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Groundwater Contaminated by Nitrates—A Case Study of Ado-Ekiti, Ekiti State, Southwestern Nigeria

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Abstract: Nitrate is one of the problematic and wide spread contaminations. Indiscriminate disposition of human and animal wastes in Nigeria especially in urban region, and lack of proper environmental sanitation geared the need for the monitoring of groundwater contamination. This research work monitored the concentration of nitrate and nitrate-nitrogen in portable water from wells in Odo Ado, Ado-Ekiti, Ekiti State, and examined the relationship between this concentration and the well depth as well as its nature (ringing). The results showed that out of 20 water wells sampled, 50% of samples contain high level of nitrate with the highest having concentration of 140 mg/L and least 49 mg/L while the remaining has acceptable concentration ranging between 3.5 mg/L and 35 mg/L with most ringed wells. The mean concentration of nitrates is 48.06 mg/L and the nitrate-nitrogen is 10.85 mg/L. The statistical correlation between the concentrations and depth showed that there is a significant difference between their means at 95% confidence using *T*-test. Out of ringed wells, five have high concentration and eight have low concentrations while two of the wells (not ringed) fall below the acceptable limit (EPA) which indicates that there are other factors such as closeness to the point source and soil texture which were not considered in this work.

Key words: Nitrate, contamination, depth, groundwater, aquifer.

1. Introduction

Nitrate contamination of the world's groundwater supply posses a series of problems to the human health, especially where the only source of drinking water is ground water. High nitrate levels found in drinking water have been proven to be the cause of numerous health conditions across the world. Both regionally and nationally, concern about nitrate contamination has prompted a number of studies dealing with the relationships between agriculture and nitrate contamination of groundwater [1-3]. Water monitoring has throughout much of Pennsylavania of relatively low concentration, but in area of intensive farming, nitrate-nitrogen concentration may approach or exceed the EPA (Environmental Protection Agency) drinking water limit of 10 mg/L; also a survey of nitrate concentration in portable water in calabar municipal showed that 80% of water samples analyzed had nitrate concentration above the international permissible limit [4]. This was related to inadequate waste disposal system and agricultural practices.

Geologic unit can contribute to groundwater nitrate level [5]. Many sources of nitrate and ammonium came from the production and use of fertilizer, anaerobic decay of organic matter, bacteria decomposition of excreta and the burning of fuels [6]. Among factors contributing to the occurrence of nitrate in the shallow groundwater are irrigation-well density, subsurface clay lenses and land use practices. Work in Nebraska, Iowa, Minnesota and Wisconsin indicates that nitrate-nitrogen levels in shallow groundwater may occur because of nutrient loading to shallow water tables and low vertical gradients and that decreasing nitrate-nitrogen concentrations with

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depth may occur because of low vertical gradients and possibility of denitrification [2, 3, 7].

Mere exposure to nitrate is not of particular interest with respect to human health. However, nitrate can be reduced endogenously (within the human body) to nitrite through bacterial and other reactions; nitrite can be further reduced to N-nitroso compounds (NOCs). Infant (< 6 months of age) exposed to nitrite has been linked to development of methemoglobinemia. NOCs are some of the strongest known carcinogen [8], can act systemically [9], and have been found to induce cancer in a variety of organs in more than 40 animal species including higher primates [10]. While some vegetables (lettuce, spinach, celery, greens, etc.), contaminated drinking water, cigarette smoking, and certain medications all contribute to daily nitrate intake in the U.S. population [11], drinking water can account for a substantial portion of that intake.

Data are generally scarce on the nitrate concentrations in private well water. So cancer studies are difficult as they relate to nitrate contamination. The population could be at risk of exposure to high levels in water, as many private rural wells are shallow and thus more susceptible to contamination. Thus, this provides a need to monitor the concentration of nitrates in the drinking water well, and a research on water quality in private wells would be a good investment of resources in order to develop a baseline to track progress or decline in private and public sub-urbanized drinking water quality.

The purpose of this study was to monitor the spread of nitrates within the chosen study area. This research aimed at determining the concentration of nitrate and nitrates-nitrogen in the groundwater to access the level of well water contamination and variables associated with the distribution of contamination. The main variables examined in this study were the depth of the well and its nature, i.e., ringed or unringed. The results of this work are to advise the local-groundwater management bodies companies sinking water-well and government on proper designing of the water well, and in making viable decision on the environmental implications of area that may be vulnerable to nitrate contamination.

2. Study Area

The site investigated is Odo-Ado in Ado-Ekiti, Ekiti State, southwestern Nigeria. A densely populated part of Ado-Ekiti city is the capital of Ekiti state with no organized waste disposal system. Wastes are generally disposed off indiscriminately and through shallow pits (for human faeces). This situation in addition to piggery farming practices around the area is bound to constitute a major quality problem to the portable water source, surface water and shallow aquifers. High concentration of nitrates in water has been largely related to inadequate waste disposal system and agricultural practices. Odo-Ado is chosen as a case study area because of its location in central part of Ado-Ekiti and will serve as a reference for the city.

Ado-Ekiti is located between latitudes 7°36′ N and longitudes 4°14′ E. The elevation of these areas varies from 390 m to 522 m and area is lowland, surrounded by several isolated hills and icebergs. The topography of the area is rugged due to the presence of crystalline basement rocks like charnokite and quartz which rise abruptly above the surrounding country rocks. Water supplies for domestic purposes are mainly from shallow hand dug, boreholes and streams.

3. Materials and Method

The samples of drinking water were collected from 20 wells across Odo-Ado, in Ado-Ekiti State. Samples were collected with nitrate test kit; the kit contains a sterilized sample bottle and information form. The samples were transported to the laboratory for nitrate and nitrate-nitrogen analysis. The concentration of nitrate ions (NO_3^-) and (NO_3-N) in mg/L was measured using a nitrate ion selective electrode. GPS (gobal position system) was used to measure the coordinate of the locations. Metal meter tape was used to determine the depth of the wells. The domestic wells are near potential point sources of contamination, such as livestock facilities and sewage disposal areas. In most areas, wells are near toilet and 30% of the samples collected from well is of about 12 m in depth, which might not be deep enough for drinking water. Also, in some areas like agric street, Fatai compound, Adebayo villa, olaleye compound, the wells are not cement grouted, so surface contamination can enter the wells.

4. Results and Discussion

The geographical parameters, i.e., depth, and the results of the analysis are presented in Table 1. Concentration of nitrate and nitrate-nitrogen was given in milligram per litre (mg/L). Fig. 1 shows the chart that depicts the concentration of nitrate and nitrate-nitrogen in 20 wells.

4.1 Concentration of Nitrate (NO_3^-) in the 20 Selected Water Wells

It was reflected from the Fig. 1 that nitrates were detected in all the 20 water samples. The concentrations of nitrate in samples range from 3.50 mg/L to 140.00 mg/L. Sample W15 has the highest concentration of 140.00 mg/L, and sample W9 has the least (3.5 mg/L). Samples W1, W2 and W20 have moderately high values of nitrate and exceed the permissible limit proposed by EPA (Environmental Protection Agency). Samples W3, W5, W7, W8, W9, W10, W11, W13, W17 and W18, all were within the permissible limit as proposed by EPA. This may be due to the low use of nitrate fertilizer and absent of deposited waste materials or domestic wastes or due to geogenic formation of the place. Sample W4, W13, W15, W16 and W19 have the high nitrate concentration that exceeds the permissible limits and may be due to excessive use of nitrogen fertilizer, livestock facilities and sewage disposition. High intake of nitrate has been linked to some unfavorable health conditions, especially in infants.

4.2 Concentration of Nitrate-Nitrogen (NO_3-N) in the 20 Selected Water Wells

It was shown that nitrate-nitrogen (NO_3-N) was

Table 1 Concentration of nitrate (mg/L) and nitrate-nitrogen (mg/L) with depths in the 20 selected drinking water wells.

Sample codes	Absorbance	NO_3^- (mg/L)	NO_3-N (mg/L)	Remarks	Depth (m)
W1	0.060	56.00	12.64	RR	10.00
W2	0.050	49.00	11.06	NR	11.70
W3	0.010	07.00	01.56	RR	17.00
W4	0.125	112.00	25.28	NR	10.50
W5	0.030	28.00	06.32	RR	18.18
W6	0.068	59.00	13.32	RR	12.50
W7	0.012	07.00	01.58	RR	20.50
W8	0.013	07.00	01.58	RR	20.20
W9	0.004	03.50	00.79	RR	20.10
W10	0.025	28.00	06.32	RR	17.30
W11	0.040	28.70	06.47	RR	24.50
W12	0.080	70.00	15.80	NR	16.20
W13	0.030	28.00	06.32	RR	19.70
W14	0.016	58.00	13.09	RR	11.20
W15	0.150	140.00	31.60	NR	18.70
W16	0.110	98.00	22.12	NR	09.70
W17	0.028	28.00	06.32	NR	19.00
W18	0.035	35.00	07.90	NR	20.00
W19	0.070	63.00	14.22	RR	12.90
W20	0.042	56.00	12.64	RR	17.90

10 mg/L nitrate-nitrogen (NO_3-N) ≡ 44.30 mg/L nitrate (NO_3^-). RR: ringed, NR: not ringed.

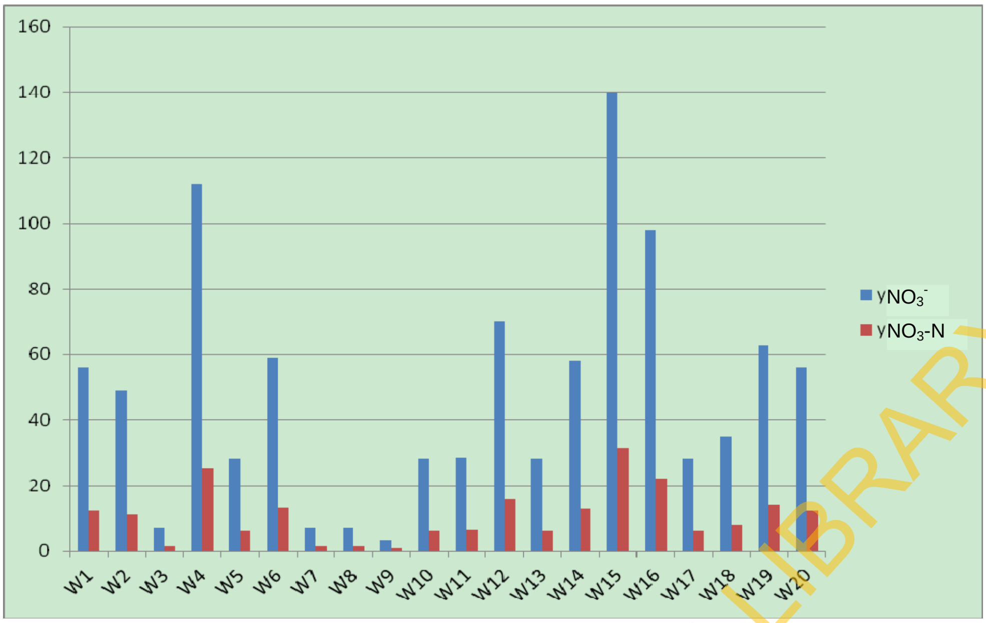

Fig. 1 Concentration of NO_3^- and NO_3-N with depth in mg/L in the 20 selected water wells.

detected in all 20 samples with concentration of sample W15 (31.60 mg/L), the highest and sample W9 (0.79 mg/L), the lowest. The concentration of sample W9 is very low compared to other samples and is below the EPA limits, which may be due to location of the well, far away from any potential sources of contamination. Samples W3, W5, W7, W8, W10, W11, W13 and W17 have slightly low concentration values of nitrates-nitrogen (NO_3-N) while samples W1, W2, W14 and W20 have slightly high values of concentration which is above the permissible limit proposed by EPA. This may also be due to the shallow depth of the wells and proximity to the source of contamination.

4.3 Statistical Analysis

For estimation of the correlation coefficients between depths and nitrate/nitrate-nitrogen concentration, *T*-test was use to test if there is a significant relationship between the depth and nitrate/nitrate-nitrogen concentration. The significant level was 95%. The average depth of the wells is 16.4 m. The depth of the shallow well is 9.7 m while the deepest is 24.5 m. The mean concentration of nitrate is 48.03 mg/L while that of nitrate-nitrogen is 10.85 mg/L. The value of *T*-test between depth and NO_3^- is 3.88 mg/L at 0.05 levels. This shows that the two means are significantly different indicating that nitrate/nitrate-nitrogen concentration depends on the factors, such as closeness to the point source, i.e., dumping site, farmshed, septic tanks etc.. Value of *T*-test for NO_3-N is 3.009 at the same level. The means implies that there is significant different with depth. The nature (casing or ringing) is an important factor which relates to the concentration of nitrate in well water. It was shown from the research that 65% of the wells sampled were ringed while the remaining 35% were not ringed. The mean concentration of nitrate in the wells with ring is 33.02 mg/L while for wells not ringed is 76 mg/L. There is little effect of ringing from the statistical analysis.

5. Conclusion

From the general results that were obtained from the analysis of 20 water samples collected from hand-dug water wells, Odo-Ado in Ado Ekiti, Ekiti State, Nigeria, 10 samples are good for drinking while the remaining 10 did not meet the limit of drinkable water as recommended by the EPA (Environmental

Protection Agency) and WHO (World Health Organization) that specified that a portable water must not contain more than 10 mg/L of nitrate-nitrogen (NO_3-N) or total nitrate (NO_3^-) of 44.3 mg/L in water. However, 10 water samples contain high concentration of nitrate—W1, W2, W4, W6, W12, W14, W15, W16, W19 and W20; and the remaining 10 samples contain low concentration, thus are good for drinking. The installation of concrete rings in hand-dug wells has little effect on the quality of water from such wells. It is however concluded from this work that out of 20 wells analyzed, only 10 are good for drinking, while the remaining 10 may find best use in washing (cleaning), for sanitary disposal of domestics and human wastes, and agricultural purposes. It is also useful in fire fighting and in building construction works.

Due to the increasing population as well as improvement in standard of living and industrialization, the demand for adequate supplies of water has increased and medical evidence has shown that our health is strongly dependent on the condition of water we take. It is therefore recommended that water well should not be dug near the dumpsites, underground fuel tanks and sewage. Also, the government can help to facilitate the supply of purified/treated water of good quality to the citizenry.

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