

**Journal of Informatics and Mathematical Sciences**

Vol. 9, No. 2, pp. 423–436, 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

# Assessing the Life Average Daily Dose (Ladd) due to Heavy Metal Contents in Water Samples from Covenant University, Canaanland, Ota, South West Nigeria

Omeje Maxwell<sup>1</sup>, Olusegun O. Adewoyin<sup>1</sup>, Emmanuel S. Joel<sup>1</sup>, Andrew Uchegbu<sup>1</sup> and Emenike Chidozie Praise God<sup>2</sup><sup>1</sup>Department Physics, College of Science and Technology, Covenant University, Ota, Ogun State, Nigeria<sup>2</sup>Department of Civil Engineering, College of Engineering, Covenant University, Ota, Ogun State, Nigeria\*Corresponding author: [maxwell.omeje@covenantuniversity.edu.ng](mailto:maxwell.omeje@covenantuniversity.edu.ng)

**Abstract.** The consumption of water with elevated concentration of lead (Pb) can prevent Hemoglobin Synthesis (Anemia) and results in Kidney diseases. A cross sectional study was conducted in to estimate the risk of exposure to lead via groundwater and bottled water ingestion pathway for the population of Covenant University, Canaanland, Ota, Ogun Sate using Perkin Elmer Optima 8000 ICP-OES. The concentration of Pb, Cr, Cd and As varies from water sample to another with the highest value of  $7.07 \mu\text{gL}^{-1}$  was noted in borehole water sample (BH1) behind John Hall. Comparing the value with the International recommended level by USEPA and WHO respectively,  $7.07\text{gL}^{-1}$  is less than  $15\mu\text{gL}^{-1}$  and  $10 \mu\text{gL}^{-1}$ . The Life Average Daily Dose (LADD) estimated in this present study reported higher in BH1 for lead (Pb) and could pose health hazard if accumulated for a long time. This work suggest measures to employ quality water treatment plant to reduce the level of heavy metals in the selected water samples and also more research on radioisotopes in the same water samples.

**Keywords.** Groundwater; Bottled water; Heavy metals ICP-OES; Chronic daily intake and hazard

**MSC.** 92C40

**Received:** May 6, 2017

**Revised:** July 1, 2017

**Accepted:** July 26, 2017

Copyright © 2017 Omeje Maxwell, Olusegun O. Adewoyin, Emmanuel S. Joel, Andrew Uchegbu and Emenike Chidozie Praise God. *This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.*

## 1. Introduction

The presence of heavy metals such as lead in drinking water resources can be dangerous for human because of toxicity and biological accumulation. The consumption of water or food which contains lead in high concentration can lead to prevent from Hemoglobin Synthesis (Anemia) and Kidney diseases. The heavy metals are the elements with a special weight 4-5 times as much as water (Duruibe et al. [14]; Raikwar et al. [42]). These elements have biological accumulation, toxicity, and environmental sustainability properties (Pekey et al. [41]). In recent years, the presence of these metals such as Arsenic (As), Cadmium (Cd), Mercury (Hg), lead (Pb), Nickel (Ni), and Chromium (Cr) in drinking water have become an international environmental and health concern (Dogaru et al. [13]; Wang et al. [53]; Ghaderpouri et al. [18]). The entry of the heavy metals in water resources can be due to the natural processes such as wastewater municipal, industrial, and agricultural sewage (Demirak et al. [12]).

Assessing the exposure and health consequences of chemicals in drinking water is a challenge: exposures are typically at low concentrations, measurements in water are frequently insufficient, chemicals are present in mixtures, exposure periods are usually long, multiple exposure routes may be involved, and valid biomarkers reflecting the relevant exposure period are scarce. In addition, the magnitude of the relative risks tends to be small (Villanueva et al. [52]). Many studies have measured the heavy metals concentration in drinking water and compared it with standard value (Arab et al. [3]; Shotyk et al. [47]; Dabeka et al. [10]; Ikem et al. [24]). Also, in some studies, carcinogenic (R) and non-carcinogenic risk (HQ) of the heavy metals which are due to drinking water consumption, have been assessed (Wang at al. [53]; Jakus et al. [26]; Muhammad et al. [35]). Metals could exert effects that are beneficial or harmful to our human body (Caussy et al. [11]). Heavy metals are especially renowned for their toxicity effects towards human beings, aquatic life and the environment. Lead is one of the heavy metals which have no known physiologically relevant role in the body (White et al. [54]). Lead from environmental pollution is not carcinogenic, but even low dose lead exposure has been shown to have detrimental and long-lasting effects on the renal, hemopoietic and nervous system (Fertmann et al. [17]).

The main target for lead toxicity is the nervous system, both in adults and children (ATSDR [4]). It can create irreversible intellectual impairment in infants and young children, even at blood lead levels below 10 mg/dL (Lanphear et al. [30]; Gump et al. [20]; Jusko et al. [28]). The continuous in exposure results with the effect progresses with insomnia, confusion, impaired concentration, and memory problems (Robson [43]). In addition to exposure to lead in the air, ingestion of lead in drinking water has become one of the major sources of human exposures to lead (Matte et al. [33]). The presence of lead in drinking water is a public health problem due to their absorption and possible accumulation in organisms (Chiron et al. [8]).

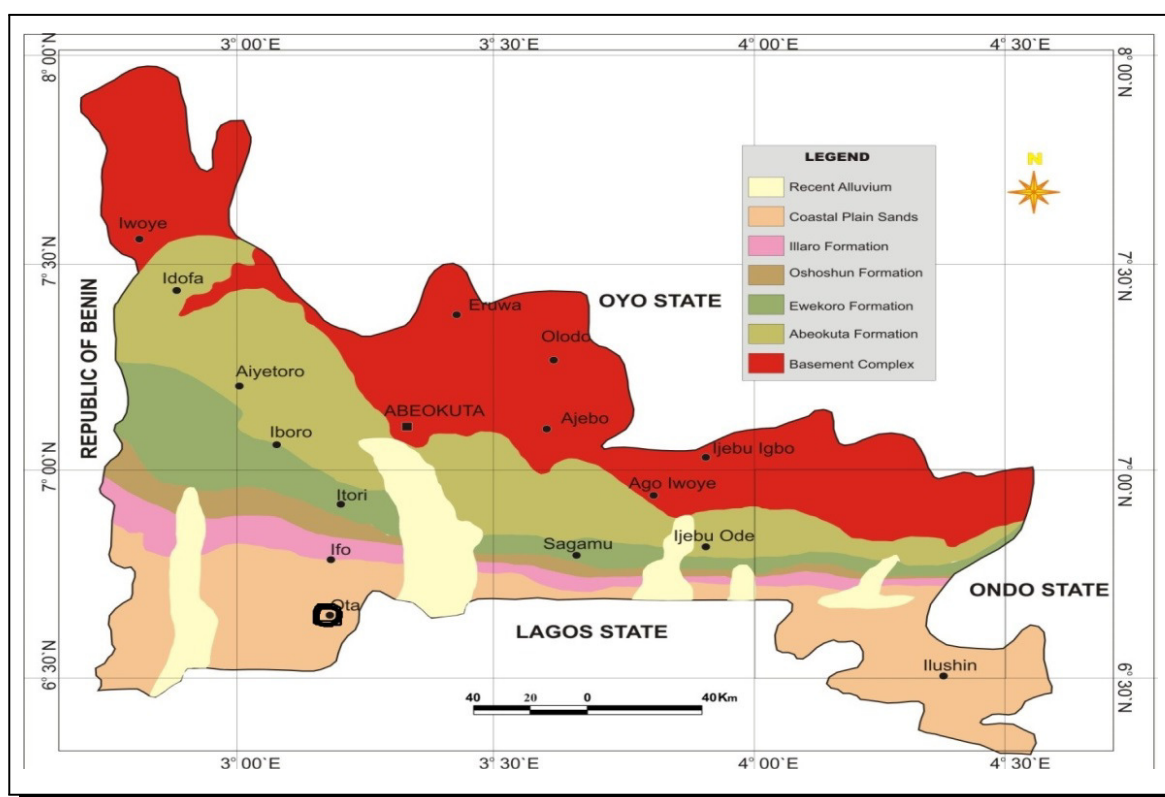
Studies to assess the LADD exposure of Pb, Cr, Cd and As contaminants in both groundwater and bottled water samples collected from Covenant University, Ota, Ogun State is needed for its potential health risks for age groups of adult men, adult women and children and to compare with the standard value because of sanitary importance of lead in drinking water.

## 2. Geology and Geographical Location of the Study Area

Covenant University is 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 (Jones et al. [27]; Omatsola et al. [39]; Bilman [5]; Olabode [38]). 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.

## 3. Sampling and Sample Preparation

Five different water samples (3 groundwater and 2 bottled water) used for consumption and domestic purposes in both Covenant University and Canaan Land were collected for this assessments. The pH was measured on the spot, by using a CONSORT C931 instrument. From each sampling point, the water samples were collected in cleaned plastic bottles pre-washed with 20% nitric acid ( $\text{HNO}_3$ ) and double distilled water. The water samples were filtered and a few drops of  $\text{HNO}_3$  were then added before sample transport to the laboratory. For ICP-AEO analysis, all the samples were stored in a refrigerator at 4-6°C in order to measure the heavy metals concentrations (Eaton et al. [15]).



**Figure 1.** Geologic map of Ogun state showing the location of the study area (circled in black) (Source: Nigerian Geological Survey Agency (2006))

### 3.1 Chemical Analysis for Heavy Metals

All filtered and acidified water samples were analyzed for heavy metals by using ICP-AEO 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 2.5  $\mu\text{g/L}$  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 1000 mg/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 Laboratory, Ibadan, Nigeria

Chemicals that display environmental and biological persistence, bioaccumulation, toxicity and long-range transport have been previously assessed quantitatively by national and international health agencies (Szabo et al. [46]). Among the databases that offer information on the toxicity of the compounds that can be found in water, two of the most widely used are the Risk Assessment Information System reference to the WHO guidelines (WHO [56]). RAIS uses the Reference Dose (RfD), expressed as an oral dose per kilogram of body weight (given in units of  $\text{mg Kg}^{-1} \text{ day}^{-1}$ ), as an estimate of the lowest daily human exposure that is likely to occur without appreciable risk of deleterious, non-cancerous effects during a lifetime. WHO proposes a very similar reference value called the Tolerable

Where  $D_i$  represents the dose of contaminant by water ingestion ( $\text{mgKg}^{-1} \text{ day}^{-1}$ ),  $C_w$  is the annual average concentration of the contaminant in water ( $\text{mg L}^{-1}$ ),  $EF$  is the exposure frequency to the contaminated media ( $\text{day year}^{-1}$ ),  $ED$  is the exposure duration (year),  $IR_w$  is the rate of water intake ( $\text{L day}^{-1}$ ),  $BW$  is the body weight of the receptor (Kg), and  $AT$  is the average lifetime of a person(year).

Table 1 shows the exposure values for the pathway of oral ingestion of water accordingly to RAIS and WHO for the calculation of doses. For systemic risk  $D_i$  is calculated by using  $AT = ED$ . Then three different indexes (systemic and carcinogenic for RAIS and an index for WHO) were calculated:

### 3.2 Chemical Toxicity Risk of Heavy Metals

The chemical toxicity was to determine the effect of the carcinogenic risks associated with chemical toxicity of Pb, Cr, Cd and As in the water sample selected for this study. The chemical toxicity risk was evaluated using the lifetime average daily dose of Pb, Cr, Cd and As through drinking water intake, and compared it with the reference dose (RFD) of  $0.6 \mu\text{g kg}^{-1} \text{ day}^{-1}$  (USEPA [50]) used as a standard criteria for Pb, Cr, Cd and As in several foreign organizations and thereby produce the lifetime average daily dose (LADD) (Equation (3))

$$\text{Ingestion LADD of drinking water} = \frac{EPC \times IR \times EF \times ED}{AT \times BW}, \quad (3.1)$$

where

$LADD$  = lifetime average daily dose ( $\mu\text{g kg}^{-1} \text{ day}^{-1}$ ),

$EPC$  = the exposure point concentration ( $\mu\text{g L}^{-1}$ ),

$IR$  = the water ingestion rate ( $\text{L day}^{-1}$ );  $EF$  = the exposure frequency ( $\text{days year}^{-1}$ ),

$ED$  = the total exposure duration (years),  $AT$  = the average time (days), and

$BW$  = the body weight (kg).

Using therefore,  $IR = 2 \text{ L day}^{-1}$ ,  $EF = 350 \text{ days}$ ,  $ED = 45.5 \text{ y}$ ,  $AT = 16,607.5$  (obtained from  $45.5 \times 365$ ) and  $BW = 70 \text{ kg}$  (for a standard man).

## 4. Results and Discussion

### 4.1 Concentration of Lead (Pb) in Water Samples from the Study Area

Table 1 presents the concentrations of Pb in different water samples. The concentrations of leading water samples varies from 2.84 to  $7.07 \mu\text{gL}^{-1}$ . The highest concentration of Pb was noted at BH2 water sample with a value of  $7.07 \mu\text{gL}^{-1}$  whereas the lowest value of  $2.84 \mu\text{gL}^{-1}$  reported in BK water sample. This higher concentration value found in BH2 water sample could be attributed to infiltration of surface sediments contaminants through the borehole due to the rainy Season. It could report when the subsurface formation is highly saturated within the study area. In all the water samples, the concentrations vary between 2.84 to  $7.07 \mu\text{gL}^{-1}$  respectively. Comparing the highest value of  $7.07 \mu\text{gL}^{-1}$  obtained from this present study with the International Reference Standard according to WHO [56] and USEPA [51] of  $15 \mu\text{gL}^{-1}$ , it can be observed that the value is far below by a factor of 2.15. More so, comparing with the National Drinking Water Quality Standard (NDWQS) for lead (Pb) concentration in water is given as  $10 \mu\text{gL}^{-1}$ , of which the values for this present study in all the water samples did not exceeded the acceptable values.

**Table 1.** Concentrations of Lead (Pb) in Groundwater and Bottled Water Samples in the Study Area, USEPA, WHO [56] and National Drinking Water Quality Standard (NDWQS)

Sample ID	Sample Location	Concentration of Lead Lead (Pb) ( $\mu\text{gL}^{-1}$ )	USEPA, WHO, ( $\mu\text{gL}^{-1}$ )	NDWQS ( $\mu\text{gL}^{-1}$ )
BH1	John Hall	7.07	15	10
BH2	New Estate	7.51	15	10
BH3	Canaan Land	6.47	15	10
HB	Hebron Water	4.42	15	10
BK	Baker Water	2.84	15	10

### 4.2 Concentration of Cadmium in the Selected Water Samples from the Study Area

Cadmium in selected water samples were measured to ascertain the level of exposure to the dwellers that rely on the water samples. The concentration varies from 0.117 to 0.145 g/L. The highest value reported in BK water sample with a value of  $0.145 \mu\text{g/L}$  whereas the lowest value of  $0.117 \mu\text{g/L}$  noted in BH1 water samples. There are variations in concentration levels in

the study area but noted that borehole samples were having less concentrations of cadmium. Comparing these values with the international reference values, it can be observed that the present study is lower as shown in Table 2.

**Table 2.** The Concentrations of Cadmium (Cd) in all the Selected Water Samples

Sample ID	Concentration (Cd) ( $\mu\text{gL}^{-1}$ )	USEPA,WHO, ( $\mu\text{gL}^{-1}$ )	NDWQS ( $\mu\text{gL}^{-1}$ )
BH1	0.117	15	10
BH2	0.114	15	10
BH3	0.131	15	10
HB	0.141	15	10
BK	0.145	15	10

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

From the table below, the concentration of As varies from 0.14 to 0.18  $\mu\text{gL}^{-1}$  with the highest value of 0.18  $\mu\text{gL}^{-1}$  noted in BH1 borehole where a lower value of 0.14  $\mu\text{gL}^{-1}$  reported in BK bottled water sample. Chronic As exposure may also cause reproductive, neurological, cardiovascular, respiratory, hepatic, hematological, and diabetic effects in humans (WHO [55]). Intake of inorganic As was recognized as a cause of skin, bladder, and lung cancer (WHO [55]; IARC [23]). A number of articles have been published on chronic As exposure and its associated health effects. Herein, the adverse health effects of As are reviewed. Engel and Smith [45] reported the relationship between cardiovascular mortality and As exposure in 30 US counties where the average As concentration in drinking water was  $> 5 \mu\text{gL}^{-1}$ . Comparing this present study with other studies according to the relationship between exposure and internal cancer risks in Finland with concentration of  $< 0.1 \mu\text{gL}^{-1}$ , with risk of bladder cancer, in Chile with concentrations varying from 0-10  $\mu\text{gL}^{-1}$  (Ferreccio et al. [16]) with the risk of lung cancer; in Nijata, Japan, the concentration of 0.5  $\mu\text{gL}^{-1}$  As was noted in drinking water, varying from 0.05  $\mu\text{gL}^{-1}$ -0.99  $\mu\text{gL}^{-1}$  with risk exposure of bladder cancer, the present study with concentration of 0.18  $\mu\text{gL}^{-1}$  and varying from 0.14-0.18  $\mu\text{gL}^{-1}$  is within range of bladder cancer exposure to the consumers. The results of the concentrations are presented in Table 3.

**Table 3.** Comparing the Arsenic Concentrations in Groundwater and Bottled Water Samples in the Study Area, USEPA, WHO [56] and National Drinking Water Quality Standard (NDWQS)

Sample ID	Concentration of Arsenic (As) ( $\mu\text{gL}^{-1}$ )	USEPA, WHO ( $\mu\text{gL}^{-1}$ )	NDWQS ( $\mu\text{gL}^{-1}$ )
BH1	0.18	15	10
BH2	0.15	15	10
BH3	0.16	15	10
HB	0.16	15	10
BK	0.14	15	10

#### 4.4 Concentration of Chromium (Cr) in Water Samples from the Study Area

Table 4 presents the concentration of chromium in some selected water samples in Covenant University and environs. The concentration of chromium values in the water samples selected ranged between  $0.03 \mu\text{gL}^{-1}$  and  $0.25 \mu\text{gL}^{-1}$  with highest concentration value of Cr of  $0.25 \mu\text{gL}^{-1}$  observed in BH1 and lowest value of  $0.03 \mu\text{gL}^{-1}$  in BH3. This higher concentration value observed in BH1 water sample could be related to infiltration of surface sediments contaminants such as chromium solders, brass fittings, fountains, and taps through the borehole as a result of rainy season by transporting these anthropogenic materials into the samples. It could report when the subsurface formation is highly saturated within the study area. In the entire water sample selected, the concentration varies from  $0.03 \mu\text{gL}^{-1}$  to  $0.25 \mu\text{gL}^{-1}$ . Comparing the highest value of  $0.25 \mu\text{gL}^{-1}$  obtained from this present study with the International Reference Standard according to WHO [55], WHO [56] of  $50 \mu\text{gL}^{-1}$  and National Drinking Water Quality Standard (NDWQS [36]) of value of  $50 \mu\text{gL}^{-1}$  respectively with this study, it was observed that the concentration of chromium level in the selected samples is within the permissible value.

**Table 4.** Concentrations of Chromium (Cr) in Groundwater and Bottled Water Samples in the Study Area, WHO [55], USEPA, WHO [56] and National Drinking Water Quality Standard (NDWQS [36])

Sample ID	Concentration of Chromium (Cr) ( $\mu\text{gL}^{-1}$ )	WHO [55] Standard	WHO [56] Standard	USEPA [49] Standard	NDWQS [36]
BH1	0.25	50	50	50	50
BH2	0.19	50	50	50	50
BH3	0.03	50	50	50	50
HB	0.20	50	50	50	50
BK	0.14	50	50	50	50

#### 4.5 Chemical Toxicity Risk of Pb, Cr, Cd and As in Water Samples from the Study Area

The chemical toxicity risk was to determine the effect of the carcinogenic risks associated with chemical toxicity of Pb in the water sample selected for this study. The chemical toxicity risk was evaluated using the lifetime average daily dose of Pb through drinking water intake, and compared it with the reference dose (RFD) of  $0.6 \mu\text{g kg}^{-1} \text{ day}^{-1}$  (Ye-Sin et al. [57]; USEPA [50]) used as a standard criteria for Pb in several foreign organizations and thereby produce the lifetime average daily dose (LADD) (Equation (4.1))

$$\text{Ingestion } LADD \text{ of drinking water} = \frac{EPC \times IR \times EF \times ED}{AT \times BW} \quad (4.1)$$

Where,  $LADD$  is lifetime average daily dose ( $\mu\text{g kg}^{-1} \text{ day}^{-1}$ ),  $EPC$  is the exposure point concentration ( $\mu\text{g L}^{-1}$ ),  $IR$  is the water ingestion rate ( $\text{L day}^{-1}$ );  $EF$  is the exposure frequency ( $\text{days year}^{-1}$ ),  $ED$  is the total exposure duration (years),  $AT$  is the average time (days) and  $BW$  is the body weight (kg). Using therefore,  $IR = 2 \text{ L day}^{-1}$ ,  $EF = 350 \text{ days}$ ,  $ED = 45.5 \text{ y}$ ,  $AT = 16,607.5$  (obtained from  $45.5 \times 365$ ) and  $BW = 76 \text{ kg}$  (for a standard man). The chemical toxicity risk for Pb over lifetime consumption was estimated and presented in Table 5.

In Table 8, the exposure dose of Pb in all the water samples ranged from 0.10 to 0.26  $\mu\text{g kg}^{-1} \text{day}^{-1}$  for men whereas value of 0.09 to 0.24  $\mu\text{g kg}^{-1} \text{day}^{-1}$  were found in the same BH2 water sample. The highest values of LADDs of 0.26 and 0.24  $\mu\text{g kg}^{-1} \text{day}^{-1}$  reported in BH2 for both adult men and women respectively. These values that were distinctly higher in this same borehole water sample for all the assessments could be due to the upward migration of ultrabasic minerals derived from magmatic and metamorphic processes of intrusive materials in groundwater bearing formation. Comparing the LADD obtained in this study and the RFD (0.6  $\mu\text{g kg}^{-1} \text{day}^{-1}$ ) that is an acceptable level, the chemical toxicity risk due to Pb in the water samples were all below the RFD. It indicates that there may not be health risks associated with Pb in the water samples which are mainly due to the chemical toxicity risk of Pb.

**Table 5.** The lifetime average daily dose (LADD) of Lead (Pb) in the water samples

Sample ID	LADD ( $\mu\text{g kg}^{-1} \text{day}^{-1}$ ) for lead	Reference Dose Level ( $\mu\text{g kg}^{-1} \text{day}^{-1}$ ) (Ye-Shin et al. [57])
BH1	0.24	0.6
BH2	0.26	0.6
BH3	0.22	0.6
HB	0.15	0.6
BK	0.10	0.6

#### 4.6 Chemical Toxicity Risk of Chromium (Cr) in Water Samples from the Study Area

The chemical toxicity risk was to determine the effect of the carcinogenic risks associated with chemical toxicity of Cr in the water sample selected for this study. The chemical toxicity risk was evaluated using the lifetime average daily dose of Cr through drinking water intake, and compared it with the reference dose (RFD) of 0.6  $\mu\text{g kg}^{-1} \text{day}^{-1}$  (Ye-Sin et al. [57]; USEPA [50]) using Equation (4.1).

In Table 7, the exposure dose of Cr in all the water samples ranged from 0.00075 to 0.0063  $\mu\text{g kg}^{-1} \text{day}^{-1}$  with the highest value found in BH1 water sample. Comparing the LADD obtained in this study and the RFD (0.6  $\mu\text{g kg}^{-1} \text{day}^{-1}$ ) that is an acceptable level, the chemical toxicity risk due to Cr in the water samples distinctly lower than the RFD. It indicates that there may not be health risks associated with Cr in the water samples which are mainly due to the chemical toxicity risk of Cr. The results are presented in Table 6.

**Table 6.** The lifetime average daily dose (LADD) of chromium in the water samples

Sample ID	LADD ( $\mu\text{g kg}^{-1} \text{day}^{-1}$ ) for chromium	Reference Dose Level ( $\mu\text{g kg}^{-1} \text{day}^{-1}$ ) (Ye-shin et al. [57])
BH1	0.0063	0.6
BH2	0.0047	0.6
BH3	0.00075	0.6
HB	0.00504	0.6
BK	0.0035	0.6



#### 4.7 Chemical Toxicity Risk of Arsenic (As) in Water Samples from the Study Area

In Table 7, the exposure dose of As in all the water samples ranged from 0.00403 to 0.0045  $\mu\text{g kg}^{-1} \text{ day}^{-1}$  with the highest value found in BH1 water sample. Comparing the LADD obtained in this study and the RFD (0.6  $\mu\text{g kg}^{-1} \text{ day}^{-1}$ ) that is an acceptable level, the chemical toxicity risk due to As in the water samples is below the RFD. It indicates that there may not be health risks associated with As in the water samples which are mainly due to the chemical toxicity risk of As.

**Table 7.** The lifetime average daily dose (LADD) of Arsenic (As) in the water samples

Sample ID	LADD ( $\mu\text{g kg}^{-1} \text{ day}^{-1}$ ) for Arsenic	Reference Dose Level ( $\mu\text{g kg}^{-1} \text{ day}^{-1}$ ) (Ye-Shin et al. [57])
BH1	0.0045	0.6
BH2	0.0037	0.6
BH3	0.00403	0.6
HB	0.00403	0.6
BK	0.0035	0.6

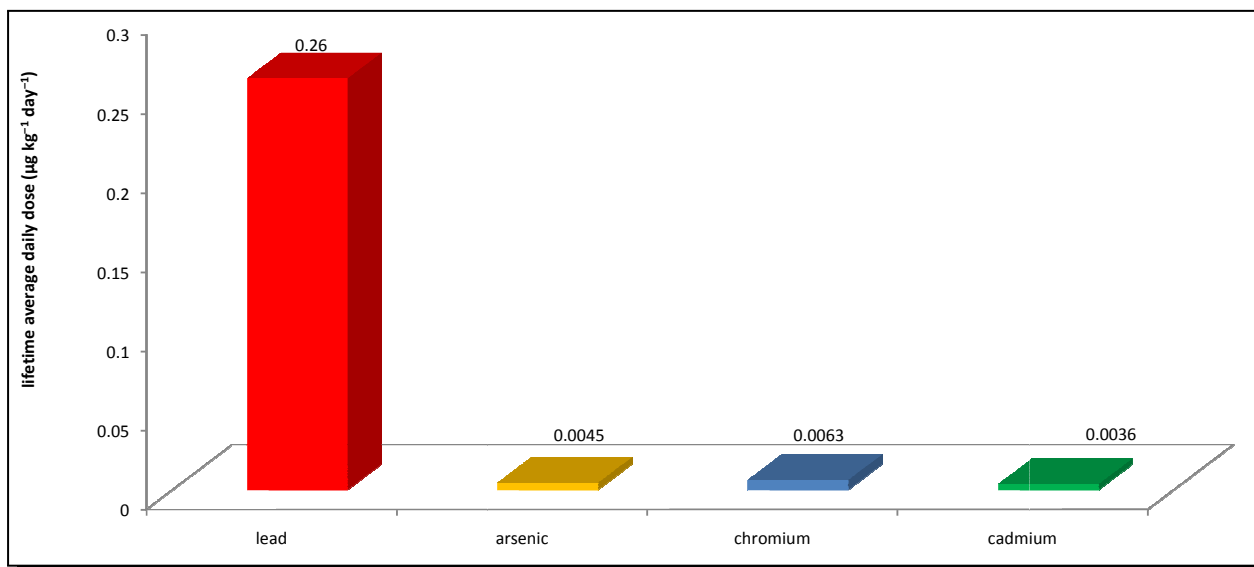
#### 4.8 Chemical Toxicity Risk of Cadmium (Cd) in Water Samples from the Study Area

In Table 8, the exposure dose of Cd in all the water samples ranged from 0.0028 to 0.0036  $\mu\text{g kg}^{-1} \text{ day}^{-1}$  with the highest value found in BK water sample. Comparing the LADD obtained in this study and the RFD (0.6  $\mu\text{g kg}^{-1} \text{ day}^{-1}$ ) that is an acceptable level, the chemical toxicity risk due to Cd in the water samples was far below the RFD. It indicates that there may not be health risks associated with Cd in the water samples which are mainly due to the chemical toxicity risk of Cd.

**Table 8.** The lifetime average daily dose (LADD) of Cadmium (Cd) in the water samples

Sample ID	LADD ( $\mu\text{g kg}^{-1} \text{ day}^{-1}$ ) for Cadmium	Reference Dose Level ( $\mu\text{g kg}^{-1} \text{ day}^{-1}$ ) (Ye-Shin et al. [57])
BH1	0.0029	0.6
BH2	0.0028	0.6
BH3	0.0033	0.6
HB	0.0035	0.6
BK	0.0036	0.6

In Figure 2, it presents the life average daily dose obtained from the borehole water sample one (BH1) and sample two (BH2) collected from John Hall and New Estate as well as water sample three (BH3) from Canaanland. Two bottled water samples labeled HB from Canaanland and BK from Bake water were compared too as well as the borehole water samples. It can be noted that the highest value of LADD for lead reported higher in BH1 than other heavy metals analyzed for this study as presented in Figure 2. It can be observed that all the values in Figure 2 are less than 0.6  $\mu\text{g kg}^{-1} \text{ day}^{-1}$  recommended as the safe level by USEPA [49].



**Figure 2.** Plot of life average daily dose ( $\mu\text{g kg}^{-1} \text{ day}^{-1}$ ) against lead, arsenic, cadmium and chromium in the Water Samples

## 5. Conclusion

The concentrations of Pb, Cr, Cd and As in selected groundwater and bottled water samples in the study area are less than the standard reported values by WHO [56] and USEPA [49] of  $15 \mu\text{gL}^{-1}$  as well as  $10 \mu\text{gL}^{-1}$  when compared with the National Drinking Water Quality Standard (NDWQS). The LADD revealed that Lead in BH1 could pose health risk considering long term accumulation; though lower than the Reference Dose Level. This research calls for further impact assessment of risk due to radioisotopes in water samples to justify the effect of human health risk either from heavy metals or radioisotopes on the inhabitants of the study area.

## Acknowledgement

The authors appreciate Covenant University for partial sponsorship.

## 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] S.O. Adegoke, T.F.J. Dessauvage and A.J. Whiteman, *Macrofauna of Ewekoro Formation (Paleocene) of Southwest Nigeria*, African Geology, University of Ibadan, 269 – 276 (1970).

- [2] American Academy of Pediatrics, Hospital discharge of the high-risk neonate, *Pediatrics* **102** (2) (1987), 411 – 417.
- [3] S. Arab and A. Alshikh, Estimating of some trace elements in mineral water in the Kingdom of Saudi Arabia, *Life Science Journal* **60** (7) (2010), 301 – 345.
- [4] ATSDR (2005), *CDC Issues Recommendations for Lead Poisoning Prevention in Newly Arrived Refugee Children*, Atlanta: Media Relations.
- [5] H.G. Billman, Offshore stratigraphy and paleontology of dahomey (Benin) embayment, *NAPE Bulletin* **70** (2) (1992), 121 – 130.
- [6] I. Borneff, Carcinogenic substances in water and soil, XXII, Mouse drinking study with 3,4-benzpyrene and potassium chromate, *Archivfür Hygiene* **152** (68) (1968), 45 – 53 (in German).
- [7] Canfield, Intellectual impairment in children with blood lead concentration below 10 microg per deciliter, *National Institute of Health* **5** (2003).
- [8] N. Chiron, R. Guilet and E. Deydier, Adsorption of cu(II) and pb(II) onto a grafted silica: Isotherms and kinetic models, *Water Research* **37** (13) (2003), 3079 – 3086, [http://dx.doi.org/10.1016/S0043-1354\(03\)00156-8](http://dx.doi.org/10.1016/S0043-1354(03)00156-8).
- [9] Colorado Department of Health (1990), Colorado case on jurisdiction over hazardous waste cleanup, *Radiation Control Division*, 283.
- [10] R. Dabeka, H. Conacher, J. Lawrence, W. Newsome, A. McKenzie, H. Wagner and K. Pepper, Survey of bottled drinking waters sold in Canada for chlorate, bromide, bromate, lead, cadmium and other trace elements, *Food Additives & Contaminants* **19** (2002), 721 – 732, <http://dx.doi.org/10.1080/02652030210140905>.
- [11] D. Caussy, Lessons from case studies of metals:investigating exposure bioavailability, and risk, *Ecotoxicology and Environmental Safety* **47** (2) (2003), 45 – 51.
- [12] A. Demirak, F. Yilmaz, A. Levent Tuna and N. Ozdemir, Heavy metals in water, sediment and tissues of *Leuciscuscephalus* from a stream in south western Turkey, *Chemosphere* **63** (2006), 1451 – 1458, <http://dx.doi.org/10.1016/j.chemosphere.2005.09.033>.
- [13] D. Dogaru, J. Zobrist, D. Balteanu, C. Popescu, M. Sima, M. Amini and H. Yang, Community perception of water quality in a mining-affected area: A case study for the Certej catchment in the Apuseni Mountains in Romania, *Environmental Management* **43** (2009), 1131 – 1145, <http://dx.doi.org/10.1007/s00267-008-9245-9>.
- [14] J. Duruibe, M. Ogwuegbu and J. Ekwurugwu, Heavy metal pollution and human biotoxic effects, *International Journal of Physical Sciences* **60** (2) (2007), 112 – 118.
- [15] A.D. Eaton, *Standard Methods for the Examination of Water and Waste Water*, 21st edn., American Public Health Association, Washington, ISBN 0875530478. pp. 343-453 (2005).
- [16] P.A. Feriance and T. Farewell Nystrom, The cadmium-stress stimulon of *Escherichia coli* K-12, *Microbiol.* **144** (1989), 1045–1050.
- [17] R. Fertmann, S. Hentschel, D. Dengler, U. Janßen and A. Lommel, Lead exposure by drinking water: An epidemiological study in Hamburg, Germany, *International Journal of Hygiene and Environmental Health* **207** (3) (2004), 235 – 244, <http://dx.doi.org/10.1078/1438-4639-00285>.
- [18] M. Ghaderpoor, G. Jahed and S. Nazmara, Determination of toxic trace element in bottled waters consumption in the Tehran, *Twelfth Environmental Health Engineering Congress* (2009), Tehran, Iran.

- [19] EPA Guidelines for exposure assessment, *Risk Assessment Forum, U.S. Environmental Protection Agency*, Washington, DC, EPA/600/Z-92/001, (1992).
- [20] B.B. Gump, P. Stewart, J. Reihman, E. Lonky, T. Darvill, P.J. Parsons et al., Low-level prenatal and postnatal blood lead exposure and adrenocortical responses to acute stress in children, *Environmental Health Perspectives* **116** (2) (2008), 249 – 255, <http://dx.doi.org/10.1289/ehp.10391>.
- [21] W.S. Hammond, Clinical data base management system, *Springer* **53** (7) (1882), 103.
- [22] M.Z. Hashmi, C. Yu, H. Shen, D. Duan, C. Shen, L. Lou and Y. Chen, *Risk Assessment of Heavy Metals Pollution in Agricultural Soils of Siling Reservoir Watershed in Zhejiang Province, China*, BioMed Research International (2013).
- [23] IARC, *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*, Vol. 63, Dry Cleaning, Some Chlorinate Solvents and Other Industrial Chemicals, Lyon, p. 245.
- [24] A. Ikem, S. Oduyungbo, N.O. Egiebor and K. Nyavor, Chemical quality of bottled waters from three cities in eastern Alabama, *Science of the Total Environment* **285** (2002), 165 – 175, [http://dx.doi.org/10.1016/S0048-9697\(01\)00915-9](http://dx.doi.org/10.1016/S0048-9697(01)00915-9).
- [25] P.M. Jakus, W.D. Shaw, T.N. Nguyen and M. Walker, Risk perceptions of arsenic in tap water and consumption of bottled water, *Water Resources Research* **45** (2) (2009), 121.
- [26] J.A. Janus and E.I. Krajnc, Integrated criteria document chromium: effects, Appendix, Bilthoven, Netherlands, National Institute of Public Health and Environmental Protection (1990).
- [27] H.A. Jones and R.D. Hockey, The geology of part of southwestern Nigerian, *Bulletin of the Geological Survey of Nigeria* **31** (4) (1964), 101 p.
- [28] T.A. Jusko, C.R. Henderson, B.P. Lanphear, D.A. Cory-Slechta, P.J. Parsons and R.L. Canfield, Blood lead concentrations < 10 microg/dL and child intelligence at 6 years of age, *Environmental Health Perspectives* **116** (2) (2008), 243 – 248, <http://dx.doi.org/10.1289/ehp.10424>.
- [29] P. Kavcar, A. Sofuoglu and S.C. Sofuoglu, A health risk assessment for exposure to trace metals via drinking water ingestion pathway, *International Journal of Hygiene and Environmental Health* **212** (2) (2009), 216 – 227, <http://dx.doi.org/10.1016/j.ijheh.2008.05.002>.
- [30] B.P. Lanphear, K. Dietrich, P. Auinger and C. Cox, Cognitive deficits associated with blood lead concentrations <10 microg/dL in US children and adolescents, *Public Health Reports* (Washington, D.C.:1974) **115** (6) (2000), 521 – 529, <http://dx.doi.org/10.1093/phr/115.6.521>.
- [31] R.D. Mackenzie, Chronic toxicity studies - II, Hexavalent and trivalent Chromium administered in drinking water to rats, *Archives of Industrial Health* **18** (1958), 232 – 234.
- [32] B.A. Matte, Impact of lead contaminated Soil on Public Health, *Springer* (2) (1992), 147 – 151.
- [33] T. Matte and D. Jacobs, *Housing and health — Current issues and implications for research and programs*, Springer, New York (2000).
- [34] 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** (3) (2010), 2855 – 2864.
- [35] S. Muhammad, M.T. Shah and S. Khan, Health risk assessment of heavy metals and their source apportionment in drinking water of Kohistan region, northern Pakistan, *Microchemical Journal* **98** (2011), 334 – 343, <http://dx.doi.org/10.1016/j.microc.2011.03.003>.
- [36] NSDWQ, Nigerian Standard for Drinking Water Quality, *Nigerian Industrial Standard* **554** (2007), 13–14.

- [37] S.O. Olabode, Siliciclastic slope deposits from the Cretaceous Abeokuta Group, Dahomey (Benin) Basin, southwestern Nigeria, *J. Afr. Earth Sci.* **46** (2006), 187 – 200.
- [38] M.E. Omatsola and O.S. Adegoke, Tectonic evolution and Cretaceous stratigraphy of the Dahomey basin, *Nigeria Geology* **18** (51) (1981), 130 – 137.
- [39] P.C. Chrostowski, Exposure assessment principles, in *Toxic Air Pollution Handbook*, D.R. Patrick (ed.), Van Nostrand Reinhold, New York (1994), 133 – 163.
- [40] H. Pekey, D. Karakaş and M. Bakoglu, Source apportionment of trace metals in surface waters of a polluted stream using multivariate statistical analyses, *Marine Pollution Bulletin* **49** (2004), 809 – 818, <http://dx.doi.org/10.1016/j.marpolbul.2004.06.029>.
- [41] M.K. Raikwar, P. Kumar, M. Singh and A. Singh, Toxic effect of heavy metals in livestock health, *Veterinary World* **1** (2008), 28 – 30.
- [42] M. Robson, Methodologies for assessing exposures to metals: Human host factors, *Ecotoxicology and Environmental Safety* **56** (1) (2003), 104 – 109, [http://dx.doi.org/10.1016/S0147-6513\(03\)00054-X](http://dx.doi.org/10.1016/S0147-6513(03)00054-X).
- [43] H.A. Schroeder and M. Mitchener, Scandium, chromium (VI), gallium, yttrium, rhodium, palladium, indium in mice: effects on growth and life span, *Journal of Nutrition* **101** (1971), 1431 – 1438.
- [44] W. Shotyk and M. Krachler, Lead in bottled waters: contamination from glass and comparison with pristine groundwater, *Environmental Science & Technology* **41** (2007), 3508 – 3513, United States Environmental Protection Agency, Risk Assessment Forum (1999).
- [45] R.R. Engel and A.H. Smith, Arsenic in drinking water and mortality from vascular disease: an ecological analysis in 30 counties in the United States, *Arch. Environ. Health* **49** (1994), 418–427.
- [46] S. Szabó, G. Szabó, C. Fodor and L. Papp, Investigation of two sewage disposal sites from the aspect of environmental impacts on soil and groundwater in the County of Hajdú-Bihar (Hungary), *Moravian Geographical Reports* **16** (2008), 37–45.
- [47] B.J. Tola, Indicative of absorption and biological effect in new lead exposure, *NCBI* **2** (1973), 134 – 141.
- [48] USEPA, Integrated Exposure Uptake Bio-Kinetic model for Lead in Children (IEUBK), US Environmental Protection Agency (2012).
- [49] USEPA Environmental Protection Agency (EPA), Cancer risk coefficients for Environmental exposure to radionuclides, United State Environmental Protection Agency, *Federal Guidance Report No. 13* (1999) (EPA. 402 R-99-001),
- [50] USEPA (United States Environmental Protection Agency), Risk assessment guidance for superfund: *Human health evaluation manual* (Part A), Washington, D.C.: United States Environmental Protection Agency **1** (1989), p. 248.
- [51] C.M. Villanueva, M. Kogevinas, S. Cordier, M.R. Templeton, R. Vermeulen, J.R. Nuckols, M.J. Nieuwenhuijsen and P. Levallois, Assessing exposure and health consequences of chemicals in drinking water: current state of knowledge and research needs, *Environ. Health Perspect* (2013) <http://dx.doi.org/10.1289/ehp.1206229>.
- [52] Z. Wang, L. Chai, Y. Wang, Z. Yang, H. Wang and X. Wu, Potential health risk of arsenic and cadmium in groundwater near Xiangjiang River, China: a case study for risk assessment and management of toxic substances, *Environmental Monitoring and Assessment* **175** (2011), 167 – 173, <http://dx.doi.org/10.1007/s10661-010-1503-7>.

- [53] L.D. White, D.A. Cory-Slechta, M.E. Gilbert, E. Tiffany-Castiglioni, N.H. Zawia, M. Virgolini and R. Bashae, New and evolving concepts in the neurotoxicology of lead, *Toxicology and Applied Pharmacology* **225** (1) (2007), 1–27, <http://dx.doi.org/10.1016/j.taap.2007.08.001>.
- [54] WHO, Guidelines for drinking-water quality: recommendations, World Health Organization (2004).
- [55] WHO, Guidelines for drinking-water quality: First addendum to volume 1, Recommendations, World Health Organization (2006).
- [56] World Health Organization, Guidelines for drinking-water quality, Vol. 2, health criteria and other supporting information, World Health Organization (1996).
- [57] K. Ye-Shin, P. Hoa-Sung, K. Jin-Yong, P. Sun-Ku, C. Byong-wook, S. Ig-hwan and S. Dong Chun, Health risk assessment for uranium in Korean groundwater, *J. Environ. Radioact.* **77** (1) (2004), 77–85.