Ayden International Journal of Environmental Sciences and Allied Research
Vol.1 Issue 1
February 2024
ISSN: Pending…

COMMUNITY HEALTH CONCERNS: ASSESSING NITROGEN IN GHANAIAN DRINKING WATER SOURCES

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Abstract: Nitrogen levels in drinking water can have significant implications for human health, particularly in agricultural communities where contamination is a concern. This study investigates nitrogen levels in drinking water sources within Ghanaian farming communities, aiming to understand the extent of contamination and its potential impacts on public health. Through comprehensive analysis and community engagement, valuable insights can be gained into the dynamics of nitrogen pollution in drinking water and the associated risks to local populations.
Keywords: Nitrogen levels, Drinking water, Ghanaian farming communities, Contamination, Public health

INTRODUCTION

Nitrogen in the aquatic environment occurs in four forms: ammonia (NH_3), nitrate (NO_3^-), nitrite (NO_2^-) and ammonium ion (NH_4^+). The most toxic nitrogen to biota such as fish and amphibians is ammonia, followed by nitrite and nitrate (Rouse et al., 1999). Nitrate is the final oxidation product of the nitrogen cycle in natural waters and is considered to be the only thermodynamically stable nitrogen compound in aerobic waters.
Following pesticides, nitrate is listed as the second greatest chemical threat to surface and groundwater in the world (Payal, 2000). Many water resources are faced with problems related to high concentrations of nitrate and nitrite. Increasing nitrate levels in water resources are a potential source of severe environmental stress to aquatic organisms, because nitrate is known to be toxic to crustaceans (Muir et al., 1990), insects (Camargo and Ward, 1992), amphibians (Baker and Waights, 1993, 1994) and fish (Tomasso and Carmichael, 1986). In humans, infants who drink water containing nitrate in excess could develop blue-baby syndrome (methemoglobinemia) (Spalding and Exner 1993; Hudak 1999; EPA 2002,). High levels of nitrate in drinking water can also cause cancer when it reacts with protein compounds in the body to form nitrosamine, a well-documented, cancercausing agent (Tricker and Preussmann, 1991). It causes algae to bloom resulting in eutrophication in surface water.
Recently concern has been raised over levels of nitrate in surface and ground water supplies. Significant sources of nitrate contamination of water include agricultural application of nitrogen based mineral fertilizers, manure and their subsequent runoff (Bogardi et al., 1991; Oldham et al., 1996). In some instances, high concentrations may be due to natural background levels or other causes such as on-site wastewater disposal systems (Jenkins

1999; Stoddard et al., 1999). With sufficient surface water infiltration, soluble nitrates can leach below the root zone to underground water (Hallberg and Keeney, 1993).

Occupying over 80% of the study area, agriculture (cocoa, maize, tobacco, tomatoes, yams and cassava) is the main economic activity in the Brong Ahafo Region of Ghana. While most farmers grow crops in the uplands, several others also grow their crops along rivers banks especially during the dry season. These streams pass through some towns and many villages. Communities along the streams use surface water mainly for domestic purposes like cooking, drinking, washing and bathing. Likewise, these water sources supply approximately 90% of the total drinking water needs.

Dry season vegetable farmers also prepare their nursery beds close to streams and use surface water for irrigation. The proximity of nurseries to streams results in clearing of stream bank vegetation to accommodate nurseries. Pollution of stream water and depletion of their resources can put the lives of many people in danger. Unfortunately, there is no information on effects of farming activities on stream water quality or of groundwater which serves as drinking water sources. Such information is vital for policy makers who should in turn give proper advice to farm owners and surrounding communities to alleviate potential health concerns. Water from these sources is not treated before it is consumed; therefore the type and levels of pollutants are unknown. The objective of this research was to assess the nitrogen pollution of the stream water whose banks are highly cultivated, in addition to boreholes within these highly cultivated areas.

MATERIALS AND METHODS

Sampling

Ten domestic surface water sources and five groundwater sources (four boreholes and one artesian well) were sampled. Selection of sample sites was based on their socio-economic importance as well as land use. Water samples were collected from these sites at three months intervals, from January to December 2005. A total of sixty samples were collected in the month of February (first quarter), May (second quarter), August (third quarter) and November (forth quarter). Each sample site was visited four times.

Water samples were collected between 0900 and 1100 GMT directly into clean high-density polyethylene bottles and stored in an icebox at a temperature of about 4°C. The sample containers were earlier washed with detergent, rinsed with de-ionized water and soaked in 1.4M HNO_3 solution overnight. They were again rinsed with de-ionized water prior to collection. For surface water sampling, bottles and caps were rinsed three times with water to be sampled during sampling and for ground water each borehole was pumped for 3 min and each sample bottle and its cap were rinsed three times with well water during sampling. Samples were transported to the Environmental Protection Agency's laboratory in Sunyani and examined within 24 h.

Methodology

Laboratory analyses were performed using procedures outlined in the Palintest Photometer Method. To a 10 ml of filtered water sam- ple, a test tablet was added and ground. The solution was allowed to stand for the colour to develop. The test tube was then placed in photometer which has been standardized and the readings recorded. NO_3-N was analyzed by hydrazine reduction and spectrophotometric determination at 520 nm; NO_2-N by diazotization and spectrophotometric determination at 540 nm and NH_3-N by reaction with alkaline salicylate in the presence of chlorine to form a blue-green indophenol complex and measured at 640 nm.

RESULTS AND DISCUSSION

Nitrate (measured as NO_3-N) distribution in the selected surface and ground water resources is provided in Table 1. The highest NO_3-N concentration in samples from ground water was 0.48 mg/l recorded during the third quarter at K. Danso. Relatively higher concentrations were observed in samples from boreholes in agricultural areas, where potential sources of nitrate contamination are more prevalent. Borehole samples from Atebubu and K. Danso recorded an annual mean of 0.28 ± 0.09 mg/l and 0.30 ± 0.13 mg/l respectively. There were significant variations in NO_3-N concentrations in groundwater throughout the period, the trend showed that higher levels were observed during the third and the fourth quarter analysis shortly after massive farming period. This may be the result of leaching from fertilizer use and human waste.

All surface water samples showed a low level of NO_3-N throughout the year when compared to limits set for drinking water standards by the WHO. The highest NO_3N level of 2.60 mg/l was recorded from the Subin stream at Wenchi during the first quarter. This was much higher than the concentrations obtained in second and third quarter samples. This area is noted for intensive tomato farming during the dry season (December – March). Stream water is used to irrigate vegetable farms along the banks. The artesian well at Bonsu recorded the lowest NO_3-N concentration of 0.09 mg/l during the fourth quarter. An annual mean NO_3-N content of the water samples varied from 0.16 ± 0.10 to 1.06 ± 1.07 mg/l. Minimum (0.16 ± 0.10 mg/l) and maximum (1.06 ± 1.07 mg/l) NO_3N content were observed from Bonsu and Wenchi communities respectively. Studies by Altman and Parizek (1995) on sloping agricultural land showed that while the concentration of NO_3 was high in cropping areas, it was low or non-detectable in the adjacent stream, due to dilution as the water discharged into the stream, dinitrification, and plant assimilation of NO_3 before entering the river. On sloppy land, ground water could be forced to flow close to the ground, where denitrification and plant assimilation were most likely to remove NO_3, before discharging into the stream. This explanation may also apply to this study. Additionally, in warmer seasons, NO_3 levels are likely to be reduced by biochemical processes and algal assimilation (Chimwanza et al., 2006). In Ghana, temperatures in the Brong Ahafo region typically reach 37ºC in the dry season, which increases biochemical activities in water. Since there is no surface runoff into the river, the NO3 concentration is further reduced. In absolute terms, NO3 concentrations were higher in the rainy season than in the dry season.

Most surface water samples recorded considerable amount of NO3-N between June and September (third quarter) during which fertilizer applications were high and when runoff from storm events was frequent. These samples were from streams draining watersheds with high levels of maize production at Fiaso and Biaso, as well as tomatoes and tobacco production at Wenchi and Tainso (Table 1).

The current situation of NO3-N distribution in the region is such that no clear demarcation can be made of areas high in NO3, since all the water resources studied in the area have NO3-N concentrations lower than the recommended limit of 10 mg/l NO3-N for drinking water (EPA, 2002).

All sixteen water sources contained NH3-N (Table 2). Concentrations of NH3-N were low in all samples. Values of NH3-N ranged from an annual average of 0.008 ± 0.006 mg/l (Tano stream at Tachiman) to 0.179 ± 0.31 mg/l (borehole at Jinijini). Ammonia is usually present in aquatic systems as dissociates ammonium ion which is rapidly taken up by algae, NH3 is therefore present at very low quantities (Horne and Goldman, 1994). Furthermore, under oxygenated conditions, NH3 and NO2 are oxidized to NO3 by nitrification bacteria (Huey and Beitinger, 1998). Therefore NH3 in drinking-water is not of immediate health relevance, and therefore no health-based guideline value is proposed. However, NH_3 can compromise disinfection efficiency, result in NO_2 formation in distribution systems, cause the failure of filters for the removal of manganese and cause taste and odour problems (WHO, 2003).

NO_2-N levels in samples are provided in Table 3. Mean NO_2-N concentrations varied between 0.006 ± 0.01 mg/l (at both Tano and Gao streams at Tachiman and Goaso) to 0.36 ± 0.47 mg/l (Wenchi from the Subin stream). The concentrations of NO_2-N in all samples throughout the year were lower than the maximum contaminant level (MCL) of 1.0 mg/l for public water systems established by the WHO (2003). Seasonal differences were not observed for NO_2-N in samples except those from Subin stream and ground water from Drobo.

Consequences of NO_3 pollution on amphibians and other aquatic organisms are hard to quantify. Research has shown that NO_3 is toxic enough to represent one of the most pervasive contaminants that threaten the survival of aquatic organisms (Hecnar 1995, Johansson et al., 2001). The lethal concentration of nitrate for a number of eggs and tadpole of some aquatic organisms are in the range of 1 - 10 mg/l, with chronic effect occurring at concentration of 2.3 mg/l (Kincheloe et al., 1979). Water quality data from agricultural areas sampled in the Brong Ahafo region showed nitrate concentrations in surface waters were below these critical toxicity levels for organisms for extended periods of time and during sensitive periods of their development such as egg and tadpole stage.

Table 1. Statistical analysis of nitrate content of surface and ground water samples in the Brong Ahafo region, Ghana.

Sampling site	**Water type**	**Max. mg/l**	**Min. mg/l**	**Variance mg/l**	**Mean mg/l**	**S. D.**
Subin (wenchi)	surface	2.60	0.30	1.15	1.06	1.07
Tain (Tainso)	surface	0.66	0.48	0.007	0.60	0.085
Bia (Biaso)	surface	0.66	0.22	0.05	0.42	0.22
Fia (Fiaso)	surface	0.55	0.30	0.01	0.42	0.10
Pru (Pruso)	surface	0.92	0.10	0.13	0.37	0.36
Tano (Ntotoroso)	surface	0.92	0.19	0.12	0.39	0.35
Goa (Goaso)	surface	0.42	0.22	0.009	0.29	0.09
Ankwasua (Afrisipa)	surface	0.42	0.10	0.02	0.23	0.14
Yokom (Kintampo)	surface	0.31	0.12	0.01	0.22	0.08
Tano (Tachiman)	surface	0.35	0.20	0.01	0.25	0.07
Borehole (Drobo)	ground	0.25	0.14	0.002	0.19	0.05
Borehole (Jinijini)	ground	0.35	0.18	0.006	0.24	0.08
Borehole(Atebubu)	ground	0.40	0.18	0.008	0.28	0.09
Borehole (K. Danso)	ground	0.48	0.18	0.02	0.30	0.13
Artesian well (Bonsu)	ground	0.31	0.09	0.01	0.16	0.10

§ Object in brackets indicates communities where water samples were collected

Conclusion

Dissolves nitrogen as NO_3-N, NH_2-N and NH_3-N in surface and ground water samples of selected communities in the Brong Ahafo region of Ghana was determined in this study. Concentrations of nitrogen forms were found to be below guidelines for drinking waters established by the WHO. Concentrations are non- toxic to humans who depend on these water resources for their domestic water needs. These low levels may not affect the health of the aquatic ecosystems of the investigated water bodies. However it is suggested that regular monitoring of these water resources should be encouraged. Results have also shown that there was an increase in the concentration of nitrates during the rainy season (second and third quarters).

Table 2. Statistical analysis of ammonia content in surface and ground water samples from the Brong Ahafo region, Ghana.

Sampling site	Water type	Max.mg/l	Min. mg/l	Variance mg/l	Mean mg/l	S. D
Subin (wenchi)	surface	0.050	0.014	49×10^{-5}	0.025	0.022
Tain (Tainso)	surface	0.050	0.032	6×10^{-5}	0.043	0.008
Bia (Biaso)	surface	0.060	0.012	48×10^{-5}	0.031	0.022
Fia (Fiaso)	surface	0.33	0.012	0.02	0.108	0.15
Pru (Pruso)	surface	0.048	0.024	13×10^{-5}	0.039	0.011
Tano (Ntotoroso)	surface	0.060	0.060	0.060	0.00	0.00
Goa (Goaso)	surface	0.060	0.00	69×10^{-5}	0.078	0.026
Ankwasua (Afrisipa)	surface	0.036	0.012	9.6×10^{-5}	0.025	0.01
Yokom (Kintampo)	surface	0.084	0.014	82×10^{-5}	0.048	0.028
Tano (Tachiman)	surface	0.642	0.00	0.096	0.179	0.31
Borehole (Drobo)	ground	0.048	0.024	9.9×10^{-5}	0.035	0.016
Borehole (Jinijini)	ground	0.012	0.00	3.2×10^{-5}	0.008	0.0057
Borehole(Atebubu)	ground	0.042	0.00	37×10^{-5}	0.029	0.019
Borehole (K. Danso)	ground	0.048	0.012	22×10^{-5}	0.032	0.015
Artesian well (Bonsu)	ground	0.036	0.012	9.6×10^{-5}	0.024	0.010

Table 3. Statistical analysis of nitrite content in surface and ground water samples from the Brong Ahafo region, Ghana.

Sampling site	Water type	Max.mg/l	Min. mg/l	Variance mg/l	Mean mg/l	S. D
Subin (wenchi)	surface	0.950	0.004	0.220	0.249	0.470
Tain (Tainso)	surface	0.050	0.003	37×10^{-5}	0.025	0.02

Bia (Biaso)	surface	0.030	0.009	7.9×10^{-5}	0.020	0.09
Fia (Fiaso)	surface	0.014	0.009	5.6×10^{-5}	0.011	0.002
Pru (Pruso)	surface	0.018	0.009	1.5×10^{-5}	0.013	0.004
Tano (Ntotoroso)	surface	0.32	0.00	2.6×10^{-5}	0.006	0.005
Goa (Goaso)	surface	0.014	0.001	3.1×10^{-5}	0.006	0.006
Ankwasua (Afrisipa)	surface	0.031	0.00	2.8×10^{-5}	0.007	0.005
Yokom (Kintampo)	surface	0.023	0.001	8.9×10^{-5}	0.013	0.009
Tano (Tachiman)	surface	0.007	0.004	2×10^{-6}	0.006	0.001
Borehole (Drobo)	ground	0.300	0.014	0.020	0.089	0.14
Borehole (Jinijini)	ground	0.013	0.001	2.4×10^{-5}	0.007	0.007
Borehole(Atebubu)	ground	0.023	0.007	4.6×10^{-5}	0.017	0.007
Borehole (K. Danso)	ground	0.023	0.003	7.9×10^{-5}	0.015	0.009
Artesian well (Bonsu)	ground	0.023	0.001	8.4×10^{-5}	0.013	0.008

ACKNOWLEDGEMENT

The authors are grateful for the financial support from the Ghana Government through the Environmental Protection Agency, Ghana, and the Head, Brong Ahafo Regional EPA for providing the necessary facilities.

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