Available Online at http://www.journalajst.com

ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

ISSN: 0976-3376

Asian Journal of Science and Technology
Vol. 14, Issue, 12, pp. 12787-12792, December, 2023

RESEARCH ARTICLE

CLIMATE CHANGE, WATER QUALITY AND WATER-BORNE MORBIDITY OF INFANTS IN OGUN STATE, NIGERIA

Anwan, Henry Robert[1]*, Ezeh, Felix Chuka[1] and Awosoji Grace Taiwo[2]

[1]Centre for Environmental studies and Sustainable Development, Lagos State University, Ojo, Lagos, Nigeria
[2]Department of Science Laboratory Technology, Ogun State Institute of Technology, Igbesa

ARTICLE INFO

Article History:
Received 11th September, 2023
Received in revised form
20th October, 2023
Accepted 17th November, 2023
Published online 23rd December, 2023

Keywords:
Cholera, Climate change, Diarrhea, Flooding, Heavy metals, Water-borne Disease and Water quality.

ABSTRACT

Water quality and its availability have implication on the health status and lifestyle of a community. Over 80% of preventable disasters, diseases, hunger and even deaths are due to improper utilization and management of water. Flooding, orchestrated by climate change has exacerbated the situation. Children below the age of 5 years old are highly vulnerable and most affected by these waterborne diseases. The pattern of water-borne diseases in relation to water quality and other environmental factors was studied among residents of Igbesa in Ado Odo-Ota LGA of Ogun state, Nigeria. Sources of drinking water were 65% among households with water sources within their premises. Common sicknesses were 75% in the wet season as compared to 25% during dry season. Sicknesses more common among children included diarrhea (58%), high fever (25%) and malaria (17%). Water parameter values and heavy metal concentrations recorded in this study were within acceptable levels. Accordingly, it was concluded that the drinking water sources in Igbesa are safe for human consumption. However, the occurrence of Cd and Co in the water samples is indicative of subtle toxic pollution in the area. This calls for proper and continuous monitoring before it gets to dangerous levels.

Citation: ***Anwan, Henry Robert, Ezeh, Felix Chuka and Awosoji Grace Taiwo,*** **2023.** "Climate change, water quality and water-borne morbidity of infants in ogun state, nigeria", *Asian Journal of Science and Technology*, 14, (12), 12787-12792

INTRODUCTION

The human body consists of about 70% water and water related ailments are the leading cause of human mortality all over the world (D. O. Omole *et al.*, 2015). This vital natural resource required for sustaining all forms of life on earth is actually responsible for more than 80% of preventable diseases, disasters and also deaths. According to the WHO (2013), about 4 billion cases of diarrhea cause 2.2 million deaths globally every year particularly in children below 5 years old. Diarrhea is loose watery stools caused by a virus such as norovirus or rotavirus bacteria such as E.coli causing the stools to occur more frequently than normal. As immune systems are progressively compromised with each bout of diarrhea, related illnesses indirectly kill millions more. Water is one of the most vital natural resources required for the sustainability of all forms of life on earth (D. O. Omole and E. O. Longe, 2018). The quality and quantity of available water have implication on the health status of a community. Over 50,000 people die daily on a global scale due to water borne diseases. Worst still, 2.3 billion people worldwide have mortality and morbidity associated with water related ailment and floods (WHO, 2013, K. N. Ibemenuga, 2013). There are innumerable waterborne diseases, disasters and deaths arising from excessive flooding across the world. Over a billion people have been displaced, killed or rendered homeless in Africa, Asia, Australia and the Americas (F. C. Ezeh 2016). According to (T. E. Ologunorisa 2006), flooding pollutes and contaminates fresh water ecosystems thus promoting the occurrence of waterborne vectors.

Waterborne diseases are conditions caused by pathogenic micro-organisms that are transmitted in water. These diseases include cholera, schistosomiasis and other gastrointestinal problems and can be spread while bathing, washing, drinking water, or by eating food exposed to contaminated water (D. F. Charon *et al*., 2005). Cholera is a severe illness caused by Vibrio choleraebacteria that affect the intestinal tract resulting in serious dehydration diarrhea that can be fatal without instant treatment. Cases of cholera are reported world-wide especially in emergency situations like areas affected by natural disasters. Good food and water hygiene can prevent it. There are 500 million cases of malaria worldwide each year resulting in 1.3million deaths (90% of whom are infants under 5years) and mostly the morbidity is in Sub-Sahara Africa. Irrigation dam construction and other water development projects are the causes of the burden of the disease but reducing mosquito populations in the household and eliminating stagnant water or covering up water containers can be essential in minimizing malaria episodes. About 200 million people are infected with schistosomiasis (also known as bilharzia), 20 million of whom experience grave consequences like liver, intestines, lungs and bladder damage (WHO, 2013). Outbreaks of waterborne diseases often occur after a severe precipitation event such as rainfall or snowfall (A. C. Lucas & H. M. Gilles, 2015). It has also been reported that climate change affects water resources through changes in evaporation, groundwater recharge, temperature, runoff and rainfall. Such changes affect the mobilization of nutrients, distribution and mobility of pollutants in freshwater systems. The resulting biological changes include pathogenic microbes in water while chemical changes include increased nutrient concentrations, water color and decreased oxygen content (I. Delpla *et al*., 2009).

Climate change is thus contributing significantly to water-borne and vector borne diseases globally and hence expanding the number of human infections with these pathogens. K. Y. Raneesh 2014 reported that climate change has led to widespread mass losses from glaciers and a reduction in snow cover. These have led to reduced water availability and hydropower potential. Accordingly, there is a projected increase in surface runoff by 10 to 40% and a general increase in drought thus exacerbating the impacts on agriculture, water supply, energy protection and people's health. M. Baiwen *et al.,* (2022) observed that with the continuous emission of greenhouse gases, the source water quality is influenced and concluded that the risk of drinking water safety will be further aggravated under climate change in future. Flooding has further exacerbated the situation. According to (M. Zhou *et al.,* 2022) flooding leads to enrichment of toxic micro-pollutants in surface water. This has implications on the fresh water resources available for human consumption (T. E. Ologunorisa, 2006). Also flooding, according to (F. C. Ezeh and H. R. Anwan, 2022), results in erosion of the topsoil, impoverishing the soil and rendering it unproductive. This in turn impacts negatively on the global food security.

There is an ever-increasing demand for water in-spite of its widespread availability. This demand is occasioned by the fact that terrestrial life is sustained only by fresh water resource which represents only 2.5% of the total global waters and this tiny quantity is not readily available for human use (D. O. Omole and E. O. Longe, 2018). Fresh water is also essential for good crop growth/yield as well as animal production (F. C. Ezeh and H. R. Anwan, 2022). The prevalence of these water borne and vector borne diseases is particularly linked to the dearth of potable water in most parts of the developing countries. In a collaborative work with the United States Environmental Protection Agency, the Southern Nevada Water Authority established that climate change would result in, among other things, increased algae blooms in water bodies. Algae blooms impair water source availability and quality. On the other hand, Tampa Bay Water authorities observed increasing vulnerability of its ground water source to saltwater intrusion and embarked on a construction of a large desalination plant as means of increasing its source of drinking water to its people (USEPA, 2019a and 2019b).Safe water, adequate sanitation and good hygiene practices are essential for young children to survive and thrive. Poor water quality continues to pose a major threat to human health. Cholera disease alone amounts to an estimated 4.1% of the total Disability Adjusted Life Year (DALY) global burden of disease and is responsible for the deaths of 2 million people every year, with estimated 88% of that burden concentrated on children in developing countries (WHO, 2011). Without access to safe water and adequate sanitation, families remain enmeshed in deplorable conditions. Young children die from preventable diseases such as cholera. Those who survive are often unable to learn in school or succeed in life because of the legacy of ill health in their early years and the burden of recurring illnesses (UNICEF, 2014). Ado-Odo/Ota Local Government Area (LGA) of Ogun State is one of the major industrial hubs of Nigeria, hosting hundreds of industrial concerns, several farms and hundreds of thousands of residential institutions and households with attendant pollution activities (A. S. Ogbiye, 2017). These pollution activities directly affect the rate of clean water in the region as more than 80% of industrial effluent discharges are also carried out without initial treatment processes as required by law (D. O. Omole and J. M. Ndambuki, 2017). Thus, freshwater sources suffer as a direct result of human activities and flood. E. O. Longe *et al.,*(2012) investigated the sources and quality of domestic water supply to 124 households in 16 communities of Ado-Odo/Ota Local Government Area of Ogun State, Nigeria. Their results show that water from all the sources investigated are generally slightly acidic, while levels of cadmium were higher than the Nigerian Standard for Drinking Water quality limit of 0.003mg/l specified for potable water supply. Also, the chemical and microbiological analyses reveal impairments in the quality of River Atuwara, a major source of domestic water supply and intake for the state public water works, with high levels of Pb, Ni and Total Coliform. D. O. Omole *et al.,* (2015) assessing water related diseases in a Nigerian Community, obtained information on the general health problems in Ota, Ogun state. Ailments directly related to water were highlighted and discussed. The information was gathered by questionnaire application, using non-quota sampling technique. The target respondents were health care workers such as doctors, nurses and pharmacists who work in hospitals and primary health care centers situated in the municipality. It was observed that among the top seven diseases that are most frequently reported in Ota, five were water related, including, malaria, typhoid, vital organ failure, cholera and skin disease. O. Oguntoke *et. al.,* (2009) examined association of water-borne diseases morbidity pattern and water quality in parts of Ibadan City, Nigeria. A well-structured questionnaire was administered to 350 residents of the selected areas to elicit information on water sourcing, handling and storage. Analysis of hospital records showed significant difference in the occurrence of water-borne diseases among residential areas ($P < 0.05$). Typhoid fever had the highest occurrence (39.3%) followed by bacillary dysentery and cholera. Another study conducted by (A. A. Mutiu *et. al.,* 2013) on water quality assessment of Iju River in Ogun State, Nigeria, reported high levels of electrical conductivity (EC), total solids (TS), biochemical oxygen demand (BOD) andhigh concentration of iron (Fe) in the entire samples. The study concluded that the river water used for irrigation of vegetable is unsuitable for aquatic life and human consumption. It is obvious, that the environmental factors, water and the problem of water borne diseases, especially diarrhea and cholera diseases are linked up via two different mechanisms; through the supply of contaminated water and or lack of potable water for personal hygiene. Numerous health impact researches have evidently recognized that the upgrading of water supply and sanitation alone is generally required but not adequate to attain broad health effects if personal and domestic hygiene are not given equivalent prominence (R. Scherlenlieb, 2013). Nigeria is a country suffering from the crippling burden of disease resulting from unsafe drinking water. The prevalent diseases of unsafe drinking water in Nigeria include cholera and diarrhea. Hence, this study examined the pattern of water-borne diseases in relation to water quality and other environmental factors that could assist in exposing the apparent intractable nature of these diseases in Ado/Odo Ota LGA, Ogun State, Nigeria.

MATERIALS & METHODS:

Study area

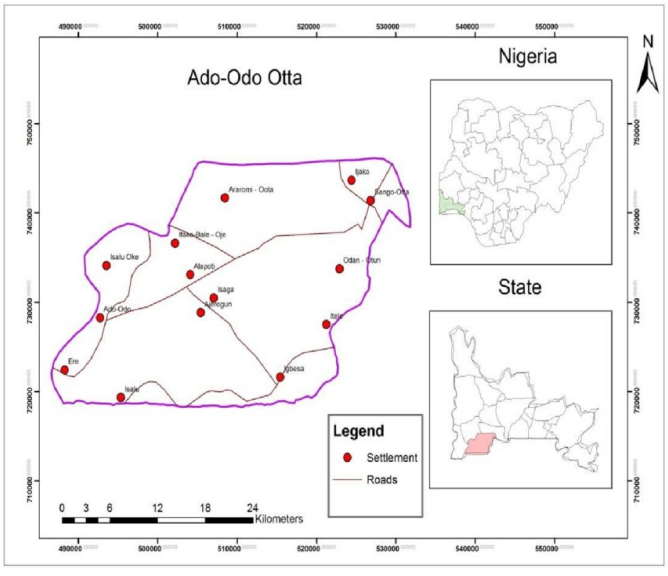

Figure 1. Map of Ado – Odo Ota local government area (S. A. Ogunyemi *et al.*, 2017)

The study area is Ado/Odo-Ota LGA, Ogun State, Nigeria (Fig. 1). With a current estimated population of 669,886 (NPC, 2006), the

LGA is the most populated of the 20 LGAs in the State. The LGA is also one of the industrial hubs with the highest concentrations of industries in Nigeria (D. O. Omole and Isiorho, 2015). It accommodates several hundred industries which include food, beverages and tobacco; pulp and paper products; chemical and pharmaceuticals; metallurgy; gas; plastics; wood processing; and non-metallic mineral products. There are various forms of water bodies including, rivers, wells and boreholes in the local government. The rivers include Atuwara River, Totowu River, Iteku River, Owo River and Olege lagoon amongst others. The most popular uses of drinking water in the study area is borehole or underground water.

Sampling technique: A multi-stage sampling technique was used in data collection. The first stage involved collection of hospital data for the purpose of identifying the pattern of water-borne diseases. Secondly, household questionnaire survey was conducted to identify popular water sources, water handling techniques and other related information. The last stage was the water sampling and water quality analyses.

Water handling and Morbidity data: Information on the morbidity of water borne diseases was collected from public hospital (General Hospital, Ota, Ogun State) and Public healthcare centers with catchments covering the study area. Data covered a period of four years, from 2015 to 2019. Based on the aggregation of hospital data, three residential areas that recorded high incidence of water-borne diseases ((Elero, Aruwe and Powerline) were purposively selected as study sites for household survey and water sampling. A well-structured questionnaire consisting of 20 questions was designed to obtain information on water sourcing, utilization, water storage as well as ailments commonly experienced by the residents.. Allocation of questionnaire was based on the population of each area; 30 respondents were sampled from each area which constituted the sample size. The 30 residents from each area were selected from 30 households. Each area was divided into ten streets, 3 households were selected from each street, totaling 90 households from the three selected areas (Elero, Aruwe and Powerline). The respondents included heads of the various households or their representatives and people who cared for infants aged 5years and below in the households, some of who were the spouses of the household heads.

Water quality analyses: Replicate water samples were collected from three sampling points in the study area (Elero, Aruwe and Powerline) in pre-cleaned plastic bottles for both physico-chemical parameters and heavy metal analyses. The water quality parameters determined included; pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness, chloride, dissolved oxygen (DO), biological oxygen demand (BOD) and chemical oxygen demand (COD) respectively. The water parameters were determined using standard method for water analysis (APHA, 1989). Heavy metal concentrations were determined for each sample by fixing 50 ml of the sample using Analar grade concentrated hydrochloric acid and concentrated nitric acid (obtained from Merck, Germany) in the ratio of 10:1 respectively. This assisted in digesting particulate matter in the sample by heating to obtain thick yellow solution, on a water bath. The sample was later cooled and made up to 100 ml with distilled water after which analysis to estimate the concentration of heavy metal was done using the Buick Atomic Absorption Spectrophotometer (H. R. Anwan, *et al.*, 2021).

RESULTS AND DISCUSSION

Water-borne Morbidity: The survey of sources of drinking water showed that 11.7% of the respondents used pipe borne water whilst 58.3% obtain their water supply from hand pump/borehole sources. Only 6.7% of the households use bottled or bagged water. Therest of the households (23.3%) obtain their water from hand dug wells (Figure: 4.1).

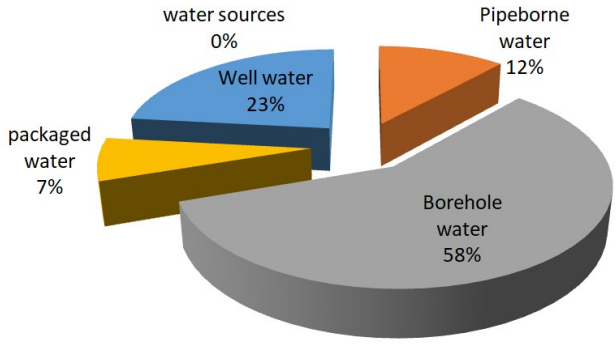

Figure 4.1. Sources of drinking water for members of the house hold

On proximity of the water sources, 35% of the respondents have borehole/well water within their premises (Figure 4.2). 65% of the respondents representing majority of the inhabitants, source for water from outside their homes (in nearby places). The water may get contaminated with disease bearing pathogens in the course of transporting the water from the source to their various homes thereby exposing households to water diseases.

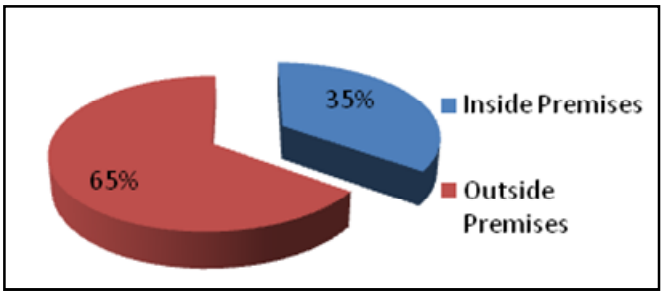

Figure 4.2. Location of source of drinking water supply

Hospital records (Figure: 4.3) listed out the most frequently reported sicknesses as malaria (58.33%) and diarrhea/vomiting (25%) which are water related diseases. These two together accounts for over 80% of reported ailments in the hospitals.

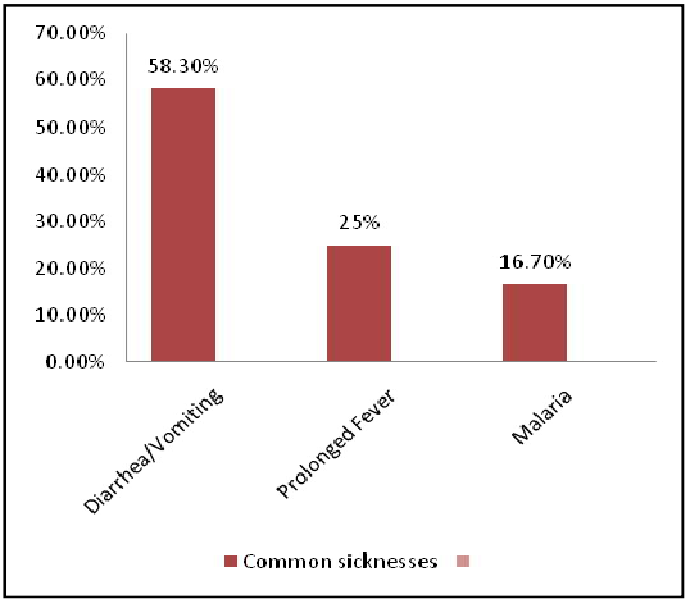

Figure 4.3. Common Sickness in Ado odo-Ota LGA

The hospital records also indicated a seasonal variation in the incidence of ailments reported. 75% of sicknesses were reported during the wet season while only 25% were recorded during dry season (Figure: 4.4).

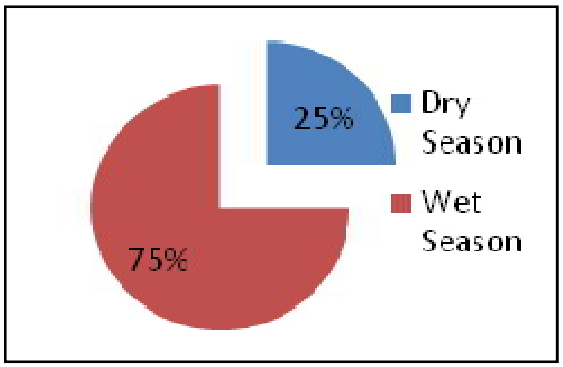

Figure 4.4. Seasonal variation of common sickness in Ado odo-Ota LGA

Table 4.1. Physicochemical parameters of water samples from Ado odo-Ota LGA

Parameters	ELERO IGBESA	ARUWE	POWERLINE	SON Standard (NIS 306:2008)
pH@25^{0}C	7.4	6.4	6.2	6.5-8.5
TDS(mg/L)	57.4	71.7	50.7	500
COD(mg/L)	5.3	3.7	3.1	7.5
Total Hardness as $CaCo_3$ (mg/L)	102	61	42.84	250
CI (mg/L)	37.4	76.8	15.3	250
Water Temperature	25	24	27	N/A
Conductivity	230	163	138	1000
Transparency	C	C	C	N/A
BOD	30	24	56	N/A
DO	3.1	4.01	2.08	N/A

Table 4.2. Concentration of heavy metals in water samples from Ado odo-Ota LGA

SAMPLING LOCATION	ELERO IGBESA	ARUWE	POWERLINE	SON Standard (NIS 306:2008)
Fe (mg/L)	0.0841	0.1324	0.009	0.3
Zn (mg/L)	0.1421	ND	ND	3.0
Cd (mg/L)	ND	0.0002	ND	0.03
Co (mg/L)	0.1982	0.0165	ND	0.03
Cu (ppm)	0.0001	0.0006	0.0004	1.0

Water quality results: The physicochemical parameters studied are given in Table: 4.1. pH values observed, ranged between 6.2 at Powerline, 6.4 at Aruwe and 7.4 at Elero. Total Dissolved Solids (TDS) was high at 71.7mg/L in Aruwe, low inn Elero and Powerline at 57.4mg/L and 50.7mg/L respectively. COD values were 3.7mg/L at Aruwe, 5.3mg/L at Elero and 3.1mg/L at Powerline. Total hardness recorded 102mg/L at Elero, 61mg/L at Aruwe and 42.8mg/L at Powerline. Chloride values observed in this study showed15.3mg/L in Powerline, 37.4mg/L in Elero and 76.8mg/L in Aruwe. Electrical conductivity of water in the area was generally low with the highest value of 230µScm^{-1} recorded at Elero. Correspondingly, 163µScm^{-1}and 138µScm^{-1} were recorded for Aruwe and Powerline respectively. Water temperature were 24^{O}C in Aruwe, 25^{O}C in Elero and 27^{O}C in Powerline. Transparency of the water samples was generally clear. BOD was high at 56mg/L in Powerline, 30mg/L at Elero and 24mg/L at Aruwe while DO values were 4.01mg/L at Aruwe, 3.1mg/L at Elero and 2.08mg/L at Powerline respectively. The presence of heavy metals including Cd and Co in the water samples is indicative of toxic pollution in the area (Table 4.2). Fe at Aruwe was 0.13mg/L, Elero, 0.08mg/L and Powerline, 0.009mg/L respectively. Zn was present at 0.14mg/L in Elero only. It was not detected at Aruwe and Powerline locations. Cd was recorded 0.0002mg/L at Aruwe only. Cd was not detected at Elero and Powerline sampling points. Co was reported in two sampling locations. 0.19mg/L was reported for Elero and 0.016 for Aruwe but was not detected at Powerline. Cu, like Fe, was found in all the sampling locations. Aruwe water sample recorded the highest value of 0.0006mg/L, Powerline water reported 0.0004mg/L while the least value of 0.0001mg/L was recorded at Elero. Overall, the heavy metal concentrations reported for the study area were all found to be within the acceptable limits allowed by SON and WHO in drinking water quality.

The study observed that majority of the respondents rely on borehole/hand pump sources for their drinking water supply. However; the improper methods of human and environmental wastes disposal constitute a great source of contamination to these water bodies. Few residents in the community could afford to buy bottled water. This shows that a substantial number of people in the community are subject to contracting water borne diseases since the majority use borehole and well water sources. Heavy metals occur as natural constituents of the earth crust, and are persistent environmental contaminants since they cannot be degraded or destroyed (J. O. Duruibe *et al.,* 2007). Heavy metal concentrations in water depend on the physicochemical parameters of the water body and the solubility of toxic metals increases as the pH decreases (H. R. Anwan, *et al.,* 2021). The metal concentrations in this study were lower than those reported in Amassoma river, Niger Delta, by (L. L. Nwidu *et al.* 2013); in Iju river by (A. A. Mutiu *et al.,* 2013) and in Agbara, (O. Ogundele and G. O. Mekuleyi, 2018). Similarly, the concentration levels of all the heavy metals reported in this study are below those reported by (S. K. Kamaruzzaman *et al.* (2011) and (M. G. Mortuza and F. A. Al-Misned 2017). All the values of heavy metals recorded in this study are below the maximum permissible limits recommended by WHO (2017), EU (2010) and SON (2007). Although iron (Fe), zinc (Zn) and copper (Cu) are heavy metals, they are essential micro-nutrients for living organisms (G. Pandey and S. Madhuri, 2014). At high concentrations however, Fe becomes toxic to living things and may result in various biochemical disorders (M. Ndukwe *et al.*, 2019). Zinc is a 'masculine' element that balances copper in the body, and is essential for male reproductive activity (K. Nolan, 2003). It serves as a co-factor for dehydrogenating enzymes and in carbonic anhydrase (Holum, 1983). Zinc deficiency causes anemia and retardation of growth and development (J. O. Duruibe *et*

al., 2007). Exposure of humans to cadmium could result in damage to bones, kidneys, DNA and nephrotoxicity (M. Ndukwe *et al.*, 2019).

CONCLUSION

Increased risks to infant mortality resulting from water borne diseases remain a major concern in Ogun state. The attitude of the residents of Ado-odo/Ota LGA towards water handling and usage exposes the children to water borne diseases since majority of the inhabitants use water from unprotected surface water sources. The values of water parameters and heavy metal concentrations recorded in this study are well below the maximum levels recommended for human consumption. Accordingly, it could therefore be concluded that drinking water sources in Igbesa are safe for human consumption.

Author Contributions

Anwan H. R. and Ezeh F. C. were involved in the conception and design of this study. Anwan H. R.,supervised the study, conducted the literature review, carried out the analysis, and drafted the manuscript. Ezeh F. C. gave advice on interpretation, and revised and edited the manuscript. Both authors read and approved the manuscript. Grace T. Bello is a graduate of Environmental Biology, Class of 2020, Ogun State Inst. of Tech., Igbesa. The student worked with the corresponding author in administering questionnaire and collection of data throughout the period of the study.

Conflicts of Interest: The authors declare no conflict of interest.

REFERENCES

A. C. Lucas, & H. M. Gilles. (2015) A Short Textbook of Preventive Medicine for the Tropics. Hodder and Stoughton, London. Sydney. Auckland. Toronto

A. Mutiu, I. Gbolahan, A. Oluwaseyi, F. H. Osoteku, Y. A. Fasuyi, T. A. Adeyemi, A. Adedokun and A. A. Adelowo. (2013) Water Quality Assessment of Iju River in Ogun State, Nigeria: Effect of Human Activities. *Journal Of Environmental Science, Toxicology And Food Technology* (IOSR-JESTFT). (6): 64-68

A. S. Ogbiye, (2017). Pollution problems and an engineering approach to the management and control of industrial effluents in Ota, Nigeria. Ph.D. Thesis, Department of Civil Engineering, Covenant University, Ota, Ogun State**,** Nigeria.

APHA (2005). Standard Methods for the Examinations of Water and Wastewater. 21st Edition. American Public Health Association/ American Water Works Association/Water Environment Federation, Washington DC.

CIA (2010). The world factbook". Central Intelligence Agency. Archived from the original on 5 January 2010. Retrieved 20 December 2008.

D. F. Charon,T. Edge, M. D. Fleury, W. Galatianos, D. Gillis, (2005) Links Between Climate, Water And Waterborne Illness, and Projected Impacts of Climate Change.

D. O. Omole and E.O. Longe. (2018). "An assessment of the impact of abattoir effluents on River 1110, Ota, Nigeria". *J. Environ. Sci. &Tech.)* (2).56-64.

D. O. Omole and J. M. Ndambuki. (2015). Nigeria's Legal Instruments for Land and Water Use: Implications for National Development. In: Evans, O. (Ed.), In-Country Determinants and Implications of Foreign Land Acquisitions. *Business Science Reference,* 1. Hershey, PA, USA, pp: 354-373.

D. O. Omole, C. P. Emenike, I. T. Tenebe, A. O. Akinde and A. A. Badejo. (2018) An Assessment of Water Related Diseases in a Nigerian Community. Covenant University, P.M.B. 1023, Ota, Ogun State, Nigeria. *Research Journal of Applied Sciences, Engineering and Technology* 10(7): 776-781.

Delpla, I. A. V. Jung, E. Baures, M. Clement, O. Thomas. (2009). Impacts of climate change on surface water quality in relation to drinking water production. *Environ. Int.* 35: 1225– 1233, DOI: 10.1016/j.envint.2009.07.001 1

E. O. Longe, D. O. Omole, and C. S. Mgbachi. (2018). Assessing the Safety Of Drinking Water Sources In Ado-Odo/Ota Local Government Area, Ogun State, Nigeria, Department of Civil and Environmental Engineering, University of Lagos, Akoka, Yaba, Lagos State, Nigeria. *Journal of Engineering Research,* (17) 1:

E.U. European Union (Drinking water) Regulations (2014). S.2. No. 122 of 2014.

F. C. Ezeh and H. R. Anwan. (2022). Spotting Specific Agricultural Practices Impacting Desertification in Zamfara State, Nigeria. *Journal of Environment and Earth Science.* Vol. 12, No.8 10-20

F. C. Ezeh. (2016). Anthropogenic Factors, Desertification and Environmentally Sensitive Area Indices for Sudano-Sahelian Region: A Case Study of Zamfara State. Unpublished PhD thesis. Centre for Environment and Science Education. Lagos State University, Ojo, Lagos.

G. Pandey and S. Madhuri, (2014). Heavy Metals Causing Toxicity in Animals and Fishes *Research Journal of Animal, Veterinary and Fishery Sciences, 2* (2), 17-23.

H. R. Anwan, M. A. Anetekhai and G. O. Mekuleyi, (2021). Assessment of physico-chemical characteristics and heavy metal concentrations of Stubbs creek, Ibeno, AkwaIbom, Nigeria. *International Journal of Advanced Academic Research*. (7) 5: 15-26

J. O. Duruibe, M. O. C. Ogwuegbuand J. N. Egwurugwu, (2007). Heavy metal pollution and human biotoxic effects. *International Journal of Physical Sciences*. 2 (5): 112-118.

K. N. Ibemenuga, K. N. (2013). Bioaccumulation and toxic effects of some heavy metals in freshwater fishes. *Animal Reseach International*. 3(3): 553-56

K. Nolan. (2003). Copper Toxicity Syndrome, *J. Orthomol. Psychiatry* 12(4): 270 – 282.

K. Y. Raneesh.(2014). Impact of Climate Change on Water Resources. *J. Earth Sci. Clim Change*. 5:185. doi: 10.4172/2157-7617.1000185.

L. L. Nwidu, B. Oveh, T. Okoriye, and N. A. Vaikosen (2012). Assesment of the water quality and prevalence of water borne diseases in Amassoma, Niger Delta, Nigeria, Niger Delta University, Bayelsa State, Nigeria. *African Journal of Biotechnology*. 7 (17). 2993-2997.

M. Baiwen, H. Chengzhi, J. Zhang; U. Mathias and P. Stefan (2022). *ACS EST Water* 2, 2, 259-261.

M. G. Mortuza and F. A. Al-Misned, (2017). Environmental contamination and Assessment of heavy metalsin water, sediments and shrimps of Red sea coast of Jizan, Saudi Arabia. *J. Aquat Pollutionand Toxicology*. :1-8

M. Ndukwe, M. Elenwo, and N. N. Ngozi Nma Odu. (2019). Proximate Composition, Minerals and Heavy Metals Content of Cassava, Plantain and Yam Flour Sold in Some Markets in Port Harcourt, Nigeria *Asian Food Science Journal.* 11(2): 1-11.

National Population Commission (NPC) (2006). Nigerian Population Census Report. National Population Commission, Abuja. 21-27.

O. Ogundele, and G. O. Mekuleyi. (2018). Physico-chemical properties and heavy metals concentration in Waste Water discharged from two industries in Agbara, Lagos State, Nigeria *International Research Journal of Public and Environmental Health*. 5 (3):32-37.

O. Oguntoke, O. J. Aboderin, A. M. Bankole (2009) Association of Water-Borne Diseases Morbidity Pattern and Water Quality in Parts of Ibadan City, Nigeria. *Tanzan J Health Res.* 11(4):189-195.

O. Olorunfemi, and G.O. Mekuleyi, G.O. (2018). Physico-chemical properties and heavy metals concentration in waste water discharged from two industries in Agbara, Lagos State, Nigeria *International Research Journal of Public and Environmental Health*. 5 (3):32-37.

OtaLocal Government Area of Ogun State, Nigeria. *Asian Research Journal of Arts and Social Sciences*. 2(1):1-11.

R. Scherlenlieb. (2013). "Priority areas for applied research. Global applied research network (GARNET) working paper no.3".

S. A. Ogunyemi, O. O. Ajileye, K. H. Muibi, A. T. Alaga, O. E. Eguaroje, S. A. Samson, O. O. Omisore. (2017). Geo-information and Distribution pattern of Petrol service station in Sango-Ota Metropolis in Ado-Odo Ota Local Government Area of Ogun State, Nigeria. *Asian Research Journal of Arts and Social Sciences.* 2(1):1-11.

S. Mushahida-Al-Noor, and S. K. Kamruzzaman, (2013). Spatial and Temporal variations in physical and chemical parameters in water of Rupsha River and relationship with Edaphic factors in Khulna, South Western Bangladesh. *International Journal of science and Research*. 2(1):457-467.

Standards Organisation of Nigeria (SON). (2007). Nigerian standard for Drinking water Quality. Abuja,Nigeria. 20: 15-19.

UNICEF (2014). Child Survival Fact Sheet: Water and Sanitation. United Nations Children's Fund, New York, NY 10017, USA. Available at www.unicef.org

United States Environmental Protection Agency (2019a). Southern Nevada Water Authority Assesses Vulnerability to Climate Change. https://www.epa.gov/arc-x/southern-nevada/

United States Environmental Protection Agency (2019b). Tampa Bay Diversifies Water Sources to Reduce Climate Risk. https://www.epa.gov/arc-x/tampa-bay/

WHO (2008). Guidelines for Drinking-water Quality. Third Edition Incorporating. The First And Second Addenda Volume 1.

WHO (2017). Guidelines for Drinking Water Quality (2nd Ed.) Vol. 3: Surveillance and Control of Community Supplies. World Health Organization Library Cataloguing in Publication Data.

WHO, (2013) Water Sanitation Health, Facts and Figures on Water Quality and Health. WHO, Water Sanitation Health, Water-related diseases.

****