

Original Research Article

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

Abstract

Aims: 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. We assessed 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.

Study design: 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.

Place and duration: The research was carried out in the Navrongo municipality of the Upper East region of Ghana from November, 2018 to April 2019.

Methodology: 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.

Results: The concentrations of heavy metals in the reservoir exceeded the **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 **WHO/FAO** permissible levels. **Cu** had the highest concentration in both sites. **FC** levels in the vegetables were above the International Commission on Microbiological Specifications for Food (ICMSF) allowable limits. The high quantities of **TC, FC**, *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 **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.

Conclusion: 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]. Wang et al, (2005) reported (rephrase) that, heavy metal determination is one of the vital ways of ascertaining the quality assurance of food.

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]. Protracted eating of vegetables with unsafe levels of heavy metals 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. Extended consumption of vegetables contaminated with low levels of heavy metals has a deleterious effect on human health [15-17].

Goo reservoir is one of the reservoirs in the KassenaNankana 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 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, running water turns to pick up contaminants such as, heavy metals, microbial organisms, trash and other pollutants from its path and eventually deposited into the reservoir (rephrased).

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. 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' N and 10° 31' N and longitude 10° 11' W. 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 544ha with a reservoir length of 240m.

2.2. Sampling and Analysis

Two sampling sites were identified and the selected vegetables were randomly harvested from each site. Sixteen samples of four different types of vegetables were harvested adding up to a total of 64 for each site. Viz a total of 128 were taken for microbial analysis and for heavy metal determination.

The edible portions of the sampled vegetables were firstly oven dried at 80 °C for about 2–3 days and weighed from time to time until a constant weight is achieved. The oven dried samples were then grounded to get a fine powder and sieved using a 2 mm sieve and stored for 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 (0.2g) in duplicates into a digestion flask and treated with 10ml of concentrated

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 heated for 2 hrs on an electric hot plate at 80–90 °C before the temperature was increased to 150 °C and the samples made to boil. In addition, concentrated HNO₃ and H₂SO₄ were added to 3–5 mL sample occasionally and digestion continued until a clear solution was achieved. The solution was made to cool and then filtered with Whatman's No. 42 filter paper and < 0.45 µm millipore filter paper. The filtrates (digested solution) were transferred to a 50 mL volumetric flask topped up to the mark with deionized water and transferred into a sample container which was rinsed with acid before the filtrate was transferred and finally 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. Concentrations of heavy metals were 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 a 100 mL of sterile saline solution for about 2 minutes under sterile conditions. Disinfection of the blender 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 were 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 were also determined using the IDEXX Colilert® and Quanti-Tray® system. Salmonella concentrations were enumerated by the direct isolation method (i.e conducted on a selective Difco™ SS Agar method). 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 (shape and size) and with Helminth eggs determined using the concentration method of the USEPA (USEPA, 1999) Rephrase.

2.4. Statistical Analysis

A one-way ANOVA to assess the differences among the sampled vegetables were conducted. The homogeneities of variances were verified via Levene's test before the analysis of variance was carried out. Duncan's test was also used to detect the significant differences amongst the means of the sampled vegetables. The significance in the procedure was set at p < 0.05 and arithmetic means with standard error attached were 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 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 [18,19]. 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: Hazard Quotient (HQ) = ADD/RfD (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) [18, 19]. In assessing the risk to health of consumers of a mixture of heavy metals, the individual HQs are added to form hazard index (HI): [Lim et al. \(2008\) Rephrase](#) reported that 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.

Table 1 Input parameters used to characterize the ADD value [19].

| 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

1. 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 100mL especially for cultivation of vegetables that are to be eaten especially without cooking [21].Table 2.

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 |
| E.coli(CFU/100mL) | 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 |

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 *Ascarislumbricoides* 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 Table3. Copper (Cu) recorded the highest mean value and showed also the water been polluted with cadmium. The levels of Lead (Pb) in the reservoir were however below detection limits. Because of the bioaccumulation nature of heavy metals analysis was conducted to determine if the vegetables irrigated were contaminated. The polluted runoff waste 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.

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[22] | 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

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 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.

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

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 [23]. The analysis showed that there was significant difference in the microbial counts between the vegetables in site A and B.

Girmayer et al, 2014 Rephrase reported mean values of microbial contaminants in vegetables irrigated with polluted water that are similar to the values recorded in this research. These coliform bacterial may have several origins some of which could be attributed to the polluted runoff waste 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.

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 [25]. 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 [26, 27]. Based on conducted studies, 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 100mL. Our findings as well as past reports in Ghana [26] intimate that this suggestion has not been complied with. The presence of helminthes eggs in the sampled vegetables suggests that these are leading sources of parasitic infections to consumers. This calls for proper washing and disinfection of vegetables 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 [28]. In order to avert this, the International Commission on Micro Biological Specification for food (ICMSF) established a permissible limit of 1×10^3 per 100/g fresh weights for FC presence in food and above these limits be regarded unsafe for human consumption. The **WHO (1989)** in this regard also set a guideline value of at 1×10^3 per 100mL as satisfactory levels of faecal coliform presence in food. The present results clearly suggest that the contamination of the vegetables have exceeded the guideline values for 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 [29]. 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 [30]. 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 [31]. 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 [32].

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 [31, 33, 34].

3.3. Heavy Metals Concentrations in Sampled Vegetables

These results from the study 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 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 [35]. 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) while Cu recorded the highest mean values in both sites. The concentration of heavy metals from the vegetables in site B were higher than that of site A and also there was significant difference in the levels of metal contaminants from the vegetables among both sites. This could be attributed to the differences in irrigation methods.

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 | | |

Our findings showed that cadmium concentrations in some of the sampled vegetables were above the WHO/FAO guideline values. Ametepey et al (2018) reported Cd values of 0.05mg/kg in vegetables grown in peri-urban centers in Tamale Metropolis, Ghana. Previous studies by Odai et al (2008) on vegetables grown on contaminated soil in Kumasi revealed high Cd values in the range of 0.68 to 1.78mg/kg. Equally Sharma et al (2007) and Weldegebriel et al (2012) recorded high mean concentrations of Cd in vegetables that were far above the allowable limits. 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 [40]. According to the WHO Cd exposure could lead to a dip in bone calcium concentration which could be fatal to life [40].

Chromium (Cr) concentrations in all the sampled vegetables were far below the WHO/FAO recommended guideline value of 5.0mg/kg. The findings of this research showed that Cr levels in the vegetables might not be risky to consumer's health. Suruchi and Pankaj (2011) reported Cr concentrations in vegetables similar to ours. 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 60mg/kg. Lente et al (2012) recorded mean values of Zn below 10mg/kg in vegetables irrigated with polluted water in Accra. Sharma et al (2007) equally recorded results similar to our findings where Zn mean values were within the maximum recommended limit. 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 40mg/kg. Therefore, the levels of Cu in the sampled vegetables were safe for consumption. Lente et al (2012) reported that the mean Cu levels were equally below the guideline values in vegetables irrigated with polluted water in Ghana. 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 damage a lot of the body organs and systems such as kidney damages and cardiovascular problems [47, 48].

In general, the results from the study showed that heavy metal contaminants were presented in different amounts of the sampled vegetables irrigated by Goo reservoir. The concentrations of Cd occur in all samples except garden egg which 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]. Khan et al (2008) reported that there are broad variations in how different plant species could take up metals. They reported that Cd, Cu and nickel could be taken up at high levels by plants from soils irrigated with

polluted water. In addition, Orisakwe et al, (2012) and Khan et al, (2008) 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.

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

There are numerous routes for 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. Huang (2008) reported that when the HQ is greater than one, there is fear of possible health effect.

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 | - | - | - | - |

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 varied

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

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 |

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 **ICMF's** and WHO's reference points for acceptable levels of FC presence in vegetables. 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.

The heavy metal contaminants in the various vegetables were below the reference permissible 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 reference permissible. 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.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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