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HIGH NITRATE CONCENTRATIONS IN SHALLOW AQUIFERS IN A RURAL AREA OF CENTRAL NIGERIA CAUSED BY RANDOM DEPOSITS OF DOMESTIC REFUSE AND EXCREMENT

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ABSTRACT

Qualitative investigations of shallow groundwaters in a rural area of Central Nigeria have shown nitrate concentrations up to 400 mg/l NO_3.

The various rock formations acting as aquifers in the area under investigation revealed slight differences with respect to nitrate contents under similar conditions. Apart from this no additional natural factors are known to affect significantly the contents of nitrate.

However, there is a significant correlation between the proximity of wells to settlements and nitrate content giving evidence that the high concentrations of nitrate are caused by domestic refuse and excrement spread in a random manner over the settlements and their surroundings.

INTRODUCTION

Investigated area

The investigations have been carried out in the Shemankar River Basin, which is mainly located in Plateau State (Fig. 1). The topography is mountainous in the north and undulating to a plain in the south with altitudes above sea level ranging from approx. 100 m (confluence with Benue River) to 1700 m (Jos Plateau).

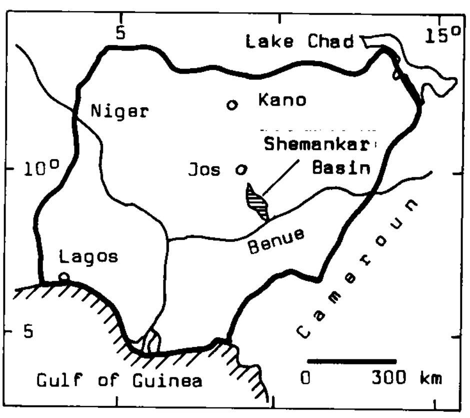


Fig. 1. Nigeria, Westafrika

The upper part of the Shemankar catchment area is built up of crystalline rocks of the crystalline basement complex of Cambrian and Precambrian age, while the lower part consists of mesozoic sedimentary rocks in the form of sandstones and shales. Parts of the basement complex are overlaid by basalt of tertiary and quaternary age.

Shemankar River Basin belongs to the climatic zone of tropical summer rains with a mean annual rainfall of approx. 1000 to 1250 mm. The average yearly temperature is approx. 27°C and the dominant vegetation is described as moist woodland-savanna mixture.

The main crops grown in the area are maize, millet, sorghum, rice, yam, groundnut, beans, bambara nut and cassava. Shifting cultivation including transitions to bush-fallow systems are the most widespread cultivation methods. Starts of more sophisticated and mechanized farming are concentrated on a few centres which are connected with planned irrigation schemes. Nomadic herdsmen putting their cattle to pasture on the untilled savanna and harvested fields also form part of the farming system.
In the villages the people keep goats, sheep, pigs and fowls.

The typical settlements are villages, little towns and hamlets. Shallow dug wells, surface waters such as rivers and ponds, and a few springs are the water sources for the majority of the population.

<u>Purpose and methods of investigation</u>

The approach of the hydrogeological survey was to collect quantitative and qualitative data about the aquifers in view of a possible integration into an irrigation scheme with priority given to improving the poor drinking water situation of the area.

After a general hydrogeological survey the major focus of the investigation was an observation network of approx. 60 shallow dug wells which were distributed throughout the area. The average depth of the wells was 13,6 m, with a minimum of 3,1 m and a maximum of 34,4 m (see appendix).

The qualitative investigations are based on water analyses performed at the end of the dry season (March) and at the end of the rainy season (October/November) in 1979. The analyses included temperature, colour, pH, electrical conductivity, ammonia, nitrate, chloride, iron, sulphate, total hardness, alkalinity and non-carbonate hardness.

In the following presentation only the component n i t r a t e as determined by means of the phenoldisulfonic acid method is considered. The tests were carried out in a field laboratory. A reliability check of a few samples was performed by a highly qualified laboratory in Europe.

RESULTS

The determined concentrations of nitrate vary from as little as 1 mg/l to 400 mg/l NO_3.

The statement of the results with respect to the geological formations of the aquifers, depth of the wells, groundwater level fluctuations, etc., does not reveal much of importance. However, the introduction of a classification system of the wells on the basis of their proximity to the settlements gives an interesting and meaningful picture (Fig. 2).

TABLE 1

Mean nitrate concentrations in mg/l NO_3 of the March and October/November 1979 investigations presented by class and geological formation.

Geological formation	Number of wells	Nitrate Concentration in mg/l NO_3					
		Class I		Class II		Class III	
		Range	Mean	Range	Mean	Range	Mean
Basement	23	1,5-4,5	3,7	1 -30	14,7	44-360	154
Sandstone	21	3,4-6,1	5,0	2,6-30	11,4	19-133	53
Shale	7	1,8-3,2	2,5		25	36-125	56
Basalt	4		7,7			19-107	57
Total	55	1,5-6,1	4,2	1 -30	14	19-360	88

Classification: I No houses near the wells (fields, barren land)
II The wells are situated in the vicinity of detached houses
III The wells are placed in villages and towns.

The data in table 1 are presented graphically in Fig. 2 with the addition of a subdivision of the classes I-III according to the sanitary condition of the wells, drainage, density and size of settlements as well as the expected flow direction of the groundwater.

The reason that a few results do not fit well into the classification system is due to special situations, e.g. use of fertilizer or reductive milieu of the groundwater.

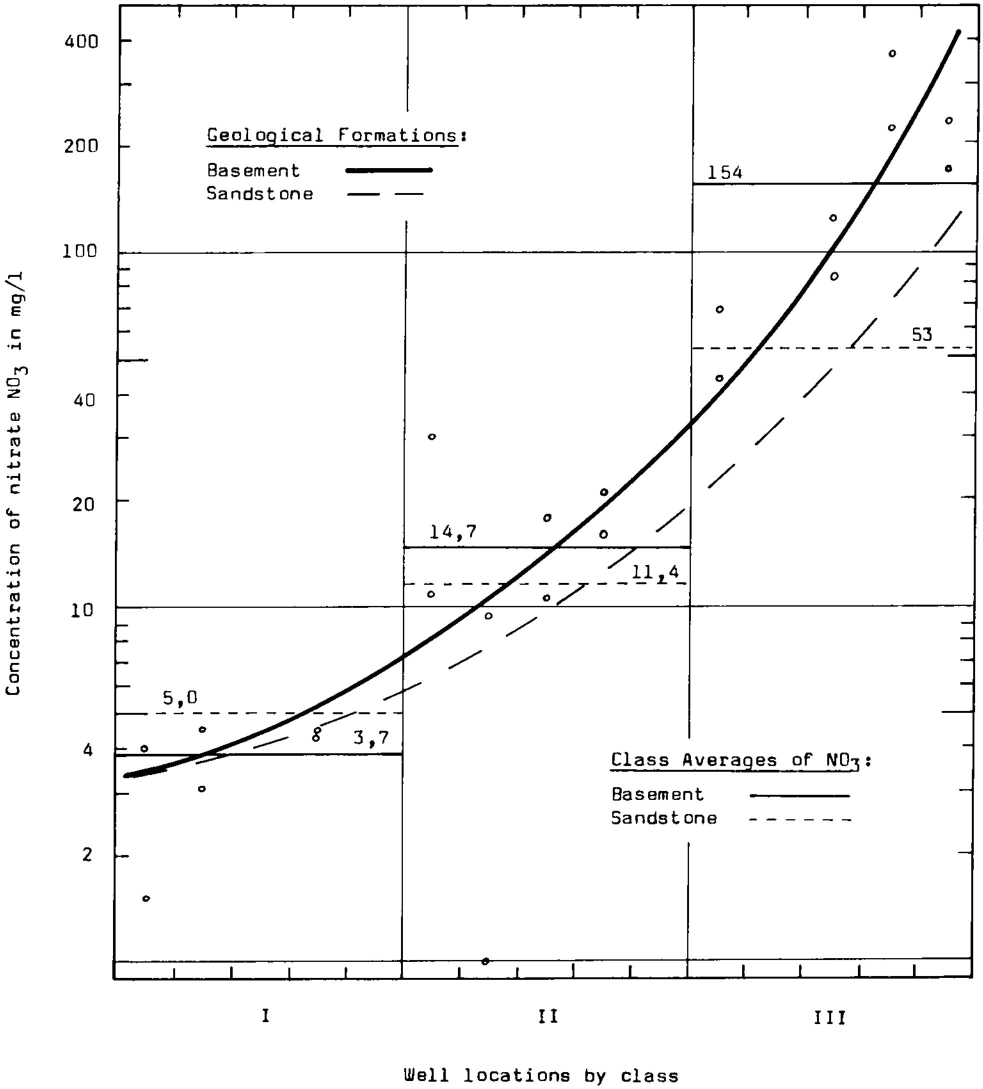
In view of the World Health Organization standards which recommend 45 mg/l NO_3 as the highest tolerable nitrate content in drinking water it can be recognized that none of the investigated wells of class I and II has reached that limit. However, more than 50 % of the tested wells within class III have a higher concentration than 45 mg/l NO_3 (Table 2).

TABLE 2

Range of nitrate content (minimum/maximum) in mg/l NO_3 compared to the 45 mg/l NO_3 limit according to WHO standards.

Geological formation	Number of samples	Range of NO_3 in mg/l	Number of samples exceeding 45 mg/l NO_3	Percentage exceeding 45 mg/l NO_3
Basement	17	42 - 400	15	88 %
Sandstone	19	6 - 249	5	26
Shale	6	31 - 125	2	33
Basalt	6	8 - 125	3	50
Total	48	6 - 400	25	52

Only wells of class III are considered.



Classification: I No houses near the wells (fields, barren land)
II The wells are situated in the vicinity of detached houses
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Fig. 2. Concentration of nitrate NO_3 in groundwater from shallow dug wells compared to proximity of well locations to settlements (means of the March and October/November 1979 results).

Although the hydrogeological situation was quite different between the two field campaigns the results differ little indicating minor seasonal fluctuations of the nitrate content in the investigated aquifers.

The total averages were:

- 49,5 mg/ 1 NO_3 in March 1979, 46 wells tested
- 50,2 mg/l NO_3 in October/November 1979, 46 wells tested.

CONCLUSIONS

According to the given results it is obvious that the high nitrate contents of groundwaters originate from organic wastes of plant refuse as well as human and animal excrement being deposited in the areas of settlements and their surroundings. Therefore, nitrate can be considered as a classical pollution indicator in the hydrogeological situation prevailing within this cultural environment which has not significantly been influenced by technology.

Two factors may certainly be of importance in view of the relatively high nitrate concentrations: the tropical climate accelerating biological decomposition of organic matters and the poor characteristics of the aquifers as to yield and permeability resulting in little distribution and dilution of the pollutants.

The tested wells in shale and basalt formations respectively are too few to draw conclusions referring to possible effects on the nitrate content. However, comparing the results from the basement and sandstone formations, it can be concluded that the wells in the sandstones contain less nitrate than the ones in the basement.

Based on experience in Ghana shallow boreholes fitted out with hand pumps can be highly affected by this problem of high nitrate concentrations. On the other hand there seems to be an indication that in general, under more or less comparable conditions, the nitrate content in Ghana is less than in Nigeria. A possible reason for this contrast may be the sanitation practices. In Ghana it is common for the settlements to have public toilets or latrines and to dump wastes at particular sites, whereas in the Shemankar area such sanitary measures are the exception.

As it is well known nitrate in drinking water can cause methemoglobinemia, especially in infants, and carcinogenic nitrosamines. There is little or nothing known about the occurrence of cases of methemoglobinamia in such areas as the one investigated. This is understandable because breast feeding is the normal diet for infants under three months of age which are mostly affected by methemoglobinamia.

If natural nutrition of infants should change in the future, e.g. by using powdered milk, drinking water sources with such high nitrate concentrations as found could cause serious health hazards.

Therefore, the aspect of pollution has to be considered in future development schemes, especially with respect to siting of shallow dug and drilled wells.

The above findings also demonstrate that in any water development scheme in developing countries any meaningful change or improvement must be made in view of the whole situation in order to avoid undesirable side effects.

REFERENCES

National Academy of Sciences, Washington, D.C., Accumulation of Nitrate, 1972

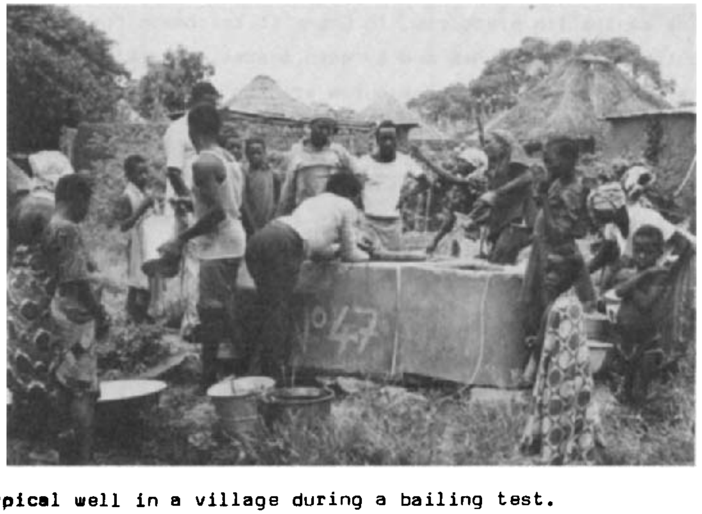
World Health Organization, Geneva, Environmental Health Criteria 5, Nitrates, Nitrites and N-Nitroso Compounds, 1977

APPENDIX

Well and aquifer characteristics

General:	dug wells with open, round shafts
Diameter:	1,2 m
Lining:	prefabricated cement tubes, top tube 0,7 m above ground
Water taking:	by means of buckets
General log:	top soil, decomposed rock, weathered rock, transition to sound rock (according to the digging technique the depth of the wells coincides approx.with the depth of the sound rock)

	minimum	maximum	average
Depth:	3,1 m	34,4 m	13,6 m
Groundwater level fluctuations:	2,6 m	25,7 m	9,9 m
Specific capacity:	1 l/min m	39,1 l/min m	11,7 l/min per meter drawdown
Permeability:	$0{,}8 \cdot 10^{-6}$ m/sec	$1 \cdot 10^{-4}$ m/sec	$3 \cdot 10^{-5}$ m/sec



Typical well in a village during a bailing test.