Original Article

Health implications of chemicals found in the drinking water supply of members of an urban community in Rivers State, South–South Nigeria

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Abstract

Background: Efforts at improving access to drinking water almost always concentrate on increasing quantity, with little attention given to the quality of water. There is, however, increasing evidence of the significant contributions of chemicals found in drinking water on health. This study tested the drinking water supply of Rumuola, a suburb of Port Harcourt, for possible chemical contamination. It also ascertained the human health implications of the detected contaminants in the water samples.

Methods: A cross-sectional, analytical study design was used. Water samples were collected from water facilities that serve most members of the community and analysed in an accredited laboratory, for nitrate, fluoride, calcium, arsenic, lead and iron, using atomic absorption spectrophotometer. A checklist was also used to assess a 30 m radius of each of the water facilities, for possible sources of contamination. An impact assessment was also carried out to ascertain the health implications of the contaminants identified in the water samples.

Results: Samples from eight water facilities were tested. All the samples contain detectable concentrations of iron, lead, nitrate, fluoride and calcium. The mean concentration of fluoride in the water samples was 0.01 mg/L; that of nitrate was 38.78 mg/L; the mean concentration of iron was 1.05 mg/L, those of lead and calcium were 0.094 and1 mg/L, respectively; while arsenic was not detected in any of the samples. The mean concentration of iron in the water samples can provide 12%–26% of the recommended daily allowance; while the mean concentration of lead of the samples is more than nine times the WHO permissible limit.

Conclusion: The concentrations of the assessed chemicals in the water supply can supply some percentage of the recommended daily intake while others can pose some adverse health effects.

Keywords: Chemical contaminants, Nigeria, Rivers State, water quality, WHO permissible limit

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Introduction

Water is essential for life, as death often results after a few days of not drinking water, especially in hot, tropical environment. Water is also important in sanitation and in maintaining personal hygiene, being used for bathing, oral hygiene and proper functioning of sanitation facilities.[1] These explain the

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recommendations by the World Health Organization that every individual should have a daily access to 2 L of water, to meet the daily drinking water needs, and at least 20 L of water, to meet the sanitation needs.[2]

Efforts at meeting these recommendations have concentrated on increasing the quantity of water supply, almost to the exclusion of the quality of water.[3] This is especially in developing countries where in most cases, only the microbiological quality of the water is considered, with drinking water often considered safe for drinking just for containing <10 *Escherichia coli* per deciliter of the water.[2]

This has been shown to be defective, considering that drinking water often contains contaminants that have adverse and/or beneficial effects and have been associated with several health conditions. Studies have shown that the trace minerals in drinking water can supply up to 20% of the total dietary requirement of the minerals;[4] able to influence the prevalence of important cardiovascular and cerebrovascular diseases in the community;[5] even as some of the trace minerals such as mercury, lead and arsenic have been found to be toxic to humans.[6]

Most of the contaminants in drinking water result from human activities and have been shown to increase with urbanisation and industrialisation.[3] These factors have become very topical in the Niger Delta region of Nigeria, with the publication of the Ogoni UNEP report[7] that showed massive chemical contamination of drinking water. We, therefore, postulated that the chemical contamination of drinking water in the Niger Delta region might not be restricted to the activities of the oil industry but likely to include other human activities, including artisanal occupational activities carried out within the community. We, therefore, tested the drinking water supply of a suburb of Port Harcourt, taking special note of possible sources of contamination, to ascertain possible contamination of the water supply. The results of this study would, therefore, help guide public health action as it would provide vital information on the other sources of contamination of drinking water supply, not only in an urban community in the Niger Delta region of Nigeria but also in other urban communities in Nigeria and other developing countries.

Methods

The study was carried out in November 2014 in Rumuola, a suburb of Port Harcourt, and one of the traditional communities of the Ikwerre ethnic group, the predominant indigenous ethnic group in Port Harcourt. The community is completely built up and unplanned, with no clear demarcation between residential and industrial areas, such that occupational activities such as vehicle repair, battery charging, welding and metal fabrication are often carried out in residential houses. The community is the host of the Rumuola waterworks that was designed to supply water to several parts of Port Harcourt. This municipal water facility is, however, rarely functional, such that most households in Rumuola community either have their own water borehole or fetch water from small, non-reticulated water facilities that were provided on philanthropy and managed by the community.

A cross-sectional, analytical study design was used. Water samples were collected from water facilities that serve most members of the community and analysed in an accredited laboratory. A checklist was also used to assess a 30 m radius of each of the water facilities, for possible sources of contamination. An impact assessment was also carried out to ascertain the health implications of the contaminants identified in the water samples.

The water facilities that were sampled for the study were those determined to serve a greater number of persons in the community. These facilities include the small, non-reticulated water borehole facilities that serve the general public, as well as the private boreholes with vending taps that provide water to the public, either free of charge or on payment. A total of 34 facilities were so identified in the community, of which a total of eight facilities – six public and two private water facilities – were randomly selected. All the selected facilities were motorised boreholes with overhead tanks.

The samples from the water facilities were collected in I L, non-reactive plastic bottles that were properly cleansed and rinsed before the collection. The samples collection process involved turning on the tap and allowing the water to run for at least I min; carefully lowering the sample container under the tap, to fill up the container, but with enough space to facilitate proper mixing by shaking; adding some drops of nitric acid, for easy identification of the trace metals; sealing and labelling the container; and then putting the sample in an iced cooler, before being transported to the laboratory for analysis. The water samples were analysed for nitrate, fluoride, calcium, arsenic, lead and iron, using atomic absorption spectrophotometer.

The observational checklist was used to assess possible sources of contamination of the water facilities, within a 30 m radius. The checklist specifically looked out for the presence of septic tank, pit latrine, refuse dump and occupational activities such as motor vehicle repair, battery charging, welding and metal fabrication that are particularly known to be capable of polluting water facility.

The data collected for the study were checked for consistency and completeness, before being analysed. Summary measures were then calculated for each outcome of interest. The mean concentration of the assessed chemicals in the samples was compared with the WHO guideline values,[8] to ascertain if they met the regulatory standard; while the health implications of drinking water from the water facilities were assessed by determining the total daily intake of the assessed chemicals, from drinking the water, and then finding out the effects of the total daily intake. For this health impact assessment, the average quantity of water taken in a day was put at 2 L for adults and 1 L for children; the recommended daily allowance (RDA) for the beneficial chemicals was as determined by the Institute of Medicine of the U.S National Academy of Science, which took into consideration the bioavailability of the various minerals;[9] while the harmful effects of the assessed chemicals are as determined by the relevant WHO documents.[3,6,8] The RDA for iron was taken as 18 mg/day for adult females and 8 mg/day for adult males; calcium as 1000 mg/day for adults and 500 mg/day for children; and fluoride as 3 mg/day for adult females, 4 mg/day for adult males and 1.5 mg/day for children. The level of arsenic considered as harmful was put at 0.01 mg/L (10 µg/L); 50 mg/L for nitrate and 0.01 mg/L (10 µg/L) for lead.

Ethical consideration

The approval to conduct the study was sought and obtained from the Research Ethics Committee of the University of Port Harcourt, Port Harcourt; while informed consent was sought and obtained from the Chiefs of Rumuola community and the owners of the sampled water facilities.

Results

A total of eight water facilities – six public and two private water facilities – were sampled. All the facilities were motorised boreholes with overhead tanks. The water samples from the facilities were found to contain detectable concentrations of iron, lead, nitrate, fluoride and calcium. The concentration of fluoride in the water samples ranged from <0.001 mg/L to 0.025 mg/L; nitrate ranged from 4.54 to 61.35 mg/L, iron ranged from 0.399 to 1.751 mg/L, lead ranged from 0.062 to 0.112 mg/L, calcium ranged from 0.145 to 2.211 mg/L; while arsenic was mostly undetectable at <0.001 mg/L. Wide variation was noted in the concentrations of the chemicals, which are attributable to the effects of human activities within the 30 m radius of the facilities. Septic tank was found within the 30 m radius of all (100%) the water facilities; 2 (25.00%) of the facilities were located close to the public dump site, while 1 (12.50%) of the facilities was located close to a vehicle repair workshop.

The mean concentrations of the mineral nutrients in the sampled water facilities and their contributions to the RDA of those who drank the water are shown in Table 1. The mean concentration of iron in the water samples was 1.05 mg/L, which can provide at least 26% of the RDA of male adults and about 12% of the RDA of female adults. The mean concentrations of fluoride and calcium in the water samples were, respectively, 0.01 and 1 mg/L, which are only able to provide <1% of the RDA of the chemicals.

Table 2 shows the average concentrations of the potentially toxic minerals in the sampled water. The average concentrations of nitrate and arsenic in the samples were below the regulatory limits, whereas the mean concentration of lead of 0.094 mg/L is more than nine times the WHO permissible limit of 0.01 mg/L.

Discussion

The study showed that the water samples contain detectable concentrations of iron, lead, nitrate, fluoride and calcium; in concentrations that have been shown to have some effects on human health.[4-6,8] This emphasises the need to consider the chemical quality of water, in the effort to improve access to drinking water, especially in urban communities.

Iron, no matter its form, is beneficial to health. It is one of the eight essential cationic minerals, important in driving the cationic processes of several normal body functions, including oxygen transport, oxidative phosphorylation, metabolism of neurotransmitters and DNA synthesis.[4,10] Iron deficiency often manifests as anaemia but can also present as delayed nerve conduction, affecting the auditory and visual systems; decreased

Table 1: The concentration of mineral nutrients in the drinking water supply of the study community

Trace mineral supplied	Average concentration (mg/L)	WHO desirable limit (mg/L)	Percentage of RDA
Fluoride	0.01	1.50	Male: 0.5 Female: 0.6 Children: 0.7
Iron	1.049	0.3*	Male: 26.23 Female: 11.66
Calcium	0.998	75	Adult: 0.2 Children: 0.2

*Levels likely to lead to consumer complaints. WHO: World Health Organization, RDA: Recommended daily allowance

Table 2: The average concentrations of the potentially toxic minerals in the drinking water supply of the study community

Trace mineral	Average concentration (mg/L)	WHO desirable limit (mg/L)	Daily average taken (mg)
Nitrate	38.78	50	77.56
Arsenic	<0.001	0.01	<0.002
Lead	0.094	0.01	0.19

WHO: World Health Organization

capacity for physical work, resulting in decreased stamina; impaired cell-mediated immunity and bactericidal capacity of neutrophils, resulting in increased susceptibility to infections; increased risk of premature birth, low birthweight and growth retardation, increased perinatal morbidity and reduced iron transfer to the foetus among other adverse health effects.[11] On the other hand, excess iron in the body is rare under normal circumstances because of the body's homeostatic mechanisms and the regular loss of iron in faeces, urine, sweat, blood, skin exfoliation and the desquamation of cells in the gastrointestinal tract.[4,10] There is, therefore, very little risk in drinking water with high iron content.

This study showed that the mean iron concentration of the drinking water of the study community was high and more than three times higher than the level known to attract consumer complaint.[8] This is consistent with findings of other studies carried out in the Niger Delta region of Nigeria,[12,13] with one of the studies recording a concentration as high as 6.2 mg/L.[13] The high iron content of ground water in the Niger Delta region is most often attributed to geologic sources;[12,13] however, the iron content of the water samples of this study show wide variation, ranging from 0.399 to 1.751 mg/L. This wide variation in the iron content points to factors that are restricted to the individual water facility, such as the use of iron pipes and storage tanks, which are likely to influence the result, and very likely to be found in some of the older water facilities of the community.

Although the high iron content of the drinking water is beneficial to health and is capable of providing more than 12% of the daily iron requirement of members of the study community, the iron concentration is, three times the level known to attract drinkers' complaint.[8] This is likely to discourage members of the community from drinking from the water facilities. There is, therefore, a need to encourage the drinking of the water, in spite of the taste and colour, as they provide a valuable source of dietary iron,[4,9] especially in the Niger Delta where the prevalence of iron deficiency anaemia can be as high as 12%, even among seemingly healthy adults.[14]

Calcium was also detected in the water samples, with a mean concentration of 1 mg/L. The presence of calcium in ground water is often from geologic sources and rarely from human activity.[4] The calcium content determines the extent of hardness of the water, which influences how the water is used for drinking and laundry. Although hard water is frustrating when used for bathing and laundry, it has, however, been shown to help reduce the risk of cardiovascular diseases.[4,5] The mean calcium concentration of the water samples is only able to supply <1% of the RDA for calcium for both children and adults. This is lower than the concentrations recorded in some parts of the Niger Delta region[15] and therefore less able to protect members of the study community from the cardiovascular diseases, which have been on the increase in recent years, in the community and similar other communities in the Niger Delta region.[16]

Fluoride was found in the water samples in a mean concentration that is only able to supply <1% of the RDA. Fluoride is essential in the formation of strong calcium phosphate matrices in teeth and bones.[6] This means that the fluoride level in the drinking water is not on its own able to protect members of the community from dental caries.[17] These are the findings in most communities worldwide and have been shown to be the underlying cause of the high prevalence of dental caries in the communities; hence, the deliberate effort is often made to add fluoride to community water supply.[6,17] This would be difficult to accomplish in Nigeria because most of the community water facilities are not reticulated and are very epileptic in their operation, such that most households rely on their individual water facility. The low concentration of fluoride in the water supply of the study community is, however, offset by the fact that most of the staple foods consumed in the community contain enough fluoride to meet the RDA.[6] These dietary sources of fluoride are also complemented by the fluoride in toothpaste, which are now widely used in Nigeria.

The mean concentration of lead of the water samples is several times higher than the WHO desirable limits, which poses significant harm to human health.[8] This high concentration of lead can be attributed to such anthropogenic sources as leaded petrol, lead acid batteries, solder, alloys, cable sheathing, pigments, rust inhibitors, glazes and plastic stabilizers.[18] It is also interesting to note that the water facility found in the study community to be located very close to a vehicle repair workshop had the highest lead concentration of 0.112 mg/L, which is about 20% higher than the mean concentration of 0.094 mg/L and 80.65% higher than the water facility with the least concentration of lead.

The concentration of lead in the drinking water exposes the children in the community to 0.094 mg/L of lead daily, which is up to the 5 μg/kg of body weight per day known to cause cumulative damage in children.[19] The possibility of lead poisoning in the study community is further increased by the possibility of the high prevalence of iron deficiency anaemia in the community,[13] which can increase the rate of absorption of lead into the body.[20] Lead is a cumulative toxin, with a half-life in blood and soft tissues of about 36–40 days, and 17–27 years in the skeletal pool of adults;[21] the biological half-life of lead in children is considerably longer.[22] Acute toxicity of lead often presents as dullness, restlessness, irritability, poor attention span, headaches, muscle tremor, abdominal cramps, kidney damage, hallucinations, loss of memory and encephalopathy;

while chronic, low-level exposure has been shown to result in various neurodevelopmental effects, mortality (mainly due to cardiovascular diseases), impaired renal function, hypertension, impaired fertility and adverse pregnancy outcomes.[18] Based on dose–response analyses, it is estimated that an accumulation of 25 μg/kg of body weight of lead in the body results in a decrease of at least 3 IQ points in children and an increase in systolic blood pressure of approximately 3 mmHg (0.4 kPa) in adults.[23]

The concentrations of nitrate in the water samples raise a red flag, even if they are mostly below the permissive limit. This is because, most of the facilities are located very close to septic tanks and refuse dump sites that can easily contaminate the water with nitrate as shown by the facility with the highest level of nitrate. Nitrate in drinking water represents a serious health hazard, especially to the foetus and infant. Studies indicate a higher prevalence of neural tube defects in the babies born to women whose water supply contains more than 3.5 mg/L, while spinal bifida is twice more likely to occur in the babies of women who ingest more than 5 mg of nitrate daily from their drinking water than women who take <0.91 mg.[24,25] Other studies have also found a link between nitrate in drinking water and methaemoglobinaemia (blue baby syndrome), a health condition found in babies that results from the oxidation of ferrous iron in haemoglobin to its ferric state, changing the haemoglobin to methaemoglobin and changing the colour of the baby to blue, with associated cyanosis, tissue hypoxaemia and death in severe cases.[26]

In view of these severe adverse health effects, there is an urgent need to take concrete actions to prevent the contamination of the water supply with nitrate. Better solid waste disposal can be achieved with better management and funding of the municipal waste disposal services that are currently in place in the study community. However, the proper separation of the water facilities from the contaminating septic tanks can only be achieved with greater and better involvement of the government in the provision of potable water and in sewage disposal. It is easier to achieve this separation with a reticulated water facility that seems to have been abandoned by most governments in the Niger Delta region.

Conclusion

There are detectable levels of the assessed chemicals in the drinking water sources of the study community, in concentrations that have been shown to have some effects on human health. Some of the chemicals can supply some percentage of the recommended daily intake while others can pose some adverse health effects. Efforts should, therefore, be made to prevent the contamination of the water sources, especially with toxic contaminants.

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Conflicts of interest

There are no conflicts of interest.

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