LOOK ACADEMIC PUBLISHERS
OPEN ACCESS

INTERNATIONAL JOURNAL OF ENVIRONMENTAL & SCIENCE EDUCATION
2017, VOL. 12, NO. 10, 2183-2194

Perception, Attitude and Health Risk Assessment of Trace Metals From Borehole Waters Collected in a Town Near Mining İndustries in Pretoria, South Africa

Joshua Oluwole Olowoyo[a], Ntebo Lion[a] & Karabo Mothata[a]

[a]Department of Biology, SMU Health Sciences University,Pretoria, SOUTH AFRICA

ABSTRACT

The availability of drinking water is fast becoming a major challenge in most of the developing countries. Reliance on well and borehole water is thus on the increase without prior effort to consider their safety for human consumption. The present study investigated the concentrations of trace metals in water samples collected from borehole in a village surrounded by mining industries with a view to determining the health implication of drinking water from these boreholes. The study further examined the attitude and perception of villagers on the quality and the treatment of the water before consumption. The study was conducted in a village surrounded by different mining companies. Water samples were collected during the summer and winter seasons from randomly selected boreholes in the village and structured questionnaires were administered in order to get information on water treatment methods used by the villagers. The trace metal content of the water was determined by Inductive Couple Plasma Mass Spectrophotometer (ICP-MS). The result showed that there was no significant difference in the concentrations of trace metals obtained for the two sampling periods ($p< 0.05$). Concentrations of trace metals such as Zn and Hg were above the recommended limit set by World Health Organization (WHO) for trace metals in water. The report from the questionnaire showed that 97% of those interviewed do not treat the water before drinking and had no any prior knowledge of trace metals in water. The report from the questionnaire further showed that 60% of those interviewed agreed that the water is available during the summer period and may become scarce during the winter season; however the respondents agreed that there is no need to get pipe borne water from any other source. The study concluded that since the majority of the people rely on these boreholes for the supply of portable water and taking into consideration the levels of Zn and Hg in some of the boreholes, it may be necessary to monitor the levels of trace metals from these boreholes regularly.

KEYWORDS
Borehole water, water purification, Zinc and Mercury

ARTICLE HISTORY
Received 20 September 2017
Revised 22 October 2017
Accepted 27 October 2017

Introduction

CORRESPONDENCE J.O. Olowoyo ✉ woleolowoyo@yahoo.com

In South Africa, water is fast becoming a scarce natural resource due to the prolonged absence of rain resulting in a drought condition. The Department of Water Affairs in the country announced measures such as water tankering, borehole drilling and rehabilitation, water conservation and demand management, as means of alleviating the current water shortages experienced in some households in the country (www.dwa.gov.za/drought, 2017). Adequate supply of clean and portable water is a fundamental requirement for human existence and the ecosystem in general (Chimphamba and Phiri, 2014).

In some part of Africa, studies have indicated different mechanisms used by rural dwellers in coping with scarcity of water within their households and also in order to reduce the impacts of climate variability on water footprint (Adejuwon et al., 2007; Nyong and Kanaroglou, 2001). In Nigeria, for example as reported by Gbadegesin and Olorunfemi (2011) some rural communities have relied on indigenous conservation strategies of traditional water sources for years which includes streams and rivers. The use of underground water extraction such as boreholes, hand dug wells have also been used both in the rural and urban areas where large scale water scheme or supply of portable drinking water from government seems impossible over the years (Aizebeokhai, 2011). In South Africa the use of borehole for domestic water has also been reported in literature (www.dwa.gov.za/drought, 2017). Nienie et al. (2017) also reported on the use of water from streams, river and borehole in a rural area of Kwilu province from the capital city of Democratic Republic of the Congo.

Borehole drilling is generally assumed as an excellent way to get access to pure and natural underground water (Johannesburg water, 2016). However in some instances, a number of water pollution in borehole water has been reported. In Malawi, Pritchard et al. (2008) reported on fluoride concentration of about 9mg/l in Kumkwawa village. Msonda et al. (2007) also reported on chemical toxicity from some borehole water in Malawi adding that the pollutants are also on the increase. The study of Botchway et al. (1996) also showed that ninety percent of the water sampled in a village that relied on groundwater for portable water had Mn levels above the detection limit while the concentrations of Fe was higher than those recommended by the WHO. The studies of Bunnell et al. (2007) and Finkelman et al. (1999) further reported that trace element pollution is now of a great concern and there is a widespread of trace elements occurring in water at concentration significantly higher than background levels.

From literature, it has been reported that mining activities may introduce trace metals into the environment which may increase the concentrations of these trace metals in soil and plants around its vicinity if unchecked and uncontrolled (Koz et al. 2012; Olowoyo et al. 2013). The sources of these trace metals in drinking water has reported by Abdulrahman et al. (2011) includes the natural and anthropogenic sources. In South Africa, mining activities have been implicated as one of the major sources which introduce trace metals into the environment (Olowoyo et al. 2013; Lion et al., 2012). The current study was carried out in a village surrounded by different mining companies and where there is a great reliance on borehole water for human consumption. The study also investigated the possible influence of these mining industries in releasing trace metals as pollutant to the underground water. The study also sought to get information on the perception and possible treatment options embarked upon by the villagers before using the underground water.

Methodology

The village (25.4037^{0} S, 27.8487^{0} E) situated north of Pretoria was chosen because of the several mining industries (5) in the area and there are no potable water supplies in these catchment areas, hence dependence on water sources mainly from boreholes for domestic, irrigation and livestock activities. Before the water sampling from the boreholes, the area has also witnessed a severe drought due to lack of rain for a period of about nine months. Borehole water samples were collected directly from the water pipe bringing out the water. The water samples were collected in two – litre plastic bottles that were initially washed with tap water and further rinsed with distilled water. Upon collection, the water samples were immediately acidified with HNO_3 in order to keep the metals in the water samples thus preventing them from adhering to the walls of the plastic bottles. The samplings were done just over a period of two seasons (summer and winter). The samples were collected from 10 different boreholes with a total of 20 samples for both seasons.

During the sampling in the summer period, questionnaires were administered to households in order to establish their perception on the importance of treating the water before drinking and establish if there are methods they use in treating the water before drinking it. The questionnaires also established their knowledge on trace metals in water, exposure and health implications of drinking trace metals polluted water and whether there are prior educations or awareness on safe water practices in the area.

The pH of the water samples were determined in the field using the pH meter model 215 and the trace metal contents (V, Cr, Mn, Co, Ni, Cu, Zn, Sr, Pb, U, Ti) of the water samples were done in an accredited laboratory using ICP – MS. The analysis was done by digesting the water samples of 100 ml with 2ml HNO_3 and 1 ml of $HClO_4$. The resulting solution was then analysed for trace metals content using ICP –MS. The digestion and analysis of the water procedure followed the methods described by APHA (1989). Levels and presence of Total coliform, *Escherichia – coli* and *Firmicutes. streptococci* were analyzed using Membrane Filtration Technique (APHA 2005).

Results and Discussion

The pH of the water samples was all within the acceptable limit set for drinking water by WHO. The water pH was between 6.85 ± 0.01 – 7.23 ± 0.02. The water samples were very clear without any noticeable impurity and there were no odour oozing out from the water.

The concentrations for all the trace metals except for Zn and Hg were all within the acceptable limit for the respective trace metals. The concentrations of Zn ranged from 2.06 ± 0.36 – 521.3 ± 2.35 ppb (Tables 1 and 2). The highest concentration for the Zn was recorded during the winter period and the value was above the recommended limit for Zn in drinking water as set by WHO. Differences obtained for the value of Zn from the different borehole water samples for the two seasons were significant ($p > 0.05$). Zinc is an important element in the body because of its role as ionic signaling in large number of cells and tissues (Nriagu 2007). However, higher concentrations of Zn in drinking water may be detrimental to human health. The high concentrations of Zn reported in some borehole water from this study may be due to corrosion pipes and some other materials used in pumping water from the boreholes. Similar observation of pipe corrosion and subsequent increase in the concentrations of Zn from pipes and other fittings were reported in the study of Gillies and Paulins (1982) and Solomons (1988). The most common adverse effects associated with long-term, excessive Zn intakes may include sideroblastic anaemia, hypochromic microcytic anaemia, leukopenia, lymphadenopathy, neutropenia, hypocupraemia and hypoferraemia (Nriagu, 2007). Patients often recover to normal blood patterns after cessation of zinc intake with or without copper supplementation.

Table 1: Concentrations of trace metals in ppb from borehole waters in April 2016

	Trace Metals										
Sites	**V**	**Cr**	**Mn**	**Co**	**Hg**	**Cu**	**Zn**	**Sr**	**Pb**	**U**	**Ti**
1	10.08±0.02	3.56±0.12	1.04±0.01	0.14±0.02	0.27±0.03	2.94±0.12	73.75±2.32	129±2.36	0.02±0.00	0.21±0.02	17.2±1.01
2	15.05±1.03	1.63±0.25	0.01±0.00	0.47±0.01	**0.66±0.1**	17.93±1.12	246±1.25	227±5.44	0.63±0.02	1.24±0.05	18.6±2.01
3	13.46±0.32	2.01±0.31	0.19±0.02	0.53±0.02	0.01	55.84±2.11	270.3±2.89	250.3±8.11	2.72±0.06	0.51±0.05	17.99±0.68
4	12.93±2.11	2.62±0.14	9.53±0.01	0.41±0.05	**0.86±0.16**	14.97±0.21	50.61±2.25	259±2.36	0.56±0.02	0.50±0.08	18.67±2.11
5	13.07±1.05	2.05±0.14	ND	0.18±0.03	**0.77±0.46**	2.52±0.02	2.06±2.36	160.6±2.59	0.01	0.24±0.03	22.05±1.02
6	15.03±2.14	2.04±0.21	0.25±0.02	0.24±0.05	0.01	3.73±0.11	**394.8±3.69**	170.7±2.44	0.12±0.00	0.15±0.01	20.93±1.35
7	14.56±0.68	1.56±0.11	ND	0.32±0.02	0.14±0.04	2.62±0.12	43.82±3.54	142.5±2.87	1.33±0.02	0.11±0.06	21.9±2.11
8	17.82±0.32	1.33±0.05	ND	0.37±0.01	0.41±0.16	5.88±0.02	30.15±3.25	256.5±6.24	0.01	0.71±0.08	23.09±1.32
9	10.07±1.54	1.77±0.10	ND	0.34±0.02	**0.47±0.14**	5.24±0.03	**502.1±8.96**	184.9±6.35	2.21±0.35	1.27±0.02	18.19±2.11
10	9.27±2.11	1.42±0.09	ND	0.27±0.05	0.01	2.71±0.05	81.84±7.82	127.8±9.11	0.18±0.06	0.30±0.03	20.16±1.29

Table 2: Concentrations of trace metals in ppb from borehole waters in July 2016

	Trace Metals										
Sites	**V**	**Cr**	**Mn**	**Co**	**Hg**	**Cu**	**Zn**	**Sr**	**Pb**	**U**	**Ti**
1	10.08±0.02	3.56±0.12	1.04±0.01	0.14±0.02	0.27±0.03	2.94±0.12	73.75±2.32	129±2.36	0.02±0.00	0.21±0.02	17.2±1.01
2	15.05±1.03	1.63±0.25	0.01±0.00	0.47±0.01	**0.66±0.1**	17.93±1.12	246±1.25	227±5.44	0.63±0.02	1.24±0.05	18.6±2.01
3	13.46±0.32	2.01±0.31	0.19±0.02	0.53±0.02	0.01	55.84±2.11	270.3±2.89	250.3±8.11	2.72±0.06	0.51±0.05	17.99±0.68
4	12.93±2.11	2.62±0.14	9.53±0.01	0.41±0.05	**0.86±0.16**	14.97±0.21	50.61±2.25	259±2.36	0.56±0.02	0.50±0.08	18.67±2.11
5	13.07±1.05	2.05±0.14	ND	0.18±0.03	**0.77±0.46**	2.52±0.02	2.06±2.36	160.6±2.59	0.01	0.24±0.03	22.05±1.02
6	15.03±2.14	2.04±0.21	0.25±0.02	0.24±0.05	0.01	3.73±0.11	**394.8±3.69**	170.7±2.44	0.12±0.00	0.15±0.01	20.93±1.35
7	14.56±0.68	1.56±0.11	ND	0.32±0.02	0.14±0.04	2.62±0.12	43.82±3.54	142.5±2.87	1.33±0.02	0.11±0.06	21.9±2.11
8	17.82±0.32	1.33±0.05	ND	0.37±0.01	0.41±0.16	5.88±0.02	30.15±3.25	256.5±6.24	0.01	0.71±0.08	23.09±1.32
9	10.07±1.54	1.77±0.10	ND	0.34±0.02	**0.47±0.14**	5.24±0.03	**502.1±8.96**	184.9±6.35	2.21±0.35	1.27±0.02	18.19±2.11
10	9.27±2.11	1.42±0.09	ND	0.27±0.05	0.01	2.71±0.05	81.84±7.82	127.8±9.11	0.18±0.06	0.30±0.03	20.16±1.29

The other element of major concern is Hg with concentrations below the detection limit of 0.01 ppb from some of the borehole water. However, concentration above the recommended limit was noticed from a borehole water sample number 7 with a value of 1.05 ± 0.26 ppb (Tables 1 and 2). Other water samples where Hg was detected ranged from 0.14±0.04– 1.05 ± 0.26 ppb during the two sampling periods. Concentrations of Hg were below the detection limit from three borehole water during the summer sampling period while the highest concentrations of 1.05 ± 0.26 ppb was recorded during the winter period. The acceptable limit for Hg in drinking water according to WHO should be 0.001 mg/l (WHO, 2004). A similar study conducted by Sallau et al. (2014) from 3 different sites in Northcentral part of Nigeria showed the values of Hg to be above the recommended limit set by WHO. The researchers attributed the source of Hg from the water samples to the fact that it was previously used by artisanal miners for sluicing of ore for recovering of gold with the aid of liquid

Hg metal. Also from the report of Nartey et al. (2011) there were variations in the concentrations of Hg from the bore hole water samples. The variations noticed from the study were attributed to the depth of the boreholes, soil type and seasonal effect.

The concentration of Cu ranged from 0.25 ± 0.12 – 55. 84 ± 1.12 ppb, Sr was in the range 127.8 ± 0.11 – 259 ± 2.36 ppb, Ti ranged between 17.35 ± 0.23 – 23.09 ± 1.32 ppb, V was in the range 9.27 ± 0.02 – 17.82 ± 0.32 ppb and Cr was in the range 0.87 ± 0.11 – 3.56 ± 0.12 ppb (Tables 1 and 2). All the trace elements were within the acceptable limit for human consumption. The correlation coefficient calculated for the trace metals showed a strong positive correlation for elements such as V and Ti, Co and Pb, Co and Zn, Co and Sr, Cu and Sr, Cu and Pb, Zn and Pb and Sr and U for both seasons.

The questionnaire administered to the householder showed that between 97% - 99% of those interviewed neither treat water nor have any idea of the impact of trace metals in water (Table 3) (Figures 1 – 4). *"I do not treat the water; have been using it like that for years, water has a natural way of purifying itself"*. The report of this study is in agreement with the findings of Uboh et al. (2014) in a study conducted in Owerri, Nigeria where greater numbers of respondents (48%) do not treat water before drinking or for any other purpose. Previous study by Ubuoh (2012) did observe that rural dwellers do not treat their drinking water because of ignorance of implications of impurities. However, it may be necessary to have a single or multiple forms for water treatment since the WHO report have suggested that unclean sources of water have been responsible for diseases such as diarrhoea, cholera, guinea worm, typhoid and intestinal worms which killed more than eight million people throughout the world each year (WHO, 2011). Manyatsi and Tfwala (2012) reported in a study from Swaziland that that one borehole out of a total of three had total coliform count of 74 per 100 mL of water, a figure that was above the acceptable limit of 10 counts per 100 mL of water. There was no any presence of *E. coli* and *F. streptococci* from our present study.

Table 3: Response on attitude towards drinking water in percentages (%)

Questions	Yes %	No%
Is there an adequate supply of drinking water?	98.5	1.5
Is water from borehole available throughout the year?	60	40
Does the water from the borehole generally have a smell?	10.8	89.2
Does the water from the borehole generally have a taste?	47.7	52.3
Does the water from the borehole looks clear?	92.3	7.7
Have you complained about water in the past year?	4.6	95.4
Are you satisfied with the water you receive from the borehole?	75.4	24.6

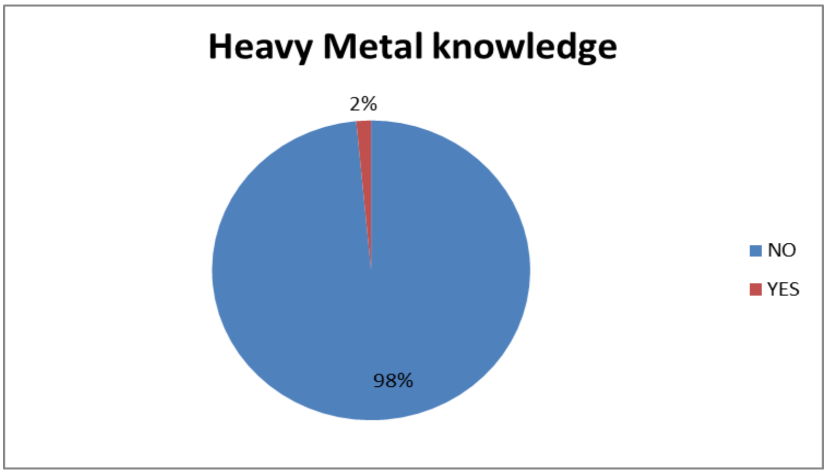

Figure 1: Percentage of people interviewed with adequate knowledge of toxic trace metals in water.

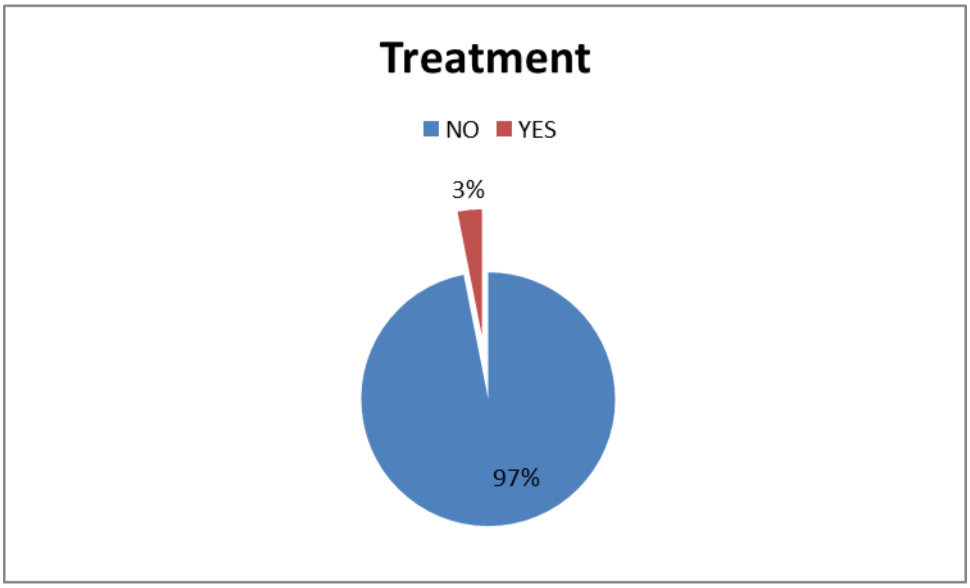

Figure 2: Percentage of those interviewed that have applied any form of treatment on the water before drinking.

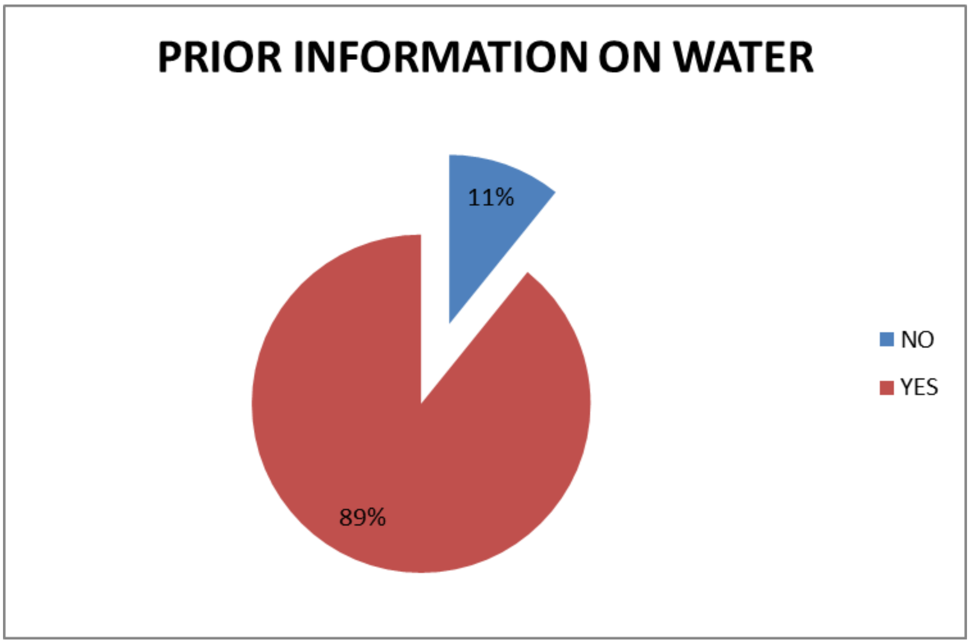

Figure 3: Percentage of people with prior information on water and its associated diseases.

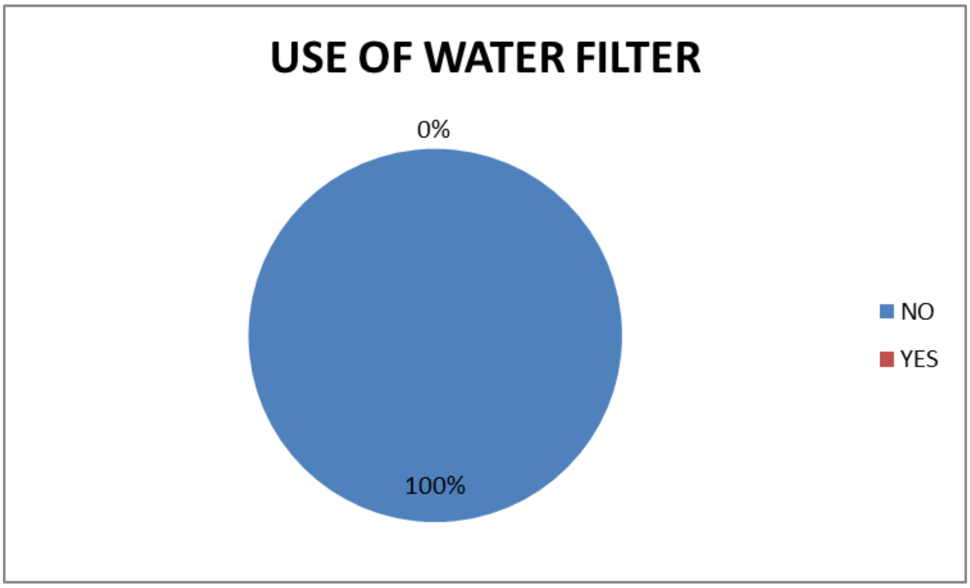

Figure 4: Percentage of those interviewed that have used water filters for water purification.

However, 90% of those interviewed pointed to the fact that government and non-governmental agencies do visit the area occasionally to offer information on safe water drinking and practices (Figure 1). The respondent (50%) also pointed out that the water from borehole at times may have a taste that has been associated with it for a long time. "*Yes we know when we drink* *water from the borehole and the water supplied by the government, we have been drinking it for years and we were never sick*". The other respondent answered by saying "*We do not need to use any water filter because the water is clear and very clean*"

The major challenge as pointed out by some of the respondents was the unavailability of these boreholes water throughout the year especially during the winter season. This may be as a result of the lack of rain which would have substituted for some other domestic water uses during this period. The respondents are not currently using any other form of water harvesting as at the time of conducting this study. This could assist in reducing the enormous stress that is placed on borehole water. Studies from other African studies have pointed to rain harvesting and digging of wells as alternative to borehole water for irrigation purposes (Aizebeokhai, 2011; Myantsi and Tfwala, 2012; Uboh, 2012). The satisfaction in terms of quality and supply was acceptable from a larger percentage (75%).

Conclusion

The present study confirmed that people living in the community where the study was conducted rely solely on boreholes for the supply of portable water that is used for various activities. It was discovered that the levels of known toxic trace metals were low except for Zn and Hg from some of the borehole waters and this may partly be due to the metal pipes that are used for pumping the water. One good thing about the water samples is that the parameters examined falls below the acceptable limit as recommended by the WHO. *E – coli* and *F. streptococci* were not found in any of the water samples despite the fact that most of the house hold still rely on pit toilets. Most of the respondents agreed that they do not treat their water before drinking and the water is associated with a particular smell. Also the high levels of Zn and Hg noted from some water sources may necessitate a periodic examination of the water. It may also be important to teach the people living around this area another form of water harvesting in order not to put unnecessary stress on the only source of water especially during the winter season. The government may also assist in looking for other alternative sources of water during the winter season.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

Joshua Oluwole Olowoyo - Professor, Sefako Makgatho Health Sciences University, Dept Of Biology, Pretoria, South Africa

Ntebo Lion – Lecturer, Sefako Makgatho Health Sciences University, Dept Of Biology, Pretoria, South Africa.

Karabo Mothata – Msc Student, Sefako Makgatho Health Sciences University, Dept Of Biology, Pretoria, South Africa.

References

Abdulrahman, A.S., Mohammad, I., Mohammad, S.H. 2011. "Inhibition of Corrosion of Mild Steel in Hydrochloric Acid by Bambusa Arundinacea." International Review of Mechanical Engineering. 5(1): 59-63.

Adejuwon, J.O., Odekunle, T.O., Omotayo, M.O. 2007. 'Using seasonal weather forecasts for adapting food production to climate variability and change in Nigeria.' In: Leary, N., Adejuwon, J., Barros, V., Burton, I., Lasco, R. (eds), *Adaptation to Climate Change*. Earthscan, London, UK (forthcoming).

Aizebeokhai, A.P. 2011. Potential impacts of climate change and variability on ground water resources in Nigeria. African Journal of Environmental Science and Technology. 5(10): 760–768.

American Public Health Association (APHA). 1989. American Water Works Association (AWWA) & Water Environment Federation (WEF): Standard Methods for the Examination of Water and Wastewater.

American Public Health Association (APHA). 2005. American Water Works Association (AWWA) & Water Environment Federation (WEF): Standard Methods for the Examination of Water and Wastewater, 21st Edition.

Botchway, C.A., Ansa-Asare, O.D., Antwi, L.A. 1996. "Natural fluoride and trace metal levels of ground and surface waters in the greater Accra region of Ghana". West African Journal of Medicine. 15: 204-209.

Bunnell, J.E., Tatu, C.A., Busho, R.N., Stoeckel, D.M., Brady, A.M.G., Beck, M., Lerch, H.E., McGee, B., Hanson, B.C., Shi, R., Orem, W.H. 2006. Possible linkages between lignite aquifers, pathogenic microbes, and renal pelvic cancer in northwestern Louisiana, USA. Environmental Geochemistry and Health. 28: 577–587. doi: 10.1007/s10653-006-9056-y.

Chimphamba, J.B., Phiri, O.L. 2014. Borehole Water Pollution and its Implication on health on the Rural Communities of Malawi. Malawi Journal of Science and Technology. 10(1).

Finkelman, R.B., Palmer, C.A., Kolker, A., Mroczkowski, S.J. 1999. Quantifying the modes of occurrence of elementals in coal, Prospects for coal science in the 21st century. In: Bao, Q.L., Liu, Z.Y. (Eds.), Proceedings of the tenth international conference of coal sciences: Prospects for coal sciences in the 21st century. Shanxi Science and Technology Press, Tayiuan, China, pp. 21–24.

Gbadegesin, A.S., Olorunfemi, F.B. 2011 "Sustainable technological policy options for rural water supply management in selected rural areas of Oyo State, Nigeria", Management of Environmental Quality: An International Journal. 22(40): 486-501, doi: 10.1108/14777831111136081.

Gillies, M.E., Paulin, H.V. 1982. Estimations of daily mineral intakes from drinking water. Human nutrition: applied nutrition. 36: 287-292.

Lion, G.N., Olowoyo, J.O. 2012. Population health risk due to dietary intake of toxic heavy metals from *Spinacia oleracea* harvested from soils collected in and around Tshwane, South Africa. South African Journal of Botan. 88: 178–182.

Manyatsi, A.M., Tfwala, S.S. 2012. The Status of Domestic Water at Velezizweni, Swaziland, Department of Agricultural and Biosystems, Engineering, University of Swaziland, Current Research Journal of Social Sciences. 4(2): 128-134.

Msonda, K.W.M., Masamba, W.R.L., Fabiano, E. 2007. A study of fluorides groundwater occurrence in Nathenje, Lilongwe, Malawi. Physics and Chemistry of the Earth. 32: 1178-1184.

Nartey, V.K., Klake, R.K., Hayford, E.K., Doamekpor, L.K., Appoh, R.K. 2011. Assessment of

Mercury Pollution in Rivers and Streams around Artisanal Gold Mining Areas of the

Birim North District of Ghana. Journal of Environmental Protection. 2: 1227-1239.

Nienie, A.B., Periyasamy, S.B., Amandine, L.B., Patience, N.A., Jean-Paul, O.A., Alphonse M.A., Crispin, K., Mulaji, C., Josué, I., Mubedi, A., Pius, T., Mpiana, C., John, P. 2017. Seasonal variability of water quality by physicochemical indexes and traceable metals in suburban area in Kikwit, Democratic Republic of the Congo. International Soil and Water Conservation Research. 1- 8 DOI : 10.1016/j.iswcr.2017.04.004.

Nriagu, J. 2007. Zinc Toxicity in Humans. Elsevier Publication. 1-7.

Nyong, A., Kanaroglou, P.S. 2001. "A Survey of Household Domestic Water-Use Patterns in Rural Semi-Arid Nigeria," Journal of Arid Environments. 49 (2): 387-400. doi:10.1006/jare.2000.0736.

Olowoyo, J.O., Odiwe, A.L., Mkolo, N.M., Macheka, L. 2013. Investigating the concentration of different elements in soil and plant composition from mining area. Polish Journal of Environmental Studies. 22: 1135–1141.

Pritchard, M., Mkandawire, T., O'Neill, J.G. 2008. Assessment of groundwater quality in shallow wells within the Southern districts of Malawi. Physics and Chemistry of the Earth Journal. 33: 812–823.

Sallau, A., Mangs, A., Adamu, M., Lar, A.U. 2014. Assessment of potentially toxic metals in soil and sediments of the Keana Brinefield in the Middle Benue Trough, Northcentral Nigeria. American Journal of Environmental Protection. 3(6-2): 77-88 doi: 10.11648/j.ajep.s.2014030602.19.

Solomons, N.W. 1988. Zinc and copper. In: Shils ME, Young VR, eds. Modern nutrition in health and disease. Philadelphia, PA, Lea & Febiger.

Ubuoh, E.A. 2012. Susceptibility of Roofing Sheets to Atmospheric - Borne Corrosive Agents in Owerri, Nigeria‖. International People-ware Appliance for Gateway to Analytical Learning (Pakistan). 1: 1- 10.

Ubuoh, E.A. Obeta, M.C. and Eze, E.C. 2014. Perception of Sources, Accessibility and Consequences of Domestic Water Supply in Mbaitoli Local Government Area of Imo State, Nigeria. Advances in Life Science and Technology. 18: 2224-7181. www.iiste.org ISSN.

WHO. 2004. Xylenes in drinking-water. Background document for preparation of WHO

Guidelines for drinking-water quality. Geneva, World Health Organization (WHO/SDE/

WSH/03.04/25).

World Health Organization (WHO). 2011. Manganese in Drinking-water Background document for development of WHO Guidelines for Drinking-water Quality. World Health Organization. WHO/SDE/WSH/03.04/104/Rev/1.

www.dwa.gov.za/drought. 2017.

www.johannesburgwater.co.za/report/. 2016