Eco. Env. & Cons. 28 (October Suppl. Issue) : 2022; pp. (S226-S232)
Copyright@ EM International
ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2022.v28i06s.038

Nitrate Contamination in Gurugram District, Haryana

Vijay Laxmi[1], Jakir Hussain[2], Supriya Singh[3], Ikbal Husain[4], Sudesh Kumar[3] and V.K. Vadiya[1]

[1]Department of Science and Technology, Mewar University, Gangrar, Chittorgarh, Rajasthan, India
[2]Upper Yamuna River Board, Ministry of Jal Shakti, New Delhi, India
[3]Department of Chemistry, Banasthali Vidyapeeth Rajasthan, India
[4]Public Health Engineering Department, Bhilwara, Rajasthan, India

(Received 12 February, 2022; Accepted 25 March, 2022)

ABSTRACT

Groundwater has witnessed a significant increase in utilisation in recent decades due to its widespread availability and typically acceptable quality. Contamination of groundwater with nitrates and the associated health hazards is one of the most prevalent challenges affecting groundwater quality around the world. Nitrate (NO_3^-) is a particularly important groundwater pollutant because of its widespread presence in aquifers and its health and environmental consequences. Nitrate is present in nature as a by-product of agricultural and animal manure, as well as in anthropogenic waste. The purpose of this study was to determine the nitrate content in groundwater in various villages in Gurugram, Sohna, Farukh Nagar, and Pataudi block of Gurugram district, Haryana, where groundwater is the primary source of drinking water. Samples of groundwater from 156 wells were collected and analyzed the nitrate concentration. The minimum nitrate concentration of 1.23 mg/l as NO_3 was observed in Sherpur village of Pataudi Block of Gurugram District. The maximum concentration (102 mg/l as NO_3) was measured for Kankrola of Gurugram block of Gurugram district. Seventy eight percent of the samples had values under 45 mg/l, 22.43 % had values between 0-10 mg/l, 26.92% had values between 11-20 mg/l, 15.38 % had values between 21-30 mg/l, 11.53 % had values between 31-40 mg/l and 22 % had values beyond 45 mg/l. All of the Sohna block samples meet the BIS 10500:2012 permissible limit. Data reveals that 34 villages exceeded out of 156 villages having the nitrate concentration (45 mg/l) above the limit.

Key words : *Ground water, Nitrate contamination, Gurugram District, Haryana*

Introduction

Water is one of the most important components for the long-term survival of life on Earth. Water is continuously circulated in the different spheres of the earth. Out of total water present on earth, only 4% is freshwater which can be used for various purposes. 68% of available freshwater is groundwater which is a major source of drinking water, the agricultural sector, and industries. The hydrological cycle would not be complete without groundwater. In India, 85% of the requirements of drinking water and 60% requirements of irrigation are fulfilled by groundwater (Kumar, 2017). Apart from the quantity of groundwater, its quality is a matter of great concern as contamination of fresh groundwater creates undesirable effects in it and makes it unfit for drinking, irrigation, and other purposes. The growing rate of urban and industrial growth is bringing about unacceptable changes in groundwater quality (Nowak *et al.*, 2012; Nagamani *et al.*, 2015).

Recently, various point and nonpoint sources have been responsible for the pollution of groundwater resources. The issue has been reported huge. Among the many pollutants which enter the water aquifers, nitrate pollution is a worldwide problem

(Rezaei *et al*., 2017; Xiaosi *et al*., 2013; Elisante and Muzuka, 2017).

It is the second most polluting groundwater pollutant, posing harm to the ecosystem (Spalding and Exner, 1993; Bachmat, 1994). Nitrate occurs naturally at low concentrations in groundwater. The rise in the use of fertilizers, agricultural wastes, and domestic sewage are some of the factors which are responsible for the elevated levels of nitrate. A high level of nitrate contamination in groundwater leads to serious health hazards (Kundu *et al*., 2008). Some of the point and non-point sources of pollution are listed as follows:

Point Sources: Accumulation of disposed waste and liquid manure, untreated domestic sewage.

Non-point sources: Agricultural runoff, geological deposition, nitrogen fixation by bacteria, precipitation of atmospheric nitrogen.

These are various sources that are held responsible for the contamination of groundwater (Rabalais, 2002; Harper *et al*., 1983; Wakida and Lerner, 2005). The widespread practice of nitrogen-rich fertilizers also boosts the nitrate level in groundwater. In natural conditions, the concentration of nitrate in groundwater mainly depends on the soil type and geology of that area. Singh and Singh, 2004 reported that a few countries of Southeast Asia, Africa and Latin, America, having dry areas, are more prone to groundwater nitrate contamination as leaching of nitrate through dry soil is most likely to occur. Considering the toxicology of nitrate, the current standard limit for nitrate concentration in drinking water, set by WHO, 2007 is 10 mg/l NO_3-N or 45 mg/l nitrates.

Consumption of nitrate-rich water causes toxicity in humans. It impairs the functioning of the cardiovascular system and the central nervous system in adults at high concentrations, and it affects the oxygen-carrying capacity of blood at low concentrations, causing methemoglobinemia or blue baby syndrome in newborns (Kundu, 2008). The human body is not poisoned by nitrate. A dose of 9 g/day of sodium/ammonium nitrate can be safely administered to a person to treat phosphatic kidney disease, although nitrate is converted to nitrite in the human body, causing side effects (Manjumda and Gupta, 2000). Nitrite interacts with hemoglobin to generate methemoglobin, lowering blood's oxygen-carrying capacity.

The presence of nitrogen in the aquatic environment affects freshwater invertebrates as well. For freshwater invertebrates, Camargo *et al*., 2005 recommended a maximum limit of 2 mg/l NO_3^-N and a maximum limit of 20 mg/l NO_3^-N for marine creatures. With increasing exposure time and concentration in water, nitrate toxicity increases. The harmful effect of nitrate is reduced when aquatic creatures' body size and water salinity rise (Camargo and Ward, 1995).

Sources of Nitrate Pollution

Several anthropogenic and natural processes can raise the quantity of nitrate in groundwater. The groundwater is contaminated by a variety of point and non-point sources. The following are the key probable sources of nitrate contamination of groundwater that should be taken into account:

(1) Extensive use of fertilizers: Increased use of nitrogen-rich fertilizers to boost crop productivity. Increased usage of nitrogen-rich fertilizers increases nitrogen loss from the soil. As a result of NO3-N buildup in the soil, the plant's need for nitrate is often less than the amount of fertilizer applied to it (Schepers *et al*., 1991).

(2) Irrigation: In irrigated agricultural areas, nitrate leakage through soil is more common. Crop irrigation with river/canal or groundwater adds a large number of ions to the soil. The crop cannot utilize all of the nitrogen fertilizers. Due to the high solubility of nitrate, it can easily percolate in groundwater.

(3) Geologic Nitrogen : Geology of any area can contribute to the nitrate percentage in groundwater. Studies conducted in the arid or semi-arid area of the Indian Thar desert showed the comparatively large quantity of nitratein groundwater samples due to the high filtration rate of water through soil (Suthar *et al*., 2009). The geological origin of nitrate in Cedar valley was also proved by the negligible change in the nitrate concentration on seasonal change and even after the establishment of a well-plannedsewerage system in this area (Lowa and Wallace, 2001).

(4) Waste Disposal : Disposal of various types of wastes is one of the major problems for nitrate pollution in the environment. Most of the domestic waste is discharged into landfills or surface water, after partial treatment or without treatment. The nitrogen present in this sludge finally reached the soil or water aquifers and increase the nitrogen contamination level. Apart from domestic waste, animal waste is a major cause of nitrate overloading in the ground as well as surface water.

In Northern India, numerous studies have found that places with more cattle had higher levels of nitrate pollution than urban areas (Singh and Sekon, 1976). Animal waste accounts for 40% of total garbage in North America, followed by crop leftovers at 30%, and municipal waste at 20-25 percent (Power and Schepers, 1989). The leaching of NO_3^-N below the surface is minimized in well-planned livestock feedlots (Mielke and Ellis, 1976).

(5) Precipitation: Atmospheric N which is present in the nitrate or ammonium form can be entered into the soil through precipitation. Most of the atmospheric $N\text{-}NO_3$ comes from combustion hence $N\text{-}NO_3$ concentration is high over the power plants or industrial areas. The main source of atmospheric ammonium is ammonia which originates from agricultural activities, waste disposal, animal wastes etc, Denmead *et al.* (1978) proved that there is a continuous exchange of ammonia between the crop and atmosphere. A considerable quantity of ammonia was escaped through the stomata of leaves. Well-fertilized vegetation with wet soil showed upward transfer of ammonia. It may be upto 27.6 g N Ha-1Hr-1. Harper *et al.* (1983) studied the microclimatic effects on the ammonia transfer from an agricultural field after the application of urea fertilizers. It was observed that there was large ammonia volatilization in summers.

Role of Nitrifying and Denitrifying Microbes in Nitrate Pollution

Urea is the most often utilized nitrogen fertilizer in Indian agricultural areas and is a medium-to-medium protein metabolism product. Urea is hydrolyzed by urobacterial and other germs using the following reaction:

$$CO(NH_2)_2 + 2H_2O \longrightarrow (NH_4)_2CO_3$$

This reaction can occur in both aerobic and anaerobic environments. Because ammonium carbonate is a weak acid and weak base salt, it easily hydrolyzes as follows:

$$(NH_4)_2CO_3 + H_2O \longrightarrow NH_4OH + NH_4HCO_3$$

Dissociation of the ammonium hydroxide is expressed by the equilibrium:

$$NH_4OH \longrightarrow NH_3 + H_2O$$

Ammonia is converted to nitrite, which is then converted to nitrate by ammonia-oxidizing bacteria (AOB) such as Nitrosomonas and nitrite-oxidizing bacteria (NOB) such as Nitrobacter. These bacteria are harmless to humans. According to the equations below (USEPA, 2002), the nitrification process is summarised as follows:

$$NH_3 + O_2 \rightarrow NO_2^- + 3H^+ + 2e^-$$

$$NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ + 2e^-$$

Nitrification is a slow exothermic reaction and occurs at low temperatures. 10 mg of ammonium nitrogen takes 55 days to convert into nitrate by this process. At moderate temperature, there is no change in the speed of reaction but above 26 ^{0}C and below 9 ^{0}C the speed of nitrification reaction increased and decreased respectively (Voznaya, 1981). In the regions having tropical and subtropical climates nitrification occurs at a higher rate comparison to those having a temperate climates.

Guidelines and Standards

The WHO has recommended that the tolerated limit of nitrate in drinking water be 50 mg/l as nitrate (equal to 11.3 mg/l as nitrate-N)to protect the health of the most vulnerable population, bottle-fed newborns (Pfnader *et al.,* 1993). In India, BIS 10500:2012 for drinking water has recommended an acceptable limit for Nitrate concentration is 45 mg/l with No relaxation.

Toxic Effects of High Nitrate

According to a study, nitrate reduction bacteria found in saltwater near the base of the tongue convert ingested nitrate to nitrite. Oral microbiota and hence nitrate reduction are influenced by a variety of factors, including nutritional status, infection, ambient temperature, and age (Gupta *et al*., 2008). When nitrate reacts with ferric (III) hemoglobin, methaeglobin is formed, severely decreasing the blood's oxygen-carrying capacity and producing chemical hypoxia. Children under the age of six months are more sensitive because foetal hemoglobin has a stronger affinity for nitrite than normal hemoglobin. The medical word for this illness is methaemoglobinaemia. It causes methemoglobinemia in cattle when they are fed or browsed foragers with high nitrate levels, in addition to people.

High risk of Cancer

Nitrate is not a carcinogen in and of itself; rather, it creates carcinogenic products when it reacts with other chemicals, i.e. N-nitroso amides and amines. Physiological study backs up the link between nitrate contamination in drinking water and higher cancer incidence. Carcinogenicity of N-nitroso compounds (more than 100) has been studied in animals, with 75-80% of them being determined to be carcinogenic (Mirvish, 1995).

Abortions

After consuming nitrate-contaminated water, animals have also had spontaneous miscarriages. In addition, excessive nitrate absorption from fodder and drinking water has been associated with significant sickness in several herbivorous species. As a result, pregnant or trying-to-be-pregnant women are advised to avoid drinking water with high nitrate levels.

Other diseases

Drinking high-nitrate water has been linked to thyroid, type 1 diabetes, cardiovascular system abnormalities, and embryo harm (Maanen *et al.,* 2000).

Study Area

Gurgaon, one of Haryana's southern districts, has been designated as a "dark zone" due to the gradually declining amount of groundwater. Gurugram district is 1200 square kilometers in size and is located in Haryana's south-eastern section. It is bordered on the north by the UT of Delhi, on the east by Faridabad, on the northwest (NW) by Haryana's Jhajjar and Rewari districts, on the west by Rajasthan's Alwar district, and the south by Haryana's Mewat district. Gurugram district is divided into four blocks: Gurugram, Sohna, Farukh Nagar, and Pataudi.

Materials and Method

One hundred fifty six (156) locations of the study region had 500 ml of water samples taken in clean polythene bottles. Before collecting samples, the sampling containers were cleaned with detergent and immersed in diluted hydrochloric acid, then washed with distilled water. After the samples were collected, they were appropriately labeled with the source, date, and time of collection, as well as other information. The samples were kept cold and out of direct sunshine. To obtain more reliable and accurate results, samples were analyzed in a short period.

Quality Control

In the field of analytical measurement, quality control is very important. The nitrate electrode was rinsed twice using double distillation. The blank determination was done by using the known external standard. The matrix impact was shown to be negligible using the addition method. After every 10 sample measurements, the linearity and sensitivity (slope of the calibration curve) was assessed by measuring three standard solutions and estimating the sensitivity. An Ion meter was used to measure nitrate concentration. The instrument was calibrated at a high metrological level using Merck Certified Reference Material (CRM) with quality reagent-grade chemicals. The American Public Health Association (APHA) 23rd Edition 2017 approved standard procedures were used to determine nitrate concentrations.

Results and Discussion

Samples of groundwater from 156 wells were collected and analyzed the nitrate concentration. Results from this analysis show the minimum nitrate concentration of 1.23 mg/l as NO_3 was observed in Sherpur village of Pataudi Block of Gurugram District. The maximum concentration (102 mg/l as NO_3) was measured for Kankrola of Gurugram block of Gurugram district. A statistical summary of nitrate can be seen in Table 1. 122 no of groundwater sources/samples were found to be within the acceptable nitrate limit set by IS 10500:2012. Nitrate contamination in the study area result is given in Table 2.

Frequency histogram

A frequency histogram is a graph in which the X-axis represents the number of observations (frequency counts) and the Y-axis represents the variable of interest. The frequency of data recorded on an interval or ratio scale is represented by a frequency histogram (Figure 1).

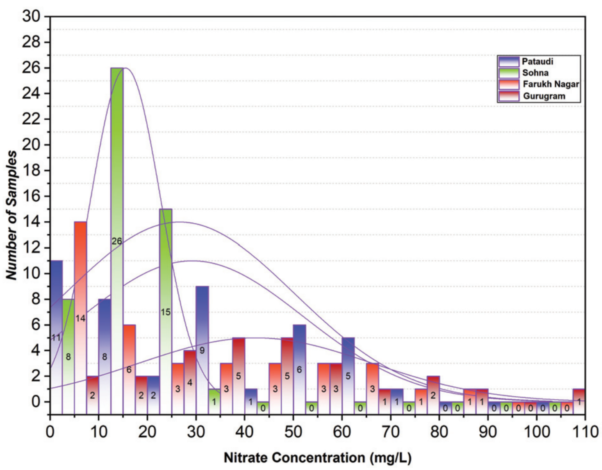


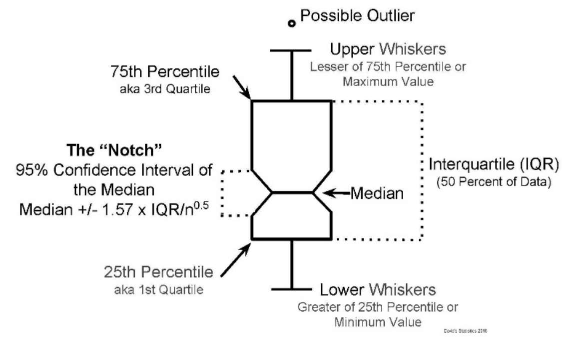
Fig. 1. Frequency distribution of nitrate concentration in Gurugram district

The frequency distribution histogram is represented as a vertical chart with bars denoting the number of observations within specific value ranges (bins). Figure 1 shows the frequency distribution of nitrate concentrations. 78% of the samples had values under 45 mg/l, 22.43 % had values between 0-10 mg/l, 26.92 % had values between 11-20 mg/l, 15.38 % had values between 21-30 mg/l, 11.53 % had values between 31-40 mg/l, and 22 % had values beyond 45 mg/l.

Notched Box and Whisker Plot

The Notched Box and Whisker Plot is a useful visual representation of data distribution through quartiles.

The boxplot shows the median, upper quartile, lower quartile, upper and lower whiskers, notch, minimum, and maximum sample statistics in their most basic form.



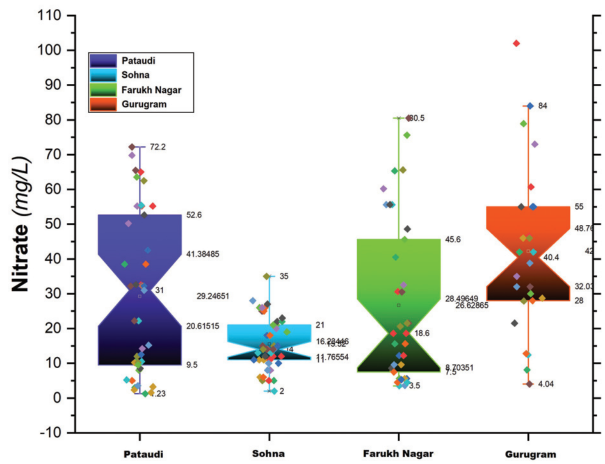


Fig. 2. Notched Box Whisker Diagram of Nitrate Concentration in Gurugram district

The IS and the WHO has set a recommended value for nitrate in drinking water of 45 mg/l as nitrate ion, based on epidemiological evidence of methemoglobinaemia in infants caused by short-term exposure, to safeguard bottle-fed infants and other similarly vulnerable population groups (WHO, 2004; BIS 10500:2012). Data reveals that in the study area there are 13 GW sources of Patodi block; 10 GW sources of Farukh Nagar block and 11

Table 1. Statistical summary of Nitrate and its comparison with IS standards

S. No.	Block	Minimum	Maxmium mg/l	Average	Standard Deviation	< 45.0 mg/l	> 45.0 mg/l
1	Gurugram	Haiderpur (4.04)	Kankrola (102)	42.21	23.92	15	11
2	Pataudi	Sherpur (1.23)	Gadaipur (72.2)	29.25	22.75	30	13
3	Sohna	Samp ki Nangli (2.0)	Bhogpur Mandi (35.0)	15.52	7.21	50	00
4	Farukh Nagar	Chandu (3.50)	S. Mohmad pur (80.5)	26.63	23.48	27	10
Gurugram District		Sherpur (1.23)	Kankrola (102)	26.39	21.43	122	34

GW sources having the Nitrate as NO_3 concentration above the permissible limit of IS 10500:2017.

The presence of nitrate in groundwater indicates that nitrate contamination is prevalent throughout the study area. Fertilizer use in particular places causes high nitrate levels, which leads to nitrate in groundwater. Some of the sites are residential areas where sewage from domestic septic tanks has contaminated the groundwater. Nitrate levels were found to be high in both shallow and deep groundwater samples. Both of these factors, as a result, lead to nitrate contamination in this area. All of the Sohna block samples meet the BIS 10500:2012 permissible limit. Data reveals that 34 villages exceeded out of 156 villages having the nitrate concentration (45 mg/l) above the limit.

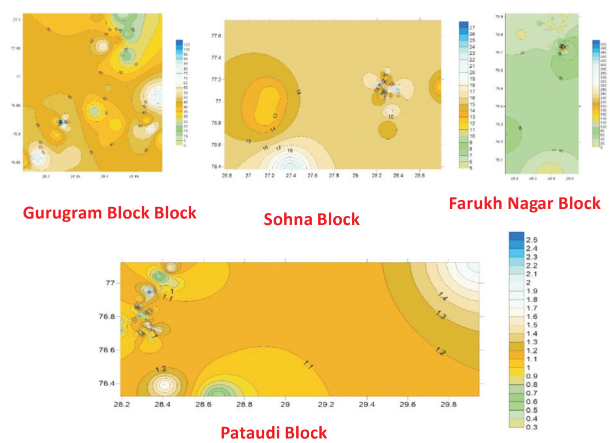
Table 2. Nitrate Concentration above the permissible limit (45 mg/l) in Gurugram District of Haryana

S.No.	Village	Block	Nitrate (mg/L)
1	Darapur	Pataudi	55.2
2	Gadai pur	Pataudi	72.2
3	Husainka	Pataudi	52.6
4	Jasat	Pataudi	65
5	Khetiawas	Pataudi	50.2
6	Mandpura	Pataudi	63.56
7	Milak pur	Pataudi	55.2
8	Nainwal	Pataudi	69.8
9	Pahari	Pataudi	65.5
10	Panchgaon	Pataudi	62.5
11	Pathredi	Pataudi	31
12	Ransika	Pataudi	55.2
13	Vazirabad	Pataudi	55.4
1	Jhund sarai	Farukh Nagar	60.2
2	Karola	Farukh Nagar	55.6
3	Kharkhadi	Farukh Nagar	65.6
4	Khentawas	Farukh Nagar	55.6
5	Kheri kanhei	Farukh Nagar	45.6
6	Kheri sultan	Farukh Nagar	48.6
7	Mushed pur	Farukh Nagar	65.3
8	S. Mohmad pur	Farukh Nagar	80.5
9	Sunder pur	Farukh Nagar	75.6
10	Taz nagar	Farukh Nagar	55.6
1	Badshahpur	Gurugram	60.7
2	Bilaspur	Gurugram	84
3	Budhera	Gurugram	73
4	Kharki Majra Dhankot	Gurugram	78.9
5	Nainwal	Gurugram	46.6
6	Sadhrana	Gurugram	55
7	Shamshpur	Gurugram	46
8	Sihi	Gurugram	46
9	Sidhrawali	Gurugram	55
10	Kankrola	Gurugram	102
11	Tatarpur	Gurugram	55

Spatial distribution of fluoride using Inverse distance weighted method

GIS stands for Geographic Information System, and it is a computerized data-based system for capturing, storing, retrieving, analysing and displaying spatial data. GIS is a general-purpose technology for handling digital geographic data and meeting the needs listed below, among others.

The inverse distance weighted (IDW) interpolation works on the idea that objects that close to each other have similier quality then theare that is far enough. This method can be use to forecast or predict the value at a particular place which is uncovered during study. It uses measured values of surrounding area and by an calculation it shows results of any unmeasured location. It gives more weight to points that are closer to the unmeasured location, and the weights decrease as distance increases, hence the term IDW method is used for this (Arif *et al.*, 2014). Spatial distribution of Nitrate in the Gurugram district is shown in Figure 3.



References

APHA, 2017. *Standard Methods for the Examination of Water and Wastewater* (23rd Edition). Washington, DC: American Public Health Association.

Arif, M., Hussain, J., Hussain, I., Kumar, S. and Bhati, G. 2014. GIS-Based Inverse Distance Weighting Spatial Interpolation Technique for Fluoride Occurrence in Ground Water. *Open Access Library Journal.* 1: 1-6. doi: 10.4236/oalib.1100546.

Bachmat, Y. 1994. Groundwater as part of the water system. In: *Groundwater Contamination and Control.* Ed. U Zoller, Marcel Dekker, Inc, New York.

Bureau of Indian Standards, 2012. Indian standard specification for drinking water (IS:10500). Manak Bhawan, New Delhi, India.

Camargo, J.A., Alonso, A. and Salamanca, A. 2005. Nitrate toxicity to aquatic animals: a review with new data for freshwater invertebrates. *Chemosphere*. 58: 1255-1267.

Camargo, J.A. and Ward, J.V. 1995. Nitrate (NO_3-N) toxicity to aquatic life: a proposal of safe concentrations for two species of nearctic freshwater invertebrates. *Chemosphere*. 31: 3211-3216.

Denmead, O.T., Nielsen, R. and Thurtell, G.W. 1978. Ammonia exchange over a corn crop. *Soil Sci Soc Am J* 42: 840-842.

Elisante, E. and Muzuka, A.N.N. 2017. Occurrence of nitrate in Tanzanian groundwater aquifers: A review. *Appl Water Sci.* 7: 71–87.

Gupta, S.K., Gupta, R.C., Chhabra, S.K., Gupta, A.K. and Gupta, R. 2008. Health issues related to N Pollution in water & air. *Curr. Sci.* 94 (11): 1469-1477

Harper, L.A., Catchpole, V.R., Davis, R. and Weier, K.L. 1983. Ammonia volatilization: Soil, plant, and microclimate effects on diurnal and seasonal fluctuations. *Agron J.* 75 : 212-218.

Kumar, M., Ramanathan, A.L., Tripathi, R., Farswan, S., Kumar, D. and Bhattacharya, P. 2017. A study of trace element contamination using multivariate statistical techniques and health risk assessment in groundwater of Chhaprola Industrial Area, Gautam Buddha Nagar, Uttar Pradesh, India. *Chemosphere.* 166: 135-145.

Kundu, M.C., Mandal, B. and Sarkar, D. 2008. Assessment of the potential hazards of nitrate contamination in surface and groundwater in a heavily fertilized and intensively cultivated district of India. *Environ Monit Assess.* 146 : 183-189.

Lowe, M. and Wallace, J. 2001. Evaluation of potential geologic sources of nitrate contamination in ground water, Cedar valley, Iron county, Utah with emphasis on the Enoch area. *Utah Geological Survey.* Survey Special Study. 100 : 50.

Majumda, D. and Gupta, N. 2000. Nitrate pollution of groundwater and associated human health disorders. *Indian Journal of Environmental Health*. 42: 28-39.

Mielke, L.N. and Ellis, J.R. 1976. Nitrogen in soil cores and ground water under abandoned cattle feedlots. *J. Environ. Qual.* 5 : 71-75.

Mirvish, S.S. 1995. Role of N-nitroso compounds and N-nitrosation in etiology of gastric, esophageal, nasopharyngeal and bladder Cancer. *Cancer Lett*. 93: 17-48.

Nagamani, C., Devi, C.S. and Shalini, A. 2015. Physicochemical analysis of water samples. *International Journal of Scientific & Engineering Research.* 6 : 2149-2155.

Nowak, B., Rocha, S.F., Aschenbrenner, P., Rechberger, H. and Winter, F. 2012. Heavy metal removal from MSW fly ash by means of chlorination and thermal treatment: Influence of the chloride type. *Chemical Engineering Journal*. 179 : 178-185.

Pfnader, W.H., Brown, J.R. and Garner, G.B. 1993. Terminology for reporting nitrate concentration. University of Missouri Extension report G9802. Available at: http://extension.missouri.edu/publications/DisplayPub.aspx?P=G9802

Power, J.F. and Schepers, J.S. 1989. Nitrate Contamination of Groundwater in North America. *Agriculture, Ecosystems and Environment.* 26: 165-187.

Rabalais, N.N. 2002. Nitrogen in Aquatic Ecosystems. *Ambio*. 31: 102-112.

Rezaei, M., Nikbakht, M. and Shakeri, A. 2017. Geochemistry and sources of fluoride and nitrate contamination of groundwater in Lar area, south Iran. *Environmental Sci Pollut Res.* doi 10.1007/s11356-017-9108-0.

Schepers, J.S., Moravek, M.G., Alberts, E.E. and Frank, K.D. 1991. Maize production impacts on groundwater quallity. *J Environ Qual.* 20: 12-16.

Singh, B. and Sekhon, G.S. 1976. Nitrate pollution of groundwater from nitrogen fertilizers and animal wastes in the Punjab, India. *Agric Environ.* 3: 57-67.

Singh, B. and Singh, Y. 2004. Balanced fertilization for environmental quality. *Fertil. News*. 49: 107-108.

Spalding, R.F. and Exner, M.E. 1993. Occurrence of nitrate in groundwater- a review. *J Environ Qual.* 22: 392-402.

Suthar, S., Bishnoi, P., Singh, S., Mutiyar, P.K., Nema, A.K. and Patil, N.S. 2009. Nitrate contamination in groundwater of some rural areas of Rajasthan, India. *Journals of Hazardous Materials.* 171 : 189-199.

USEPA, 2002. Nitrification. Distribution system issue paper. Office of Water, Office of Ground Water and Drinking Water, U.S. Environmental Protection Agency, Washington, DC.

Voznaya, N.F. 1981. Role of microorganisms in matter cycle. In: *Chemistry of Water and Microbiology,* Mir Publishers, Moscow, 221-273.

Wakida, F.T. and Lerner, D.N. 2005. Non-agricultural sources of groundwater nitrate: a review and case study. *Journal of Water Research*. 39: 3–16.

WHO, 2007. Nitrate and nitrite in drinking-water. Background document for development of WHO Guidelines for Drinking-water Quality. World Health Organization, Geneva (WHO/SDE/WSH/07.01/16).

World Health Organization (WHO), 2004. Guidelines for drinking water quality, vol. 1 recommendations (3rd). Geneva: WHO.

Xiaosi, S., Huang, W. and Yuling, Z. 2013. Health Risk Assessment of Nitrate Contamination in Groundwater: A Case Study of an Agricultural Area in Northeast China. *Water Resour Manage.* 27: 3025–3034.