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Determination of Nitrate, Sulphate and Phosphate in Borehole Drinking Water Iruekpen, Edo State

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Abstract
The study of borehole water was conducted to investigate nitrate (NO_3^-), sulphate (SO_4^{2-}) and phosphate (PO_4^{3-}) concentrations in drinking water and its associated health implication to residents and its environs. Samples were collected from borehole around the vicinity of Iruekpen town using polythene plastic containers and were analyzed for the nitrate, sulphate and phosphate levels following within the permissible limits recommended by the World Health Organization (WHO) standards. From the results, it was found that Nitrate has a mean value of 0.054 mg/l. above permissible values of 250mg/l WHO (2011) guidelines standard. Sulphate has a mean value of 0.850 mg/l over-exceeded permissible values of 250mg/l WHO standard (2011) and Phosphate with a mean value of 0.022 mg/l which fall below than the permissible values of 250mg/l WHO (2011) guidelines standard. Hence, the results indicated that the borehole water is contaminated and unsafe for human consumption. This therefore, calls for appropriate treatment measures before the consumption of these waters by the populace to avoid long term accumulative health problems of these pollutants.

***Keywords**: Borehole water, nitrate, sulphate, phosphate and health implications*

Introduction

Water is the most important natural resources without which life would be nonexistent. Availability of safe and reliable source of water is an essential prerequisite for sustainable development. Deserts are not habitable because of lack of water (Asonye,*et al.,* 2007).Surface waters such as rivers, streams, lakes and dams and ground water such as wells and boreholes are the principal sources of water. Ground water (borehole) quality and availability remain one of the most critical environmental and sustainability issues of the twenty-first century byWorld Health Organization, (2002). In recent years, because of rapid urbanization, growth population and industrialization, the rate of discharge of pollutants into the environment which find their way into these water bodies is higher than the rate of purification (Reza, and Gurdeep, 2009). It is believed that surface water is generally more polluted than ground water; hence the use of ground water (borehole) as the major source of drinking water is preferred. Ground water can also be contaminated through various ways such as seepage from effluent waters, vehicle maintenance, sewage and domestic water, mining activities fertilizer from agricultural activities etc. (Adekunle, 2009). Ground water constitutes over 90% of the world's readily available freshwater resources (Reza, and Gurdeep, 2009) with remaining 10% in lakes, streams, dams and rivers. However, groundwater is not only a valuable resource for drinking water supply, but also a vital component of the global water cycle and the environment. As such, groundwater provides water to rivers, lakes, ponds and wetlands helping to maintain water levels and sustain the ecosystems (Kim,*et al.,* 2003). Safe potable water is essential for healthy living and for water to be regarded as safe for drinking; it must meet certain physical, chemical and microbiological criteria set by American Public Health Association, (2012).

Borehole Water (Groundwater)

Borehole water iswidely used as a source, for drinking water supply and irrigation in food production (Suthra, *et al.,* 2009). However, groundwater is not only a valuable resource for water supply, but also a vital component of the global water cycle and the environment. The groundwater (borehole) water contamination by chemical species such as heavy metals, sulphate, nitrates, phosphate, fluorides, microorganisms etc. can affect the health status of humans who is the ultimate user of the water. These chemical species find their way into the water aquifer through leaching. Such human activities that introduce these unwanted species to the groundwater are processing of metals, exploration, production and eventual exploitation of oil, agricultural activities, and mining and through indiscriminate disposal of the byproducts of these human activities has added to the already overburdened situation (Adefemi, and Awokunmi, 2009). The manner in which the inhabitant of a particular area disposes wastes can also contribute to the level of contamination of the groundwater. The groundwater can be easily polluted through wastes, sewage and effluents that originate from homes, industries and commercial centers through percolation into the water underground.

Water is a necessity, to maintain good health; water must be kept safe and free of contamination/pollution of any type. Good drinking water supply to Nigerian's teeming populace is a perennial problem that has defied solution. As such, great concern must be given to the quality of drinking water as it is very critical for the overall socio-economic development of any society and, should engage the attention of individuals, groups, government and non-governmental organizations (Adetunde, and Glover, 2010).

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The study therefore, stresses on the need that public should be provided with an alternative water source for drinking and domestic purposes. The acute water shortage forced many people to drink untreated water obtained from surface and underground sources thereby exposing them to hazardous chemicals and infectious agents. This has made many researchers to focus their attention towards evaluation of physicochemical and microbial characteristics of water supplies (Okonkwo, and Okorie, 2011).Contamination of water bodies has increasingly become an issue of serious environmental concern. Clean water is a priceless and limited resource that man has begun to treasure only recently after decades of pollution and waste (Silberberg, 2003). Potable water is an essential ingredient for good health and the socio-economic development of man but it is lacking in many societies (Udom, *et al.,* 2002). All Natural waters contain many dissolved substances. Contaminants such as bacteria, viruses, heavy metals, nitrates and salt have polluted water supplies as a result of inadequate treatment and disposal of waste from humans and livestock, industrial discharges and over-use of limited water resources (Singh and Mosley, 2003). To avoid groundwater pollution from effluent leachate, the community water and sanitation Agency (CWSA) recommends that pit latrines should be constructed at least 100 feet (30m) downhill of boreholes (CWSA, 2003). In addition, World Health Organization, (2006a) asserted that a minimum of 50 feet (15m) between a pollution source and downstream water abstraction point will be satisfactory. Water has different types of physical, chemical and biological impurities. These require different tests to determine the level of these contaminants in the water. To obtain water of good quality, it should be tested for trace metals, heavy metals, organic materials and biological contaminants. For water to be considered as good for drinking then it should pass all these tests and it should also contain required amount of mineral level (Umar, 2006). Previous studies on boreholes water from Kano, (Sa'eed and Mahmoud, 2014) had reported that, most of the physicochemical parameters analyzed were within the maximum permissible limit set by World Health Organization, (2020). This work was set to explore a wider scope of various local Governments within the Kano metropolis. Nitrate-containing compounds in the soil are generally soluble that means they dissolve easily in waterAgency for Toxic Substances and Disease Registry,(2011). Thus, nitrates flow easily into groundwater. Microbes break down animal and human organic wastes in soil and water to ammonia. This breakdown process of converting organic wastes into ammonia, which oxidizes into nitrite and nitrate, is referred to as Nitrification process (Oladeji, 2017). Plants uptake phosphate from soil mostly in the orthophosphate forms. Natural soil phosphate level is often low enough to limit crop production. Both inorganic phosphate fertilizers (treated rock phosphate) and organic phosphate sources (animal manures) are equally adept at supplying the

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orthophosphate ion and correcting phosphate deficiencies in soil (Edwards,*et al.,* 1990). The primary biological importance of phosphates is components of nucleotides which serve as energy storage within cells Adenosine Triphosphate (ATP). Phosphorus is also found in bones and the enamel of mammalian teeth whose strength is derived from calcium phosphate. It is also found in the exoskeleton of insects and phospholipids (Huttuner,*et al.,* 2006). In addition, it functions as a buffering agent in maintaining acid base homeostasis in the human body. Sulphate is produced in the environment from the oxidation of elemental sulphur, sulphide minerals or organic sulphur. It is naturally occurring compound containing sulphur and oxygen present in various mineral salts that are found in soil forming salts with variety of elements like barium, calcium, magnesium, potassium and sodium (Kamar, *et al.,* 2011). Sulphate may be leached from the soil into groundwater and commonly found in most water supplies.

Borehole Water Quality

The quality of groundwater is of vital concern for mankind since it is directly linked with human welfare. According to Ranjana (2010), the quality of public health depends to a greater extent the quality of groundwater. Though groundwater quality is believed to be quiet good compared to surface water, its quality is the sum of natural: geology of the environment and anthropogenic influences: withdrawal, land use change, and solid waste dumping (Chapman, 1996). Water quality parameters reflect the level of contamination in water resources and show whether water is suitable for human consumption. Contaminated water is unacceptable due to health effects, poor taste and aesthetic value to consumers (Suthra, *et al.,* 2009).

Statement of the Problem

The important of human health cannot be overemphasized, therefore, this research has highlighted some of the problems involved when consuming unsafe borehole water which contains nitrate, sulphate and phosphate undermine the dangerous health risk implications and the enormous risk associated with those compounds that are deadly. Such diseases are; Blue-babysyndrome, gastrointestinal cancer, vascular dementia, adsorptive secretive functional disorders of the intestinal mucosa.

Aims and Objectives

The aim of this study is to determine some anions in boreholes drinking water and the health risk implications. While the objectives is to determine concentrations of nitrate (NO^{3-}), sulphate (SO_4^{2-}) and phosphate (PO_4^{3-}) in borehole drinking water

Location of the Study Area

The study area is situated within latitude 6^0 30^1 N and longitude 6^0 35^1 E as shown in Figure 1. It lies between the fringes of the Savannah to the North and the forest to the South. It is made up of Sandy topsoil that could easily be cleared and cultivated,

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relatively weed-free. It has a flat landscape devoid of rocks and mountains, and good for agricultural purposes. This has been responsible for good crop yield in the region, especially yams. The position of the study area is a favorable climatic zone that enhanced agricultural development and the entire economic structure of the area.

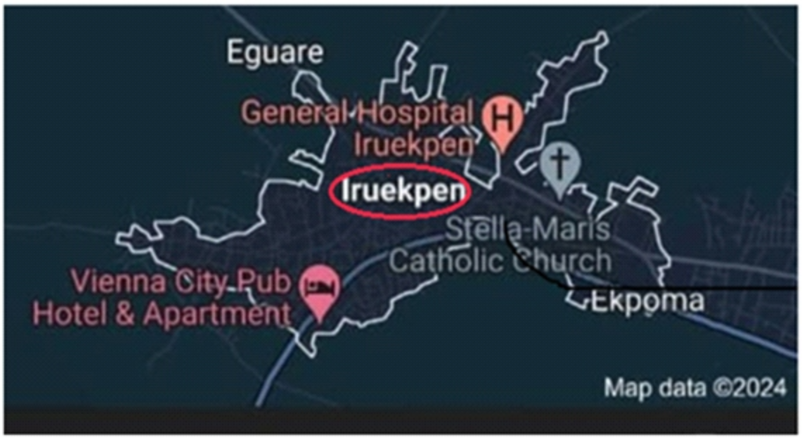

Figure 1: *Map of Iruekpen in Edo State as the study area location*

Borehole Water Contamination

Contamination of water has increasingly become an issue of serious environmental concern (Akpoveta, *et al.,* 2011). The habit of indiscriminate waste disposal, poor agricultural practices, septic tanks, pit latrines and graves near boreholes and poor well construction contribute to borehole water contamination (Singh and Mosley, 2003; Lu, 2004). These account for the presence of coliform bacteria in borehole water and lead to possible diseases if consumed without any form of treatment. According toWorld Health Organization,(2018), contaminated water can transmit diseases such as diarrhea, cholera, dysentery, typhoid and polio. Among these water-related diseases, diarrhea has a higher death possibility percentage. This shows that it is important to certify the quality of water used for domestic purposes to prevent these deadly diseases.

Nitrates in Borehole Water

Nitrate is a family of chemical compounds containing atoms of nitrogen and oxygen occurring naturally. Nitrate is critical to the continuation of life on the earth, since it is one of the main sources from which plants obtain the element nitrogen. The element is required for the production of amino acids which in turn are used in the manufacture of proteins in both plants and animals (Edori,*et al.,* 2016). Nitrate contamination of groundwater results from leaching of fertilizer, septic tank leachate, answered sanitation, pit latrines, animal waste or human waste

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mineralization of decomposing or oxidation of decaying matter by soil micro-organisms (Suthra, *et al.,* 2009). Nitrate can readily be transported beneath the soil zone because it is relatively soluble and not prone to ion exchange (Stumm and Morgan, 1996). Nitrate can be endogenously reduced to nitrite, which can then undergo nitrosation reaction in the stomach with amines to form a variety of N-nitroso compounds (NOC). These compounds are carcinogens, thereby causing health hazards like impairing the ability of the blood to carry oxygen (Blue-baby syndrome or infantile methemoglobinemia), gastrointestinal cancer, vascular dementia, adsorptive secretive functional disorders of the intestinal mucosa. Nitrate contamination can be treated by technologies such as ion exchange; denitrification and reverse osmosis or anaerobic reduction in the subsurface which can limit nitrate contamination of groundwater (Kapoor and Viraraghavan, 1997).Nitrate is not especially dangerous but certain bacteria sometime present in digestive tract convert nitrates into nitrites, which are highly toxic. Nitrates are widely present in substantial quantities in soils and in most water. Nitrates are products of oxidation of organic nitrogen by bacteria present in the soils and in the water where sufficient oxygen is present.

Sulphate in Borehole Water

Most of the metallic sulphates are soluble in water which implies possible leaching of sulphate from the top soil to the surface water, and underground water. Sulphate concentrations in the groundwater have about 69% violations with respect to the World Health Organization stipulated limits (250 mg/L) for sulphate ions in drinking water. The excessive levels of sulphate in water can lead to laxative effects in humans, while moderate levels could induce salty taste in drinking water depending on the associated anions. Oxidation of sulphide from sulphurous gases discharged to the atmosphere which often result in acid rain water containing detectable levels of sulphate at industrial areas may also lead to the high sulphate content. This means that there is a significant difference in sulphate values among the boreholes water samples. The results also showed that agriculture wastes especially runoff from fertilizer application contributed to concentrations of nitrate and phosphate in the groundwater sample. The foregoing may be responsible for the salty taste of water from deep aquifers within the study area (Emenike, *et al.,*2018b). The elevated sulphate concentration is also associated with the excessive use of agro-chemical and dissolution of basement rocks.

Phosphate in Borehole Water

Phosphorus is essential to the growth of biological organism including both their metabolic and photosynthetic process. Phosphorus occurs naturally in bodies of water mainly in the form of phosphate (i.e a compound of phosphorus and oxygen.

Phosphorus, as phosphate is usually not a concern in ground water, since it is tenaciously held by soils through both electrostatic and non-electrostatic mechanism and usually does not leach in most soils. However, in sandy soils that contain little clay, phosphate can leach through the soil and impact borehole water supply perhaps, the greatest concern with phosphorus is contamination of streams and lakes via surface run off and erosion by Organization of Assabet River (2002).

Phosphates constitute a very important pollution problem whenever it is found in significant amount. It promotes algal growth and/ or microphytes, leading to the cyclic problem of eutrophication (Thriodore, 2004). The high level of phosphate ion in the drinking water is attributed to the proximity of the settlements to those places where farming activities is taking place all year around.

Health Implications

Nitrate in borehole water involves various risks for human consumption. Mortalities as a result of methaemoglobinaemia are a reality. New information became available on earlier cases of methaemoglobinaemia, while spontaneous abortion may constitute a further risk related to nitrate in water. Microbiological pollution seems to aggravate the situation, increasing the risk of methaemoglobinaemia at lower nitrate concentrations and should be avoided. The risks associated with nitrate ingestion have to be evaluated in terms of the total dietary intake of nitrate and nitrite. The intake of nitrate, and particularly nitrite from cured meat, has to be taken into account in this calculation. At higher nitrate concentrations livestock is also at risk and nitrate poisoning of livestock has been recorded in southern Africa and elsewhere (Edori, and Kpee,2016).

Materials and Methods

The borehole water sample was collected from the study area with a view to determine Nitrate (NO_3^-), Sulphate (SO_4^{2-}) and Phosphate (PO_4^{3-}).In the preparation of reagents, chemicals of analytical grade purity (chromic acid) were used, and all glass water bottles (250ml) involved were sterilized with deionized water, rinsed and dried at room temperature. The borehole water was then pumped to fill the Polyethylene plastic bottles,eachof the three bottles were labels for identification of the water sampled collected from the borehole. The bottles were sendingto the laboratory in an insulated box to prevent external factors like high temperatures from changing some of the water parameters. Analysis was commenced within 12hrs and sampling Standard methods were followed as listed by American Public Health Association, (2012).

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Determination of Nitrate (NO_3^-), Sulphate (SO_4^{2-}) and Phosphate (Po_4^{3-})
$25cm^3$ of water samples was pipetted into the sample cell, $20cm^3$ of sodium nitrate ($NaNO_3$) reagent powder was measured with measuring cylinder, 250ml of distilled water was added and pour in volumetric flask,this was mix vigorously for 2-minute to dissolve the powder. The sample concentration was recorded at 500nm.

In determine sulphate (SO_4^{2-}), 25 cm^3 of water samples was pipetted into the sample cell, 15g of sodium sulphate ($NaSO_4$) powder was measured with measuring cylinder and100ml of distilled water was measured and pour in volumetric flask, this was swirled to mix and dissolve the powder. The cell was allowed to stand undisturbed for 5-minutes. The sample concentration was recorded at 450nm.

Finally, in phosphate (PO_4^{3-}), $25cm^3$ of water sample was pipetted into the cell, 2.5g of sodium molybdovanadate reagent powder was measured with measuring cylinderand $25cm^3$ of distilled water was added and this was swirled to mix and dissolve the powder. The mixture was allowed to stay for 3-minutes and the sample concentration was recorded at 430nm. Hence, the nitrate, sulphate and phosphate used portable data logging spectrophotometer (721models),and the values obtained were all recorded.The entire blank samples were treated in the same manner American Public Health Association, 2012).

Results and Discussion
Results on borehole water analysis were carried out in order to determine the Nitrate (NO_3^-), Sulphate (SO_4^{2-}) and Phosphate (PO_4^{3-}).

Table 1:Shown results on borehole water analysis

Parameters	Frequency (nm)	Results	WHO, 2011
Nitrate (NO_3^-)	500	0.054	250ml/g
Sulphate (SO_4^{2-})	450	0.850	250ml/g
Phosphate (PO_4^{3-})	430	0.022	250ml/g

The results of borehole water conducted to determine nitrate (NO_3^-), sulphate (SO_4^{2-}) and phosphate (PO_4^{3-}) concentrations was shown in Table 1. The determination was done to ascertain the quality of drinking borehole water as regard to health implications. The nitrate analysis was done with a mean value of 0.054 mg/l. Though, the value is high but not exceeds the values set by World Health Organization, (2011). The result indicated that water source containing high levels of nitrate (100 mg/l) is contaminated and should not be used for preparation of infant foods. Therefore, this calls for appropriate treatment measures before the consumption of this populace to avoid long term accumulative health problem.

The sulphate analysis was done with a mean value of 0.850mg/l. The sulphate values obtained exceeded the permissible range (250 mg/l) based on World Health Organization, standard (2011). The result shows that water above the permissible value (250mg/l) is unfit for consumption and may induce respiratory ailments in humans due to offensive odor and taste causing those exposed to water with higher concentrations of sulphate. Sulphate levels in water are expected to be around 250 mg/l. Therefore this, calls for adequate treatment and well-disposal of waste from humans and livestock, industrial discharges and over-use of limited water resources. The phosphate analysis was equally done with a mean value of 0.022 mg/l. The value obtained was below World Health Organization, (2011) permissible guideline value of (250 mg/l).The result indicated that the concentrations of phosphate ions might increase during the wet season when agricultural activities are at their peaks, thus, it caused health hazards such as blue baby syndrome in the case of excess phosphate. However, it was established that, high phosphorous concentration played better role in causing eutrophication of water bodies (World Health Organization, 2004).

Conclusion

In conclusion, the borehole drinking water from the study areas were analyzed and found to be below/above 250mg/l World Health Organization, standard for drinking water. Based on the results, the values obtained in nitrate, sulphate and phosphate indicated that the borehole drinking water is generally originated from anthropogenic activities and natural accumulation of nitrate in the groundwater. Thus, this indicated that the borehole water are unsafe for drinking purpose, and if it must be consumed it must be regularly treated to avoid health implications. Hence, information on drinking water quality should be considered as a reflection of quality of life. However, people may be aware of the dangers associated with the consumption of unsuitable borehole drinking water.

Recommendation

It is recommended that water from the borehole in the study area should not be used as drinking water to avoid dangerous health implications, except it is treated to meet the World Health Organization parameter standards for portable water before it released for public consumption.

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