UNIVERSITI PUTRA MALAYSIA

NITRATE LEACHING IN SOILS TREATED WITH ACTIVATED SLUDGE, CATTLE MANURE AND CHEMICAL FERTILIZERS

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By

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Nitrogen fertilizers have been recognized as an important factor in crop's yield level, however more application of N fertilizers in the soil have some adverse effects on environment and especially on ground water contamination. Perception and recognition the factors influencing nitrate transport through soil profile is helpful for fertilizer management to minimize adverse impacts on environment and nitrate leaching below the root zone. In this study, 15 large cylindrical lysimeters with 1 m height and 0.56 m diameter were filled with clay and sandy loam soil and planted with maize to investigate nitrate leaching under different types of N-fertilizer; activated sludge (20 ton/ha), cattle manure (40 ton/ha) and chemical fertilizer (containing 70 kg N/ha). Also 3 lysimeters with 1.4 m height were used to investigate the effect of soil depth in nitrate leaching in sandy loam soil. Totally the study involved nine treatments. Nitrate concentrations in the soil and drainage water samples were analyzed by spectrophotometer method and nitrate mass were calculated in irrigation water, soil and drainage water. Crop production for different

treatments has been compared too. The nitrate-N concentrations were higher than 10 mg N/L (the maximum acceptable concentration) in 60% of the observations for OFcl. The Nitrate-N concentrations were higher than 10 mg N/L in 48 and 51% of the samplings for the CFcl and OFcl treatments, respectively. The Nitrate-N concentrations were almost always lesser than 10 mg/L in the lysimeters containing sandy loam soil. Results illustrate nitrate leaching from activated sludge and organic fertilizer in clay loam soil was significantly greater than the other treatments (110 kg/ha and 229 kg/ha respectively). Among all treatments of this study organic manure in clay loam soil had the greatest nitrate accumulation in soil (15.17 mg/kg) and chemical fertilizer in sandy loam soil had the least (8.56 mg/kg). Experimental results also showed that manure application could result in NO_3^--N accumulation increase in the deeper soil profiles compared with mineral fertilization and activated sludge. The results demonstrate that nitrate, from the activated sludge and chemical fertilizers, transported through the soil profile is more than the organic manure after the 75 cm depth, and the accumulation of organic fertilizer is mostly 60 to 90 cm depth from the soil surface.

Keywords:

Activated sludge, chemical fertilizer, ground water contamination, nitrate leaching, organic manure, soil type

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

RESAPAN NITRAT KE DALAM TANAH YANG TELAH DIRWAT DENGAN BAHAN KUMLOAHAN AKTIF, BAJA BERASAKAN KIMIA DAN NAJIS HAIWAN

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Baja Nitrogen sememangnya telah dikenalpasti sebagai satu faktor yang penting dalam tahap pengeluaran hasil tanaman, walaubagaimanapun lebihan kadar penggunaan baja Nitrogen ke atas tanah boleh mendatangkan impak negatif terutamanya untuk alam sekitar dan pencemaran air bawah tanah. Adalah penting untuk mengenalpasti dan mengetahui faktor-faktor yang mempengaruhi kadar resapan nitrat melalui lapisan tanah dalam perkara pengurusan baja untuk mengurangkan impak negatif terhadap alam sekitar dan juga pengaliran nitrat di bawah pada zon akar tanaman. Dalam kajian ini, 15 buah silinder lysimeter berukuran 1 m tinggi dan 0.56 m garispusat telah dipenuhkan dengan tanah liat dan tanah gembur berpasir dan seterusnya ditanam dengan maize untuk dilakukan ujikaji kadar resapan nitrat untuk baja Nitrogen yang berbeza; sisa aktif (20 ton/ha), baja organik (40 ton/ha) dan baja kimia (mengandungi 70 kg N/ha). 3 buah lagi silinder lysimeter berukuran 1.4 m tinggi telah digunakan untuk mengkaji kesan kedalaman

tanah dalam kadar resapan nitrat untuk tanah gembur berpasir. Keseluruhannya 9 jenis rawatan yang berbeza telah dilakukan. Kepekatan nitrat di dalam tanah dan sampel air saliran telah diuji dengan kaedah spectrophotometer dan berat nitrat dikira dalam tanah, air pengairan dan saliran. Hasil tanaman untuk semua jenis rawatan yang berbeza juga telah dibuat perbandingan. Kepekatan N-nitrat adalah lebih tinggi berbanding 10 mg N/L (kepekatan maksimum yang boleh diterima) dalam 60% pemerhatian untuk OFcl. Kepekatan N-Nitrat adalah lebih tinggi daripada 10 mg N/L dalam 48 dan 51% sampel rawatan CFcl dan OFcl masing-masing. Kebiasaannya, kepekatan N-Nitrat adalah lebih rendah berbanding 10 mg/L dalam lysimeters yang mengandungi tanah gembur berpasir. Keputusan ujian menunjukkan resapan nitrat dari sisa aktif dan baja organik dalam tanah liat menunjukkan jumlah yang jauh lebih tinggi berbanding dengan rawatan-rawatan yang lain (masing-masing 110 kg/ha dan 229 kg/ha). Di dalam kajian ini baja organik bagi tanah liat menunjukkan kadar pengumpulan nitrat dalam tanah yang tertinggi (15.17 mg/kg) dan baja kimia di dalam tanah gembur berpasir menunjukkan jumlah yang paling rendah (8.56 mg/kg). Hasil eksperimen juga menunjukkan penggunaan baja boleh menyebabkan peningkatan $N0_3$-N terkumpul terutamanya bagi lapisan tanah yang lebih dalam berbanding dengan baja mineral dan sisa aktif. Keputusan ujian menunjukkan bahawa nitrat dari sisa aktif dan baja kimia dibawa melalui profil tanah adalah lebih berbanding baja organik bagi kedalaman melebihi 75 cm, dan kebiasaannya pengumpulan baja organik adalah di antara kedalaman 60 hingga 90 cm dari permukaan tanah.

Kata Kunci

Sisa aktif, baja kimia, pencemaran air bawah, resapan nitrat, baja organik, jenis tanah

I dedicate this thesis to my beloved country, Iran

And

To my parents, Nosratollah Mostofi and Maliheh Maali…your essence is in

everything I accomplish…

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I certify that an Examination Committee has met on 22 January 2009 to conduct the final examination of Nooshin Mostofi on her Master of Science thesis entitled "Nitrate leaching in soils treated with activated sludge, cattle manure and chemical fertilizer" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the Master of Science.

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DECLARATION

I declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously and is not concurrently submitted for any other degree at UPM or at any other institutions.

……..

NOOSHIN MOSTOFI

Date: 12 September 2009

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List of Abbreviations

Abbreviations	Meaning
AScl	Activatel Sludge in Clay Loam soil
ASsl	Activated Sludge in Sandy Loam soil
EEC	European Economic Community
°C	Degrees Celsius
BD	Bulk Density
CFcl	Chemical Fertilizer in Clay Loam soil
CFsl	Chemical Fertilizer in Sandy Loam soil
Cmic	Microbil Biomass Carbon
D	Day
DMRT	Duncan Multiple Range Test
DNA	Deoxyribonucleic Acid
E	Energy
EC	Electrical Conductivity
EDTA	Ethylene Diamine Tetra Acetic Acid
EPA	Environmental Protection Agency
Ha	Hectare
Hr	Hour
L	Litre
L/capita.d	Litre per capita per day
Meq	Milli equivalents per liter
Mt/yr	Million ton per year
NPK	Nitrogen-Phosphorus-Potassium fertilizer
OFcl	Organic Fertilizer in Clay Loam soil
OFsl	Organic Fertilizer in Sandy Loam soil
P.V.C.	Poly Vinyl Chloride
RNA	Ribonucleic Acid
SAR	Sodium Adsorption Ratio
SAS	Statistical Analysis System
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
WHO	World Health Organization
Yr	Year

CHAPTER I

INTRODUCTION

1.1 General

The rising population of the world has directly placed significant pressure on various authorities and infrastructures, mainly in providing more food and water. In order to successfully feed the growing world's population, a continued increase in the production of food is therefore a necessity. Obviously, the areas under cultivation and renewable water resources are restricted all over the world. Hence, it is important to produce more crops per hectare so as to increase the amount of the food produced. One way of enhancing the production of crops is the usage of organic and inorganic fertilizers. However, some studies have shown that the continued use of fertilizers may result in a decline in the quality and productivity of soil. It is undeniably that fertilization is an important cause of groundwater contamination with nitrate in agricultural soils (Rimski-Korsakov *et al*., 2004; Zebarth *et al*., 1998 and Strebel *et al*., 1989). Saving the world's water resources from contamination with chemicals and reuse of agricultural water is very important. This is specifically vital in the arid and semi-arid countries, where water scarcity is serious and ground water has an important role in providing drinking and irrigation water. In low precipitation regions, even reuse of drainage water extracted from the drainage system is required.

1.2 Statement of the Problem

A sustainable agricultural management will depend on a more efficient use of renewable resources, such as animal manure and sludge from waste water treatment processes. Nitrogen fertilizers are widely used in agriculture to synchronize the levels of soil available nitrogen with crop's nitrogen requirements during the season, to increase crops nitrogen uptake and to enhance the yield. After the growing season, a part of these organic or inorganic fertilizers remains in the soil and is converted to various forms of nitrogen such as nitrate. This nitrate can leave the root zone in heavy precipitation, and also by excessive irrigation even when land is cropped annually. Over application of fertilizers will generally cause nitrate accumulation in the soil and nitrate leaching via soil pores and cracks. Various long-term experimental studies have indicated that the accumulation of nitrate in soil is a result of interaction among the soil productivity; soil moisture status and the efficient use of nitrogen fertilizer (Yang *et al*., 2006).

Plant takes up nitrogen mostly in inorganic form. This may partly explain why the N (nitrogen) uptake of plant from organic N sources is commonly found to be lower than that of inorganic N sources. The use of organic nitrogen sources presents challenges in N availability for crops. Organic farming still suggests organic fertilizers to take into account the environment and public health as the main concerns. The nitrogen which is not utilized during the cropping season may be mineralized outside the season and it becomes prone to leaching. The potential for N leaching is thus generally considered to be greater when manure is applied, as compared to inorganic fertilizer.

Statistical data show that the consumption of nitrogen fertilizer is growing rapidly in developing countries. High concentrations of NO_3^- in the surface water bodies can result in eutrophication, algal blooms, aquatic mortality, methemoglobinemia, gastric cancer, growth inhibition, thyroid hypertrophy, reproductive toxicity and ulceration of the mouth and stomach lining (Gupta et al., 1999b).

Nitrogen leaching in irrigated agriculture should receive considerable attention, because of possible pollution of groundwater. Nitrate pollution of groundwater is of particular concern because of the large number of people in city and rural areas relying on groundwater for drinking. Large amounts of N-fertilizer with poorly managed irrigated systems may lead to NO_3^- leaching and pollution of groundwater. In this study, the impact of nitrate leaching was investigated in order to minimize the pollution of the groundwater with best fertilization management practices.

Integration of knowledge, related to environmental conditions of a certain area with the soil, water and crop management practices, helps to prevent the simultaneity of the unfavourable processes leading to nitrate leaching. In this way, water resources may be protected from nitrate pollution of agricultural origin. Contamination of ground water depends on many factors, including the soil type, climate, geological and agricultural practices. The effective approach to minimize the movement of nitrate into groundwater is to develop a site-specific improved N fertilization and irrigation management practices to increase the N uptake efficiency, decrease N loss, and minimize leaching losses below the root zone.

Measuring and predicting nitrate concentration and mass loading from agricultural activities as non point source of pollution for groundwater seems to be useful for pollution control. In this study, quality of the drainage water and mass of nitrate leaching was monitored to provide information for different kinds of fertilization practices.

1.3 Objectives

The objectives of the study include:

1. To compare the movement of nitrate in two soil types (clay and sandy soil);
2. To compare the various types of fertilizer (cattle manure, chemical fertilizer and activated sludge) in the case of nitrate movement:
    I) to assess the accumulation and movement of nitrate in the soil profile;
    II) to determine the concentration of nitrate in drainage water;
    III) to survey on the mass of nitrate-N leaching;
3. To assess the effect of soil depth in nitrate leaching.

CHAPTER II

LITERATURE REVIEW

2.1 The Effects of N Fertilizer

High yielding crops require a substantial supply of N, and most crops prefer to take up N as nitrate. A good supply of nitrate in the soil is an asset, but too much of it is a liability (Sethi, 2005). Under applying N can result in decreased yields and profits, while over application can potentially increase the accumulation of nitrate-N (NO_3^--N) in soils and the potential losses to ground and surface waters (Tarkalson *et al*., 2006).

2.1.1 The Characteristics of Cattle Manure

Animal manure is a valuable resource, both as a nutrient and as a soil conditioner. In organic farming, where the use of mineral nitrogen fertilizer is prohibited, a high utilization of nutrients in manure is especially important. Part of the animal manure is handled as solid manure where urine and feces are mixed with bedding material often consisting of cereal straw (Thomsen, 2001).

The determination of crop available N from manures is based on the contents of NH_4^+, NO_3^- and organic N in the manure. Solid manures such as cattle manure

collected from feedlot surfaces have a large proportion of the N in the organic fraction (Tarkalson *et al*., 2006)

However, it is difficult to predict the availability of manure N to plants since both N turnover processes and losses of manure N influence its availability. The net mineralization of manure N is variable, and at the same time, there may be net immobilization of N during a period following the application of manure, mainly after the application of anaerobically stored manures (Sùrensen, 2001). Manured soils have higher contents of organic C and N, but lower pH and bulk densities as compared to soils receiving various mineralized fertilizers, especially the ones which are lacking P, indicating that a long-term application of manures could efficiently prevent the leaching of applied N from and increase N content in the ploughed layer (Meng *et al*., 2005).

In general, when organic manures are added to soil, an ideal condition for denitrification will develop. Labile forms of organic C are used as an energy source by a large population of heterotrophic microbes. When the biological O_2 demanded by microbes exceeds the supply, the anaerobic microenvironment necessary for denitrification is created. In addition, the application of organic manures stimulates the production of N_2O through nitrification, as this process is also increased when aeration becomes restricted (Meng *et al*., 2005). Some chemical characteristics of cattle manure (Antoun, 1982), are shown in (Table 2.1).