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ENSURING AVAILABILITY AND SUSTAINABLE MANAGEMENT
OF WATER AND SANITATION FOR ALL

Groundwater quality in shallow unconfined sedimentary aquifers in Bida, Nigeria

A. Idris-Nda[1], H.D. Salihu[1], A.M. Jimada[2], & A. Babadoko[3] (Nigeria)

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A study on the water quality of unconfined shallow aquifers was conducted with the aim of assessing physicochemical and bacteriological contamination of groundwater as a result of poor design of water and sanitation facilities in Bida, Nigeria. The study was conducted using a grid-based approach on wells, boreholes, surface water and households. The water has a high Total Dissolved Solids. Slightly acidic pH and mean distance of wells to waste disposal facilities is 12m. Chemical parameters that occur in high concentrations are sulphates, chlorides, nitrates and sodium and total coliform is very high. Contamination of deeper sources of water from the dug wells is both lateral and vertical with contamination plume spreading to better planned areas. Surface water has the least contamination and is proposed for water supply. Sanitation facilities should be upgraded from pit to ventilated improved pit latrines.

Introduction

The study area, Bida lies on latitude 9°05'08″N and longitude 6°00'36″E at an altitude of 151m with a total surface area of 51 km square. It is located in central Nigeria and is the second largest city in Niger State, one of the 36 federating states in Nigeria, with a population of 224,132 projected to 2015 from the 2006 population census using an annual growth rate of 3.4%. The area is drained mainly by River Landzu which runs in the E-W direction and cuts the town roughly into two. Houses in the area are built close to each other and consist of old buildings that are over 100 years old and more modern ones.

The area is underlain by rocks belonging to the Maastrichtian Bida Basin and comprises basically of sandstones, siltstones, mudstones, shale and clay, and is in places capped by the lateritic ironstone. Groundwater in the area occurs in three aquifer levels which are unconfined, semiconfined and confined occurring at 3-60m, 80-150m and >170m respectively (Idris-Nda, 2010). Groundwater use is mostly restricted to the use of hand dug wells and shallow boreholes all placed within the unconfined aquifer. As a result of the complete failure of the public water supply system attention has turned fully to the use of groundwater as the main source of water supply for the inhabitants.

Sanitary facilities consist of shallow pit latrines and pour flush (locally known as soakaway) and open defecation by children. Waste disposal is by use of open dumps located in open spaces between houses and the drainage systems which have consequently become littered with all kinds of wastes including polythene bags, which are the common packaging materials in the area.

Due to the high population density within a relatively small area, water and sanitation facilities coexist side by side and both are mostly in direct contact with the water table. This situation is likely to have a negative impact on the water quality, owing to the poor design of both water and sanitary facilities.

Aim and objectives

The work is aimed as assessing the effects of poor design and construction of water and sanitation facilities in Bida, central Nigeria.

The main objectives include:

- Determine water and sanitation facilities design and proximity in the area

- Determine the water level and direction of groundwater flow
- Determine the physicochemical and bacteriological composition of groundwater
- Propose strategies for effective use and sustainability of water and sanitation facilities.

Methodology
In order to meet the objectives of the research work the following methodology was adopted.
- Sampling of wells, boreholes and households in the area was conducted using the grid-based approach. The area was divided into 250m x 250m grids and samples were taken within each alternative grid. Wells, boreholes and sanitary facilities within each grid were carefully recorded and questionnaires administered to respondents within the grid. Coordinates of locations were established using a hand-held Global Positioning System, Etrex Legend H.
- Questionnaires, oral interviews and visual inspection were used to determine water and sanitation facilities in 250 households.
- Depth and water levels of wells and boreholes were determined using a water level dip meter. Some of the installed boreholes were lifted slightly to access the depth and water level.
- 100 water samples were taken in glass and plastic bottles across the area and taken to the laboratory for analysis using standard analytical methods (Atomic Absorption Spectrometry, Titrimetric and Flame Photometry). Physical parameters of pH, Eh, Conductivity, Temperature and Total Dissolved Solids, were taken at the point of sampling. Microbial analysis was conducted using the American Public Health Association (APHA, 2005) standards for the examination of water and wastewater. All other analysis were in conformity with this standard.
- Direction of groundwater flow was determined by using water table elevation contour maps derived from measured results. The differences in water table elevation between wells with the highest and lowest elevations were connected to form a triangle from which the direction of groundwater flow was determined. Vertical flow components were computed from sieved samples using empirical methods. Downward flow component was indicated by the negative hydraulic gradient computed from the water level elevations.

Results and discussion

Water and sanitation facilities
Field surveys and questionnaire analysis showed that the area has 250 to 350 boreholes and 30 to 50 hand dug wells, with the exception of a few hand pump operated boreholes (less than 5%) all others are motorised and pump water to elevated plastic facilities and discharged through 3 – 5 fetching points for public use. 10% of the boreholes are located in individual households for private use. With the exception of five hand dug wells that are concrete lined, all others are unlined. The average access to water is one borehole per 680 people, this is considered inadequate. According to the Humanitarian Charter and Minimum Standards in Humanitarian Response (The Sphere Project, 2004) the number of people per source depends on the yield and availability of water at each source, a maximum of 500 people is recommended per borehole and 400 per single-user open well assuming accessibility of constant water supply for at least eight hours a day.

Sanitation facilities consist of open dug pits covered with a slab and pour flush system using two chambered septic tanks. The pit latrines have a depth range of 3 – 6m and are mostly in direct contact with the water table especially during rainy season which lasts for about seven months. The septic tank consist of two interconnected chambers, the first chamber is where the waste is first discharged into and the second chamber contains the sewage which is allowed to drain freely into the surrounding rocks through perforations made in it. The first chamber is cemented while the second is not, they are constructed up to depth ranges of 2 – 3m. The average distance of the sanitary facilities to the water facility in the area is 12.2m. If the local hydrogeological conditions are ignored, pit latrines can cause significant public health risks via contaminated groundwater (Buitenkamp and Richert, 2008).

Water level and groundwater flow direction
Depth of hand dug wells range from 14 to 8m with a mean depth of 10.94m, mean depth of boreholes on the other hand is 37.83m. Water level in the hand dug wells range from 14 to 8m while in boreholes the range is from 12 to 8m. Since the water is in an unconfined state it is at atmospheric pressure and thus occurred at almost the same level in both hand dug wells and boreholes placed in it. The town has a mean elevation of

145m above mean sea level, mean elevation of water level is 136.8m with boreholes having a mean elevation of 134.8m and hand dug wells 132m, surface water is at an elevation of 138m. Figure 1 is the graph of mean water level elevation in the area. Groundwater flow is principally in the SE-NW direction with a minor E-W flow component (figure 3). Determining flow direction is important for mapping recharge areas and contaminant migration path.
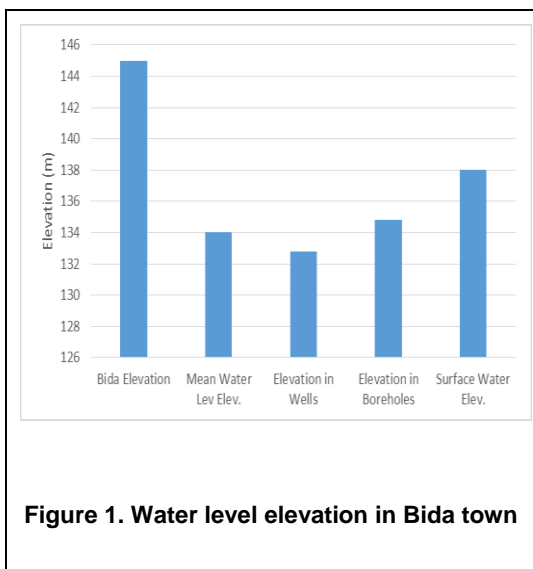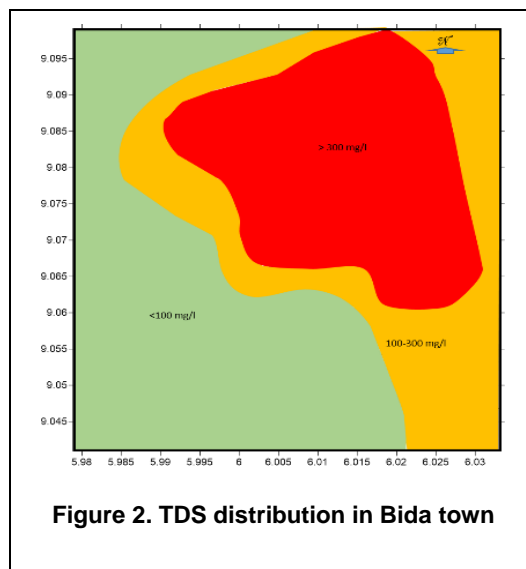

Figure 1. Water level elevation in Bida town

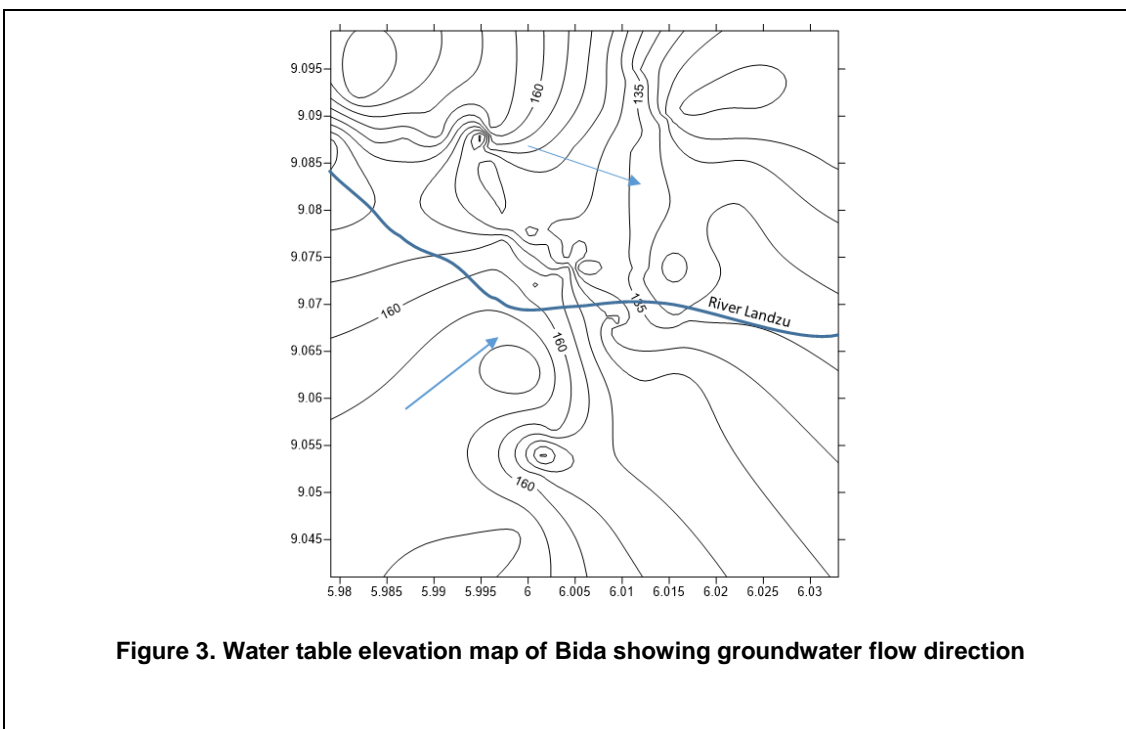**Figure 2. TDS distribution in Bida town**

Figure 3. Water table elevation map of Bida showing groundwater flow direction

Physicochemical and bacteriological composition of groundwater

Table 1 is the results of the mean values of physical parameters of groundwater in Bida area, generally pH is slightly basic at 8.72, Eh (redox potential) which is a measure of the tendency of the solution to either gain or lose electrons and a common measurement for water quality, is -80.1 indicating water that is more in the reduced state with a high tendency to donate electrons. Mean temperature is 29°C, Electrical Conductivity (EC) which is an indication of the dissolved chemical constituents of the water is 0.402mS/cm while Total Dissolved Solids (TDS) which is a measure of the combined content of all inorganic and organic substances

contained in the water and is used as an aggregate indicator of the broad presence of a broad array of chemical contaminants, is 258mg/l. Surface water has the least TDS value of 32mg/l while dug wells have the highest with 385mg/l and boreholes occupy an intermediate position with 148mg/l. Even though the acceptable limits for TDS is 1000mg/l some dug wells in the area have concentrations above this limit. Figure 2 is the map of the area showing TDS concentration in both wells and boreholes. Concentration is found to be higher in areas that are more densely populated than in low populated areas with better sanitary facilities.

Table 1. Results of physical parameters of groundwater

Parameter	Groundwater Mean	Boreholes	Dug Wells	Surface water
pH	8.72	8.78	8.65	7.67
Eh (mV)	-80.10	-84.95	-74.53	-65.10
Temperature (°C)	29	28	29	24
Conductivity (mS/cm)	0.402	0.231	0.599	0.050
TDS (mg/l)	258	148	385	32

Table 2. Results of mean concentration of chemical parameters of groundwater

	Sodium	Calcium	Potassium	Magnesium	Sulphate	Phosphate	Chloride	Bicarbonate	Nitrate	Nitrite
Dug Wells	68	28	49	43	92	3	67	15	57	0.1
Boreholes	21	13	14	10	27	1	19	5	17	0.1
Surface Water	18	20	12	8	20	4	10	10	3	0
NDWQS	200			20	100		250		50	0.2

Laboratory analysis of the chemical and bacteriological constituents of the water shows that sulphates, chlorides, nitrates and sodium are the chemical constituents that occur in high concentrations with sulphate and nitrates exceeding the WHO (2006) and NDWQS (2007) standards (100 and 50 respectively) for drinking water. Sulphate concentrations range from 230 to 80mg/l while nitrate ranges between 110 and 13mg/l. Chloride concentration ranges between 180 and 20mg/l. Total coliform ranges from 200 to 12cfu/100ml, faecal coliform and faecal streptococci ranges from 80 to 6cfu/100ml and 73 to 1cfu/100ml respectively, WHO limit is 0cfu/100ml for all parameters.

Table 3. Results of mean concentration of Trace Elements in water

	Iron	Fluoride	Chromium	Zinc	Copper	Nitrite
Dug Wells	0.7	0.6	0.3	2.5	1.2	0.1
Boreholes	0.1	0.3	0.1	0.3	0.2	0.1
Surface Water	0.1	0.1	0.0	0.1	0.3	0.0
NDWQS	0.3	1.5	0.05	3	1	0.2

Table 4. Results of mean concentration of microbial parameters in groundwater

Parameter (cfu/100ml)	Total Coliforms	Faecal Coliforms	Faecal Streptococci
Wells	89	24	23
Boreholes	20	1	0
Surface Water	13	2	0

Photograph 1. Public water supply with borehole and septic tank

Source: WEDC - Source

Mitigation strategies will involve the following:
- Improving the present unlined pit latrines by upgrading to the Ventilated Improved Pit (VIP) latrines. As a very general guideline it is recommended that the bottom of the pit latrines should be at least 2 m above groundwater level, and a minimum horizontal distance of 30 m between a pit and a water source is normally recommended to limit exposure to microbial contamination (WEDC, 2012).
- Closing down all wells and boreholes placed on shallow aquifer sources and replacing them with well-designed boreholes ones that targets deeper sources of water.
- Groundwater development should be monitored and licensed to protect the resource.
- Surface water should be developed for public water supplies to reduce over dependence on groundwater sources.

Conclusions

Common constituents as a result of domestic waste that lead to groundwater contamination and which can be potentially harmful include chloride, copper, nitrate, nitrite and sulphate while bacteriological constituents are mainly coliform bacteria (USGS, 2015). All these parameters are found to be present in concentrations considered above acceptable limits in the groundwater of Bida area. Concentrations are generally higher in dug wells than in boreholes but lowest in the surface water. Transmission of the contaminants was found to be vertically downwards to the deeper water sources and laterally to areas not presently seriously affected.

Lessons learnt

- Groundwater in shallow unconfined aquifers is vulnerable to contamination from human activities on the surface, especially poor sanitary facilities like pit latrines.
- Contamination plume may spread laterally to unaffected areas and also downwards to deeper sources.
- In densely populated areas groundwater development should be through well designed wells and boreholes and the water should be treated been used for drinking.

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References

APHA, (2005). Standard methods for the examination of water and wastewater. American Public Health Association (21st Ed.) Washington DC, USA.

Buitenkamp, M., Richert, S. A. (2008). Europe's sanitation problem - 20 million Europeans need access to safe and affordable sanitation. Women in Europe for a Common Future (WECF), The Netherlands

Idris-Nda, A. (2010). Hydrogeophysical and Hydrogeochemical characterisation of the Bida Basin aquifer system. Unpb PhD thesis, Federal University of Technology, Minna, Nigeria.

NDWQS (2007). Nigerian Standards for Drinking Water Quality, Nigerian Industrial Standards, Standards Organisation of Nigeria, Abuja, Nigeria.

The Sphere Project (2004). Humanitarian Charter and Minimum Standards in Disaster Response, Geneva, Switzerland.

WEDC. Latrine slabs: an engineer's guide, WEDC Guide 005 (2012). Water, Engineering and Development Centre The John Pickford Building School of Civil and Building Engineering Loughborough University. p. 22. ISBN 978 1 84380 143 6.

WHO (2006). Guidelines for Drinking Water Quality. World Health Organisation, Geneva, Switzerland.

USGS (2015) Water Science School. Groundwater quality. U.S. Department of the Interior, U.S. Geological Survey. http://water.usgs.gov/edu/earthgwquality.html

Contact details

About the author: Dr Idris-Nda, Abdullahi is a lecturer at Federal University of Technology, Minna with particular interests in groundwater, mining and environmental management. Mr. Salihu Haruna Dantata is also a lecturer on environmental management and remediation. Mr. Jimada Abdulkadir Mohammed is the head of sanitation with specialisation on latrines design and groundwater protection. Dr. Aliyu Babadoko is a lecturer at the Federal Polytechnic Bida with research interests in microbiology and the environment.

Idris-Nda Abdullahi
Dept. of Geology, F.U.T. Minna, Nigeria.
Tel: +234 8036273815
Email: idrisnda@futminna.edu.ng
www: http://futminna.edu.ng

Salihu Haruna Dantata
Dept. of Geology, F.U.T. Minna, Nigeria.
Tel: +234 8036352939
Email: Salihu.dantata@futminna.edu.ng
www: http://futminna.edu.ng