EFFECTS OF FARM DAIRY EFFLUENT ON SOIL PROPERTIES

BY

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DECLARATION

I herby declare that this project work is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

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CERTIFICATION

his is to certify that the project entitled "Effects of Farm Dairy Effluent on Soil Properties" by kande, Benjamin Taiwo meets the regulations governing the award of the degree Bachelor of ngineering (B. ENG.) of the Federal University of Technology, Minna, and it is approved for s contribution to scientific knowledge and literary presentation.

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DEDICATION

I dedication this project to the Almighty God, the one who was, who is and who is to come and also to my dearest parents; Mr Sunday Kehinde Akande and Mrs Susan Adetola Akande who have being the strong pillar in making the house to stand.

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ABSTRACT

Farm dairy effluent in Maizube is the liquid waste generated from the milking process which is discharged to a portion of the farm land. Its effects on the soil properties (chemical and physical) were determined in this project work. This was done by taking soil samples from two different locations in triplicate and analysing their chemical and physical properties accordingly. The data collected were analysed using descriptive statistics and paired-sample T-test. One of the locations was with dairy effluent (sample A) while the other without dairy effluent (sample B). The results obtained from the analysis of sample A were compared with that of sample B in terms of physical properties in relation to previous works. Also, the chemical properties of the two samples (A and B) were compared with the FAO and the USDA soil standard rating to determine their variations. From the analysis of the result for sample A and B, it was clear that there is no significant differences for both samples except for magnesium and calcium with level of significant which are 0.046* and 0.008*, respectively.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

Dairy effluent is a natural fertilizer and soil conditioner and, if managed efficiently, can enhance pasture growth and improve soil structure. Farm dairy effluent (FDE) is the mixture of dairy cow feaces and urine deposited during milking and subsequently diluted with wash down water during the cleaning of the milking area and the associated holding yards. Thus, FDE is a very dilute organic effluent composed of a soluble fraction and an organic solids fraction; the solids content is generally less than 1% (Longhurst *et al.*, 2000; Barkle *et al.*, 2001).

Irrigation of FDE onto pasture is increasingly being recognized as a means for biological treatment and recognizes the fact that FDE is a resource to be utilized for its mineral content rather than a waste for disposal. Land application of FDE can provide valuable minerals and organic matter for pasture. However, inappropriate application rate or timing can lead to poor utilization by plants, causing nitrate leaching and groundwater contamination; surface water contamination; water logging of soils; soil nutrient imbalances and or animal health problems (Wang *et al.*, 2004). For instance, in New Zealand, land application of FDE has become the preferred treatment method to minimize the risk of contamination of surface waters and to address cultural concerns about the addition of waste material to waterways. For example, since 1993 the proportion of Waikato farmers who irrigate FDE onto pasture rose from 35% to nearly 70% in 1997 to effectively 100% in 2004 (Barkle *et al.*, 2000).

Effluents are wastes produced from industries and they vary depending on the human activities that produce them. Production of these wastes is an integral part of industrial activities but unfortunately our inability to anticipate or predict the types and magnitude of undesired consequence of unbridled release of effluents in our environment, coupled with the growth of industrialization have resulted in massive and destructive operations in our ecosystem.

Effluent is a broad term that includes sewerage, sludge and wastewater from industrial plants, such as dairy factories and slaughter houses, and FDE. Recent publications have addressed aspects of effluent application, such as:

- the effects of industrial and sewerage effluents on soil biochemical properties (Spier 2002),
- the effects of dairy factory effluent on particular soil properties (Degens *et al.*, 2000; Cameron *et al.*, 2002, 2003), and
- the relationship between FDE application and groundwater quality (Particularly related to nitrate leaching (Di *et al.*, 1998a,b; close *et al.*, 2001 and Cameron *et al.*, 2002).

Although, industrial processes are desirable, at the same time, the serious and irreversible damage done to the environment through their apparently innocuous discharge of effluents are unquantifiable. Until now, effluents are discharged into rivers, estuaries, lagoons, or the sea without any form of treatment. However, despite the treatment being employed by some industries, it is still impossible to remove all undesirable properties from effluents.

In Nigeria today, the Federal Environment Protection Agency (FEPA) is doing everything to see that various industries comply with the standard required of their effluent before they are discharged into the environment (Uaboi–Egbenni *et al.*, 2009).

The ever increasing pressure of over exploitation of natural resources has affected severely the quality of environment (Sandeep, 2005). Environment pollution is becoming the global problem in which pollution is an important issue, as water is used directly for various purposes. Over the last few decades, a large scale usage of chemical in various human activities has grown very fast, particularly in a country like India, which has to go for rapid industrialization in order to sustain over growing large problem in area of health and sanitation.

Several carcinogenic and mutagenic compounds are found in human environment (Naik *et al.*, 2007). Majority of industries are water based and a considerable volume of waste water is discharged to the environment either treated or inadequately treated leading to the problem of surface and ground water pollution. The capital costs and operating wastewater treatment system are rising on one hand and on the other is pressing demand for the treatment of wastewater generated by increased residential and industrial development. In recent years, there has been an increased interest in alternative and innovative technologies which will prone to be low cost, low maintenance and energy efficient (Abrami *et al.*, 2005).

1.2 Statement of the problem

With the recent expansion of dairy farming, the disposal of farm dairy effluent (FDE) has become increasingly important. Current practice within the dairy farming sector is to dispose this effluent either through storage in effluent ponds and sporadic irrigation to land or through continual irrigation to land.

1.3 Objective of the study

- To investigate the effects of dairy effluent on soil properties.

1.4 Justification of the study

The purpose of this work is to address the effect of farm dairy effluent application on soil properties in the context of the Resources Management Art (RNA), which places an emphasis on sustainable environmental management and among other things, the safe-guarding of lives supporting capacity of water bodies and soil.

1.5 Scope of the study

This project is carried out to know the effects of dairy effluent on a particular soil type by collecting soil samples of the soil with effluent and without effluent (control). The study is limited to Maizube Farm in Niger State, Nigeria.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Farm Dairy

The very dilute mixture of water, urine, faeces is called dairy farm effluent (Barkle *et al.*, 2000). The dairy waste consists mainly of raw materials lost during handling and processing and cleaning materials carried into the processing water. The composition involves substantial concentration of fat, milk protein, lactose, lactic acid, minerals, detergents and sanitizers (www.dairyforall.com). Farm dairy effluent contains all the major elements required for plant growth and as such is a useful source of minerals (Longhurst *et al.*, 1999).

2.2 Oxidation Pond Effluent

In oxidation pond effluent, despite the general trend towards land-based irrigation systems for treating FDE, there are still significant numbers of dairy farmers operating the two-stage pond system (anaerobic followed by aerobic pond). For example, during 1996/97 about 35% of farms in the Waikato region were using this waste treatment system (Parminter 1998). The primary purpose of the ponds in treating FDE is to reduce the biological and chemical (especially N and P) impact on receiving waterways. The first stage of the process (in the anaerobic pond) involves the anaerobic decomposition of organic wastes. In the second stage (aerobic pond), micro-organisms and algae use the remaining minerals and the sun's energy to further reduce the oxygen demand of the effluent on the receiving water prior to discharge (Warburton 1977; Hickey *et al.*, 1989;Teranaki Regional Council, 1990, Grogan 1990, Selvarajah 1996).

Nutrient-rich farm-dairy effluent (FDE), which consists of cattle excreta diluted with wash-down water, is a by-product of dairy cattle spending time in yards, feed-pads, and the farm dairy.

Traditionally, FDE has been treated in standard two-pond systems and then discharged into a receiving fresh water stream. Changes brought about primarily due to the Resource Management Act 1991 of New Zealand have meant that most regional councils now prefer dairy farms to land treat their FDE. This allows the water and nutrients applied to land in FDE to be utilised by the soil-plant system. Research on the effects of land-treating FDE, and its effects on water quality, has shown that between 2 and 20% of the nitrogen (N) and phosphorus (P) applied in FDE is leached through the soil profile. In all studies, the measured concentration of N and P in drainage water was higher than the ecological limits considered likely to stimulate unwanted aquatic weed growth. Gaps in the current research have been identified with respect to the application of FDE to artificially drained soils, and the lack of research that has taken place with long term application of FDE to land and at appropriate farm scale with realistic rates of application. Whilst the land treatment of FDE represents a huge improvement on the loss of nutrients discharged to fresh water compared with standard two-pond systems, there is room for improvement in the management of FDE land-treatment systems. In particular, it is necessary to prevent the direct discharge of partially treated FDE by taking into account soil physical properties and soil moisture status. Scheduling effluent irrigations based on soil moisture deficits results in a considerable decrease in nutrient loss and may result in a zero loss of raw or partially treated effluent due to direct drainage (Houlbrooke *et al.*, 2004).

2.3 Dairy Waste Classification.

In United State of America, there are two types of dairies that Department of Natural Resources (DNR) regulates, cheese making and whey processing. These are few dairies that churn butter, bottled milk, produce ice cream and other dairy products, such as yoghurt, but except for two better manufacturers these dairies tend to discharge their waste water to publicly owned treatment works and are not directly regulated by DNR. Waste water generated during cheese making comes from washing of the cheese vats, the pipelines, milk separator, milk pasteurizer, the inside of the milk trucks, and other equipment. Most dairies use a "clean in pipe" (CIP) system which pumps cleaning solution through all equipment in this order; water rinse, caustic solution (sodium hydroxide) wash, water rinse, acid solution (phosphoric or nitric solution) wash, water rinse and sodium hypo-chlorite disinfectant (Tchbanologlous and Stenurel, 2003). The 5-days biochemical oxygen demand (BOD_5) is a measure of the organic pollutant concentration in the waste water and is proportional to the amount of milk or whey lost to the sewer. Normal dairy production plant waste water is in the range of 2000 to 3000mg/l which is 10 times the strength of domestic sewage. The BOD_5 can go much higher if a milk spill occurs and the pH can fluctuate widely if used CIP chemicals are carelessly discharged. It is important for dairies to manage their waste water discharge to avoid upsetting their biological treatment process (Matthew and Meyer, 2001).

2.4 Waste Characteristics

These agricultural wastes are characterized mainly by compound of carbohydrates, fats, proteins, cellulose, semi cellulose, and lignin. The waste is suitable for being degraded by micro-organisms except lignin which is resistant to microbial decay and only decomposable after pre-treatment. Liquid wastes containing dissolved organic solids, biological treatment is appropriate while solid waste with a high organic content are amendable to composting or incineration. Livestock wastes are solid, semi-solid, and liquid depending upon how the production operation is designed and operated. The characteristics of livestock wastes are affected by decision on how the wastes are to be handled (Obi and Ebo 1994).

2.5 Nutrient Value of Effluent

Dairy effluent is an asset that can either be utilized to its fullest potential or let go to waste. A nutrient budget can give the value of your effluent but the real savings only come from managing the distribution of the nutrients onto pasture. If this is done correctly, savings in fertilisers can give a return on investment that will more than pay for the cost of installing or upgrading an effluent system that works for your farm. A well designed system and management plan will enable as much as 80 to 90% retention of the nutrient value. A badly designed system and poor management can waste more than 50% of the nutrient value. A good effluent system is one of the few capital costs on a farm where you can get a return on your investment by savings made through cost reductions (i.e. fertiliser). As fertiliser becomes more expensive, the return on investment is greater. Farm dairy effluent offers a source of nitrogen (N), phosphorus (P), potassium (K) and sulphur (S), as well as trace elements to increase pasture or crop production. The organic matter in the effluent will also improve soil water holding characteristics, aeration and drainage, and will make soil less prone to compaction and erosion. The composition of effluent from the farm dairy is extremely variable. This variation arises from differences in the actual nutrient content of the faeces and urine (varies with diet, age and season), as well as the amount of washdown water used at the farm dairy which dilutes the effluent. The nutrient composition of effluent also changes during storage (http:// www.dairy.nz/file/field/29052).

2.6 Elements in Dairy Effluent

2.6.1 Nitrogen

Nitrogen conversions and losses from dairy effluent vary depending on the amount excreted from animals, exposure to the atmosphere before suspension in water, the time the effluent is held in storage ponds and the method of land application. Accordingly, these conversions and losses vary significantly between dairy farms and are difficult to quantify, so data must therefore be seen as indicative only (www.dairyfortomorrow.com).

2.6.2 Phosphorus

Minimal Phosphorus is lost throughout collection and conveyance of dairy effluent, and it can be assumed that all phosphorus collected will be available for reuse, providing that solids from separation, sludge from effluent ponds and liquid effluent are all considered. The quantity of phosphorus within dairy effluent will vary with location and feed type, and particularly with dietary P forms and levels (Ebeling *et al.* 2003).

2.6.3 Potassium

Typically, dairy pastures and supplementary feeds contain between 1% and 3% of their total dry matter (DM) as K. However, the quantity of potassium (K) within dairy effluent will vary with location and feed type and quantities (Ebeling *et al.* 2003). Small amounts of K are exported in milk, and the remainder is passed out in excrement. Minimal potassium is lost throughout collection and conveyance of dairy effluent on the farm, and it can be assumed that most potassium collected will be available for reuse.

2.6.4 Sodium

In relation to sodium, the suitability of water for application to land should be evaluated on the basis of a range of criteria that indicate the potential of the water to harm plant growth or to create soil conditions hazardous to plant growth or to animals or humans in contact with the plants or soil (ANZECC & ARMCANZ, 2000). Dairy effluent sodicity levels are assessed through calculation of the sodium adsorption ratio (SAR), which is a measure of the amount of sodium present in the effluent relative to calcium plus magnesium (Rengasamy and Olsson, 1993).

2.6.5 Trace element and contaminant excess

Care is required in the application of dairy effluent to land, because trace elements (copper, zinc etc.), heavy metals (cadmium, arsenic, chromium, mercury etc.), therapeutic compounds and organic materials from pesticides can occur in dairy effluent (McBride and Spiers, 2001, Wang *et al.*, 2004). Although most dairy effluent is unlikely to have excess concentrations of these contaminants, an excess build-up can result in the over-application of these to land and a subsequent build-up in the soil. When trace element or contaminant levels in a soil become excessive, there is the potential for impacts on productivity and the environment, and the risk of plant and animal uptake to levels that can pose a threat to the health of stock or humans. Bolan *et al.* (2003) found that in New Zealand, metals, and especially Zn and Cu, in dairy effluent originated from feed or therapeutic treatments, especially from feed additives and growth promoters.

A study by McBride and Spiers (2001) of both liquid and solid dairy manures in New York state, USA, indicated that concentrations of heavy metals such as cadmium, lead and mercury were low and that those of Cu and Zn were elevated. They concluded that although a significant proportion of Cu and Zn could be attributed to feed additives, some could be attributed to contamination of the manure by soil or other wastes (feed, bedding, therapeutics etc).

2.7 Managing trace elements in dairy effluent

Apart from monitoring of dairy effluent trace element and containment levels before land application and adherence to the thresholds no guidelines were found for the management of trace elements and containments, especially Cu and Zn, in dairy effluent. Practices that minimise the addition or accumulation of these constituents to dairy effluent in the first place are probably the best course of action, but these may not always be practical. Dilution of effluent may be another option. More research is required to determine thresholds for trace elements and contaminants in dairy effluent that is to be applied to land to avoid the development of adverse impacts (www.dairyfortomorrow.com).

2.8 Soil Physical Properties

As in the Cameron *et al* (2003) example, effluent irrigation has been linked to changes in hydraulic conductivity. Irrigation with slaughterhouse effluent has been observed to enhance clay aggregation (Churchman and Tate 1986), while the irrigation of a range of organic wastes, such as compost, sawdust, and poultry manure onto tropical soils, resulted in increases in total porosity, macroporosity, saturated hydraulic conductivity, and water retention (Mbagwu 1989). Similarly, the addition of sewerage sludge and compost to an Italian sandy loam increased total porosity and the stability of soil aggregation (Pagliai *et al.*, 1981). Likewise, the irrigation of dairy factory effluent affected a range of physical properties of Horotiu and Te Kowhai soils: the hydraulic conductivity of both soils was increased; the bulk density of the Horotiu soils decreased, whereas the Te Kowhai soils exhibited no change; and the macroporosity of both soils was not affected (Sparling *et al.*, 2001). A decrease in soil hydraulic conductivity and a change in micropore and macropore flow, due to aggregate collapse (Menneer *et al.*, 2001); or no change in soil physical properties, presumably due to only short-term effluent irrigation (Spier *et al.*, 1999). Other soil physical properties can also be affected, particularly by long-term effluent application. For example, effluent irrigation can decrease soil bulk density (Bernal *et al.*, 1992; Sparling *et al.*, 2001); however, changes in soil physical properties are difficult to quantify because they tend to occur only over the long term and soil physical properties are notoriously variable and difficult to measure with a high degree of accuracy, repeatability and precision. The measurement issue is particularly problematic if the experimental approach is one of an "affected" site and a "control" site. In addition, there may be seasonal variation in soil physical properties and the effects of FDE irrigation have to be separated from the effects of stock management (Monagahan *et al.*, 2005).

2.9 Soil Biological Properties

Changes in soil chemical and physical properties are affected by and affect soil biological properties. The mineralisation of FDE results from a sequence of different microbial and extracellular enzyme activities; hence, the microbial turnover of FDE is affected by the FDE loading rate (Barkle *et al.*, 2000, 2001). Not only is the total soil microbial biomass affected by FDE, but also the addition of readily available C can result in a more diverse and dynamic microbial system than inorganically fertilized soil (Peacock *et al.*, 2001). Ghani *et al.*, (2005) further showed that regular applications of dairy factory effluent encouraged nitrogen immobilization, particularly at low temperatures because the regular supply of soluble carbon prolonged microbial immobilization; however, at higher temperatures enhanced soil microbial activity may respire most of the carbon within a short time and therefore minimize the negative effects on nutrient availability for plant growth.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The study was carried out in Maizube farm along Minna-Bida Road, Niger State, Nigeria. Maizube farm falls within Bosso Local Government Area with latitude $9^0 37^I$N and longitude $6^0 30^I$E having an average temperature range of 24°C to 30°C. The climate is sub-humid tropical with mean annual rainfall of about 1200 mm (90% of the rainfall is between June and August). The study area is predominately sandy clay type of soil as shown in table 3.1 and the study sites are areas with dairy effluent that is used for banana plantation, and control for cultivating maize. The effluent was released into an oxidation pond and being discharged to the field after getting to a certain level through an outlet as shown in plate 3.1. The land application of FDE started about 7 years ago.

Table 3.1: Particle size distribution of the test soil.

Sample label	Sand (%)	Silt (%)	Clay (%)	Textural class
A1	48.12	13.00	38.88	Sandy Clay
A2	47.07	12.57	40.36	Sandy Clay
A3	43.32	16.50	40.18	Sandy Clay
B1	51.15	12.26	36.59	Sandy Clay
B2	50.40	10.33	39.27	Sandy Clay
B3	49.72	10.20	40.08	Sandy Clay

A - Soil treated with dairy effluent.

B - Soil not treated with effluent (control).

Plate 3.1 Pond containing effluent

3.2 Materials

Soil auger, Metre rule, Nylon and Marker.

3.3 Procedure for Samples Collection

Materials such as metre rule, nylon (black and white), marker and soil auger were used for the collection of the soil samples. Before the collection of the soil samples, the soil auger was marked out with the marker and a total numbers of six soil samples were collected with the aid soil auger of which three soil sample were taken randomly on each portion of land between 0-40cm depth at different points and released every sample into the labeled nylon for easy identification. It was ensured that each location at which soil samples were being taken was away from disturbed area such as gateway and was not taken immediately after cultivation (Plate 3.2).

Plate: 3.2 Collection of soil samples

3.4 Determination of Chemical Properties

3.4.1 Determination of soil pH

Apparatus

Glass electrode, pH meter, paper portion cups, stirring rod, washing bottle.

Reagent

0.01M ($CaCl_2$) and standard buffer solution 4 and 7.

Procedure

10g of air dried 2mm sieved soil was weighed in duplicate into paper portion cups. Into one, 25ml distilled water was added and 25ml of 0.01M $CaCl_2$ added into the other. They were stirred for 1minute and left for 15minutes and stirred again for 1minute and after 15minutes standing the pH was read on the pH meter by inserting the electrode into the soil suspension. The pH meter before usage was standardized with buffer solution of pH 4 and 7.

3.4.2 Determination of phosphorus

Apparatus

Centrifuge, mechanical shaker, centrifuge tubes, measuring cylinder, volumetric flasks, pipette, spectrophotometer, weighing balance.

Reagent:

1M Ammonium floride (NH_4F), 0.5N hydrochloric acid (HCL), Ammonium molybdate ($(NH_4)_6MO_7O_{24}.4H_2O$), stannous chloride ($S_nCl_2.2H_2O$) and distilled water.

Procedure

1g of air dried 2mm sieved soil was weighed into a centrifuge tube and 7ml of the extracting solution (ammonia Flouride and hydrochloric acid) added, shaking for 1 minute on a mechanical shaker and then centrifuged at 2000r.p.m taken for 15 minutes. 2ml of clear supernatant was then taken into a test tube. 5ml of distilled water and 2ml of ammonium molybdate were added and mixed properly.1ml of stannous chloride solution was added and mixed thoroughly again. After 5 minute but not later than 20 minutes, absorbance was read on the spectrophotometer at 660nm wavelength. A blank was prepared without soil sample.

3.4.3 Determination of exchangeable bases (Ca^{2+}, Mg^{2+}, Na^+, K^+)

Extraction of the cations from soil.

Apparatus

Volumetric flask, filter paper, suction pump, Buchner funnel, weighing balance.

Reagent

IN ammonium acetate (NH_4OAC) and distilled water.

Procedure:

10g of air-dried 2mm sieved soil was weighed into a volumetric flask, and 40ml of NH_4OAC was added. It was covered and left to stand overnight. The suspension was then leached with more NH_4OAC to a mark of 100ml using the suction pump filted with a Buchnnel funnel lined with filter paper.

3.4.4 Determination of sodium and potassium in soil extract

Apparatus

Flame photometer

Procedure

The flame photometer was standardized with Na standard of 0, 20, 40, 60, 80, and 100MgL^{-1} after which the concentration of Na in the soil extract was read on the flame photometer. The photometer was also standardized with K^{+1} standard of 0, 10, 20, 30, 40 and 50 MgL^{-1} after which the concentration of K^{+} in the soil extract was read on the flame photometer.

3.4.5 Determination of calcium and magnesium in the soil extract (Complexometric titration with EDTA disodium salt)

Apparatus

Volumetric flask, burette, pipette, measuring cylinder and retort stand

Reagent

0.01M ethylene diamine tetra acetic acid disodium salt (EDTA disodium), Ammonium chloride-ammonium solution ($NH_4Cl.NH_4OH$), 10% sodium hydroxide solution (NaOH), 4% potassium ferrocyanide (KFeCN), 1% potassium cyanide (KCN), 5% Hydroxyl amine hydrochloride (NH-$_2$OH.HCl), Erichrome Black T indicator, Murexide indicator, Ethyl alcohol

Procedure

25ml of extract were taken in duplicate and distilled water to the 150ml mark. 25ml of extracting solution (NH_4OAC) was taken as blank for soil extract. The soil extract blank was also made up of 150ml mark with distilled water. 10 drops each of KCN, KFeCN and $NH_2OH.HCl$ were then added to all the flasks and were then left to stand for 30minutes.

In the first set of flasks, for magnesium determination 15ml of $NH_4Cl.NH_4OH$ was added and 4 to 5 drops Erichrome Black T indicator and titrated with EDTA disodium salt solution.

In the second set of flask for calcium determination 10ml of NAOH was added with a little of murexide indicator and titrated with EDTA disodium salt.

3.4.6 Determination of total nitrogen

Apparatus:

Digestion apparatus, digestion flask, measuring cylinder, distillation flask, burette, pipette, volumetric flask, measuring cylinder, weighing balance and tripod stand.

Reagent:

0.01N sulphuric acid (H_2SO_4), selenium (Se), potassium sulphate (K_2SO_4) boric acid mixed indicator, 10N sodium hydroxide (NaOH), 20% boric acid (HBO_3) indicator solution, bromocresol green and methyl red indicators, ethanol.

Procedure

0.2g of air-dried 0.5mm sieved soil was weighed into digestion flask and few drops of distilled water was added and allowed to stand for 30 minutes. 5g of catalyst mixture (K_2SO_4 plus selenium powder) was added together with 15ml of concentrated H_2SO_4. The digestion flask was then heated for about 2 hours until when the digestion was clear. After cooling the flask, a little distilled water was added and the content was into a 100ml volumetric flask and then distilled water added to make up to mark. 10ml of the digest was then taken into a distillation flask. 10ml of 2% HBO_3 was taken into a flask and placed under the condenser of the distillation apparatus. 10ml of 10N NaOH was added to the 10ml digest in the digestion flask and the distillation process carried out until the distillate reaches 35ml mark of the HBO_3 flask. This distillate was then titrated with 0.01N H_2SO_4. A blank was run without soil sample.

3.4.7 Determination of copper, zinc and iron

Apparatus

Beakers, 150ml capacity (glass or Teflon)

Reagents

Nitric acid (HNO_3) concentrate, perchloric acid ($HClO_4$) concentrate and hydrochloric acid (HCl) 0.1M

Procedure

2g of air-dried soil was weighed into 150ml beaker and 20ml concentrate HNO_3 was added and the mixture was allowed to stand for 1hour and 15ml of concentrated $HClO_4$ was carefully added. Digestion on hot plate at about 200-225^{0}C until the mixture turns yellow then the digest was dissolved in 0.1M HCl and was filtered into a 250ml volumetric flask and made up to mark. Afterwards the various elements in the extract were determined by using atomic absorption spectroscopy method.

3.4.8 Determination of Electrical Conductivity

Reagent

Distilled or deionised water

Procedure

Prepare a 1:5 soil:water suspension by weighing 10 g air-dry soil (<2 mm) into a bottle. Add 5 mL deionised water. Mechanically shake at 15 rpm for 1 hour to dissolve soluble salts. Calibrate the conductivity meter according to the manufacturer's instructions using the KCl reference solution to obtain the cell constant. Rinse the cell thoroughly. Measure the electrical conductivity of the 0.01M KCl at the same temperature as the soil suspensions. Rinse the conductivity cell with the soil suspension. Refill the conductivity cell without disturbing the settled soil. Record the value indicated on the conductivity meter. Rinse the cell with deionised water between samples.

3.4.9 Determination of Organic Carbon

Apparatus

0.5mm sieve, weighing balance, burette, pipette, measuring cylinder and conical flask.

Reagents

1N $K_2Cr_2O_7$, 0.5N $FeSO_4$, H_2O, Barium diphenylamine sulphonate indicator, concentrated H_2SO_4

Procedure

1g of 0.5mm sieve soil was weighed and into a 250ml conical flask with the aid of a pipette, 10ml of 1N $K_2C_{r2}O_7$ solution was added to the soil sample and swirled. 20ml of concentrated H_2SO_4 was carefully added to the soil sample and allowed to cool.

After cooling, 100ml of distilled water was added to the sample. A blank was also prepared in the same way but without the soil sample 4-5drops of barium diphenylamine sulphonate indicator was added to the solution and solution was titrated using 0.5N $FeSO_4$ to a greenish cast end point.

3.4.10 Determination of Organic Matter

Organic matter =Organic carbon ×1.724. "Van Bernmelen" factor. (1)

3.4.11 Determination of Sodium Adsorption Ratio (SAR)

$$SAR = [Na^+]/(([Ca^{2+}]+[Mg^{2+}])/2)^{1/2} \quad (2)$$

Where;

Na=Sodium concentration (conc.)(Meq/L) = (Mg/L in effluent)/22.97

Ca=Calcium concentration (conc.)(Meq/L) = (Mg/L in effluent)/(40.08×0.5)

Mg=Magnesium concentration (conc.)(Meq/L) = (Mg/L in effluent)/(24.32×0.5)

3.5 Determination of soil physical properties

3.5.1 Soil moisture content

The direct method (gravimetric method) which is the most widely used and simplest method for measuring soil moisture content was adopted. The apparatus such as core rings, electric weighing balance, electric oven, and desiccators were used. Soil samples were collected from the field into core and covered immediately, the soil was weighed using an electric weighing balance. The soil samples were transferred into an oven and set at 105°C while the covers of the cores were removed. The soil samples were allowed to oven dry in the oven for about 24hours. The soil samples were then transferred into a dessicator and allowed to cool and weighed again after cooling to obtain oven dry weight. The soil moisture content is expressed as;

Soil moisture content by weight (%) =

$$\frac{[(weight\ of\ wet\ soil + core) - (weight\ of\ dry\ soil + core) \times 100]}{[(weight\ of\ dry\ soil + core) - core]} \quad (3)$$

3.5.2 Bulk density

Bulk density was determined using the apparatus such as bulk density sampler, core ring, weighing balance, electric oven and moisture can. The core soil samples were collected with the bulk density sampler, the wet soil samples were weighed, the height and cross sectional area of the ring was measured. The soil samples were transferred into moisture can and oven dried at temperature of about 105°C for 24hours. The oven dry weights were recorded. Bulk density is expressed as;

$$Bulk\ Density(\mathrm{g\ cm^{-3}}) = \frac{[weight\ of\ ovendried\ soil(g)]}{[Field\ Volume\ of\ the\ Sample(cm^3)]} \quad (4)$$

3.5.3 Particle density

Particle density was determined using pyenometer, hot plate, electronic weighing balance, spatula and distilled water as reagent. The pyenometer bottle was weighed empty. 10g of 2mm sieved soil was weighed and transferred into the pyenometer bottle, the bottle and soil was weighed, the bottle and soil was half filled with water and boiled on a hot plate to expelled the entrapped air, boiling was continued for the next 10minutes, the bottles and soil was then filled with water and the lid inserted into it. The bottle, soil and water were then weighed. The entire sample was discarded and the bottled was then filled with only water and weighed, the density of water at the observed temperature was taken. Particle density was then calculated using the relation;

$$D_p = \frac{dw(Wps-Wpa)}{\{(Wps-Wpa)-(Wpsw-Wpw)\}} \qquad (5)$$

Where;

Dp = particle density

dw = Density of water at observed temperature

Wps = weight of pyenometer plus soil sample

Wpa = weight of pyenometer filled with air

Wpsw = weight of pyenometer filled with soil and water

Wpw = weight of pyenometer filled with water at observed temperature

3.5.4 Porosity

The porosity of the soil samples were obtained from the values of the bulk densities using the expression;

$$Porosity(\%)(void\ ratio) = 1 - \left[\frac{Bulk\ Density}{Particle\ Density}\right] \times 100 \qquad (6)$$

3.5.5 Hydraulic conductivity

After the collection of the soil samples from the field by using the core rings. Core rings of known diameter and height were used in collecting the samples. Hydraulic conductivity was determined using core ring, bowl, electrical weighing balance, 10ml and 100ml measuring cylinder, retort stand and reagent such as distilled water. Using the Constant-Head Permeability apparatus for undisturbed soils, the core rings with the soil samples covered at one end by white cloth fastened with rubber band were subjected into a bowl of water in order to saturate. After 24 hours, the soil samples were removed from and allowed to drain for some couples of minutes. Each of the core ring with soil sample was held vertically with the clamp on a retort stand and another core ring was placed on it, fastened with cellotape and beaker was placed at the based. 10ml of water was added through the upper core ring, stop watch started to count immediately and at every 5minutes, the beaker is removed and readings was taken with the aid of 10ml measuring cylinder to take the readings. Calculate hydraulic conductivity (K) using the formular:

$$K = \frac{QL}{HAT} \qquad (7)$$

Where;

K = Hydraulic Conductivity (cm/sec)

Q = Quantity of water conducted

L = length of the two cores (cm)

H = Difference in pressure head (cm)

T = Time interval (min)

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Presentation of Results

The Physical and Chemical Properties of the study site is presented in table 4.1. The data collected were analysed using descriptive statistics and paired-sample T test.

Table 4.1 Physical and Chemical Properties of soil treated with dairy effluent and control

Parameter	With effluent (sample A)			Mean	Control (sample B)			Mean	Sig.(2-tailed)
pH in water	6.7	6.2	6.3	6.40	6.9	6.8	6.6	6.8	.093
pH in $CaCl_2$	5.2	5.1	5.8	5.37	5.8	6.1	6.0	5.97	.122
Organic Carbon (%)	1.22	1.92	0.72	1.29	0.53	0.78	1.26	0.86	.482
Organic Matter (%)	2.10	3.31	0.72	2.04	0.91	1.34	2.17	1.47	.637
Total Nitrogen (%)	0.30	0.40	0.25	0.32	0.42	0.31	0.28	0.34	.774
Sodium (Cmol/Kg)	0.65	0.61	0.64	0.63	0.59	0.38	0.74	0.57	.575
Potassium (Cmol/Kg)	1.01	1.04	0.89	0.98	1.92	0.84	1.00	0.92	.576
Magnesium (Cmol/Kg)	2.00	1.50	1.80	1.57	0.80	0.80	0.60	0.73	.046*
Calcium (Cmol/Kg)	2.40	2.50	1.80	2.23	0.80	1.20	0.60	0.87	.008*
Eectrical Conductivity (dS/m)	0.21	0.25	0.28	0.25	0.23	0.10	0.26	0.19	.378

AvailP (Mg/Kg)	8.04	7.15	7.74	7.64	8.34	6.96	11.32	8.87	.408
Zinc (Mg/Kg)	9.10	8.70	6.40	8.07	10.10	7.20	[illegible]	[illegible]	[illegible]
Copper (Mg/Kg)	3.37	1.95	1.60	2.31	4.63	0.95	3.82	3.13	.478
Iron (Mg/Kg)	31.50	28.10	17.20	25.60	22.30	18.20	19.20	19.90	.277
SAR	0.07	0.08	0.09	0.08	0.11	0.07	0.16	0.11	.289
Moisture Content (%)	49.98	29.84	34.62	37.81	26.19	18.10	29.34	24.54	.122
Bulk Density (g/cm^3)	1.11	1.42	1.36	1.30	1.44	1.65	1.46	1.52	0.81
Particle Density (g/cm^3)	2.12	2.11	2.11	2.11	2.02	2.09	2.02	2.04	.109
Porosity (%)	47.64	32.70	35.55	38.63	28.71	21.05	27.72	25.83	0.59
Hydraulic Conductivity (cm/min)	0.015	0.014	0.016	0.015	0.015	0.015	0.015	0.015	.916

Where *Significant at $P < 0.05$

4.2 Discussion of Results

4.2.1 Soil Chemical Properties

Soil pH

The soil pH reaction in water is slightly acidic, in $CaCl_2$ is strongly acidic for sample A, while the soil pH in water and in $CaCl_2$ for sample B both are moderately acidic respectively according to USDA soil rating but the pH both samples is insignificant. The pH within the range 6 and 7.5

is required for the proper plant growth. In case of banana, it will grow in most soil, but to thrive, they should be planted in a rich, well drained soil and they prefer an acid soil with a pH between 5.5 and 6.5. From the result, the pH is averagely alright for the plant growth.

Organic carbon

Soil organic carbon measured in percentage, the result on both the sites, irrigated with effluent and the control is high since values are greater than 0.75 (FAO, 1974) which is higher on soil with effluent and the two samples have insignificant differences.

Organic Matter

Organic matter for sample A with 2.04% is very high and for sample B with 1.47% is moderate as stated by USDA soil rating and the organic matter for the two samples have insignificant differences.

Total Nitrogen

Nitrogen is one of the essential elements for plant growth and development and is present in dairy effluent. From the results, land irrigated with dairy effluent is 0.32% and control is 0.34% while by the USDA standard (>0.300%), they are both very high with insignificant differences.

Available Phosphorous

From the result, the available phosphorous for the area with effluent is 7.64mg/kg and the control site phosphorous is 8.87mg/kg, which is moderate, falling within the range of 7-20mg/kg according to USDA soil standard rating and with insignificant difference.

Exchangeable Cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+})

The results show that potassium with 0.98Cmol/kg and 0.92Cmol/Kg is high, calcium with 2.23Cmol/Kg is low and 0.87Cmol/Kg is very low, magnesium with 1.56Cmol/Kg is moderate and 0.73Cmol/Kg is low and sodium with 0.63Cmol/Kg and 0.57Cmol/Kg is moderate for sample A and B respectively based on USDA soil rating. While sample A and B for sodium and potassium is with insignificant differences, calcium and magnesium have significant differences ($P < 0.05$). Magnesium was elevated in the effluent treated soil and significantly different from that in the control soil. Similarly, calcium in the effluent treated soil was significantly different from that from the control soil at $P < 0.05$. The elevated values of both magnesium and calcium in the dairy effluent treated soil is in agreement with previous works that effluent irrigation can increase soil exchange capacity and/or exchangeable cations (K, Na, Ca, Mg) (Bernal *et al.*, 1992, Tomer *et al.*, 1997, Menner *et al.*, 2001, Hawke and Summers, 2003).

Trace Elements (Cu^{2+}, Fe^{2+}, Zn^{2+})

The results of the analysis shows that there were no significant differences between the trace elements in the effluent treated soil and the control site. However, while Zn and Cu decreased in magnitude in the treated soil, Fe increased in magnitude. This could be attributed to the scraping and conveyance systems for the effluent, which are made of iron.

Electrical conductivity

Electrical conductivity with 0.25dS/m for sample A and 0.195dS/m for sample B are low according to USDA soil standard rating and both samples have insignificant differences. The effluent does not pose any salinity hazard to the soil. However, continuous monitoring is advised to ensure that the permissible limit is not exceeded with time.

Sodium Adsorption Ratio (SAR)

Sodium hazard is usually expressed in terms of sodium adsorption ratio (SAR) as given in equation (2). The SAR values ranged from 0.07- 0.11 for the control and from 0.07 – 0.09 in the effluent treated soil. These values fall far below the permissible limit, and therefore pose no sodium hazard to the soil. The elevated values of both calcium and magnesium in the effluent treated soil counteracted the presence of the relatively high sodium in the effluent treated soil to reduce the SAR value.

4.2.2 Soil Physical properties

It was observed from Tables 4.1 that the moisture content, bulk density, particle density, porosity and hydraulic conductivity for sample A have mean values of 37.81%, 1.30g/cm^3, 2.11g/cm^3, 38.63% and 0.015cm/min, respectively with insignificant differences, while that of sample B have mean values are 24.54%, 1.52g/cm^3, 2.04g/cm^3, 25.83% and 0.015cm/min for moisture content, bulk density, particle density, porosity and hydraulic conductivity, respectively with insignificant differences. Although Mathan (1994) noted an increase in hydraulic conductivity, most researchers have observed a decrease in hydraulic conductivity with effluent (Clanton and Slack 1987, Cook *et al.*, 1994, Magesan *et al.*, 1998). The effect of land application of FDE on the hydraulic conductivity of soil is not clearly understood. There are two mechanisms suggested for a decrease in hydraulic conductivity which are; biological clogging of soil pores by microbial growth and the production of extra-cellular carbohydrate (Magesan *et al.*, 1999). If FDE application decreases hydraulic conductivity, this will affect the soil chemical properties and increase the potential for overland flow. Soil physical properties can be affected, particularly by long-term effluent application. The result of this study (Table 4.1) shows that effluent decreased bulk density from 1.52g/cm^3 to 1.30 g/cm^3, and the percentage of the moisture content at effluent area was also higher than the control. This may be as a result of increase in organic matter content. These results are in agreement with earlier findings (Bernal *et al.*, 1992; Sparling *et al.*, 2001). Generally, changes in soil physical properties are difficult to quantify because they tend to occur only over the long term and soil physical properties are notoriously variable and difficult to measure with a high degree of accuracy, repeatability and precision.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

From this research work, it can be concluded that the sample area at the Maizube farm having effluent is not significantly different from those not having effluent except for the elements Magnesium and Calcium. This is supported by the fact that cow milk which is part of what effluent contains is constituted of calcium and magnesium. Although no significant difference was noticed in other tested soil physical and chemical properties at the maizube farm, it can be noticed from table 4.1 that soils with effluent has higher value for organic matter, organic carbon, sodium, potassium, calcium, magnesium, electrical conductivity, iron, moisture content, and particle density.

From the literature reviewed, most researchers reported that the physical and chemical properties of the soil can be affected positively by the application of dairy effluent in enriching the soil by increasing soil nutrient in term of properties such as sodium, potassium, phosphorus, magnesium, calcium, organic carbon and organic matter. The reason for the difference in result obtained from this research is thought to be due to the following:

1. The land without effluent been cultivated for maize each year and fertilizer application is being used on the soil. This might have increased the total nitrogen and phosphorus of the soil.
2. Due to much water being used in washing animal waste, leaching of the nutrient down the soil could have occurred and thus be the reason for the lower value for nitrogen, zinc, copper and phosphorus observed.

5.2 Recommendations

Breeds of cow are different and such could be the richness of their effluent materials, for this reason, it is recommended that difference in the richness of the cow milk be examined as to be able to compare it with result obtainable from different effluent site, that gave reports different from the one obtained from this research work.

Similar research should be done on the soil of the same soil property type that has not been in use over a year with the same crop planted on it.

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APPENDICES

Appendix: 1 Statistical Analysis of Chemical Properties

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T-TEST PAIRS=pH CaCl OC OM TN Na K Mg Ca EC AvailP Zn Cu Fe SAR WITH pH2 CaCl2 OC2 OM2 TN2 Na2
K2 Mg2 Ca2 EC2 AvailP2 Zn2 Cu2 Fe2 SA
   R2 (PAIRED)
  /CRITERIA= CI(.9500)

  /MISSING=ANALYSIS.
```

T-Test

```
[DataSet0]
```

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	pH in water (Sample A)	6.4000	3	.26458	.15275
	pH in water (Sample B)	6.7667	3	.15275	.08819
Pair 2	pH in CaCl (Sample A)	5.3667	3	.37859	.21858
	pH in CaCl (sample B)	5.9667	3	.15275	.08819
Pair 3	Organic Carbon (%) (Sample A)	1.2867	3	.60277	.34801
	Organic Carbon (%) (Sample B)	.8567	3	.37099	.21419
Pair 4	Organic Matter (%) (Sample A)	2.0433	3	1.29593	.74821
	Organic Matter (%) (Sample B)	1.4733	3	.64049	.36979
Pair 5	Total Nitrogen (%) (Sample A)	.3167	3	.07638	.04410
	Total Nitrogen (%) (Sample B)	.3367	3	.07371	.04256
Pair 6	Sodium (Cmol/Kg) (Sample A)	.6333	3	.02082	.01202
	Sodium (Cmol/Kg) (Sample B)	.5700	3	.18083	.10440
Pair 7	Potassium (Cmol/Kg) (Sample A)	.9800	3	.07937	.04583
	Potassium (Cmol/Kg) (Sample B)	.9200	3	.08000	.04619
Pair 8	Magnesium (Cmol/Kg) (Sample A)	1.5667	3	.40415	.23333
	Magnesium (Cmol/Kg) (Sample B)	.7333	3	.11547	.06667
Pair 9	Calcium (Cmol/Kg) (Sample A)	2.2333	3	.37859	.21858
	Calcium (Cmol/Kg) (Sample B)	.8667	3	.30551	.17638
Pair 10	E/C (µS/cm) (Sample A)	2.4967E2	3	32.00521	18.47822
	E/C (µS/cm) (Sample B)	1.9367E2	3	85.50049	49.36373
Pair 11	Avail P (Mg/Kg) (Sample A)	7.6433	3	.45281	.26143
	Avail P (Mg/Kg) (Sample B)	8.8733	3	2.22839	1.28656
Pair 12	Zinc (Mg/Kg) (Sample A)	8.0667	3	1.45717	.84130
	Zinc (Mg/Kg) (Sample B)	8.5333	3	1.46401	.84525
Pair 13	Copper (Mg/Kg) (Sample A)	2.3067	3	.93735	.54118
	Copper (Mg/Kg) (Sample B)	3.1333	3	1.93371	1.11643
Pair 14	Iron (Mg/Kg) (Sample A)	25.6000	3	7.47061	4.31316
	Iron (Mg/Kg) (Sample B)	19.9000	3	2.13776	1.23423
Pair 15	SAR (Sample A)	.0800	3	.01000	.00577
	SAR (Sample B)	.1133	3	.04509	.02603

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	pH in water (Sample A) & pH in water (Sample B)	3	.619	.575
Pair 2	pH in CaCl (Sample A) & pH in CaCl (sample B)	3	.058	.963
Pair 3	Organic Carbon (%) (Sample A) & Organic Carbon (%) (Sample B)	3	-.571	.613
Pair 4	Organic Matter (%) (Sample A) & Organic Matter (%) (Sample B)	3	-.676	.527
Pair 5	Total Nitrogen (%) (Sample A) & Total Nitrogen (%) (Sample B)	3	.015	.991
Pair 6	Sodium (Cmol/Kg) (Sample A) & Sodium (Cmol/Kg) (Sample B)	3	.784	.427
Pair 7	Potassium (Cmol/Kg) (Sample A) & Potassium (Cmol/Kg) (Sample B)	3	-.945	.212
Pair 8	Magnesium (Cmol/Kg) (Sample A) & Magnesium (Cmol/Kg) (Sample B)	3	.786	.425
Pair 9	Calcium (Cmol/Kg) (Sample A) & Calcium (Cmol/Kg) (Sample B)	3	.836	.370
Pair 10	E/C (µS/cm) (Sample A) & E/C (µS/cm) (Sample B)	3	.164	.895
Pair 11	Avail P (Mg/Kg) (Sample A) & Avail P (Mg/Kg) (Sample B)	3	.480	.681
Pair 12	Zinc (Mg/Kg) (Sample A) & Zinc (Mg/Kg) (Sample B)	3	.273	.824
Pair 13	Copper (Mg/Kg) (Sample A) & Copper (Mg/Kg) (Sample B)	3	.520	.652
Pair 14	Iron (Mg/Kg) (Sample A) & Iron (Mg/Kg) (Sample B)	3	.494	.671
Pair 15	SAR (Sample A) & SAR (Sample B)	3	.554	.626

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
pH in water (Sample A) - pH in water (Sample B)	-.36667	.20817	.12019	-.88378	.15045	-3.051	2	.093
pH in CaCl (Sample A) - pH in CaCl (sample B)	-.60000	.40000	.23094	-1.59366	.39366	-2.598	2	.122
Organic Carbon (%) (Sample A) - Organic Carbon (%) (Sample B)	.43000	.86966	.50210	-1.73034	2.59034	.856	2	.482
Organic Matter (%) (Sample A) - Organic Matter (%) (Sample B)	.57000	1.79232	1.03479	-3.88236	5.02236	.551	2	.637
Total Nitrogen (%) (Sample A) - Total Nitrogen (%) (Sample B)	-.02000	.10536	.06083	-.28172	.24172	-.329	2	.774
Sodium (Cmol/Kg) (Sample A) - Sodium (Cmol/Kg) (Sample B)	.06333	.16503	.09528	-.34661	.47328	.665	2	.575
Potassium (Cmol/Kg) (Sample A) - Potassium (Cmol/Kg) (Sample B)	.06000	.15716	.09074	-.33041	.45041	.661	2	.576
Magnesium (Cmol/Kg) (Sample A) - Magnesium (Cmol/Kg) (Sample B)	.83333	.32146	.18559	.03479	1.63187	4.490	2	.046
Calcium (Cmol/Kg) (Sample A) - Calcium (Cmol/Kg) (Sample B)	1.36667	.20817	.12019	.84955	1.88378	11.371	2	.008
E/C (µS/cm) (Sample A) - E/C (µS/cm) (Sample B)	5.60000E1	86.23804	49.78956	-158.22717	270.22717	1.125	2	.378
Avail P (Mg/Kg) (Sample A) - Avail P (Mg/Kg) (Sample B)	-1.23000	2.04985	1.18348	-6.32212	3.86212	-1.039	2	.408
Zinc (Mg/Kg) (Sample A) - Zinc (Mg/Kg) (Sample B)	-.46667	1.76163	1.01708	-4.84279	3.90946	-.459	2	.691
Copper (Mg/Kg) (Sample A) - Copper (Mg/Kg) (Sample B)	-.82667	1.65316	.95445	-4.93334	3.28001	-.866	2	.478
Iron (Mg/Kg) (Sample A) - Iron (Mg/Kg) (Sample B)	5.70000	6.67757	3.85530	-10.88801	22.28801	1.478	2	.277
SAR (Sample A) - SAR (Sample B)	-.03333	.04041	.02333	-.13373	.06706	-1.429	2	.289

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ET NAME DataSet0 WINDOW=FRONT.
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ndix: 2 Statistical Analysis of Physical Properties

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Paired Samples Statistics

	Mean	N	Std. Deviation	Std. Error Mean
moisture content for sample A	37.8133	3	9.96157	5.75132
moisture content for sample B	24.5433	3	5.79811	3.34754
hydraulic conductivity for sample A	.015100	3	.0007000	.0004041
hydraulic conductivity for sample B	.015033	3	.0003055	.0001764
bulk density for sample A	1.2967	3	.16442	.09493
bulk density for sample B	1.5167	3	.11590	.06692
particle density for sample A	2.1133	3	.00577	.00333
particle density for sample B	2.0433	3	.04041	.02333
porosity for sample A	38.6300	3	7.93194	4.57951
porosity for sample B	25.8267	3	4.16623	2.40537

Paired Samples Correlations

		N	Correlation	Sig.
1	moisture content for sample A & moisture content for sample B	3	.471	.688
2	hydraulic conductivity for sample A & hydraulic conductivity for sample B	3	-.842	.363
3	bulk density for sample A & bulk density for sample B	3	.713	.495
r 4	particle density for sample A & particle density for sample B	3	-.500	.667
ir 5	porosity for sample A & porosity for sample B	3	.733	.476

Paired Sample

		Paired Difference						
					95%			
		Mean	Std. Deviation	Std. Error Mean	Lower			
Pair 1	Moisture content for sample A - moisture content for sample B	1.32700E1	8.85470	5.11226	-8.72629			
Pair 2	hydraulic conductivity for sample A - hydraulic conductivity for sample B	.0000667	.0009713	.0005608	-.0023461			
Pair 3	bulk density for sample A - bulk density for sample B	-.22000	.11533	.06658	-.50648	.06648		
Pair 4	particle density for sample A - particle density for sample B	.07000	.04359	.02517	-.03828	.17828		
Pair 5	porosity for sample A - porosity for sample B	1.28033E1	5.63916	3.25577	-1.20512	26.81179	3.933	