International Journal of Biology; Vol. 11, No. 1; 2019
ISSN 1916-9671 E-ISSN 1916-968X
Published by Canadian Center of Science and Education

Microbial and Chemical Risk Assessment of River Bukuruwa Used as Drinking Water by Farming Communities

Isaac Ofori[1], John A. Larbi [1,], Amina Abubakari [1, 2], Matthew G. Addo[1] & Godwin Essiaw-Quayson[1]

[1] Department of Theoretical and Applied Biology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

[2] Department of Laboratory Technology, Faculty of Health Sciences, Kumasi Technical University, Kumasi, Ghana

Correspondence: Amina Abubakari, Department of Theoretical and Applied Biology, Kwame Nkrumah University of Science and Technology, Kumasi-Ghana. Tel: 233-264-250-658. Fax: 233-3220-22387. E-mail: aminaabubakari@yahoo.com

Received: July 20, 2018 Accepted: September 16, 2018 Online Published: December 14, 2018

doi:10.5539/ijb.v11n1p22 URL: https://doi.org/10.5539/ijb.v11n1p22

Abstract

Water is very vital for the sustenance of life and according to World Health Organization; potable water should be free from any health risk. However due to in adequate supply of potable water, many rural dwellers have no choice but to depend on streams and rivers as source of drinking water which becomes the vehicle for the transmission of infections due to a host of microorganisms both pathogenic and non-pathogenic present in these water bodies. This study therefore quantified and assessed the microorganisms present in river Bukuruwa in Techiman in the Brong Ahafo Region of Ghana. Water was aseptically collected into sterile sampling bottles with caps and analyzed in the laboratory through standard microbiological protocols. Microbial organisms such as Feacal coliforms, E.coli and Salmonella spp. as well as physicochemical parameters such as pH, conductivity, turbidity, Sulphate (SO_4^{2-}), Fluoride (F^-), Phosphates (PO_4^{3-}), Nitrites (NO^{2-}) and Nitrates (NO^{3-}) were quantified and assessed, respectively. The highest load of faecal coliforms in the river water at a point in this study was found to be 9 x 10^2 per 100 ml and pH values ranging from 5.31 to 6.84 with variations within the sampling points. The observational survey revealed human beings competing with farm animals for the same source of water and again farming activities were carried out very close to the river banks which may increase the chance of infections which needs serious attention by policy makers and implementers.

Keywords: Microbial, Risk, Assessment, River and Communities

1. Introduction

Water is essential to the existence of man and all living things and hence a satisfactory (adequate, safe and accessible) supply must be available to all. Improving water access and its quality are essential for increasing hygiene and sanitation levels that affect productive lives of people, enhance enrolment and retention of children in schools, enhance women's dignity and ability to lead, reduce morbidity and mortality, reduce pre and post natal risks and prevent vector and water borne diseases. (Ghana government water policy document, 2007) The two main problems man contends with water are the quantity (source and amount) and quality (Adeniyi, 2004). In view of its occurrence and distribution pattern, water is not easily available to man in the desirable amount and quality. This is a problem experienced in most cities and towns in the developing nations not to mention their rural settings. These factors have led to the growing rate of water borne diseases like typhoid fever and cholera experienced in this part of the world (Edwards, 1993). The quality of water is a reflection of the source of environment and the activities of man including the use and management measures (Oluyemi et al., 2010). In most rural areas in Ghana and other West African countries, the only way to access drinking water is either rivers or streams or for the more fortunate ones, from rudimentary wells: none of which offer any of water fit for drinking. Surface water resources hence constitute the basis of existence of large number of rural dwellers and even in towns and cities in West Africa. However industrial development, harmful sewage and effluent discharge, deforestation and unsustainable land exploitation all tend to threaten the quality of this surface water. Moreover, intensified agricultural production also create problems of fertilizers and pesticides runoff and all these deteriorate the quality of the water resource which would have been reliable source of safe water for the growing population. Research has shown that different

qualities of wastewater or raw water are generated by various urban activities which eventually end up in the water bodies (Raschid-Sally & Jayakody, 2008).

Contaminants such as bacteria, viruses, heavy metals, nitrates and salts find their way into water supplies as a result of inadequate treatment and disposal of waste (human and livestock), industrial discharges and over-use of limited water resources (Singh & Mosley, 2003). About 95% of the people within the community get their source of drinking water from this river and others equally use the same source for unrestricted vegetable irrigation especially in the dry season

The main objective of this study therefore was to monitor and assess the microbial quality of the river used as a source of drinking water by the rural dwellers. The steps used to achieve the objective were; to determine the levels of faecal coliforms, *E.coli* as indicator organisms, to assess the level of *Salmonella spp.* as a pathogenic organism and finally to evaluate the levels of physic-chemical parameters. It is believed that the outcome will help policy makers to establish policies based on informed decisions to prevent disease outbreaks within these communities.

2. Material and Methods

2.1 Study Area

River Bukuruwa rises out of a spring located at Baamure in the south-east of Techiman municipality (Figure 1) and runs eastwards through some farming communities in the Techiman municipality and merges with river Fia at a site near Kaniago forest (a rural farming community in the Techiman municipality (Survey department of Ghana, 1977). The Techiman municipality is one of the administrative districts in the Brong Ahafo region of Ghana located at latitude 7^0 34' 60N, longitude 1^0 55'60W sharing common boundaries with Wenchi, Kintampo, Nkoranza, Offinso in the Ashanti region, Techiman, the municipal capital is the second largest town in the region. It is about 126 km northwest of Kumasi and 392 km from Accra. The municipality is home to the famous Techiman market, the largest food crop market in Ghana. Its strategic location as a commercial centre and a major transit point attracts a large number of people in and out of the municipality daily for business.

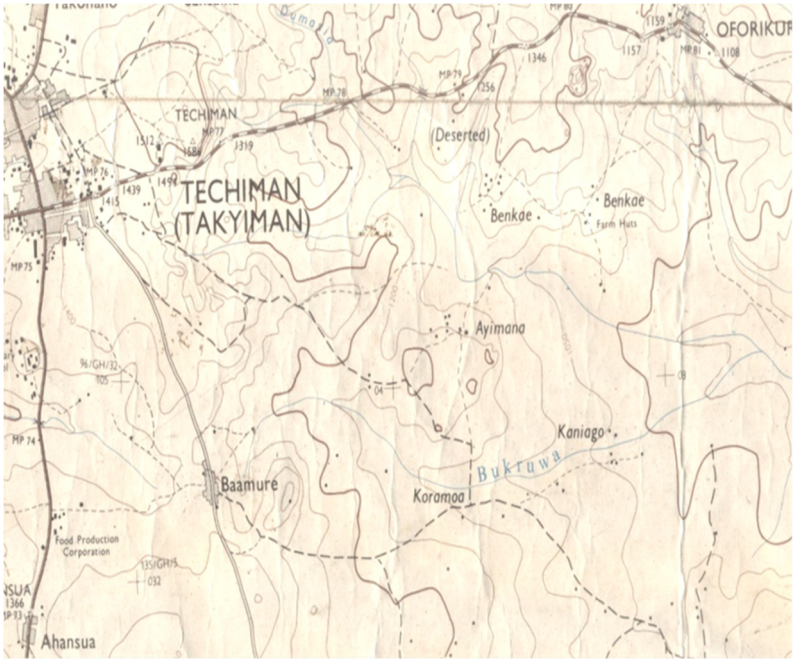

Figure 1. Map of Techiman municipality showing river Bukruwa and the sampling points (Baamure, Kroamoa and Kaniago)

2.2 Selection of Sampling Sites

Selection of sampling points was done based on the fact that, folks in the community fetch water at those sites for drinking and other domestic purposes. The sampling sites included Baamure located upstream, Kroamoa at the mid-stream and Kaniago at the downstream and also Anyimana near a refuse dump site on the other side of the river.

2.3 Sample Collection

Sterile water Sample containers with caps were used aseptically to collect the water samples and stored at 4 ^{0}C in a cooling box containing cooling element. Samples were then transported to the Chemical Laboratory of the college Agricultural and Renewable Natural Resources, KNUST, Kumasi within 24hrs for physicochemical analysis and the Microbiology Laboratory of the Department of Theoretical and Applied Biology, KNUST for the microbial analysis. Samples were collected every two weeks from January to April 2011 covering both the dry and the wet seasons.

Determination of microbial loads

Feacal coliform and E. coli

The most probable number (MPN) method was used to determine feacal coliforms in the samples. Serial dilutions of 10^{-1} to 10^{-6} were prepared by picking 1ml of the sample into 9 ml sterile distilled water. 1 ml aliquots from each of the dilutions were inoculated into 5 ml of MacConkey Broth with inverted Durham tubes and incubated at 44 ^{0}C for 18-24 hours.Tubes showing colour change from purple to yellow and gas collected in the Durham tubes after the 24 hrs were identified as positive for feacal coliform and counts per 100ml were calculated from an MPN tables. From each of the positive tubes identified, a drop was transferred into a 5ml test tube of trypton water and incubated at 44 ^{0}C for 24hrs. A drop of Kovac's reagent was then added to the tube of trypton water. All tubes showing a red ring colour development after gentle agitation indicates the presence of indole and recorded as presumptive for thermotolerant coliform (*E. coli*) and counts per 100 ml were calculated from MPN tables.

2.4 Salmonella spp

10 ml of manufactured formula of buffered peptone water (BPW) was prepared in a universal bottle and serial dilutions of the samples added. It was incubated at 37 ^{0}C for 24hrs. 0.1ml of the sample was placed in 100ml of Selenite Broth in universal bottle and incubated at 44 ^{0}C for 48hrs. Swaps of the bottle were transferred into an SS agar and incubated for 48 hrs at 37 ^{0}C. Black colonies on the SS agar indicate the presence of salmonella spp. and counts per 100ml were made using MPN tables.

2.5 Determination of Physico-chemical Parameters

pH was determined in-sito at the sampling site whilst collecting the samples with a portable Suntex sp-707 pH meter and colour determination was done by the Platinum-Cobalt method. Collected water sample was first filtered into a clean beaker in order to prevent interferences by turbidity. 10 ml of the filtered sample was put into a cuvet and placed into a Wagtech Potolab photometer 7100 series which has been pre-calibrated with coloured standards of known platinum cobalt concentrations. Photometer readings were recorded and reported in colour units (CU).

2.6 Conductivity and Turbidity

A 10ml sample of the water was put into a cuvet and placed into the chamber of a Wagtech Potolab Photometer 7100 series. A wavelength of was selected and measurements taken for conductivities directly in µS/cm.

10ml of water sample was poured into a cuvet and then inserted into the chamber of a Wagtech Potolab photometer 7100 series. Turbidity was selected on the photometer and readings taken.

Hardness of the water ample was determined by filtering 50ml of the water sample using a filter paper to obtain a clear solution of the sample water about 10ml of the filtered sample was put into a beaker. One tablet each of *Hardicol No 1* and *Hardicol No 2* was crushed and mixed with the sample in the test tube to dissolve and the sample was allowed to stand for about 30 minutes until the particles were completely dissolved. A wavelength of 570nm was selected on the photometer and readings taken.

Sulphate (SO_4^{2-}) and Fluoride (F^-)

About 10ml of the test sample was filtered and put into a test tube. One Sulphate turb tablet was crushed and mixed with the sample to dissolve. A cloudy solution indicates the presence of sulphates. The solution was allowed to stand for 5 minutes and then mixed again to ensure uniformity. A wavelength of 520 nm was selected on a Wagtech photometer and readings taken. About 10ml of the test sample was filled into a test tube. One fluoride No 1 tablet was crushed and mixed to dissolve. Another tablet of fluoride NO^2 was also crushed and mixed with the sample to dissolve. The solution was allowed to stand for 5 minutes for full colour development. A wavelength of 570nm was selected on the photometer and readings taken.

Phosphates (PO_4^{3-}) and Nitrites (NO_2^-)

One Phosphate HR tablet was mixed with 10ml filtered water sample to dissolve and allowed to stand for about 10 minutes to allow for full colour development. A wavelength of 490nm was selected on the photometer and

readings taken. A measuring syringe was used to take 1 ml of the filtered sample and transferred into a test tube and made up to 10 ml with distilled water. One Nitrophot No 1 and one Nitrophot No 2 tablets were crushed and mixed with the sample to dissolve. The test tube was capped immediately and allowed to stand for exactly 2 minutes for full colour development. Photometer readings were then taken.

Nitrates (NO_3^-)

A Nitratest tube was filled with 20ml of the water sample and one level spoonful of nitratest powder and one nitratest tablet were added. The test tube was capped and shaken thoroughly for 1 minute. Afterwards it was allowed to stand for about 2 minutes and gently inverted three or four times to aid flocculation and then allowed to stand for further 2 minutes to ensure complete settlement. It was then uncapped and the mouth wiped with a clean tissue. About 10 ml of the clear solution was then decanted into another test tube. One nitrocol tablet was crushed and mixed to dissolve.

This was allowed to stand for 10 minutes for full colour development. A wavelength of 570nm was selected on the photometer and readings taken in the usual manner.

2.7 Data Analysis

Data was statistical analyzed using Microsoft Excel (2010) and Statistical Package for Social Science (SPSS version 20). Analysis of Variance (ANOVA) was used to determine the differences in the Mean values of the parameters at the various sampling sites.

3. Results

3.1 Microbial Analysis

The water samples from all the sites were contaminated with both faecal indicator microorganisms as well as pathogenic *salmonella spp*. The mean feacal coliform counts per 100ml for all the sampling points ranged between $4.35x\ 10^1$ and $3.32x\ 10^2$. At the Kroamoa sampling site the feacal coliform numbers ranged between $2.30x\ 10^1$ and 9.0×10^1 with a mean count of $4.35x\ 10^1$. The Kaniago site recorded a mean value of 3.32×10^2 within a range of 2.3×10^1 to 9.30×10^2 counts per 100 ml of water samples. The Baamure sampling site recorded a mean value of 5.73×10^1 within a range of 9.00×10^0 and 9.30×10^1. However there were no significant differences in the feacal coliform numbers (cfu/100ml) between the sampling sites at $p \leq 0.05$ significant level. The mean E. coli numbers (cfu/100ml) of all the water samples analyzed ranged between 2.58×10^1 and 8.75×10^1. The E.coli populations recorded at Kroamoa ranged between 2.3×10^1 and 4.0×10^1 with a mean value of 2.58×10^1 whilst Kaniago recorded a mean value of 8.75×10^1 within a range of 9.0×10^0 and 2.30×10^2. The Baamure sampling site recorded a mean value of 3.45×10^1 which falls within a range of 2.30×10^1 and 4.30×10^1 counts per 100ml of water. There was no significant difference between the mean populations of E. coli at the various sampling points at $p \leq 0.05$ significant level. For all the water samples taken from the various points along river Bukuruwa, Salmonella was not identified in any of them.

3.2 Physicochemical Parameters

The pH values of the river ranged from 5.31 to 6.84 with the lowest and the more acidic pH value recorded at the Kaniago sampling site during the dry season and the highest also at Kaniago recorded within the rainy season. The highest pH of 6.84 falls within the range of 6.5-8.5 set by the World Health Organization (WHO) for drinking water (WHO, 2008). Meanwhile the lower pHs of 5.31 and 5.56 recorded at Kaniago and Baamure are slightly acidic and fall outside the permissible range for quality drinking water. The Baamure site recorded a pH range of 5.56 to 6.00 whilst the Kroamoa site recorded a range of 6.21-6.50.

There was statistically significant difference in the mean pH values of the sampling sites along the river at $p<0.05$ significant level. Turbidity values ranged from 0.00 to 6.00 NTU at Kroamoa. The lowest turbidity values at the Kroamoa site were recorded during the rainy season. However the highest of 6.00 NTU was recorded both in the dry and the rainy season. Turbidity measurements also ranged between 2.00 to 6.0 NTU at Kaniago whilst the values at Bamure are in the range of 1.00 to 6.00 NTU. The maximum turbidity values of 6.00 NTU was however higher than the standard for a drinking water which is <5NTU. There is no significant difference statistically among the turbidity measurements at the various sampling sites at $p<0.05$ significant level. The mean total hardness of the river as sampled from the three sampling sites is in the range: 0.00 to 10mg/l of CaCO3. The total hardness level at Kroamoa falls within 5.00-10mg/l whereas that of Kaniago and Baamure is from 0.00 -5.00mg/l and 0.00 to 10.00mg/l respectively. The maximum mean total hardness among the three sampling sites was recorded at Kroamoa. There was a statistically significant difference in the mean total hardness values recorded for the sampling sites at $p<0.05$ significant level. The highest nitrate concentration (0.75mg/l) was recorded at the Kroamoa sampling site during the rainy season whilst none was recorded during some sampling periods. A mean

nitrate concentration of 0.231mg/l was recorded for Kroamoa, 0.066mg/l for Kaniago and 0.069mg/l for Baamure sampling sites. Concentrations of nitrate at the various sampling sites however fall far below the WHO guideline value of 50mg/l for drinking water. There were no significant variation in the mean nitrate levels recorded for the sampling sites at the $p< 0.05$ significant level. The nitrite (NO_2^-) concentrations determined recorded its maximum value of 0.70mg/l at the Kaniago sampling site and the lowest of 0.01mg/l at the Kroamoa and Baamure sites. The mean concentration values (mg/l) showed 0.248 at Kaniago, 0.176 at Baamure and 0.069 at Kroamoa. Nitrite concentrations were generally high as compared to the WHO guideline value of 0.2mg/l for drinking water. A p value of 0.389 indicates no significant variation of the nitrite concentration among the sites at $p<0.05$ significant level. The phosphate (PO_4^{3-}) concentration measured ranged between 0.04mg/l and 4.78mg/l. the maximum value was recorded at the Kaniago sampling site whilst the minimum was reached at the Baamure site. The mean concentration values recorded 0.701mg/l at Kroamoa, 1.006mg/l at Kaniago and 0.869mg/l at the Baamure site. The mean phosphate concentrations at all the sampling sites were higher than the WHO guideline values for phosphate in drinking water. Sulphate concentrations (mg/l) of the water samples from the various sites recorded a maximum of 5.00mg/l at all the sampling sites; ie Baamure, Kaniago and Kroamoa Mean sulphate concentrations (mg/l) for the sampling sites are Baamure (1.503). Kaniago (1.503) and Kroamoa (3.333) There is no significant variation of sulphate concentrations in the water samples at the various sampling sites at $p<0.05$ significant level. The concentrations of fluoride indicated a maximum mean value of 0.136mg/l with a range of 0.00 to 0.32mg/l recorded at the Baamure sampling site. Statistically, there is no significant difference of the fluoride concentration among the sampling sites at $p<0.05$ significant level. The highest mean conductivity of the water samples was recorded at Kaniago at 420.83µS/cm within a range of 390- 455µS/cm. Water samples from Kroamoa showed the least electrical conductivity with a mean of 294.83 which ranged between 160-425µS/cm. The range of colour determined was between 0.00 and 185 Colour Units (CU) recorded at Kroamoa in the dry season. In general the colour values recorded in the dry season were quite higher than those in the rainy season. There were no significant variation between the sampling sites in terms of the colour of the water samples at $p<0.05$ significant level.

4. Discussions

The presence of indicator organisms in water or food establishes contamination resulting from faecal matter from either man or animal which could pose significant health risk to consumers (UN Annual water report, 2010). This study revealed presence of some indicator organisms such as feacal coliforms and E. coli in all the water samples analyzed at the various sampling points which therefor contamination and may pose serious health threat the rural dwellers depend on these water sources for drinking. The occasional razing of herds of cattle on vegetation around river banks which was observed in this study may lead to contamination due to the observation that these animals eventually may end up releasing feacal materials around the river. When this occur storm water may eventually wash these materials into the water body and hence contaminate the water (Raschid-Sally & Jayakody, 2008). Kroamoa had a heap of refuse just about 100 m away from the sampling site and the possibility of human excreta being washed from the site during rainfalls could not be ruled out. However the level of indicator organisms was relatively lower compared to the other site but their presence alone could not be under estimated (Sivapalasingam et al., 2004). Again the presence of feacal coliform and E.coli in the water sample gives an indication of the presence of other potentially harmful bacteria in the water which serves as the drinking water source for these rural communities (Ashbolt et al., 2001). The World Health Organizatin, emphasizes that, these indicator bacteria must not be present in a drinking water (WHO, 1996). Meanwhile all the water samples analyzed showed no presence of salmonella spp. in them which meets WHO standard in that respect.

The study of the various physico chemical parameters along various sampling points of river Bukuruwa ie; Baamure (upstream point) Kroamoa (mid-stream) and Kaniago (downstream) showed some variations in pH as it flowed from upstream to downstream. The mean pH values at the various points indicated slightly acidic and this could be attributed to various run-offs from agricultural lands into the river course and may also be due to the geology of the underlying rocks of the river bed (Oluyemi et al., 2010). A particular problem associated with acidification is the solubilization of some metals when the pH falls below 4.5. The resultant increased metal concentrations can be toxic to aquatic organisms and render the water unsuitable for drinking and other uses (WHO, 2007). Monitoring and reducing farming activities very close to banks of the river will help to maintain the river safe to the barest minimum level suitable for drinking (Oliveira et al., 2012).

Nitrate is a form of nitrogen and vital nutrient for growth, reproduction and survival of organisms. High nitrate levels (>1mg/l) are not good for aquatic life (Johnson et al., 2010). Mean nitrate concentration for all the sampling sites were relatively lower and fell far below the WHO guideline value of 50 mg/l for drinking water. This is however in agreement with an observation in a WHO drinking water quality report which concluded that the nitrate concentration in ground water and surface water is normally low but can reach high levels as a result of

leaching or runoffs from agricultural fields or contamination from human or animal waste (WHO, 2003). The highest nitrate concentration was recorded at Kroamoa, the midstream point of the river. This could be related to the closeness of farmlands to the sampling point and a possibility of the effluents from their dump site being washed into the river (Amoah et al., 2005). The nitrate concentration in the dry season was relatively higher than the wet season. This is in agreement with a study by Wolfhard and Reinhard (1998) who concluded that nitrates are usually built up in the dry season and that higher levels of nitrates are only observed during early rainy seasons. This is because initial rains flush out deposited nitrate from near surface soils and nitrate level reduces drastically as the rainy season progresses. The Nitrite concentration recorded at the sampling sites was generally on the higher side compared to the minimum permissible levels in drinking water. The elevated nitrite levels may be due to run offs from the farm lands near the sampling points into the river since nitrite is also a major component in fertilizers. The mean Phosphate concentrations in all the sampling points were higher as compared to the standard guideline value of drinking water by the WHO (2008). Land use around the Bukuruwa river is predominantly for farming and could be a possible explanation to the high levels of phosphate from run offs during the rainy season. Other sources may be due to firm rock deposits and interaction between the water and sediment from dead plants and animals remains at the bottom of the river.

The mean Conductivity values of the water samples ranged from 160 to 455µS/cm. the maximum mean conductivity is however higher than the WHO permissible limit for electrical conductivity which is 300µS/cm. The nature of soil type coupled with run offs might account for the presence of such large amount of dissolved ions in water and hence the increase in conductivity (Oluyemi, 2010).

Sulphate concentrations recorded at the various sampling sites were generally low and do not pose much health risk to users for drinking purposes. The maximum concentration of fluoride was determined as 0.136mg/l. Permissible limit for fluoride concentration in potable water is 1.0-1.5mg/l (WHO, 2003). Fluoride has a significant mitigating effect against dental caries at low concentrations (Dissanayake, 1991). However continuous consumption of higher concentrations of 4mg/l or more can cause dental fluorosis and in extreme cases can even lead to skeletal fluorosis (Dissanayake, 1991). The maximum turbidity value of 6NTU was higher than the standard value of < 5 NTU for drinking water. It gives an indication of the possible presence of contaminants in such a water sample which could harbor pathogenic organisms. Meanwhile turbidity values as low as 0.00 NTU were also recorded in some samples as well.

5. Conclusion

Water samples from river Bukuruwa which serves as the main drinking water resource for some rural communities in the Techiman municipality revealed that, total hardness of the water was within the permissible limits for drinking and domestic use.

Parameters such as turbidity, nitrite, lead, conductivity, phosphate and colour contents were however found to be little above the standards set by the World Health Organization.

The study revealed the presence of feacal coliform and E. coli in all the water samples indicating possible contamination of the river water by feacal matter.

Self-purification ability of the river revealed that concentrations of most parameters did not decrease as the river flows from the upstream end to the downstream hence exhibits poor self-purification potential.

6. Recommendation

The Municipal Assembly should as matter of health importance providing quality source of water, such bore-hole to the communities.

Policy should be implemented and enforced to prevent farming activities close to river banks.

Tree planting a long river banks should be encouraged.

Water fetched from the river by the rural folks should at least be boiled and filtered to render the water safe for drinking.

Conflict of interests

The author claim that there is no conflict of interest

References

Adeniyi, I. F. (2004). The Concept of Water Quality in Ife Environmentalist. *Official Bulletin of Nigerian Society for Environmental Management (NISEM) O.A.U, 1*(1), 2.

Amoah, P., Drechsel, P., & Abaidoo, C. (2005). Irrigated urban vegetables production in Ghana: Sources of pathogen contamination and health risk elimination. *Irrigation and Drainage, 54*, 49-61.

Asbolt, N. J., Grabow, W. O. K., & Snozzi, M. (2001). Indicators of Microbial Water quality, In Fewtrell L. & Bartram J. (Eds.), *Water quality Guidelines, Standards and Health Assessment of risk and risk Management for Water Related infectious Disease* (pp. 289-315). WHO Water Series, London, IWA Publishing.

Dissanayake, C. B. (1991). The Fluoride Problem in the Ground Water of Sri Lanka, - Environmental Management and Health Intl. *Journal of Environmental Studies, 19*, 195-203.

Edwards, D. D. (1993). Trouble Waters in Milwaukee, Am. *Soc. Microbial News, 59*, 342.

Government of Ghana, Ministry of Water Resources, Works and Housing: National Water Policy Document (2007).

Oliveira, M., Vinas, I., Usall, J., Anguera, M., & Abadias, M. (2012). Presence and survival of E. coli O157:H7 on lettuce leaves and in soil treated with contaminated compost and irrigation water. *Int. J. Food Microbiol., 156*, 133-140.

Oluyemi, E. A., Adekunle, A. S., Adenuga, A. A., & Makinde, W. O. (2010). Physico-Chemical Properties and Heavy Metal content of water sources in Ife North Local Government Area of Osun State. Nigeria. *African Journal of Environmental Science and Technology, 4*(10), 691-697.

Raschid-Sally, L., & Jayakody, P. (2008). 'Drivers and characteristics of wastewater agriculture in developing countries: Results from a global assessment, Colombo, Sri Lanka', IWMI Research Report 127. *International Water Management Institute, Colombo,* 35.

Singh1, S., Mosley, L. M. (2003). Trace metal levels in drinking water on Viti Levu, Fiji Islands. *S. Pac. J. Nat. Sci., 21*, 31-34.

Sivapalasingam, S., Friedman, C. R., Cohen, L., & Tauxe, R. V. (2004). Fresh produce: A growing cause of outbreaks of foodborne illness in the United States, 1973 through 1997. *J Food Prot. 67*, 2342-2353.

Survey Department of Ghana. (1977). Map of Techiman, Sheet 0702a3 North B-30.

UN- Water Global Annual Assessment of Sanitation and Drinking Water Report, (2010).

WHO (1996). *Guidelines for Drinking Water quality* (2nd ed., Vol 2). Health Criteria and other supporting information, WHO Geneva, 1996

WHO (2003). *Nitrate and Nitrite in Drinking Water, Background document for preparation of WHO Guidelines' for Drinking Water Quality*. Geneva, (WHO/SDE/WSH/03.04/56)

WHO (2007). *pH in drinking water Background Document for Preparation of WHO Guidelines for drinking water Quality*. Geneva, World Health Organization (WHO/SDE/07.01/1)

WHO (2008). *Guidelines for Drinking Water Quality* (3rd ed., Vol 1). Incorporating the first and Second Addenda, WHO, Geneva (2008): ISBN 978 92 4 154761 1

Wolfhard, S., & Reinhard, B. (1998). The Heterogeneity of Runoff and its Significance for Water Quality Problems. *Hydrological Sciences Journal, 43*, 103-113.