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Full Length Research Paper

Effect of population and level of industrialization on underground water quality of Abia state, Nigeria - physico-chemical properties

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The physico-chemical properties of underground waters in Abia State, Nigeria were determined with a view to ascertaining the effect of population density and level of industrialization on the water quality parameters using Aba (a relatively industrialized city) and Umuahia (a city with very few industries) as a case study. Underground waters of Aba had mean pH value of 4.43 ± 0.13 which was significantly lower ($P < 0.05$) than a mean value of 5.17 ± 0.09 obtained for Umuahia. Underground waters of high population density areas had mean pH value of 4.29 ± 0.16 which differed significantly from 4.88 ± 0.13 obtained for medium population density areas. Low population density areas had significantly higher pH with a value of 5.23 ± 0.10. Levels of total dissolved solids, Ca^{2+}, Mg^{2+}, K^+, Na^+, SO_4^{2-}, PO_4^{3-}, NO_3^-, Cl^-, and NH_4^+ in the underground waters were also influenced by population density and industrialization. Significant relationship among some of these minerals were obtained, which indicated that they had common source.

Key words: Industrialization, Nigeria, population density, quality, underground, water.

INTRODUCTION

Water is one of the most vital natural resources necessary for the existence of life. In most urban cities in various countries such as Nigeria, it is the duty of the government to provide portable water. Most often this responsibility is not adequately discharged causing the inhabitants of those cities to look elsewhere to meet their water needs. The alternative may be unwholesome. In Abia State of Nigeria, the inability of the government to provide sufficient portable water has led private individuals to sink boreholes. Water from these boreholes is pumped out ‘raw’ and sold to the public without any form of treatment and is used for drinking and other household activities. As a result of the lucrative nature of this business, a lot of boreholes have sprung up in the major cities of Abia State. Groundwater, if abstracted from an adequately protected source has undoubtedly bacteriological and physical qualities comparable to those of treated water (Okoye and Adeleke, 1991). The slow percolation and horizontal flow through the ground is superb filtration, removing pathogens including viruses and bacteria (Chanlett, 1979; Pelig-Ba, 1996). The quality limitations result from mineralization by the dissolved carbon dioxide as the water passes over rock deposits and also from pollutants leached down from the earth surface. These processes could raise the concentrations of cations such as Ca^{2+}, Mg^{2+}, K^+ and anions like Cl^- and PO_4^{3-} above acceptable levels.

Moreover, poor sanitation practices or lack of them, improper municipal and industrial waste disposal systems could pose pollution problems to underground water supplies. For example, influent seepage of urine and leachate from polluted surroundings, a pit latrine or soak-away, sited upstream and near a borehole, could enrich the underground water with phosphate and nitrate (Okoye and Adeleke, 1991). Improper disposal of by-products of beer brewing, soap making and textile industries could lead to liberation of high levels of Ca^{2+}, Mg^{2+}, K^+ Cl^-, PO_4^{3-} and SO_4^{2-} into the environment which could be leached down into underground waters.

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Table 1. Effect of level of industrialization on the physical properties of underground waters of Abia State, Nigeria.

Level of industrialization	Location	Physical properties			
		Temp ^{0}C	Colour (Hz)	Turbidity (mg/l)	TDS (mg/l)
High	Aba	$28.2^a \pm 0.04$	$0.12^a \pm 0.03$	$0.01^a \pm 0.00$	$101.93^a \pm 4.02$
Low	Umuahia	$28.2^a \pm 0.12$	$0.02^b \pm 0.00$	0.01a ± 0.00	90.51b ± 3.68

TDS = Total dissolved solids.
Mean values on the same column with the same superscript are not significantly different at 5% level of probability.

In Abia State, environmentalists are concerned about the indiscriminate locating of boreholes in the cities of the State. Sometimes boreholes are located too near and down stream of latrines or soakaway pits belonging to adjoining buildings or very close to municipal and industrial waste dump sites. The quality of water from the boreholes cannot be guaranteed. The amount of pollutants in the waters will depend on the human population and level of industrialization of the area where the underground water is being exploited. Presently there is no information on underground water contamination in Abia State and also the influence of population and industrialization on the quality of underground water in Nigeria has not been reported. The objective of the first part of this study is to determine the effect of population and level of industrialization on the physico-chemical properties of underground waters of two cities (Aba and Umuahia) in Abia State of Nigeria.

MATERIALS AND METHOD

The study area

Abia State is one of the states in the South-eastern Nigeria. Aba and Umuahia are the two major cities in the State. Aba has so many large and medium scale industries while Umuahia is a "civil servants' city" with very little small scale industries. Aba in this study represented industrialized city while Umuahia represented non-industrialized town.

Sampling

Each of the two cities studied had been delineated into three zones by the Abia State Town Planning Authority. These zones were delineated based on population density. Low population density zones of each of the cities were areas having human population less than 600/km^2, medium population density zones have population between 600 and 3,000/km^2 while the high population density zones have population greater than 3000/km^2.

Ten boreholes were randomly chosen in each of the population density zones in each of the cities. The total number of bore holes studied was thirty in each city and a total of 60 for the two towns. Plastic containers each of two liters capacity were used in the collection of samples. The container was first washed with detergent, rinsed with distilled water and then with 5% nitric acid and finally with distilled –deionised water. At each sampling point, the plastic container was rinsed twice with water to be collected. The underground water was pumped out and allowed to run for sometime (15 – 20 min) prior to collection of water sample to ensure representative sample. An aliquot of the water sample was put in a plastic beaker and the temperature taken using a thermometer. The sample bottle or container was then filled with water and the container lid immediately replaced to minimize oxygen contamination and the escape of dissolved gases. The samples were thereafter stored in an ice packed cooler for analysis. Prior to each laboratory determination, the sample bottles were brought out to equilibrate with the environment.

Laboratory analysis

The pH of the water samples were determined with HANNA 211 pH meter. The colour and turbidity were measured with UNICAM spectrophotometer at 430 and 700 nm, respectively. The total dissolved solids in the water samples were determine gravimetrically and the electrical conductivity was determined with HANNA 200 conductivity metre. Calcium and magnesium in the samples were determined titrimetrically using EDTA. Potassium and sodium were determined using JENWAY PFP7 flame photometer (Isaac and Kerber, 1971). Sulphate and phosphate contents of the water samples were determined by turbidimetric and molybdenum blue colorimetric methods, respectively.

Statistical analysis

The data obtained were subjected to analysis of variance. Experimental means were compared using the DUNCAN new multiple range test (DNMRT). Relationships between parameters were examined using correlation analysis.

RESULTS AND DISCUSSION

The effect of level of industrialization on the physical and chemical properties of underground waters of Abia State is shown in Tables 1 and 2. Underground Waters of Aba were significantly more colored than those of Umuahia. The industrialized town, Aba has so many textile industries, these industries make use of dyes in achieving the desired textile colors. Effluents from these industries enter the environment and get leached down the soil profile into the underground waters. Umuahia does not have such industries, this therefore accounts for the differences in the level of coloring between underground waters of Aba and Umuahia. Apart from dyes, metallic ions can impart color to underground water. Industrial and human activities liberate metallic ions into the environment which eventually get leached down into the underground waters. These activities become more pronounced under high human population density. That is the reason behind the higher color intensity of the under-

Table 2. Effect of level of industrialization on the chemical properties of underground waters in Abia State, Nigeria.

Level of industrialization	Location	Chemical properties										
		pH	Elec. Cond.	Ca (mg/l)	Mg (mg/l)	K (mg/l)	Na (mg/l)	SO_4^{2-} (mg/l)	PO_4^{3-} (mg/l)	NH_4^+ (mg/l)	NO_3^- (mg/l)	Cl^- (mg/l)
High	Aba	4.43^b ± 0.13	68.47^b ± 2.73	38.53^a ± 2.81	22.04^a ± 2.81	3.52^a ± 0.77	6.90^a ± 0.74	0.33^a ± 0.13	0.04^a ± 0.01	0.25^a ± 0.02	0.03^a ± 0.01	55.88^a ± 4.53
Low	Umuahia	5.17^a ± 0.09	59.23^b ± 1.70	20.13^b ± 1.93	9.18^b ± 1.08	2.07^b ± 0.46	5.30^a ± 1.01	0.10^b ± 0.01	0.01^b ± 0.00	0.17^b ± 0.01	0.00^b ± 0.00	21.27^b ±1.70

Elec. Cond. = Electrical conductivity.
Mean values on the same column with the same superscript are not significantly different at 5% level of probability.

Table 3. Effect of population density on the physical properties of underground waters of Abia State, Nigeria.

Population density	Physical properties			
	Temp (^{0}C)	Colour (Hz)	Turbidity (mg/l)	TDS (mg/l)
High	28.7^a ± 0.10	0.13^a ± 0.04	0.01^a ± 0.00	101.93^a ± 4.02
Medium	28.6^a ± 0.13	0.06^b ± 0.03	0.01^a ± 0.00	90.51^b ± 3.68
Low	28.4^a ± 0.16	0.02^b ± 0.00	0.01^a ± 0.00	76.60^c ± 3.22

Mean values on the same column with the same superscript are not significantly different at 5% level of probability.
TDS = Total dissolved solids.

Table 4. Effect of population density on chemical properties of underground waters of Abia State, Nigeria.

Population density	Chemical properties										
	pH	Elec. Cond.	Ca (mg/l)	Mg (mg/l)	K (mg/l)	Na (mg/l)	SO_4^{2-} (mg/l)	PO_4^{3-} (mg/l)	NH_4^+ (mg/l)	NO_3^- (mg/l)	Cl^- (mg/l)
High	4.29^c ± 0.16	75.88^a ± 2.67	37.67^a ± 3.97	18.02^a ± 1.89	5.32^a ± 0.99	9.44^a ± 1.40	0.38^a ± 0.17	0.43^a ± 0.02	0.29^a ± 0.02	0.04^a ± 0.02	47.86^a ± 5.96
Medium	4.88^b ± 0.13	61.56^b ± 1.77	32.01^a ± 2.67	15.80^a ± 2.67	2.12^b ± 0.59	5.23^b ± 0.77	0.17^b ± 0.07	0.10^b ± 0.00	0.21^b ± 0.01	0.00^b ± 0.00	39.47^a ± 6.46
Low	5.23^a ± 0.10	54.15^c ± 1.97	18.31^a ± 1.83	13.01^b ± 0.52	0.95^c ± 0.26	3.65^b ± 0.44	0.09^c ± 0.05	0.01^c ± 0.00	0.14^c ± 0.01	0.00^b ± 0.00	28.40^b ± 3.69

Mean values on the same column with the same superscript are not significantly different at 5% level.

ground water in zones of high population density compared to those of medium and low population density (Table 3). The mean turbidity values obtained in this study were within the limit described as safe for drinking water by the World Health Organization (WHO, 1983). The low turbidity status of these underground waters could be due to the fact that when water seeps down ward or percolates through the ground, most of the particulate matter that may have been leached down from the surface are flittered out by the over laying soil layers (Chanlett, 1979; Pelig-Ba, 1996, Fetter, 1980). The mean total dissolved solids in these waters were also influenced by level of industrialization and population density. Aba, the relatively industrialized city had significantly higher amount of dissolved solids (101.93 ± 4.02 mg/l) than Umuahia (90.51 ± 3.68 mg/l) (Table 1). Underground waters of high and medium population density zones had higher total dissolved solids than those of low population density zones.

The pH of the underground waters studied were all outside the range of values acceptable for drinking water by World Health Organization (WHO, 1983). They were below 7.0 indicating that the underground waters in the two cities were all acidic. pH values of underground waters of Aba, was more acidic than those of Umuahia. The levels of acidic anion Cl^- of the waters followed the same trend as the water pH. It could therefore be surmised that Cl^- is responsible for the acidity of the underground waters. Chloride is a by-product of soap manufacturing industries, so many of such industries are

Table 5. Correlation coefficient matrix showing the relationship between the various minerals in the underground waters.

	Mg	Ca	K	Na	$Cl^{=}$	PO_4^{3-}	SO_4^{2-}	NO_3^-
Ca	0.529**							
K	$0.070^{n.s}$	$0.162^{n.s}$						
Na	$0.121^{n.s}$	0.205^{ns}	0.711**					
Cl^-	0.518**	0.681**	0.087^{ns}	0.036^{ns}				
PO_4^{3-}	-0.073^{ns}	-0.124^{ns}	0.304^{ns}	0.267^{ns}	-0.098^{ns}			
SO_4^{2-}	0.231^{ns}	0.284^{ns}	0.148^{ns}	0.349^{ns}	0.074^{ns}	0.053^{ns}		
NO_3^-	0.102^{ns}	-0.160^{ns}	0.206^{ns}	0.244^{ns}	-0.113ns	0.508**	0.023^{ns}	
NH_4^+	-0.013^{ns}	0.184^{ns}	0.565**	0.410^{ns}	-0.107^{ns}	0.290^{ns}	-0.012^{ns}	0.214^{ns}

** = significant at 1% level of probability; * = significant at 5% level of probability; ns = not significant at 5% level of probability.

prevalent in Aba but non existent in Umuahia. pH much below 7 can impart a sharp taste to water and if the water is pipe-borne, can lead to corrosion of plumbing. Studies elsewhere have shown that low pH values were obtained in underground waters in some other parts of Nigeria. Reported pH range of underground water in Onitsha and environs, in the eastern part of Nigeria was 4.8 to 5.1; and in the Midwest (in villages around Benin city), ninety percent of the underground water samples studied gave 5.5 (Atuma and Ogbeide, 1984). In Lagos State, the reported range was 4.3 to 7.8 (FMHE, 1981). Okoye and Adeleke, (1991) obtained mean value of 6.1 for underground waters of Akure in South-western Nigeria. It could be surmised that pH below 7 is characteristic of ground waters in Southern Nigeria.

The levels of calcium and magnesium were higher in industrialized town (Aba) with mean values of 38.53 ± 2.81 mg Ca/l and 22.04 ± 1.67 mg mg/l respectively than in Umuahia with mean values of 20.13 ± 1.97 mgCa/l and 9.18 ± 1.08 mg mg/l. Population density also influenced Mg but not Ca levels in the underground waters studied. Underground waters from high and medium population density zones had higher Mg content than those of the low density zones. Potassium contents of the underground waters were affected by level of industrialization and population density. High population density zones had higher levels of potassium and sodium than the medium and low population density areas. The levels of Ca, Mg, K and Na in these waters were within the acceptable limits of the WHO standards (WHO, 1983).

Total sulphate, phosphate, nitrate and ammonium ions were higher in Aba water samples than in Umuahia (Table 2). Population density also affected the levels of these ions in the waters studied. Underground waters from the high population density zones consistently had higher levels of these parameters over the lower population density zones. In high population density zones of the two cities studied, boreholes were located indiscriminately, sometimes very close to soakaway pits. Seepage of urine and human excreta into the underground water would lead to increase in PO_4^{3-}, NO_3^- and NH_4^+ contents of the waters. Household wastes are also carelessly heaped randomly within the high population density zones. These wastes mineralize and liberate PO_4^{3-}, NO_3^- and NH_4^+ into the environment and are subsequently leached down into the underground waters. The primary adverse effect associated with human exposure to nitrate is methemoglobinema. Nitrate converts hemoglobin to methemoglobin by oxidizing the Fe^{2+} in hemoglobin to Fe^{3+} which cannot transport oxygen. High level Fe^{3+}-hemoglobin in human blood can cause cyanosis, characterized by bluish skin and lips (Al-Dabbagh et al., 1986). On the other hand, very high level of phosphorus in the body could cause bone decalcification and severe kidney disease. However levels of SO_4^{2-}, PO_4^{3-} , NO_3^- , and NH_4^+ in the waters studied were within the limits of WHO standards for drinking water (WHO, 1983)

Relationship between the various minerals in the underground waters

Correlation analysis was used to examine the relationship between the various minerals in the underground waters. Calcium correlated positively and significantly with magnesium (r = 0.529, P <0.05) and chloride (r = 0.0681, P < 0.01). Magnesium also correlated positively and significantly with chloride (r = 0.518, P < 0.01) while potassium correlated significant with sodium (r = 0.711, P < 0.01). Phosphate correlated positively with nitrate (r = 0.508, p < 0.01). The significant correlation coefficients obtained among the various minerals are indications that they originated from common sources (Isirimah, 2002).

Conclusion

The results obtained in this study indicated that with the exception of pH which was outside the WHO acceptable limit for drinking water, all other quality parameters determined were within the limits of acceptable WHO standards. There was strong influence of level of industrialization and population density on the amount of these parameters.

Aba and Umuahia which were used as case study are still growing, there is therefore the need for constant monitoring of the underground water quality to ensure that the water quality parameters do not build up to levels that will be of environmental concern.

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