

Soil nitrate and nitrite in different soil profiles of Peri-Urban and horticultural farm soils of Gaborone as indicators of nitrogen leaching.

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Abstract

Soil nitrite (NO_2^-) and nitrate (NO_3^-) along the soil profile can be used as indicators of nitrogen loss by leaching. Preliminary studies have shown that excess usage of fertiliser is common amongst farmers who were aiming to increase crop yield. As such a study to assess levels of nitrite and nitrate in soil profiles in relation to fertiliser use of peri-urban horticultural farms around Gaborone in Botswana was conducted at four farms in Matebele, Glen Valley (NAMPAAAD (National Master Plan for Arable Agriculture and Dairy Development)), Kopong and Ramaphatle from 1st July 2013 to 30 May 2014. Soil profiles were sampled for nitrite and nitrate at different depths (0-30cm, 30-50cm and 50-80cm). Factors that could alter the leaching ability of soil being soil pH and moisture content were also assessed. Generally in all profiles, moisture content increased with depth from 5.14% (g/g) at 0-30cm to 12.52 % at 50-80cm. Soil pH decreased with depth from 6.9 to 6.0 in Kopong, 7.1 to 6.3 in Matebele and 5.1 to 4.0 in Ramaphatle. Soil nitrite content increased from 0.406 $\mu\text{g/g}$ soil to 0.746 $\mu\text{g/g}$ and from 0.009 $\mu\text{g/g}$ soil to 0.018 $\mu\text{g/g}$ soil with depth in Matebele and Kopong respectively and decreased with depth from 0.103 $\mu\text{g/g}$ soil to 0.014 $\mu\text{g/g}$ soil and from 0.06 $\mu\text{g/g}$ soil to 0.03 $\mu\text{g/g}$ soil in Glen Valley and Ramaphatle respectively. Soil nitrate content decreased with depth from 0.005 $\mu\text{g/g}$ soil to 0.003 $\mu\text{g/g}$ soil (Kopong), from 0.012 $\mu\text{g/g}$ soil to 0.007 $\mu\text{g/g}$ soil (Matebele) and from 0.038 $\mu\text{g/g}$ soil to 0.006 $\mu\text{g/g}$ soil in Nampaad respectively with the exception of Ramaphatle where it remained constant down the soil profile (0.01 $\mu\text{g/g}$ soil). Glen Valley soil had higher nitrate content (0-30cm) of 0.38 $\mu\text{g/g}$ soil, which was more than both Matebele (0.012 $\mu\text{g/g}$ soil) and Kopong (0.005 $\mu\text{g/g}$ soil) soils. Higher moisture content at greater soil depths explains the presence of nitrite and nitrate ions owing to the mobility in solution. Field tests have revealed that Glen Valley soil is clayey, as such leaching of nitrite and nitrate is lower due to predominance of micropores compared to sandy loams soils of Kopong and Ramaphatle, thus higher nitrite and nitrate content on the surface soil. The study indicates an increase in soil nitrite and nitrate with depth in soils that have higher moisture content in the lower parts of the soil profile. Thus overwatering in these study farms is resulting in leaching of soil nitrogen and could result in contamination of ground water.

Key words: Moisture, nitrates nitrite, soil respiration, pH, soil testing

Résumé

Le nitrite de sol (NO_2) et le nitrate (NO_3), le long du profil du sol peuvent être utilisés comme indicateurs de pertes d'azote par lessivage. Des études préliminaires ont montré que l'excès d'utilisation d'engrais est commun parmi les agriculteurs qui visaient à augmenter de rendement des cultures. En tant que tel, sur une étude visant à évaluer les niveaux de nitrites et de nitrates dans les profils de sol par rapport à l'utilisation d'engrais des fermes horticoles périurbains autour de Gaborone au Botswana a été menée dans quatre fermes, ceux de Matebele, la vallée de Glen (NAMPAAAD (National Master Plan for Arable Agriculture and Dairy Development- Plan Directeur National pour l'Agriculture Arable et le Développement des Produits Laitiers), Kopong et Ramaphatle, à partir du 1^{er} juillet 2013 au 30 mai 2014. Les profils de sol ont été échantillonnés pour les nitrites et les nitrates à différentes profondeurs (0-30cm, 30-50 cm et 50-80cm). Les facteurs pouvant altérer la capacité de lessivage des sols étant le pH du sol et la teneur en eau ont également été évalués. En général, dans tous les profils, l'augmentation de la teneur en eau à une profondeur de 5,14% (g / g) de 0-30cm à 12,52% à 50-80cm. Le pH du sol diminué avec la profondeur de 6,9 à 6,0 à Kopong, de 7,1 à 6,3 à Matebele et de 5,1 à 4,0 à Ramaphatle. La de la teneur en nitrites de sol a augmenté de 0,406 ìg / g de sol à 0,746 ìg / g et de 0,009 ìg / g de sol à 0,018 ìg / g de sol avec la profondeur dans Matebele et Kopong respectivement, et a diminué à une profondeur de 0,103 ìg / g de sol à 0,014 ìg / g sol et de 0,06 ìg / g de sol à 0,03 ìg / g de sol de la vallée de Glen et Ramaphatle respectivement. La teneur en nitrate du sol a diminué avec la profondeur de 0,005 ìg / g de sol à 0,003 ìg / g de sol (Kopong), de 0,012 ìg / g de sol à 0,007 ìg / g de sol (Matebele) et de 0,038 ìg / g de sol à 0,006 ìg / g de sol dans Nampaad respectivement à l'exception de Ramaphatle où elle est restée constante sur le profil du sol (0,01 ìg / g de sol). Le sol de la Vallée de Glen a eu une plus forte teneur en nitrate du sol (0-30 cm) de 0,38 ìg / g de sol, qui est plus qu'aux sols de deux, Matebele (0,012 ìg / g de sol) et Kopong (0,005 ìg / g de sol). Le taux d'humidité supérieur à une plus grande profondeur du sol explique la présence des ions de nitrites et de nitrates en raison de la mobilité en solution. Les essais sur le terrain ont révélé que le sol de la vallée de Glen est argileux, ainsi, le lessivage des nitrates et des nitrites est inférieur à cause de la prédominance des micropores rapport aux sols terreux sableux de Kopong et de Ramaphatle, donc plus élevé en contenu de nitrite et de nitrate sur la surface du sol. L'étude indique une augmentation de nitrite et de nitrate du sol avec la profondeur dans les sols qui ont une teneur plus élevée de l'humidité dans les parties inférieures de la surface du sol. Ainsi l'arrosage excessif dans les études de ces fermes se traduit par lessivage de l'azote du sol et pourrait entraîner la contamination des eaux souterraines.

Mots clés: humidité, nitrates nitrites, la respiration du sol, pH, l'analyse du sol

Background

Urban population increase has increased the demand for horticultural produce. This has prompted farmers to use fertilisers and pesticides to realize higher crop yields. However, these inputs are sometimes used excessively with little knowledge of the soil nutrient status. This causes soil pollution, affects surface water (eutrophication) and ground water (leaching),

changes agricultural soil biota which are supposed to play an important role in nutrient cycling.

Literature summary

Excessive nitrogen fertiliser use accompanied by over irrigation can result in nitrogen leaching in the soil profile and contaminating ground water. Nitrogen contamination of ground water in the form of nitrite and nitrate can render the water unsafe to drink due to potential health risks such as methemoglobinemia (Morris *et al.*, 2003). Excess N accompanied by low oxygen diffusion down the soil profile also alters microbial diversity as it tends to promote denitrifiers, thus, changing microbial diversity, which in turn can affect nutrient cycling. Agriculturally important soil microbiota are also sensitive to changes of pH and nutrient availability which is brought on by presence of pesticides and nitrogen fertilizers. Thus assaying for the presence of nitrate and nitrite in the soil profile will give us an indication on nitrogen movement down the profile. The changes in soil biota that may occur due to nutrient alteration, can be detected by soil respiration

Site and methodology

The study was carried out from 1st July 2013 to 30 May 2014 on farms surrounding Gaborone i.e., Kopong, Glen valley, Matebele and Ramaphatle. Four sites were selected from each of the fields, each site bearing 4 sub sampling points resulting in each field having 16 sampling points. Using either a soil profile (1m x 1m x 1m) or soil auger soil samples were taken at depth ranges 0- 30cm, 30-50cm, 50-80cm. The soil samples collected from the fields were analysed for soil moisture by gravimetric method. Soil pH was determined by preparing a 1:2 soil to water suspension and then read on a Corning pH meter. Soil nitrite in the samples was determined by using the Giess-Ilsovy method (Eltun, 1995). The soil nitrate was first converted to nitrite and then analysed using the Giess-Ilsovy method thereafter absorbance readings taken on a spectrophotometer according to Shanthi and Balasubramanian (1994). Soil respiration as an indicator of microbial activity was determined by setting up CO₂ traps of NaOH in the field and then titrating the CO₂ traps with HCl.

Results and application

Higher moisture content at greater soil depths implies overwatering of crops as these areas had very little rainfall during the sampling season. Excess water increases mobility of NO₂⁻ and NO₃⁻ ions which is evident in the positive tests for NO₃⁻ and NO₂⁻ at greater soil depths (Table 1). Glen valley soil is clay as such permeation of mobile NO₃⁻ and NO₂⁻ is lowered due to soil structure, thus higher levels on the surface soil. Soil nitrate and nitrite content is useful as an indicator of nitrogen leaching and excess watering of crops evident in high moisture at greater depth is a factor in the increased loss of fertiliser-N to ground water due to the mobility of NO₃⁻ and NO₂⁻. In this study it was also apparent that farms that use municipal waste water being Glen valley, Matebele, had higher NO₃⁻ and NO₂⁻ content owing to the nitrogen rich waste water. Essentially, high moisture levels and excess supply of fertiliser aids in the loss of both nitrogen and water down the soil profile. Intensive

Table 1. Assessment of soil from peri-urban horticultural farms around Gaborone.

Site	Depth (cm)	% moisture§	pH	Nitrite (µg/g soil)	Nitrate (µg/g soil)	CO ₂ ‡
Kopong	0-30	5.86±0.65	6.9±0.7	0.009±0.003	0.005±0.001	34.7±3
Kopong	30-50	5.08±0.17	6.3±0.5	0.010±0.004	0.004±0.001	
Kopong	50-80	6.40±0.25	6.0±0.7	0.018±0.001	0.003±0.001	
NAMPAAD	0-30	6.39±0.21	5.3±0.9	0.103±0.010	0.038±0.005	82.5±4
NAMPAAD	30-50	9.93±0.16	5.3±1.4	0.069±0.010	0.004±0.001	
NAMPAAD	50-80	12.52±2.37	5.8±1.7	0.014±0.001	0.006±0.001	
Matebele	0-30	5.15±0.29	7.1±0.8	0.406±0.05	0.012±0.001	101.8±6
Matebele	30-50	8.32±0.22	6.1±0.2	0.810±0.05	0.011±0.001	
Matebele	50-80	10.54±0.35	6.3±0.7	0.746±0.04	0.007±0.002	
Ramaphatle	0-30	4.10±0.92	5.1±0.5	0.06±0.001	0.01±0.003	82.5±4
Ramaphatle	30-50	7.52±1.02	5.6±0.1	0.03±0.001	0.01±0.003	
Ramaphatle	50-80	6.47±0.89	4.0±0.4	0.03±0.001	0.01±0.001	

‡ mg/0.314 m² surface soil

§ on dry weight basis

farming will ultimately result in the contamination of ground water which in some instances farmers use for subsistence.

Acknowledgement

The work is being funded by RUFORUM grant GRG-72 whose financial backing is greatly appreciated. The University of Botswana's role in providing laboratory space and equipment is also greatly appreciated.

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