

PAPER • OPEN ACCESS

## Health Risk Assessment of Groundwater in Omu-Aran, Nigeria

To cite this article: O O Elemile *et al* 2021 *IOP Conf. Ser.: Mater. Sci. Eng.* **1036** 012006

View the [article online](#) for updates and enhancements.

# Health Risk Assessment of Groundwater in Omu-Aran, Nigeria

O O Elemile<sup>1</sup>, E M Ibitogbe<sup>1</sup>, J R Adewumi<sup>1,2</sup>, O P Folorunso<sup>3</sup> and C O Osueke<sup>4</sup>

<sup>1</sup>Department of Civil Engineering, College of Engineering, Landmark University, Omu-Aran, Nigeria

<sup>2</sup>Department of Civil Engineering, School of Engineering and Engineering Technology, Federal University of Technology, Akure, Nigeria

<sup>3</sup>Department of Civil Engineering, Faculty of Engineering, Ekiti State University, Ado-Ekiti Nigeria

<sup>4</sup>Department of Mechanical Engineering, College of Engineering, Landmark University, Omu-Aran, Nigeria

\*Correspondence Author: [ibitogbe.enoch@lmu.edu.ng](mailto:ibitogbe.enoch@lmu.edu.ng)

**Abstract.** Pollution of groundwater by bathroom, laundry and kitchen effluent has been documented to have non-desirable health and environmental effects. There is little information about the quality of groundwater and associated health effects in Omu-Aran. The present research therefore meets the need to investigate the levels of heavy metals, the pollution effects, and the long term human health risk effect on local inhabitants in Omu-Aran. Thirty water samples were collected from five hand dug wells (HWs) in different parts of Omu-Aran spanning a period of three months and the heavy metal parameters were determined using standard protocol. The non-carcinogenic risk was evaluated using hazard index (HI) according to United States Environmental Protection Agency (USEPA) risk assessment method. Data analysis was carried out by the use of descriptive statistics. From the result, mean values and SD of heavy metals in the water samples obtained from selected HWs ranged from  $0.16 \pm 0.13$  to  $0.29 \pm 0.18$  mg/L,  $0.29 \pm 0.02$  to  $1.36 \pm 0.07$  mg/L,  $0.00 \pm 0.00$  to  $0.72 \pm 0.04$  mg/L,  $0.00 \pm 0.00$  to  $0.51 \pm 0.09$  mg/L,  $0.01 \pm 0.01$  to  $5.26 \pm 0.07$  mg/L, and from  $0.03 \pm 0.01$  to  $12.96 \pm 2.82$  mg/L for Al, Fe, Mn, Cr, Cu, and Zn respectively. The heavy metals were all above the WHO limits except Pb and Fe. The hazard index values ranged from 1.406 to 10.075 indicating significant non-carcinogenic risk. The findings of the study, has shown that there is considerable amount of heavy metal pollution which stems from anthropogenic sources. There was no observable risk via dermal pathways based on hazard quotient values while non-carcinogenic risk via ingestion was observed for all the locations. There is therefore a need to bring awareness to the community for the purpose of ensuring safety of its active water sources.

## 1. Introduction

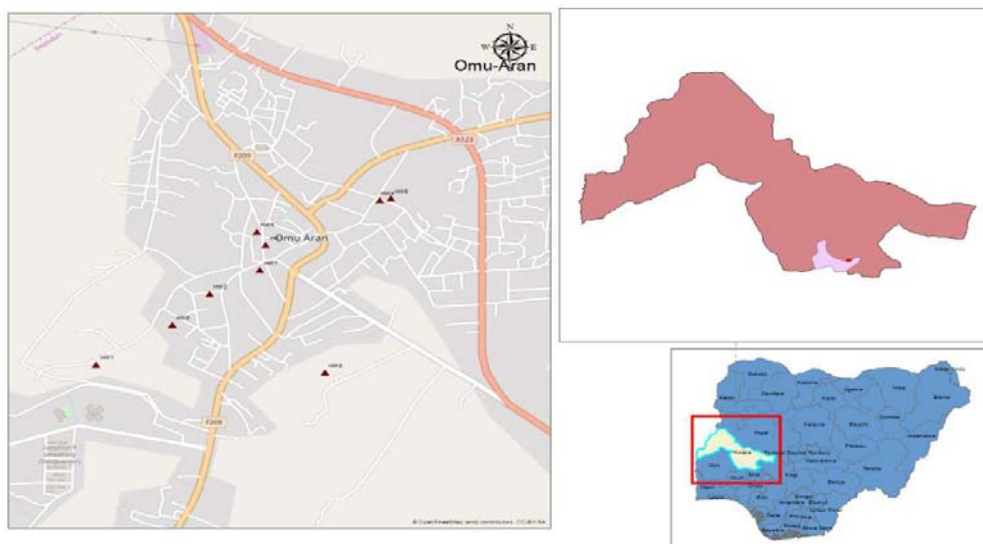
Heavy metals generally exist as trace substances usually in quantities that do not pose any health risk. There is, however, a high risk that toxic and recurrent waste will be disposed of in the surroundings due to anthropogenic activities in improperly protected landfills, atmospheric deposition, grey water and kitchen effluents [10, 14]. The pristine nature and the availability of groundwater for different purposes makes it a very reliable source in comparison to water obtained from the surface [5]. Although natural features and anthropogenic activities play a role in the quality of groundwater [1], scientists have found that heavy metal pollution in the environment is significantly caused by the latter [9]. In addition, this progressive decline in groundwater quality and purity can be attributable to human activities, particularly in view of the rapid growth, farm activities, urbanization and industrial development [18]. Heavy metals are a known set of pollutants impacting the quality of groundwater, which presents a safety threat to living organisms. [1] suggest that their being highly persistent is because they bio-accumulate in the environment. Toxic heavy metals such as lead, arsenic and mercury retain harmful effects on plants, animals and human health. In the same way, chromium can be ingested through food and water. High



exposure can lead to chronic neurological effects of the gastrointestinal system [3, 17]. If the heavy metal levels surpass the prescribed limit, they may lead to chronic disorders, such as liver conditions, high blood pressure, kidney problems, skin irritation, etc. [19, 20]. This makes all the more important to identify and characterize the nature of the risk and the dangers it poses to human health [15]. Risk assessment refers to the systematic detection and characterisation of the toxicity of a chemical. This will help to generate a qualitative (descriptive) risk analysis focused on the negative effects reported (chronic and carcinogenic) and the numerical risk level (calculation of health risk). Over the years, Omu-Aran has developed into a peri-urban region witnessing incredible expansion of human, businesses and economic activities with a consequent increase in the production of wastewater. Unfortunately, this community lacks the potential for wastewater treatment and segregation before disposal thus, wastes from the residential areas, schools, hotels, hospitals, and abattoirs in the area are handled by the residents since they have no central systems. The result of these practices make it almost inevitable for uncontrolled levels and contents of heavy metals in the immediate vicinity. A study by [7] showed that soil was contaminated as a result of abattoir pollution. However, there has been no documented study in terms of establishing the heavy metal pollution status to the immediate environment of the residential areas. This research therefore looked at the levels of heavy metals, the effects of contamination and the long-term consequences of human health threats on the local inhabitants of Omu-Aran.

## 2. Study Area

Omu-Aran is positioned in the southern part of Kwara State as shown in Figure 1. It occupies a land area of 73.7 km<sup>2</sup> and located on latitude 8°08'00"N and longitude 5°06'00"E with an average elevation of 564m above sea level [6]. Having an estimated 150,000 persons, (Bureau office of Statistic, 2018), it is the third largest town in Kwara state. The vegetation is largely guinea savannah while the climate is tropical maritime monsoon [15]. The average annual rainfall is 1262.8 mm while the average annual maximum temperature 35.8 °C.



**Figure 1:** Location map showing collected samples.

## 3. Sampling Method and Analysis

Figure 2 shows one of the hand dug wells where groundwater samples were obtained between October and December in compliance with the protocol of [19] while Figure 3 shows an open dump which is one of the point source of pollution to the hand dug well at Latinwo area, Omu-Aran. Thirty (30) samples were collected bi-monthly across five locations from five (5) hand dug wells. The Hand dug wells are

designated as follows HW<sub>1</sub> – Hand dug well at Aperan, HW<sub>2</sub> – Hand dug well at Egbe garage, HW<sub>3</sub> – Hand dug well at Latinwo, HW<sub>4</sub> – Hand dug well at Mode, HW<sub>5</sub> – Hand dug well at Igangu. Prewashed polyethylene bottles were used in collecting according to the method adopted by [18]. Sample preparation was done prior to analysis using the method prescribed by [2]. Heavy metal (Fe, Mn, Cu, Zn, Pb, Al, Cr) concentrations were then determined by using bulk scientific (AAS.AA 320 N).



**Figure 2:** Resident using dug well at Igangu, Omu-Aran well site



**Figure 3:** Point source pollution at

#### 4. Risk Assessment

Risk assessment is a tool developed in order to measure and evaluate likely health risk associated with the exposure to certain elements such as heavy metals which could be injurious to the human health. Contamination of drinking water gives rise to many health challenges. Water-invasive toxic chemicals may have well-advanced health risks resulting its frequent exposure. This segment was used to evaluate the overall likely, non-carcinogenic effect of metals using the Hazard Index (HI) method. According to [12], risk assessment entails hazard tracing, exposure valuation, dose response and estimating the risk effect. Generally, exposure could happen through dermal pathways or by ingestion. In estimating the risk related with exposure to heavy metals, chronic daily intake (CDI) ( $\text{mgkg}^{-1}\text{day}^{-1}$ ) via ingestion ( $\text{CDI}_{\text{ingest}}$ ) and dermal contact ( $\text{CDI}_{\text{dermal}}$ ) were evaluated by the equation as shown in equations 1 and 2 obtained from [19];

$$\text{CDI}_{\text{ingest}} = \frac{(Ci \times IR \times CF \times FI \times ED \times EF)}{(BW \times AT)} \quad (1)$$

$$\text{CDI}_{\text{dermal}} = \frac{(Ci \times CF \times SA \times AF \times ABS \times ED \times EF)}{(BW \times AT)} \quad (2)$$

where Ci (mg / L) is level of chemical impurity in potable water; IR (L/day) is daily rate of ingestion of water; EF (days/year) is the frequency of exposure; ED (years) is the length of exposure; FI is the fraction ingested and is usually 1; CF ( $\text{L}/\text{cm}^3$ ) is the converting factor; BW (kg) is the bodyweight; AT (day) is the average exposure period; SA ( $\text{cm}^2$ ) refers to area of exposed skin surface; AF is the skin adherence factor.

$$\text{Hazard quotient (HQ)} = \frac{\text{CDI}}{\text{RfD}} \quad (3)$$

$$\text{Hazard Index (HI)} = \sum \text{HQ} = \text{HQ}_{\text{ingest}} + \text{HQ}_{\text{dermal}} \quad (4)$$

Hazard quotient, HQ is the ratio of chronic daily intake (CDI) to the corresponding reference dose (RfD). The RfD values for Cr, Mn, Cu, Zn, Pb and Fe are 0.003, 0.14, 0.0371, 0.30, 0.0035 and 0.70 mg.kg<sup>-1</sup>.day<sup>-1</sup>. The hazard index (HI) is evaluated by the summation of HQs. HQ and HI are described in equations 3 and 4 respectively. HI value below 1 shows no significant non-carcinogenic risk while the likely non-carcinogenic risk would be above 1 [19]. The summary of assumed values is illustrated in Table 1.

## 5. Results and Discussion

### 5.1 Heavy metal evaluation

Water quality is an entire summary of its constituent parameters in terms of Physical, Microbial and Chemical (heavy metals). The factors that affect these parameters do not depend only on natural characteristics of reservoirs but also on human related discharges. The statistical summary and limit values of heavy metal parameters according to [19] for drinking waters is presented in Table 2. Concentrations for Al, Fe, Mn, Cr, Cu and Zn ranged from 0.16 ± 0.03 to 0.29 ± 0.08, 0.29 ± 0.02 to 1.36 ± 0.07, 0.00 ± 0.00 to 0.72 ± 0.04, 0.00 ± 0.00 to 0.51 ± 0.09, 0.01 ± 0.01 to 5.26 ± 0.07, 0.03 ± 0.01 to 12.96 ± 2.82 mg/L respectively while lead was not undetected as there was no anthropogenic activity causing lead contamination around the wells. This situation agrees with [7] who reported undetected Cu and Cd values for groundwater samples.

**Table 1:** Input parameters to calculate chronic daily intake.

Exposure parameters	Symbols	Unit	Value
Concentration	Ci		from analysis
Ingestion rate	IR	liters/day	2
Conversion factor	CF	liter/cm <sup>3</sup>	1 x 10 <sup>-3</sup>
Fraction ingested	FI		1
Exposure frequency	EF	days/year	365
Exposure duration	ED	Years	70
Body weight	BW	Kg	70
Average time	AT	days/years	25550
Surface area	SA	cm <sup>2</sup>	5700
Skin adherence factor	AF		0.07
Adsorption factor	ABS		0.001

The mean concentration of Al, Mn, Cr, Cu, Zn were above standard WHO limit of 0.1, 0.2, 0.05, 2.0 and 5.0 mg/L, respectively. The mean values of Pb and Fe did not exceed WHO permissible values of 0.01 mg/L and 3 mg/L respectively. The value of Al at all the HWs were above standard limit. Moreover, the concentrations in this study were much lower than 0.4310 mg/L reported by [15]. Aluminum is introduced into groundwater via interaction with rocks and leaching from soil [20]. The high values of Fe at HW<sub>1</sub> could be due to dissolution of iron minerals from water-rock interaction [15]. However, the values are higher than values (0.002 to 0.568 mg/L) from a study carried out previously [4]. The values of Mn fell within permissible limit set by WHO (0.2 mg/L) with the exception of HW<sub>5</sub>. This could be due to close proximity to the road as well as poor maintenance practice as the well has no cover giving enough room for exposure. The observed values of Cu in this study were higher compared to 1.984 ± 0.066 mg/L while Cr was lower than reported values reported by [11]. Zn was observed to be higher than very high across all the sampled wells apart from HW<sub>2</sub>. This suggest percolation of

rainwater from the roof top of houses in the surrounding [6]. The reported values in this study exceed results reported by [13].

**Table 2:** Statistical summary of heavy metal concentration in groundwater samples collected from the study area.

Parameters (mg/L)	HW <sub>1</sub>		HW <sub>2</sub>		HW <sub>3</sub>		HW <sub>4</sub>		HW <sub>5</sub>		Standard WHO
	Mean	Std. dev	Mean	Std. dev	Mean	Std. dev	Mean	Std. dev	Mean	Std. dev	
<b>Pb</b>	-	-	-	-	-	-	-	-	-	-	0.01
<b>Al</b>	0.22	0.01	0.29	0.08	0.16	0.03	0.23	0.02	0.18	0.04	0.10
<b>Fe</b>	1.36	0.07	0.44	0.02	0.48	0.05	0.54	0.07	0.29	0.02	3.00
<b>Mn</b>	0.00	0.00	0.11	0.08	0.00	0.00	0.00	0.00	0.72	0.04	0.20
<b>Cr</b>	0.00	0.00	0.02	0.01	0.31	0.18	0.02	0.02	0.51	0.09	0.05
<b>Cu</b>	0.12	0.01	0.01	0.01	0.13	0.03	0.15	0.02	5.26	0.07	2.00
<b>Zn</b>	12.96	2.82	0.03	0.01	12.03	1.56	12.12	2.40	10.03	1.40	5.00

## 5.2 Health Risk Assessment

Table 3 shows HQ and HI values for the oral and dermal pathways as it relates to the health of consumers. The HQ<sub>dermal</sub> (hazard quotient by dermal pathway) of all trace elements at all the sampling locations were less than one except for Pb which was not detected for any of the samples. Cr was not detected for at HW<sub>1</sub> hence the nil value. Likewise, Mn was not detected at HW<sub>3</sub> and HW<sub>4</sub> locations. This indicates that these metals posed little danger by dermal absorption. However, in the case of HQ<sub>ingestion</sub> (hazard index by oral ingestion), Cr was above one at HW<sub>3</sub> and HW<sub>5</sub> whereas Cu is greater than one at HW<sub>5</sub> which suggest non-acceptable health risk at these locations. Zn poses health risk since it exceeds unity for all locations with the exception of HW<sub>5</sub>. All other HQ<sub>ingestion</sub> values are < 1, which suggests no adverse non-carcinogenic health effect is posed even if the water is used for drinking. However, health effects could arise as a result of the synergistic effect of these trace metals. Conversely, the HI values are all above one with a range of 1.41 to 10.08 and are relatively higher as compared to values reported by [11]. The HI value at HW<sub>5</sub> was the highest, which denotes a relatively higher risk than other wells as shown in Figure 4.

## 6 Conclusion

This study was conducted to evaluate the associated health risk with exposure to heavy metal in the study area of Omu-Aran due to improper waste disposal methods. Risk assessment via dermal and ingestion pathways were investigated for water samples taken from majorly used HDWs by the residents. The average values of heavy metals (Al, Mn, Cr, Cu and Zn) across the wells exceed permissible values given by WHO except for Pb and Fe which was within limit. The order of toxicity of heavy metals based on mean concentrations found in drinking water in the region under review: Zn > Cu > Fe > Mn > Cr > Al > Pb. Zn had the highest concentration of 12.96 mg/L while Pb had the lowest value of 0.00 mg/L. This result is helpful in understanding the state of the drinking water source. It also provides relevant information such as is required by stakeholders to respond adequately to the current pollution in the area. It is therefore recommended that protective and preventive measures are to be carried out by residents to keep their waters close to pristine conditions.

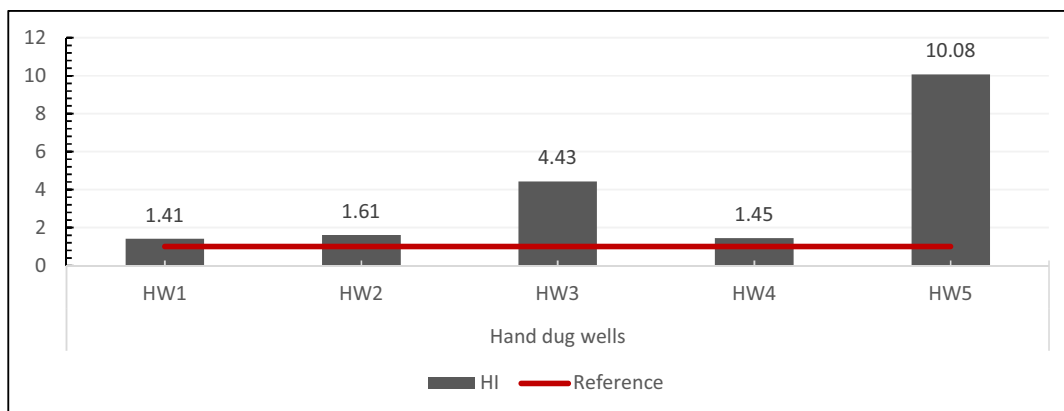


Figure 4: Summary of HI values for each hand dug well.

Table 3: HQ and HI values for oral and dermal pathways as it relates to health effect.

	Location									
	HW <sub>1</sub>		HW <sub>2</sub>		HW <sub>3</sub>		HW <sub>4</sub>		HW <sub>5</sub>	
	HQ ingest	HQ dermal	HQ ingest	HQ dermal	HQ ingest	HQ dermal	HQ ingest	HQ dermal	HQ ingest	HQ dermal
<b>Cr</b>	0.00	0.00	2.18E-01	4.36E-05	3.35	6.69E-04	1.6E-01	3.2E-05	4.90	9.78E-05
<b>Mn</b>	4.07E-04	8.00E-08	2.31E-02	4.61E-06	0.00	0.00	0.00	0.00	1.47E-01	2.93E-05
<b>Cu</b>	8.76E-02	1.75E-05	8.76 E-02	1.75E-05	1E-01	1.99E-04	1.12E-01	2.23E-05	4.05	8.09E-04
<b>Zn</b>	1.25	2.51E-04	1.25	2.51E-04	9.55E-02	2.28E-04	1.146	2.30E-04	9.55E-01	1.90E-04
<b>Pb</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Fe</b>	5.54E-02	1.11E-05	1.79 E-02	3.57E-06	1.96E-02	3.91E-06	2.21E-02	4.41E-06	1.18E-02	2.35E-06
<b>Al</b>	6.24E-03	1.25E-06	8.37 E-03	1.67E-06	4.59E-03	9.15E-07	6.68E-03	1.33E-06	5.14E-03	1.03E-06
	<b>HI=ΣHQs 1.41</b>		<b>1.61</b>		<b>4.43</b>		<b>1.45</b>		<b>10.08</b>	

Reference

[1] Adewoyin O O, Kayode O T, Omeje O, Odetunmbi O A and Shukla S K 2019 Risk assessment of heavy metal and trace elements contamination in groundwater in some parts of Ogun State *Cogent Engineering* **6**(1) 1–12. <https://doi.org/10.1080/23311916.2019.1632555>

[2] American public association (APHA) 1992 Standard Methods for Examination of Water and waste 18th ed. American Public Health Association, Washing ton D.C

[3] ATSDRA Agency for Toxic Substances and Disease Registry 2007 Toxicological Profile for Lead ATSDR Atlanta Georgia USA

[4] Boateng T K, Opoku F, Acquah S O and Akoto O 2015. Pollution evaluation, sources and risk assessment of heavy metals in hand - dug wells from Ejisu - Juaben Municipality Ghana. *Environmental Systems Research* <https://doi.org/10.1186/s40068-015-0045-y>

- [5] Chabukdhara M, Gupta S K, Kotecha Y and Nema A K 2017 Groundwater quality in Ghaziabad district, Uttar Pradesh, India: Multivariate and health risk assessment. *Chemosphere* **179** 167–178. doi: 10.1016/j.chemosphere.2017.03.086
- [6] Elemile O O, Raphael D O, Omole D O, Oloruntoba E O, Ajayi E O and Ohwavorua N A 2019 Assessment of the impact of abattoir effluent on the quality of groundwater in a residential area of Omu - Aran Nigeria *Environmental Sciences Europe* <https://doi.org/10.1186/s12302-019-0201-5>
- [7] Elemile O O, Raphael O D, Omole D O, Oluwatuyi O E, Ajayi E O, Umukoro O and Elemile M G 2019 Assessment of the impact of abattoir activities on the physicochemical properties of soils within a residential area of Omu-Aran, Nigeria IOP Conference Series: *Materials Science and Engineering* **640**(1) <https://doi.org/10.1088/1757-899X/640/1/012083>
- [8] Emenike P C, Tenebe I, Ogarekpe N, Omole D and Nnaji C 2019 Probabilistic risk assessment and spatial distribution of potentially toxic elements in groundwater sources in Southwestern Nigeria. *Scientific Reports* **9**(1) 1–15 <https://doi.org/10.1038/s41598-019-52325-z>
- [9] Kasassi A, Rakimbei P, Karagiannidis A, Zabaniotou A, Tsiouvaras K, Nastis A and Tzafeiropoulou K 2008 Soil contamination by heavy metals: Measurements from a closed unlined landfill. *Bioresource Technology* **99**(18) 8578–8584. <https://doi.org/10.1016/J.BIORTECH.2008.04.010>
- [10] Khan S, Cao Q, Zheng Y M, Huang Y Z and Zhu Y G 2008 Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing China. *Environmental Pollution* **152**, 686–692
- [11] Kwame T, Francis B and Akoto O 2019 Heavy metal contamination assessment of groundwater quality: a case study of Oti landfill site, Kumasi *Applied Water Science* **9**(2) 1–15 <https://doi.org/10.1007/s13201-019-0915-y>
- [12] Lee J S, Chon H T and Kim K W 2005 Human risk assessment of As, Cd, Cu and Zn in the abandoned metal mine site. *Environmental Geochemistry and Health* **27**(2) 185–191 <https://doi.org/10.1007/s10653-005-0131-6>
- [13] Oyatayo K T, Songu G, Amos G and Ndabula C 2015. Assessment of Heavy Metal Concentration in Hand Dug Well Water from Selected Land Uses in Wukari Town , (November), 1–10.
- [14] Ali S S, Anwar Z and Khattak J Z K 2012. Microbial analysis of drinking water and water distribution system in new urban Peshawar. *Current Research Journal of Biological Sciences* **4**(6) 731-737
- [15] Şener Ş, Şener E and Davraz A 2017 Assessment of groundwater quality and health risk in drinking water basin using GIS. *Journal of water and health* **15**(1) 112-132
- [16] Sojobi A O 2016 Evaluation of groundwater quality in a rural community in North Central of Nigeria. *Environmental monitoring and assessment* **188**(3) 192
- [17] Samantara M K, Padhi R K, Sowmya M, Kumaran P and Satpathy K K 2017 Heavy metal contaminations major ion chemistry and appraisal of the groundwater status in coastal aquifer, Kalpakkam Tamil Nadu *India Groundwater for Sustainable Development* **5**(49–58), 49– 58 doi: 10.1016/j.gsd.2017.04.001
- [18] Tirkey P, Bhattacharya T, Chakraborty S and Baraik S 2017 Assessment of groundwater quality and associated health risks: A case study of Ranchi Jharkhand India *Groundwater for Sustainable Development* **5** 85–100. doi: 10.1016/j.gsd.2017.05.002
- [19] United States Environmental Protection Agency 2000 EPA Drinking Water Standards and Health Advisory Office of Water Washington, D.C., (June) 1–30 Retrieved from <https://web.ics.purdue.edu/~peters/HTML/docs/drinking-water-standards.pdf> [http://www3.epa.gov/region09/water/drinking/files/dwsha\\_0607.pdf](http://www3.epa.gov/region09/water/drinking/files/dwsha_0607.pdf)
- [20] WHO 2011 Guidelines for drinking-water quality (4th ed.) Geneva Switzerland: environmental health criteria. <http://www.who.int>