Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268	Vol. 14	No. 4	pp. 877-880	2015

Original Research Paper

Nitrate Pollution in the Groundwater of Different Cropping Systems of Varanasi District, Uttar Pradesh, India

Mahendra Prasad† and Priyankar Raha
Department of Soil Science & Agricultural Chemistry, Banaras Hindu University, Varanasi-221 005, U. P., India
†Corresponding author: Mahendra Prasad

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 23-12-2014
Accepted: 03-03-2015

Key Words:
Nitrate
Groundwater
Pollution
Cropping system

ABSTRACT

The occurrence of high nitrate levels in groundwater has to be recognized as a threat to humans and animals. Infant methaemoglobinaemia and nitrate poisoning in livestock occur at unexpected times and places. Nitrate pollution in the groundwater is one of the major pollution problems. In the last few decades nitrate concentration in groundwater has increased dramatically. Groundwater contamination by nitrate (NO_3^-) is a global problem and is most often associated with leachates derived from fertilizers and animal or human wastes. The study presented here was carried out in Varanasi district. The nitrate content in water was investigated during premonsoon (March-April, 2013) and postmonsoon (November-December, 2013) seasons and compared with the standard values given by WHO. Eighty four, from different cropping systems (i.e. rice-wheat, rice-vegetable, vegetable-vegetable, pulse-pulse, orchard and sugarcane) groundwater samples were collected from the bore wells. The analysis of nitrate in these water samples reveals that some villages have a high concentration of nitrate, exceeding permissible limits of WHO (45 mg/L), which is due to the more than the required quantity of nitrogen based fertilizers, water, manure and pesticides are used extensively which all contribute to the non point source contamination of nitrates in groundwater of the study area.

INTRODUCTION

Nitrate contamination of groundwater is a worldwide problem (Kyllmar et al. 2004, Liu et al. 2005). Nitrate is soluble and negatively charged and thus has a high mobility and potential for loss from the unsaturated zone by leaching (Chowdary et al. 2005). Many studies showed a high correlation and association between agriculture and nitrate concentration in groundwater (Jordan & Smith 2005, Dunn et al. 2005) that has an impact on the economy, ecosystem and human health (Addiscott et al. 1991). This problem is likely to be more acute in areas where intensive cropping is practiced for a long period of time with liberal use of nitrogenous fertilizers (Burkart & Stoner 2007). Non point pollution caused by fertilizers and manures used in agriculture, often dispersed over large areas, is a great threat to fresh groundwater system. Intensive use of chemical fertilizers in farms and indiscriminate disposal of human and animals wastes on land results in leaching of the residual nitrate, causing high nitrate concentration in groundwater. Consequently, the groundwater resources, contaminated with high levels of nitrate (>45 mg/L as NO_3^--N), are an environmental hazard. Incidences of nitrate pollution in groundwater have been reported by several workers (Hantzsche & Finnemore 1992, Starr & Gillham 1993).

Increasing nitrate concentrations in shallow groundwater continue to be of international concern with respect to human health. The rising concentrations of NO_3-N in shallow groundwater and surface waters are closely associated with the intensification of agricultural production with increasing application of inorganic N fertilizers (Kumazawa, 2002, Ju et al. 2006). The health effect of nitrate in drinking water is related to nitrate, which may result from microbially reduced nitrate and can be the cause of methaemoglobinaemia in infants, known as “blue baby syndrome” (Walton 1951). Additionally, cancers and damage to liver and other organs by nitrate occurs due to the formation of nitrosomines (N-nitroso compounds), group of carcinogens produced from reaction of nitrite with amines, amides and other nitrogenous compounds (Menzer 1991). Therefore, the regulatory health limit of 45mg/L of NO_3^- is applied as safe drinking water quality standard in most developed countries (Westerhoff 2003).

BACKGROUND OF THE STUDY AREA

Physiographic location: Geographically, the district Varanasi is situated at 25°18' of northern latitude, 83°36' of eastern longitude and at an altitude of 80.71 m above the mean sea level in the Indo-Gangatic plain of eastern Uttar Pradesh (Fig. 1). The district Varanasi having alluvial soil lies in a semi-arid region to sub-humid belt of northern India. The district is surrounded by district St. Ravidas Nagar in the east, Chandauli in the west, Jaunpur in north and Mirzapur district in the south.

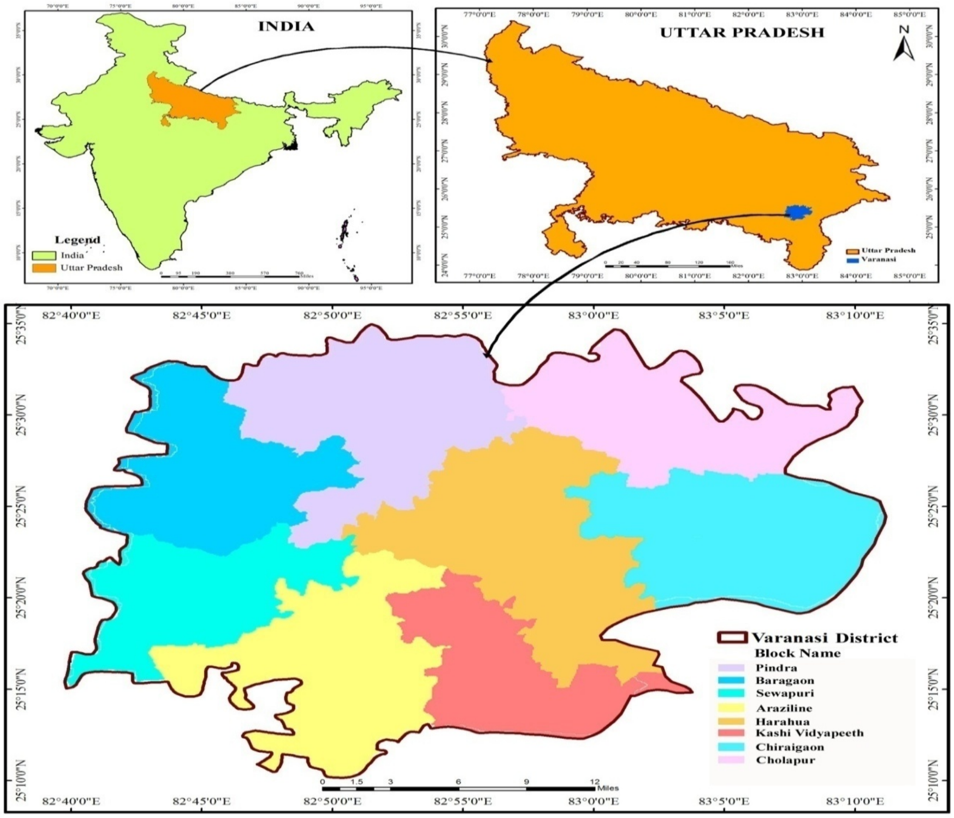

Fig. 1: Location map of the study area.

Climatic conditions: The district Varanasi falls in a semi-arid to sub-humid climate with moisture deficit index of 20-40%. It is often subjected to extreme weather conditions. The mean annual precipitation is 1100 mm. The area occasionally experiences winter cyclonic rain during December to February. In terms of percentage of total rainfall, about 84% is received from June to September, 0.7% October to December, 6% from January to February and 9.3 % from March to May as pre-monsoon rain. The mean relative humidity of this area is about 68% with a maximum 82% and minimum 30% during July to September and April to early June, respectively. The minimum and maximum average temperature in the area, range from 4.4° to 28.2°C, respectively. The temperature begins to rise from February onward until the summer often exceeding 45°C in the month of May and June. During these extremely hot months desiccating winds blow from west to east and dust storms frequently occur.

MATERIALS AND METHODS

For assessment of nitrate content in groundwater, 84 samples were collected from the areas of different cropping systems viz., rice-wheat, rice-vegetable, vegetable-vegetable, pulse-pulse, orchards and sugarcane in Varanasi district (Fig. 2) during pre-monsoon (March-April, 2013) and post-monsoon (November- December, 2013) season following standard protocols (Kundu et al. 2009). The samples were collected from bore wells. The water samples (1000 mL) were collected in polythene bottles and preserved by toluene in the laboratory. Nitrate content in water was determined colorimetrically (Nelson et al. 1954).

RESULTS AND DISCUSSION

Agricultural practices in the study area of Varanasi district are given in Tale 1. The compiled data of 84 groundwater samples of different cropping systems are presented in Table 2. The mean nitrate content in groundwater of different cropping systems of Varanasi district varied significantly among the different cropping systems. On average being the highest (39.27 mg/L in premonsoon and 23.94 mg/L in postmonsoon) in rice-vegetable cropping system (Table 2). The range of nitrate in groundwater was observed as 1.25-95.00 mg/L in the cultivated areas of different cropping systems of Varanasi. Hundred percent groundwater samples were contaminated with nitrate, but 26.9%, 33.3%,

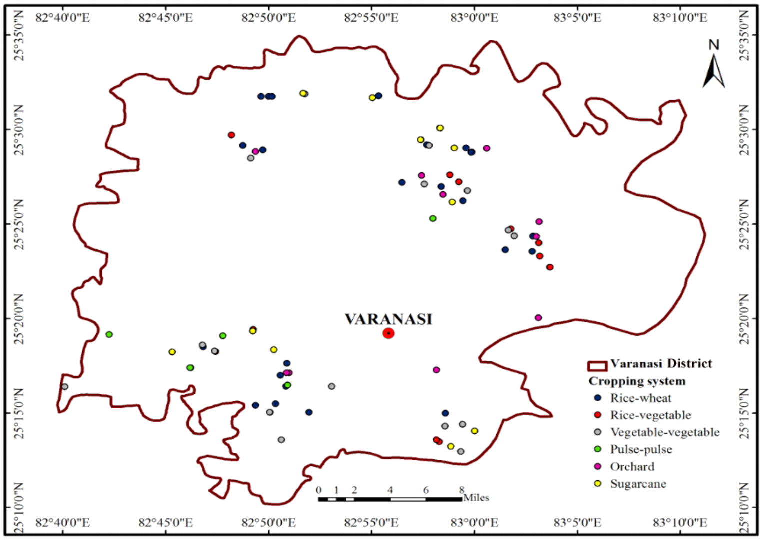

Fig. 2: Groundwater sampling locations of Varanasi district.

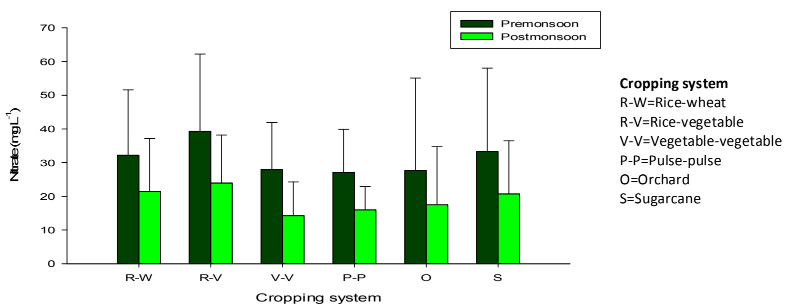

Fig. 3: Seasonal variation in nitrate content in groundwater of different cropping systems of Varanasi district.

5.5%, 10.0% and 18.2% pre-monsoon samples and 11.54%,16.6%,5.5% 10% and 18.1% postmonsoon samples in the cultivated areas of rice-wheat, rice-vegetable, vegetable-vegetable, orchard and sugarcane cropping system respectively, in Varanasi district have crossed the permissible limit of WHO for drinking water purpose. Higher concentration of nitrate in groundwater of rice-vegetable and rice-wheat cropping systems is an anthropogenic pollutant contributed by use of nitrogenous fertilizers, human and animal waste. Nitrate has been linked to agricultural activities due to excessive use of nitrate fertilizers, which is reflected in the present study. The groundwater samples in both pre-monsoon and post-monsoon period of the pulse-pulse cultivated areas of Varanasi have not crossed the limit of WHO. Thus, doses and methods of application of nitrogen fertilizer could be the major cause of nitrate contamination and toxic range for human consumption.

The concentration of nitrate in groundwater of different cropping systems was higher in pre-monsoon than post-monsoon (Fig. 3). Evapotranspiration leading to accumulation of salts in groundwater and the non-availability of recharge water are some of the reasons for higher nitrate content in groundwater during pre-monsoon. The nitrate concentration in groundwater has decreased in post-monsoon when compared with pre-monsoon season, due to the change in the volume of drainage reaching the water table and not by the change in concentration (Beck et al. 1985).

CONCLUSION

Nitrate content in the groundwater of different cropping systems of Varanasi district, Uttar Pradesh, India indicate that, considering all the cultivated areas of Varanasi district in an average, only 12.75% groundwater samples have crossed the limit of WHO. Thus, at present the overall situation of nitrate contamination of drinking water of Varanasi district is not alarming. But, this situation should not be ignored in near future. The sources of nitrate pollution in the study area are agricultural activities and human and animal wastes. Fertilizer was found as the main source of nitrate pollution in the study area. The appropriate remedial meas-

Table 1: Agricultural practices in the study area of Varanasi district.

S.No.	Cropping system	Ground water level(m)	Dose of nitrogenous fertilizer (kg/ha)	Irrigation schedule (Time of application)
		Range	Range	
1.	Rice-wheat	16-110	80-120	3-4
2.	Rice-vegetable	40-107	70-140	3-5
3.	Vegetable-vegetable	15-128	80-200+FYM	4-6
4.	Pulse-pulse	55-122	30-50	Rainfed-1
5.	Orchard	20-107	40-100	1-2
6.	Sugarcane	58-128	80-120+FYM	3-4

Table 2: Nitrate content in the groundwater of different cropping systems of Varanasi district.

S.No.	Cropping system	Premonsoon		Postmonsoon	
		Nitrate (mg/L)	% of samples crossed the permissible limit(WHO)	Nitrate (mg/L)	% of samples crossed the permissible limit(WHO)
1.	Rice-wheat	32.24±19.35	26.92	21.45±15.66	19.23
2.	Rice-vegetable	39.27±22.96	33.33	23.94±14.26	16.66
3.	Vegetable-vegetable	27.92±13.98	5.55	14.28±9.98	5.55
4.	Pulse-pulse	27.14±12.78	Nil	15.95±7.00	Nil
5.	orchard	27.63±27.49	10.00	17.46±17.25	10.00
6.	Sugarcane	33.24±24.81	18.18	20.70±15.76	18.18
Range		27.14-39.27		14.28-23.94	
Mean		31.24		18.96	
±S.D.		4.70		3.67	
C.V.		15.04		19.33	

ures should be implemented in order to improve the human health as well as animal health of the polluted area.

REFERENCES

Addiscoott, T.M., Whitemore, A.P. and Powlson, D.S. 1991. Farming, Fertilizers and the Nitrate Problem. CAB International: Wallinford, U.K., pp. 170.

Beck, B. F., Asmussen, L. and Leonard, R. 1985. Relationship of geology, physiography, agricultural land use and groundwater quality in Southwest Georgia. Groundwater GRWAAP, 23(5): 627-634.

Burkut, M. R. and Stoner, J. D. 2007. Nitrogen in groundwater associated with agricultural systems. In: Hatfield, J. L., Follett, R. F., (Eds.), Nitrogen in the Environment: Sources, Problems, and Management. Academic Press: Amsterdam, The Netherlands, pp. 177-202.

Chowdary, V.M., Rao, N.H. and Sarma, P.B.S. 2005. Decision support framework for assessment of non-point-source pollution of groundwater in large irrigation projects. Agric. Water Manag., 75: 194 -225.

Dunn, S.M., Vinten, A.J.A., Lilly, A., DeGroote, J. and McGechan, M. 2005. Modelling nitrate losses from agricultural activities on a national scale. Water Sci. Technol., 51(3-4): 319-27.

Hantzsche, N.N. and Finnemore, E.J. 1992. Predicting groundwater nitrate nitrogen impacts. Groundwater, 30(4): 490-500.

Jordan, C. and Smith, R.V. 2005. Methods to predict the agricultural contribution to catchment nitrate loads: designation of nitrate vulnerable zones in Northern Ireland. J. Hydrol., 304(1-4): 316-29.

Kundu, M.C. and Mandal, B. 2009. Nitrate enrichment in groundwater from long-term intensive agriculture: its mechanistic pathways and prediction through modelling. Environ. Sci. Technol., 43: 5837-5843.

Kyllmar, K., Mårtensson, K. and Johnsson, H. 2004. Model-based coefficient method for calculation of N leaching from agricultural fields applied to small catchments and the effects of leaching reducing measures. J. Hydrol., 304 (1-4): 343-54.

Liu, A., Ming, J. and Ankumah, R. O. 2005. Nitrate contamination in private wells in rural Alabama, United States. Sci. Total Environ., 346(1): 112-120.

Menzer, R.E. 1991. Water and soil pollutants. In: Amdur, M.O., Doull, J., Klaasen, C.D. (Eds.), Toxicology: The Basic Science of Poisons. Casarett & Doull's, New York, pp. 872-809.

Nelson, J.L., Kurtz, L.T. and Bray, R.H. 1954. Rapid determination of nitrates and nitrites. Anal. Chem., 26:1081.

Starr, R.C. and Gillham, R.W. 1993. Denitrification and organic carbon availability in two aquifers. Groundwater, 31(6): 934-948.

Walton, G. 1951. Survey of literature relating to infant methaemoglobinaemia due to nitrate contaminated water. American Journal of Public Health, 41: 986-996.

Westerhoff, P. 2003. Reduction of nitrate, bromated and chloride by zero valent iron (Fe0). J. Environ. Eng., 129(1): 10-16.