Environmental Research Journal 2 (6): 311-316, 2008
ISSN: 1994-5396

Nitrate: Health Effect in Drinking Water and Management for Water Quality

Ibrahim A. Cissé and Xumei Mao
Department of Environmental Sciences and Engineering,
China University of Geosciences, 430074, Wuhan, P.R. China

Abstract: Nitrate is a common nitrogenous compound due to natural processes of the nitrogen cycle; anthropogenic sources have greatly increased the nitrate concentration, particularly in groundwater. The largest anthropogenic sources are septic tanks, application of nitrogen-rich fertilizers to turf grass and agricultural processes. Levels of nitrates in groundwater in some instances are the safe levels proposed by the EPA (Environmental Protection Agency) and thus, pose a threat to human health. Particularly in rural, private wells, incidence of methemoglobinemia appears to be the result of high nitrate levels. Methemoglobinemia, or blue baby syndrome, robs the blood cells of their ability to carry oxygen. Many methods are used to clean-up nitrate from consumption water. Technical regulation and issues required for management were developed in this study.

Key words: Nitrate, drinking water, management

INTRODUCTION

In my country drinking water is at risk from nitrates contamination. In Mali, only 5% of the population has access to drinkable water. The country has got 24000 modern spots and 200000 traditional wells. Mali is watered by 2 big rivers (the Senegal River and the Niger River). Out of the 24562 moderns spot, the water of 1406 water pots contains some nitrates higher than 100 mg L^{-1}. In addition to pollution mainly noticeable in areas where, the sheets of water are less deep with high concentration of cattle mainly in the lower delta of Niger.

All these waters need to be treated in to avoid hydric diseases. Nitrate is a problem as a contaminant in drinking water (primarily from groundwater and wells) due to its harmful biological effects. High concentrations can cause methemoglobinemia and have been cited as a risk factor in developing gastric an intestinal cancer. Due to these heath risks, a great deal of emphasis has been placed on finding effective treatment processes to reduce nitrate concentrations to safe levels. An even more important facet to reduce the problem is prevention measures to stop the leaching of nitrate from the soil. Some suggest that reducing the amount of fertilizers used in agriculture will help alleviate the problem and may not hurt crop yields. Other new developments in leach pits and slurry stores help to control the nitrate that comes from stored manure.

By installing these prevention methods and reducing the amount of fertilizer used, the concentration of nitrate in the groundwater can be reduced over time. Treatment processes, such as ion exchange can have an immediate effect on reducing levels in drinking water. These processes do not remove all the nitrate, but can help to bring the concentration down to the suggested level of 10 mg L^{-1}.

ENVIRONMENTAL PROTECTION AGENCY REGULATIONS

In Mali, the service of Hydraulic is in charge of the regulation of water quality on all the extent of the territory as in the United States Environmental Protection Agency, which is currently establishing National Primary Drinking Water Regulations for over 80 contaminants under the Safe Drinking Water Act (Vogt and Cotruvo, 1987). The goal is to reduce the contaminant concentrations of all drinking water to levels near those prescribed in the Maximum Contaminant Level Goals (MCLGs) previously established by the EPA (Vogt and Cotruvo, 1987). MCLGs are non enforceable health goals at which no known or anticipated adverse effects on health of persons occur and which allow an adequate margin of safety (Vogt and Cotruvo, 1987).

The Maximum Contaminant Levels (MCLs) are to be set as close to the MCLGs as possible (Vogt and Cotruvo, 1987). In the case of nitrate concentrations, the MCL has

Corresponding Author: Ibrahim A. Cissé, Department of Environmental Sciences and Engineering, China University of Geosciences, 430074, Wuhan, P.R. China

been set at 10 mg L^{-1} (ppm) as nitrogen which is also the proposed MCLG (Vogt and Cotruvo, 1987). For many contaminants, carcinogenicity is the primary characteristic which determines the MCL; however, because there are no conclusive epidemiological studies which link nitrate to cancer in humans, carcinogenicity was not taken into account in the establishment of the MCL for nitrate (Kamrin, 1987). The determining factor in the EPA's decision to set the MCL at 10 mg L^{-1} was the occurrence of methemoglobinemia in infants under of 6 months. The MCL reflects the levels at which this condition may occur (Kamrin, 1987).

Although, the MCL for nitrogen was set at 10 ppm nitrate-nitrogen, in 1976 the EPA suggested that water having concentrations above 1 ppm should not be used for infant feeding. This guideline is very conservative and nitrate concentrations below 10 ppm are probably harmless as well. However, because concentrations this low are common, the EPA hopes this guideline will induce people in rural areas to have their wells tested so that severe nitrate contamination is detected and serious health problems are avoided in the future.

TECHNICAL ISSUES REQUIRED FOR MANAGEMENT

The major technical issues relate to developing both an adequate data set to identify the spatial and temporal patterns of nitrate contamination and an understanding of the major processes affecting nitrate behaviors in the soil and groundwater system.

Nitrate loads and contamination processes: The importance of the local conditions on the ultimate nitrate concentrations in groundwater means that future works should be focused on areas at risk of groundwater contamination. This requires identifying the areas to be targeted for detailed studies and improved management of various land use activities. For each area at risk, the factors needing to be addressed relate to the nitrogen loading and the resultant leaching of nitrate to the water table and the behaviour of nitrate within a groundwater plume. These are:

For the soil and unsaturated zones, an integrated approach to land planning, both rural and urban, is needed from soil scientists, agronomists and hyrdrogeologists to develop techniques to minimise nitrate loads from particular activities. There is a need to understand the soil and unsaturated zone processes and the generation of nitrate leachate and its migration to the water table processes contributing to leaching for strategic land uses in risk areas and the effects of changes in land management practices on leaching; the key drivers of nitrate loads through soil to the water table and a quantitative assessment of leaching potential for different soils, land uses and management practices. This includes better understanding of nitrogen uptake by plants in particular soil and climatic regimes and the kinetics of nitrate migration through the unsaturated zone and the likely flux of nitrate to reach the water table. This may include verification of existing and development of new modeling tools, including instrumented monitoring sites.

In the saturated zone, there is limited predictive capability for the longer-term attenuation processes within a groundwater plume. Groundwater samples from individual bores may record lower concentrations than others in the same area, which may reflect conditions in an aquifer system and the pathways by which nitrate may migrate within the aquifer system; there is a need to fully understand the groundwater flow system in the vicinity of any of the types of nitrate sources so that the data generated on the nitrate loads and the monitoring that has been or may be introduced is able to be interpreted effectively; t is generally assumed that once a nitrate plume is generated, it will continue to migrate down gradient toward a receiving environment with no loss of nitrate. Herbicide and excess NO^{-}_3 were more frequent in unconsolidated aquifers than in bedrock aquifers (Burkart and Kolpin, 1993).

From a site management perspective this can have implications for the sitting of nitrate generating developments an understanding of nitrate dilution, dispersion and attenuation, as well as appropriate to identify the impacts on receiving waters and to asses the health risk which may result in potable aquifers with nitrate concentrations above drinking water standards and such an understanding will include detailed understanding of denitrification processes and establishing guidelines for identifying sites where denitrification may occur.

The vertical extent of nitrate contamination within an aquifer is not well understood. More detailed documentation of vertical as well as lateral and temporal conditions would assist in understanding the distribution and potential migration of high nitrate groundwater with in aquifer systems. Leakage of nitrate through to deeper groundwater systems and the factors which may allow this to occur need to be considered. Detailed understanding of the variation in groundwater nitrate concentrations, including the relationship of recharge to nitrate concentration is currently inadequate. This has implications in understanding the behaviour of nitrate plume migration and the ability to utilise nitrate affected resources; in urban areas there is a need to identify the impact of sewers on nitrate sources in groundwater and the distribution of nitrate contaminated ground waters on receiving water environments, including the ratio of N:P, is necessary to establish the impact of discharge of nitrate contaminated groundwater and the sitting of potentially contamination activities close to receiving waters. Concentrations of nitrate (and ammonium) are likely to be low in most rural contain halite, NaCl and trona, $NaHCO_3$; these form a wide sabkha plain in the Fala of Molodo (Segou area), which is the former course of the Niger River (Valenza *et al.*, 2000).

Policy implications: The implementation of the technical programs outlined above will in some cases require or result in major education programs, improved planning practices and perhaps environmental protection regulations. The overall objective is to reduce accession of nitrate below the root zone by careful management. Some general policy directions to achieve a reduction in the load of nitrate to groundwater and their implications are presented below.

Management of farm wastes: Farming practices which better manage animal waste loadings on paddocks will assist in minimizing the load of nitrate to the water table. More intensive animal husbandry requires well designed waste collection, management and effluent reuse schemes. More efficient waste management could result in better economic returns in the longer term.

Urban development applications: New urban development proposals need to clearly establish the total nitrogen balance resulting from the development including household and industrial effluent, disposal of solid waste (a point source of nitrate), fertilizers applications to household and urban gardens. Appropriate development guidelines should be adopted and implemented by local planners. In areas, where there is a potable groundwater resource, the implications of drawdown of water levels and potential migration of nitrate contamination into the zone of groundwater extraction will need to be identified. Similarly, the implications of developments on water bodies need to be established.

Groundwater monitoring of urban supply bores: Routine monitoring of urban groundwater supply wells should be conducted and the analytical results made available on relevant state groundwater data bases. Although, this practice is conducted in some States this should be mandatory. The data should be regularly interpreted and reported. In the event of major water resource nitrate concerns for health or environment, nitrate protection zones should be established. The criteria for assigning such a zone should be based on the beneficial use of the groundwater. Establishing the form of such a zone may be either site/area specific for major problem areas requiring specific investigations. In smaller zones, a series of generic criteria could be developed.

Monitoring of domestic water bores: All bores used for domestic purposes should be analysed for presence of nitrate on a regular basis and the results forwarded to a central state groundwater data base. This may require alteration of the bore classification in some areas which currently refer to stock and domestic bores.

Community participation in groundwater protection: Diffuse sources dominate nitrogen loads to aquifers and can realistically only be effectively managed by landowners who are aware of the potential for contamination and the means to reduce and/or prevent it. Groundwater protection is within the issues addressed by the Landcare movement but received scant attention mainly due to the lack of available information on these factors, at a community level and in many cases, in resource management authorities. Knowledge generation and transfer are required.

PROBLEMS ASSOCIATED WITH HIGH LEVEL OF NITRATE IN WATER

High nitrate levels in water can cause methemoglobinemia or blue baby syndrome, a condition found especially in infants under 6 months. The stomach acid of an infant is not as strong as in older children and adults. This causes an increase in bacteria that can readily convert nitrate to nitrite (NO_2). Do not let infants drink water that exceeds 10 mg L^{-1} NO_3-N. Sporadic cases and occasional fatalities occurred through the 1980s and 1990s, most often resulting from ingestion of nitrate-contaminated well water by infants (Shearer *et al.*, 1972). 2,473 infants were studied in communities with medium-high and low concentrations of nitrates in the drinking water in coastal plain of Israel (Shuval and Gruener, 1972). They found that 3 1.5% of the infants up to 60 days of age in the study population have MetHb levels higher than 1.7% as against 21.9% for the controls.

Nitrite is absorbed in the blood and hemoglobin (the oxygen-carrying component of blood) is converted to methemoglobin. Methemoglobin does not carry oxygen efficiently. This results in a reduced oxygen supply to vital tissues such as the brain. Methemoglobin in infant blood cannot change back to hemoglobin, which normally occurs in adults. Severe methemoglobinemia can result in brain damage and death. Some Russian studies (Johnson and Kross, 1990), suggest that the increasing levels of methemoglobinemia due to the water ingestion of contaminated wells by nitrates are not only the case of babies.

Pregnant women, adults with reduced stomach acidity and people deficient in the enzyme that changes methemoglobin back to normal hemoglobin are all susceptible to nitrite-induced methemoglobinemia. The most obvious symptom of methemoglobinemia is a bluish color of the skin, particularly around the eyes and mouth. Other symptoms include headache, dizziness, weakness or difficulty in breathing. Take babies with the above symptoms to the hospital emergency room immediately. If recognized in time, methemoglobinemia is treated easily with an injection of methylene blue.

In fact, most of the nitrate, we consume is from our diets, particularly from raw or cooked vegetables. This nitrate is readily absorbed and excreted in the urine. However, prolonged intake of high levels of nitrate is linked to gastric problems due to the formations of nitrosamines. N-nitrosamine compounds have been shown to cause cancer in test animals. Studies of people exposed to high levels of nitrate or nitrite have not provided convincing evidence of an increased risk of cancer. Other epidemiologic investigations established a correlation particularly strong the exposure to nitrates enters drink water and the incidence of cancer gastric (Rolando *et al*., 1981; Gilli *et al*., 1984; Jensen, 1982; Leclerc *et al*., 1991).

CLEAN UP NITRATE FROM WATER

There is no simple way to remove all nitrates from water. Finding and correcting the source nitrate contamination is the best of course and action. Although, it common to think of boiling, softening or filtration as a means of purifying water, none of these methods reduce nitrate contamination. In fact, boiling water that contains high nitrates can actually increase the nitrate concentration. Reverse osmosis, ion exchanges and distillation units could conceivably provide home treatment for removing nitrates from water, but processes can be complicated, expensive and generally require routine maintenance. Activated carbon and other simple filters do remove nitrate s any significant degree. Home treatment are generally not recommended, particularly as permanent solution to assure nitrate-free water for infant use.

However, where raw water resources used for the production of drinking water contain too many nitrates, the professionals of water implement various techniques so that distributed water is in conformity with the standards. Can be a question, first of all, of dilutions: To mix a nitrate resource too charged with another resource which contains only very little of it or at all, so that the mixture obtained has a nitrate concentration satisfying the standard. Several techniques of treatment, approved by the ministry for Health make it possible, moreover, to eliminate nitrates during the production process of drinking water. These treatments are not known perfectly by our companies specialized in the production and the distribution of drinking water: The denitratation by exchanging resin of ions: Water to treat cross-piece of the resins, which fix the ions nitrates and replace tem in equal quantity by ions chlorur. Denitrification is a biological technique of treatment: Bacterial cultures consume nitrates and release from nitrogen and oxygen. The elimination of ammonium and nitrates is enough complex. It is a proceeding, which comprises a aerobic slap and a anaerobic slap. At the time of the stages aerobic two bacteria are brought into play. Initially the nitrosomonas. Who transforms ammonia into nitrite. Then the nitrobacteria transform nitrite into nitrate. One calls commonly these 2 processes nitrification and then the anaerobic bacteria take the changing. These bacteria transforms nitrate nitrogen some (gas atmospheric).

This slap is call denitrification. It can be to realize with much of bacteria anaerobic, such as the achromobacter, the bacillus and the pseudomonas. The first slap of denitrification again transforms nitrate into nitrite and this one is then transform diazotize some (N2). This gas can be reject freely in the atmosphere without causing damage the environment.

METHOD OF NITRATE CONCENTRATION MEASUREMENT

The spectrophotometer UV/Visible was used to measure the concentrations of nitrate in this study. The absorbances of all NO_3-N samples were measured at 220 nm. The calibration curve (Standard curve) was used to calculate the concentration of Nitrate contained into each sample. All the results were reported the table.

RESULTS AND DISCUSSION

Mali is located in the Sahel region of West Africa; the main activity of population is faming. Therefore, Intensive agricultural practices, essential to achieve high crop and livestock yields, presents particular risks to water sources. Fertilizers and pesticides can readily penetrate the ground water sources and run off during rainfall adds to the level of contaminants in surface waters and ground water.

Table 1: Data: about wells water quality monitoring in different areas in Mali. It contains: The number of wells, the perennially and the Nitrates concentrations per area

Areas	No. of well/area	Perennially (%)	NO_3-N (mg L^{-1})
Kayes	4300	53	2257
Koulikoro	3987	52	2469
Sikasso	4632	78	2686
Ségou	3789	74	1520
Mopti	3920	71	1593
Tombouctou	1965	91	1533
Gao	1419	67	963
Kidal	350	73	217
Bamako	200	85	130

In this investigation, the results indicated that Sissako area has the highest number of well and the percentage of perennially is 78 (Table 1); that means the risk of nitrates contamination is average. The same phenomenon is observed in the following areas: Mopti, Segou and Kidal. On the other hand, the areas which have the high risk of nitrate contamination are: Kayes, Koulikoro and Gao; because the percentages of well perennially in these areas are weak (Table 1). According the percentage of well perennially found in Tombouctou and Bamako (Table 1), the risk of nitrate contamination is very weak. The result showed that the risk of nitrate contamination is possible in whole areas in Mali; but the highest of nitrates level in ground water depend to the agricultural activities by using fertilizers or pesticides and livestock yields.

Although, the amount of nitrates concentration found in each area depends to the total numerous of wells examined. More the numerous is high more the total nitrates concentrations also increase as demonstrated in the Table 1. In this investigation, Bamako area has the lowest level of nitrate (Table 1). The highest level of nitrate concentration was found in Sikasso area (Table 1).

Indeed, pesticides were found to have polluted the water in villages in northern Mali in a survey conducted in 1999. Tombouctou, Gao and Kidal are in northern. A European Commission Humanitarian Office (ECHO) grant enabled a water quality improvement programme, including construction of new wells, cleaning up storage depots of expired pesticides and sealing contaminated wells; it also provides, medical care for the victims of poisoning. ECHO has estimated that there at least 85,000 L of obsolete pesticides throughout northern Mali.

CONCLUSION

The main concern with high levels of nitrate in groundwater is the increased incidence of methemoglobinemia. Also known as blue-baby disease, it causes the child to develop a bluish or grayish tint around the extremities. If left untreated the baby will not receive enough oxygen through the blood and could die. This problem arises primarily in rural areas where nitrate levels are not well monitored. With regard to the nitrate problem in groundwater the best suggestion to avoid health risks is to have wells checked frequently and to reduce the fertilization of fields. The overload of nitrogenous fertilizers to the soils actually kills the biota that helps to provide nitrogen to the soil, which the crop plants can use. By using much lower amounts of fertilizers these crops may still be as productive as those produced under heavily fertilized soils, due to the healthier environment for the microbes. If the farmer adds large amounts of fertilizer in the beginning then he is forced to use more and more each year. Using only moderate to low amounts at the outset allows the farmer to avoid the entrapment into this vicious cycle. Furthermore, many of the aforementioned prevention methods can be incorporated to help reduce nitrate leaching from the soil into the groundwater. Slurry stores and concrete lagoon pits can greatly reduce the concentration of nitrate. By avoiding over-irrigation of a field both turf grass managers and farmers can help to control the leaching of nitrate to the groundwater.

REFERENCES

Burkart, M.R. and D.W. Kolpin, 1993, Hydrologic and Land-Use Factors Associated with Herbicides and Nitrate in Near-Surface Aquifers. J. Environ. Quality, 22: 646-656. American Society of Agronomy, Crop Science Society of America and Soil Science Society of America 677 S. Segoe Rd., Madison, WI 53711 USA. www.actis-tm.com/consumer.htm. ISBN: 0-295-97019-7.

Gilli, G., G. Corrao and S. Favilli, 1984. Concentrations of nitrates in drinking water and incidence of gastric carcinomas: First descriptive study of the Piemonte Region, Italy. Sci. Total Environ. (STE), 34: 35-48. PMID: 6710137.

Johnson, C.J. and B.C. Kross, 1990. Continuing importance of nitrate contamination of ground water and wells in rural areas. Am. J. Ind. Med., 18 (4): 449-456. DOI: 10.1002/ajim.4700180416. http://rais.ornl.gov/tox/profiles/nitrates_f_V1.shtml. ISBN: 014797-55-8.

Jensen, O.M., 1982. Nitrate in drinking water and cancer in northern Jutland, Denmark, with special reference to stomach cancer. Ecotoxicol. Environ. Saf., 6: 258-267. PMID: 7106030.

Kamrin, M.A., 1987. Health Implications of Groundwater Contaminants. In: D'Itri, F.M. and Wolfson, L.G. (Eds.). Rural Groundwater Contamination, Lewis, Chelsea, Agris Record:US8840046,MI., pp: 225-233. ISBN: 08-737-11009. http://www.nal.usda.gow.

Leclerc, H., P. Vincent and P. Vandevenne, 1991. Nitrates in drinking water and cancer [Article in French]. Bull. Acad. Natl. Med., 175 (4): 651-66. Discussion 666-71. Links. PMID: 1793248. www.ncbi.nlm.nih. gov/pubmed/1933481.

Rolando, A., M. Orellana, E. Medina, A.H. Coulson, J.W. Sayre and R. Detels, 1981. Epidemiology of Gastric Cancer in Chile: I-Case-Control Study. Int. J. Epidemiol., 10: 53-56. PMID: 7239763. http://ije. oxfordjournals.org/cgi/ content/abstract/10/1/53.

Shuval, H.I. and N. Gruener, 1972. Epidemiological and toxicological aspects of nitrates and nitrites in the environment. Am. J. Pub. Health (AJ PH), 62:1045-51 PubMed Central (PMC) is the U.S. National Institutes of Health (NIH) free digital archive of biomedical and life sciences journal literature. www.actahort.org/ members/showpdf? booknrarnr.

Shearer, L.A., J.R. Goldsmith and C. Young *et al*., 1972. Methemoglobin levels in infants, in an area with high nitrate water supply. Am. J. Public Health (AJPH), 62: 1174-80. PMID: 5068711. pmep.cce.cornell.edu/ facts-slides-self/ facts/nit-heef-grw85.html-18k.

Valenza, A., J.C. Grillot and J. Dazy, 2000. Influence of groundwater on the degradation of irrigated soils in a semi-arid region, the inner delta of the Niger River, Mali. Hydrogeol. J., 8: 417-429. Springer Berlin/Heidelberg. DOI: 10.1007/PL00010977. www. springerlink.com/content/76qbrpfcmrt5bp4a/.

Vogt, C. and J. Cotruvo, 1987. Drinking Water Standards: Their Derivation and Meaning. In: D'Itri, F.M. and Wolfson, L.G. (Eds.). Rural Groundwater Contamination, pp: 213-215. Rural groundwater contamination. In: D'Itri, F.M. Wolfson, L.G. (Eds.). Chelsea, Mich. (USA): Lewis Publishers, 1987, pp: 213-223. ISBN: 08-737-11009. Agris Record: US8840045. www.nal.usda.gov.