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# Scenario of Nitrate contamination in Groundwater: Its causes and Prevention

**Hemant W. Khandare***

**Department of Geology, M.G. College, Armori, dist. Gadchiroli, MH-441208, India.**

****Corres.author: hkhandare@yahoo.co.in***
***Phone No.:09422819263***

**Abstract :** Groundwater quality is one of the most important aspects in water resource studies [1,2]. The major hydrochemical parameters for ascertaining the quality of water for potable purposes are – Total dissolved solids, Nitrate & Fluoride. Nitrogen is a major constituent of the earth's atmosphere and occurs in many different gaseous forms such as elemental nitrogen, nitrate and ammonia. Natural reactions of atmospheric forms of nitrogen with rainwater result in the formation of nitrate and ammonium ions. Nitrate is one of the most common groundwater contaminants in rural areas and is reported from several areas in Tamil Nadu, Orissa, Karnataka, Maharashtra, Bihar, Gujarat, Madhya Pradesh & Rajasthan. The sources of nitrate in the groundwater were attributed to bedrock dissolution in the course of groundwater migration. Other common sources of nitrate include human sewage and livestock manure. Nitrate is also a common constituent of chemical fertilizers. High nitrate level in drinking water leads to infant methaemoglobinaemia (blue-baby syndrome), gastric cancer goiter, metabolic disorder, birth malformations, hypertension and livestock poisoning. In fact the increased concentration of hydrotoxicants have created socio-economic problem and adversely affected the livelihood of inhabitants. Therefore, for sustainable health and development, immense and immediate efforts are required to combat the problem. In the present communication the extent of problem, distribution of Nitrate in groundwater, their health effects, and remedial measures will be discussed comprehensively.

**Keywords—**Nitrate Pollution, Occurrences of Nitrate in India, Health effects and prevention.

## Introduction :

Groundwater contamination by nitrate is a global problem and Nitrate is a wide-spread contaminant of ground and surface water worldwide. Nitrate ($NO^{3-}$) is one of the integral parts in the growth of life and it is a compound of nitrogen and oxygen, being normal part of human diet, found in many foodstuffs, particularly in leafy vegetables, fish & meat. Nitrate levels can be high in streams and rivers due to runoff of nitrogen fertilizer from agricultural fields and urban lawns. It is essential for the growth of many plants species, including most of those which are edible, but it becomes a problem if it gets into water in which it is not equired. This leads to major environmental problem and also as a health hazard [3]. Nitrate is mainly used in inorganic fertilisers. It is also used as an oxidising agent, in the production of explosives, and as purified potassium nitrate for glass

making. Sodium nitrite is used as a food preservative, especially in cured meats. Nitrate is sometimes also added to serve as a reservoir for nitrite.
The problem of nitrate pollution in groundwater is a common global phenomenon and has been reported by various authors. Nitrogen is a major constituent of the earth's atmosphere; comprising nearly 80 % of the air we breathe[4]. There are many sources of nitrogen (both natural and anthropogenic) that could potentially lead to the pollution of groundwater with nitrates, the anthropogenic sources are really the ones that most often cause the amount of nitrate to rise to a dangerous level[5]. The primary source of all nitrates is atmospheric nitrogen gas. This is converted into organic nitrogen by some plants by a process called nitrogen fixation. Dissolved Nitrogen in the form of Nitrate is the most common contaminant of ground water. Some chemical and micro-biological processes such as nitrification and denitrification also influence the nitrate concentration in ground water.

**Occurrences of Nitrate in India :**
Nitrate is one of the most common groundwater contaminants in rural areas and is reported from several areas in Tamil Nadu, Orissa, Karnataka, Maharashtra, Bihar, Gujarat, Madhya Pradesh , Rajasthan and other parts of India. As per the BIS Standard for drinking water the maximum desirable limit of Nitrate concentration in ground water is 45 mg/l with no relaxation. It is estimated that around 37.7 million Indians are affected by waterborne diseases annually, 1.5 million children are estimated to die of diarrhoea alone and 73 million working days are lost due to waterborne disease each year. Concentration of nitrate above 50 mg/l in drinking water should generate concern due to the health implications[6]. The occurrences of Nitrate in ground water have been shown on **the Table-1** by different districts of different states in India where nitrate has been found in excess of 45 mg/l in ground water.

**Table 1: List of Districts Showing Localized Occurrence of Nitrate ( >45 mg/litre) in Ground Water in Different States of India**

| Sl. No. | State | Parts of Districts having Nitrate > 45 mg/litre |
|---|---|---|
| **1** | Andhra Pradesh | Adilabad, Anantpur, Chittoor, Cuddapah, East Godavari, Guntur, Hyderabad, Karimnagar, Khammam, Krishna, Kurnool, Mahbubnagar, Medak, Nalgonda, Nellore, Nizamabad, Prakasam, Ranga Reddy, Srikakulam, Visakhapatnam, Vizianagaram, Warangal, West Godavari |
| **2** | Bihar | Aurangabad, Banka, Bhagalpur, Bhojpur, Kaimur(Bhabua), Patna, Rohtas, Saran, Siwan |
| **3** | Chattisgarh | Bastar, Bilaspur, Dantewada, Dhamtari, Jashpur, Kanker, Kawardha, Korba, Mahasamund, Raigarh, Raipur, Rajnandgaon |
| **4** | Delhi | Central Delhi, New Delhi, North Delhi, North West Delhi, South Delhi, South West Delhi, West Delhi |
| **5** | Goa | North Goa |
| **6** | Gujarat | Ahmadabad, Amreli, Anand, Banaskantha, Bharuch, Bhavnagar, Dohad, Jamnagar, Junagadh, Kachchh, Kheda, Mehsana, Narmada, Navsari, Panchmahals, Patan, Porbandar, Rajkot, Sabarkantha, Surat, Surendranagar,Vadodara, |
| **7** | Haryana | Ambala, Bhiwani, Faridabad, Fatehabad, Gurgaon, Hissar, Jhajjar, Jind, Kaithal, Karnal, Kurukshetra, Mahendragarh, Panchkula, Panipat, Rewari, Rohtak, Sirsa, Sonepat, Yamuna Nagar |
| **8** | Himachal Pradesh | Una |
| **9** | Jammu & Kashmir | Jammu, Kathua |
| **10** | Jharkhand | Chatra, Garhwa, Godda, Gumla, Lohardaga, Pakaur, Palamu, Paschimi Singhbhum, Purbi Singhbhum, Ranchi, Sahibganj |
| **11** | Karnataka | Bagalkot, Bangalore, Belgaum, Bellary, Bidar, Bijapur, Chikmagalur, Chitradurga, Davangere, Dharwad, Gadag, Gulburga, Hassan, Haveri, Kodagu, Kolar, Koppal, Mandya, Mysore, Raichur. Shimoga, Udupi, Uttara Kannada |
| **12** | Kerala | Alappuzha, Idukki, Kollam, Kottayam, Kozhikode, Malappuram, Palakkad, Pathanamthitta, Thiruvananthapuram, Thrissur, Wayanad |
| **13** | Maharashtra | Ahmednagar, Akola, Amravati, Auragabad, Beed, Bhandara, Buldana, Chandrapur, Dhule, Gadchiroli, Gondia, Hingoli, Jalgaon, Jalna, Kohlapur, Latur, Nagpur, Nanded, Nandurbar, Nashik, Osmanabad, Parbhani, Pune, Sangli, Satara, Solapur, Wardha, Washim, Yavatma |

| | | |
|---|---|---|
| **14** | Madhya Pradesh | Anuppur, Ashok Nagar, Balaghat, Barwani, Betul, Bhind, Bhopal, Burhanpur, Chhatarpur, Chhindwara, Damoh, Datia, Dewas, Dhar, Gwalior, Harda, Hoshangabad, Indore, Jabalpur, Jhabua, Katni, Khandwa, Khargaon, Mandla, Mandsaur, Morena, Narsimhapur, Neemuch, Panna, Raisen, Rajgarh, Ratlam, Rewa, Sagar, Satna, Sehore, Seoni, Shahdol, Shajapur, Sheopur, Shivpuri, Sidhi, Tikamgarh, Ujjain, Umaria, Vidisha |
| **15** | Orissa | Angul, Balasore, Bargarh, Bhadrak, Bolangir, Baudh, Cuttack, Deogarh, Dhenkanal, Gajapati, Ganjam, J.Singhpur, Jajpur, Jharsuguda, Kalahandi, Kendrapara, Keonjhar, Khurda, Koraput, Malkangiri, Mayurbhanj, Nawapada, Nayagarh, Phulbani, Puri, Sambalpur, Sundergarh, Sonapur |
| **16** | Punjab | Amritsar, Bhathinda, Faridkot, Fatehgarh Sahib, Firozepur, Gurdaspur, Hoshiarpur, Jalandhar, Kapurthala, Ludhiana, Mansa, Moga, Muktsar, Nawan Shahr, Patiala, Rupnagar, Sangrur |
| **17** | Rajasthan | Ajmer, Alwar, Banaswara, Baran, Barmer, Bundi, Bharatpur, Bhilwara, Bikaner, Chittaurgarh, Churu, Dausa, Dhaulpur, Dungarpur, Ganganagar, Hanumangarh, Jaipur, Jaisalmer, Jalor, Jhalawar, Jhunjhunun, Jodhpur, Karauli, Kota, Nagaur, Pali, Partapgarh, Rajsamand, Sirohi, Sikar, Sawai Madhopur, Tonk, Udaipur |
| **18** | Tamil Nadu | Chennai, Coimbatore, Cuddalore, Dharmapuri, Dindigul, Erode, Kancheepuram, Kanyakumari, Karur, Madurai, Namakkal, Nilgiris, Perambalur, Pudukkottai, Ramanathapuram, Salem, Sivaganga, Theni, Thiruvannamalai, Thanjavur, Tirunelveli, Thiruvallur, Trichi, Tuticorin, Vellore, Villupuram, Virudhunagar |
| **19** | Uttar Pradesh | Agra, Aligarh, Allahabad, Ambedkar Nagar, Auraiya, Badaun, Baghpat, Balrampur, Banda, Barabanki, Bareilly, Basti, Bijnor, Bulandshahr, Chitrakoot, Etah, Etawa, Fatehpur, Firozabad, GB Nagar, Ghaziabad, Ghazipur, Hamirpur, Hardoi, Jaunpur, Jhansi, Kannauj, Kanpur Dehat, Lakhimpur, Mahoba, Mathura, Meerut, Moradabad, Muzaffarnagar, Raebareli, Rampur, Sant Ravidas Nagar, Shahjahanpur, Sitapur, Sonbhadra, Sultanpur, Unnao |
| **20** | Uttrakhand | Dehradun, Hardwar, Udhamsinghnagar |
| **21** | West Bengal | Bankura, Bardhaman |

Source: [15]

The sources and distribution of nitrate in groundwater have been studied in some details in Botswana[7], Namibia [8] and South Africa[9]. These studies have shown that pollution by anthropogenic activities is the main source of high and variable levels in groundwater. The soil/rock-water interactions can result to weathering and enrichment of the groundwater with ammonium ions, since groundwater quality is a function of the chemical composition of the soil/rock through which it passes[10].

[11] found similar stream nitrate concentrations in stream water from plutonic bedrock (quartz, granite) and from metamorphic and sedimentary bedrock (schist and slate). The nitrate content in basaltic aquifers is well within the desirable limit of BIS (45 mg/l). But in granitic aquifers the ranges of nitrate were found to be 22.2 to 178 mg/l. Because nitrate contamination is common in basic extrusive granite formation. Nitrate reserves of 2000 to > 25,000 kg N ha–1 are stored in soils of the temperate zone depending on the thickness of soils, climate, clay content and the stabilisation of organic material[12].

## Major sources of nitrate pollution:

1. There are numerous sources in environment that contribute to the total nitrate content of natural waters, e.g. atmosphere, geological features, anthropogenic sources, atmospheric nitrogen fixation and soil nitrogen. It has been observed that in sandy soil with low water holding capacity and high permeability, movement of pollutants like chloride and nitrate is much quicker than in clayey soil. This is probably the main cause for high nitrate in areas with sandy soil. Nitrate is highly soluble and readily moves with water through the soil profile. In areas of excess rainfall or over-irrigation, nitrate will be leached below the plant's root zone and may eventually reach the groundwater.
2. Wastewater in the upper soil layer either from the cesspools or the disposal ponds could infiltrate to the groundwater aquifer. The absence of a sewage system encourages such types of contamination by nitrate. Thus, the level of nitrate in groundwater will continue to increase as the sources of contamination. These

sources are more dangerous than the leaching ones, because of the daily use of water, which then recharges the aquifer.

3. Nitrate in ground water can be derived from natural sources or from point sources, such as sewage disposal systems and livestock facilities causes pollution of surface water, ground water and wells through percolation. Waste materials are one of the anthropogenic sources of nitrate contamination of groundwater. Surface water runoff from fertilized farmland and animal feedlots is a major potential source of nitrate contamination. Septic tanks are another example of anthropogenic source nitrogen contamination of the groundwater. Many areas of the United States and other countries have reported significant contamination of groundwater from septic tanks. Ground water contamination is usually related to the density of septic systems[13].
4. The use of nitrogen (N)-fertilizer in agriculture has significantly increased over the past 30 years to meet the food and living requirements of the speedily growing population. Therefore, the use of nitrate in fertilizers causes a foremost predicament in groundwater contamination. Some of the fertilizers infiltrate with the irrigation and/or rainwater to recharge the aquifer. The increased uses of nitrate fertilizers in the villages enhance the contamination of groundwater. The local farmers of the study area admitted the use of excessive nitrate fertilizers and believe that it is necessary to have better agricultural productivity.
5. The interaction of nitrogen compounds with the surrounding media leads to oxidation of nitrogen compounds, which finally contaminate the aquifer. Generally, organic matter -nitrate bearing- is distributed on the surface or near surface of the ground (sewage water, cesspools and drainage) produces nitrate.

## Toxic effects of high nitrate :

High nitrate level in drinking water leads to infant methaemoglobinaemia (blue-baby syndrome), gastric cancer goiter, metabolic disorder, birth malformations, hypertension and livestock poisoning.

## Blue-baby Syndrome (Methemoglobinemia or infant cyanosis) :

Nitrates are especially toxic to children less than six months of age. Children who ingest nitrate may not have developed an immune system that can ward off the compound. The condition known as "blue-baby syndrome" may occur. Cases of blue-baby syndrome usually occur in rural areas which rely on wells as their primary source of drinking water. Often these wells become contaminated when they are dug or bored and are located close to cultivated fields, feedlots, manure lagoons or septic tank[3]. Methemoglobinemia is the condition in the blood which causes infant cyanosis, or blue-baby syndrome. [14]. Nitrate reacts with haemoglobin leading to formation of methaemoglobin in which iron is in ferric (III) state, greatly lessening the capacity of the blood to carry oxygen and causing chemical suffocation very young children are susceptible because foetal haemoglobin has a great affinity for nitrite than normal haemoglobin. This disease is called methaemoglobinaemia.

## Stomach and Gastrointestinal Cancer :

Nitrate itself is not carcinogenic, but instead acts as a “procarcinogen”, i.e. it reacts with other chemicals (amines and amides) to form carcinogenic compounds (N-nitroso) compounds. The physiological studies provide strong support indicating the association between nitrate contamination of drinking water and increased cancer rates. N-nitroso compounds has been associated with 15 different types of cancers, including tumors in the bladder, stomach, brain, esophagus, bone and skin, kidney, liver, lung, oral and nasal cavities, pancreas, peripheral nervous system, thyroid, trachea, acute myeleocytic leukemia and T and B cell lymphoma[16]. More than one hundred of these N-nitroso compounds have been tested for carcinogenicity in animals and 75-80% of them have been found to be carcinogens.

## Abortions :

Spontaneous abortions in animals due to ingestion of high nitrate contaminated water have also been observed. It has also been observed that in many herbeivorous animals excess of nitrate ingestion through fodder and drinking water causes severe ailments. Therefore, it has been suggested that women who are pregnant or trying to become pregnant should not consume water containing high levels of nitrate[18].

**Other diseases** : Cases of incidence of type-I diabetes, thyroid and cardio-vascular system disorder and embryo toxicity have also been observed due to drinking of high nitrate water[17].

## Prevention:

- Steps can be taken to prevent the child from becoming a victim of methemoglobinemia. Residents of rural areas should have their wells tested, especially if pregnant women or infants are consumers of the well water. If the well is contaminated, other water source alternatives are other safe wells, bottled water, a new, deeper well, or a water purification system which is capable of removing the nitrates [19]. [14]suggests that because cyanotic babies usually contract methemoglobinemia from the water used to prepare their formulas, formulas which use diluted whole milk are less risky than those prepared from powdered or evaporated milk which require large amounts of water in preparation. Breast feeding or the use of bottled water in formula preparation offers the safest solution, especially if the groundwater quality is unknown [19].
- Inculcation of awareness amongst rural and urban population regarding harmful effects of quality parameters. Avoid the sewage disposal directly to ground water. Installation of reverse osmosis, Ion-exchange and electrodialysis plants in affected areas. Avoid indiscriminate use of nitrogenous fertilizers and promotion of use of bio-fertilizers and bio-pesticides. Construction of wells/tubewells in low nitrate & fluoride areas. Supplementation of ascerbic acid, methionine, and methylene blue has been found to be effective in overcoming the problem of nitrate toxicity. Promotion of breast feeding at least upto the age of 6 months of the infant[20]
- Use of fertilizers should be restricted and always according to the manufacturer's instructions. Farmers should use management practices that are both environmentally and economically sound and application of the fertilizers should be on proper time. If these remedial measures are not taken immediately, then the concentration of nitrate would increase and creating environmental and health hazard[20]
- Wells should be located uphill (upgradient) and at least 100 ft. away from septic tanks and fertilized area. Ensure that the well casing extends above the ground[20]
- Water containing high nitrate levels can be safely used for bathing, cleaning dishes, washing laundry, or other uses where water is not ingested. [20]
- Identify any potential sources of nitrate on your property and find ways to manage those sources. Maintaining the septic system regularly would help avoid system failure, which could lead to water contamination, the spread of disease, and the need for costly repairs. Following are the guide lines[20]

a. Heavy vehicles should not run above the septic tank, and drain - pipes.

b. Reputable contractor should be hired to pump-out septic tank every 2 to 3 years.

## Conclusion:

The higher concentration of nitrate may be due to excessive use of fertilizers, pesticides and insecticides. Various workers have related nitrate in groundwater from different sources viz. leakage from septic tank, leaching from animal waste and nitrogen fertilizers [21].The nitrate poses some unique problems to groundwater because it moves quickly through the soils with percolating water and it often indicates potential biological contamination. The groundwater resources contaminated with high levels of nitrate (> 45 mg/1 as NO3 or 10 mg/1 as NO3- N) are an environmental hazard. Urea is common type of fertilizer used in the agriculture due to its higher N content, highly solubility and non-polarity. Urea is first converted to ammonium carbonate and then to nitrate. In comparison with this, the solubility of phosphate fertilizers is low and it adsorbed on the soil. It is opined that the wells located in the area under double crop have comparatively higher nitrates than those located near the single coop. Since the water is occurring at higher depth, the denitrification process would not be very effective due to longer residence time of infiltrating water in vadose zone and degradation of organic carbon during the longer course of percolation[22].

## References :

1. Ackah M, Agyemang O, Anim AK. Assessment of groundwater quality for drinking and irrigation: the case study of Teiman-Oyarifa Community, Ga East Municipality, Ghana. Proceedings of the International Academy of Ecology and Environmental Sciences, 1(3-4): 2011, 186-194

2. Sayyed, M.R.G. and Wagh, G.S. An assessment of groundwater quality for agricultural use: a case study from solid waste disposal site SE of Pune, India. Proceedings of the International Academy of Ecology and Environmental Sciences, 1(3-4): 2011, 195-201.
3. WHO, Nitrate and nitrite in drinking-water Background document for development of WHO Guidelines for Drinking-water Quality, 2007 WHO/SDE/WSH/07.01/16.
4. Berner, E. And Berner, R. *The Global Water Cycle*,. New Jersey: Prentice Hall. 1987, 102-119
5. Hallberg, G. R. And Keeney, D. R. In Nitrate. Alley, W. A., (ed.), *Regional Groundwater Quality*, 1993, 297-322. New York: Van Nostrand Reinhold.
6. World Health Organisation (WHO) *International Standards for drinking water* (3rd ed.). Geneva, 2006, 346-385.
7. Vogel, H., Mokokwe, K., & Setloboko, T. *Nitrate hotspot and salinity levels in Groundwater in the central District of Botswana*. Environmental Geology Division, Department of Geological Survey, Lobatse, Botswana, 2004, 34.
8. Wrabel, J. Investigation of the processes leading to nitrate enrichment in the Kamtsas quartzite aquifer, Namibia. In: Vogel, H., & Chilume, C. (eds.), *Environmental Geology in Semi-arid Environmental*, 2005, 134-139.
9. Tredoux, G., Engelbrecht, J. E. P., & Talma, A. S. Groundwater nitrate in arid and Semi-arid parts of southern Africa. In: Vogel, H., & Chilume, C. (Eds.), *Environmental Geology in Semi-arid Environment* 2005, 121-131.
10. Amadi, A. N. Effects of urbanization on groundwater quality: A case study of Port-Harcourt, Southern Nigeria. *Natur. Appl. Sci. J., 11*(2), 2010, 143-152.
11. Johnson, C. J., Bonrud, P. A., Dosch, T. L., Kilness, A. W., Senger, K. A., Busch, D. C.,and Meyer, M. R., Fatal Outcome of Methemoglobinemia in an Infant, *Journal of the American Medical Association*, v. 257, 1987, 2796-2797.
12. Stahr, K., Rück, F. and Gaiser,T. Soil Nitrogen-Reserves and Mineralisation as Affected by Climate, Soil and Land use.- In: *Köhler, W. (Ed.): The Terrestrial Nitrogen Cycle as Influenced by Man. Nova Acta Leopoldina. Deutsche Akademie der Naturforscher Leopoldina, Halle (Saale), Bd. 70, Nr. 288, S.* 1994, 213- 235.
13. Hallberg, G.R. and Keeney, D.R., Nitrate, Alley, William A., ed., *Regional Ground-water Quality*, Van Nostrand Reinhold, New York, 1993,.297-322.
14. Comly, H. H. Cyanosis in infants caused by nitrates in well water. *Journal of the American Medical Association, 257,* 1987, 2788-2792.
15. Jain, S. K. and Sharma, V. Contamination of Ground Water By Sewage, CGWB, ministry of water resources. 2008, Government of India, Faridabad.
16. Mirvish, S.S. Role of N-nitroso compounds and N-nitrosation in etiology of gastric, esophageal, nasopharyngeal and bladder Cancer, Cancer Lett. 93, 1995, 17-48.
17. Van Maanen, J.M. Albering, H.J. and de kok, T.M. Risk of childhood diabetes mellitus and guideline for nitrate in drinking water, Environ Health Prospect, 108, 2000, 457.
18. Ozha, D.D. Rising nitrate & fluoride levels in ground water – a challenge ahead for sustainable health & socio-economic development of Rajasthan. India Water Week 2012 – Water, Energy and Food Security : Call for Solutions, 2012, 10-14.
19. Janssen LHJM, Visser H, Roemer FG Analysis of large scale sulphate, nitrate, chloride and ammonium concentrations in the Netherlands using an aerosol measuring network. *Atmospheric Environment*, 23(12): 1989, 2783–2796.
20. FAO (Food and Agricultural organization), FAO Production year book 1990, United Nations, Rome, Stat. Ser. No. 100, 44, 1991 b.
21. Babu P, Bhai HY, Sinha M. Nitrate Contamination in groundwater in Maregaon Taluka, Yavatmal District. Gondwana Geological Magazine (Special), v. 11, 2007, 107-111.
22. Tiwari, R.N. Assessment of groundwater quality and pollution potential of Jawa Block Rewa District, Madhya Pradesh, India. Proceedings of the International Academy of Ecology and Environmental Sciences, v. 1(3-4), 2011, 202-212.


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