Aplinkos tyrimai, inžinerija ir vadyba, 2014. Nr. 1 (67), P. 16–24
Environmental Research, Engineering and Management, 2014. No. 1(67), P. 16–24
http://erem.ktu.lt

ISSN 1392–1649 (print)
ISSN 2029–2139 (online)

Correlation Analysis of Groundwater Colouration from Mountainous Areas, Ghana

Richard Amfo-Otu[1], Joseph Boateng Agyenim[2] and George Buddy Nimba-Bumah[3]

[1]*Presbyterian University College Ghana, Department of Environmental and Natural Resources Management*
[2]*University of Cape Coast, Institute for Development Studies*
[3]*Ghana Urban Water Limited, Koforidua*

crossref http://dx.doi.org/10.5755/j01.erem.67.1.4545

(Received in June, 2013; accepted in March, 2014)

Access to potable water is important for human development but inhabitants of mountainous areas face challenges of water supply due to inadequacy of the available surface water. Groundwater thus becomes the other alternative. The research was done on the groundwater quality with respect to colouration in five boreholes in some second cycle schools located in mountainous areas of the Akuapim North district. Four samples each were taken from the five boreholes for laboratory analysis. Colour, iron, manganese and some physical parameters were analysed and the results were compared with the World Health Organisation guidelines and the Ghana Urban Water Limited standard for drinking water. The results showed that conductivity and turbidity were all within the acceptable standards for drinking water. Colour strongly correlated positively with iron (r = 0.869), turbidity (r = 0.858), conductivity (r = 0.727) and manganese (r = 0.681), but pH (r = -0.715) strongly correlated negatively. Even though iron and manganese have no known health effects, they were associated with the colouration of the groundwater causing aesthetic problems for the users of the boreholes. Construction of a simple filter bed with aeration facility is critical to remove iron and manganese from the water to make it potable to the consumers.

Keywords: *groundwater, correlation, physicochemical parameters, mountainous, colouration*

1. Introduction

Water is important for the development of every nation and access to potable water is critical for human survival. Provision of safe, clean, accessible and affordable drinking water is considered to be a fundamental human right (UN 2010). This is because water is a basic necessity of life. Access to potable water will contribute to the attainment of Millennium Development Goal 7 which seeks to “half by 2015 the proportion of the population without sustainable access to safe drinking water and sanitation”. Water quality analysis is critical in ensuring that water consumed by the population meets the required quality standards. Groundwater resources are said to be of good quality but contact with geological formation and composition of soil minerals influences the quality of water extracted.

Mountainous dwellers are faced with water supply challenges due to the limited available surface water. The presence of ranges of hills influence the cost of pumping water for supply and can lead to low pressure in the water supply network. Since the surface water supply is a major challenge, the groundwater becomes an alternative water resource for exploitation to meet the water demand of the population. Aitemo et al. (2012), in their study on the quality of drinking water from some selected boreholes from the Akuapim North municipality, report of high levels of iron (3.99 mg/l) and manganese (1.2 mg/l) which affect the groundwater quality. They argue that the situation affects students in some communities due to the fact that this is the only available source of water to meet their daily water demand. Even though Fe and Mn have no known specific health effect, they influence the colour of water, creating aesthetic and taste problems for consumers, as well as depositing black stains in distribution lines (Amfo-Otu et al., 2012; El-Naggar, 2010; Casey, 2009).

The use of a correlation coefficient in the groundwater pollution research plays an important role in assessing how the parameters relate to each other (Daraigan et al., 2011). The correlation coefficient which measures the degree of association between two variables helps researchers describe how the parameters relate to each other and influence water quality in the way that appropriate water management strategies or options could be instituted (Kumar & Sinha, 2010). Correlation analyses of groundwater physicochemical parameters have been done by other researchers where colour was not a problem. Strong positive correlation coefficients (r) of some physicochemical parameters were observed between turbidity-iron (0.923) and EC -TDS (0.999) (Antony et al. 2008). Weak negative correlation was found between pH-Fe (-0.365), pH-Turb (-0.359) and pH-Mn (-0.249) by Daraigan et al. (2011). The relationship between the colour and other physicochemical parameters, such as pH, turbidity, conductivity, Fe and Mn for groundwater in mountainous areas is limited in the literature concerned. The correlation analysis of groundwater quality in the study area by Atiemo et al. (2012) has not been examined yet. Therefore, this study aims at the use of correlation analysis in assessing how colouration of groundwater is associated with iron, manganese, pH, turbidity and conductivity of water.

2. Methods

2.1. Study area

The study was conducted in the Akuapem North Municipality in the Eastern Region of Ghana which is located at the southern end of the Eastern Region and about 58 km from the nation's capital city, Accra. The municipality is located between latitudes 5°80'000'' and 6°10'000''and longitudes 0°20'000'' and 0°00'000''. The geology is dominated by rocks of the Precambrian age, the Togo series and the Birimian series (www.http://akuapemnorth.ghanadistricts.gov.gh). These formations consist of igneous and metamorphic rocks (Gyau-Boakye & Dapaah-Siakwan, 2000). The district is mountainous, with hills ranging between 381-500 metres above the sea level. There are three main sources of the water supply in the district which are rivers, pipe borne and boreholes/wells. The percentage of rural dwellers with access to potable water is 26.7%, while the percentage for urban dwellers with water access is 67.2% (Akuapem North District Assembly, 2006). The municipality has about nine (9) Senior High and Technical Schools offering various programs of studies.

2.2. Sampling and laboratory analysis

The groundwater samples were taken into acid-washed distilled water-cleaned 1000mL bottles for physicochemical analysis. Four samples each were taken from five different boreholes to give a total of 20 water samples from five second cycle schools located in five different communities in the Akuapem North Municipality. The samples were taken from August 2011 to February 2012, a period of seven months. Samples were transported to the Ghana Urban Water Limited (GUWL) Laboratory at Koforidua for analysis. The analyses focused on the parameters such as temperature, pH, colour, conductivity, turbidity, Fe and Mn using standard methods for examination of water and wastewater (APHA, 1995).

Physical parameters were analysed using the appropriate methods. Turbidity of the groundwater was tested using a nephelometric method, pH was determined based on potentiometric measurement using a standard hydrogen electrode and a reference electrode. A calibrated conductivity meter was used to analyse electric conductivity. Iron and manganese were analysed using a spectrophotometer after acid digestion of the water samples.

2.3. Statistical analysis

The mean and standard deviation of each measured parameter was computed for the five sample locations. This is done to allow for easy comparison of the data from the various boreholes. The mean values are presented in Table 1. Pearson correlation is used to examine the relationship or association between two variables which gives the indication that the changes in one variable are associated with those in another variable. The Microsoft Excel Software was used in carrying out the statistical analysis at 95% and 90% confidence interval.

The Pearson product moment correlation coefficient was computed using:

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{\left[n\sum x2 - \left(\sum x\right)2\right] \cdot \left[n\sum y2 - \left(\sum y\right)2\right]}} \qquad (1)$$

According to Pallant (2011, p. 134), a correlation coefficient can be described as: small correlation - $0.10 \leq r \leq 0.29$, medium correlation - $0.30 \leq r \leq 0.49$ and large correlation - $0.50 \leq r \leq 1.0$. The positive and the negative point to the direction of the relationship, where the positive indicates an increase in one variable associated with an increase in the other, whilst the negative correlation means an increase in one variable related to a decrease in the other. The coefficient of determination which explains the changes in one variable as explained by the changes in the other variable (r^2) was calculated.

3. Results and discussion

Table 1. Mean values of groundwater quality parameters

Parameters	Adukrom	Akropong	Larteh	Mamfe	Mampong	WHO	GUWL
pH	6.91	6.62	7.02	7.1	7	6.5-8.5	6.5-8.5
Colour (TCU)	34.25	34.5	21	14	17.75	15	5.0
Turbidity (NTU)	2.03	2.03	1.85	1.5	1.8	5	5
Conductivity (μS/cm)	247	378.75	189.5	207.75	162.5	500	-
Temperature (^{0}C)	25.2	25.15	25.2	25.3	25.1	-	-
Fe (mg/L)	0.71	0.92	0.28	0.02	0.46	0.3	0.3
Mn (mg/L)	0.21	0.24	0.05	0	0.21	0.1	0.1

Source: Field data, 2011

The resultsResults of the groundwater from the boreholes analysis presented in Table 1 show the average temperature range of 25.1- 25.3 °C. The mean pH from each of boreholes varied from 6.62 to 7.09 indicating that the conditions were near neutral and within the secondary drinking water standard (6.5 – 8.5) as indicated in the World Health Organisation guidelines (WHO, 2006). The low standard deviations of 0.02-0.07 show that there is very little variation in the values. Acidity in water may aid dissolution of some soil minerals into water. The mean pH of water from the communities contradicts the findings of Ateimo et al. (2012) that water from the district was mildly acidic.

The average colour values of the water samples from Akropong, Mampong, Larteh and Adukrom were all above the recommended limit of 15 TUC by the WHO and GUWL value of 5 TUC. No specific health effect is known to be attributable to water colouration; it is oftentimes associated with customer complaints and causes aesthetic problems (Amfo-Otu et al. 2012; El-Naggar 2010). In this case it is a major problem for groundwater users due to high colour levels which do not make this water aesthetically appealing for consumption and washing.

Turbidity of the water samples was below the acceptable levels of 5 NTU as given by WHO. The low turbidity values imply that the boreholes were constructed and developed properly. Conductivity for all water samples were below the limit of 500 (μS/cm) recommended by WHO. Conductivity which indicates ionic activities in water has no known health effects but can contribute to its hardness. The samples from Akropong showed higher conductivity (378.75 μS/cm) compared to the other boreholes from the other communities. Concentrations of iron and manganese detected in the boreholes from Akropong, Mampong and Adukrom were above the recommended levels unlike those from Mamfe and Larteh. This confirms the findings of Ateimo et al. (2012) who reported of high iron and manganese concentrations for groundwater from the district. It is commonly said that iron and manganese have no known health effects but can cause consumers aesthetic (odour, colour and taste) problems. These may also cause cosmetic effects such as skin or tooth discolouration (USEPA, 2006). However the New Hampshire Department of Environmental Services (2013) has indicated that high levels of manganese in drinking water may affect neurological function in infants.

Table 2. Correlation coefficients among selected water quality parameters

Parameters	pH	Colour	Turbidity	Conductivity	Temperature	Iron	Manganese
pH	1.000						
Colour	-0.715	1.000					
Turbidity	-0.612	0.858	1.000				
Conductivity	-0.880	0.727	0.473	1.000			
Temperature	0.205	0.031	0.099	-0.026	1.000		
Iron	-0.899	0.869	0.805	0.736	-0.149	1.000	
Manganese	-0.723	0.681	0.690	0.487	-0.147	0.883	1.000

Source: Field data, 2011 ± .444 critical value .05 (two-tail), ± .561 critical value .01 (two-tail)

3.1. Correlation analysis

From the Pearson correlation output, pH showed strong negative correlation with colour (r = -0.715), turbidity (r = - 0.612), conductivity (r = -0.880), iron (r = -0.899) and manganese (r = -0.723). This means that changes in pH of water are associated with those in turbidity, conductivity, iron and manganese concentrations. A negative correlation implies that a decrease in pH is related to an increase in turbidity, conductivity, iron and manganese levels in groundwater and vice versa. It implies that as water becomes more acidic, more iron and manganese are dissolved from the soil minerals into it. The coefficient of determination for pH-Fe (r^2 = 0.808) and pH - Mn (r^2 = 0.523) as shown in Figs 1 and 2, which implies that changes in the level of Fe and Mn are 80% and 52%, is explained by the changes in pH respectively.

A weak negative correlation between pH-Fe (-0.365), pH-Turb (-0.359) and pH-Mn (-0.249) were found by Daraigan et al. (2011). This is contrary to the findings of this study which indicates a strong correlation instead. The pH, however, shows a weak positive correlation with temperature (r = 0. 31). Colour has a strong positive correlation with turbidity (r = 0.858), conductivity (r = 0.727), iron (r = 0.869) and manganese (r = 0.681) but shows a weak correlation with temperature (r = 0.31). The coefficient of determination for colour-turbidity (r^2 = 0.736), colour-conductivity (r^2 = 0.529), colour-Fe (r^2 = 0.757) and colour-Mn (r^2 = 0.468) implies that 73.6% of the change in the colour of groundwater can be explained by the change in turbidity, 52.9% - by change in conductivity, 75.7% - by that in Fe concentration and 46.8% - by the change in Mn levels in water. Turbidity correlated positively with temperature, iron and manganese, while correlation with conductivity was strong but moderate. This implies that the presence of iron and manganese at an appropriate temperature will be associated with turbidity of groundwater. Conductivity exhibited strong positive correlation with iron, moderate with manganese and weak negative correlation with temperature. It is not surprising because conductivity deals with ionic species in water, and iron and manganese exist in an ionic form but not temperature. Weak negative correlations were found between temperature and iron and temperature and manganese. Iron and manganese showed strong positive correlation.

Table 3. Coefficient of determination for groundwater quality parameters

Parameters	R – Value	Coefficient of determination (R^2)	Shared variance
Colour – Fe	0.869	0.755	75.5
Colour – Mn	0.681	0.464	46.4
Colour – Turb	0.858	0.736	73.6
Colour – Cond	0.727	0.529	52.9
Colour – pH	-0.715	0.511	51.1
pH – Fe	-0.899	0.808	80.8
pH – Mn	-0.723	0.523	52.3

Source: Field data, 2011

4. Conclusion

Groundwater quality is crucial for the life of mountainous dwellers due to limited availability of surface water. Conductivity, pH and turbidity of all the water samples analysed are within permissible limits. All the physicochemical parameters of groundwater studied in the mountainous district of Akuapim North are correlated with each other and this indicated how changes in one parameter associate with the others. This determination of physicochemical parameters gives an opportunity for the proper management measures to be taken for sustainable potable water delivery. Fe and Mn levels are high in most of the samples and exceed the WHO drinking water limit. However, comparison of the physical parameters with the WHO drinking water quality standards shows that the samples are potable except the colour. It is important to evaluate the redox potential of oxidation of Fe in the future groundwater studies in the area since it has not been covered by the current study.

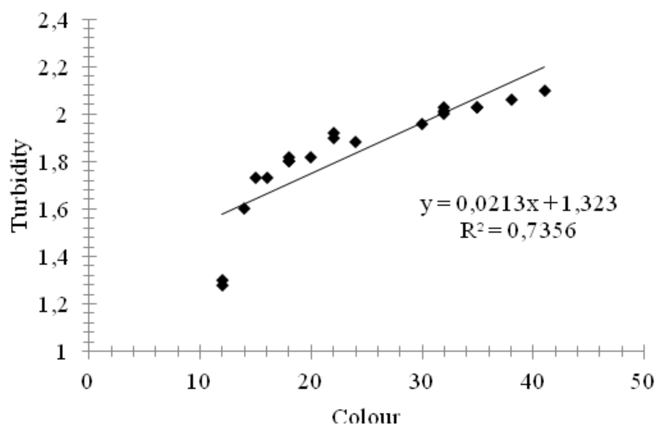

Fig. 1. Linear relationship between turbidity and colour

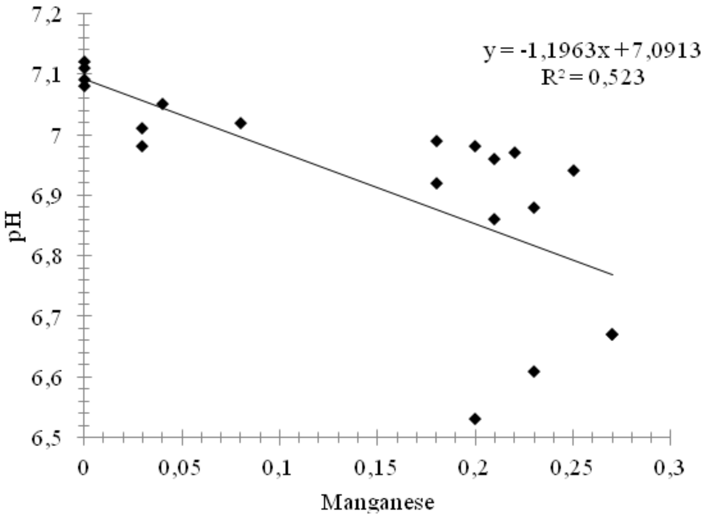

Fig. 2. Linear relationship between pH and manganese

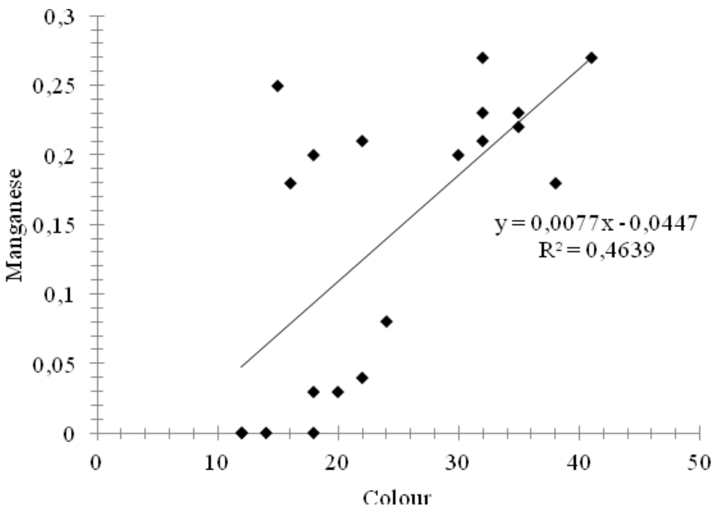

Fig. 3. Linear relationship between manganese and colour

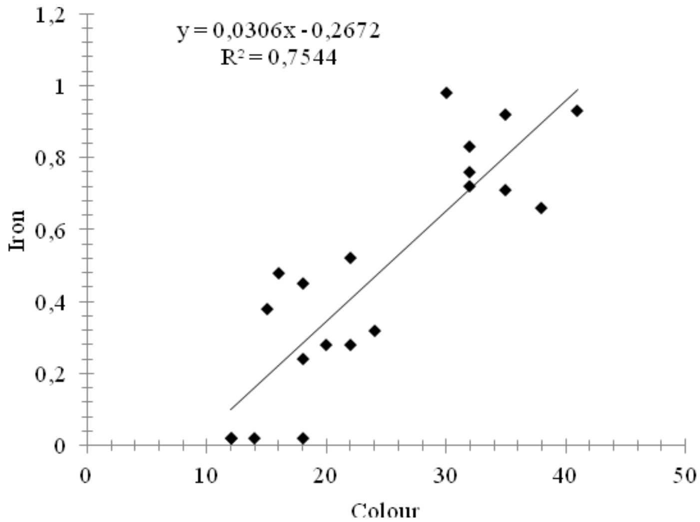

Fig. 4. Linear relationship between iron and colour

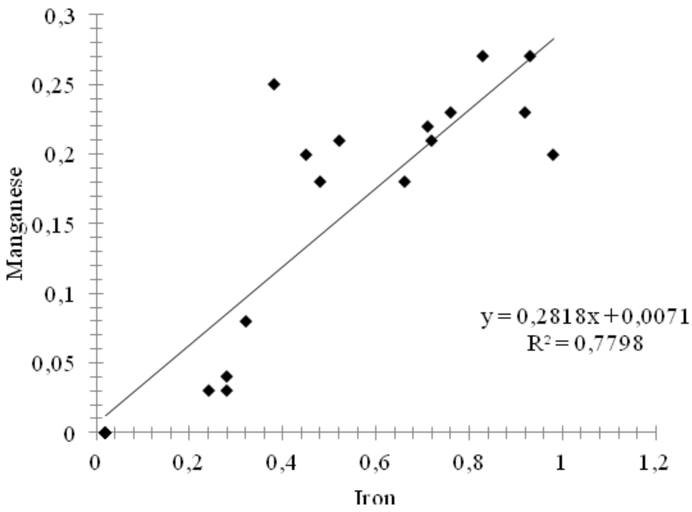

Fig. 5. Linear relationship between manganese and iron

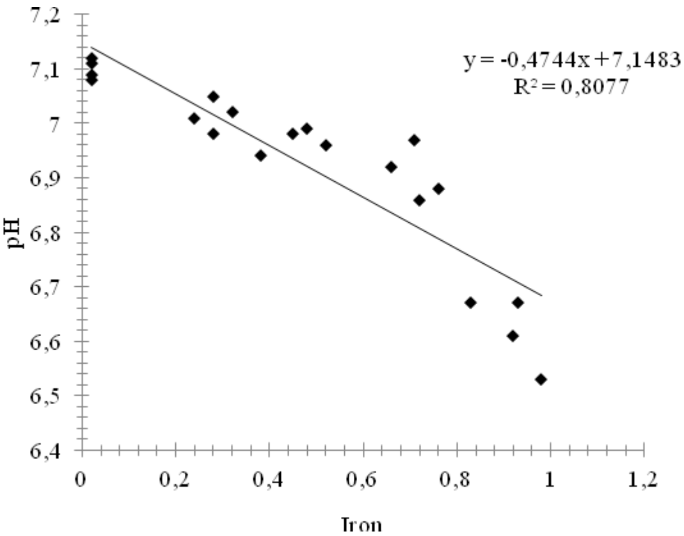

Fig. 6. Linear relationship between pH and iron

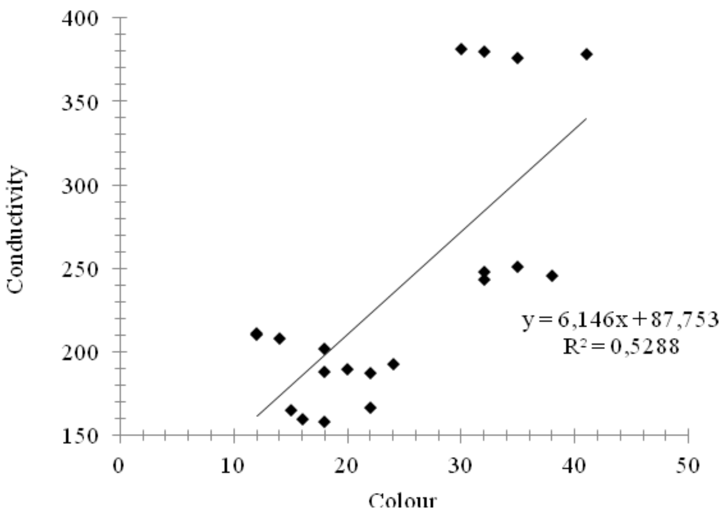

Fig. 7. Linear relationship between pH and iron

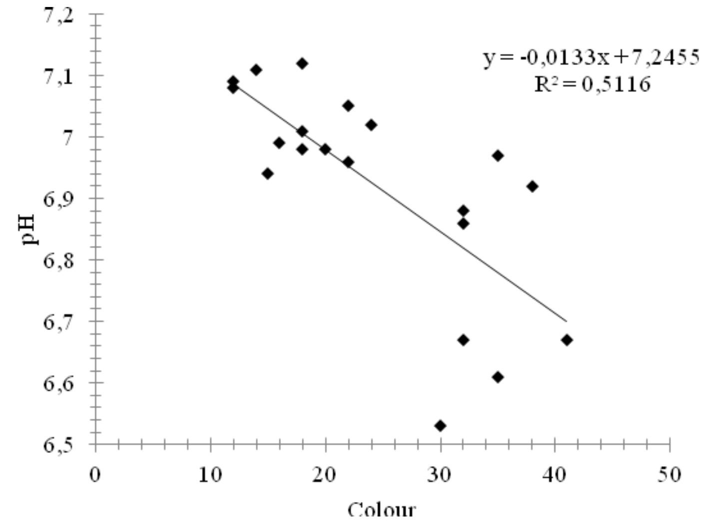

Fig. 8. Linear relationship between pH and colour

Table 4. Groundwater Quality Data

Community	pH	Colour	Turbidity	Conductivity	Temperature	Iron	Manganese
ADU	6.92	38	2.06	246	25.4	0.66	0.18
AKR	6.67	32	2.01	380	25.7	0.83	0.27
LAR	7.02	24	1.88	193	25.7	0.32	0.08
MAF	7.12	18	1.8	202	25.7	0.02	0
MAM	6.96	22	1.92	167	25.3	0.52	0.21
ADU	6.86	32	2	243	24.9	0.72	0.21
AKR	6.61	35	2.03	376	25.3	0.92	0.23
LAR	7.09	12	1.28	210	25.1	0.02	0
MAF	7.05	22	1.9	187	25.2	0.28	0.04
MAM	6.99	16	1.73	160	25	0.48	0.18
ADU	6.88	32	2.03	248	25.2	0.76	0.23
AKR	6.53	30	1.96	381	24.9	0.98	0.2
LAR	7.01	18	1.8	188	25.1	0.24	0.03
MAF	7.11	14	1.6	208	25.3	0.02	0
MAM	6.98	18	1.82	158	25.4	0.45	0.2
ADU	6.97	35	2.03	251	25.3	0.71	0.22
AKR	6.67	41	2.1	378	24.7	0.93	0.27
LAR	6.98	20	1.82	190	24.8	0.28	0.03
MAF	7.08	12	1.3	211	25.1	0.02	0
MAM	6.94	15	1.73	165	24.7	0.38	0.25

Source: Field data, 2011 MAM-Mampong, MAF-Mamfe, LAR-Larteh, AKR-Akropong, ADU-Adukrom

Acknowledgement

Much appreciation goes to the laboratory staff of Ghana Urban Water Limited and the headmasters of the schools in the communities where samples were collected for the study.

References

Akuapem North District Assembly. 2006. Water and Sanitation in Akuapem North Municipality. Online: www.http://akuapemnorth.ghanadistricts.gov.gh.

Amfo-Otu, R., Omari, S. & Boakye-Dede, E. 2012. Assessment of Physico-chemical Quality of Groundwater Sources in Ga East Municipality of Ghana. Environment and Natural Resources Research; Vol. 2, No. 3, 19-24. URL: http://dx.doi.org/10.5539/enrr.v2n3p19.

Antony, S. A., Balakrishnan, M., Gunasekaran, S. & Natarajan, R. K. 2008. A correlation study of the ground water quality in the Manali Petroleum Industrial Region in Tamil Nadu, India. Indian Journal of Science and Technology,Vol.1 No 6, 1-11. Online: http://www.indjst.org.

APHA 1995. Standard methods for examination of water and wastewater, 19th edition, Washington, D. C: American Public Health Association.

Atiemo, M. S., Dumolga, A. V., Adu Kumi, Yeboah, S. A., Kuranchie-Mensah, H. & Palm, L. M. N. D. 2012. Investigating the quality of drinking water from selected boreholes in the Akuapem North District in the Eastern Region of Ghana. Elixir Pollution, 46, 8046-8050.

Casey, T. J. 2009. Iron and Manganese in Water Occurrence, Drinking Water Standards, Treatment Options. Aquavarra Research Publications Water Engineering Papers 3, p 1-6.

Daraigan, S. G., Ahmed S. Wahdain, A. S., Ahmed S. Bamosa, A. S. & Obid, M. H. 2011. Linear correlation analysis study of drinking water quality data for AlMukallan City, Hadhramout, Yemen. International Journal of Environmental Sciences Volume 1, No 7, p 1692-1701.

El-Naggar M. H. Development Of Low-Cost Technology For The Removal Of Iron and Manganese From Ground Water In Siwa Oasis. Journal of Egypt Public Hrtzlth Assor, Vol. 85, No. 3, p 169-188.

Gyau-Boakye, P. & Dapaah-Siakwan, S. 2000. Groundwater as Source of Rural Water Supply in Ghana. Journal of Applied Science and Technology, Vol. 5, No 1 & 2, pp 77-86.

Jmp, Unicef, Undp & Who 2010. UN-Water Decade Programme on Advocacy and Communication (UNW-DPAC).

Khan, S. M. M. N. & Kumar, A. R. 2012. Interpretation of Groundwater Quality using Correlation and Linear Regression Analysis from Tiruchengode taluk, Namakkal district, Tamilnadu, India. Journal of Chemical and Pharmaceutical Research, 4(10):4514-4521.

Kumar, N. & Sinha, D. K. 2010. Drinking water quality management through correlation studies among various physico-chemical parameters: A case study. International Journal of Environmental Sciences, 1(2): 253-259. Online: http://www.ipublishing.co.in/jesvol1no12010/EIJES1023.pdf.

New Hampshire Department of Environmental Services 2013. Iron and/or manganese in drinking water, Environmental fact sheet, WD-DWGB-3-8 Available at http://www.des.state.nh.us/ws.htm.

Pallant, J. 2011. SPSS Survival Manual: A Step by Step Guide to Data Analysis Using SPSS fourth Edition. Allen & Unwin, Australia.

Patel, R. L. & Dhiman, S. D. 2011. Temporal variation and regression analysis of Groundwater Quality Parameters: A Case Study. National Conference on Recent Trends in Engineering & Technology, 13-14.

Salkind, N. J. & Rsamussen, K. 2007. Encyclopaedia of Measurement and Statistics Voloume 1. Sage Publications Inc, London.

USEPA. 2006. “Drinking Water Contaminants Website”, U.S. Environmental Protection Agency, Washington, D.C. Online: http://www.epa.gov/safewater/mcl.html.

World Health Organisation. 2006. Guidelines for Drinking-Water Quality, First Addendum to Third Edition, Volume 1; Online: www.who.int/water_sanitation_health/dwq/gdwq0506.pdf.

Richard Amfo-Otu – Department of Environmental and Natural Resources Management.
Main research areas: water quality analysis, environmental quality, solid waste management, healthcare waste management, wastewater treatment, Soil quality, poverty and environmental issues, development and environmental degradation, food safety and hygiene, environmental risk assessment, environmental toxicology, wildlife conservation.
Address: Department of Environmental and Natural Resources Management,
P.O. Box 393,
Presbyterian University College
Akropong-Akuapem
Ghana
Tel.: +233243331041
Email: *richard.amfo-otu@presbyuniversity.edu.gh*

Joseph Boateng Agyenim – Institute for Development Studies, University of Cape Coast
Main research areas: Water resources management, climate change and food security; he is also concerned with managing the environmental changes as a result of climate change and human activities.
Address: Institute for Development Studies,
P.O. Box 01
University of Cape Coast'
Cape Coast, Ghana
Tel.: +233 8182442
E-mail: *jagyenim@ucc.edu.gh*

George Buddy Nimba-Bumah – Aqua Scientificals
Main research areas: water quality analysis, environmental quality, quality of water supply services, water distribution, water treatment technologies, waste management, wastewater treatment, Utility management.
Address: Aqua Scientificals
P. O. Box CJ 175
Koforidua, Ghana
Email: *gbuddy19@yahoo.com*

Koreliacinė kalnuotų vietovių požeminio vandens spalvų analizė Ganoje

Richard Amfo-Otu[1], Joseph Boateng Agyenim[2] ir George Buddy Nimba-Bumah[3]

[1]*Presbyterian kolegija, Aplinkos ir gamtos išteklių vadybos katedra*
[2]*Cape Coast universitetas, Vystymosi studijų institutas*
[3]*Ganos miesto vandens apribojimų organizacija*

(gauta 2013 m. birželio mėn.; atiduota spaudai 2014 m. kovo mėn.)

Prieinamumas prie geriamojo vandens yra labai svarbus žmogaus visokeriopam vystymuisi, tačiau taip anaiptol yra ne visur. Kalnuotose vietovėse gyvenantys žmonės turi daug problemų susijusių su vandens tiekimu ir paviršinio vandens tinkamumu vartoti. Todėl požeminis vanduo čia tampa pagrindine alternatyva. Tiriamajame darbe buvo atlikta požeminio vandens kokybės analizė, susijusi su spalvos kitimu penkiuose skirtinguose gręžiniuose šalia antrosios pakopos mokyklų, esančių kalnų rajonuose, Akuapem Šiaurės rajone. Laboratoriniams tyrimams atlikti iš penkių gręžinių buvo paimta po keturis bandinius. Buvo išanalizuoti fiziniai parametrai: spalva, geležis, manganas ir kt., o rezultatai buvo palyginti su Pasaulio sveikatos organizacijos teikiamomis rekomendacijomis ir Gana miesto vandens apribojimų geriamajam vandeniui standartais. Rezultatai parodė, kad vandens laidumo ir drumstumo vertės pagal geriamojo vandens standartus buvo priimtinos. Spalva labai teigiamai koreliavo su geležimi ($r = 0,869$), drumstumu ($r = 0,858$), savituoju laidžiu ($r = 0,727$) ir manganu ($r = 0,681$), tačiau pH ($r = –0,715$) koreliacija buvo stipriai neigiama. Nors geležis ir manganas neturi nepageidaujamo poveikio sveikatai, jų buvimas vandenyje yra glaudžiai susijęs su požeminio vandens spalvos kitimu ir estetinių problemų atsiradimu gręžinių vartotojams. Vandeniui valyti labai svarbu pastatyti įprastą rezervuarą su vandens filtrais ir aeravimu, siekiant pašalinti geležį ir manganą iš vandens, kad jis taptų visapusiškai tinkamas vartotojams.