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Nitrate pollution with modernization of Indian agriculture

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Abstract
Nitrate formed by biochemical activities of microorganisms or addition of chemically synthesized forms in the lithosphere and biosphere that enters hydrosphere with relative ease, as all these environmental components are dynamically interconnected. Balancing the amount of N needed for optimum plant growth while minimizing the NO_3- that is transported to ground and surface waters remains a major challenge for everyone attempting to understand and improve agricultural nutrient use efficiency. Strategies for reducing NO_3- loss through drainage include improved timing of N application at appropriate rates, using soil tests and plant monitoring, diversifying crop rotations, using cover crops, reducing tillage, optimizing N application techniques, and using nitrification inhibitors. Maximum permissible limits of nitrate concentration in water prescribed by ICMR is 10 as NO_3-N (mg/l) and 45 as NO_3- (mg/l). The production of food grains has increased by 2% in the last 5 years as against an 8.6% rise in population. There are many sources of nitrate accumulation in water and hence food, *viz*., over-fertilization of crops, intensive agricultural rotation cycles and increased urbanization. Encourage the use of biofertilizers instead of chemical fertilizers. It is suggested to Shift into organic agriculture for the management of pest and disease.

Keywords: Nitrate, nitrogen, fertilizer, crops and plant growth

Introduction

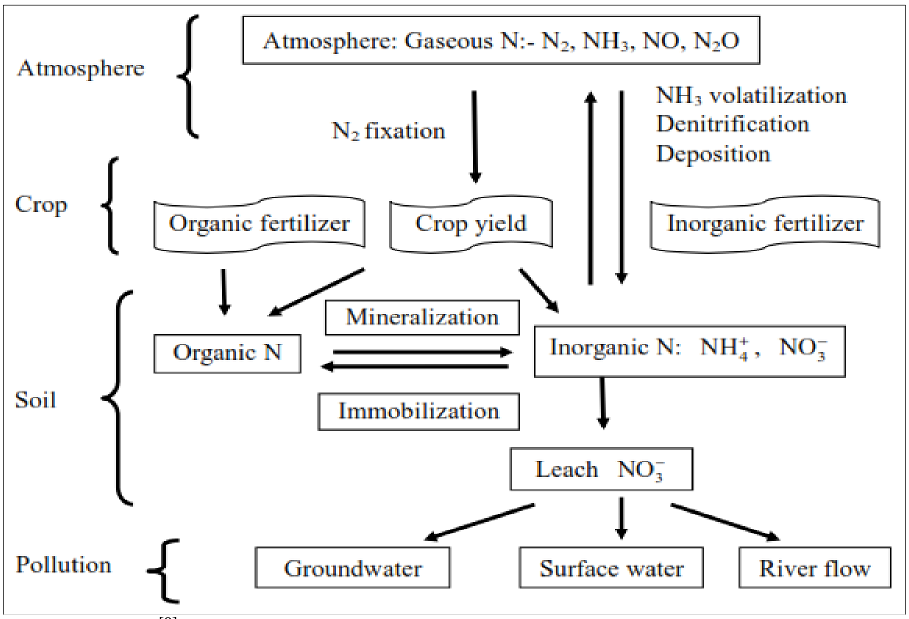
Modernization of agriculture makes use of hybrid seeds of single crop varieties, high-tech equipment, fertilizers, pesticides and water. The increased concentrations of nitrogen, phosphorus, and potassium contained in most of the fertilizers that are used in modern agriculture pollute the groundwater quality thereby affecting the wellbeing of human and animal populations through the way of bio-magnification. By the introduction of modern high yielding varieties and the development of irrigation facilities during the 2000s, the consumption of chemical fertilizer has increased markedly. The too much use of nitrogen as a fertilizer interrupts the biogeochemical nitrogen cycle, resulting in environmental problems.

Human-made changes in global nitrogen significantly affect the sustainability of food production and the health of the environment. The availability of nitrogen has been a driving force behind the green revolution but excess use and inefficient practices can lead to over-enrichment, causing soil acidification and groundwater pollution. These problems are set to intensify as population, urbanization, and increase food demand.

Pathway of Nitrogen from Origin (Atmosphere) towards Crop, Soil and Emit pollution in different water streams

Nitrogen is both an essential nutrient and a major pollutant in terrestrial ecosystems. Such as an important component of essential plant nutrients, nitrogen plays an important role in increasing crop yields and crop quality.78% of gaseous nitrogen (N_2), appears to be a virtually limitless reservoir, the very strong triple bond between the two nitrogen atoms makes this gas quite inert and not directly usable by plants and animals. Introduction of reactive nitrogen such as nitrate (NO_3^-), ammonium (NH_4^+), or urea, which rapidly hydrolyses to form, to the terrestrial biosphere, that is, fertilization, has been recognized as the most effective method for increasing food production. However, additional nitrogen used in fertilization has certainly disturbed the biogeochemical nitrogen cycle of natural ecosystems, resulting in various global, regional, and local environmental problems such as stratospheric ozone depletion, soil acidification, and especially NO_3^- pollution of ground and surface waters. In contrast to NH_4^+ ions, NO_3^- ions are not absorbed by the negatively charged colloids that dominate most soils. Therefore, NO_3^- ions move downward freely with drainage water and are thus readily leached from the soil.

Such as leaching losses not only cause some serious environmental problems, but also reduce ecosystem productivity. The figure shows the simplified pathway of nitrogen from the atmosphere to create pollution in different pathways.



Khajuria (2016) [8]

Fig 1.

Sources of nitrate pollution

Exogenous sources: Nitrate (NO_3^-) is found naturally in the environment and is a key plant nutrient. It is present at varying concentrations in all plants and is a part of the nitrogen cycle. Nitrate can influence both surface water and groundwater as a significance of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures), from wastewater disposal and oxidation of nitrogenous waste products in human and other animal excreta, including septic tanks. Nitrate can also occasionally reach groundwater as a consequence of natural vegetation. Surface water nitrate concentrations can change rapidly owing to surface runoff of fertilizer, uptake by phytoplankton, and denitrification by bacteria, but groundwater concentrations generally show relatively slow changes.

- Wastes containing organic nitrogen
- Naturally occurring nitrates ions
- Water
- Food: leafy vegetables
- Nitrate bearing rocks
- Contamination from agro-based industries

Endogenous sources: nitrate and nitrite by diet or *via* the oxidation of nitric oxide to nitrite, vascular and gastrointestinal nitric oxide production can be enhanced through various means based on lifestyle and food choices.

✓ Endogenous nitrate of body

Sources of nitrate pollution in water

Cultivation in areas where the soil layer is relatively thin, or has poor nutrient buffering capacity, or where there are changes in land use;

- Over fertilization of crop for intensification of agricultural activity;
- Spread cultivation of crops which require high fertilizes doses and which leave the soil bare over long periods (maize, tobacco and vegetables);
- Drainage systems which lead to drainage of fertilizers;
- Intensive agricultural rotation cycles involving frequent plugging and extensive areas of bare soils during winters;
- Organic fertilizers form animal husbandry;
- Increased urbanization.

Nitrate accumulation in plants

Uncertain weather can increase nitrate accumulation in the plants as the low photosynthesis results in nitrate not being converted to the plant proteins as efficiently. Meanwhile, very rapid growth during warm weather may lead to the accumulation of nitrates in immature plants. Nitrates are mostly lower in mature plants, however, these mature plants may still have toxic concentrations. Nitrate typically accumulates in the lower portion of the plant. Drought affecting plants in its early growth stages will also be likely to cause nitrate accumulation.

- Plants take N primarily in the form of nitrate
- Vegetative stages are most likely to have high nitrate levels
- Drought or cloudy weather are often associated with accumulation
- Forage crops are more likely to contain high nitrate concentrations

Common crops and weeds that have potential to accumulate nitrate

Plants vary in the amount of nitrate that accumulates in various tissues. Certain weeds, such as pigweed, Kochia, and lambsquarter, frequently are high in nitrate. Oats and millet cut for hay at the immature stage can also have high nitrate concentrations. Sorghum and Sudangrasses can store higher amounts of nitrates. Brome and orchard grass store very little nitrate under regular growing conditions. Legumes generally do not contain high nitrate concentrations. Alfalfas, vetches, trefoils, peas and clovers generally do not accumulate nitrates.

Table 1.

Agricultural crops	Weeds
Oat	Pigweed
Canola	Bull thistle
Barley	Fire weed
Wheat	Lambs quarters
Rye	Nightshade
Corn	Wild safflower
Sugar beets	Canada thistle
Flax	Smart weed
Sorghum	Kochia
Pearl millet	White rag weed
Sudan grass	Russian thistle

Saskatchewan Ministry of Agriculture (2008) [17]

Classification of vegetables according to nitrate content

Variation ranging from a low of 0.1 mg/100 g (peas and Brussels sprouts) to a high of 480 mg/100 g (rucola or rocket). In terms of plant anatomy, the nitrate content ofvegetable organs can be listed in descending order (most to least) as petiole> Leaf> stem > root >influorescence> tuber> bulb > fruit > seed. The accumulation of nitrate is subject to factors such as genotype, soil conditions, growth conditions (i.e., nitrate uptake, nitrate reductase activity, and growth rate), and storage and transport conditions.

Table 1.

Class	NO_3^-(mg/100 g fresh weight)	Vegetables
Very low	20	Artichoke, asparagus, broad bean, eggplant, garlic, onion, green bean, mushroom, pea
Low	20 to 50	Broccoli, carrot, cauliflower, cucumber, pumpkin, chicory
Middle	50 to 100	Cabbage, dill, turnip, savoy cabbage
High	100 to 250	Celeriac, Chinese cabbage, endive, fennel, kohlrabi, leek, parsley
Very high	>250	Celery, cress, chervil, lettuce, red beetroot, spinach, rocket (rucola)

Hord *et al*., (2009)

Maximum permissible limits of nitrate in water prescribed by different countries and organizations

In and around areas of high urbanization and industrialization, municipal and industrial trashes can contribute to high levels of nitrate to the groundwater (Handa, 1983) [5]. As and when the nitrate-rich groundwater is pumped out and used for drinking, it causes a number of health disorders in humans. Different organizations and countries have set standards for NO3 in potable water to safeguard public health from the hazards associated with a high concentration of nitrate.

The nitrate pollution of groundwater can well be perceived from the fact that terrestrial waters in uninhabited and less polluted regions like high altitude lakes, glaciers have negligible nitrate content. In Central Himalayan snow and ice, NO_3^- content is about 0.5 mg/l (Lunkad, 1994) [9] while world's average river water contains 1.0 mg/l NO_3^- and the ultimate sink of terrestrial waters, the oceans, on average, have 0.67 mg/l NO_3^- (Mason and Moore, 1985) [12].

Table 2.

Country/Organization	Concentration as NO_3^-N (mg/l)	Concentration as NO_3^- (mg/l)
WHO	10	45
US Environmental Protection Agency	10	45
ICMR	10	45
Canada	10	45
Denmark	11.3	50
Finland	6.8	30
USA	10	45

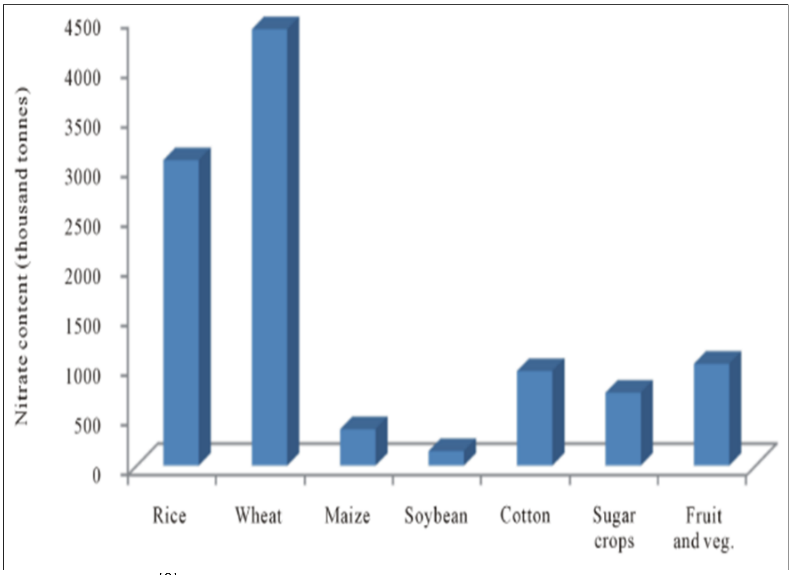
Majumdar (2000) [11]

Impact of Nitrate Consumption: Case Study of Punjab, India

The Green Revolution technology is the introduction of high yielding varieties of seeds for major crops, and get sufficient amount of food grains, creation and utilization of energized well irrigation and lift irrigation facilities, use of high doses of fertilizers and pesticides, and extensive use of farm machinery directed at improving farm productivity. The consumption of fertilizers (NPK) has been stagnant even the growth rate increase by 3.9%, which differs from area to area during the ninth plan. Subsequently, the growth rate of fertilizer has been increased by 6.7% in the eleventh plan of the agricultural sector. The production of food grains in Punjab has increased by 2% in the last 5 years as against an 8.6% rise in population.

The green revolution technology had put great pressure on the ecological system of the Punjab state, leading to a fall in the level of groundwater table, soil resources deterioration and environmental pollution from farm chemicals. After rice, wheat highly content of nitrate in respect of other agricultural products. Whereas the high yield of crop production, the growth of chemical fertilizer is increasing by the future prediction.

The time series of nitrate consumption is strongly correlated with the high yield of wheat production the same studied in China. The extreme use of fertilizer has resulted is not just higher contents of nitrate in wheat yield it also shows the groundwater contamination which leads to mixed water quality in the state of Punjab in India.

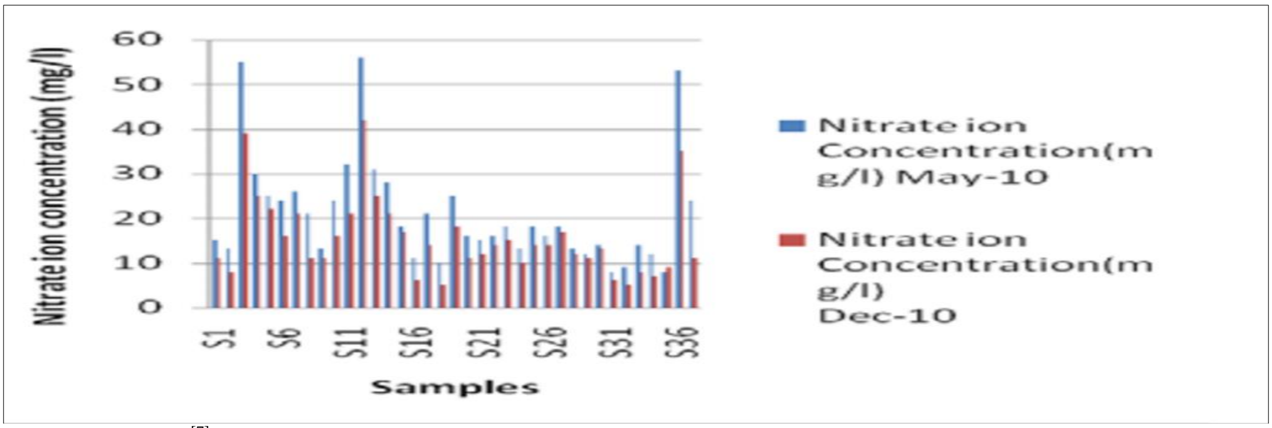


Khajuria (2016) [8]

Fig 2.

Nitrate Pollution in the Groundwater Around Sagar Town, M.P.

The Nitrate ion concentration was determined for 37 samples during the summer and winter and the result is presented in the Graph. The values were compared with the standard values given by WHO, which shows that the Nitrate ion concentration in the three water samples S3 (55mg/l) S12 (56mg/l) and S36 (53mg/l) were showing higher value for May-2010 (>50mg/l), which is unsuitable for drinking purpose (presented in the Graph). Concentration of Nitrate was found decreased during December-2010 indicating the dilution by rainwater in the study area. Higher concentration of Nitrate in groundwater is an anthropogenic pollutant contributed by the use of nitrogenous fertilizers, human and animal waste. Nitrate has been linked to the agricultural activities due to extreme use of nitrate fertilizers.



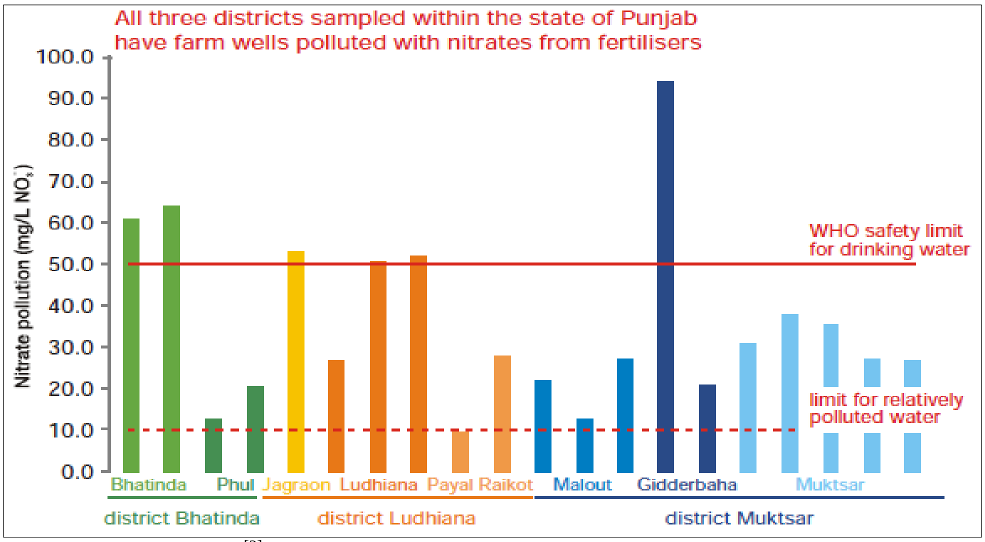
Jhariya *et al.* (2012) [7]

Fig 3.

Nitrate concentration in each blocks (or tehsils) in Punjab where 50 groundwater wells were sampled in rice and wheat farms

Drinking water extracted from artesian wells in agricultural areas Punjab showed high pollution with nitrates, and this pollution correlates with intensive farming practices where nitrogen fertilizers are applied in excess Ten of 50 sampled wells, i.e., 20 percent of all sampled wells, have nitrate levels above the safety limit of 50 mg/L NO_3^- for drinking water established by the World Health Organisation (WHO).

The three sampled districts show groundwater wells that are highly polluted with nitrates, and 44 percent of the farming villages sampled (8 of 18 villages), have wells with pollution higher than the safety limit for drinking water this nitrate pollution is clearly linked with excess use of synthetic nitrogen fertilizers.

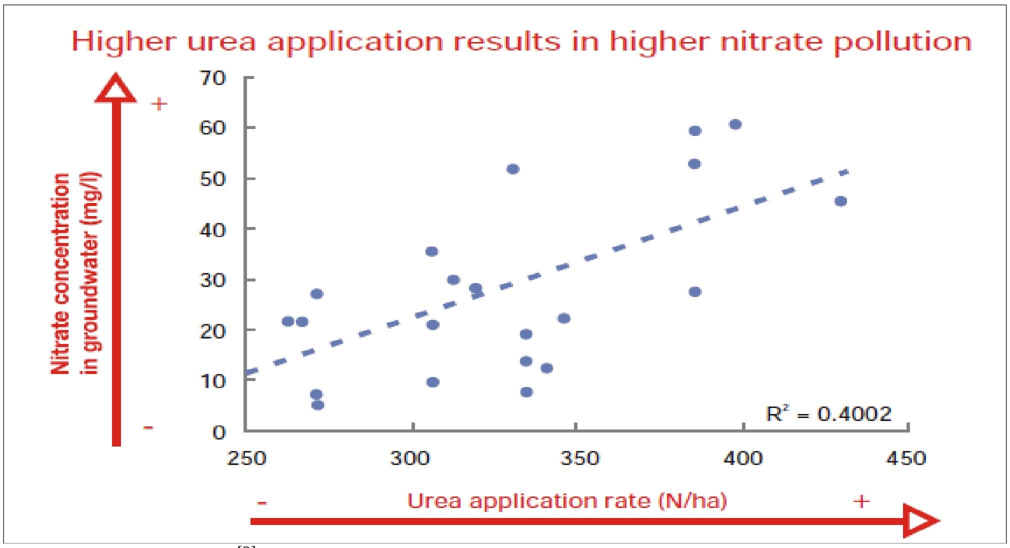


Greenpeace India (2009) [2]

Fig 4.

Relationship between nitrogen application rate in a farm and nitrogen concentration in the groundwater well in the same farm

The correlation between the application of nitrogen in the farm (mostly urea) and the nitrate pollution found in the groundwater well on the same farm the higher application of nitrogen (urea), the higher nitrate pollution found in the drinking water from the same farm. The data recorded on agronomic practices show that nitrogen application is higher than the averages reported by the Fertiliser Association of India for Punjab (210 kg N per hectare for 2006-07), while the data we recorded from 50 farmer interviews show an average application rate of. The nutrient demand of the crops is only about 100 Kg N per hectare, and scientific studies show that the best option is to add this nitrogen through organic fertilizers (legumes, manure, etc.) to ensure soil fertility (Mader *et al.*, 2002) [10].

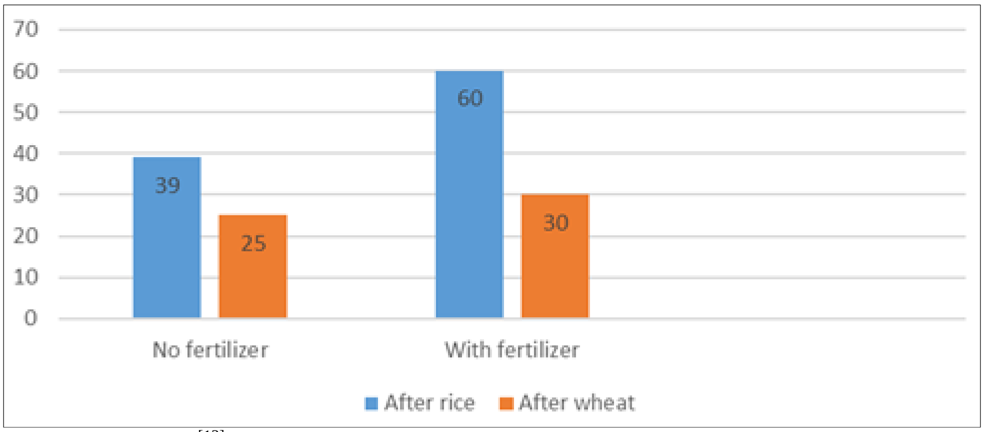


Greenpeace India (2009) [2]

Fig 5.

Nitrate in 60 cm soil profile after two years of rice and wheat crops

Vegetation retards NO_3^--N leaching from the root zone by absorbing nitrate and water. Rooting habits/patterns of different plants exert a profound influence on NO_3^- mobility in the rooting zone. Maximum leaching of NO_3^--N below the root zone occurs from heavily fertilized shallow-rooted crops, such as potato (*Solanum tuberosum* L.), maize (*Zea mays* L.) and rice (*Oryza sativa* L.), as well as heavily manured vegetable crops. In the predominant rice-wheat cropping system of Punjab, NO_3^- leaching to 60 cm during the rice crop was used by the subsequent wheat crop, which has a deeper and more extensive root system.



Milkha *et al*. (2009) [13]

Fig 6.

Groundwater content Nitrate-N in different cropping systems

Nitrate-N in the groundwater in the different cropping system classes such as high land crops, mixed crops, banana, and paddy. High Nitrate-N concentration of groundwater was observed at high land crop use and followed by mixed crops. Most of the wells were not exceeded the recommended level for drink water standards. Concentration of Nitrate-N in paddy and banana land use had less than the recommended level of 10 mg/L. The hydro-geochemical atlas of orathanadu has moderate nitrate content due to the higher usage of fertilizers.

Table 3.

Land use	Mean nitrate –N (10 mg/l)
High land crops	11.63
Mixed crops	10.73
Banana	5.43
Paddy	5.35

Chitravel *et al*., (2013) [3]

Nitrate and nitrite contents of edible components of vegetables

Table 4.

Vegetables	Nitrite	Nitrate
	mg/100 g fresh weight	mg/100 g fresh weight
Carrot	0.002–0.023	92–195
Mustard leaf	0.012–0.064	70–95
Lettuce	0.008–0.215	12.3–267.8
Spinach	0–0.073	23.9–387.2
Cabbage	0–0.041	25.9–125.0
Wax gourd	0.001–0.006	35.8–68.0
Cucumber	0–0.011	1.2–14.3
Eggplant	0.007–0.049	25.0–42.4

Hord *et al*., (2009)

Groundwater nitrate contamination in different regions of India

Table 4.

Study site	State	Range (mg/l)
Ludhiana	Punjab	0.31-13.3
Kanpur	Uttar Pradesh	1.0-166
Hooghly	West Bengal	0.01-4.56
Nadia	West Bengal	0.01-5.97
Anantapur	Andhra Pradesh	3.0-684
New Delhi	Delhi	0.04-98.3
Jaipur	Rajasthan	26-459
Sri Ganganagar & Hanumangarh	Rajasthan	0.34-278.68
Sri Ganganagar	Rajasthan	7.10-162
Krishna delta	Maharashtra	10-135
Sopore	Kashmir	32-91

Chaudhary (2011) [1]

Factors/ causes of high nitrate content in plant

Shade: Conversion of nitrates into amino acids and proteins is linked closely with photosynthesis. Light is the energy source for these activities, so shaded plants or lower leaves may be higher in nitrates than plants grown in full light.

Weather: Not all drought conditions cause high nitrate concentrations in plants. The moisture may be present in the soil along with the nitrate to permit absorption and accumulation. If the major supply of nitrate for the plant is in the dry surface soil, very little nitrate is absorbed by plant roots. In plants that survive through drought, nitrate levels are often high for several days following the first rain. The nitrate level in plants can rise and fall. If the source of stress is drought, and timely rain allows the plant to recover, the nitrate level falls as the plant uses the nitrate in the production of new plant tissue. If drought persists, so does the nitrate. Frost, hail and low temperatures all interfere with normal plant growth and can cause nitrate to accumulate in the plant. Frost and hail can injury or completely terminate the leaf area of the plant. A decrease of leaf area limits photosynthetic activity, so nitrate absorbed by the roots accumulates in the stem or stalk. Most plants require temperatures above 13°C for active growth and photosynthesis. Nitrate may be absorbed quickly by the plants when temperatures are low, but conversion to amino acids and protein occurs at very slow exposure of temperature.

Herbicides: However herbicides, such as 2, 4-D tend to disturb normal plant processes and can result in temporary high nitrate content in the plants; however, spraying pastures and silage crops to control weeds may actually reduce the nitrate hazard of these feeds, especially when weeds high in nitrates are killed.

Disease: Plant diseases interfere with normal growth and development. It can cause nitrate to accumulate by interfering with nitrate decrease, protein synthesis or manufacture and translocation of carbohydrates.

Insect Predation: Leaf damage caused by insect predation can result in reduced photosynthesis and may result in the accumulation of nitrate.

Why to regulate nitrification in agricultural systems?

This binding is sufficiently strong to limit NH_4^+ – N loss by leaching. In contrast, NO_3^-, with its negative charge, does not bind to the soil, and is liable to be leached out of the root zone. Several heterotrophic soil bacteria denitrify NO_3^- [i.e., convert NO_3^- into gaseous N forms: N_2O (a potent greenhouse gas) NO3-, and N under anaerobic or partially anaerobic conditions. The N loss during and 2 following nitrification reduces the effectiveness of N fertilization and at the same time can cause serious N pollution (Clark, 1962; Jarvis, 1996) [4, 6]. In alkaline soils, NH_4^+ can be lost via volatilization, thus reducing somewhat the advantage of nitrification inhibition (Rodgers, 1983; Sahrawat, 1989) [15, 16]. Rapid conversion of NH_4^+ to NO_3^- in the soil results in the inefficient use of both Soil-N and applied N. Soil Organic-N is also subject to nitrification, making it liable to N loss by the same pathways as fertilizer -N (Dinnes *et al.,* 2002; Subbarao *et al.,* 2006a, 2009ab) [18-20].

In addition, the assimilation of NO3- by plants requires more metabolic energy than is required for the assimilation of NH_4^+ (20 mol of ATP per mole of NO_3^- vs. 5 mol of ATP per mole of NH_4^+ (Salsac *et al.,* 1987); thus NH_4^+ assimilation is energetically more efficient than NO_3^- for plants. In addition, the assimilation of NO_3^-, but not NH_4^+ Author's personal copy results in the direct emission of N_2O from crop canopies, further reducing nitrogen-use efficiency (NUE) Consequently, maintaining N in NH_4^+ form is advantageous even after taking into consideration the potential negative effects on rhizosphere acidification from NH_4^+ uptake and metabolism (caused by H^+ excretion).

Management of nitrate leaching

Among the various alternatives available to reduce nitrate leaching are cover crops, using specific management practices, use of nitrification inhibitors or controlled-release fertilizers, site-specific crop management, variable rate application, appropriate scheduling of irrigation, sprinkler and drip irrigation with fertigation, banding and split application, chlorophyll measurement or colour chart based nitrogen application, foliar application, etc.

Enhancing fertilizer N use efficiency by ensuring measures such as balanced application of nutrients, proper coordination of N and irrigation management, and site-specific and need-based nutrient management can substantially control the leaching of nitrate N beyond the root zone of crops. There are two general approaches to minimize environmental pollution arising due to N use in agriculture: one is the optimum use of the ability of crop plants to compete with other processes which lead to the losses of N from the soil-plant system to the environment and the other is the direct reduction of the rate, duration and extent of loss through the loss processes themselves.

Conclusions

Prevention is always better than cure, which suggests that apart from judicious application of water and fertilizers in cultivated fields, water containing dangerous levels of nitrate should not be used as drinking water. This is possible only when the levels of nitrate in water are known, which can be done by regular monitoring of the drinking water. We need to check the excessive accumulation of nitrate in water and food as it is a serious threat to human and animal health There are many sources of nitrate accumulation in water and hence food, *viz.,* over-fertilization of crops, intensive agricultural rotation cycles and increased urbanization, etc. Nitrate accumulation in food and water can be minimized by growing cover crops, using specific management practices, proper scheduling of irrigation, and efficient fertilizer management practices. The problem is not slowly caused by N fertilizer management nor any other single factor but is a combination of the soil management practices and inherent physical, chemical, and biological characteristics of the soil.

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