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AK Kanthle
1. Department of Agriculture, Development and Farmer Welfare and Bio Technology, Government of Chhattisgarh, Mungeli, Chhattisgarh, India
2. Indira Gandhi Krishi Viswa Vidyalaya, Chhattisgarh, India

K Tedia
Indira Gandhi Krishi Viswa Vidyalaya, Raipur, Chhattisgarh, India

NK Lenka
Indian Institute of Soil Science, Nabibagh, Bhopal, Madhya Pradesh, India

Corresponding Author:
AK Kanthle
1. Department of Agriculture, Development and Farmer Welfare and Bio Technology, Government of Chhattisgarh, Mungeli, Chhattisgarh, India
2. Indira Gandhi Krishi Viswa Vidyalaya, Chhattisgarh, India

Review on role of soil quality in nitrate leaching

AK Kanthle, K Tedia and NK Lenka

Abstract
Soil quality is linked intrinsically to soil organic matter (SOM), because it is important in maintaining good soil physical conditions (e.g. soil structure, aeration and water holding capacity), and contributes to soil fertility being an important nutrient reserve. Organic matter contains most of the soil reserve of N and large proportions of other nutrients. The amount of SOC in soils of India is relatively low, ranging from 0.1 to 1% and typically about 0.5%. With increase in global population and agriculture intensification, there is a global concern of decrease in SOC and overall soil quality which impairs the critical soil functions. Nitrate being an anion is easily lost from the soil through leaching due to the overall negative charge of the clay micelle. Nitrate is the primary form of leached N and is also the highly leached fertilizer nutrient in agricultural soils. SOC content has a vital role in regulating nitrate leaching.

Keywords: Soil organic carbon, soil quality, nitrate leaching, infiltration, detoxification

Introduction
Soil organic carbon (SOC) provides multiple functions crucial for sustainable food production. Apart from the role in maintenance of soil fertility, it regulates infiltration and storage of water, retention and cycling of nutrients, detoxification of harmful chemicals and filtering and buffering actions in the soil. Thus, the SOC plays a major role in regulating the quality of soil and water – the two vital natural resources for agriculture.

Soil organic carbon
Adelman and Tabidian (1996) [1] used a modified version of a solute transport model for the Eastern Sandhills of Nebraska to assess the risk of nitrate contamination for combinations of fertilizer and irrigation rates at various soil carbon levels. They concluded that soils with high carbon concentrations had minimal leaching compared to soils with lower concentrations. Soils high in carbon have an active population of denitrifying bacteria possibly causing denitrification and in turn reduce nitrate leaching. Similar findings were reported by Garg *et al*., (2014) in a glass column study. In a comparative study to investigate the leaching kinetics of nitrate (NO_3^-) in agricultural (pH = 7.2) and non-agricultural soils (pH = 6.8) of Uttar Pradesh, they showed the efficacy of native SOC in reducing nitrate leaching. Their results showed that leachable NO_3^- was higher in columns (84 mg kg^{-1} soil) with agriculture soil in comparison to non-agricultural soil (clay to clay loam) columns (30 mg $kg^{-1}$of soil) due to lower SOC content in the agricultural soil (clay loam).

Added soil organic carbon also regulates the movement and leaching of nitrate in the soil profile. McCracken *et al.*, (1994) [11] in a lysimetric study reported the contributions of hairy vetch (*Vicia villosa* Roth) and NH_4^+ N sources on NO_3^- leaching in corn (*Zea mays* L.) production using ^{15}N stable isotopes on a silt loam (fine, mixed, mesic Typic Paleudalf) soil. Generally, cover crop effects were larger than N-source effects in containing nitrate leaching. They concluded that the NH_4^+-N source/rye cover system leached consistently less NO_3^- than the vetch N source/vetch cover system, even though the fraction of water discharged was not consistently different.

Soil texture
Among soil properties, soil texture is the dominant factor affecting nitrate leaching. The other factors include soil compaction level, antecedent soil moisture content and rate of irrigation. Soil texture influences nitrate leaching by affecting water infiltration and water holding capacity. Kissel *et al.*, (1973) [8] reported that nitrate can also be readily leached in Vertisols under proper moisture conditions. The authors stated that fertilizers were moved into cracks that extend to appreciable depths. Sapek (1996) [13] indicated that NO_3^- can move through fine-textured soil at the rate of 80 cm deep per year as compared to 400 cm per year in sandy soil. Kucke and Kleeberg (1997) [9] reported less N leaching from loam soil than from sandy soil

despite the fact that fine-textured soil often has a greater amount of NO_3^--N than coarse-textured soil. Paz and Ramos (2004) [12] indicated that in sandy soils with high permeability and infiltration, large amount of NO_3^- is leached with increased risk of groundwater pollution.

Gaines and Gaines (1994) [6] conducted an experiment to determine the effect of soil texture and SOC on NO_3^- retention. Sand, sand: peat Green mix (85:15), a loamy sand, and sandy clay loam soils were placed in 2x3 inch metal cylinders and soaked in a 240 ppm solution of NO_3^--N for seven days to saturate the soil with NO_3^- ions. The columns were leached with water to collect 10 soil percolate samples of 50 ml each until a total volume of 500 ml was collected. The result showed that soil texture affected the retention of NO_3^--N in the sand, which adsorbed the least amount of NO_3^--N at 119 ppm, followed by the Greens mix at 125 ppm, loamy sand at 149 ppm, and sandy clay loam at 173 ppm. Soils with more silt, clay, and organic matter retained more NO_3^- than the straight sand.

Soil types

Francis *et al.*, (1995) [4] from a two-year (1993 to 1995) study on a freely-draining Templeton silt loam soil of New Zealand also observed reduced nitrate leaching under cover crops as compared to bare follow in both years of the experiment. In a similar study, Sattell *et al.*, (1999) [14] conducted a three-year (1993 to 1995) experiment on a loamy soil to assess the efficacy of cereal rye cover crops in retaining applied nitrate as compared to fallow plots. The nitrate leaching over the three-year period under properly managed cover crops was 29, 19 and 62 lb/acre as compared to 43, 49 and 92 lb/acre in the fallow plots. Fraser *et al.*, (2010) [5] conducted a seven-year (2000 to 2007) study on a Wakanui silt loam soil at Canterbury, New Zealand to observe the impacts of tillage intensity and winter cover crops on nitrate leaching. They reported the use of winter cover crops reducing NO_3^- leaching under different tillage levels. The nitrate leached under the cover crop treatments were 93, 73 and 124 kg N ha^{-1} as compared to 208,192 and 200 kg N ha^{-1} without cover crops under high intensity, minimum and no-tillage treatments, respectively.

Using various organic manures, Loganathan (2014) [10] conducted an experiment in reddish brown earth soils collected from non-agricultural lands in Sri Lanka. By incorporating green manures (*Sesbania rostrata*, Gliricidia, sunhemp and Azolla) they showed that nitrate loss was significantly ($P = 0.022$) different for each treatment. The highest amount of loss was observed in azolla (19.66 mg) followed by urea (17.54 mg), Sesbania (15.34 mg), Giliricidia (13.14 mg) and sunhemp (11.2 mg). Nitrate loss was less in green manure (Sesbania, Sunhemp and Gliricidia) added soil than inorganic fertilized soil within one month period, indicating the favorable role of added carbon in reducing nitrate leaching.

Zhou *et al.*, (2006) [15] conducted an experiment to study the leaching loss and transformation of three kinds of nitrogen fertilizers (nitrate fertilizer, ammonium fertilizer, and urea fertilizer) in two contrasting soils (clay loam and sandy loam soil) after fertigation. They concluded that N leached from a clay loam soil is less, ranging from 5.7% to 9.6% of the total N added as fertilizer, compared to sandy loam soil (ranging between 16.2% and 30.4%). Fang *et al.*, (2006) [3] in a two-year (2000 to 2002 on silt loam soil) experiment with two soil moisture content and four N treatments (0, 100, 200, and 300 kg N ha^{-1}) in an intensive wheat–maize double cropping system (wheat–maize rotation) in the North China Plain showed that the NO_3^-N leached below the 100 cm soil depth varied with treatments and crop/season types, ranging from 0 kg ha^{-1} to 80 kg ha^{-1} for wheat and from 0 to 165 kg ha^{-1} for maize. There was a general increase in NO_3^-N leaching with N application rate irrespective of the soil moisture levels. Soil NO_3^-N leaching in the maize seasons was generally higher than in wheat seasons due to higher downward water flow as a result of the concentrated summer rainfall. Chhabra *et al.*, (2010) [2] reported that nitrogen lost through leaching in form of NO_3^- is the most dominant in coarse textured soils such as sand, and sandy loam and the losses are higher than fine textured soil.

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