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Nitrate Contamination in Ground Water Sources of Jahazpur Tehsil, North West India: Causes, Effects and Prevention

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ABSTRACT

Serious health problems are linked to excessive nitrate (NO_3^-) concentration in drinking water. The aim of the present study was to assess the causes, determine the effects and discuss possible prevention strategies of NO_3^- toxicity in a river basin and in a hilly terrain area of Jahazpur Tehsil, North West India. For this purpose, ground water samples were collected from three different sources: dug wells (DW), hand pumps (HP) and bore wells (BW). Results indicated that water in DW and HP/BW located in the hilly terrain area contained significantly more nitrates concentration as compared to the respective water sources located in the river basin area. Nitrate levels were relatively higher in DW than in HP/BW in both areas. About 50% of the water samples from the hilly terrain and 35% from the river basin showed higher than the permissible limits NO_3^- concentration. Results showed large variation in NO_3^- concentration ranging from 0.28 to 334.40 mg/l, river basin area range was 0.28 to 277.00 mg/l whereas in hilly terrain area 1.72 to 344.40 mg/l. Excessive use of nitrogenous fertilizers, on site sanitation, mismanagement of animal waste and leakage of septic tanks in domestic area were identified as possible causes of excessive NO_3^- concentration in river basin. In the hilly terrain additional causes of elevated NO_3^- include, geogenic activities, high water table compared to river basin and poor well structure. Moreover, shallow DW neighboring to agricultural land, exhibited higher NO_3^- concentration as compared to those in domestic area.

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1. Introduction

Ground water is generally fresh under natural conditions, although not always necessarily of good chemical quality. Chemical composition of recent ground water is the result of geogenic processes and anthropogenic activities (Lake et al., 2003; Widory et al., 2004; Liu et al., 2005; Roa, 2006). Demand of groundwater has increased in recent time due to rapid growth in population and need for increased agricultural and industrial production. As a consequence, pollution of water bodies by numerous factors has also shown a rise. Nitrate is one of the common pollutants in groundwater, especially in agricultural areas. High nitrate concentration in ground water is found in intensively cultivated and irrigated agricultural areas, or due to intensive feedstock farms. The major sources of nitrate are inorganic fertilizers, septic tanks, poor dug wells, diffusive sewerage systems (Piskin, 1973; Canter, 1997), landfills, use of waste water for irrigation, and industrial wastes (Brindha and Elango, 2013). Nitrate concentration tends to be higher in locations with the amount of rainfall is low due to reduced dilution effect (Saxena and Saxena, 2014). WHO (1993) standard for nitrate level was originally set up at 45 mg/l for drinking water, and has been adjusted to 50 mg/l (Chetti and Smith 1995; Canter 1997). The Indian standard for drinking water quality specifies 45 mg/l as the maximum allowable limit (BIS, 2003). Nitrate consumption above the maximum permissible limit is of concern for human health as it causes methaemoglobinemia known also as the Blue baby syndrome (WHO, 1984; Majumdar, 2003). It is a condition where the haemoglobin of blood becomes unable to carry oxygen and leads to cyanosis and asphyxia (WHO, 2007). Infants under 6 month of age are more prone to met-haemoglobinemia. This disease is caused by the bacterial reduction of nitrate to nitrite in the intestinal tract. The nitrite then enters the blood-stream and combines with the haemoglobin to form methaemoglobin, which reduces the blood's capacity to transport oxygen. (Gupta et al., 2008) reported that high nitrate in water may result in health effects such as cancer, increased infant mortality, abortions, birth defects, recurrent diarrhea, recurrent stomatitis, histopathological changes in cardiac muscles, alveoli of the lungs and adrenal glands, as well as deterioration of the immune system of the body, illness in respiratory and reproduction system, thyroid problems (Dutt et al., 1987; Moore and Matalon, 2011) and Cancer (WHO, 1984). In India, higher NO_3^- concentration in ground water has been reported from different hydrogeological terrains (Somasundaram et al., 1993). Population in rural areas in Jahazpur tehsil, Bhilwara, NW India is mostly depending on agricultural base activities, use inorganic fertilizers in agricultural activities, and do not have proper animal waste dumping and sanitation facilities which increase NO_3^- concentration in ground water. Population water needs of this area are mainly met by ground water sources. Hence, this study is aim to determine NO_3^- level in ground water sources, its main sources, impact on human health and providing preventive majors to reduce NO_3^- concentration in drinking water.

2. Material and Method

2.1. Study Area and hydrogeology

Jahazpur tehsil is situated between 25⁰21'6"N to 25⁰46'23"N longitude and 75⁰2'50"E to 75⁰27'42"E latitude in Bhilwara district (Rajasthan, India). The climate of the tehsil is generally dry except in the short south-west monsoon season. The average annual rainfall in the tehsil is 280-630 mm. Jahazpur belt rocks are considered as early proterozoic (Sinha Roy et al., 1998) and these rocks are encompassed by quartz, soda feldspar, biotite, potash feldspar, hornblende, actinoite along with zircon and apatite. Tehsil is divided into two geographical areas one is the plain of river basin (Banas river) and another is the hilly terrain. The Banas river drains a basin of 45,833 km^2, and is located in east-central Rajasthan, between latitudes 24^0 15' and 27^0 20'N and longitudes$73^0$25' and 77^0 00' E. It is a seasonal river that dries up during the summer. The total length of the river is about 512 km.

2.2. Methodology

Ground water samples from ninety villages located in the broader rural area of the river basin and the hilly terrain areas of Jahazpur tehsil, North West India) (Figure 1) were collected in precleaned polythene bottles during June 2014 from dug wells (DW), bore wells (BW) and hand pumps (HP). Nitrate ion concentration was measured by using UV-VIS spectrophotometer (Double beam UV-1800 UV-VIS spectrophotometer, resolution of 1 nm, wavelength range is 190 to 1100 nm and wavelength accuracy ±0.1 nm at 656.1 D2 and ±0.3 nm (190 to 1100 nm) (APHA, 2012). Temperature and pH (Digital PH-200, pH / Temp Meter Tester Temperature Hydroponics) were determined on site using by portable instruments. To study the vertical variation in nitrate concentration in groundwater, the information regarding the depth of wells, structure of wells, thickness of soil zone, elevation of land forms, area of cultivation were collected during field trips.

3. Results and Discussions

Nitrate (NO_3^-) concentration in ground water of the hilly terrain area of Jahazpur tehsil, NW India was found relatively higher than in the river basin area (Figure 2).

Comparison of NO_3^- level with the standards set by the World Health Organization (WHO, 2007) indicated that around 50 % of water samples originated from the hilly terrain area and 35 % from the river basin area are exceeded WHO standard (Table 1). The results showed that ground water of the hilly terrain area is more polluted than the river basin area.

Nitrates in the study area ranged from 0.28 mg/l to 334.40mg/l. Specifically in the sources of the hilly terrain area nitrates (NO_3^-) varied from 1.72 to 334.40 mg/l whereas in the river basin from 0.28 to 277.00

Figure 1. The location map of study area

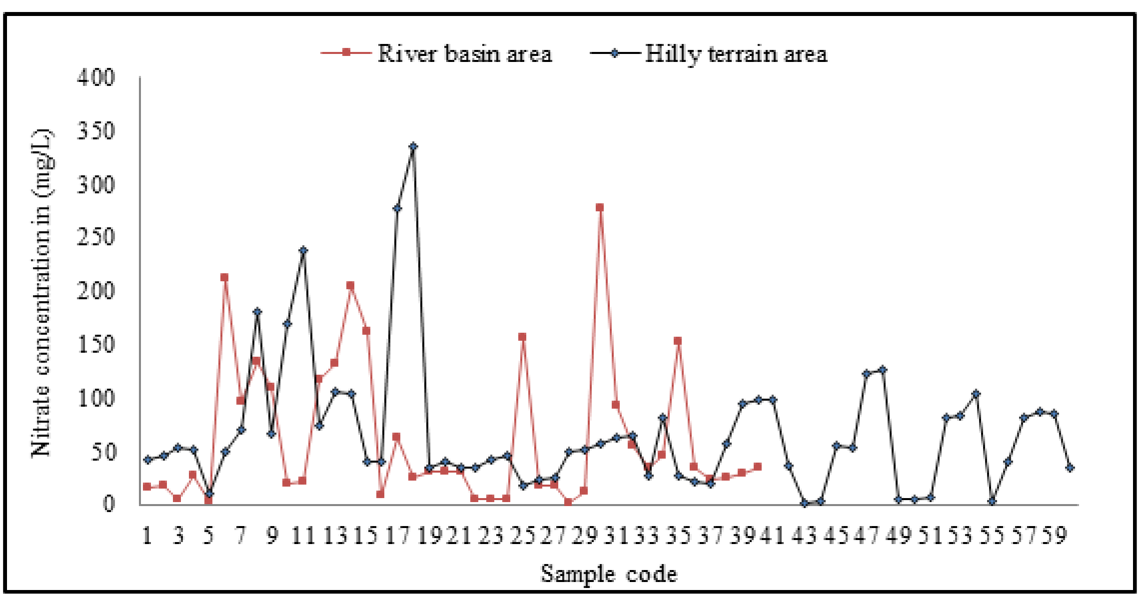

Figure 2. Nitrate concentration in ground water of the Hilly terrain area and River basin area of Jahazpur tehsil, NW India.

Table 1. *Comparison of nitrate concentration with WHO standards (50 mg/l) (WHO, 2007).*

Location	Water samples	Samples exceeding WHO limits		Samples within WHO limits	
	(N°)	(%)	(N°)	(%)	(N°)
Whole study	100	44 %	44	56%	56
Hilly Terrain	60	50%	30	50%	30
River Basin	40	35%	14	65%	26

Table 2. *Range and mean values of nitrate concentration in dug wells (DW) hand pumps (HP) and bore wells (BW) ground water samples.*

	River basin area			Hilly terrain area		
Source	N°	NO_3^- range	Mean concentration	N°	NO_3^- range	Mean concentration
DW	20	0.28-277.00	83.51	29	1.72-334.4	87.08
HP	9	12.36-161.0	67.66	6	35.25-98.56	59.79
BW	11	3.10-62.93	18.55	25	9.64-103.2	46.67
Total	40	0.28-277.00	62.08	60	1.72-334.4	67.51

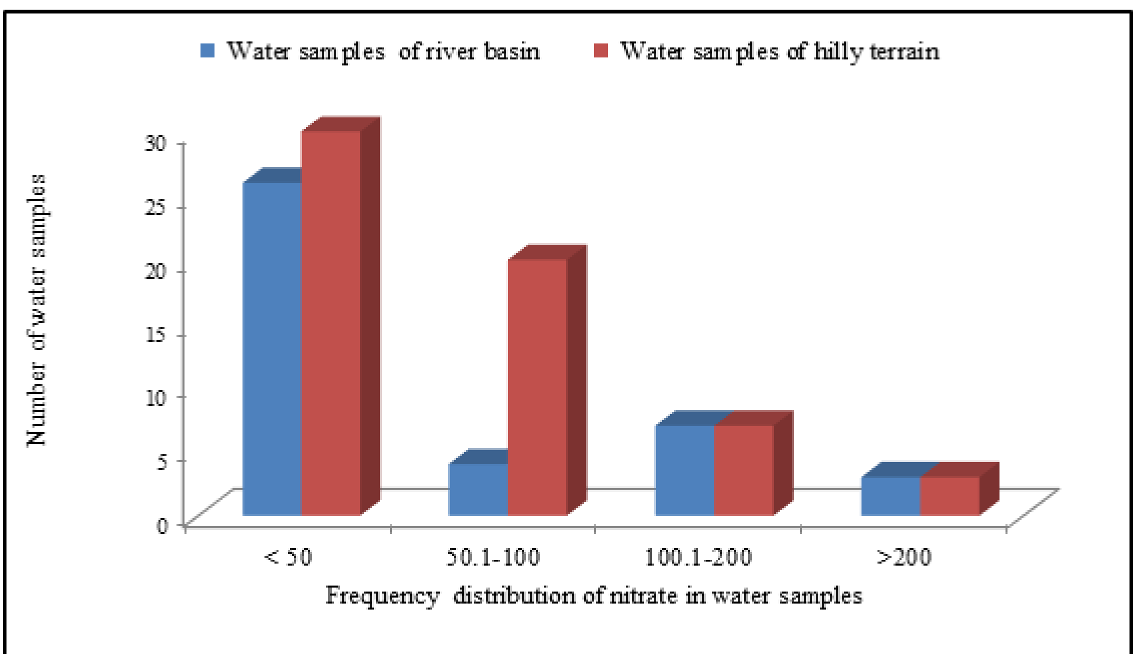

Figure 3. Frequency of nitrate in DW, HP and BW water.

mg/l. Mean NO_3^- concentration in the DW, HP and BW in the hilly terrain area was 87.08, 59.79 and 46.67 mg/l and in the river basin samples 83.51, 67.66 and 18.55 mg/l respectively (Table 2).
Ground water samples can be classified into four categories (Figure 3) on the basis of nitrate range. In 25 samples of river basin and 29 of hilly terrain nitrate concentration was reported within prescribed limit of WHO (> 50 mg/l), 5 samples in river basin and 20 samples in hilly terrain were found in range 50.1-100 mg/l whereas 7 of each area were found in range 100.1-200 mg/l and extremely high nitrate content range (>200 mg/l) was reported in 3 samples of each area. The most alarming condition of nitrate pollution is samples falling in <100 mg/l and the ground water sources belong to these categories needed immediate action plan to reduce the nitrate level.
Level of nitrate in water samples collected from the DW in hilly terrain area and river basin area was reported higher than the HP and BW as indicated in Figure 4.
62 % DW samples in hilly terrain area and 50 % samples in river basin area have higher nitrate concentration (>50 mg/l); 38.71% HP/BW samples in hilly terrain area and 20 % samples in river basin area exceeded the maximum describe limit. The different range of depth of wells indicated that nitrate level is higher in wells located in shallow depths (Figure 5) and land cultivated intensively in both areas and in domestic areas higher nitrate level was reported in wells located near densely populated area, dumping site of animal waste and on site sanitation places, and the wells that poorly structured.
In the river basin area soil is deeper than in the hilly terrain areas, water table is low, and depth of wells is more and wells are better structured with cemented walls. The rise up in water level in wells is less in monsoon season compared to hilly terrain area which reducing nitrate percolation. Wells in the hilly terrain are mostly located in lower land forms and surrounding by high elevated land forms which help in the rise up water level, nitrogen salts flow with rain water and enriched the land near the wells with nitrate and get flushed into wells water.

3.1. Sources of high nitrate in ground water

High nitrate (NO_3^-) levels may be present in drinking-water due to the anthropogenic and geogenic activities. Irrational use of manures and synthetic nitrogenous fertilizers on agricultural increase nitrate concentration in ground water. During field visits no major or/and minor industries were found in river basin area as well as in the hilly terrain area that could possibly transport the nitrate rich waste in the different water sources (DW, BW/HP). Hence, the possibility of water contamination with nitrates originated from industrial activities is rather low. The common synthetic fertilizers used in the study area for agricultural purposes are potash, nitrogen–phosphorous–potassium (NPK), DAP, ammonium sulphate and urea which laden with nitrogen. The absence of rational application of these fertilizers may account for the increased nitrate content in the groundwater of this area.
In rural areas a cattle farming is also an important source of income for the people living. Dumping of animal waste in big piles near domestic wells increases the nitrate level in shallow depth domestic wells through leaching waste. Also, the leakage of wastewater from septic tanks in the settlements will also lead to a high concentration of nitrate in groundwater collected from wells located in these areas. It is felt that the sources for nitrate in the groundwater of this area are diversified from fertilizers, improper management of animal waste, and sewage disposal and geogenic activities. In river basin area wide thickness of soil zone, deep water table, higher depth of wells, good structure of dug wells decreasing nitrate level compared to hilly terrain. Poor structure of wells, shallow depth, uneven land forms, presence of rocks, narrow zone of soil increasing nitrate level in water sources.

3.2. Impact of high nitrate content

Elevated NO_3^- level in ground water is harmful for human being as well as livestock. Nitrate consumption above the maximum permissible limit is of concern for human health and livestock poisoning. At sub-lethal levels of nitrate abortion and poor milk production have been recorded for lactating cows WRC Report (2009). During the field visits it was witnessed that in monsoon season (July-August months) animals of study area drink rain water stored in ponds and places which is laden with high nitrate concentration. Higher rate of livestock mortality was reported during these months. The social, health, and economic impacts of contaminated ground water depends on spatial distribution of nitrate, dependence of the populace on nitrate contaminated water, awareness of water quality, levels education and economic status of populace at risk. Good nourishment and medical care could be reason for this decline. Higher income group of society could escape the ill effects of nitrate contaminated water.

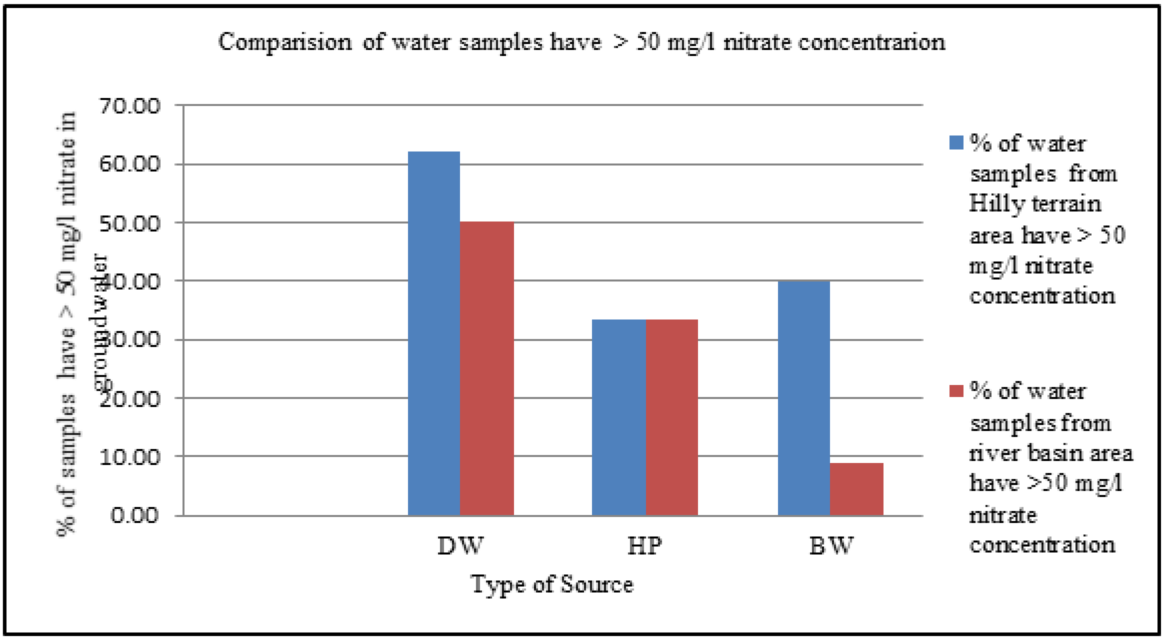

Figure 4. Comparison in sources DW, HP and BW exceeding limit (> 50 mg/l) of nitrate content in ground water in Hilly terrain area and River basin area of Jahazpur tehsil, NW, India.

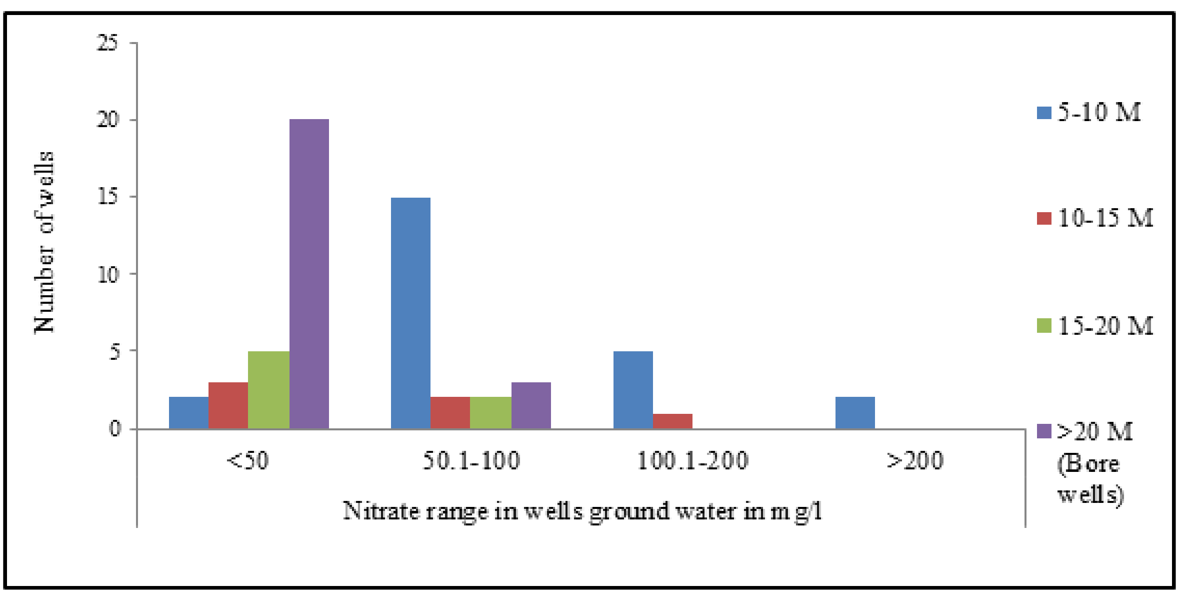

Figure 5. Correlation between depth of wells and nitrate level.

3.3. Prevention of nitrate content in ground water sources

The removal of nitrate or other pollutants from groundwater before using it for drinking purposes can be achieved by a number of available options. Methods that fit to the terrain conditions in the study area is of fundamental importance since most of the population suffer from poverty and low education level. Leaching of nitrate from the inorganic fertilizers can be minimized by control use of nitrogenous fertilizers, motivating farmers for organic farming, crop rotation, use animal wastes as manure, storage of animal wastes on non-penetrating floors such as cemented surface to avoid the leaching of these wastes and mixing with groundwater. Maintenance of poor dog wells structure and de-nitrification techniques are useful to reduce the nitrate content. On site sanitation in rural areas is big problem that also elevate nitrate in ground water in domestic dug wells, it should make compulsory to every family to construct proper sanitation facility in house, and government should assist for this to the poor families of the society and also formation of viable policies at government level and implement properly to improve the socioeconomic and education levels of people mostly living rural areas of tehsil.

4. Conclusions

The range of nitrate (NO_3^-) in hilly terrain area was ranged from 1.72 to 334.40 mg/l and in river basin from 0.28 to 277 mg/l. Dug wells of study area are found more polluted compared to bore wells/ hand pumps, and relatively more dugs wells located in agricultural land compared to wells located in domestic areas. Nitrate level in shallow depths wells was reported higher and level decreased with depth of wells. The elevated NO_3^- concentration in ground water of hilly terrain areas and river basin is due to excessive use of fertilizers, pesticides, insecticides, leaching of animal waste, leakage of septic tanks, onsite sanitation. Except these factors others also play important role in hilly terrain areas are geogenic activities, poor structure and depth of wells, narrow zone of soil and location of wells at lower land forms. Cemented wall in wells prevent the filtration of nitrate salt in wells that also reducing the nitrate in river basin areas. If animal waste is used in the agricultural fields as manure and the application of fertilizers can be reduced, more pollution to groundwater can be curtailed. Other preventing majors are educating people, economic assistance and cementing the dumping site for animal waste and reduction on site sanitation through awareness. This study will give the understanding on the present status of nitrate in ground water, causes of excess NO_3^-, effects on human health and livestock and also provide the preventing major's for excess NO_3^-.

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