Journal of Water Resource and Protection, 2016, 8, 337-344
Published Online March 2016 in SciRes. http://www.scirp.org/journal/jwarp
http://dx.doi.org/10.4236/jwarp.2016.83028

Quality Assessment of River Offin along a Canopy Cover Gradient

Janice Dwomoh Abraham[1], Isaac Fosu[1], Daniel Agyapong[1], Kwame Nkrumah Hope[2], John Abraham[3]

[1]Department of Science Education, College of Agriculture Education, University of Education, Winneba, Ghana
[2]Department of Crop and Soil Sciences Education, College of Agriculture Education, University of Education, Winneba, Ghana
[3]Department of Entomology and Wildlife, School of Biological Sciences, University of Cape Coast, Cape Coast, Ghana
Email: jonnieabraham@daad-alumni.de

Received 1 February 2016; accepted 21 March 2016; published 24 March 2016

Abstract

The potential effect of canopy cover on the quality of River Offin which serves as drinking water for communities including Hwediem, Mprim and Boanim in the Mampong Municipality of the Ashanti region of Ghana was studied. These communities exemplify Ghanaian farming communities. Often, rural farmers do not have access to clean water. Using the part of the river serving these communities as a test case, we assessed the quality of water along a gradient of three different levels of canopy cover (closed, semi-closed and open canopy) where residents frequently access water. Physico-chemical tests showed that, the level of most of the physical and chemical properties of the water under all three different canopy covers was within the acceptable limits set by the World Health Organization. There was low turbidity where the canopy was closed resulting in relatively lower faecal coliforms. Total dissolved solids were also less where canopy cover was closed. Therefore, the general water quality could be potentially improved by planting trees along the river to form canopy.

Keywords

Water Quality, Watershed, Farming, Runoff Water, Canopy Cover

1. Introduction

Watersheds are naturally protected by their riparian forests from deterioration. These forests stabilize the river's flow [1] and maximize quality by controlling erosion and sediment concentrations in streams, decreasing turbid-

How to cite this paper: Abraham, J.D., Fosu, I., Agyapong, D., Hope, K.N. and Abraham, J. (2016) Quality Assessment of River Offin along a Canopy Cover Gradient. *Journal of Water Resource and Protection*, **8**, 337-344.
http://dx.doi.org/10.4236/jwarp.2016.83028

ity, reducing pesticide and other chemical load, reducing nitrogen levels and other pollutants level [2]-[6]. Recent increases in deforestation as a result of intensified anthropogenic activities pose major threats to surface-water quality [7]. Agricultural activities in general are the driving force of degradation of water quality [8] which is becoming a global problem [9]. Human conversion of forested areas along river basins into agricultural lands causes river systems to undergo progressive changes in water quality [10] by introducing harmful sediments, nutrients, bacteria, organic wastes, chemicals, and metals into surface water bodies.

Deforestation has observable effects on surface water characteristics such as changes in the water physico-chemical parameters [11]. For instance, heavy rainfall washes soil from deforested and agricultural lands directly into streams. Soil contains loads of contaminants and is transported into surface water bodies through runoff. This leads to increased water turbidity, suspended solids and total dissolved solids [12] in water and eventually affects the aesthetics e.g. colour and morphology of water bodies. Moreover, sediments from runoff water contain organic nutrients which when in excess increase the concentration of total nitrogen and phosphorus in the water [13]. This creates serious ecological stress and public health risks [14]. Improper application of chemicals and acidic fertilizers also decrease the pH of the water bodies making them more acidic [15].

Increasing loads of organic materials in water bodies cause an increase in biochemical oxygen demand (BOD) and consequently reduce dissolve oxygen (DO) in water [16], a condition that affects aquatic biodiversity. Furthermore, leaching from rocks and agricultural lands can cause an increase in the concentration of cations such as calcium and magnesium [17] as well as causing hardness of the water and making it difficult to use for domestic activities.

Turbidity of water promotes microbial proliferation such as coliform bacteria (e.g. total coliforms, faecal coliforms, *Escherichia coli* and intestinal enterococci (faecal streptococci)) [18] [19]. The main sources of these pathogenic micro-organisms are faeces of human and other warm-blooded animals [20] which are washed directly into water bodies through runoff water. Faecal coliforms and intestinal enterococci are good indicators for assessing faecal pollution [21]. They indicate the possible presence of pathogenic bacteria, viruses, and protozoans [22]. Faecal contamination of water results in enteric infection which is of great public health concern.

River Offin, one of the major water bodies in Ghana, is an important source of water to several communities dotted along its course. It originates from the Mampong Municipality in the Ashanti Region and extends to join River Pra in the Central region. Communities that rely on this river for water include Hwidiem, Mprim, Boanim, Bepoa and major towns like Dunkwa-on-Offin and Offinso. Several anthropogenic activities, including farming occur along the river (J.D. Abraham, personal observation). Many of the communities along the river are rural whose residents are farmers. The farming activities of residents have resulted in varying degrees of canopy opening along the river. Often there is little or no access to clean drinking water in rural communities [23]-[25]. Due to the importance of the health of farmers and rural dwellers in general, this study investigated the quality of water available to rural communities using River Offin. Water running through three communities namely Hwidiem, Mprim and Boanim representing parts of the river with closed, open and semi-closed canopy respectively was studied. Information from this study could be harnessed to improve the quality of water in this and other rivers and streams.

2. Materials and Methods

2.1. Water Sampling Points

For the purpose of this study, three sections of the river served as sampling points where water was collected over twelve consecutive weeks and analysed for quality. The three sampling points were named OF1, OF2 and OF3. OF1 was a forested area with a closed canopy (>90% closed) and served as the river head. OF2 was a sampling point that lied within the Mprim village. This sampling point was the main part of the river where inhabitants of the village fetched water for their household activities. Inhabitants of the village also washed their clothes along the banks at this sampling point. This sampling point was relatively open without much canopy cover over the water (>90% open). OF3 was the third sampling point along River Offin. It lied within a cocoa farm and had a semi-closed canopy (~60% closed). The direction of water flow was from OF1 through OF3. The sampling points were about 2 km apart.

2.2. Collection, Handling and Transportation of Water Samples

Water samples were collected from the sampling points along the river using sterile plastic bottles weekly for twelve consecutive weeks (Oct. 26, 2014 to Jan. 11, 2015). A water sample collector wearing nitrile gloves (Beaucare Medical Ltd, North Yorkshire, UK) and a nose mask collected 750 ml of water each from all the sampling points, the bottle was labeled and put one ice immediately to prevent bacterial growth. Sample collection was done in the mornings between 6:00 and 9:00. The samples were transported to the laboratory under refrigeration for physico-chemical and microbial analysis.

2.3. Laboratory Analysis Conducted

Physico-chemical analysis conducted included pH, turbidity, total hardness, total dissolved solids, concentrations of nitrate, phosphate, calcium, magnesium, potassium and sodium. Microbial analysis conducted included total and faecal coliforms determination.

2.4. The Physico-Chemical Analysis

Quality indicators such as pH and turbidity were measured using hand-held pH meter and turbidity meter respectively. Total dissolved solids (TDS) were determined using the gravimetric method and total hardness was determined using the titration method. Potassium, sodium, nitrate, calcium and magnesium were determined using flame photometer. All measurements were replicated 12 times. The TDS was determined by filtering 100 ml of water sample that was well-mixed through a standard glass fiber filter. Vacuum was applied for two to three minutes after the sample had passed through the filter. An evaporating dish which was heated in an oven at 180˚C for one hour before being placed in a desiccator was then transferred into a balance to determine its weight (x). The evaporating dish was then transferred onto a steam bath on a hot plate. The 100-ml filtrate sample from the filter flask was poured into the evaporating dish and evaporated to dryness. The evaporating dish residue was transferred to a drying oven where it was dried at 180˚C until a constant weight (y) was attained. The TDS was calculated as follows:

$$\text{TDS}\left(\text{mg}/1\right) = \frac{y - x\left(\text{mg}\right)}{\text{Sample volume}\left(1\right)}.$$

Furthermore, total hardness was determined following [26] by placing 50 ml of water sample in an evaporating dish and 0.5 ml of buffer solution added to it. Six drops of indicator solution was added as it was being stirred. Where water was hard, the samples turned red. The titrating solution was added slowly from the burette with continuous stirring. An endpoint was reached when the colour changed from red to blue. Total hardness was calculated as follows:

$$\text{CaCO}_3 = \frac{\text{Titration solution}\left(\text{ml}\right)\times 1000}{\text{Sample volume}\left(\text{ml}\right)}.$$

The concentration of potassium, sodium, nitrate, calcium and magnesium were determined with a flame photometer following [27] [28].

2.5. Total and Faecal Coliforms

Total and faecal coliforms were determined by the most probable number (MPN) method following [29]. Samples of water collected were diluted from 10^{-1} to 10^{-6} by pouring 1 ml of the sample into 9 ml of sterile distilled water. For each dilution, 1 ml aliquots were inoculated into 5 ml of MacConkey Broth and incubated at 35˚C for total coliforms and 44˚C for faecal coliforms for 18 - 24 hours. Tubes showing colour change from purple to yellow after 24 hours were identified as positive for both total and faecal coliforms. Counts per 100 ml were calculated from the most probable number (MPN) tables.

2.6. Data Analysis

Physico-chemical parameters measured and mean microbial loads were subjected to analysis of variance (Minitab version 17; Minitab Inc, State College, PA). This was followed by Tukey's test (Minitab) where significant differences were observed.

3. Results

The physico-chemical properties of the three sample collection points (OF1, OF2 and OF3) are shown in **Table 1**.

There were significant differences in the total hardness (F = 3.56, d. f = 2, P = 0.043), turbidity (F = 12.88, d.f = 2, P < 0.001), total dissolved solids (F = 11.39, d.f = 2, P < 0.001), pH (F = 3.76, d.f = 2, P = 0.034), concentrations of Na^+ (F = 5.15, d.f = 2, P = 0.011), K^+ (F = 17.51, d.f = 2, P < 0.001), Mg^{2+} (F = 3.74, d.f = 2, P = 0.034), PO_4^{3-} (F = 41.25, d.f = 2, P < 0.001) and NO_3^- (F = 5.52, d.f = 2, P = 0.009) at the three water collection points with different degrees of canopy cover (**Table 1**). However, there was no significant difference in the concentration of Ca^{2+} (F = 1.86, d.f = 2, p = 0.171) in the water at the three sampling points (**Table 1**).

The total coliforms in the closed canopy area of River Offin ranged from 0.03 × 10^6 mpn/100ml of water to 89 × 10^6 mpn/100ml (n = 10). The mean total coliform count was 33.97 ± 8.66 × 10^6 mpn/100ml of water and the median was 34 × 10^6 mpn/100ml of water. At OF2 which had no canopy cover, total coliform ranged from 0.06 × 10^6 mpn/100ml of water to 45 × 10^6 mpn/100ml (n = 10). The mean total coliform count in this area was 23.65 ± 5.67 × 10^6 mpn/100ml of water and the median was 27.5 × 10^6 mpn/100ml of water. At OF3, total coliform ranged from 0.06 × 10^6 mpn/100ml of water to 72.5 × 10^6 mpn/100ml (n = 10). The mean coliforms in this region was 27.75 ± 7.33 × 10^6 mpn/100ml of water and the median was 27.5 × 10^6 mpn/100ml of water (**Figure 1(a)**).

The faecal coliforms in the closed canopy area (OF1) of River Offin ranged from 0.24 × 10^6 - 8.9 × 10^6 mpn/100ml (n = 8). The mean faecal coliform count in this area was 3.35 ± 0.95 × 10^6 mpn/100ml of water and the median was 2.58 × 10^6 mpn/100ml of water. At OF2, where there was no canopy cover, faecal coliform ranged from 0.28 × 10^6 - 4.5 × 10^6 mpn/100ml of water (n = 8). The mean faecal coliform count was 2.26 ± 0.45 × 10^6 mpn/100ml of water and the median was 2.38 × 10^6 mpn/100ml of water. At OF3 where the canopy was semi-closed, faecal coliforms ranged from 0.24 × 10^6 - 27.5 × 10^6 mpn/100ml (n = 8). The mean coliform count in this area was 6.51 ± 3.13 × 10^6 mpn/100ml of water and the median was 4.28 × 10^6 mpn/100ml of water (**Figure 1(b)**).

There were no significant differences in both the total coliforms (F = 0.50, d.f = 2, P = 0.61) and faecal coliforms (F = 1.34, d.f = 2, P = 0.28) at the three respective areas of sample collection.

4. Discussion

The acceptability of water to a people is largely influenced by the quality of the water [30]. River Offin serves several communities and so it was important for its quality to be assessed. For water to be declared potable, there are standards that the physico-chemical and microbial properties must meet. Total hardness of the river water was higher at the sections with closed and semi-closed canopy probably because the trees there exude chemicals into the water [31]. Such root exudates could disinfect water and improve quality at these sections. Our findings suggest that water in River Offin is softer than water from other rivers in Ghana e.g. River Oti [32]. Turbidity was highest at the semi-closed canopy. The high turbidity at this sampling point could be attributed to the cocoa farm that the river passes through. Runoff water from the cocoa farm could carry with it sand and other debris which potentially increases the turbidity of water. Farming activities close to water bodies likely increase turbidity as a result of surface runoff into water [12]. Turbidity of the water at all three sampling points was however below 5.0 NTU which is the acceptable limit set by Canada for drinking water [6]. In spite of any

Table 1. Mean values of physical and chemical properties of water samples collected at portions of River Offin with closed canopy (OF1), open canopy (OF2) and semi-closed canopy (OF3).

Sampling site	Total hardness (mg/l)	Turbidity (NTU)	TDS (mg/l)	pH	Na^+ (mg/l)	K^+ (mg/l)	Mg^{2+} (mg/l)	PO_4^{3-} (mg/l)	NO_3^- (mg/l)	Ca^{2+} (mg/l)
OF1	44 ± 5.28 **a**	0.6 ± 0.31 **b**	49 ± 3.12 **b**	6.8 ± 0.06 **a**	6.3 ± 0.13 **a**	1.3 ± 0.06 **a**	0.9 ± 0.13 **a**	11.1 ± 0.58 **a**	0.07 ± 0.007 **b**	6.0 ± 0.52 **a**
OF2	25 ± 6.10 **b**	2.5 ± 0.46 **b**	70 ± 2.73 **a**	6.6 ± 0.02 **b**	5.0 ± 0.33 **b**	0.7 ± 0.13 **b**	0.5 ± 0.15 **b**	5.8 ± 0.18 **b**	0.10 ± 0.006 **a**	6.3 ± 0.59 **a**
OF3	33 ± 3.45 **ab**	4.8 ± 0.42 **a**	69 ± 4.33 **a**	6.8 ± 0.11 **ab**	4.2 ± 0.26 **b**	1.2 ± 0.18 **a**	0.6 ± 0.08 **ab**	9.9 ± 0.44 **a**	0.08 ± 0.006 **ab**	7.5 ± 0.65 **a**
Acceptable value		5*	1000†,‡	6.5 - 8.5†,‡					50†	

Columns with different letters indicate statistical differences in the parameters measured. NTU, Nephelometric Turbidity Unit; TDS, Total Dissolved Solids; WHO, World Health Organisation; EPA, Environmental Protection Agency of the United States of America. *Acceptable value by Canadian standards; †Acceptable value by WHO standards; ‡Acceptable value by EPA standard.

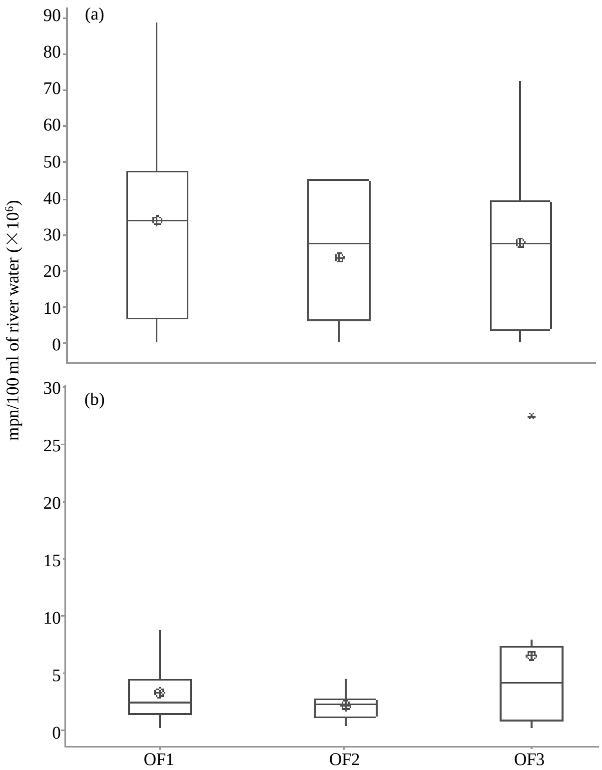

Figure 1. Total coliform (a) and faecal coliform (b) of River Offin.

standards set, it is very important to improve turbidity of water however low it might be since it is caused by suspended particles in water. Microorganisms could attach themselves to these suspended particles in water and contaminant it [18] [19]. Therefore, simple filtration of turbid water could reduce the chances of high microbial load [30]. The United States' standard for turbidity as at 2000 was 1.0 NTU probably for this reason [33]. In 2012, the United States Environmental Protection Agency reiterated that turbidity should never go beyond 5.0 NTU [34].

The amount of total dissolved solids in water may affect the acceptability of water for drinking although it has no health concerns at the concentrations found in drinking water [30]. Despite this, total dissolved solids of water of less than 600 mg/l is considered to be good. However, a level of TDS of more than 1000 mg/l is unacceptable and renders drinking water unpalatable. Water from the three collection points of River Offin were all below the threshold of palatable water. Although water from all three points was palatable, water from the closed canopy area was significantly more palatable indicating the importance of canopy cover over water.

The recommended pH of drinking water by WHO is 6.5 to 8.5. This notwithstanding, it has been suggested that water with pH lower than 7 is likely to be corrosive to metallic pipes [30]. Water from all three sampling points ranged between 6.6 and 6.8. There was no significant difference in the pH of water at the different sampling points. Since water in the three sampling points is not piped, there should be no problem with the possibility of the corrosive pH in the short term. The low pH of the water renders it effective for disinfection with chlorine [30].

The concentrations of sodium, potassium, magnesium and calcium in water from the three sampling points were rather low and below the threshold to make water unpalatable. No health concerns have been suggested by the WHO on the concentrations of sodium, potassium, magnesium and calcium in water. However, sodium could make water unacceptable in terms of taste if it exceeds 200 mg/l. The amount of sodium detected at all three collection points ranged from 4.2 - 6.3 mg/l. These are ideal values. The level of potassium detected ranged between 0.7 and 1.3 mg/l which is far below the recommended requirement which is more than 3000 mg/l. Although significant differences were found in the levels of sodium, potassium and magnesium in all three collection points, these did not pose any health concerns as no limits have been set by WHO. The WHO has no limits for these chemicals because the levels detected in water are always lower than what will raise a health concern [30]. The level of nitrate in water for drinking should not exceed 50 mg/l. At all three sample collection points, the level of nitrate does not exceed 0.1 mg/l.

Water in River Offin had relatively high total coliforms in all three sampling points. The high amount of total coliforms in the water poses health risks to the inhabitants of the surrounding villages who depend on the water for their livelihood. Indeed a high amount of total coliforms is indicative of a high probability of disease causing organisms in water [33]. It is therefore not surprising that faecal coliforms were detected in all three sampling points. This poses a threat of water-borne diseases in the surrounding villages. Although the detection of faecal coliform is bad for the communities, the amount was lower where there was minimal disturbance to the canopy and less agricultural activities. In the semi-closed canopy area where turbidity was highest, faecal coliform was also highest. Micro-organisms are able to attach themselves to suspended particles and high turbidity could increase the persistence of coliforms in water. It is therefore important that water is kept clean and activities like farming that could increase turbidity are done away from water bodies.

5. Conclusion

In conclusion, the physico-chemical properties of water close to the source of River Offin are good and largely meet the WHO standard for drinking water. The major concerns however are the high amounts of total coliforms in the water, the detection of faecal coliforms and relatively high turbidity at the sampling point with semi-closed canopy. This study suggests that high turbidity could likely account for the high faecal coliform in water. The high turbidity is as a result of farming activity close to the river water and it is advised that farming should not be done close to the river water. Closed canopy cover contributed to lower turbidity, total dissolved solids and pH. The low turbidity contributed to a relatively lower faecal coliform. Therefore, the quality of water could be increased by planting trees along all water bodies.

Acknowledgements

We are grateful to the Chemistry and Microbiology laboratories at Kwame Nkrumah University of Science and Technology (KNUST) for providing us space for physico-chemical and microbial analysis.

References

[1] Belay, A.A., Haq, S.Md.A., Chien, V.Q. and Arafat, B. (2010) The Challenges of Integrated Management of Mekong River Basin in Terms of People's Livelihood. *Journal of Water Resource and Protection*, **2**, 61-68. http://dx.doi.org/10.4236/jwarp.2010.21007

[2] Mayer, P.M., Reynolds, S.K., McCutchen, M.D. and Canfield, T.J. (2006) Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness: A Review of Current Science and Regulations. EPA/600/R-05/118. U.S. Environmental Protection Agency, Cincinnati. http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=2000O182.TXT

[3] Blumenfeld, S., Lu, C., Christophersen, T. and Coates, D. (2009) Water, Wetlands and Forests. A Review of Ecological, Economic and Policy Linkages. Secretariat of the Convention on Biological Diversity and Secretariat of the Ramsar Convention on Wetlands, Montreal and Gland. CBD Technical Series No. 47.

[4] Irshad, S. and Khan, S. (2012) Impacts of Protection on Water Quality, Quantity and Soil of Himalayan Moist Temperate Forests of Galliyat. *Science*, *Technology and Development*, **31**, 91-98.

[5] Christensen, V.G., Lee, K.E., McLees, J.M. and Niemela, S.L. (2012) Relations between Retired Agricultural Land, Water Quality, and Aquatic-Community Health, Minnesota River Basin. *Journal of Environmental Quality*, **41**, 1459-1472. http://dx.doi.org/10.2134/jeq2011.0468

[6] Dessie, A. and Bredemeier, M. (2013) The Effect of Deforestation on Water Quality: A Case Study in Cienda Micro Watershed, Leyte, Philippines. *Resources and Environment*, **3**, 1-9.

[7] Firdaus, R. and Nakagoshi, N (2013) Assessment of the Relationship between Land Use Land Cover and Water Quality Status of the Tropical Watershed: A Case of Batang Merao Watershed, Indonesia. *Journal of Biodiversity and Environmental Sciences* (*JBES*), **3**, 21-30.

[8] Capel, P.D., McCarthy, K.A. and Barbash, J.E. (2008) National, Holistic, Watershed Scale Approach to Understanding Sources, Transport, and Fate of Agricultural Chemicals. *Journal of Environmental Quality*, **37**, 983-993. http://dx.doi.org/10.2134/jeq2007.0226

[9] Fadaei, A. and Sadeghi, M. (2014) Evaluation and Assessment of Drinking Water Quality in Shahrekord, Iran. *Re-*

sources and Environment, **4**, 168-172.

[10] Ayivor, J.S. and Gordon, C. (2012) Impact of Land Use on River Systems in Ghana. *West African Journal of Applied Ecology*, **20**, 83-95.

[11] Masese, F.O., Raburu, P.O., Mwasi, B.N. and Etiegni, L. (2012) Effects of Deforestation on Water Resources: Integrating Science and Community Perspectives in the Sondu-Miriu River Basin, Kenya. In: Oteng-Amoako, A.A., Ed., *New Advances and Contributions to Forestry Research*, InTech. http://www.intechopen.com/books/new-advances-and-contributions-toforestry-research/effects-of-deforestation-on-water-resources-integrating-science-and-communityperspectives-in-the-so

[12] Kebede, W., Tefera, M., Habitamu, T. and Alemayehu, T. (2014) Impact of Land Cover Change on Water Quality and Stream Flow in Lake Hawassa Watershed of Ethiopia. *Agricultural Sciences*, **5**, 647-659. http://dx.doi.org/10.4236/as.2014.58068

[13] Benavides, F. and Veenstra, J.N. (2005) The Impact of Tropical Deforestation on River Chemical Pollution. *Global NEST Journal*, **7**, 180-187.

[14] Dosskey, M.G., Vidon, P., Gurwick, N.P., Allan, C.J., Duval, T.P. and Lowrance, R. (2010) The Role of Riparian Vegetation in Protecting and Improving Chemical Water Quality in Streams. *Journal of the American Water Resources Association* (*JAWRA*), **46**, 261-277. http://dx.doi.org/10.1111/j.1752-1688.2010.00419.x

[15] Divya, R.T., Sunil, B. and Latha, C. (2011) Physico-Chemical Analysis of Well Water at Eloor Industrial Area-Seasonal Study. *Current World Environment*, **6**, 259-264.

[16] Ahiarakwem, C.A. and Onyekuru, S.O. (2011) A Comparative Assessment of the Physico-Chemical and Microbial Trends in Njaba River, Niger Delta Basin, Southeastern Nigeria. *Journal of Water Resource and Protection*, **3**, 686-693. http://dx.doi.org/10.4236/jwarp.2011.39079

[17] Rajiv, P., Hasna, A.S., Kamaraj, M., Rajeshwari, S. and Sankar, A. (2012) Physico Chemical and Microbial Analysis of Different River Waters in Western Tamil Nadu, India. *Research Journal of Environment Sciences*, **1**, 2-6.

[18] Shittu, O.B., Olaitan, J.O. and Amusa, T.S. (2008) Physico-Chemical and Bacteriological Analyses of Water Used for Drinking and Swimming Purposes in Abeokuta, Nigeria. *African Journal of Biomedical Research*, **11**, 285-290.

[19] Ojo, O.I., Otieno, F.A.O. and Ochieng, G.M. (2012) Groundwater: Characteristics, Qualities, Pollutions and Treatments: An Overview. *International Journal of Water Resources and Environmental Engineering*, **4**, 162-170.

[20] Ouattara, N.K., Passerat, J. and Servais, P. (2011) Microbiological Water Quality in Rivers of the Scheldt Drainage Network (Belgium): Impact of Urban Wastewater Release. Daniel Thevenot. 8th World Wide Workshop for Young Environmental Scientists WWW-YES 2009: Urban Waters: Resource or Risks? Arcueil, June 2009.

[21] Páll, E., Niculae, M., Timea, K., Șandru, C.D. and Spînu, M. (2013) Human Impact on the Microbiological Water Quality of the Rivers: Review. *Journal of Medical Microbiology*, **62**, 1635-1640. http://dx.doi.org/10.1099/jmm.0.055749-0

[22] Jadoon, W.A., Arshad, M. and Ullah, I. (2012) Spatio-Temporal Microbial Water Quality Assessment of Selected Natural Streams of Islamabad, Pakistan. *Records*: *Zoological Survey of Pakistan*, **21**, 14-18.

[23] Cotruvo, J.A. and Trevant, C. (2000) Safe Drinking Water Production in Rural Areas: A Comparison between Developed and Less Developed Countries. *SchriftenrVer Wasser Boden Lufthyg*, **108**, 93-123.

[24] Massoud, M.A., Al-Abady, A., Jurdi, M. and Nuwayhid, I. (2010) The Challenges of Sustainable Access to Safe Drinking Water in Rural Areas of Developing Countries: Case of Zawtar El-Charkieh, Southern Lebanon. *Journal of Environmental Health*, **72**, 24-30.

[25] Rost, K.T., Ratfelder, G. and Topbaev, O. (2015) Problems of Rural Drinking Water Supply Management in Central Kyrgyzstan: A Case Study from Kara-Suu Village, Naryn Oblast. *Environmental Earth Sciences*, **73**, 863-872. http://dx.doi.org/10.1007/s12665-014-3299-1

[26] Betz, J.D. and Noll, C.A. (1950) Total-Hardness Determination by Direct Colorimetric Titration. *Journal of the American Water Works Association*, **42**, 49-56.

[27] Hald, P.M. (1947) The Flame Photometer for the Measurement Sodium and Potassium in Biological Materials. *The Journal of Biological Chemistry*, **167**, 499-510.

[28] Amrutkar, R.D, Thube, A.E. and Kulkarni, S.C. (2013) Determination of Sodium and Potassium Content Present in Water Sample Collected from Girna and Godavari River by Flamephotometry. *Journal of Pharmaceutical Science and Bioscientific Research*, **3**, 105-107.

[29] Sarkodie, P.A., Adzi, A. and Kuffour, C. (2014) Pollutant Levels of the Lake Water in Lake "Tadie". *International Journal of Scientific Research and Engineering Studies*, **1**, 24-29.

[30] Thompson, T., Fawell, J., Kunikane, S., Jackson, D., Appleyard, S., Callan, P., Bartram, J. and Kingston, P. (2007) Chemical Safety of Drinking-Water: Assessing Priorities for Risk Management. World Health Organisation Library

Cataloguing-in-Publication Data.

[31] Rovira, A.D. (1969) Plant Root Exudates. *Botanical Review*, **35**, 35-57. http://dx.doi.org/10.1007/BF02859887

[32] Abdul-Razak, A., Asiedu, A.B., Entsua-Mensah, R.E.M. and de Graft-Johnson, K.A.A. (2009) Assessment of the Water Quality of the Oti River in Ghana. *West African Journal of Applied Ecology*, **15**, 1-12.

[33] Swistock, B.R., Sharpe, W.E. and Clark, J.A. (2000) What Do the Numbers Mean? The Pennsylvania State University, University Park.

[34] United States Environmental Protection Agency (2012) 2012 Edition of the Drinking Water Standards and Health Accessories. Office of Water, US Environmental Protection Agency, Washington DC.