EFFECT OF NITROGEN - FERTILIZER APPLICATION ON THE MIGRATION OF NITRATES IN PADDY FIELD ECOSYSTEM,

A CASE STUDY FROM KOBEIGANE, NORTHWESTERN PROVINCE, SRI LANKA.

by

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DECLARATION

The work is describe in this thesis was carried out by me at the Faculty of Applied Sciences under the supervision of Dr. Chandrajith and Prof. Rupasinghe. A report on this has not been submitted to any other university for another degree.

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Affectionately dedicated

To my Parents and Teachers

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ABSTRACT

The nitrate anion is very soluble in water and is not influenced by soil colloids, and hence is subject to leaching. The seeping water dissolves soil nitrate and therefore any excess nitrate that are present in this ground water recharge zone are carried to the groundwater. Loss of nitrate is undesirable, because in drinking water it is considered to be a health hazard and it may cause eutrofication. After apply fertilizer the characteristics of nitrates vertical transport in a paddy soil, Daduru Oya basin in intermediate zone, were selected for this study. The main aim of this study is to evaluate spatial variations of nitrate in water, which is seeping to the groundwater.

Three artificially constructed wells were established in the paddy field. First sets of samples were collected from constructed wells, dug wells around the paddy fields and nearby tank before the cultivation. To analyses the variation of nitrate in constructed wells, water samples were collected after 3, 7 and 14 days after the fertilizer application. After 2 months of first sampling, second sets of samples were collected from dug wells and tank. The contents of nitrate, phosphate, electrical conductivity, pH, Temperature and rainfall were measured.

The result of this study provide evidence that nitrate losses from paddy soils was one of the potential factors relating ground and surface water pollution. Because after fertilizer- application, nitrate and phosphate contents of water collected from constructed wells, dug wells around the paddy field and nearby tank are increased considerably. The correlation coefficient between the nitrate content and the distance from rice field found to be negative and significant both before and after fertilizer application. This case study clearly illustrates the factors that affect for nitrate and phosphate mobility. Variation of nitrate and phosphate concentrations of water collected from constructed wells mainly depends on rainfall, soil characteristics and type and amount of fertilizer. When nitrate and phosphate concentrations variations were compared in three constructed wells, it was found that nitrate-leaching rate was greater than that of phosphate. This suggest that the different mobilities of nitrate and phosphate losses in different soils.

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CHAPTER 1
INTRODUCTION

1.1 General Introduction

The transport of agricultural chemicals such as fertilizer and pesticides through soils into groundwater has become a major concern among researches all over the world, due to their environmental impacts. Therefore the demand for understanding the movement and transport of these agricultural pollutants zone has increased considerably over the last decade. Agrochemicals and plant nutrients, particularly nitrogen account for most of our surface and subsurface water quality problems (Heatwole, 1995). Over 90% of the total nitrogen added to the environment by human activity, is from agricultural activity (Botkin and Keller, 1998).

Different types of fertilizers are used with the slope purpose of improving soil fertility so that it can support larger harvests (Jandon, 1992). Farmers first deplete the soil by "excessive and repeat planting" and then try to replenish the resulting less productive soil by putting more and more nitrogen based fertilizer on the land in an attempt to keep crop yields constant. Excessive use of nitrogenous fertilizers will cause to contaminate ground and surface waters. Nitrate is a problem as contaminate drinking water (primarily from groundwater and wells) due to its harmful biological effects. High concentrations can cause methemoglobinemia, and have been cited as a risk factor in developing gastric an intestinal cancer.

The concentration of nitrate in drainage water depends on the volume of through drainage and the amount of nitrate that is available to be leached. Loss of nitrate from farm lands is undesirable due to a) an economic loss to farmers, b) health hazard when present in drinking water and b) cause eutrophication (Alan, 1993). Therefore study the nutrient dynamics of irrigated paddy fields systems is very important and which will enable to understand the movements of nutrients under different physcio-chemical conditions.

In Sri Lanka nitrogenous fertilizers such as urea are used heavily for agricultural fields. Paddy cultivation is the major agricultural practice in Sri Lanka and fertilizer is heavily used in the paddy rice fields (Dissanayake et al., 1984). In intensive rice systems, the indigenous nitrogen supply is never sufficient and mineral nitrogen fertilizer inputs represent the largest part of the nitrogen cycle. More than 20% of nitrogen fertilizer produced worldwide is used in the rice fields of Asia, but nitrogen recovery efficiency in most paddy fields is only about 25-40% of applied nitrogen (Dobermann & Fairhurst, 2000). The balance is lost due to process such as leaching; denitrification, ammonia volatilization and losses from runoff water. Nitrogen losses from denitrification range from 25 to 90% while that is from ammonia volatilization range from 0-60% of applied nitrogen. Leaching losses as nitrate and ammonium vary from 0-60% of applied nitrogen (Rice Symposium 80, 1980). Therefore the main source of nitrate pollution in the groundwater results from the actions of agricultural practices.

Under normal conditions, about 75% of the nitrates percolate through soil covers and reach the groundwater table. Therefore farming is a major cause of ground water pollution by nitrates and it would be much considerable during the period of cultivation, which is the time that farmers apply nitrogen rich fertilizers to their fields (Dissanayake & Weerasooriya, 1985). As well as, a close relationship has been proved among the nitrate contents of groundwater and the quantity, manner, sort and frequency of applied fertilizers. Owing to the application of constantly increasing quantities of fertilizers in arable land, groundwater non-point pollution has become a worldwide problem (Duijvenbooden et al., 1981). Nitrate does not just pollute surface water but are so soluble and that they leach down through the soil in to the groundwater and contaminate sources of potable water such as springs and wells.

The nitrate ion, being negatively charged, is not adsorbed by most soils. It remains in the soil solution until it is taken up by plant roots, leached out of the soil in drainage water or denitrified. The magnitude and frequency of leaching events must be characterized in order that a full assessment of their potential impact can be made. Since leaching process is dynamic in time and space, it is necessary to understand the nature and properties of soils. and their associated hydrological characteristics. Sorption and degradation kinetics determine the availability of elements for leaching, but soil properties such as organic matter content, texture and structure determine the pathways that water solutes and suspended follow. Cultivation practices such as tillage and drainage treatments. which chance the soil's intrinsic properties. can also influence leaching mechanisms (Royal society of chemistry. 1998). As well as irrigation practices increase chance of nitrate leaching.

Some of the factors that influence the magnitude of nitrate leaching can be summarized as follows;

a) Rate, time, source, and method of nitrogen fertilization.

b) Use of nitrification inhibitors

c) Intensity of cropping and crop uptake of nitrogen

d) Soil characteristics that affect percolation

e) Quantity, pattern and time of precipitation and/or supplemental irrigation.

1.2 Aims of the study

When water moves on the surface of a soil, it dissolves some nitrates that are present in the surface layers of soils. Another part of the precipitation seeps in to the soils and recharges the groundwater. The seeping water dissolves soil nitrates and therefore any excess nitrates that are present in this groundwater-recharged zone are carried to the groundwater. Loss of nitrate is undesirable because in drinking water it is considered to be a health hazard and it may cause eutrophication.

1.3 Objectives of the study

The main objective of this study is to understand the vertical transport of nitrate in paddy fields due to application of nitrogenous fertilizer. The effect of soil type, rainfall and irrigation practices are considered during the study. Other aim of this study is estimate and monitor the effect of fertilizer application on the potable waters in and around the paddy fields.

1.4 Study Area

A paddy field system, irrigated by Daduru Oya which flowing through the northwestern province of Kurunegala district is selected for this study. Daduru Oya is one of the major river system out of the 103 major rivers of Sri Lanka. Daduru Oya irrigates 2616 sq. kilometers and figure 1:1 illustrated the location of the study area. The study area belongs to the intermediate climate zone of Sri Lanka where the mean annual rainfall varies 1525 to 2285 mm and means annual temperature is around 27 °C.

1.4.1 Rice Cultivation

Of the estimated total extend of 0.65 m hectares has of rice lands in Sri Lanka. out of which about 20% is situated in the intermediate zone. In Sri Lanka the rice cultivation is primarily governed by the rainfall seasonality resulting in two distinct cropping seasons namely the Maha season (Northeast monsoon-October to February) and Yala season (Southwest monsoon-May to September). The Maha season is selected for this study.

1.4.2 Water Resources

The area is drained mainly Daduru Oya and its small tributaries. Most of people in this area use open dug wells for their domestic purposes and small number of people use tube wells. Most dug wells of this area are located closed to the paddy fields due to scarcity of water in other areas. Most of the drinking water wells are unprotected and polluted water can leach through the loose soil cover and mixed up with groundwater. Furthermore farmers use agro chemicals heavily as pesticides and fertilizers for their paddy and that can contribute to the water pollution.

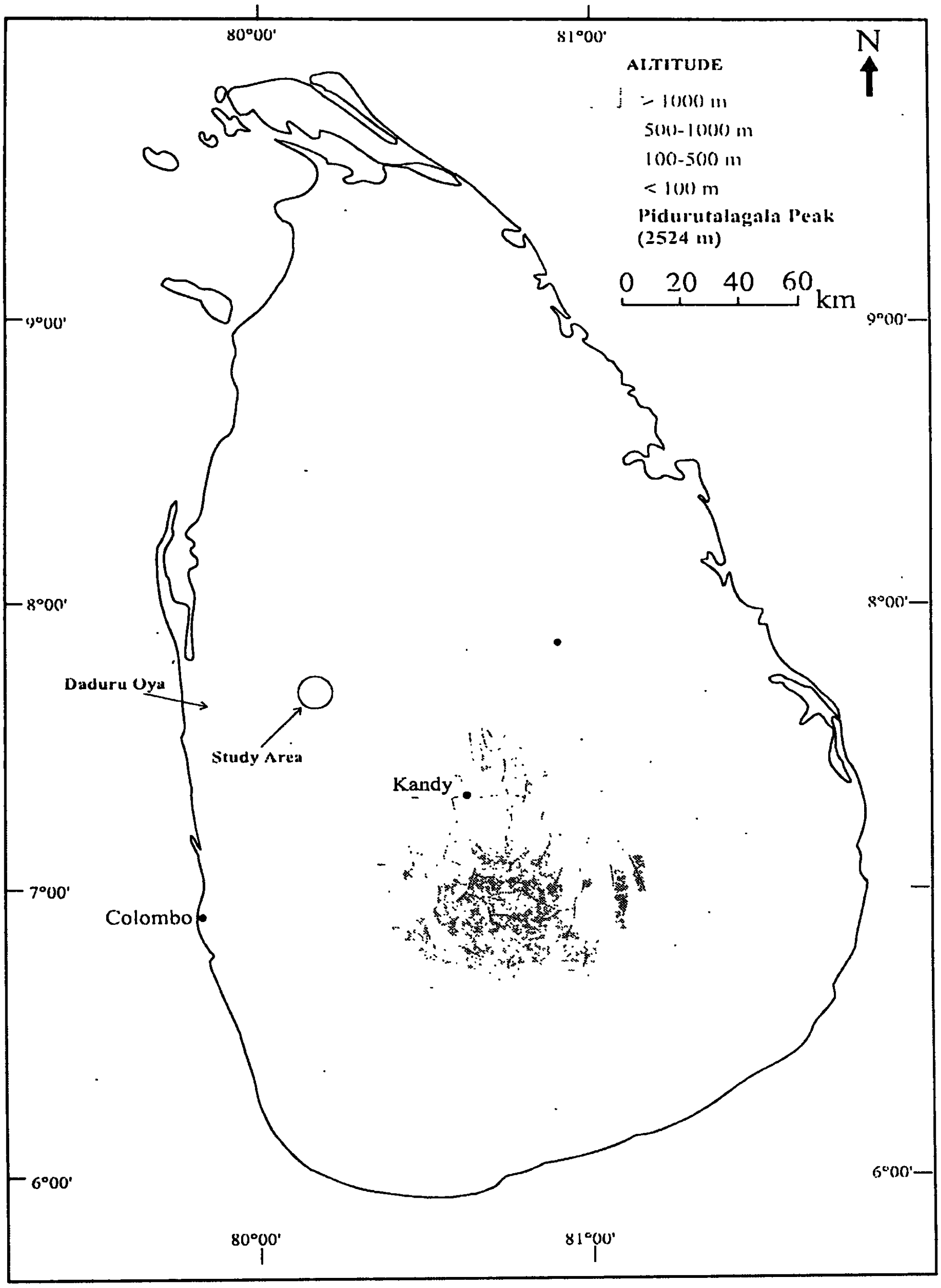

Figure 1.1: Major river basins of Sri Lanka, Daduru Oya basin and the location of the study area (Energy and science Authority of Sri Lanka, 1991).

CHAPTER 2
NITRATES IN THE ENVIRONMENT

2.1 Nitrogen Cycle

Nitrogen is one of the most important and most complex global cycles. It occurs in many different forms in the natural environment such as gaseous nitrogen, nitrate, and ammonia. Nitrogen is the most abundant element in the atmosphere, composing nearly 80% of the air we breathe (Berner and Berner, 1987). Gaseous nitrogen can be found in many forms, the major ones consisting of N_2, N_2O, NO, NO_2, NH_3. Some of these gases readily react with rainwater to produce nitrate and ammonium ions in solution. These ions can become part of the soil layer composition, or even enter into a groundwater solution.

Nitrate is a common nitrogenous compound in the environment and plays an important role in the nitrogen cycle, because of its high anthropogenic inputs. The largest anthropogenic source of nitrate is the application of nitrogen-rich fertilizer for agricultural fields. Figure 2.1 shows the movement and reaction of nitrogen in soils and ground water. Briefly inorganic nitrogen in the atmosphere is transformed by lightning or bacterial uptake to nitrate or ammonia. By for the greater amount (approximately 90%) is converted by biological activity. The process of converting inorganic, molecular nitrogen in the atmosphere to ammonia is called nitrogen fixation (Botkin and Keller, 1998).

Nitrification may be broadly defined as the biological conversion of organic and inorganic compounds from a reduced state to a more oxidized state (Wetzel and likens, 1979). Ammonium (NH_4^+) fertilizers, when used in well-drained soils may be converted in to nitrates. The conversion of ammonium occurs in two steps and is conducted by two types of bacteria: *Nitrosomonas* sp., responsible for the conversion of ammonium (NH_4^+) in to nitrite (NO_2^-), and *nitrobacter* sp., responsible for the conversion of nitrite in to nitrate.

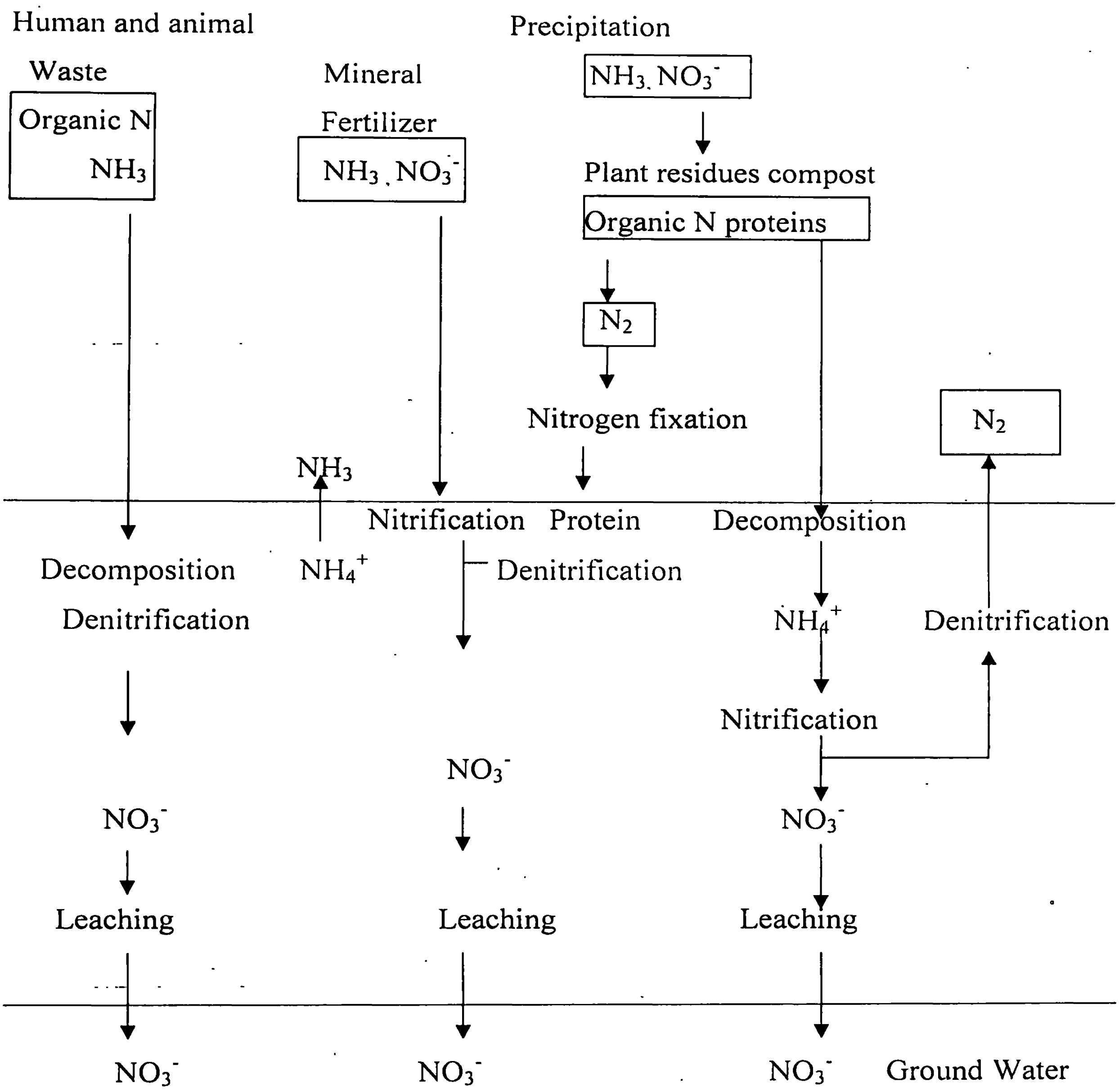

Figure 2:1 Movement and reaction of nitrogen in soils and ground water (Dissanayake and Weerasooriya,1987).

This biochemical reaction is called nitrification. Ammonification is the process where by nitrogenous compounds in plant and animal tissues are decomposed to produce ammonia (Fitzpatrick, 1974). When organisms die, other bacteria are able to convert the organic compounds containing nitrogen back to nitrate, ammonia, or by a series of chemical reactions, to molecular nitrogen, when it is the returned to the atmosphere.

The process of releasing fixed nitrogen back to molecular nitrogen is called denitrification (Botkin and Keller, 1998).

2.2 Importance of nitrate for plants

Plants are known to need 16 essential elements to grow, although more than 90 elements can be absorbed by plants. The most essential elements are carbon, oxygen, hydrogen, nitrogen, calcium, potassium, magnesium, phosphorus, sulfur, chlorine, iron, boron, manganese, zinc, cupper, and molybdenum (Miller and Donahve, 1997). The principal soil storehouse for large amounts of the nutrient anions is soil organic matter. Decomposition of organic matter releases nutrients anions. Organic matter holds more than 95% of the soil nitrogen, often half or more of the total soil phosphorus, and as much as, 80% of the soil sulfur.

Nitrogen is one of the major elements out of other all elements. Nitrogen is an essential constituent of amino acids, nucleic acids, nucleotides, and chlorophyll. It promotes rapid growth (increased plant height and number of tillers) and increased leaf size, spikelet number per panicle, percentage filled spikelets in each panicle, and grain protein content. Thus nitrogen affects all parameters contributing to yield. Leaf nitrogen concentration is closely related to the rate of leaf photosynthesis and crop biomass production. When sufficient nitrogen is applied to the crop, the demand for other macronutrients such as phosphorus and potassium is increased (Dobermann and Fairhurst, 2000).

Nitrate-nitrogen and ammonium-nitrogen are the major sources available for uptake. Most absorbed ammonium-nitrogen is incorporated in to organic compounds in the roots, where as nitrate-nitrogen is more mobile in the xylem and is also stored in the vacuoles of different plant parts. Nitrate-nitrogen may also contribute to maintaining cation-anion balance and osmo-regulation to fulfill essential functions as a plant nutrient. Nitrate-nitrogen must be reduced to ammonia through the action of nitrate and nitrite reeducates. Nitrogen is required through the growth period, but the greatest requirement is between the early to midtillering and panicle initiation stages. Sufficient nitrogen supply during ripening is necessary to maintain photosynthesis during grain filling, and increased the protein content in the grain. Nitrogen is mobile within the plant and, because nitrogen is translocated from old senescent leaves too younger (Dobermann and Fairhurst, 2000).

Nitrogen deficiency is the most commonly detected nutrient deficiency symptom in rice. Old leaves and some times all leaves become light green and chlorotic at the tip. Leaves die under severe nitrogen stress. Therefore to prevent this position nitrogenous fertilizers are added.

2.3 Nitrogenous fertilizers in the environment

2.3.1 Soil fertilization

The essential nutrients are present in all soils but one or more of these are invariably present in inadequate amounts of plant usable form, which makes external addition necessary. Since each element has certain specific functions to perform, one cannot substitute for another. If a soil is deficient in event one nutrient, it cannot support a good crop unless deficiency of this element is made up. This is essential where fertilizers and other source of nutrient step in to farming.

Mineral fertilizer application is the most widely used nutrient management practice. The recommended nutrient doses for different situations are applied using chemical fertilizers. Generally, all phosphorus and potassium fertilizers are placed in the soil. Nitrogen is applied as basal and topdressing (Singh and Singh, 2000).

2.3.2 Fertilizers

Fertilizers are mined or manufactured as commercial products that contain one or more essential plant nutrients. For a material to qualify as a fertilizer, it should contain nutrients in appreciable amount in readily or potentially usable form. Fertilizers are used with the slope purpose of improving soil fertility. So that it can support larger harvests. Fertilizers represent the most common currency used by farmers to deposits plant nutrients in to their soils to ensure that adequate nutrients are available to feed the crops (Jandon, 1992). Obviously the more nitrogen fertilizer a farmer uses the greater the chance of nitrate pollution of groundwater. "Farmers still consider nitrogen fertilizer 'cheap insurance' against crop failure". So the farmer would, financially speaking, much rather add too much nitrogen than too little. To add to this problem, it is very difficult to determine exactly how much nitrogen a crop will need before harvest time due to yearly change in yields and weather conditions.

Plant roots do not absorb fertilizers granules as they come in a manure heap. Plants absorb nutrients in specific ionic forms, which either a fertilizer furnishes when it dissolves in soil water, or various chemical and biological agents in the soil convert fertilizer currency in to local currency acceptable roots. Since fertilizer use is determined primarily by soil fertility status and nutrient requirement of crops, a brief discussion of these two aspects is considered necessary (Jandon, 1992).

2.3.3 Nitrogen fertilizers

There are many kind of fertilizer namely nitrogen fertilizer, phosphate fertilizers, and potassium fertilizers. One potentially large source of nitrogen pollution of groundwater is the application of nitrogen-rich fertilizers. Nitrogen is the central to the growth and development of all plants and required in large amounts. It is a paradox that nitrate, the form of nitrogen most commonly taken up by plants from soil solutions, is often present in these solutions at vanishingly low concentrations, frequency becoming limiting to plant growth (Dobermann and Fairhurst, 2000). The large demand for nitrogen by high production agriculture has thus resulted in a very rapid increase in the application rate of fertilizer nitrogen. This practice increases the level of nitrogen in soil solutions to meet the demands that these crops place on the soil resources. Table 2.1 summarizes the major nitrogen fertilizers, which are used for the agricultural purposes.

Table 2:1 Nitrogen fertilizer sources for rice (Dobermann and Fairhurst , 2000)

Name	Formula	Content	Comments
Ammonium nitrate	NH_4NO_3	33-46% N	Acidifying, apply to up land rice only
Ammonium chloride	NH_4Cl	28% N	Acidifying
Ammonium sulfate	$(NH_4)_2SO_4$	21%N, 24% S	Acidifying
Ammonium bicarbonate	NH_4HCO_3	17% N	Non- acidifying
Urea	$CO(NH_2)_2$	46%N	Acidifying
Monoammonium phosphate (MAP)	$(NH_4)_2HPO_4$	11%N, 22% P	Soluble, quick-acting, acidifying
Diammonium phosphate (DAP)	$(NH_4)_2HPO_4$	18-21%N, 20%P	Soluble, quick-acting, acidifying
Urea phosphate	$CO(NH_2)_2, H_3PO_4$	18%N, 20 %P	Soluble, quick-acting

2.3.4 Urea- $CO(NH_2)_2$

In Sri Lanka, urea is the main nitrogenous fertilizer, which used in greatest amounts. Urea contains 46% nitrogen and it is attracted the attention of many researchers. In soil, it rapidly hydrolyses and the enzymes, which are released in to soil by many microorganisms, catalyze the reaction. Since urea is a cheap fertilizer than others, it use heavily in paddy fields.

The first synthesis of urea was achieved in 1824 by the German chemist F. Veler. He showed that on evaporation of a solution of ammonium cyanate those later changes in to urea. According to the present concept, the isomerization of ammonium cyanate takes place (Koren, 1976).

$$(N= C- O) \quad NH_4 \rightarrow \quad (O= C =N)$$
$$NH_4 \rightarrow O=C\ (NH_2)_2$$

In addition to the marked improvements in size, strength, and density of granular urea, this fertilizer material has a number of other noteworthy characteristics. These include a) less tendency to stick and cake than ammonium nitrate, b) lack of sensitivity to fire and explosion, and c) less corrosiveness to handling and application equipment (Tisdale et al., 1993).

Doubts about the agronomic suitability of urea impeded its adoption. Many agriculturists had reservations about using because of potential problems related to a) harmful effects of biuret, an impurity normally found at low concentrations on germination and early growth of seedlings, b) phytotoxicity of urea to seed and seedlings due to the high concentration of ammonia released during hydrolysis and/or the accumulation of nitrate during nitrification; and c) ammonia loss from urea exposed on soil surface (Tisdale et al., 1993)

2.4 Problems with excessive use of nitrogen fertilizers

In intensive rice systems, the indigenous nitrogen supply is never sufficient and mineral nitrogen fertilizer inputs represent the largest part of the nitrogen cycle. In most Asian countries, irrigated rice farmers apply 100-150 $KgNha^{-1}$ to dry season rice crops and 60-90 $KgNha^{-1}$to wet season crops (Dogermann and Fairhurst, 2000). Rice plants can absorb fertilizer nitrogen from the floodwater or the soil near the floodwater at very high rates if the application coincides with high plant demand. Rates approaching $10Kgha^{-1}d^{-1}$ have been measured for urea broadcast in to the floodwater at the panicle initiation stage about 40 day after transplanting. But as the root system and canopy develop prior to this high demand, fertilizer nitrogen is subject to the greatest looses through ammonia volatilization and leaching. Excessive uptake also leased to increased risk of disease and lodging (Kirk and Olk, 2000). Therefore early nitrogen applications must be managed with great care, taking in to account the intrinsic soil nitrogen supply and rates of loss.

Excessive or improper fertilizer use may leads to serious environmental hazards. Problems of nitrate toxicity in drinking water, eutrophication of lakes and build up heavy metals, such as cadmium, have already been observed in certain localities.

Nitrogenous and phosphatic fertilizers can cause environmental problems in particular. According to the Ahmed (1995) the amount of nitrogen fertilizer taken up by plants may be 40-60% of that is applied, this is called uptake efficiency. The balance is lost through denitrification/volatilization and leaching.

2.4.1 Leaching

If there is excess rain, so that water drains through the soil profile soluble substances are removed (Alan, 1993). This process called leaching. Mainly nitrates are leached out of the soil in drainage water. Chemical fertilizers do not supply humus, so the nutrient and water holding capacity of the soil may be less than with organic fertilizers. This lower capacity of the soil may be less than with organic fertilizers. This lower capacity leads to faster leaching of nutrients from the soil. The nutrient loss is aggravated by the higher solubility of chemical fertilizers (Robert, 1978).

The nitrate anion is very soluble in water and is not influenced by soil colloids. Because nitrate ions, being negatively charged, are not adsorbed by the also negatively charged clay colloids, and hence subject to leaching (Tan, 1994). Consequently, it is highly mobile and subject to major leaching losses when both soil nitrate content and water movement are high. Nitrate leaching is generally a major nitrogen loss mechanism from field soils (Tisdale et al., 1993).

The transport of surface-applied agricultural chemicals through soils and in to groundwater has become a major concern among environmentalist and public in general. A review of available information includes that agriculture is the major contributor of non point source pollution in our water supply. Fertilizer in surface water may also contribute to fertilizer residues in ground water through recharge/discharge mechanisms between surface water and ground water. Chemicals and nutrients (particularly nitrogen) account for most of our surface and sub surface water quality problems.

Due to large volume of water infiltration and deep leaching, ground water contamination through macrospores in soils is a major concern among environmentalists. Flow through macrospores can allow surface applied chemicals to move rapidly through the root zone, posing problems of economic loss and environmental damages. This 'preferential flow' or fast flow of some fraction of chemicals may be important, if a significant amount of chemical reaches groundwater before it can be attenuated by the soil. It has been observed that when event of rain occurs immediately after fertilizer application, and is flushed rapidly through the macro pores passing the root zone in a relatively short time. On the other hand, a high intensity rain event may move through the soil and bypass the solute as the result of previous lighter rainfall events (Heatwole, 1995).

Nitrate is readily leached from most soils, whether produced by nitrification of ammonium or added in fertilizers. It takes about 1-4 weeks for nitrification to be completed under good growing conditions, so that if a heavy rainfall soon after application of the fertilizer ammonium nitrogen, which is adsorbed by soils as an exchangeable cation, is conserved where as nitrate nitrogen might be lost by leaching (Alan, 1993).

2.4.2 Volatalization/Denitrification

Nitrogen loss to the atmosphere through denitrification (change the nitrogen compounds in to nitrous oxide) may contribute to 'greenhouse gases' in the atmosphere, there by exacerbating the problem of the breaking down of the ozone layer. Nitrogen losses can be particularly high from highly cultivated and fertilized lands-supplied with either organic or inorganic fertilizer sources.

Surface application of urea is most efficient when they are washed in to the soil or applied to soils with low potential for volatilization. Conditions for best performance of surface applied urea are cold or dry soils at the time of application and/or the occurrence of significant precipitation, probably more than 0.25 cm, with the first 3 to 6 days following fertilization. Movements of soil moisture containing dissolve ammonia and diffusion of moisture vapor to the soil surface during the drying process probably contributes to ammonia volatilization at or near the soil surface (Tisdale et. al., 1993).

2.5 Behavior of urea in paddy soils

Kirk and Olk (2000) showed, from the rate of movement through the soil of fertilizer nitrogen broadcast in to the floodwater, that the rapid uptake of broadcast nitrogen is largely due to superficial roots in the floodwater and aerobic floodwater soil interface. Urea broadcast in to the floodwater moves downward by mass flow and diffusion and is simultaneously hydrolyzed to ammonium by a reaction catalyzed by the enzyme urease. Because urease activity is much lower in the floodwater than in the soil, the ammonium is largely formed in the soil as the urea moves downward.

Ammonium and other reactants will also move between the floodwater and soil both upward and downward with ammonia being lost from the floodwater by volatilization. Thus, following urea broadcasting, a pulse of ammonium moves down through the soil at a rate depending on urease activity and soil transport properties. Over the range of conditions found in rice fields, the rate of downward movement is only 1 or 2 cm in a week (Kirk and Olk, 2000).

Some urea may be absorbed directly by roots in the floodwater, but the ammonium must be absorbed largely from the soil where it is formed, because urease activity in the flood water is low and may ammonium reaching the floodwater is rapidly volatilized.

2.5.1 Hydrolysis of urea in the soil

When applied to soil, urea is hydrolyzed by the enzyme urease to ammonium. Depending on soil pH, the ammonium may form ammonia, which can be volatilized at the soil surface, as represented in the following equations.

$$CO(NH_2)_2 + H^+ + 2H_2O \xrightarrow{\text{urease}} 2NH_4^+ + HCO_3^-$$

$$NH_4^+ \longrightarrow NH3 + H^+$$

Urease, which catalyzes the hydrolysis of urea, is abundant in soils. Large numbers of bacteria, fungi, and actinomycetes in soils process urease. A small group of bacteria, known as *urea bacteria,* have exceptional ability to decompose urea. Activity of urease increases with the size of the soil microbial population and with organic matter content. The presence of fresh plant residues often results in abundant supplies of urease (Tisdale et al., 1993).

Urease activity is highest in the rhizophere, where microbial activity is high and where it can accumulate from plant roots. Activity of rhizosphere urease varies, depending on the plant species and the season the year. Although temperatures up to 37C° favor urease activity, hydrolysis of urea occurs at temperatures down to 2C° and lower (Tisdale et al., 1993).

Study the hydrolysis of urea in the soil that with an increase in the rate of application of ureace the decomposition of urea is faster; within 10 min 2 cm^3 of urease hydrolyzed 27.2% of urea, and 10 cm^3, 99.9% within 22hr. The activity of urease and the rate of decomposition of urea intensified with a rice in the temperature (Koren, 1976).

The rate of decomposition of urea in various types of soil is not uniform and depends on the properties of soil. Usually clays soils have greater urealytic capacity than sandy soils fertile soil with a high humus content retain more ureace than poor soils; the ammonification of urea is faster in the case of neutral reaction of the soil than in acidic or alkaline conditions (Koren, 1976).

The affects of soil moisture on urease activity are generally small in comparison to the influence of temperature and pH. Hydrolysis rates are probably highest at soil moisture contents optimum for plants. Soil moisture contents between 24 and 100% have little effect on the hydrolysis rate of urea (Tisdale et al., 1993).

Free ammonia inhibits the enzymatic action of urease. Since significant concentrations of free ammonia can occur at pH values above 7, some temporary inhibition of unease by free ammonia occurs after the addition of urea because so pH in the immediate vicinity of the urea source may reach value of up to 9. High rates of urea fertilization and its confinement to bands and other methods of localized placement could thus create conditions restrictive to the enzymatic action of urease (Tisdale et al., 1993).

Due to hydrolysis of urea in the soil formed ammonium. Then with the help of microorganisms, ammonium is nitrified to nitrate in the thin oxidize surface layer and the rice-rhizophere. Nitrate is highly mobile, however, and may leach or diffuse in to the reduced soil layer, where it is quickly lost due to denitrification and leaching.

2.6 Factors influence the magnitude of nitrate leaching

2.6.1 Rainfall

A feature worthy of note is the influence of the climate on the levels of nitrates in the groundwater of Sri Lanka. The most of the wet zone of Sri Lanka has a greater nitrate levels than the Dry zone. The rainfall influences the distribution of nitrates in the groundwater by raising and lowering the groundwater table. In the wet zone of Sri Lanka, the water table as expected is shallow, and hence easy migration of the nitrates from the topsoil in to the relatively shallow water table results in a high nitrate content. In the dry zone of Sri Lanka however, the water table is deep and inspite of a high fertilizer input in to the soil, the groundwater contains very low nitrates mainly due to the problems associated with the migration of the nitrogenous species deep in the water table (Dissanayake and Weerasooriya, 1985). Therefore in the agricultural sector of the dry zone however, there is a slight negative correlation indicative of other factors influencing the migration of the nitrates in to the water (Dissanayake et al., 1984).

2.6.2 Temperatures

The magnitude of nitrate leaching is mainly depending on nitrification and denitrification process. Both nitrification and denitrification process are biologically mediated reactions, and the amount of each is determine by water temperature. An increase in temperature would increase the rates of both nitrification and denitrification, but denitrification rates are most affected so, other things being equal, higher water temperatures would lead to a reduction in nitrate concentration (Arnell, 1996).

2.6.3 Soil characteristics that affect percolation

The type of soil, sand silt or clay, its texture, structure, permeability and under drainge is the important characteristics under this category. Loose, permeable, sandy soils will have a larger infiltration capacity than a tight, clayey soil. A soil with good under drainage, there is the facility to transmit the unfiltered water downward to a groundwater; storage would obviously have a higher infiltration capacity. When the soil occurs in layers, the transmission capacity of the layers determines the overall infiltration rate. Also, a dry soil can absorb more water than one whose pores are already full. As well as the land use has a significant influence (Subramanya, 1984).

Texture is an important soil characteristic because it greatly modifies water intake rates (infiltration), water storage in the soil and soil fertility. For instance, a coarse sandy soil is easily wetted, but it also dried rapidly and easily loose plant nutrients, which are drained away in the rapidly lost water. High clay soils (over 30% clay) have very small particles that fit tightly together, leaving little open pore spaces, which means there is little room for water to flow into the soil (Miller and Donahve, 1997).

Soil structure influences many important properties of the soil, such as the rate of infiltration of water. Both granular (spheroidal) and single grain (structure less) soils have rapid infiltration rates; blocky and prismatic soils have moderate rates; and platy and massive soil conditions have slow infiltration rates (Miller and Donahve, 1997).

As well as the infiltration ability is mainly depend on the soil porosity and permeability. Pore spaces (called voids) in a soil consist of that portion of the soil volume not occupied by solids either mineral or organic. The volume of water-contained underground depends on the formation, which is termed the porosity of the underground formation (Bitwas, 1998). Irregular in size, shape, and direction sands have large and continuous pores. But clays, although containing more total pore space because of the minute size of each clay particles, have very small pores, which transmit water slowly. The most rapid water and air movement is in sands and strongly aggregated soils, whose aggregates act like sand grains and pack to form many large pores.

2.6.4 Irrigation practices, fertilizers, and crops

The more irrigation takes place the greater chance for nitrate leaching. Burkart and Kolpin (1993) show that a frequency of excess nitrate was also larger where irrigation was used within 3.2 Km of a well (41%) than where no irrigation was used (24%). Slow release fertilizers are a nitrogen source that can reduce the chance for leaching. Therefore fertilizer application rate, time, source and method influenced the magnitude of nitrate leaching. Nitrogen use efficiency depends on the crop variety, planting density and weeds. Therefore amount of nitrate leaching depend on crops.

2.7 Nitrate of Groundwater

Groundwater is an extremely valuable resources and pollution of groundwater resource is a matter of serious concern. Among the major threats to groundwater from which drinking water supplies are obtained are leachates from human and animal waste matter, along with other chemical pollutants. Industrial and agricultural leachate often contributes significantly to groundwater pollution. Among the chemical species that pollute groundwater supplies are nitrates (Dissanayake, 1988).

In general, the average nitrate levels in the groundwater of Sri Lanka are below the danger level of 40 mg/l specified by the World Health Organization. In Jaffna, however, these levels are exceeded. The nitrate concentrations appear to show a marked increase in areas of high population density, extensive fertilizer usage and in areas of the wet zone where atmospheric electric discharge and frequent (Dissanayake and Weerasooriya, 1987).

2.8 Health effects of nitrates

Nitrates do not just pollute streams. They are so soluble that they leach down through the soil in to the groundwater that feeds, springs and wells. Therefore, nitrate is a problem as a contaminant in drinking water (Primarily from groundwater and wells) due to its harmful biological effects. Nitrate in itself is relatively non-toxic; it can reduce bacterially to nitrite in the intestines of newborn infants and may result in the diseases methaemoglobinemia. Infant mortality from methaemoglobinemia is rare where nitrate nitrogen concentration in drinking water are less than 10 mg/l, but its incidence increase with increasing concentrations. Nitrate can also react with other substances, such as amines, in the stomach or lungs to form N-nitrosoamines, which have been found to induce tumours in laboratory animals. Although human tumours are not directly linked to these compounds, exposure to the compounds may pose a risk of human cancer. As well as a study of the incident of various types of human cancer in relation to nitrate concentrations in Sri Lanka revealed a significant positive correlation for stomach, small intestine, oesophagus and liver cancers, as well as total malignant cancer incidence and begin tumours (Dissanayake and Weerasooriya, 1987). Cases of blue baby syndrome usually occur in rural areas, which rely on wells as their primary source of drinking water. Often these wells become contaminated when they are dug or bored and are located close to cultivated fields, feed lots or septic tanks (Comly, 1987).

2.9 Eutrophication

There is also concern about nitrate discharge in to lakes from rivers as a possible contribute to eutrophication. Enrichment with nitrogen and phosphorus increased the growth of waterweeds and microorganisms to create difficulties for water supply and drainage authorities and damage the amenity value of lakes and rivers (Cooke, 1981).

CHAPTER 3

MATERIALS AND METHODS

3.1 Construction of artificial wells

One and half meter long PVC tubes with 12 cm of diameter were used for the collection of percolating water from the paddy soil layers. Small holes were prepared at the lower part of each tubes (Figure 3.1). These small holes help to seep water into the tube. The PVC pipes were then buried vertically in the paddy field (Figure 3.2). 125 cm long part of the PVC pipe was buried in the earth and the remaining was kept on the surface. The tops of the pipes were closed using plastic lids for prevent accumulation of rainwater and surface water of the paddy fields (Figure 3.3). Three artificially constructed wells were established in different paddy fields for the collection of seeping water. Three constructed wells were labeled as A, B, and C for easy identification. Constructed well A was located some 1100m away from the well B and 300m away from well C.

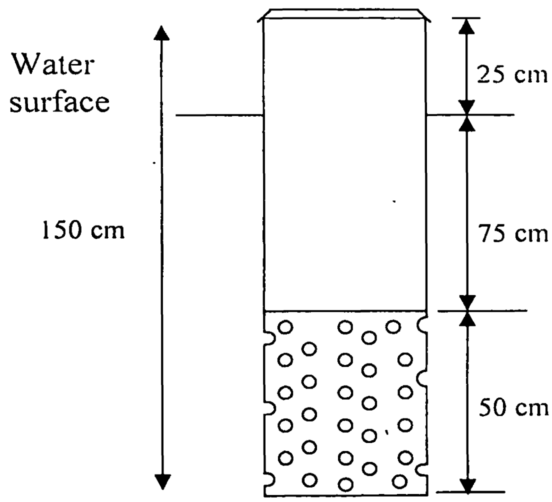

Figure 3.1: Schematic diagram of the constructed well which later buried on the paddy fields.

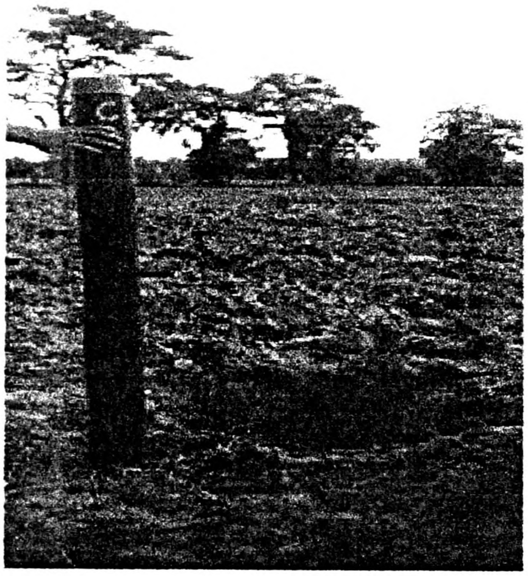

Figure 3.2: The constructed well which buried on the paddy fields.

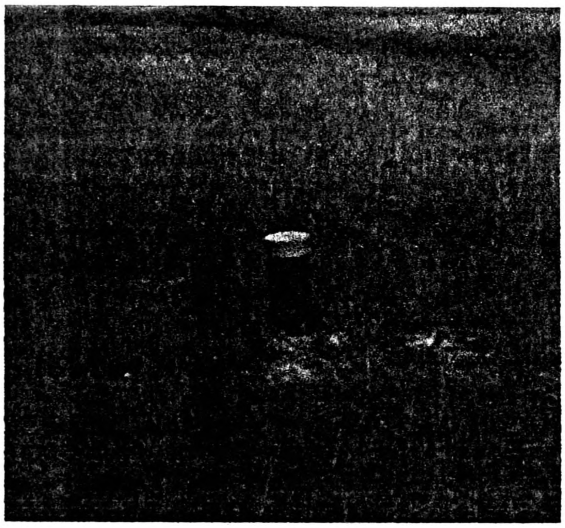

Figure 3.3: The picture of the artificially constructed well on the paddy fields.

3.2 Sampling procedures

Water samples from artificially constructed wells, dug wells around the paddy fields, surface water from drainages and the irrigation tank were collected to study the nitrate and other physico-chemical parameters. Figure 3.4 has shown these all-sampling locations. Totally 37 samples were collected for this study. From which 23 samples were collected from constructed wells and twelve water samples were collected from dug wells and remain two water samples were collected from the tank nearby. All dug wells which were used for this study, were situated around paddy fields. Six dug wells were selected for sampling and its were labeled as 1, 2, 3, 4, 5 and 6 for easy identification. All the dug wells and the tank water are used for drinking and other domestic purposes. The collection of water samples from artificially constructed well were carried out based on the application of N- fertilizers by farmers. A set of samples was collected before applied fertilizers and another set of samples were collected after the application of fertilizer. This was done after 3, 7 and 14 days after the application of fertilizers. This collection procedure was repeated depending on the reapplication of N-fertilizers to the paddy field. One set of samples was taken from dug wells before the fertilizer application and another set from the same wells were obtained after two months of first sampling. As well as one sample was taken from tank before the fertilizer application and another sample from the same tank was obtained after two month of first sampling. At that time rice were grown up and farmers were used fertilizers several times to their cultivation.

Water samples were collected to pre-cleaned 300 ml plastic bottles. All sampling bottles were rinsed several times with distilled water and in the field, these bottles were further rinsed with the sampling water prior to the collection. Sampling bottles were filled completely to minimize the air cap. To prevent the mixing of water in constructed wells, syringes were used to collect the sample from well. All samples were kept cool in a refrigerator at about 4C° until the analysis has been performed.

Furthermore the daily rainfall was measured during the entire period of the study and the water temperature was also recorded during the sampling. Soil samples from each locations were collected and analyzed the their grain sizes.

3.3 Sample Preparations

The main object of the laboratory analysis is to obtain the chemical quality data of water. Therefore sample preparation is very important part of the chemical analysis. All water samples were filtered before the analysis. Some water samples were diluted to an optimum concentration range since high concentrations of element were present.

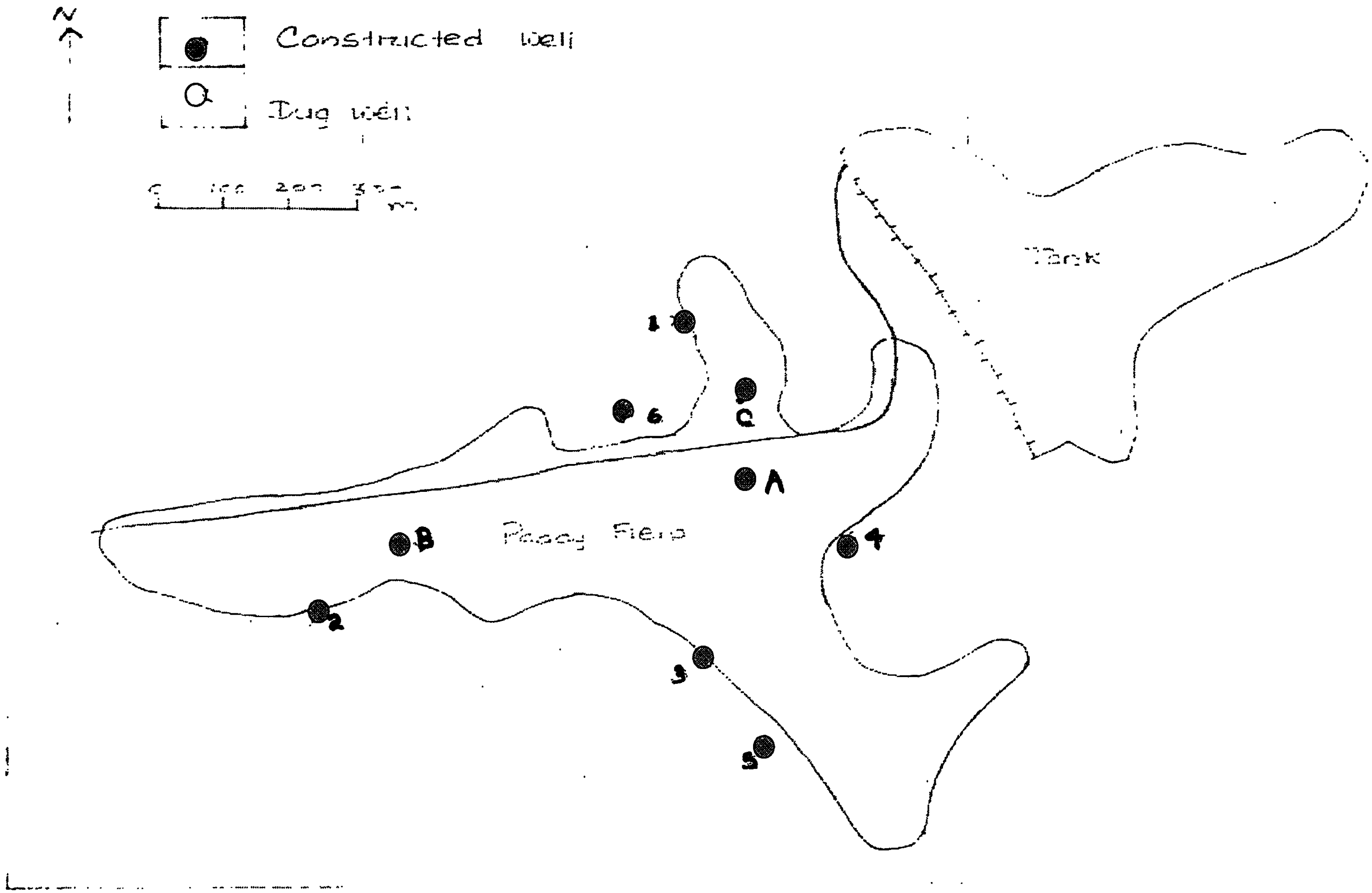

Figure 3.4: Selected Locations in the Study area

3.4 Determinations of chemical parameters in water

The chemical analysis for water was carried out at the Analytical Laboratories of the Department of Geology and Department of Civil Engineering, University of Peradeniya. All chemical analysis was carried out using standard methods for the examination of water and wastewater (Hach Company, 1996).

3.4.1 pH

The pH scale measures the logarithmic concentration of hydrogen (H^+) and hydroxide (OH-) ions, which make up water (H+ + OH- =H2O). pH was measured directly, with the help of pH meter. Samples were applied to the opening in the glass electrode consists of a special glass membrane, which is sensitive to H+ ions in solutions. For this analysis WTW pH 320-microprocessor pH meter were used. The pH meter was calibrated using buffer standards of pH - 4.0 and 10.0.

3.4.2 Electrical Conductivity

The electrical conductivity is measurement of the ability of water to pass an electrical current and it indicates the amount of total dissolve solids (TDS) in the sample solution. It is affected by presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anion or cations of sodium, manganese, calcium, iron and aluminum. (Wetzel and Likens, 1979). Electrical Conductivity was measured with the help of the Ecoscan Con 5 conductivity meter. Conductivity probe was placed in the sample and slightly agitated the probe to remove any air bubbles. The readings were obtained directly from the instrument. The unit of electrical conductivity of the instrument was recorded in ms (mili siemens/ cm) or µs (micro siemens/ cm).

3.4.3 Nitrate

Nitrate is usually most prevalent form of nitrogen in water because its end product of aerobic decomposition of organic nitrogen. Nitrate from natural sources is attributed to the oxidation of nitrogen of air by bacteria and to decomposition of organic material to the soil. Fertilizers may add nitrate directly to water and soil resources. In the determination of the nitrate ions in water, Hach DR- 2010 spectrophotometer was used. The cadmium reduction method with the No. 355 program of the spectrometer was used. Nitra Ver-5 nitrate reagent powder pillows were used for the measurement at 500 nm. The readings were obtained directly from the instrument and nitrate and nitrate-nitrogen were recorded in mg/l.

3.4.4 Phosphates

Phosphate is another important chemical parameter present in natural waters. In the determination of phosphate ions in water, Hach DR-2010 spectrophotometer was used. The Ascorbic Acid reduction method with 490-preprogramme spectrometer was used for the determination. One Phos Ver 3 low level orthophosphate determination reagent powder pillows were used for the development of colour of the sample. The readings were obtained directly from the instrument and phosphate, phosphate-phosphorus and P_2O_5 were recorded in mg/l at the wavelength of 890 nm.

CHAPTER 4
RESULT AND DISCUSSION

4.1 Characteristics of vertical transport of nitrate and phosphate in paddy soils

The study of the nutrition (particularly nitrate) vertical transport in paddy soil ecosystem is very important due to various scientific reasons such as human and animal health, soil and water pollution, agriculture and nutrition, soil fertility and ecology. This study is particularly important in an agricultural economy based country such as Sri Lanka where a most of the people lives close to the soil–water–plant system and depend on agriculture.

As discussed in chapter 2 the magnitude of nitrate leaching depends on many factors such as;

Rate, time, source, and method of nitrogen fertilization
Soil characteristics that affect groundwater percolation
Quantity, pattern and time of precipitation and / or supplemental irrigation
Use of nitrification inhibitors
Intensity of cropping crop uptake of nitrogen

However during this study, factors such as rainfall pattern, soil characteristics and rate and time of nitrogen fertilization are considered for the study. Table 4.1 illustrates the results obtained from three artificially constructed wells for leaching experiments, surface water and dugs wells around the paddy fields.

4.2 Variation of chemical parameters in constructed well-A

4.2.1 Nitrates

Nitrates are highly soluble salts. When water moves on the surface of a soil, it dissolves nitrates that are present in the surface layers of soils. Another part seeps through the soil layers and recharges the groundwater. The seeping water dissolves soil nitrates and therefore nitrates that are present in the groundwater recharge zone are carried and contaminate the groundwater.

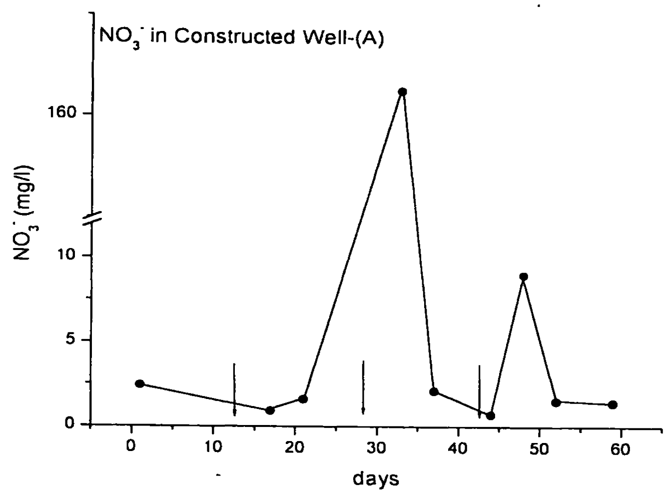

Figure 4.1: Variation of nitrates in the constructed well-A. The arrow indicates the application date of fertilizer to the field.

The variation of the nitrate concentration of groundwater in artificially constructed well (A) with respect to the fertilizer application is shown in figure 4:1. It is clear that the ground water is affected by application of urea fertilizers. However constructed well-A shows lower nitrate contents 3 days after the application of fertilizer. The nitrate content of the water collected from constructed well-A is 2.4mg/l before the cultivation whereas it is 0.9mg/l after the application of fertilizer which is two times lower. It is important to note that the heavy rainfall (1130mm) was recorded just before the application of fertilizer (figure 4.2). Table 4:1 is also given the amount of rainfall and rainfall variation during the study period. Therefore it is important to note that the most of the fertilizer applied to the cultivation is washed away or absorb by the plant instead of seeping through the soil layers. Spalding at el. (2001) has shown similar observation that the nitrate concentrations declined ~10 to 20 mg /l due to rain. Dissanayake et al. (1984) have illustrates the variation of the maximum nitrate levels with respect to the rainfall of the agricultural sector of the dry zone of Sri Lanka. In this respect, negative relation can be observed between rainfall and nitrate concentration of groundwater.

As noted in the Chapter 2, farmers repeatedly apply nitrogenous fertilizer to their cultivation. However after the second and third occasion the effects of rain fall is restricted and hence the nitrate contents are higher than that of before fertilizer application. However the nitrate content is higher just after the fertilizer application and then gradually decreases. Therefore the content was lower after 7 and 14 days of fertilizer application. That indicates the nitrate was leached rapidly through the soil cover and contaminated groundwater, instead of retaining in the surface layers of soils.

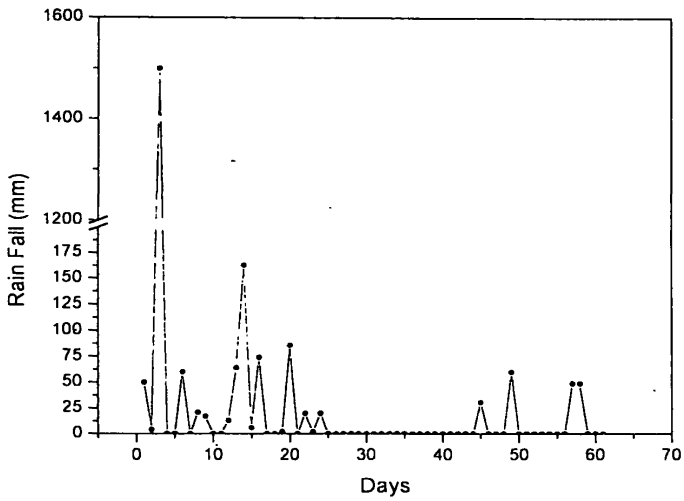

Figure 4.2: Rainfall variation in the area during the study periods.

As illustrated in figure 4.1, three days after the second application of fertilizers, nitrate concentration of constructed well was significantly higher than the third application. The highest nitrate content of 162.5mg/l were recorded in the constructed well A, just after the second time of application of fertilizer.

The concentration of nitrate after third time applications of fertilizer, the content of nitrate is less than that of the previous fertilization. Both occasions the effect of rainfall is lower, but different type of fertilizer was applied later two occasions. First and second occasions 33 kg/acre of urea was applied to the paddy field and third time 33 kg/acre of both urea and ammonium sulfate were applied to the paddy field. But urea has 46 % N content and ammonium sulfate has only 21 % N content (table 2.1). Therefore second time application the contents of nitrogen were higher than third time. Due to this reason nitrate leaching in second time after soil fertilization is significantly higher than that of the third occasion, due to application of higher amount of nitrogen fertilizer to the paddy field. Therefore the leaching of nitrate through soil layers depends on rainfall and type and amount of fertilizer used for the paddy field.

4:2:2 Phosphates

Phosphate is one of the essential nutrients for plant growth. High inputs of phosphate fertilizer in intensive cropping areas have been the practice for several decades. It has resulted in significant phosphorus enrichment in soil profiles. It is recognized that agricultural activities have contributed to the non-point source pollution of inland water and contributed to important environmental issues. Phosphorus enters water bodies not only as inorganic phosphate ions (PO_4^{3-}, $H_2PO_4^{3-}$, HPO_4^{2-}). But also in inorganic polymers, organic phosphorus compounds in living microorganisms and dead detritus. Only some of these forms are immediately available in plant and algal growth, but others may become so microbial activity in the water (Brain, 1980).

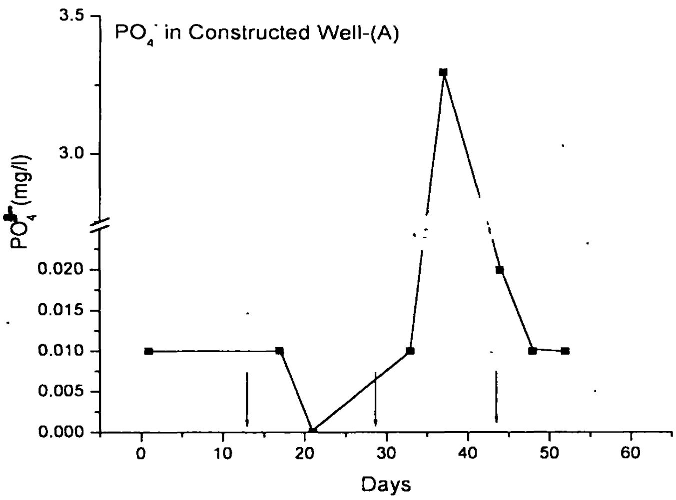

Figure 4.3: Variation of phosphates in the constructed well-A. The arrow indicates the application date of fertilizer to the field.

Figure 4.3 shows the variation of phosphate concentration of water collected from constructed well -A. Fertilizers have applied three times and after the fertilizer application the samples were taken consecutively after 3, 7 and 14 days and phosphate concentration has measured. After the first fertilizer application, phosphate concentration was not change considerably. As discuss under the nitrates. the heavy precipitation decreases the ground penetration.

But after the second application of fertilizer, phosphate concentration of water is increased considerably as similar to nitrate variation. After 7 days, phosphate concentration of water has reached up to 3.3 mg/l. Zhang at el. (2003) reported the effect of phosphate fertilizer application on phosphorus losses from paddy soils in Taihu lake region in China and concluded that phosphorus losses from paddy soils was one of the potential factors relative water eutrophication. That study explained the movement of leachate from the surface soil layer down to deeper levels indicates that applied phosphorus can move quickly down to lower layers of the profile. But when compare the both nitrate and phosphate mobility, nitrate-leaching rate is higher than the phosphate leaching rate. Therefore higher nitrate concentration is appeared 3 days after applying fertilizer and higher phosphate concentration is appeared 7 days after applying fertilizer in second occasion.

4:2:3 pH, Total dissolved solids and Temperature.

pH is an important factor which influence chemical and physical quality of groundwater and soil. pH of soil depends on various factors such as the oxygen supply, decomposed organic matter and some soluble salts present in the soil. The pH of soil also influences inorganic transformation of soluble ions and control the adsorption and release of ions of essential nutrients at soil water interface. Table 4:1 summarizes the pH of constructed well water before and after applying fertilizer and pH variation is shown on figure 4.4. The pH of the water collected from constructed well is 8.04 before cultivation where as it is 7.8 after 3 days of application of fertilizer in first occasion. It is important to note that the heavy rainfall (1130 mm) was recorded just before the application of fertilizer as mentioned previously. Rainfall is slightly acidic (6.5) and therefore heavy rainfall is caused to reduce the pH of well water. However considerable effect on water pH not observed before and after the application of fertilizer. The pH of well water varies from 8 to 8.1 in constructed well-A.

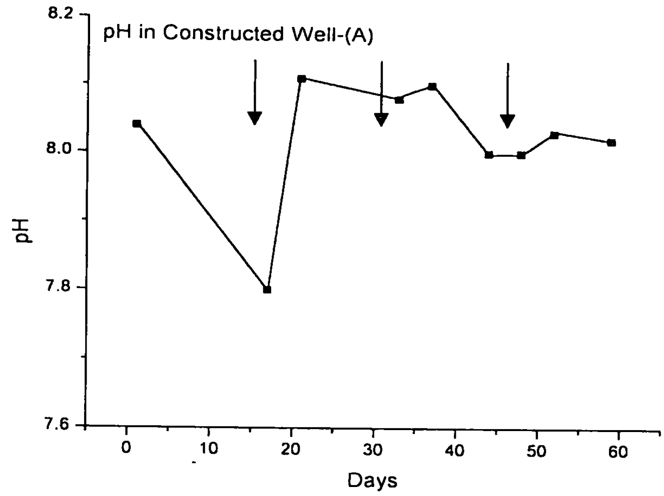

Figure 4.4: Variation of pH in the constructed well-A. The arrow indicates the application date of fertilizer to the field.

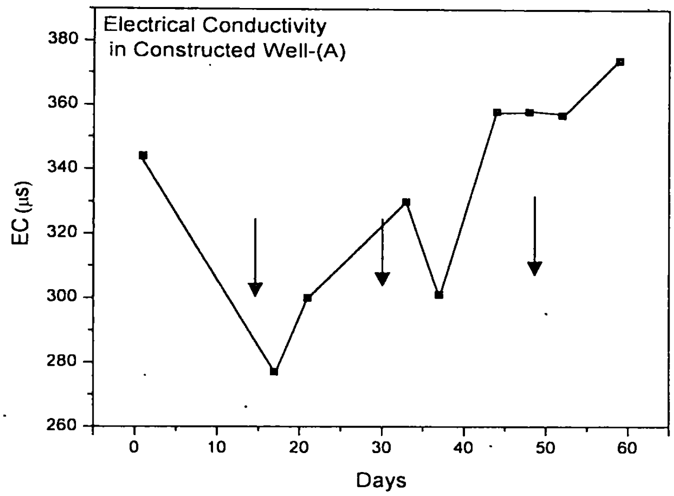

Figure 4.5: Variation of EC in the constructed well-A. The arrow indicates the application date of fertilizer to the field.

The electrical conductivity of solution also gives an estimate of the total amount of dissolved solids such as chloride, nitrate, sulfate and phosphate anions or sodium, manganese, calcium, iron and aluminum cations. Figure 4.5 illustrates the electrical conductivity of samples collected for this study. As illustrated in figure 4.5 electric conductivity of constructed well-A water is increased gradually after fertilizer application because total soluble ions are increased due to the fertilizer application.

The rate of all biological and chemical process depends on temperature. Temperature affects the oxygen contained of the water, the rate of photosynthesis by aquatic plants, metabolic rate of aquatic organisms and the sensitivity of organisms to toxic waste and diseases. Water and air temperature measurement is important for this study. Because high temperature is cause to increase the evaporation. Therefore nitrogen loss to the atmosphere through volatilization is increased with increasing temperature. Due to volatilization, nitrate leaching and groundwater nitrate can be decreased. Table 4.1 is shown water and air temperature for each sample. All water temperatures were above 27C°. Therefore considerable nitrogen can be loss as volatilization from the paddy field and this can effect the leaching of nitrogen into the groundwater.

4.3 Variation of chemical parameters in constructed well-B

Table 4.1 the chemical parameters obtained from water which was collected from the constructed well, named as "B". It was located some 1100m away from the well "A" and 1200m away from well "C". It represents a different paddy field and applied different cultivations and treatment procedures than well "A".

4:3:1 Nitrate

Figure 4.6 has shown the relation between the nitrate concentration of groundwater (constructed well B) and time. Arrows have shown the time of fertilizer application. Before applied fertilizer nitrate, the concentration is high than after applied fertilizer. However the constructed well-A has shown similar observation.

As shown in figure 4.6, before the cultivation the nitrate content of the water collected from constructed well-B is 4.1 mg/l whereas it is 3mg/l 3 days after the application of fertilizer. It is important to note that the heavy rainfall (1130 mm) was recorded just before the application of fertilizer as mentioned previously (figure 4.2). As well as after application fertilizer rainfall was very restricted and most days it was zero. Therefore ability of nitrate leaching is minimum.

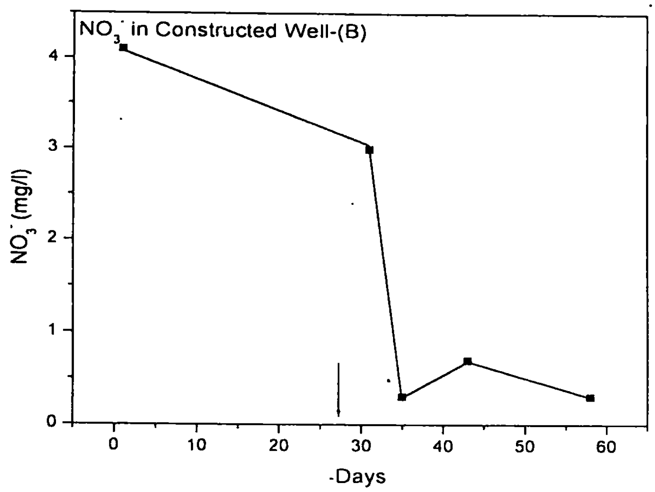

Figure 4.6: Variation of nitrate in the constructed well-B. The arrow indicates the application date of fertilizer to the field.

4.3.2 Phosphates

The variation of phosphate concentration of artificial well-B with the application of fertilizer has shown in figure 4:7. Three days after application fertilizer, the phosphate concentration of well water is raising and then gradually decreased. The phosphate concentration of the water collected from constructed well is 0.02mg/l before the cultivation whereas it is 1.82mg/l after application of fertilizer, which is 91 times higher. It is important to note that the animal dung has applied to the paddy just before the collection of water sample (3 days after fertilizer application) and this cause to increase phosphate content considerably. Zhang at el. (2003) have taken the similar result and described the effect of different phosphate fertilizer application rates on phosphorus losses paddy soil in the Taihu lake region in china.

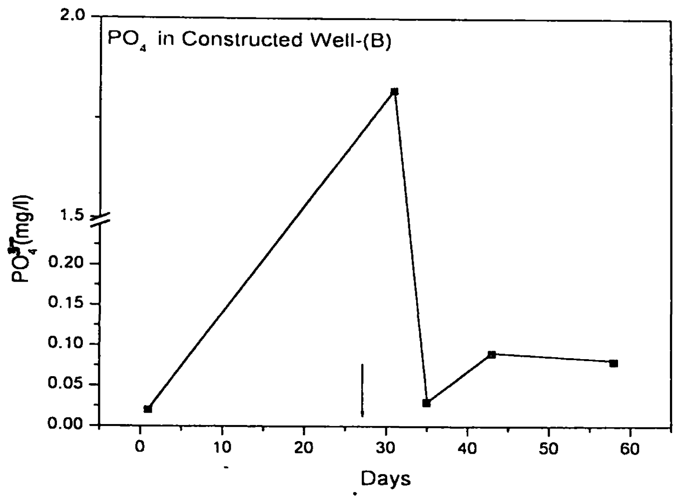

Figure 4.7: Variation of phosphate in the constructed well-B. The arrow indicates the application date of fertilizer to the field.

4.3.3 pH, total dissolves solids and Temperature

According to the figure 4.8, fertilizer is not considerable effect on water pH. But as shown in figure 4.8, pH of water collected from constructed well-B is 7.88, just 14 days after applying fertilizer and it is reduced up to 7.48 after 30 days. It is important to note that the heavy rainfall was recorded during time period (figure 4.2). Rainfall is slightly acidic (6.5) and therefore heavy rainfall is caused to reduce the pH of well water. All pH readings are neutral or slightly alkaline and varies from 7.48 to 7.93 of constructed well-B.

Table 4:1 has shown the electrical conductivity of B- constructed well water before and after applies fertilizer. 7 days after the application of fertilizer, electric conductivity is gradually increased. Electrical conductivity estimates of the total amount of soluble salts. Therefore this indicates that total dissolves solids have increased during this period due to fertilizer application and method of irrigation practices. Electrical conductivity of all water samples collected from constructed well-B varies from 691 to 971 μS and it is higher than collected water from constructed well-A which shows the EC of 277 to 374 μS.

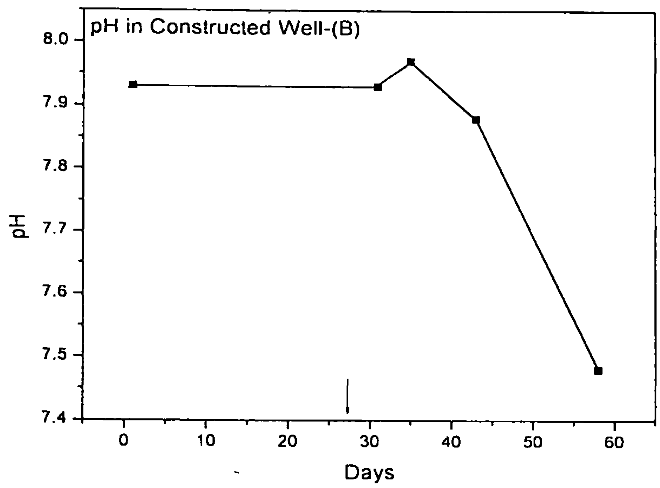

Figure 4.8: Variation of pH in the constructed well-B. The arrow indicates the application date of fertilizer to the field.

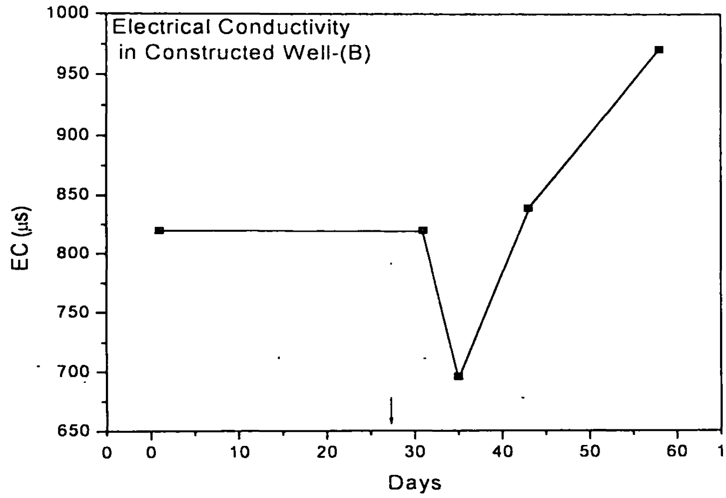

Figure 4.9: Variation of EC in the constructed well-B. The arrow indicates the application date of fertilizer to the field.

The rate of all biological and chemical process depends on temperature. All water temperatures are above 26C°. Therefore considerable nitrogen loss as volatilization from the paddy field and this effect the reduction of nitrate leaching.

4.4 Variation of chemical parameters in constructed well-C

Table 4.1 the chemical parameters obtained from water which was collected from the constructed well, named as "C". It was located some 300m away from the well "A" and 1200m away from well "B". It represents a different paddy field and applied different cultivations and treatment procedures than well "A" and well "B".

4.4.1 Nitrate

In the constructed well-C, lower nitrate contents were reported 3 days after the application of fertilizer which is similar the observation of constructed well-A and B. As shown in figure 4.10, the nitrate content of the water collected from constructed well is 11.6 mg/l before the cultivation and it is reduced up to 7.6 mg/l after the application of fertilizer. It is important to note that the heavy rainfall (1130mm) was recorded before the application of fertilizer as mentioned previously (figure 4.2). Therefore nitrate concentration of well water and nitrate leaching depends on the precipitation. However in figure 4.10 is shown considerable leaching after applying fertilizer. Many researches have explained this kind of phenomena. Burkart and Kolpin (1993) have shown that farming is a major cause of ground water pollution is that nitrate problems are most common in the spring, which is the time that farmers apply nitrogen fertilizer to their fields. They found that samples of water from wells surrounded by more than 25% land in Corn and Soybean have a dramatically larger frequency of excess nitrate (30%) than wells with approximately 25% of the surrounding land in corn or soybean (11%).

As noted in artificially constructed well-A, farmers repeatedly apply nitrogenous fertilizer to their cultivation. When consider the nitrate contents variation in second and third occasion after application of fertilizer is similar. But first occasion is differing from other two times. That means highest nitrate concentration of water is appeared after seven days in second and third occasion and it is decreased on 14 days. But after apply urea in first occasion; highest nitrate concentration was appeared after three days. It indicate first time nitrate-leaching rate was high than second and third times. Because considerable rainfall has obtain in first time after apply fertilizer and obtaining rainfall was very less other two times, and most days it was zero (Figure

4.2). Therefore nitrate-leaching rate is high in first time due to influence of rainfall because nitrate ions soluble in water and its migration through the soil profile. Dissanayake and Weerasooriya (1985) have explained about this process.

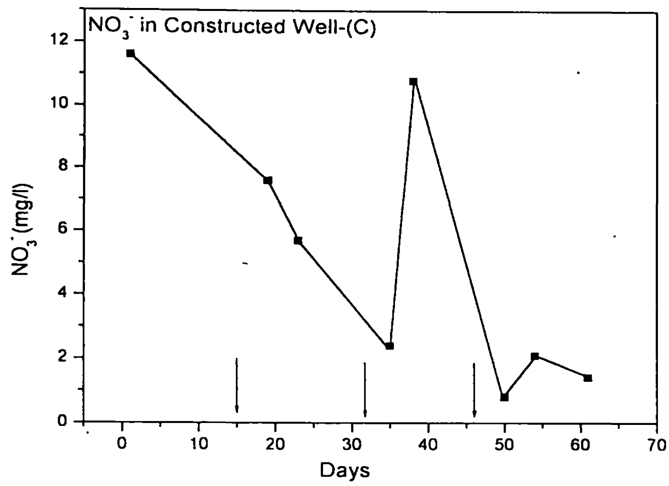

Figure 4.10: Variation of nitrate in the constructed well-C. The arrow indicates the application date of fertilizer to the field.

After applying fertilizer in second occasion, highest nitrate concentration (10.8mg/l) of water collected from constructed well-C is less than highest nitrate contents of water collected from constructed well-C after applying fertilizer in third occasion (2.1mg/l). But applied amount of fertilizer is similar in both time (Table 4.2). However rainfall is restricted in second occasion than in third occasion (figure 4.2). Therefore it is important to note that the most of the fertilizer applied to the cultivation is washed away or absorb by the plant instead of seeping through the soil layers.

4.4.2 Phosphate

In figure 4:11 has shown considerable phosphate contents of water collected from constructed well-C. It has increased with corresponds to fertilizer application. It indicates that phosphate leaching is increased due to fertilizer application and that can be contaminated the ground water. However phosphate concentration variation pattern is similar in all occasions. The phosphate concentration is increased gradually up to 7 days and decreases later. The constructed well-B has shown similar result for phosphate. But highest nitrate contents are shown 3 days after application of fertilizer. Therefore that illustrate the ability of nitrate penetrate through the soil profile is higher than the ability of phosphate penetration through the soil profile.

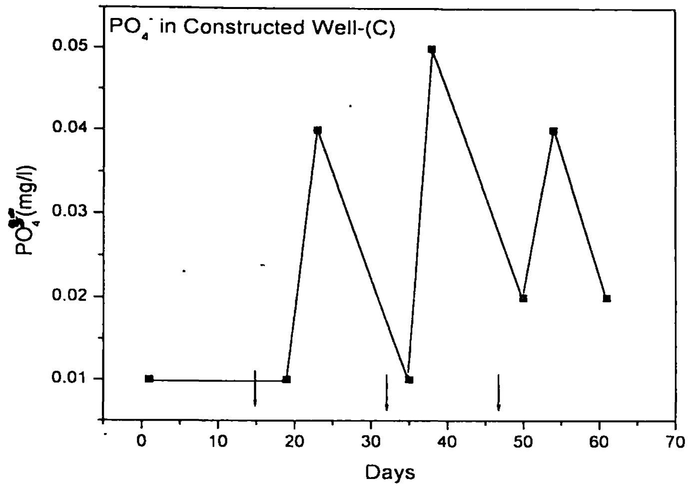

Figure 4.11: Variation of phosphate in the constructed well-C. The arrow indicates the application date of fertilizer to the field.

4.4.3 pH, Total dissolves solids and Temperature

According to the figure 4.12, pH of the water collected from constructed well-C is decreased 7 days after application of fertilizer. The pH is 7.65 before the cultivation whereas it is decreased up to 7.33, seven days after application of fertilizer in first occasion. However later two times has obtained similar result. Table 4.1 has shown the electric conductivity of constructed well-C water before and after apply fertilizer. As shown in figure 4.13, electric conductivity of the constructed well water is tending to increase after application of fertilizer. The similar result to this has shown for constructed well-A and C.

The rate of all biological and chemical process depends on temperature. As well as nitrification, denitrification/volatilization depends on the temperature. Therefore water temperature measurement is very important. All samples have high temperature values of water collected from well C (above 27C°) as similar well A and B. Therefore this causes to increase the volatilization and reduce the nitrate leaching.

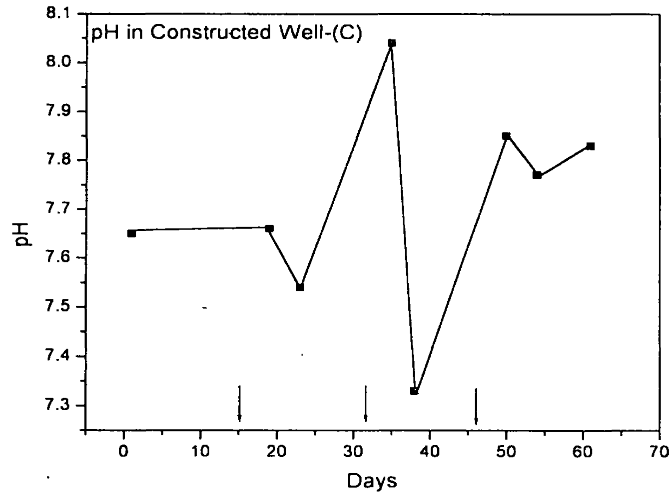

Figure 4.12: Variation of pH in the constructed well-C. The arrow indicates the application date of fertilizer to the field.

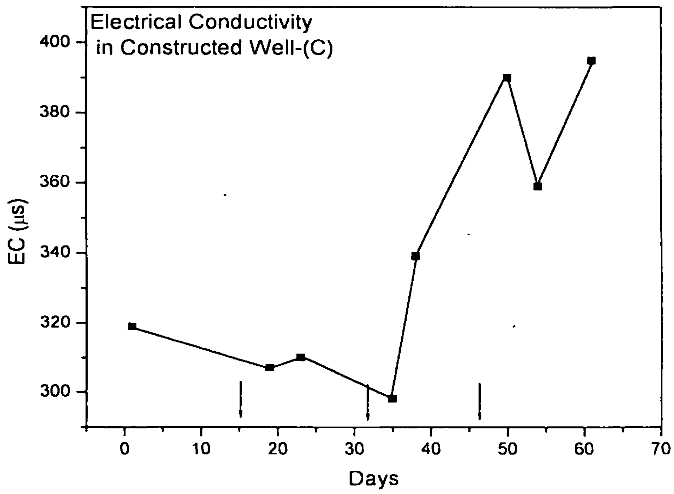

Figure 4.13: Variation of EC in the constructed well-C. The arrow indicates the application date of fertilizer to the field.

Day	Rainfall mm	(A) NO_3^- mg/L	(A) PO_4^{3-} mg/L	(A) pH	(A) EC µs	(A) Water Temp. C°	(B) NO_3^- mg/L	(B) PO_4^{3-} mg/L	(B) pH	(B) EC µs	(B) Water Temp. C°	(C) NO_3^- mg/L	(C) PO_4^{3-} mg/L	(C) pH	(C) EC µs	(C) Water Temp. C°
1	37.6	2.4	0.01	8.04	344	28	4.1	0.02	7.9	820	28	11.6	0.01	7.65	319	28
2	3.01															
3	1129.6															
4	0															
5	0															
6	45.2															
7	0															
8	15.8															
9	12.8															
10	0															
11	0															
12	9.8															
13	48.2															
14	122.8															
15	4..5															
16	55.7															
17	0	0.9	0.01	7.8	277	29										
18	0															
19	1.5											7.6	0.01	7.66	307	30
20	64.8															
21	0	1.6	0	8.11	300	26										
22	15.1															
23	1..5											5.7	0.04	7.54	310	30
24	15.1															
25	0															
26	0															
27	0															
28	0															
29	0															

30	0															
31	0						3	1.82	7.93	820	28					
32	0															
33	0	162.5	0.01	8.08	330	31										
34	0															
35	0						0.3	0.03	7.97	696	29	2.4	0.01	8.04	298	28
36	0															
37	0	2.1	3.3	8.09	301	31										
38	0											10.8	0.05	7.33	339	28
39	0															
40	0															
41	0															
42	0															
43	0						0.7	0.09	7.88	839	28					
44	0	0.7	0.02	8.10	358	27										
45	23.3															
46	0															
47	0															
48	0	9	0.01	7.08	358	28										
49	45.2															
50	0											0.8	0.02	7.85	390	27
51	0															
52	0	1.5	0.01	7.77	357	28										
53	0															
54	0											2.1	0.04	7.77	359	28
55	0															
56	0															
57	36.9															
58	36.9						0.3	0.08	7.48	971	26					
59	0	1.4	0.08	8.02	374	28										
60	0															
61	0											1.4	0.02	7.83	395	26

Table 4:1 Chemical and physical parameters of Constructed wells (A) , (B) and (C)

Date	Location	Fertilizer quantity (Kg/acre)
2003/11/27	Constructed well A (1st time)	33
2003/12/13	Constructed Well A (2nd time)	33
2003/12/28	Constructed well A (3rd time)	33
2003/12/11	Constructed well B (1st time)	65
2003/11/29	Constructed well C (1st time)	49
2003/12/15	Constructed well C (2nd time)	33
2003/12/30	Constructed well C (3rd time)	7

Table 4.2 Fertilizer quantity applied to the paddy field where have Constructed wells (A) , (B) and (C)

4.5 Characteristics of nitrate and phosphate in drinking water wells

The study of the characteristics of nitrate movement is very important because nitrate leaching through soil profile can contaminate groundwater. One of the main aims of this study is estimate and monitor the effect of fertilizer application on the potable waters in and around the paddy fields. Most of the drinking water wells in the study area are located close to the paddy field system. Nitrate in drinking water is considered to be undesirable and can cause health hazards. The current public health stands recommended by WHO for safe drinking water is 10 mg/l as nitrate–nitrogen or 45mg/l as nitrate. Bearing mind the nitrate in drinking water can cause of the disease such as methmoglobinemia, a blood disorder primarily affecting infant under 6 months of age and have been cited as a risk factor in developing gastric and intestinal cancer.

Six dug wells, which are located very close to the paddy field of the study area, were selected as monitoring wells (figure 3.4). The contents of nitrate, phosphate, pH and EC were measured before the cultivation and two month after the cultivation. The depth of the dug wells varies from few to several tens of meters. All wells are used for drinking and other domestic purposes.

Figure 4.14 is shown nitrate concentration of dug wells before the paddy cultivation and 2 months after the cultivation. During this period, fertilizer has been applied several times to the nearby paddy fields. As shown in figure 4.14, the nitrate concentration of groundwater is significantly higher after the cultivation. In some wells the nitrate contents is doubled after cultivation. The nitrate content of dug wells varies from 0 to 3.4 mg/l prior to the cultivation but it is 0.9 mg/l to 6.2 mg/l after the cultivation. This clearly indicates the effect of agriculture on the content of nitrates in groundwater around paddy fields.

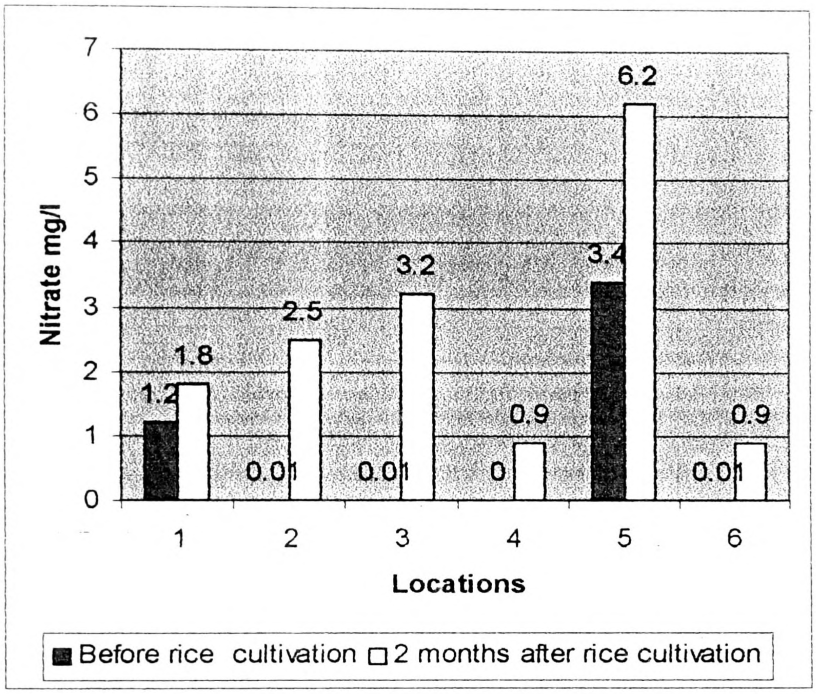

Figure 4.14: Nitrate concentration of dug wells before the paddy cultivation and 2 months after rice cultivation.

Figure 4.15 illustrates the variation of nitrate before and after the rice cultivation with respect to the distance from the paddy fields. In both cases the correlation coefficient between the nitrate content and the distance from rice field found to be significant. But only one location (location 5) indicates somewhat deviated results become and it has contained considerable higher amount of nitrate even before the rice cultivation. This noticeable deviation is due to the pit latrine soak way situated just 14.5 m from the dug well. Dissanayake (1988) expressed concern that a construction of pit latrine soak ways may pose a threat to potable groundwater supplies. The most immediate threat is the microbiological contamination of groundwater, although chemical pollution, particularly nitrate, may in the longer term represent a more serious problem. Even though soil is usually the most effective layer in protecting groundwater by attenuating pollutants, pit latrines bypass this layer and thus increase the risk of nitrate contamination of groundwater.

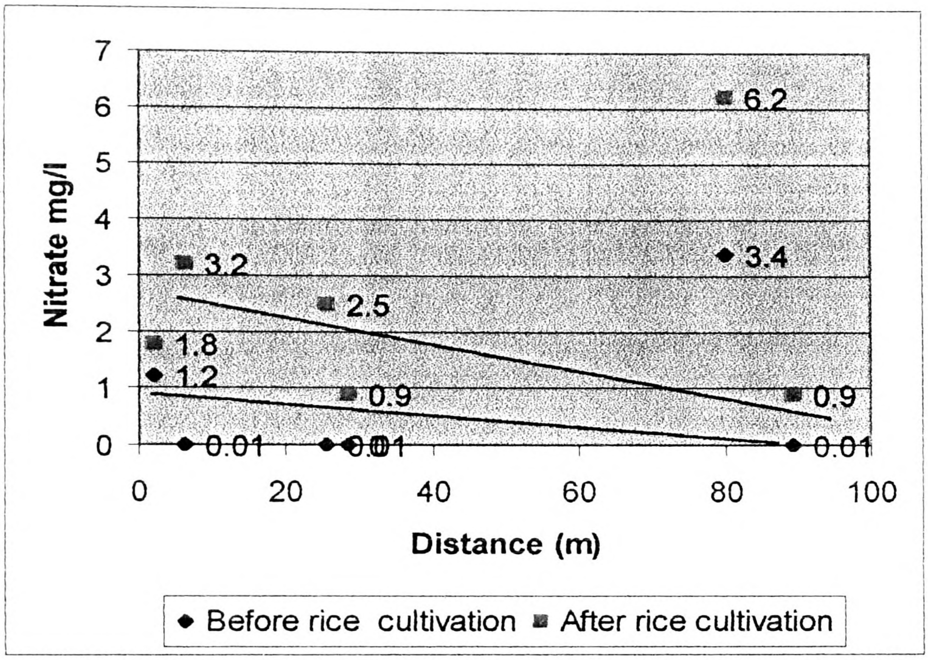

Figure 4.15: Variation of nitrate before and after the rice cultivation with respect to the distance from the paddy fields.

Figure 4.16 has shown phosphate concentration of wells before cultivation and 2 month after the cultivation. Most wells phosphate concentration was increased due to after the two month of rice cultivation. Therefore fertilizer application is considerably affect the contents of phosphate concentration in groundwater. Electric conductivity of dug wells before and after applied fertilizer is illustrated in table 4.3 and figure 4.17. All dug wells have high values of electric conductivity, which estimates of the total amount of soluble salts. Therefore these wells have high amount of soluble salts. It indicates total soluble solids of dug wells are rose due the fertilizer application.

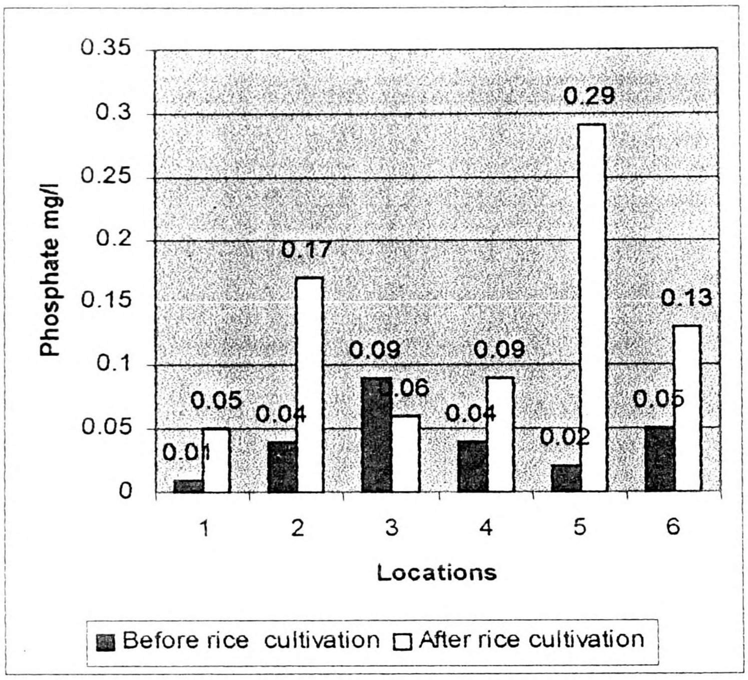

Figure 4.16: Phosphate concentration of dug wells before the paddy cultivation and 2 months after rice cultivation.

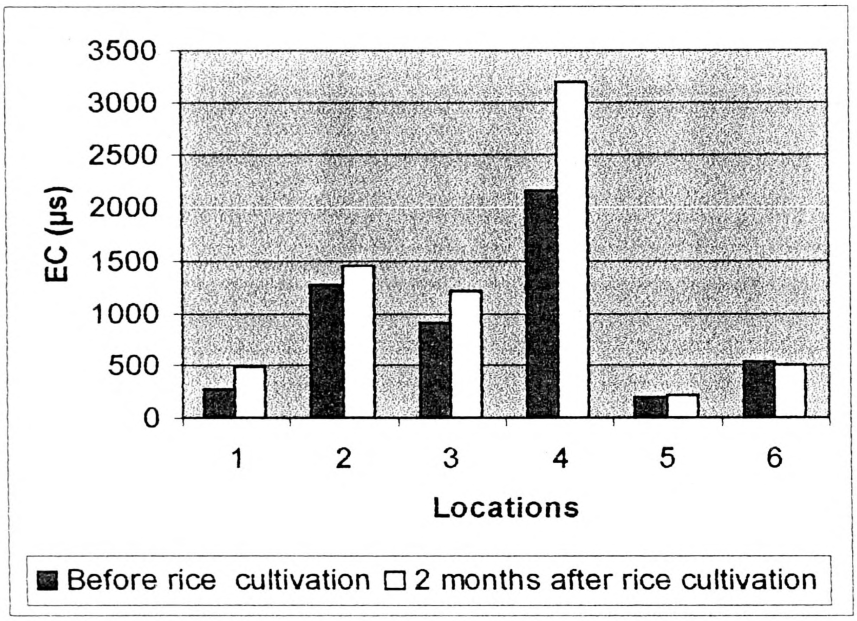

Figure 4.17: EC of dug wells before the paddy cultivation and 2 months after rice cultivation.

4.6 Variation of chemical parameters in the Tank

Before the rice cultivation and 2 month after the cultivation, nitrate, phosphate, pH, and EC variation of the near by tank were measured and shown in table 4.3. It shows higher nitrate, phosphate and electric conductivity values two month after cultivation of rice. The nitrate content of the water of the tank is 0.4 mg/l before the cultivation whereas it is 1.6 mg/l two months after the cultivation and which is four times higher. As well as phosphate content of the water collected from tank is 0.01 mg/l before the cultivation whereas it is 0.06 mg/l two months after cultivation paddy field, which is six times higher as observed in nitrates. Electric conductivity of tank water is also increased from 341µS to 369µs and pH decreased from 8.2 to 7.8. Therefore these observations are shown clearly that the fertilizer application is caused to significant effect on ground and surface water contamination. Chen et al. (2003) have proved the similar result for this. They have shown excessive chemical fertilizer application in the region has led to an increase of nitrate in the groundwater, which is turn contributed to eutropication of the Tai lake.

4.7 Soil Texture and nitrate leaching in Paddy fields

Nitrogen fertilizers or manure used on a sandy soil are more vulnerable to leaching to groundwater than nitrogen used on a clay soil. The coarse-textured soils (sandy soils) have in the paddy field where has artificially constructed well (A) and clay soils in the paddy where have artificially constructed well (B) and (C). As well as nitrate mobile rate is high of artificially constructed well A (maximum value = 162.5mg/l) than nitrate mobile rate of artificially constructed well B and C (maximum values 3.0mg/l and 10.8 mg/l respectively). Because water moves rapidly through sandy or other coarse-textured soils. Nitrates move along with the water in a soil. Nitrogen loss to the groundwater from clay soils is smaller than those for the coarse-textured soils. Nitrate ions (NO_3^-) are negatively charged and are not retained by clay particles. Clay soils do not specifically retain nitrates. Water movement through clay soils is very slow and small. Water does not pass easily through clay soils so nitrates, which only move with water, do not leach to groundwater. Pore space in clay soils is often filled with water. Water-filled pores of clay soils lack oxygen. Lacking oxygen, a group of soil bacteria, called facultative anaerobes, substitute nitrates for oxygen for respiration. When bacteria use nitrates as a substitute for oxygen, they convert nitrates to nitrogen gas through a process called denitrification. More nitrates are lost by denitrification in clay soils than in sandy soils. Nitrate losses through denitrification in clay soils reduce the amount of nitrates that can potentially leach to groundwater.

Date	Location	NO_3^- mg/L	PO_4^{3-} mg/L	pH	EC µs	Water Temp. C°
2003/11/15 (Before cultivation)	1	1.2	0.01	7.9	261	27
	2	0	0.04	7095	1264	26
	3	0	0.09	7.88	894	26
	4	0	0.04	7.33	2170	26
	5	3.4	0.02	8.0	184	26
	6	0	0.05	8.06	529	25
	Lake	0.4	0.01	8.2	341	17
2004/01/14 (2 months after cultivation)	1	1.8	0.05	7.93	469	26
	2	2.5	0.17	7.80	1456	26
	3	3.2	0.06	7.72	1209	27
	4	0.9	0.09	7.55	3190	26
	5	6.2	0.29	8.0	214	27
	6	0.9	0.13	8.13	504	26
	Lake	1.6	0.06	7.8	369	26

Table 4.3 Chemical and physical parameters of dug wells and tank

CHAPTER 5

CONCLUSIONS AND RECOMMENDATION

Many farmers apply nitrogen as fertilizers or manures to their crops. Nitrogen applied through fertilizers or manure is converted to plant-available-nitrate by bacteria living in the soil. The growing plants consume part of these nitrates.

The results of this study provide evidence that nitrate losses from paddy soils was one of the potential factors coursing groundwater pollution. After fertilizer application, nitrate and phosphate contents increases in water collected from artificially constructed wells. This indicates that fertilizer can easily leach through the soil layers and contaminate the groundwater and also surface waters. However the soil type and the climatic conditions prevailing during the period of fertilizer application are the main controlling factors.

This case study clearly illustrates the factors that affect for nitrate and phosphate mobility. Variation of nitrate and phosphate concentrations of water collected from constructed wells mainly depends on rainfall, soil characteristics and type and amount of fertilizer. In fact that nitrate concentrations in the leachate from the high nitrogen application rate was significantly greater than from the low nitrogen application rate. In some causes nitrate and phosphate concentrations of water collected from constructed wells A, B and C is decreased after fertilizer application due to the effect of heavy rainfall. Because nutrients are washed away instead of seeping through the soil layers or dilutes the contents. When nitrate and phosphate concentrations variations were compared in three constructed wells, it was found that nitrate-leaching rate was greater than that of phosphate. This suggest that the different mobility of nitrate and phosphate losses in different soils.

The result of this study provide evidence that nitrate losses from paddy soils was one of the potential factors relating ground and surface water pollution. Because two months after paddy cultivation, nitrate and phosphate contents of water collected from dug wells around the paddy field are increased considerably. It indicates clearly that the groundwater contamination is occurred due to fertilizer application. However the water samples collected from the nearby tank is also given the same result. Therefore fertilizer application is cause to surface water pollution greatly. The correlation coefficient between the nitrate content and the distance from rice field found to be negative and significant both before and after fertilizer application.

Further studies are necessary to understand the nitrate movement in the paddy field ecosystem. The followings would be useful in this regard;

- Identify the groundwater nitrate variation during the period of fertilizer application- water samples can be collected after fertilizer application after 3, 7, and 14 days from the dug wells around the paddy field.
- Identify the surface runoff pollution due to fertilizer application- water samples can be collected from streams, which flow through the paddy field before and after fertilizer application.
- Identify the factors that effect percolation of water- soil permeability, slope, hydraulic gradient and microbiological activities would be very useful to consider.

Although nitrate pollution from agriculture has received a lot of attention, many wells have been polluted with nitrates due to misuse of fertilizer on paddy cultivation that were close to shallow water wells. Mismanagement of fertilizer nitrogen is more common in rural areas. This misuse results from lack of knowledge of the relationship between excessive nitrogen use on rice fields and groundwater pollution.

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