Nitrate and drinking water from private wells: Will there be an epidemic of cancers of the digestive tract, urinary bladder and thyroid?

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Abstract

Purpose: To estimate the nitrate levels in private wells located in different parts of Enugu and discuss the future health implications following chronic ingestion of well water.

Materials and Methods: The map of Enugu was used to divide the city into many 25 units, using grid lines 1 cm apart. Cluster sampling method was used to collect samples. These samples were sent to two laboratories for estimation of nitrate levels. The people drawing water from the different wells were interviewed to determine what they used the water for.

Result: The subjects who were interviewed said they ingested the water. The nitrate levels found in these wells (median value of 31 mg/L) were significantly higher than the internationally accepted levels of nitrate in water for ingestion, ($P < 0.0001$).

Conclusion: High nitrate levels drinking water is dangerous to health and can cause methemoglobinemia in children. It may also increase cancer risk in adults because nitrate is endogenously reduced to nitrite and subsequent nitrosation reactions give rise to N-nitroso compounds (NOCs), which are highly carcinogenic and can act systemically.

Key words: Cancer, contamination, nitrates, private wells

Date of Acceptance: 01-Jul-2013

Introduction

Nitrate is a natural occurring oxide of nitrogen and is an essential component of all living things. The main adult human intake of nitrate is from food rather than from water. Vegetables such as spinach, greens, lettuce and carrots contain significant amounts of nitrate.[1] Drinking water normally contributes only a small percentage of our total nitrate intake. Although low levels of nitrate may occur naturally in water, excess nitrate may occur in ground water, streams and private wells contaminated by flood, septic tanks, poorly disposed human and animal wastes, municipal sewage treatment systems and fertilizers in agricultural communities.[2,3] High level of nitrate in drinking water can be dangerous to health.[4] A nitrate level of up to 3 ppm i.e., 3 mg/L is generally believed to be naturally occurring and safe for drinking.[5] Beyond this level, contamination is suspected.

The use of well water by the Nigerians generally to satisfy their water needs for drinking, cooking and other domestic needs is wide spread.[6-8] The inhabitants of Enugu, South East of Nigeria are not exempt from this practice. Well water, which may contain high concentrations of nitrates or *Helicobacter pylori*, has been shown to be a risk factor for gastric cancer.[9]

The essence of this study is to estimate the nitrate levels in private wells located in different parts of Enugu and discuss

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Access this article online

Quick Response Code:

Website: www.njcponline.com

DOI: 10.4103/1119-3077.127543

PMID: 24553028

the future health implications following chronic ingestion of well water.

Materials and Methods

The study was conducted in the city of Enugu, Southeastern Nigeria. The map of Enugu was used to divide the city into many 25 units, using grid lines 1 cm apart. Cluster sampling method was used and one water sample was taken from a private well-located in each of these 25 units. This method ensured that every component layout of the metropolis was represented. In addition, the people drawing water from the different wells were interviewed to determine what they used the water for.

These samples were sent to two laboratories, i.e., Juhel Pharmaceutical Nigeria Limited, makers of Ivy bottled water and the Safety Molecular Laboratory at the University of Nigeria Enugu campus, for estimation of nitrate levels. Juhel Pharmaceutical Industry uses the British Pharmacopia (B.P.) reference standard for qualitative estimation of the nitrate levels in water. Distilled water is used as standard, because its nitrate content is 0.2 ppm or less. The B.P. test kit is added to this standard water. The resultant solution is light blue in color. The same test kit is added to samples of water collected from the private wells and the intensity of blue coloration that results is matched against the standard reference solution prepared. They should be the same. When the nitrate content of the sample is higher than 0.2 ppm (0.2 mg/L), the resultant solution becomes dark blue in color. The higher the nitrate contents in the sample, the darker the blue color.

The safety molecular laboratory at the University of Nigeria Enugu campus determined the concentration of nitrates in these well water samples. Isklar Norwegian water, with nitrate concentration of 0.3 mg/L, was used as the control. The procedure for determination of the nitrate concentration in the well water samples starts with reducing nitrate to nitrite using zinc. The nitrite reacts with sulfanilic acid and N-1-naphthylethylene diamine to produce a red compound. The intensity of the red color is measured spectrophotometrically at 520 nm, using Eppendorf BioPhotometer. The intensity is directly proportional to nitrate concentration in the water sample.

Statistical analysis

The parameters computed were the median and the test for statistically significant difference between the nitrate levels in well water samples and the accepted safe levels in drinking water. The Wilcoxon signed rank test for one sample population was used for the latter computation.

Result

There were many wells seen, with an average of one well to five houses in many parts of Enugu, i.e., five houses shared one well. All 25 wells studied, had varying degrees of high nitrate contamination by the qualitative and quantitative tests.

People collecting water from these private wells were interviewed. They were unanimous in saying that they used the water to service their drinking water needs, for cooking and domestic washings. Many described boiling the water to make it safe for drinking. They were happy to drink the water because of the colorless and tasteless properties.

The nitrate concentration found ranged from 9 to 843 (ppm) mg/L, with a median value of 31 mg/L [Tables 1 and 2].

Table 1: Nitrate levels in well water by qualitative analysis from 25 sites in Enugu

Site for obtaining sample	Result: Intensity of blue color	Status: (Nitrate content)
Uwani		
Site (i)	++++	Very very high
Site (ii)	++	High
Independence layout		
Site (i)	++	High
Site (ii)	++	High
Awkunawnaw		
Site (i)	++	High
Site (ii)	++	High
GRA	++	High
Trans-Ekulu		
Site (i)	++	High
Site (ii)	++	High
Phase 6-Trans Ekulu		
Site (i)	+++	Very high
Site (ii)	++	High
Ogui		
Site (i)	++++	Very, very high
Site (ii)	++	High
Ogbette (coal camp)		
Site (i)	++	High
Site (ii)	++	High
Thinkers corner	++	High
Maryland	+++	Very high
Asata	++	High
New haven	++	High
Achara layout		
Site (i)	++	High
Site (ii)	++	High
Abakpa		
Site (i)	++	High
Site (ii)	+++	Very high
Emene	++	High
Garriki	++	High

+=Normal reaction during qualitative analysis, indicated by light blue colour; Nitrate content in that water sample is 0.2 ppm or less (ppm=part per million) ++, +++, ++++=Indicate varying degrees of abnormal reaction, i.e., darker blue color meaning that nitrate levels are above 0.2 ppm; GRA=Government reserved area

Using the Wilcoxon Signed Rank test for one sample population, the $P < 0.0001$ at an alpha level of 0.05. The nitrate levels found in these wells were significantly higher than the internationally accepted levels of nitrate in water for ingestion.

Discussion

We found high levels of nitrates in most of the wells sampled (i.e., a median of 31 mg/L) and used by inhabitants of Enugu. This is thrice the acceptable safe limit for drinking. Most of the inhabitants who were interviewed said they ingested the water after boiling or before using for preparing infant food. Their action was based on the understanding that boiling made it safer for ingestion, not knowing that it increased the concentration of nitrate in that water even more. In 2004, high nitrate levels (88 mg/L) recorded from wells in the Hausa Quarters of Katsina Ala town, (Nigeria) correlated with reports by the inhabitants of a mysterious disease that killed many babies under 1 year of age.[10]

Table 2: Nitrate levels in well water by quantitative analysis from 25 sites in Enugu

Sample no.	Concentration of nitrate; mg/L
Uwani	
Site (i)	347
Site (ii)	24
Independence layout	
Site (i)	56
Site (ii)	22
Awkunawnaw	
Site (i)	31
Site (ii)	31
GRA	21
Trans-Ekulu	
Site (i)	61
Site (ii)	62
Phase 6 of Trans-Ekulu	
Site (i)	80
Site (ii)	25
Ogui	
Site (i)	843
Site (ii)	66
Ogbette (coal camp)	
Site (i)	9
Site (ii)	27
Thinkers corner	18
Maryland site	80
Asata	39
New haven	34
Achara layout	
Site (i)	44
Site (ii)	16
Abakpa	
Site (i)	16
Site (ii)	15
Emene	15
Garriki	33
Control sample (Isklar Norwegian water)	0.3

GRA=Government reserved area

Over a century ago, the first studies linked drinking water and its associated contaminants with cancer risk.[11] In spite of this information, which is widely available in literature, there is still poor public water supply in most cities in Nigeria. Between 2004 and 2005, Nigeria benefitted from a World Health Organization/United Nations Children's Fund (WHO/UNICEF) pilot project that assessed drinking-water quality in the country. That the pilot project showed that nationally, average nitrate levels were lowest for the utility piped water supplies (1.67 mg/L) and highest for boreholes and tube wells (35.32 mg/L).[10] In Enugu, South Eastern Nigeria, where this study was performed, piped urban water supply from government Water Corporation is still grossly inadequate. It has been so since 1970 because the major infrastructure for public water supply was damaged during the preceding 30-month Nigerian civil war. This was not rehabilitated enough after that civil war, before expansion of the city and the attendant steady population increase compounded the water needs of the inhabitants. The citizens, therefore, depend on collecting water from sources that should be considered unsafe, especially private wells and water tanker vendors.

Some of the water vendors and citizens of Enugu are often seen taking turns to siphon water from wells and streams that are not protected from flooding and farms. These water sources, unlike government public water supply are untreated and untested for harmful contaminants. With a median of 31 mg/L of nitrate found in the well water, i.e., thrice the acceptable safe limit for drinking, these citizens are taking heavily contaminated water and are therefore 3 times more likely to suffer the toxic effects of excessive nitrate ingestion.

In advanced societies where there is awareness about safety of water ingested by people, both public and private drinking water source analysis and nitrate monitoring are part of government policy. There is no documented evidence that such an exercise is carried out in our locality for these private wells, which unfortunately serve the majority of the populace. Indeed the WHO/UNICEF exercise (of 2004-2005) for assessment of drinking-water quality in Nigeria, commented that there were no reliable water quality data that could be used to establish a baseline for the status of drinking-water quality.[10]

A nitrate level of up to 3 ppm i.e. 3 mg/L is generally believed to be safe for drinking.[4] Regulation of drinking-water quality is so important that the United States Congress passed the safe drinking water act in 1974. This law requires

the environmental protection agency (EPA) to determine safe levels of contaminants in water, at which no adverse health effects are likely to occur[12,13] As a consequence of that law, the regulation for nitrate, became effective in 1992 and EPA set the maximum contaminant level (MCL) for nitrate as 10 mg/L (or 10 ppm).[13,14] The possible health risks and exposure over a lifetime with an adequate margin of safety were considered in deciding this maximum acceptable contaminant level.[13] Surprisingly, the current national standard for drinking water in Nigeria (NIS 554:2007), allows a maximum contaminant level of 50 mg/L for nitrate.[15] This should be considered too high and therefore unsafe for ingestion because current water standard for nitrate is based on levels considered low enough to protect infants from methemoglobinemia.[14]

The lowest concentration of nitrate in this study of private well water was 9 mg/L; however, it is known that concentrations of 4 ppm or more indicate possible pollution.[5] Concentrations of 11-20 ppm is generally regarded as safe for human adults and livestock, but not safe for infants because their digestive systems cannot absorb and excrete nitrate.[5] Water with concentrations of 21-40 ppm should not be used as drinking water source, except for a short period of time.[5] Incidentally 75% of the wells studied had nitrate concentrations in excess of 21 mg/L and 32% had nitrate concentration in excess of 50 mg/L. Many of these wells, which have been in use for over a decade, are therefore unsafe drinking water sources. Nitrate overload had also been noted in over 61.5% of hand dug wells and other water sources elsewhere in Enugu state, Nigeria.[8]

It is obvious from the result of this study that many people in Enugu are ingesting excessive nitrates [Tables 1 and 2]. High nitrate levels, which indicate that water has been contaminated, is dangerous to health[3] and medical literature is replete with studies about nitrate contamination of public water supply and private wells. Nitrate contamination of drinking water causes methemoglobinemia in children with its attendant hypoxia and death if untreated and that remains the main reason its content in urban water supply is regulated. It may also increase cancer risk in adults because nitrate is endogenously reduced to nitrite and subsequent nitrosation reactions give rise to N-nitroso compounds (NOCs), which are highly carcinogenic and can act systemically.[16,17] These highlight the risks taken by inhabitants of Enugu, when they consume water from contaminated and unregulated sources chronically.

According to the World Health Organization, most adults ingest 20-70 mg of nitrate - nitrogen per day, with most of this coming from foods such as lettuce, carrots, celery, beets and spinach and greens.[18] When foods containing nitrate are eaten as part of a balanced diet, the nitrate exposure is not thought to be harmful because both ascorbic acid and beta-carotene found in fresh fruits and vegetables act as antioxidants. In addition, ascorbic acid reduces nitrates to nitric acid in the digestive tract and prevents the conversion of nitrite to N-nitrosamines and there lies the anticancer effects of vegetables.[3,9] Unfortunately, drinking water is not taken with antioxidants or vitamin C and that increases exposure to nitrates, when the water source is contaminated. Cigarette smoke on the other hand, enhances endogenous nitrosation.[3] It is not nitrate *per se* that is a health concern, rather nitrite and NOCs. In the human body, nitrate is turned into nitrite by the bacteria in saliva, the stomach, colon or an infected bladder.[19,20]

Nitrite then reacts with certain substrates such as amines, amides and amino acids to produce NOCs, which are some of the strongest known carcinogens. These have been found to induce cancer in a variety of organs in more than 40 animals species including higher primates.[17] For these reasons NOCs may cause cancer in the oral cavity, esophagus,[20] stomach,[9,20-22] the proximal colon[3,11] and urinary bladder.[3] Drinking water contaminated with nitrates is a plausible risk factor for developing many cancers. For colon cancer, the reason adduced is based on the colon's direct risk exposure to waterborne contaminants and the consequent nitrosation.[3,11,19] For cancer of the bladder, it is been found that 70% of orally ingested nitrate is excreted in urine where it is converted to nitrite by bacteria and endogenous nitrosation occurs in the bladder.[3] Nitrosation byproducts appear in the urine after oral ingestion of nitrate in drinking water. NOCs are carcinogenic in the bladder and this has been corroborated by studies in Spain.[23-25]

Ward *et al*.[26] also found that high nitrate ingestion from drinking water sources was associated with an increased risk of the thyroid cancer. This occurs when high levels of nitrates are ingested in water because nitrate competes with iodide for uptake by the thyroid, thus potentially affecting thyroid function. This reduces the levels of the thyroid hormones triiodothyronine (T_3) and thyroxin (T_4), which increases thyroid stimulating hormone (TSH) levels. Chronic stimulation of the thyroid gland by TSH can lead to proliferative changes in follicular cells and neoplasia. Nitrate and nitrite are also precursors in the endogenous formation of NOCs, which are potent animal carcinogens that cause thyroid and many other tumors in animal models.[26]

From these obvious dangers of drinking water contaminated with nitrate, it will not be out of place to worry that an epidemic of different cancers may occur sooner or later, given that many people have ingested contaminated well water for over a decade in Enugu. What is even more worrying is that cancers of esophagus, stomach and urinary bladder are very difficult to treat; and cancer epidemics of these three will amount to health calamity of unimaginable proportion. It is, therefore, reasonable to advise commencement of public health education programs, which will enlighten both the populace and government, about the dangers of

drinking unwholesome water; contaminated with high levels of nitrates and the importance of providing proper public water schemes with standard water treatment facilities, for the governed. This is very important because even a small increase in cancer risk from contaminated drinking water will translate into a very large public health problem.

Acknowledgments

I am grateful to Dr. Ifeanyi E. Okoye, the Managing Director of Juhel Pharmaceutical industry and Dr. Emmanuel O. Nna of the Safety Molecular Laboratory, University of Nigeria Enugu campus, for their assistance in analyzing the nitrate concentrations in the well water samples and the latter also for the statistical analysis of the results obtained.

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How to cite this article: Njeze GE, Dilibe U, Ilo C. Nitrate and drinking water from private wells: Will there be an epidemic of cancers of the digestive tract, urinary bladder and thyroid?. Niger J Clin Pract 2014;17:178-82.
Source of Support: Nil, **Conflict of Interest:** None declared.