A REVIEW ON CONTAMINATION AND LEACHING OF NITRATE IN THE GROUND WATER

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Abstract

The release of nitrates from lands is a large-scaleobservable fact. It has now international interest.Maintenance offragile agro-ecosystems in order to reach sustainable agricultural output while caring the environment has involved the interest of scientists and policy makers. Nitrate leaching could be a foremostmenace to environment in diverse agricultural situations. By proper management of agricultural systems, these leaching losses and as well as the nitrate contamination can be reduced and managed. Nitrate pollution of water leads to a number of health risks to human beings and natural world. In the background of the challenge of increasing foodstuff production with decreasing cultivable lands challenging heavy appliance of nitrogen leading to enhanced nitrate leaching. An understanding of the outcome of nitrate in groundwater is essential for managing risks coupled with nitrate pollution, and to protect groundwater supplies and groundwater-dependent surface waters.This review discusses the occurrence of nitrate leaching including the adverse impact and management of nitrate pollution.

Keywords-*Nitrates, groundwater, leaching, pollution*

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Introduction

Nitrogen is a very important nutrient component in agriculture. It is absorbed by plants in the form of either ammonium (NH_4^+) or nitrate (NO_3^-).Conversions of the forms of nitrogen in soil-plant systems depend on the mineralization and immobilization (Rao and Puttanna, 2000).Groundwater nitrate pollution has become a significant global environmental problem (Burden, 1982; Spalding and Exner, 1993; Rao, 2006).Though the main source of nitrate pollution is direct application of nitrogen-based fertilizers to land but discharge from septic tanks and leaking sewers, atmospheric deposition, landfilling, deforestation, disposal of industrial effluent, animal excreta from dairy industries, the spreading of sewage sludge and manure to land etc. can also contribute (Wakida and Lerner, 2005; Rao and Puttanna, 2000). A simple 'equation' summarizes the problem at the root of the nitrate issue:"Availability=Vulnerability". Any nitrogen in the soil that is available to crops is usually in one of two forms: ammonium, which is readily converted to nitrate, or nitrate itself. Nitrate is freely soluble and is not adsorbed on to non-acid soils and is therefore vulnerable to being washed out of the soil by rain or irrigation water. We need to limit the vulnerability of nitrate. The cost of compliance is already significant.When crops are growing fast they need a generous supply ofnitrate in the soil, but once they have ceased to grow and absorb nitrate we need to ensure that there is as little nitrate there as possible. Whether or not untimely nitrate becomes nitrate pollution depends onthe fate of rainfall or irrigation water falling on the soil. This is determinedlargely by the physical behaviour of water in the soil. (Addiscott, 2005).

Occurrence of nitrate

Nitrate lost from the soil by leaching makes its way into groundwater orinto surface waters – that is, streams, rivers and lakes – from which it mayeventually reach the sea where it remains a potent source of controversy, particularly in the estuaries and bays in which rivers meet the ocean. Only a small proportion of this nitrate may have come from fertilizer. The rest is from mineralization in the soil, some are from grazing animals or the application of manuresand someare from the ploughing up of old grassland and some, as from the deposition of variousforms of nitrogen from the atmosphere (Addiscott, 2005). The issues involved differ somewhatbetween ground- and surface waters, but the two categories can interact. Many streams, for example, begin in a boggy area where groundwaterseeps out from an exposed aquifer.Contribution of nitrogen from rivers has now doubled in comparison to the marine waters as they did 100 years ago (Vitouseket al., 1997). Eutrophication is therefore a problem in marine as well as in fresh waters. It has caused startling changes in the growth of aquatic plants and algae in coastal waters (Nixon, 1995). The excessive algal growth in particular has destroyed critical aquatic habitats and lowered the concentration of dissolved oxygen, thereby killing fish and shifting the balance between marine organisms (Howarthet al., 2000). This eutrophication threatens the long-term sustainability of fisheries and the use of coastal waters for recreation.

Application of nitrogen fertilizers can cause increase in concentration of nitrates and nitrites in crops. In India, NO_3^- contents of cereals, pulses, leafy vegetables, roots and tubers and condiments and spices are found from the diet in Andhra Pradesh (Ushaet al., 1993), all of which are above permissible limit. Moreover, 50% of the nitrate in dried tea was found to be released into infusion (Regina et al., 1998). In China, different vegetable samples contained nitrate and nitrite more than the permissible limit (Pang et al., 1996). In Brazil, nitrate in pasteurized milk crossed their legal permissible limit (Seraphim et al., 1998). Nitrate contents in some varieties of rice in Pakistan have exceeded the permissible level set by WHO (Salah-ud-Din et al., 1996). In Poland, maximum acceptable limit of nitrates was exceeded in 8.2% of the samples of radish and 65% of lettuce (Jozef and Anna, 1999). The nitrate contents in greenhouse vegetables (lettuce, cucumber, radish) were greater than in field-grown vegetables. Reduction of nitrate content in potato(Yefimov et al., 1992), spinach(Dressel et al., 1984), lettuce(Dressel et al., 1984), kohlarabi(Dressel et al., 1984), carrot, white mustard, buckwheat, oats, ryegrass ((Dressel et al., 1984) green manure crops, cucurbit, fodder crops and radish (Jinan and Allen, 1989) by the use of nitrification inhibitors has also been reported.

Nitrate leaching and groundwater pollution

Many investigators (Handa 1983; Sankaranarayana et al. 1989; Sehgal et al. 1989; Bulusu and Pande 1990; Rao 2006) have reported that the contribution of nitrate from the fertilizer to the groundwater can vary from as little as 3 mg/L to as much as 1,800 mg/L.

The quantity of nitrate leaching to groundwater is governed by many factors such as texture and hydraulic conductivity of the soil (Kohler et al., 2006), nature of the crops grown (Singh and Sekhon, 1977), quantity of nitrogenous fertilizers used (Burkart and Stoner, 2007), depth of the aquifer (Power and Saikh, 1995), nature of sand and gravel underlying the profile, and so on. However, the overriding factor controlling the nitrate leaching is the intrinsic hydrologic system (Kulabako et al., 2007) or geologic makeup (Lorite-Herrera and Jimeı`nez-Espinosa, 2008) of the concerned area. The activity of denitrifying organisms which convert nitrate to gaseous N_2 or N_2O along the profile may also have some role in this regard (Rivett et al., 2008). Most of the earlier researchers, except a few (Nolan and Hitt, 2006;Gurdak, and Qi, 2006), have studied the individual influence of these and other factors but have not made an integrated approach taking into consideration the interplay of all the relevant factors on nitrate leaching and its enrichment of groundwater. A thorough understanding of the mechanistic pathways for such enrichment may be helpful in developing strategies for curbing the nitrate contamination and thereby the degradation of precious aquifer resources of any nation (Kundu and Mondal, 2009a).

Excess nitrates leach down the soil profile with percolating water. Leaching of nitrates is more likely to occur in sandy soils, but it takes place in fine textured soils also (Jones and Schwab, 1993). Nitrate leaching is a global problem. Recently, there have been many studies made in India which point to the danger of nitrate leaching and subsequent pollution of ground waters. Due to increased agricultural activity which is necessary for enhanced food production and also due to industrial activity, there is an increasing evidence of nitrate pollution of groundwater. In agriculturally intensive areas in Punjab (Bijay et al., 1994), Delhi (Datta et al., 1997; Maharashtra (Deshpande et al., 1999), Andhra Pradesh (Rao, 1998; Reddy et al., 2009), West Bengal (Kundu and Mandal 2009a; Kundu et al., 2009; Kundu and Mandal, 2009b; Kundu, et al.,2008), Rajasthan (Suthar et al. 2009; Chaudhary et al. 2010; Suthar , 2011), Kashmir where fertilizer applications are high, there is ample evidence of pollution of groundwater by nitrates. Even in semi-arid regions in Deccan plateau (Patra and Rego, 1997) and arid regions of Rajasthan (Ozha et al., 1993), where the intensity of agriculture is less, nitrate leaching was found prevalent. Another important area is industrial and urban centres where nitrate pollution of groundwater was found rampant (Rangarajan et al., 1996). This phenomenon was attributed mainly to dumping of animal manures, organic wastes from industries and sewage on to the soil. In most of the above studies, nitrate concentrations in groundwater exceeded the permissible limit of 45 mg/l. Three fourth of world population live in developing countries like India where there is an alarming trend of groundwater pollution by nitrates (Bijay et al., 1994). The groundwater pollution due to nitrates is increasing in India. The water quality assessment studies carried out in 17 Indian states by NEERI showed that out of 4,696 water samples, 1,290 samples (27%) have nitrate exceeding the drinking water standard (Bulusu and Pande 1990). Nitrate concentrations reaching a maximum of about 450 mg NO_3/L was observed (Rao 1998, 2002) in the lower portions of Vamsadhara and Godavari river basins.

Treatment of groundwater for the removal of nitrates or prevention of nitrate from reaching groundwater is possible. Chemical methods such as catalytic removal of nitrate from water, abiotic degradation of nitrates using zero valent iron and electrokinetic processes(Chew and Zhang, 1999), biotechnological methods such as use of vegetable oil for denitrification (Hunter, 1999), reduction of agricultural nitrate loading through microbial wetland processes (Iverson and Hoffman, 1996), using sulphur and limestone autotropic denitrification and physical methods such as application of reverse osmosis and nanofiltration have been reported. These processes are at present considered costly even in advanced countries (Rao, 1999). A recent study conducted in Bulgaria (Pulido-Bosch et al., 1997) has shown that when groundwater is being tapped in pockets, nitrates from surrounding soil profile can migrate and accumulate in such pockets and this phenomenon was observed in soils which are otherwise low in nitrate concentration. Such studies serve as warning to countries like India of nitrate pollution where groundwater exploitation is growing at a tremendous rate.

Minimizing nitrate leaching

All thetechnologies available for decontaminating nitrate-containing drinking water are very costly. Hence, it is necessary to minimize nitrate leaching from agricultural as well as nonagricultural activities. In developed countries the approach to reducing nitrate pollution is largely based on changing the land use pattern which may involve the conversion from agricultureto nonagricultural use (Alkemede et al., 1998), conversion to grasslands(Parkinson, 1993),change in cropping system(Joosten et al., 1998)or reduction in fertilizerdose involving a reduction in food production, wouldnot be appropriate in India and other developing countries where the challenge is to maximize food production withno increase in cultivable land. In developing countries the stress will be on maximizing the fertilizer use efficiency.By adopting the following improved methods of nitrogenfertilizer use (Rao and Puttanna, 2000), nitrate leaching can be minimized in the country like India.

- Substituting part of the inorganic fertilizers with organicfertilizers, i.e. adopting integrated nutrient managementsystems.

- Matching the plant needs and fertilizer applications byusing appropriate split applications.
- By using improved crop management practices.
- Use of slow-release fertilizers [urea-aldehyde polymericcompounds, coated fertilizers].
- Use of nitrification inhibitors and urease inhibitors.Chemicals known to be safe should be used.
- Choosing the right cropping systems.
- Intercepting nitrate by means of trees or other deeprooted, nitrate mining crops (e.g. alfalfa) or by diggingditches.
- Establishment of information systems and monitoringnetworks.
- Education of the population in general and farmers inparticular.

Conclusion

Nitrate originating from agriculture could be a majorthreat to environment in many situations. It is important that proper assessment of nitrate pollution should be madeby extensive analysis of soil and groundwater samples. It is possible to minimize this threat by proper managementof agricultural systems and by adopting appropriate policymeasures. Elevated nitrate concentrations in groundwater may lead to the derogation of precious aquifer resources and the eutrophicationof surface waters. Since nitrate leaching cannot be totally avoided in most cases one can think of either using the nitrate containing water for irrigation purposes or use of some kind of remediation technique to remove the nitrate ions before using the water for drinking. A comprehensive account of methods and techniques for nitrate removal should be sort out. Remediation techniques include water table adjustments to increase denitrification, bioremediation using Pseudomonas and Bacillus, aquatic plants like Lemma, Wolffia, urticularia and pteridophites, bank filtration, etc. Considering the health effects of these chemical constituents, WHO (1998) and Bureau of Indian Standards (BIS 1992) have set guidelines for the maximum permissible levels in drinking water. In the case of nitrate, WHO has set a guideline value of 11.3 mg/l as nitrate–N whereas BIS desirable concentration is 10.2 mg/l as nitrate–N and Maximum permissible concentration is 22.6 mg/l as nitrate–N. Mitigation is difficult due to the long-term, diffuse and continuing nature of the problem (Hiscock et al., 2007). Options for alleviation are primarily continued implementation of land-use control measures, such as protection zones designed to reduce subsurface nitrate loading (Silgram et al., 2005; Hiscock et al., 2007) and reliance on natural attenuation processes. Evidence for retardation of nitrate in groundwater has not been identified, though the process has been observed in some soils due to the presence of poorly crystalline materials that carry variable surface charge, and therefore adsorb otherwise inert anions such as nitrate and chloride (Clay et al., 2004).

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