were higher than that of adults. This indicated that the potential health risk for children would be greater than that of adults. The variations in THQ values for adults and children could be traceable to the fact that intake of meals, body weight and age amongst them vary. Males and females as per records exhibit differences in HI (THQ) values via the consumption of vegetables contaminated with heavy metals [53,54].

4. CONCLUSION

The samples of tomato, garden egg, cabbage and lettuce randomly collected from Goo irrigation site within Navrongo township all established to be contaminated with coliforms beyond the limits of International Commission on Microbiological Specifications for Food (ICMSF) and WHO's reference points for acceptable levels of FC presence in vegetable. The high TC and FC counts found in these vegetables suggest that the consumption of these vegetables could be a possible source of risk to human health. The incidence of parasitic

helminthes in the vegetables calls for proper washing of them before consumption. The presence of salmonella in the vegetables makes them a potential source of gastroenteritis and typhoid fever. This calls for urgent curative measures, including sensitization of the populace and good sanitation to reduce the levels of contamination of vegetables and the potential health menace linked with the consumption of such vegetables. Cu recorded the highest mean values in both sites but was below the allowable limit and therefore does not pose any risk to the consumer.

The heavy metal contaminants in the various vegetables were below the reference limits of WHO/FAO except Cd. For children the HQ values for all metals except Zn and Pb exceeded one signaling a possible source of health risk. Also, for adults the Cd and Cr were greater than one except Cd for garden egg which was below. The HI for both children and adults surpassed one which could present health risk. It was discovered that the different irrigation methods had impacts on the levels of contaminants on the vegetables especially the microbial ones whereby the channel flooding irrigation reduced the levels of contamination.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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