Journal of Informatics and Mathematical Sciences
Vol. 9, No. 2, pp. 273–281, 2017
ISSN 0975-5748 (online); 0974-875X (print)
Published by RGN Publications
http://www.rgnpublications.com

Proceedings of
International Conference on Science and Sustainable Development (ICSSD)
"The Role of Science in Novel Research and Advances in Technology"
Center for Research, Innovation and Discovery, Covenant University, Nigeria
June 20-22, 2017

Research Article

Carcinogenic Risk of Arsenic (As) in Groundwater and Bottled Water Samples in Covenant University and Canaanland, Ota, Ogun State, Nigeria

Adewoyin Olusegun Oladotun*, Omeje Maxwell, Joel Emmanuel Sunday and Aborishade Ehimeje

Department of Physics, Covenant University, Ota, Ogun State, Nigeria
***Corresponding author:** olusegun.adewoyin@covenantuniversity.edu.ng

Abstract. This study was conducted in order to estimate the carcinogenic risk of heavy metals exposure via the consumption of groundwater and bottled water for the population of Covenant University and Canaanland, Ota, Ogun state using Perkin Elmer Optima 8000 ICP-OES. The chronic daily intake (CDI) in all the samples ranged from 0.005 and and $0.014 \mu g L^{-1} kg^{-1} d^{-1}$which was found to be negligible of potential risk on the inhabitants of different age groups. The carcinogenic Risk (R) for all the samples ranged between 0.01 and 0.025 $\mu g L^{-1} d^{-1}$. The R for all the age groups was found to be less than the acceptable level of EPA. The highest carcinogenic risk in Arsenic was found in children, which could be attributed to their lower body weight. However, all the values measured were observed to be below the recommended level by USEPA and WHO respectively.

Keywords. Canaanland; Carciniogenic; Covenant; Optima; USEPA; Perkin

MSC. 97M60

Received: June 19, 2017 **Revised:** July 10, 2017 **Accepted:** July 25, 2017

1. Introduction

Groundwater is the major source of drinking water for over half of the global population ([4], [10]) and is generally considered to have better water quality than surface water. The quality of groundwater is being compromised by the presence of contaminants, thereby making it one of the problems confronting the public health in different parts of the world in recent time. One of such trace and toxic elements present in the subsurface that is capable of affecting the quality of groundwater is Arsenic ([17], [6], [5], [3]). It has been identified that exposure to arsenic through drinking water over a long period of time is the cause of multiple adverse health effects including diabetes; peripheral neuropathy; cardiovascular diseases; and skin, lung, bladder and kidney cancers ([19], [26]). The occurrence of arsenic in drinking water has been reported in 105 countries with impact on 226 million people all over the world ([4], [11]). Although arsenic is abundant in both the solid and aqueous environment, its presence within groundwater is receiving much attention as groundwater represents a major drinking water resource because the geology, hydrogeology and geochemistry of the aquifer system remain important controls of arsenic speciation and mobility within the solid-aqueous environment [11].

The interaction of chemical, biochemical, water and other geological materials introduces different inorganic materials into the groundwater system [10]. Arsenic is introduced in groundwater mainly through oxidative weathering and geochemical reactions. Other sources may include improper disposal of glass, metal, semiconductor, mining and pesticides which can percolate into the subsurface and affect groundwater. Literature revealed that several approaches have been engaged to remove arsenic from contaminated water but each of these methods suffered from one disadvantage or another [12]. Several studies have been conducted to determine the extent and severity of groundwater Arsenic contamination in different parts of the world most of which focus on health. Rahman et al. [17] conducted a study to determine the status of arsenic contamination in groundwater in Nadia part of India. The health effect of arsenic in groundwater of Patna area of India was studied by Chakrabaorti et al. [5]. Bondu [3] reported the occurrence of high arsenic concentrations in groundwater collected from a fractured crystalline bedrock aquifer in western Quebec (Canada). McGrory et al. [11] did a spatial analysis on the occurrence and the possible risk of drinking arsenic contaminated water in Ireland. Kumar et al. [10] was able to assess trace element contamination and its health hazard in groundwater by the use of multivariate statistical technique. The present study is conducted with the sole aim of determining the extent and severity of exposure to groundwater arsenic contamination to the inhabitants of Canaanland and Covenant University in Ogun state Nigeria, who largely depend on groundwater as a source of drinking and other domestic purposes.

2. Geology and Geographical Location of the Study Area

Covenant University and Canaanland are both in Ogun State, which falls within the Eastern Dahomey (Benin) Basin of south-western Nigerian that stretches along the continental margin of the Gulf of Guinea. Rocks in the Dahomey basin are Late Cretaceous to Early Tertiary in age ([9], [15], [2], [14]). The stratigraphy of the basin has been classified into Abeokuta Group, Imo Group, Oshoshun, Ilaro and Benin Formations. The Cretaceous Abeokuta Group consists of Ise, Afowo and Araromi Formations consisting of poorly sorted ferruginized grit, siltstone and mudstone with shale-clay layers.

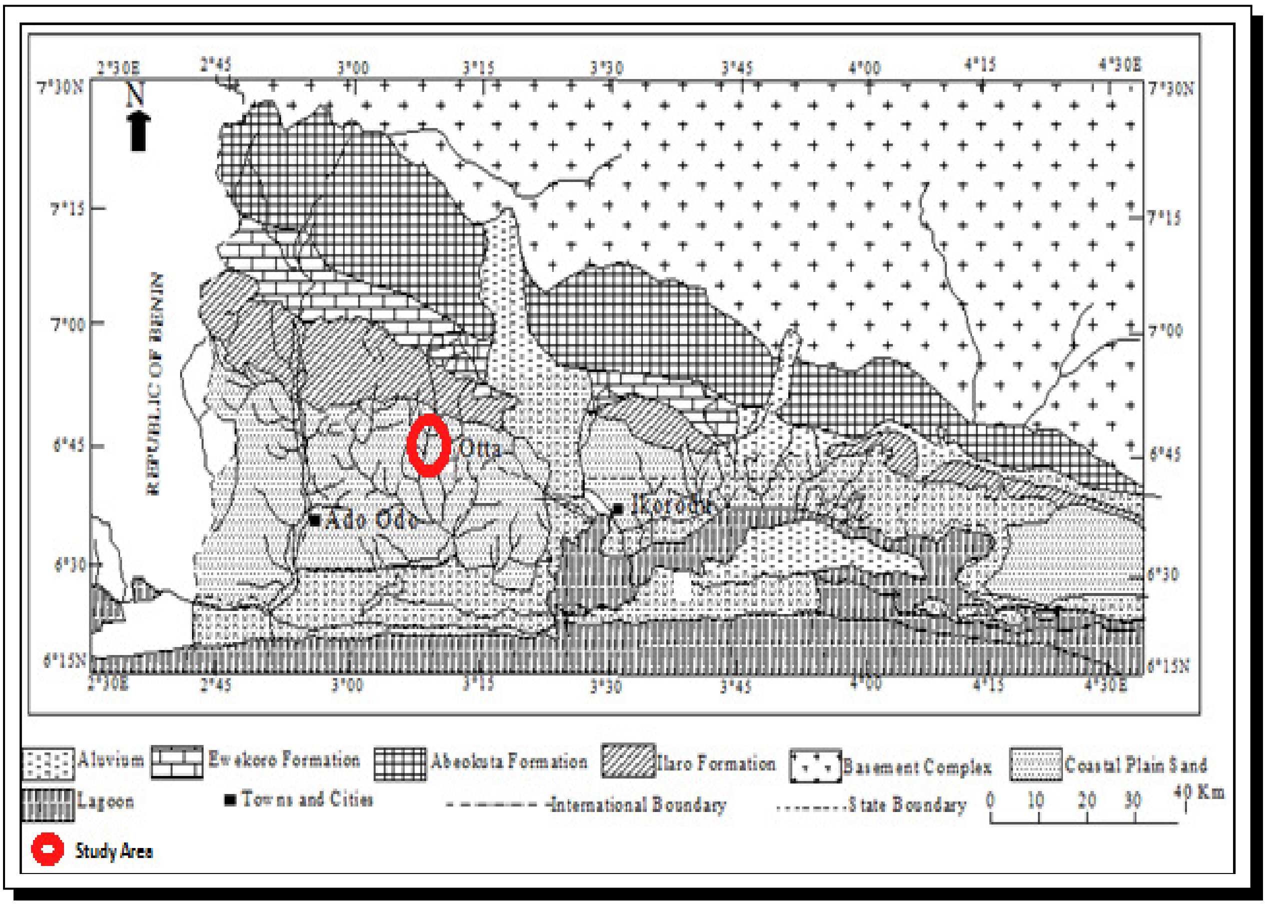

Figure 1. Geologic map of Ogun state showing the location of the study area

3. Methodology

3.1 Sampling and Sample Preparation

Five different samples of water (3 groundwater and 2 bottled water) that are used for drinking and domestic purposes in both Covenant University and Canaanland were collected for assessment in this study. The distance between the three boreholes varied between 150 to 250 m as a result of the locations of functional boreholes within the area of study. The pH of each water sample was measured at the point of collection with the aid of CONSORT C931 instrument. The water samples were filtered before they were collected in very clean plastic bottles that had been pre-washed with 20% nitric acid (HNO_3) and double distilled water. A few drops of nitric acid (HNO_3) were then added and the samples were stored in the refrigerator at 4-6°C before they were transported by a vehicle to the laboratory for analysis [7]. The samples were labeled A, B, C, D and E for easy identification, samples A, B and C are groundwater samples collected around the study area while samples D and E are bottled water samples very dominant in the area of study.

3.2 Sample Analysis for Heavy Metal Concentration

All filtered and acidified water samples were analyzed for heavy metals by using Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-OES) under standard operating conditions. In view of data quality assurance, each sample was analyzed in triplicate and after every 10 samples two standard; one blank and another of 2.5µg/L of respective metal were analyzed on atomic adsorption. The reproducibility was found to be at 95% confidence level. Therefore, the average value of each water samples was used for further interpretations. Standard solutions of all eight elements were prepared by dilution of 1000mg/L certified standard solutions from the manufacturer for corresponding metal ions with double distilled water. All the acids and reagents used were of analytical grade. All these analyses were performed in the International Institute for Tropical Agriculture (IITA) Laboratory in Nigeria.

3.3 Health Risk Assessment

Chronic daily intake (CDI) is an indices for measuring the various channels through which heavy metals enter into human body. This can be through several pathways such as through food chain, dermal contact and inhalation. These other channels of exposure are very negligible when compared to oral intake ATSDR [1]. The CDI through water ingestion was calculated using (3.1) according to the modified equation from USEPA [21], and Chrostowski [8].

$$\mathrm{CDI} = \frac{\mathrm{C} \times \mathrm{DI}}{\mathrm{BW}}, \tag{3.1}$$

where, C, DI and BW represent the concentration of heavy metals in water (μg/L), average daily inake rate (2L/day) and body weight (72 kg), respectively (Muhammad [13]). The carcinogenic risk (R) of heavy metal ingestion due to drinking water during lifetime was calculated according to Patrick [16] using (3.2).

$$\mathrm{R} = \mathrm{CDI} \times \mathrm{SF}. \tag{3.2}$$

In (3.2), CDI is the Chronic Daily Intake (mg/kg^{-1}d^{-1}), and SF is the safety factor of contaminants slope for Arsenic, which is 1.75 μgkg^{-1}d^{-1} according to USEPA [22]. The acceptable level of R according to EPA and WHO is respectively less than 1E-6 (One cancer in 1000000 people) and less than 1E-4 (One cancer in 10000 people) (USEPA [22], WHO [24]).

4. Results and Discussion

4.1 Concentrations of Arsenic (As) in the Water Samples from the Study Area

From Table 3.1, the concentration of Arsenic (As) varied from 0.14 to 0.18 μgL^{-1} with the highest value of 0.18 μgL^{-1} noted in sample A where the lowest value of 0.14 μgL^{-1} was observed in sample E. The concentration measured in samples C and D were observed to be equal (Table 1), which could be as a result of the similarity in the geological composition of the water bearing formations of the two boreholes. In another case, sample C could be the borehole source for sample D. Michael and Klen [12] reported the relationship between cardiovascular mortality and Arsenic exposure in 30 US counties where the average As concentration in drinking water was > 5 μgL^{-1}. Comparing this present study with other studies according to the relationship between exposure and internal cancer risks in Finland with concentration of < 0.1 μgL^{-1}, with risk of bladder cancer, in Chile with concentrations varying from 0-10 μgL^{-1} with the risk of lung cancer; in Nijata, Japan, the concentration of 0.5 μgL^{-1}Arsenic was noted in drinking water, varying from 0.05 μgL^{-1}-0.99 μgL^{-1} with risk exposure of bladder cancer, the present study with concentration of 0.18 μgL^{-1} and varying from 0.14-0.18 μgL^{-1} is within the range of bladder cancer exposure to the consumers.

Table 1. Concentration of Arsenic in water samples

s/n	Sample ID	Concentration of Arsenic (μgL^{-1})
1	A	0.18
2	B	0.15
3	C	0.16
4	D	0.16
5	E	0.14

The result of the samples collected in the study area was compared with the recommended standards by USEPA [23], and WHO [25] and National Drinking Water Quality Standards (NDQWS). It was observed that the concentration of Arsenic in the samples tested was much less than the international recommended standards (Figure 2).

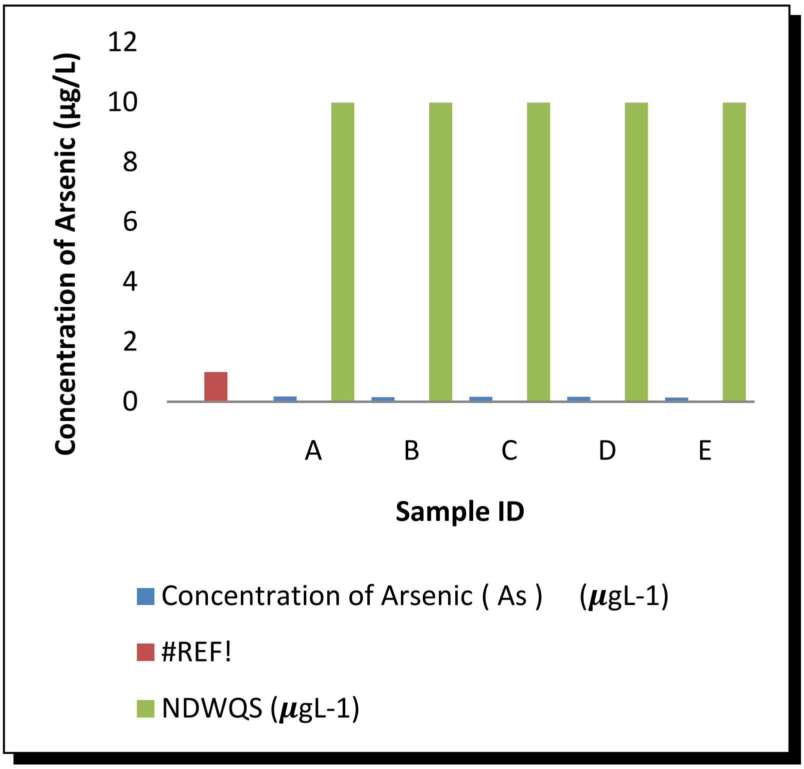

Figure 2. Comparison of arsenic concentrations in water samples in the study area with recommended standards (USEPA (1989) [23]; WHO (2006) [25]) and national drinking water quality standard (NDWQS)

4.2 Chronic Daily Intake (CDI) of Arsenic (As) in Water Samples from the Study Area

The Chronic Daily Intake (CDI) was calculated for both adults and children that depend on these water sources for consumption using (3.2) in accordance with Chandra et al. [7], and USEPA [22]. In this equation, CDI is Chronic Daily Intake (mg/kg-d), C is the concentration of Arsenic in drinking water (μgL^{-1}), DI is the mean daily intake of water (Ld^{-1}), and BW is the body weight (kg) Muhammad et al. [13] and Roychowdhury [18]. Due to lack of existing data for DI and BW of Population in Nigeria, the data suggested by WHO and EPA was used. Hence, DI for adult men was taken to be (17-45.5 years old), adult women (17-45.5 years old) and children (4-14 years old) are 2.723, 2.129, 1.8 L, respectively. The body weight (BW) for adult men, adult women and children are 76, 64 and 22.3 kg according to USESPA [20] and WHO [25], respectively.

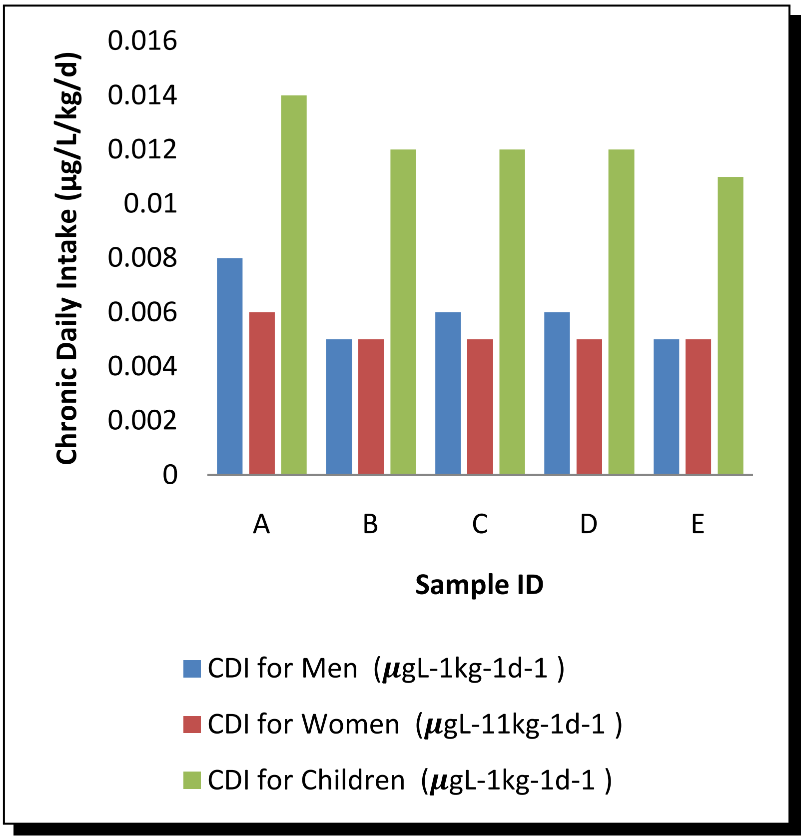

Figure 3. Comparison of Chronic Daily Intake in the samples across various age groups

Figure 3 showed the chronic daily of water intake for different age groups (men, women and children) in the study area. For men, CDI ranged between 0.005 to 0.008 $\mu gL^{-1}kg^{-1}d^{-1}$ with the highest value of 0.008$\mu gL^{-1}kg^{-1}d^{-1}$ noted in sample A whereas lower value of 0.005$\mu gL^{-1}kg^{-1}d^{-1}$reported in samples B and E respectively. For women, CDI ranged between 0.005 to 0.006 $gL^{-1}kg^{-1}d^{-1}$ with the sample A reporting highest than other samples with the same value of 0.005 $\mu gL^{-1}kg^{-1}d^{-1}$. In the same way, the CDI for children varied from 0.012 to 0.014 $\mu gL^{-1}kg^{-1}d^{-1}$with the lowest value of 0.012 $\mu gL^{-1}kg^{-1}d^{-1}$reported in samples B, D and E water respectively whereas the highest value of 0.014 $\mu gL^{-1}kg^{-1}d^{-1}$ was also noticed in sample A. Chronic exposure to arsenic causes dermal effects such as melanosis, leucomelanosis, keratosis, Bowen's disease, and cancer. The levels found in all the samples were significant but higher exposure was noted in children's daily intake.

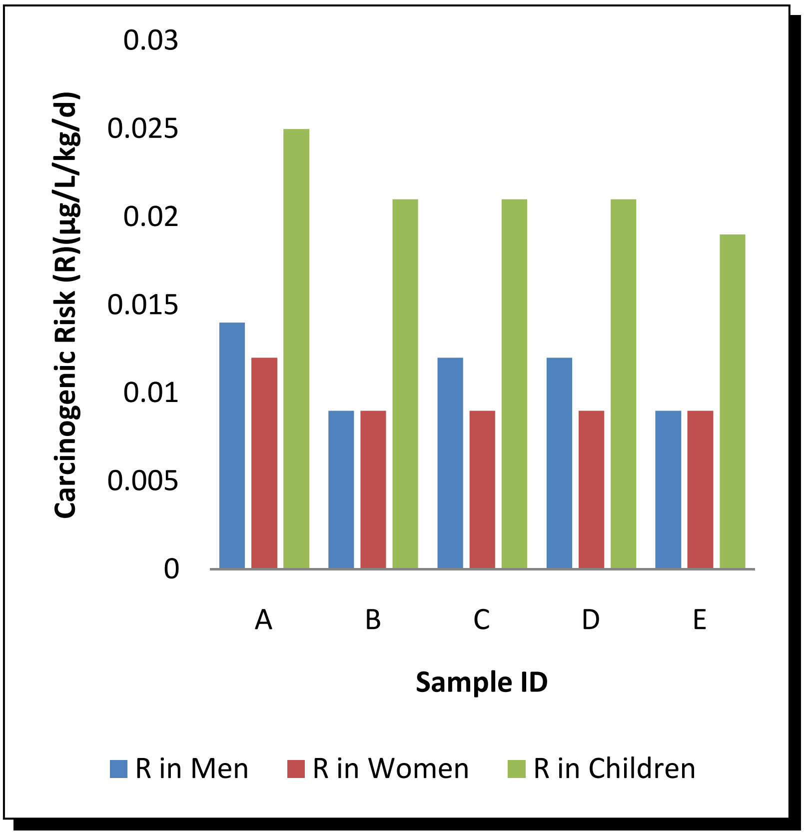

Figure 4. Comparison of the Carcinogenic Risk (R) of exposure to Arsenic of each sample with the Age groups

The result showed in Figure 4 revealed that carcinogenic risk as a result of exposure to Arsenic is higher in children than the other age groups, which makes them prone to risks. The reason for the higher risk in children could simply be attributed to their smaller body weights, which subjects them to the risk of this metal. This explains why children are the most affected in the case of outbreaks of diseases.

5. Conclusion

The measure of Arsenic exposure in groundwater and bottled water samples consumed to the inhabitants of Covenant University and Canaanland was estimated using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). The concentration of Arsenic was highest in sample A and lowest in sample E with values of 0.18 and 0.14 μg/L, respectively. The chronic daily intake (CDI) and carcinogenic risk (R) were estimated for all the water samples across different age groups. The highest values of chronic daily intake and carcinogenic risk was found in children consuming water sample A. The values observed were 0.014 and 0.025 $\mu gL^{-1}kg^{-1}d^{-1}$ for both CDI and R respectively.

Acknowledgements

The authors wish to appreciate the management of Covenant University for providing financial support for this project.

Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

All the authors contributed significantly in writing this article. The authors read and approved the final manuscript.

References

[1] ATSDR, Toxicological profile for di-(2-ethylhexyl) phthalate (Update), TP-92/05, US Dept Health and Human Services, Agency for Toxic Substances and Disease Registry, Atlanta, GA, 147 (1993).

[2] H.G. Billman, Offshore stratigraphy and Paleontology of Dahomey (Benin) Embayment, 1992.

[3] R. Bondu, V. Cloutier, E. Rosa and M. Benzaazoua, Mobility and speciation of geogenic arsenic in bedrock groundwater from the Canadian shield in western Quebec, Canada, *Science of the Total Environment* **574** (2017), 509 – 519, `https://www.ncbi.nlm.nih.gov/pubmed/27648529`.

[4] A. Bretzler and C.A. Johnson, The geogenic contamination handbook: addressing arsenic and fluoride in drinking water, *Applied Geochemistry* **63** (2015), 642 – 646.

[5] D. Chakrabortia, M.M. Rahmanb, S. Ahameda, R.N. Duttac, S. Patid and S.C. Mukherjeee, Arsenic groundwater contamination and its health effects in Patna district (Captiral of Bihar) in the middle Ganga plain, India, *Chemosphere* **152** (2016), 520 – 529, `https://www.sciencedirect.com/science/article/pii/S0045653516302922`.

[6] D. Chakraborti, M.M. Rahman, A. Mukherjeea, M. Alauddin, M. Hassan, R.N. Dutta, S. Pati, S.C. Mukherjee, S. Roy, Q. Quamruzzman, M. Rahman, S. Morshed, T.I.S. Sorif, Md. Selim, Md. R. Islam and Md. M. Hossaini, Groundwater arsenic contamination in Bangladesh-21 tears of research, *Journal of Trace Elements in Medicine and Biology* **31** (2015), 237 – 248.

[7] S. Chandra, S. Ahmed, E. Nagaiah, S.K. Singh and P.C. Chandra, Geophysical exploration for lithological control of arsenic contamination in groundwater in middle Ganga plain, India, *Physics and Chemistry of the Earth* **36** (2011), 1358 – 1362.

[8] P. Chrostowski, Risk assessment and accepted regulatory cleanup levels, *Remediation Journal* **4** (1994), 383 – 398.

[9] H.A. Jones and R.D. Hockey, The geology of part of S.W. Nigeria, *Geol. Surv. Nigeria Bull.* **31** (1964), 87.

[10] M. Kumar, A.L. Ramanathan, R. Tripathi, S. Farswan, D. Kumar and P. Bhattacharya, A study of trace elements contamination using multivariate statistical techniques and health risk assessment in groundwater of Chhaprola industrial area, Gautam Buddha Nagar, Uttar Pradesh, India, *Chemosphere* **166** (2017), 135 – 145, `https://www.ncbi.nlm.nih.gov/pubmed/27693874`.

[11] E.R. McGrory, C. Brown, N. Bargary, N.H. Williams, A. Mannix, C. Zhang, T. Henry, E. Daly, S. Nicholas, B.M. Petrunic, M. Lee and L. Morrison, Arsenic contamination of drinking water in Ireland: a spatial analysis of occurrence and potential risk, *Science of the Total Environment* **579** (February 1, 2017), 1863 – 1875, doi:10.1016/j.scitotenv.2016.11.171.

[12] H.A. Michael and M.R. Klen, Impacts of physical and chemical aquifer heterogeneity on basin-scale solute transport: vulnerability of deep groundwater to arsenic contamination in Bangladesh, *Advances in Water Resources* **98** (2016), 147 – 158.

[13] S. Muhammad, M.T. Shah and S. Khan, Arsenic health risk assessment in drinking water and source apportionment using multivariate statistical techniques in Kohistan region, Northern Pakistan, *Food Chem. Toxicol.* **48** (2010), 2855 – 2864.

[14] S.O. Olabode, Siliciclastic slope deposits from the Cretaceous Abeokuta Group, Dahomey (Benin) Basin, southwestern Nigeria, *J. Africa. Earth Sci.* **46** (2006), 187 – 200.

[15] M.E. Omatsola and O.S. Adegoke, Tectonic evolution and Cretaceous stratigraphy of the Dahomey basin, *Nigeria Geology* **18** (1981), 130 – 137.

[16] L. Patrick, Toxic metals and antioxidants: part II the role of antioxidants in arsenic and cadmium toxicity (Toxic Metals Part II), Alternative Medicine Review 8 (2003), 106 – 128.

[17] M.M. Rahman, D. Mondal, B. Das, M.K. Sengupta, S. Ahamed, M.A. Hossain, A.C. Samal, K.C. Saha, S.C. Mukherjee, R.N. Dutta and D. Chakraborti, Status of groundwater arsenic contamination in all 17 blocks of Nadia district in the state of West Bengal, India: a 23-year study report, *Journal of Hydrology* **518** (2014), 363 – 372, doi:10.1016/j.jhydrol.2013.10.037.

[18] T. Roychowdlury, Groundwater arsenic contamination in one of the 107 arsenic-affected blocks in West Bengal, India: status, distribution, health effect and factors responsible for arsenic poisoning, *International Journal of Hygiene and Environmental Health* **213** (2010), 414 – 427.

[19] A. Shrivastara, A. Barla, S. Singh, S. Mandraha and S. Bose, Arsenic contamination in agricultural soils of Bengal deltaic region of West Bengal and its higher assimilation in monsoon rice, *Journal of Harzadous Materials* **324** (2017), 526 – 543.

[20] USEPA, National water quality inventory report to congress, accessed online on 10/07/2017, `https://www.epa.gov/waterdata/2004-national-water-quality-inventory-report-congress` (2004).

[21] USEPA, Plastic pellets in the aquatic environment: Sources and recommendations, EPA Oceans and Coastal Protection Division Report 842-B-92-010. Washington, DC (1992).

[22] USEPA, U.S. Environmental Protection Agency Nanotechnology White Paper – External Review Draft (2005).

[23] USEPA, U.S. Environmental Protection Agency, Ambient Water Criteria Document Addendum for Phthalate Esters, Final Draft, PB91-161653, Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH (1989).

[24] WHO, World Health Organization, Guidelines for drinking-water quality, 3rd edition (2004).

[25] WHO, World Health Organization, The world health report: Working together for health (2006).

[26] WHO, World Health Organization; Guidelines for drinking-water quality, 4th edition (2011).