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NITRATE IN DRINKING WATER: HOW SAFE IS THIS IN AFRICA AND ASIA?

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Abstract: Drinking water is one of the essential needs of life. Water comes from either a natural surface or a ground source. One of the rights of man is access to safe water. Unsafe water is due to anthropogenic and non-anthropogenic sources. One of the problems caused by these sources is the elevation of nitrate in water. Elevated nitrate in the body makes it harder for red blood cells to carry oxygen, this can be very dangerous for infants and some adults. Infants exposed to high amounts of nitrate may develop "blue baby syndrome". The aim of the paper is to find out how safe drinking waters are in terms of nitrate in Africa and Asia. To do this, selected articles were reviewed to determine the content of nitrate in different countries. The results were compared with national and international reference standards.

Key words: Water, unsafe, nitrate, blue baby, non-anthropogenic sources, distillation,

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INTRODUCTION

Water they say, is life. It means it is essential for life. It has got many uses for man, animals, plants, and others. One of its uses is drinking. According to Olaoye and Olaniyan (2012), it was noted that the quality of drinking water is a powerful environmental determinant of health.

WHO (2010) estimated, about 4.6 billion people globally, drink unclean water and 88% of diarrhea disease reported across the world is linked to unsafe water, sanitation, and hygiene. Also, about 10-20 million deaths recorded globally, are attributed to waterborne diseases (Yasin et al., 2015). Out of the record of death, more than 2.5 people die of diarrhea, children aged less than 5 years are affected in parts of Asia, Africa, and Latin America (Gambo et al., 2015).

Water from rain, well, borehole, stream, river, and waterfalls are the sources of drinking water in developing world. There are not many opportunities for pipe borne water, for this singular reason, most of the waters are polluted through lack of good sanitation and hygiene. Clean drinking water is a high priority for everyone, especially people who live in rural areas. Other sources of pollution of these waters are increases in industries, vehicles, unpaved roads, expired tyre and other natural and anthropogenic activities.

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For continuous regular intake of safe water, it is always good to subject the environment and water into constant evaluations. Therefore, good quality water analyses should be based on metals, physico-chemical and biological parameters. One of the parameter to be determined is nitrate.

Then what is nitrate? Nitrate (NO3-) is water soluble, it exists as a salt of nitric acid. Part of the physical characteristics of nitrates is odorless and tasteless which are formed when nitrogen from ammonia and other sources mix with water. Nitrogen and nitrates occur naturally, the increase in nitrates in drinking water have been caused by fertilizer input in agricultural practices. Elevated nitrate levels in drinking water cause skin rashes, hair loss, birth defects and "blue baby syndrome," a potentially fatal blood disorder in infants (Stett, 2012). National Institutes of Health, USA linked increased risk of thyroid cancer with high nitrate levels in public water supplies (Manassaram et al., 2006).

According to CDC (2014), the primary occupational routes of exposure to nitrates are inhalation and dermal routes. Also, the primary route of exposure to nitrates general population is ingestion. While inhalation and dermal exposures are known in non-occupational settings on some occasions but are not the primary routes of exposure for the general population.

Children less than 4 months old are most at risk of adverse health effects from overexposure to nitrates. Because most of the children foods/ feeds are prepared with nitrate-contaminated water. A vegetable is known to be the most important source of human exposure, while it is meat in the diet (nitrite is used as a preservative in many cured types of meat). Vomiting and diarrhea can exacerbate nitrite formation in infants and has been reported to be a major contributor to MetHb risk in infants independent of nitrate/nitrite ingestion (McDonagh et al. 2013). At the oxidative stress peaks, pregnant women and their fetus might be more sensitive to toxicity from nitrates at or near the 30th week of pregnancy (Skold et al. 2011). Populations that may become symptomatic at lower levels of MetHb than predicted include patients with oxygen transport or delivery conditions like anemia, cardiovascular disease, lung disease, sepsis and presence of other structural hemoglobin variants. Part of the conditions that increase the risk of developing methemoglobinemia is enzyme deficiencies such as G6PD deficiency and RBC methemoglobin reductase deficiency/impairment as well as other genetic factors (Gordon 2012).

The aim of the paper is to find out how safe drinking waters are in terms of nitrate in Africa and Asia. To do this, selected articles were reviewed to determine the content of nitrate in different countries. The results were compared with national and international reference standards.

NITRATE IN DRINKING WATER IN ASIA – ISSUES

Kim et al., (2013) study was conducted at an experimental station at the National Academy of Agricultural Science, Suwon city, Gyeonggi province, South Korea. The worked on 66 rainwater samples collected from 2009 to October 2011. The result of the nitrate was between 36.1 and 40.0 mg/L in farming and non-farming periods respectively. In comparison with the WHO standard. The water is acceptable for consumption.

Sivamanikandan and John, (2015) studied the physicochemical characteristics of river water in Theni District, Tamilnadu, India, they recorded 4.50 – 7.65 mg/L for nitrate content. Also, Sajil Kumar and James (2013) in groundwater (Post-monsoon- 2-9 mg/L, Pre-monsoon-1-63 mg/L) and Bhat and Sharma (2015) too worked on groundwaters obtained in Sambhar Lake in India. Their results were: 7.69 – 28.45 mg/L. In comparison with Eastern Mediterranean Region and WHO standards, it was observed that the results were in total agreement with results obtained.

Tayne (2005) analyzed wells and obtained >5 and <70 mg/L, Sabareza et al. (2014) analyzed river water, they got 5 mg/L and 17.71-21.73 mg/L for surface water and rainwater respectively and Flores and Zafaralla (2012) recorded 0.01 18.20 mg/L for Mananga river water. These different water sources in The Philippines are within the 50 mg/L national water standard.

In Papua New Guinea, Ayoko et al. (2007) studied water obtained from surface and ground waters (boreholes). Their results were <0.1 and 0.1 mg/L. Kafia et al. (2009) determined nitrate in river water flowing in Erbil, Kurdistan, Iraq. The nitrate value in the river water was 1.5 to 9 mg/L. River water from Lower Mekong Basin, Cambodia had nitrate value of 0.19-0.29 mg/L (MRC, 2008).

In Thailand, the nitrate content of different drinking water have been worked upon by many scholars, for example, Pattanapipitpaisal and Suraruk (2012), Makaroom et al. (2013) and Hengsuwan et al. (2015) took their researches on the ground, surface water and drilled well respectively. Their results were 0.01 – 5.97 mg/L, 5.28 - 17.93 mg/L and not detected respectively. From the results, groundwater contained highest values. The high value was not only unique in Thailand, same was observed by Molla et al. (2015) in Bangladesh – 0.08-2.80 (surface water) and 2.10-5.20 mg/L (groundwater). In river waters from Anuradhapura, Sri Lanka, Perera et al (2014), obtained 1.45-5.28 mg/L (paddy area) and 1.05-5.28 mg/L (non-paddy area).

Semenyiih River in Selangar, Malaysia was subjected to nitrate analysis in 2013 by Al-Badaii et al. (2013). They recorded 4.23-8.53m g/L. In the same country, but different sources, Yusoff et al. (2013), determined river water (2.40-5.80 mg/L), Leachate (41.85-44.88 mg/L) and groundwater (7.45-12.67 mg/L). Kura et al. (2013) conducted their research on water ground from Kapas, Island, they reported 0.4-10.6 mg/L. From these results, it could be deduced that the drinking waters were suitable for consumption in terms of nitrate toxicity.

Nitrate values for rainwater from Southern Brazil were between 3.35 and 72.7 mg/L (Facchini Cerqueira et al. (2014). WSD (2015) reported – pump water (<2.5-14 mg/L) and surface water (1.4-2.9 mg/L) from Hong Kong. Lastly, Al-Ghamdi et al. (2014), reported 5.6-37.6 mg/L in surface and ground waters obtained from Al-Makhwah Region, Saudi Arabia.

NITRATE IN DRINKING WATER IN AFRICA – ISSUES

In Ethiopia, Yasin et al. (2015) determined nitrate in tap waters, protected and unprotected wells and springs collected at Kersa District and Jimma Zone. They were able to conclude that the values ranged between 1.92 and 2.55 mg/L and 1.92-42.39 mg/L respectively.

Akoto et al. (2011) studied rainwater samples from Ramia (0.11-0.32 mg/L), Antobuasi (0.01-0.42) and Wawasi (0.09-0.32 mg/L) all in Ghana. Also, in Akporkloe, Southestern, Ghana, Addo et al. (2013), worked on open wells and reported 0.69-1.41 mg/L. Elsewhere in Nigeria, the followings results were reported: wells from Udu community, Delta State had 0.001-0.72 mg/L. Olomukoro and Oviojie (2014), rainwater from Warri, Delta State, 0.09-0.41 mg/L (Olowoyo, 2011), harvested rainwater from Ogbomoso, Oyo State, 3.54-39.0 mg/L (Olaoye and Olaniyan, 2012) and wells from Mista-Ali Town, Bassa LGA, Plateau State, 6.0-8.0mg/L (Kangpe et al., 2014).

Far away in Ifangni District, Cotonou, Benin, Fatombi et al. (2012), worked on surface and well waters. They reported 1.30-33.0 mg/L and 21.1-102 mg/L respectively. Kushe (2009), reported 0.0-4.7 mg/L for groundwater found in Dedza, Malawi.

Maiga et al. (2014) gave their values (13.4-46.5 mg/L) for greywater samples obtained from Kologoudiesse, Burkina Faso and Likambo (2014) had 0.0-20.0 (Borehole) and 9.68-891 (Groundwater) from Yei County, South Sudan.

In Cameroon, Sorlini et al. (2013), studied waters from boreholes, open wells, rivers, piped water and lakes. From their reports, they obtained 0.0-27.6 mg/L. Wirmvem et al. (2013), worked upon ground and surface waters. Their results were 0.0-20 mg/L.

Somewhere in Bilda, Algeria, Hamaidi-Chergui et al. (2013) worked on Chiffa River, they got 0.00-7.00 mg/L same authors obtained between 8.0 and 30.50 mg/L for samples from different boreholes in the same country, Ain Defla region.

South African waters were not left out in this study. Akoth and Palamuleni (2015) obtained their results as follows: boreholes (0-11.1 mg/L) and Spring Waters (1.8-17.1 mg/L), Olivier et al. (2008) had 0.0-0.8 mg/L thermal and spring waters from Limpopo and Samie et al. (2013) recorded Nd-46.99 mg/L from boreholes located in Mopani District.

Most countries adopted The World Health Organisation (WHO) guidelines for drinking-water quality. The guidelines are not mandatory, but they are used as a guide for water safety. Below are the maximum acceptable standards set for WHO, Asia, Africa and Eastern Mediterranean Region.

HOW SAFE ARE THE DRINKING WATERS?

Generally, the results of nitrate concentrations in the reviewed studies from Asia were generally low compared to those recommended by Eastern Mediterranean Region and WHO. For the purpose of the study, none out of the water samples from Asia was above the recommended values, However, there are some water samples from Africa that were above acceptable status. Examples are waters from South Sudan, Republic of Benin, Ethiopia and Burkina Faso, especially ground waters. The elevations may be attributed to nitrate concentration in groundwater and surface water which can reach high levels as a result of leaching or run-off from agricultural land or contamination from human or animal wastes, improper well construction, well location, overuse of chemical fertilizers. Sources of nitrate that can enter the well include fertilizers, septic systems, animal feedlots, industrial waste, and food processing waste. Wells may be more vulnerable to such contamination after flooding, particularly if the wells are shallow, have been dug or bored, or have been submerged by floodwater for long periods of time (CDC, 2015). Also, rain or irrigation water can carry the nitrates down through the soil to the groundwater below.

The Health risk assessment of the water samples using table 1 and figure 1 showed that most drinking water from Asia are not polluted, but concerted efforts should be put in place to prevent them been polluted. Drinking water that has 41-100 mg/L are risky for adults and young livestock. The water is unacceptable. Apart from these, there were more of the countries nitrate value that was below the maximum limit. This indicated that the exposed population is safe at these levels.

According to CDC (2015), heating, boiling, mechanical filters or chemical disinfection cannot remove nitrate from water. Only reverse osmosis and distillation systems can remove nitrates from your water.

The differences in the nitrate contents of the water selected in the literature may be due to the geographical origin, the soil and water contents of nitrate and analytical methods employed by the different authors and countries.

Drinking Water Standards (mg/L) – Asia and Africa
(**Data source:** WHO, 2013)

Country	Maximum Acceptable	Maximum Allowable
Thailand	45	45
India Philippines	45	
Papua New Guinea	50	
Malaysia	45	
Cambodia	10	
Sri Lanka	50	
Saudi Arabia	50	
Brazil	50	
Sudan	50	
Algeria	50	
Cameroon		
Burkina Faso		
Ethiopia	50	
Ghana	50	
Nigeria	50	
Benin Republic		
South Africa	50	
Malawi		
Tunisia	45-50	

Drinking Water Standards (mg/L) – Eastern Mediterranean Region and WHO		
WHO	50	
Egypt	44	
Iraq	50	
Jordan	50	
Lebanon	50	
Morroco	50	
Oman	45	
Palestine	50	
The Syrian Arab Republic	44	

CHEMICAL FACT SHEET OF NITRATE AND NITRITE IN DRINKING WATER GUIDELINE VALUES

Nitrate: 50 mg/l as nitrate ion (or 11 mg/l as nitrate-nitrogen) to protect against methemoglobinemia in bottle-fed infants (short-term exposure).

Nitrite: 3 mg/l as nitrite ion (or 0.9 mg/l as nitrite-nitrogen) to protect against methaemoglobinaemia in bottle-fed infants (short-term exposure).

Combined nitrate plus nitrite: The sum of the ratios of the concentrations as reported or detected in the sample of each of its guideline value should not exceed.

OCCURRENCE

In most countries, nitrate levels in drinking water derived from surface water do not exceed 10 mg/l, although nitrate levels in well water often exceed 50 mg/l; nitrite levels are normally lower, less than a few milligrams per litre.

BASIS OF GUIDELINE VALUE DERIVATION

Nitrate (bottle-fed infants): In epidemiological studies, methemoglobinemia was not reported in infants in areas where drinking water consistently contained less than 50 mg of nitrate per litre.

Nitrite (bottle-fed infants): Application of body weight of 5 kg for an infant and drinking-water consumption of 0.75 litre to lowest level of the dose range associated with methemoglobinaemia, 0.4 mg/kg body weight. This is supported by accepting a relative potency for nitrite and nitrate with respect to methemoglobin formation of 10:1 (on a molar basis).

LIMIT OF DETECTION

Nitrate: 5 mg/l or lower should be achievable using biological denitrification (surface waters) or ion exchange (groundwaters).

Nitrite: 0.1 mg/l should be achievable using chlorination (to form nitrate).

ADDITIONAL COMMENTS

Nitrite can occur in the distribution system at higher concentrations when chloramination is used, but the occurrence is almost invariably sporadic. Methaemoglobinaemia is, therefore, the most important consideration, and the guideline derived for protection against methemoglobinemia would be the most appropriate under these circumstances, allowing for any nitrate that may also be present.

Methaemoglobinaemia in infants appears to be associated with a simultaneous diarrhoeal disease. Authorities should, therefore, be all the more vigilant that water to be used for bottle-fed infants is microbiologically safe when nitrate is present at concentrations near the guideline value or in the presence of endemic infantile diarrhea. Water should not be used for bottle-fed infants if the concentration of nitrate is above 100 mg/l but can be used if the concentration is between 50 and 100 mg/l if the water is microbiologically safe and there is increased vigilance by medical authorities.

All water systems that practice chlorination should closely and regularly monitor their systems to verify disinfectant levels, microbiological quality, and nitrite levels. If nitrification is detected (e.g. reduced disinfectant residuals and increased nitrate levels), steps can be taken to modify the treatment train or water chemistry in order to minimize nitrate formation. Efficient disinfection must never be compromised (WHO, 2011).

Infants, pregnant women, nursing mothers, or elderly people are the most vulnerable to nitrate contaminants. It is always advisable to constantly subject drinking waters to test for nitrate if water samples are tested, the results should be compared with table 1 and figure 1 for interpretation. From the table, it could be deduced that water with the 0-40ppm limit is suitable for consumption for both humans and livestock. 41-100 ppm is risky, over 100 should not be used for drinking. According to CDC (2015), removal of nitrate from water can be done by using ion exchange, distillation, and reverse osmosis as treatment processes. Whereas heating or boiling of the water may not remove nitrate, the reason is that part of the water will evaporate during the boiling process, dryness of the water will increase the concentration of nitrate if the water is boiled. The use of filters or chlorination does not remove nitrate from water.

Table 1. Nitrate levels and Interpretations
Source: Skold *et al*. (2011)

Nitrate Level, ppm (parts per million)	Interpretation
0-10	Safe for humans and livestock. However, concentrations of more than 4 ppm are an indicator of possible pollution sources and could cause environmental problems.
11-20	Generally safe for human adults and livestock. Not safe for infants because their digestive systems cannot absorb and excrete nitrate.
21-40	Should not be used as a drinking water source but short-term use acceptable for adults and all livestock unless food or feed sources are very high in nitrates.
41-100	Risky for adults and young livestock. Probably acceptable for mature livestock if feed is low in nitrates.
Over 100	Should not be used as drinking water for humans or livestock.

Nitrate-N specifications (mg/L) (DWAF)		
Potability class	Ideal	< 6
	Acceptable	6 - 10
	Marginal	10 - 20
	Poor	20 - 40
	Unacceptable	> 40
Livestock	Acceptable	< 110

Figure 1. Nitrate level and interpretation (Colour)
Source: Skold et al. (2011)

CONCLUSION

From the literature reviewed, the nitrate contents in most of the drinking waters are low. This showed that as at the time of publishing the papers, the water samples are safe for consumption. It advisable to constantly monitor the nitrate content. This is just to ascertain that the waters are not polluted before been used or consumed.

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