PHYTOREMEDIATION OF SOME HEAVY METALS FROM POLLUTED SOILS USING BERMUDA GRASS (*Cynodon dactylon*)

BY

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MATRIC No. 2005/21671EA

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FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

DECEMBER, 2010

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BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B. ENG.), DEGREE IN AGRICULTURAL AND BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

DECEMBER, 2010.

DECLARATION

I hereby declare that this project work is a record of a research work that was under taken 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 Information derived from personal communications, published and unpublished work were duly referenced in the text.

Solomon, Ehichoya Charles

10/01/2014

Date

CERTIFICATION

This is to certify that the project entitled "Phytoremediation of some Heavy Metals from Polluted Soils using Bermuda grass (*Cynodon dactylon*)" by Solomon, Ehichoya Charles meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

Engr. Mrs. H. Mustapha	13/01/2011
Supervisor	Date
Engr. Dr. A.A. Balami	13-02-2011
Head of Department	Date
External Examiner	10/12/2010
	Date

DEDICATION

This project is dedicated to my loving parents, Mr and Mrs Solomon, my very supportive and caring uncle, Mr. Destiny Enakhimion, my brothers, sisters, other family and friends who have really been supportive in many ways towards the completion of my project and degree programme as a whole.

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My immense and special gratitude goes to my dear parents Mr and Mrs Solomon for their priceless contributions towards my education right from the beginning. May the Lord God Almighty in His divine and infinite mercy grant them long life with peace and happiness to reap and enjoy the fruit of their labour in Jesus name (Amen). My appreciation goes to my very supportive and caring uncle, Mr. Destiny Enakhimion, my sisters, brothers and also other family members who have been morally and financially supportive. May God Almighty bless you all.

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ABSTRACT

Studies on *Cynodon dactylon* was investigated using industrial waste water. Physiochemical analysis of the waste water was carried out to observe the parameters present. Analysis of soil texture using hydrometer method was carried out to determine the percentage of sand, silt and clay present in the soil area considered for this study. Soil and plant analysis before and after planting was carried out using Atomic Absorption spectrophotometer method to determine the concentration of heavy metals in the plant and through the use of phyto-extraction method to determine the heavy metals present in the soil. Pre-soil analysis was carried on the soil area with zinc having the highest concentration of about 14.2mg/l for both control and uncontrolled samples while lead, mercury and arsenic were below determination level. Pre-plant and post plant analysis were carried on both control and uncontrolled specimens. Pre-plant analysis shows Lead was below determination level (BDL) for both control and uncontrolled samples. Zinc had the highest concentration of 1.22mg/l for the uncontrolled and 1.25mg/l for the controlled samples. There was significant changes as a result of the irrigating the uncontrolled sample with industrial waste water. Post plant analysis also shows zinc having the highest concentration but it was observed that the control sample had more chlorine than the uncontrolled sample. This research can further be used to investigate the concentration of different metals in the soil in order to determine possibility of plants growing effectively on that soil area and also *Cynodon dactylon* should be used for long term reclamation of a polluted soil area because of its ability to reduce the concentration of heavy metals such as Zinc, Iron and Copper that may retard plant growth.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Phytoremediation is a bioremediation process that uses various types of plants to remove, transfer, stabilize, and/or destroy contaminants in the soil and groundwater (Leon and Kochia, 2002). It also defined as the use of living green plants for in situ risk reduction and/or removal of contaminants from contaminated soil, water, sediments, and air. Specially selected or engineered plants are used in the process. Risk reduction can be through a process of removal, degradation of, or containment of a contaminant or a combination of any of these factors. Phytoremediation is an energy efficient, aesthically pleasing method of remediating sites with low to moderate levels of contamination and it can be used in conjuction with other more traditional remedial methods as a finishing step to the remedial process (Rufus and Chaney, 2003). Phytoremediation may be applied wherever the soil or static water environment has become polluted or is suffering ongoing chronic pollution. Examples where phytoremedation has been used successfully include the restoration of abandoned metal-mine workings, reducing the impact of sites where polychlorinated biphenyl have been dumped during manufacture and mitigation of on-going coal mine discharges (Rupassara et.al., 2002). Generally the use of phytoremediation is limited to sites with lower contaminant concentrations and contamination in shallow soils, streams and groundwater (Greger and Landberg, 1999). However, researchers are finding that the use of tree (rather than plants) allows them to treat deeper contamination because tree roots penetrate more deeply into the ground (Schnoor, 2003). Contaminants such as metals, pesticides, solvents,

explosives, crude oil and its derivatives, have been mitigated in phytoremediation projects worldwide. Many plants such as mustard plants, alpine pennycress and pigweed have proven to be successful at hyperaccumulating contaminants at toxic waste sites. Phytoremediation is considered a clean, cost-effective and non-environmentally disruptive technology, as opposed to mechanical cleanup methods such as soil excavation or pumping polluted waste water (Mendez and Maier, 2008). Over the past 20 years, this technology has become increasingly popular and has been employed at sites with soils contaminated with lead, uranium, and arsenic. However, one major disadvantage of phytoremediation is that it requires a long-term commitment as the process is dependent on plant growth, tolerance to toxicity and bioaccumulation capacity. The cost of the phytoremediation is lower than that of traditional processes both in situ and ex situ the plants can be easily monitored the possibility of the recovery and re-use of valuable metals (by companies specializing in "phyto mining") it is potentially the least harmful method because it uses naturally occurring organisms and preserves the environment in a more natural state. Phytoremediation is limited to the surface area and depth occupied by the roots. Slow growth and low biomass require a long-term commitment with plant-based systems of remediation, it is not possible to completely prevent the leaching of contaminants into the groundwater (without the complete removal of the contaminated ground, which in itself does not resolve the problem of contamination) the survival of the plants is affected by the toxicity of the contaminated land and the general condition of the soil (Mendez and Maier, 2008). Bio-accumulation of contaminants, especially metals, into the plants which then pass into the food chain, from primary level consumers upwards and/or requires the safe disposal of the affected plant material (Rupassara *et al.*, 2002). A range of processes mediated by plants or algae are useful in treating

environmental problems: phytoextraction, Phytostabilization, phytoaccumulation, Phytovolatilization, phytodegradation, Rhizofiltration (Aken and Schnoor, 2002)

1.2 STATEMENT OF THE PROBLEM

The contamination of the environment with various industrial waste water due to indiscriminate disposal in some State in the country where there are industries sited, causes so many environmental effects on human, soil, and animals that live on the surface of the land. The unsafe disposal of the water to the environment pose the question on how to remove the contaminants before disposing, in order to reduce the harmful effect to the environment.

1.3 OBJECTIVES OF THE STUDY

i. To identify the type of contaminants in the industrial waste water.

ii. To determine the kind of plant suitable for the removal of the contaminants from the soil.

iii. To compare soil and plant analysis between the Bermuda grass irrigated with waste water and Bermuda grass irrigated with tap water.

1.4 JUSTIFICATION OF THE STUDY

Phytoremediation of some heavy metals using various plants such as sunflower, alfalfa, sudan grass and Bermuda gras has been carried out by various researchers such as Leon and Kochia, (2002), Greger and Landberg, (2008) for the purpose of reclaiming that particular land area from some heavy metals that may pollute the soil and retard plant growth. No research work on Phytoremediation of some heavy metals from polluted soil using Bermuda grass has been

published in the country. Hence, for this study, identifying the type of contaminants present in industrial waste water used for irrigating Bermuda grass by carrying out physiochemical analysis will help in identifying the concentration of various metals in the waste water and further analysis on the soil area and Bermuda grass will help to check the concentration of various heavy and trace metals. The process of removing the contaminants from the soil will reduce the hazardous effect on the soil, plants and humans and therefore make the soil arable for agricultural practices

1.5 SCOPE OF THE STUDY

The scope of this project work covers the use of untreated industrial waste water collected from International Breweries and Beverages industries (IBBI) Kaduna for the irrigation of Bermuda grass which is used for the removal of heavy metals and other contaminants present in the soil. Physiochemical analysis on the waste water will be carried out to check the concentration of metals present and also analysis on the soil sample and Bermuda grass using Atomic Absorption Spectrophotometer and phyto-extraction method will also be employed to investigate the concentration of heavy metals in the soil and plant. Observations on daily and weekly basis will be taken on the growth of Bermuda grass before post planting analysis will be carried out. This research will help in evaluating the performance and growth of Bermuda grass considering the time exhausted for this study.

CHAPTER TWO

2.0 LITERATURE REVIEW

Pollutants given off by various industries and factories are often considered to be one of the prime factors contributing to air, water and soil pollution. According to the Environmental Protection Agency (EPA), it has been estimated that industrial pollution is responsible for almost 50 percent of the pollution present in the Country. There are various wide-ranging effects, as well as serious consequences, of industrial pollution on the ecological balance of the atmosphere.

2.1 GLOBAL WARMING

Global warming is one of the most common and serious consequences of industrial pollution. The emission of various greenhouse gases such as CO2, methane (CH4), among others from various industries, increases the overall temperature of the earth, resulting in global warming. Global warming has various serious hazards, both on the environment as well as on human health. It results in melting of glaciers and snow-capped mountains, causing an increase of the water levels in seas and rivers, thereby increasing the chances of flood. Apart from this, global warming also has numerous health risks on humans, such as increase of diseases such as malaria and dengue, cholera, Lyme disease and plague, among others.

2.2 AIR POLLUTION

Industrial pollution, as stated above, is one of the major causes of air pollution. With the increase in the number of industries and factories due to the industrial revolution; air pollution also has increased significantly. The emissions from various industries contain large amounts of

such as carbon dioxide, sulphur and nitrogen, among various environmental and health hazards such as acid rain, and various skin disorders in individuals (Nathanson and Cooper, 2009).

2.3 WATER POLLUTION

Pollution emitted from the industries is also one of the major factors contributing towards water pollution. Dumping of various industrial waste products into water sources, and improper contamination of industrial wastes, often result in polluting the water. Such water pollution disturbs the balance of the ecosystem inside, resulting in the death of various animal and plant species present in the water (Warren and Hammer, 2001)

2.4 SOIL POLLUTION

Soil pollution is defined as a phenomenon is which the soil loses its structure and fertility due to various natural and artificial reasons. Dumping of industrial wastes is one of the prime factors contributing towards soil pollution. Industrial wastes contain large amounts of various chemicals which get accumulated on the top layer of the soil, resulting in loss of fertility of the soil. Such loss of fertility ultimately results in changes in the ecological balances of the environment due to reduction in plant growth (Warren and Hammer, 2001).

2.5 OTHER COMMON EFFECTS OF INDUSTRIAL POLLUTION

Certain other common effects of industrial pollution include damaging buildings and structures, increasing the risk of various occupational hazards such as asbestosis, pneumoconiosis, among others (Speight, 1999).

2.6 DESCRIPTION OF PHYTOREMEDIATION AND ITS MECHANISMS

Phytoremediation is a bioremediation process that uses various types of plants to remove, transfer, stabilize, and/or destroy contaminants in the soil, wastewater and groundwater. There are several different types of phytoremediation mechanisms. These are: Rhizosphere biodegradation, Phytostabilization, Rhizofiltration, Phytodegradation, Phytovolatilization and Phytoextraction (Leon and Kochia, 2002)

2.6.1 Rhizosphere Biodegradation.

In this process, the plant releases natural substances through its roots, supplying nutrients to microorganisms in the soil. The microorganisms enhance biological degradation. Certain soil dwelling microbes digest organic pollutants such as fuels and solvents, producing harmless products through a process known as *Bioremediation.* Plant root exudates such as sugars, alcohols, and organic acids act as carbohydrate sources for the soil micro flora and enhance microbial growth and activity. Some of these compounds may also act as chemotactic signals for certain microbes. The plant roots also loosen the soil and transport water to the rhizosphere thus additionally enhancing microbial activity (Hannink, *et. al.,* 2001).

2.6.2 Phyto-stabilization

In this process, chemical compounds produced by the plant immobilize contaminants, rather than degrade them, also uses certain plants to immobilize soil and water contaminants. Contaminant are absorbed and accumulated by roots, adsorbed onto the roots, or precipitated in the rhizosphere. This reduces or even prevents the mobility of the contaminants preventing

migration into the groundwater or air, and also reduces the bioavailability of the contaminant thus preventing spread through the food chain. This technique can also be used to re-establish a plant community on sites that have been denuded due to the high levels of metal contamination. Once a community of tolerant species has been established the potential for wind erosion (and thus spread of the pollutant) is reduced and leaching of the soil contaminants is also reduced (Meagher, 2000).

2.6.3 Phyto-accumulation (also called Phyto-extraction)

In this process, plant roots sorb the contaminants along with other nutrients and water. The contaminant mass is not destroyed but ends up in the plant shoots and leaves. This method is used primarily for wastes containing metals. At one demonstration site, water-soluble metals are taken up by plant species selected for their ability to take up large quantities of lead (Pb). The metals are stored in the plant's aerial shots, which are harvested and either smelted for potential metal recycling/recovery or are disposed of as a hazardous waste. As a general rule, readily bio-available metals for plant uptake include cadmium, nickel, zinc, arsenic, selenium, and copper. Moderately bio-available metals are cobalt, manganese, and iron. Lead, chromium, and uranium are not very bio-available. Lead can be made much more bio-available by the addition of chelating agents to soils. Similarly, the availability of uranium and radio-cesium 137 can be enhanced using citric acid and ammonium nitrate, respectively (Meagher, 2000).

2.6.4 Hydroponic Systems for Treating Water Streams (Rhizofiltration)

Rhizofiltration is similar to Phyto-accumulation, but the plants used for cleanup are raised in greenhouses with their roots in water. This system can be used for ex-situ groundwater

treatment. That is, groundwater is pumped to the surface to irrigate these plants. Typically hydroponic systems utilize an artificial soil medium, such as sand mixed with perlite or vermiculite. As the roots become saturated with contaminants, they are harvested and disposed of. Repeated treatments of the site can reduce pollution to suitable levels as was exemplified in Chernobyl where sunflowers were grown in radioactively contaminated pools (Meagher, 2000).

2.6.5 Phyto-volatilization

This process, plants take up water containing organic contaminants and release the contaminants into the air through their leaves. The contaminant may become modified along the way, as the water travels along the plant's vascular system from the roots to the leaves, whereby the contaminants evaporate or volatilize into the air surrounding the plant. There are varying degrees of success with plants as phytovolatilizers with one study showing poplar trees to volatilize up to 90% of the TCE they absorb (Hannink *et al.*, 2001).

2.6.6 Phyto-degradation

In this process, plants actually metabolize and destroy contaminants within plant tissues or it could be said that Phytodegradation is the degradation or breakdown of organic contaminants by internal and external metabolic processes driven by the plant. Ex planta metabolic processes hydrolyze organic compounds into smaller units that can be absorbed by the plant. Some contaminants can be absorbed by the plant and are then broken down by plant enzymes. These smaller pollutant molecules may then be used as metabolites by the plant as it grows, thus becoming incorporated into the plant tissues. Plant enzymes have been identified that

breakdown ammunition wastes, chlorinated solvents such as TCE (Trichloroethane), and others which degrade organic herbicides (Greger and Landberg, 1999).

2.7 HYDRAULIC CONTROL OF POLLUTANT

In this process, trees indirectly remediate by controlling groundwater movement. Trees act as natural pumps when their roots reach down towards the water table and establish a dense root mass that take up large quantities of water. A poplar tree, for example, pulls out of the ground 30 gallons of water per day and a cottonwood can absorb up to 350 gallons per day. There are two such uses for plants (Greger and Landberg, 1999):

2.7.1 Riparian Corridors

Riparian corridors and buffer strips are the applications of many aspects of phytoremediation along the banks of a river or the edges of groundwater plumes. Phytodegradation, phytovolatilization, and rhizodegradation are used to control the spread of contaminants and to remediate polluted sites. Riparian strips refer to these uses along the banks of rivers and streams, whereas buffer strips are the use of such applications along the perimeter of landfills.

2.7.2 Vegetative Cover

Vegetative cover is the name given to the use of plants as a cover or cap growing over landfill sites. The standard caps for such sites are usually plastic or clay. Plants used in this manner are not only more aesthically pleasing they may also help to control erosion, leaching of contaminants, and may also help to degrade the underlying landfill.

2.8 LIMITATIONS AND CONCERNS OF POLLUTANTS

The toxicity and bioavailability of biodegradation products is not always known. Degradation by-products may be mobilized in groundwater or bio-accumulated in animals. Additional research is needed to determine the fate of various compounds in the plant metabolic cycle to ensure that plant droppings and products do not contribute toxic or harmful chemicals into the food chain. Scientists need to establish whether contaminants that collect in the leaves and wood of trees are released when the leaves fall in the autumn or when firewood or mulch from the trees is used. Disposal of harvested plants can be a problem if they contain high levels of heavy metals. The depth of the contaminants limits treatment. The treatment zone is determined by plant root depth. In most cases, it is limited to shallow soils, streams, and groundwater. Pumping the water out of the ground and using it to irrigate plantations of trees may treat contaminated groundwater that is too deep to be reached by plant roots. Where practical, deep tilling, to bring heavy metals that may have moved downward in the soil closer to the roots, may be necessary (Hannink, *et. al.*, 2001).

Generally, the use of phytoremediation is limited to sites with lower contaminant concentrations and contamination in shallow soils, streams, and groundwater. However, researchers are finding that the use of trees (rather than smaller plants) allows them to treat deeper contamination because tree roots penetrate more deeply into the ground. The success of phytoremediation may be seasonal, depending on location. Other climatic factors will also influence its effectiveness. The success of remediation depends in establishing a selected plant community. Introducing new plant species can have widespread ecological ramifications. It should be studied beforehand and monitored. Additionally, the establishment of the plants may

require several seasons of irrigation. It is important to consider extra mobilization of contaminants in the soil and groundwater during this start-up period. If contaminant concentrations are too high, plants may die. Some phytoremediation transfers contamination sacross media, (e.g., from soil to air). Phytoremediation is not effective for strongly sorbed contaminants such as polychlorinated biphenyls (PCBs). Phytoremediation requires a large surface area of land for remediation (Schwitzguebel, 2000).

2.9 ADVANTAGES OF PHYTOREMEDIATION COMPARED TO CLASSICAL REMEDIATION

According to Schnoor, (2002), the following advantages of Phytoremediation were stated below:

i. It is more economically viable using the same tools and supplies as agriculture.
ii. It is less disruptive to the environment and does not involve waiting for new plant communities to recolonise the site.
iii. Disposal sites are not needed.
iv. It is more likely to be accepted by the public as it is more aesthetically pleasing then traditional methods.
v. It avoids excavation and transport of polluted media thus reducing the risk of spreading the contamination.
vi. It has the potential to treat sites polluted with more than one type of pollutant.
vii. It is passive and solar.
viii. It is faster than natural attenuation.
ix. The amount of contaminated material going to landfills can be greatly reduced.

x. Energy can be recovered from the controlled combustion of the harvested biomass.

xi. It is low impact and public acceptance of phyto-remediation is expected to be high.

2.10 APPLICABILITY

The principal application of phyto-remediation is for lightly contaminated soils, sludge and waters where the material to be treated is at a shallow or medium depth and the area to be treated is large, so that agronomic techniques are economical and applicable for both planting and harvesting. In addition, the site owner must be prepared to accept a longer remediation period.

Plants used to decontaminate soils must do one or more of the following (Hannink, *et. al.*, 2001):

i. Take up contaminants from soil particles and/or soil liquid into their roots,

ii. Bind the contaminant into their root tissue, physically and/or chemically,

iii. Transport the contaminant from their roots into growing shoots,

iv. Prevent or inhibit the contaminant from leaching out of the soil.

The plants should not only accumulate, degrade or volatilize the contaminants, but should also grow quickly in a range of different conditions and lend themselves to easy harvesting. If the plants are left to die in situ, the contaminants will return to the soil. For complete removal of contaminants from an area, the plants must be cut and disposed of elsewhere in a nonpolluting way. Some examples of plants used in phytoremediation practices are water hyacinths *(Eichhornia crassipes)*, poplar tress *(Papulus spp)*, forage kochia *(Kochia spp)*, alfalfa *(Medicago sativa)*, Kentucky bluegrass *(Poa pratensis)*, *Scirpus spp*, coontail *(Ceratophyllum*

demersvm L.), American pondweed *(Potamogeton nodosus)* and the emergent common arrowhead *(Sagittaria latifolia)* amongst others. Typically, researchers look for suitable phytoremediation properties among both cultivated and wild varieties of plants. If suitable wild species are not available, researchers can try to improve the effectiveness of phytoremediation by introducing different genetic varieties. One way this is done is by soaking seeds in a mutation-producing chemical, then screening the germinated seedlings for contaminant tolerance in artificial solutions containing various concentrations of the particular contaminant(s) of concern. Testing is carried out in batches of at least 50,000 seedlings at a time. The most tolerant and vigorously growing plants are analyzed for their contaminant content and the best of them are bred to produce a line of improved plants. A major barrier to the implementation of phytoremediation is that it is new and not fully developed (Schwitzguebel, 2000). There is little regulatory experience with phytoremediation and it has to be considered on a site by site basis. Furthermore, the intrinsic characteristics of phytoremediation limit the size of the niche that it occupies in the site remediation market (Greger and Landberg, 1999).

Phytoremediation is used for the remediation of metals, radionuclides, pesticides, explosives, fuels, Volatile Organic Compounds (VOCs) and Semi-Volatile Organic Compounds (SVOCs). Research is underway to understand the role of phytoremediation to remediate per chlorate, a contaminant that has been shown to be persistent in surface and groundwater systems. It may be used to cleanup contaminants found in soil and groundwater. For radioactive substances, chelating agents are sometimes used to make the contaminants amenable to plant uptake (Greger and Landberg, 1999).

2.11 BERMUDA GRASS AS THE PLANT USED FOR WASTE WATER REMEDIATION

Bermudagrass *(Cynodon sp.)* is a grass native to east and North Africa, Asia and Australia and Southern Europe. The name Bermuda grass derives from its abundance as an invasive species on Bermuda, it does not occur naturally there. It is a resilient perennial grass popular in the golf and turf grass industries, owing to its ability to generate a variety of textures, its rapid recovery, and its low-growing nature that allows it to tolerate very close mowing. It is widely used in landscaping because of its ability to grow well in a wide range of soil conditions, as well as its fast growth rate. Seeded Bermuda grass can spread to provide full coverage of 1,000 square feet within four to six weeks after planting, and it maintains active growth through the warm summer when many other grasses temporarily decline. Despite its economic importance and the fact that the grass family (Poaceae) in general is one of the better-studied plant families, bermudagrass represents a subfamily (Chloridoideae) that is underexplored at the DNA level.

Cynodon dactylon produces seeds through the runners and rhizomes; its growth begins at temperature above 15^0c (59^0F) with optimum growth between 24-37^0c (75-99^0F). In winter the grass becomes dormant and turns brown. Its growth is promoted by full sun and retarded by full shade. The blades are grey-green in colour and are short usually about 2-15 cm (0.79-5.91 inch) long with rough edges. The erect stem can grow 1-30 cm (0.39-12 inch) tall. Moreover, many bermudagrass genotypes are polyploidy, receiving not one but two or more sets of chromosomes from each parent. Polyploidy is thought to offer advantages such as the preservation of multiple alleles (slightly different versions of a gene) that provide adaptation to a broader range of

environments or a wider range of pests than otherwise would be possible. However, polyploidy also tend to hinder the rate at which breeders can make genetic changes in the crop (Greger and Landberg, 1999).

2.12 SEED TYPES

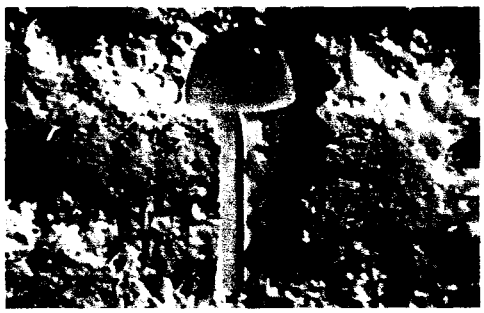
Bermuda seed is available in several forms-hulled, unhulled and coated. The unhulled seed is the natural form which germinates in 7-14 days. The hull of the seeds removes between 4-7 days for germination. The coated seed has been pelleted with clay containing nutrients to improve ease of planting and establishment.

2.13 SEEDING AND IRRIGATION

Bermuda grass seed should be planted in late spring or early summer when night time temperatures are consistently above 65 deg F (18 deg C). Plant 2 to 3 pounds of hulled seed, or 3 to 5 pounds of un-hulled seed, or 3 pounds of coated seed per 1000 square feet of lawn. Sow half of the seed in one direction, and the other half at right angles to the first half. Rake the seed in lightly, covering no more than 1/8 inch with pulverized manure, peat moss or another fine soil material and then firm the seedbed. Apply water evenly and with a fine spray in order not to disturb the newly planted seed. Keep the soil continually moist for 10 to 14 days or until the new lawn is well sprouted and has had a chance to get established.

The key in plates 1, 2 and 3 is used to check the growth process of the Bermuda grass from the time the seeds were planted to determine the length at which it can grow under 3-4 weeks. These ornamental grasses grow on a wide range of soils but best in relatively fertile, well drained soils;

they are adapted over a broad range of soil pH (4.5-8.5), but grows best when the pH is above 5.5.These Bermuda grasses grow best with mean daily temperatures above 24°C or over an optimal range of 17-35°C. They spread rapidly by rhizomes and stolons and spread over 2m/month during the growing season and a single plant can form a dense sward up to 25m across in 2.5 years. Irrigation water with salinity up to 10.8dS/cm can be used for plants growing on sandy soil, 6.1 dS/cm for those growing on loam and 3.6 dS/cm for those planted on clay soil



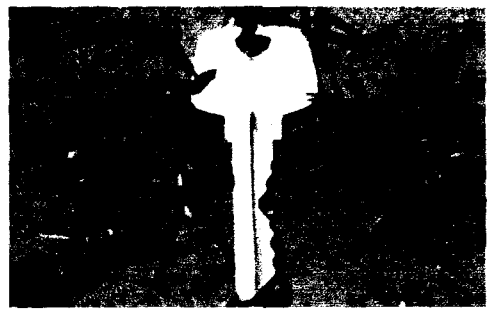


Plate1: Emergence – 5 days old Bermuda Plate 2: 2 weeks old Bermuda grass

Plate 3: 3 weeks old Bermuda grass (Bervard, 2006)

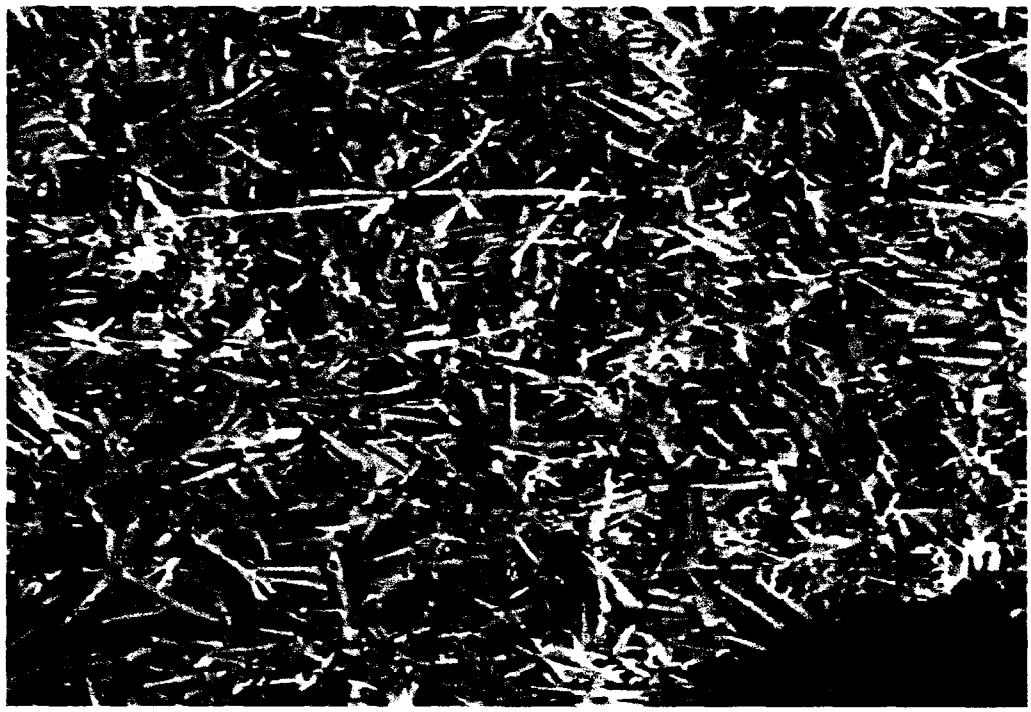


Plate 4: common Bermuda grass (Harlan *et al.*, 2003)

Hybrid Bermuda (plate 4) requiring an average annuall rainfall range of 625- 1750mm are very drought tolerant by virtue of rhizome survival through drought induced dormancy over periods of up to 7 months. They are tolerant of salinity, flooding and heavy grazing and serve as an excellent ground cover for soil conservation.

2.14 TYPES OF HYBRID BERMUDA GRASS, AND THEIR APPLICATIONS.

i. Sunturf is a natural hybrid of *C. dactylon* and *C. transvaalensis*. It is originated in South Africa and introduced in USA in 1949. The color of this hybrid is dark green. It forms a very dense turf with fine textures. It's a low growing variety. This is commonly used in lawns.

ii. Tifgreen Bermuda grass is a hybrid of Cynodon dactylon and C. transvaalensis. This hybrid has the capacity to resists disease, poor irrigation circumstances, high traffic and droughts. It is low growing, dark green grass and spreads quickly. This grass can regenerate quickly as well.

iii. It is for this reason that it's quite extensively used in Golf course greens, tees, lawns and commercial landscapes. Weed control chemicals and pest are can not reach damage to Tifgreen grass.

iv. Tifdwarf (*C. dactylon* x *C. transvaalensis*), this variety is a vegetative mutant of Tifgreen. Tifdwarf is mostly similar with Tifgreen but its leaves and internodes are much shorter than Tifgreen. The green color is also darker than Tifgreen.

v. Tifdwarf becomes reddish-purple in color immediately after the winter. For its superior putting quality it is popularly used for golf greens, tennis courts and bowling greens and such.

vi. Pee Dee (*C. dactylon* x *C. transvaalensis*) is also a mutant of Tifgreen. It is a dark green dwarf variety. The texture is very fine and can spread rapidly. For its fast growth, it is quite popular for use in golf greens.

vii. Tifway type is the combination of nice looks and toughness. It is the product of cross between Cynodon dactylon and C. transvalensis germplasma. It is dark green in color with fine textured leaves. The specialty of this grass is that it is persistent, and can grow and spread quickly.

viii. It also has a property to recover quickly from injury. It is a high quality Bermuda hybrid. Tifway is primarily used for sports fields, golf course fairways, commercial and

residential lawns. During winter, Tifway becomes dormant but can recover quickly when temperatures rise. This grass can also survive in shallow waters.

ix. Tifway II is the next improved variety of Tifway. This variety has a better resistant capacity to nematode infestations. It can tolerate the cooler temperatures. But it is not as persistent as Tiflawn. It needs a extra maintenance care for keeping the lawn attractive.

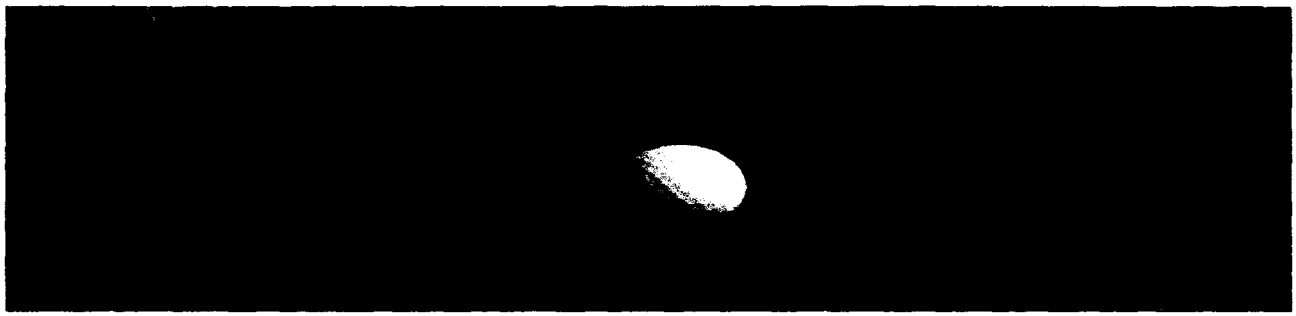


Plate 5: Improved Bermuda grass (Harlan *et al.*, 2003).

2.15 IMPROVED COMMON BERMUDA GRASS

"Improved" common types are mostly seeded varieties and are darker green, deeper rooted, medium textured and moderately denser compared to the common Bermudagrass. They are general purpose, turf-type Bermuda grasses used for lawns, parks, roadsides and sports turfs. These should be used in areas where improved characteristics are desired when compared to common but quality and level of maintenance will be lower than the vegetative hybrid improved cultivars. Seedland sells several turf-type "seeded" improved varieties. The vegetative hybrids are generally used in more intensive maintenance turfs such as low mowed and fine golf greens. Hybrids can only be established from sod or sprigs (Lynng and Richard, 1996)

2.16 PLANT USED FOR REMEDIATION OF INDUSTRIAL WASTE WATER AND ITS ECONOMIC IMPORTANCE

2.16.1 Sunflower

According to Dempewolf *et al. (2008),* several species of sunflowers are of economic importance. Below is a list of species that have a widespread use in society. Many more species of Asteraceae of narrow distribution, especially in tropical regions, are used locally for various medicinal and food purposes. The economic importance of many species of sunflowers is yet to be fully explored.

i Oils

Niger seed oil; *Guizotia abyssinica L.f.,*

Asteroideae: *Millerieae*, northeast tropical Africa Safflower oil, *Carthamus tinctorius*

Carduoideae: *Cynareae,* central Asia Sunflower oil, Helianthus annuus L.,

Asteroideae*: Helianthea,*

ii Food

Artichoke, *Cynara cardunculus L.,*

Carduoideae: *Cynareae, Eurasia Endive*, *Cichorium endivia L.*

Cichorioideae: *Cichorieae*, Europe Jerusalem artichoke, *Helianthus tuberosus L.,*

Asteroideae: *Heliantheae*, North America Lettuce *(Lactuca sativa L)*

:ii Ornamentals

Black-Eyed Susans, Rudbeckia hirta L.,

Asteroideae: *Heliantheae*, USA, Canada *Chrysanthemums*, *Chrysanthemum* several species, *Asteroideae: Anthemideae*, Asia

Dahlias : Dahlia, *coccinea Cav., Dahlia pinnata Cav.,*

Asteroideae: *Coreopsideae*, *Mexico Echinaceas, Echinacea purpurea L., Moench, Echinacea paradoxa.*

Asteroideae: *Heliantheae*, North America Marigolds, *Tagetes erecta L.,* Asteroideae:*Tageteae,*

Several species *Asteroideae: Anthemideae, Europe Zinnias, Zinnia angustifolia Kunth, Zinnia peruviana (L.) L., Zinnia violacea Cav.,*

Asteroideae: Heliantheae, Mexico, South America Medicinal Anti-malarial, *Artemisia annua L.,*

Asteroideae: *Anthemideae*, eastern Asia

Chamomile tea, *Matricaria recutita L.,*

Asteroideae: *Anthemideae*, Europe Echinacea tea, *Echinacea purpurea L., Moench.*

Asteroideae: *Heliantheae*, North America Industrial

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 DESCRIPTION OF THE STUDY AREA

The project site is located at Gidan kwano campus, Federal University of Technology, Minna. It is situated about 65 meters from the school of agriculture research and teaching farm. The portion used for the experiment is an arable land where Sorghum is the dominant crop grown. The latitude and longitude of the site is between lat. $09^{o}\ 22^{l}\ 48^{ll}$ and Long. $06^{o}\ 56^{l}\ 36^{ll}$

3.1.1 Climate

The site is located in the sub –humid tropics, the area is influenced by two dominant Musses, the southern-western monsoon which flows from the Atlantic Ocean and northern eastern dry harmattan originating from Sahara desert. They are responsible for two distinct wet/rainy and dry seasons. The mean annual rainfall is about 1338mm and falls between May and October/November the length of growing period is about 180-200 days or 6-7 months. Effective length of wet season is 190 days. Length of dry season is about 5 month. The potential annual evapotranspiration is approximately 1,242.7mm the mean annual air temperature is about 27.2^{o} with the highest and lowest occurring in the month of March and September respectively. The relative humidity falls between 50 to 70% annually. With total annual mean value of about 65%. (Hassan, 2006)

3.1.2 Geology and Topography of the Area

The forest geology is under lained by three major geological formations, namely rocks of basement complex which belong to late pre-combination and Paleozoic age, cretaceous nupe and stone and recent deposits of aluminum origin.

The basement complex is composed of banded neisses and magmatites meta-sediments, the meta-sediment comprising schist, phyllotes, quartzite's and marble are metamorphosed representative of ancient sediments such as lays, and stones and limestone respectively. Observed that the basement complex consist mainly of metamorphic rocks with local granite and basic instructions. (Hassan, 2006)

3.1.3 Geomorphology

The forest field is near level easy water lodged (Fadama), high to low spot, few number of rock of igneous origin, having a relatively flat terrain. Canopy of tick, antihill. The relief assumes a convex form where the drainage channels are more frequent such as in the northern part of the region. (Hassan, 2006)

3.1.4 Irrigation process

500ml of industrial waste water was used to irrigate the Bermuda grass on daily basis i.e. morning and evening for a period of 4 weeks while 500 ml of tap water was used to irrigate the Bermuda grass that served as the control plant.

3.2 MATERIALS USED

Bermuda grass, industrial waste water, tap water hoe, measuring tape, plastic containers, rulers and an auger

3.3 EXPERIMENTALS METHODS

The equipment used for the analysis was through the use of Atomic Absorption spectrophotometer for the determination of heavy metal through the process of phyto-extraction method. (Anderson and Ingram, 1996)

Soil analysis was carried out and some of the traceable elements detected are Zn, Cu, Fe, Mn, Pb, Hg.

Arsenic and Soil P^H of 5.6, i.e the soils at the study is slightly acidic while the textural class is found to be sandy loam (SL) while for the salinity assessment i.e. electrical conductivity of the soil is at 25°C which refer to the lowness of the soil in term of electrical conductivity.

3.3.1 Water Analysis

3.3.1.1 Industrial waste water (Gray water)

The method used for the chemical analysis of industrial waste water from (IBBI) Kaduna was the phytoextraction method. Some of the physiochemical parameters determined in the industrial waste water are: Heavy metals (Aluminum and Manganese), Biochemical Oxygen Demand (B.O.D), Chemical Oxygen Demand (C.O.D), Total Phosphorus, Total Nitrogen, Acidity, Suspended Solid, Dissolved Soild, P^H and Electrical conductivity

3.4 Equipment/Apparatus used

Atomic Absorption Spectrophometry (A.A.S), Spectrophotometry, pH meter, Hydrometer, Measuring cylinder, Kjeldahl digestion block, Distillation unit or Apparatus, Electrical Conductivity meter, Hot furnace, Oven (Electrical), Auto clave, centrifuge and Flame photometer.

3.5 Method of Determination

PSA (Particle size Analysis) was determined by hydrometer method

Heavy metals were determined Phyto extraction method and Dilute Hydrochloric method.

Electrical conductivity (Ec) using ohm Electrical conductivity meter.

Phosphorus- Bray No 1 method

3.6 PROCEDURES FOR DETERMINATION OF PARAMETERS

3.6.1 Biochemical Oxygen Demand (BOD)

This was determined by the dissolved oxygen of the water sample on the first day and the same water sample was incubated at room temperature for 5 days in the dark before the titration for oxygen using Winkler-azides method. (Nathanson and Cooper, 2009)

BOD_5 (mg/l) = dissolved Oxygen supplied from day 1 to day 5.

3.6.2 Chemical Oxygen Demand (COD)

50mls of sample was taken. 5mls of sulphuric acid and 1ml of potassium dichromate was added. This was digested for 30minutes after which potassium iodide and starch indicator were added. This was then titrated with thiosulphate.

3.6.3 Phosphorus

This was determined by measuring 10ml of water sample into micro-kjadahl flask, 1 ml of conc. H_2SO_4 was added followed by 5ml of conc. HNO_3. This solution was digested on a digestion rack until the volume was reduced to 1ml and the solution turned colourless. The solution was allowed to cool and 20ml of distilled water and 1 drop of phenolphthalein indicator was added to the solution. 1M NaOH was added in drops until a faint pink tinge was observed. This could be made back to 100ml with distilled water.

Standard phosphate solution was also prepared by accurately weighing 0.2195g anhydrous potassium di-hydrogen phosphate, KH_2PO_4 and dissolving it in 1 litre distilled water. Various concentrations were then prepared from the standard after digestion.

Molybdate reagent (II) (25g of $(NH_4)_6\ MO_7O_{24}.H_2O$) was dissolved in 175ml distilled water. 280 ml of conc. H_2SO_4 was carefully added to 400ml of distilled water which was then made up to 1 litre. The different solutions were then run on a spectro-photometer at 690nm in order to measure the intensity of the blue colour developed and was developed and was used to prepare standard calibration curve for phosphate. The samples were treated the same way and the phosphate phosphorus determined was extrapolated from the standard curve.

Calculations were done using the equation:

$$PO_4\text{-P (mg/l)} = \frac{\text{reading from curve x 1000 x D}}{\text{Ml of sample}} \quad (3.1)$$

3.7 DETERMINATION OF METALS USING ATOMIC ABSORPTION SPECTROPHOTOMETER (AAS)

3.7.1 Magnesium

Magnesium stock solution was prepared by dissolving 8.3606g magnesium chloride 6-hydrate, $MgCl_2.6H_2o$ in distilled water and makes it up to 1 litre.

Magnesium standard solution was also prepared by diluting 10ml stock magnesium solution into 1 litre of water. Different concentrations were then prepared from the standard solution ranging from 5-40 mg/l. These were then run through AAS with magnesium cathode lamp installed at 285.2mm. Standard calibration curve was drawn by plotting concentration of standards against absorbance. The samples were acidified with 1ml conc. Nitric acid and autoclaved at 121^0C for 1 hour to solubilize the particulate matter content and also run through AAS.

Magnesium is calculated using equation;

$$Mg\ (mg/l) = \text{reading from the curve} \times D$$

$$\text{Where } D = \frac{\text{ml sample + ml water + 1ml acid}}{\text{ml of sample}} \quad (3.2)$$

3.7.2 Copper (Cu)

Stock copper solution was prepared by dissolving 3.9296g copper sulphate 5-hydrate in distilled water which is made up to 1 litre. Standard solution was also by dissolving 5ml of stock solution in 100ml of distilled water from where different concentrations were then prepared in the range of 5ml-20mg/l. These were run through AAS to determine the absorbance level using copper cathode lamp at 324.7mm and calibration curve is drawn from this. These samples were also run to determine copper with AAS. It is calculated using equation:

Cu (mg/l) = reading from the curve ×D

$$\text{Where D} = \frac{\text{ml sample + ml water + 1ml acid}}{\text{ml of sample.}} \qquad (3.3)$$

3.7.3 Zinc (Zn)

Stock zinc solution was prepared by dissolving clean 100mg zinc metal in 1ml Hcl and was made up to 1 litre with distilled water. Standard zinc solution was then prepared by making 10ml of zinc stock solution to 1litre with distilled water. Different concentrations were prepared from standard solution in the range of 0.1-0.5mg/l which is determined for zinc with AAS using zinc cathode lamp at 213.8mm. the calibration curve is drawn from the results. The samples were carefully analysed for zinc concentration.

It is calculated using the equation: Zn (mg/l) = reading from curve x D

$$\text{Where D} = \frac{\text{ml sample + ml water + ml acid}}{\text{ml of sample}} \qquad (3.4)$$

Where D = $\frac{\text{ml sample + ml water + ml acid}}{\text{ml of sample}}$ (3.4)

3.7.4 Iron (Fe)

Stock iron solution was prepared by dissolving 5.0503g Iron (II) ammonium sulphate, Fe $(NH_4)_2$ $(SO_4)_2$ in 1 litre distilled water. Standard iron solution was prepared from stock solution by dissolving 20ml of stock solution in 1 litre of water from where different concentrations was then prepared and determined for iron with AAS using iron cathode lamp at 248.3nm. The samples were run through AAS to determine iron and the results are extrapolated from the calibration curve.

Iron is calculated using the equation below;

Fe (mg/l) = reading from the curve x D

Fe (mg/l) = $\frac{\text{ml sample + ml water + 1ml acid}}{\text{ml of sample}}$ (3.5)

3.7.5 Lead (Pb)

Stock lead was prepared by dissolving 1.5985g Lead nitrate, Pb $(NO_3)_2$ in 1 litre distilled water.

Standard lead solution was then prepared by dissolving 10ml lead stock solution in 1 litre of distilled water from where different concentrations where then prepared and determined for iron with AAS using Lead cathode.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

Table 4.1: Physiochemical analysis of industrial waste water

Parameter	Units	Measured values
Aluminum	mg/l	0.509
Manganese	mg/l	0.138
BOD	mg/l	8.08
COD	mg/l	483
Phosphorus	mg/l	0.26
NO_3- nitrogen	mg/l	18.8
Acidity	mg/l	0.02
Suspended solid	mg/l	107
Dissolved solid	mg/l	1.72
pH	-	4.75
Electrical conductivity	µS/cm	3.29

Table 4.4: Plant analysis before and after planting For Bermuda grass irrigated with industrial waste water (uncontrolled)

Parameters	Measured values (before) (mg/l)	Measured values (after) (mg/l)
Cl	0.95	1.05
Mn	0.66	0.82
Zn	1.22	3.45
Mo	0.35	1.22
Pb	BDL	BDL

Table 4.5: Soil analysis before and after planting For Bermuda grass irrigated with tap water (control plot)

Parameters	Measured values (before) (mg/l)	Measured values (After) (mg/l)
Zn	14.20	13.71
Cu	6.88	6.87
Fe	10.22	10.25
Mn	0.61	0.64
Pb	BDL	BDL
Hg	BDL	BDL
Ar	BDL	BDL

Table 4.6: Plant analysis before and after planting For Bermuda grass irrigated with tap water (control)

Parameters	Measured values (before) (mg/l)	Measured values (after) (mg/l)
Cl	0.96	1.08
Mn	0.63	0.77
Zn	1.25	2.96
Mo	0.33	1.13
Pb	BDL	BDL

4.2 DISCUSSION OF RESULTS

Fig.4.1shows Zinc having a better concentration on all the soils tested including the control plant soil. The concentration range between 14.20ug/l before analysis; after planting and subjecting to industrial waste water, the level reduced to about 14.08ug/l.

Zinc is a very mobile element in the series of heavy metals and apart from being metallic, they show similarities in their properties and are quite different from the reactive S- block metals in the periodic table of elements. Transitional elements are typical metals with high melting and boiling point. It has a high density with metallic luster. While Manganese, in terms of utilization from the soils after and before planting shows a very low level in all the treatments. The soils before planting has a concentration level of 0.61mg/l while the control account for about

0.64mg/l. After planting, a level of 0.60mg/l was gotten from the soil area irrigated with waste water. The level of Iron (Fe) is the second in levels of heavy metals sighted in the study site. The result shows that the result obtained before planting was 10.22mg/l while after planting was 10.18mg/l. there was reduction in the level of iron, Fe concentration.

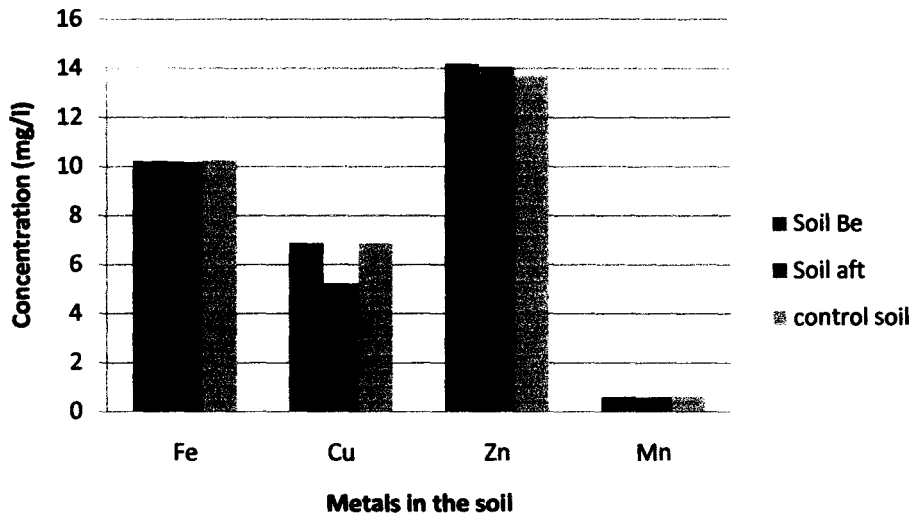


Fig.4.1: Soil analysis showing concentration against metals in the soil

Fig.4.2 shows Molybdenum (Mo) post planting result for Bermuda grass irrigated with tap water (control) having a level of 1.13ug/l while the pre and post planting results for Bermuda grass irri gated with waste water was found to be 0.35ug/l and1.22ug/l respectively. Post-planting result of 1.22ug/l showed a better level of concentration. Molybdenum, Mo was utilized in the plant by a simple method of transformation processes, where the element is more upward to the plant. Zinc, Zn concentration in the plant ranges from 1.25ug/l- 2.96ug/l (i.e. pre and post- planting results respectively, for control) while pre and post-planting results for the un-controlled showed a value of 1.22ug/l- 3.45ug/l. The post- planting results showed a better level of Zinc concentration. The industrial waste water has a significant role in the development of the plant based on the height.

For the uncontrolled, pre and post planting result for Manganese, Mn were 0.66ug/l and 0.82ug/l respectively, while the control showed a value or result of 0.63ug/l for pre- planting and 0.77ug/l for post- planting; it was observed that Manganese was much from the waste water probably as a result of the high accumulation of Manganese content in the waste water.

The level of Manganese in the plant was higher for post-planting result of the uncontrolled compared to that of the controlled.

Pre and post results for the uncontrolled in terms of Chlorine level were 0.95ug/l and 1.05ug/l respectively, while pre and post results for the control were 0.96ug/l and 1.08ug/l respectively. This result shows that the level of chlorine in the control was higher for post- planting result compared to the uncontrolled and this may be as a result of the Chlorination of urban board water for cleansing and reduction of contaminants.

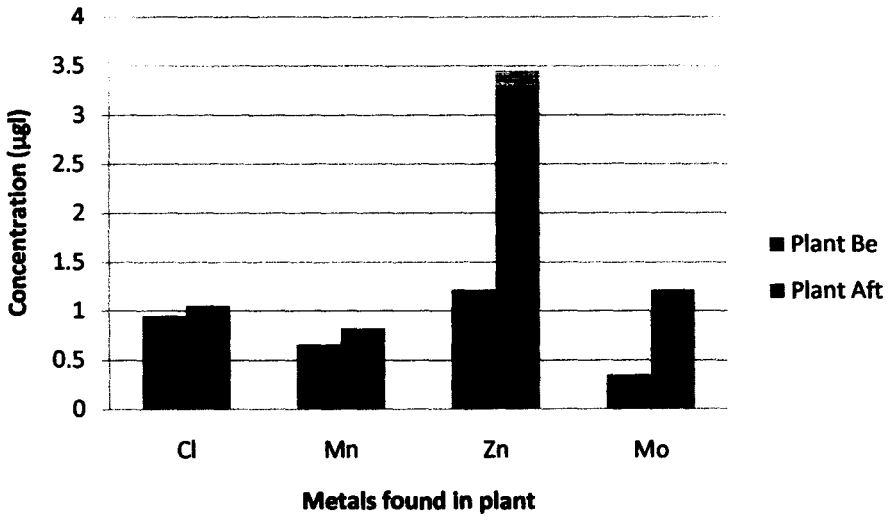


Fig.4.2: Plant analysis showing concentration against metals found in the plants

From Fig.4.3 and based on the plant height, it showed that heavy metals concentration can retard the growth and development of plant most especially *Cynodon dactylon.* Two Bermuda grass were planted closely and irrigated with waste water while the other two Bermuda grass were planted closely and irrigated with tap water. The spacing between the two groups of Bermuda grass was 150cm. Water was applied for a duration of 4 weeks and the plant height showed a significant growth of 5.7cm maximum, on those plants that were subjected to ordinary water of pH, 7.0. The corresponding results of the plants that were irrigated with industrial waste water showed a significant growth of 5.10 cm indicating that the height was retarded as a result of the heavy metals concentration. The growth of the plants were monitored weekly and the height of the Bermuda grass irrigated with tap water from the 1^{st}, 2^{nd}, 3^{rd} and 4^{th} week were 4.75, 4.85, 5.11 and 5.70 cm respectively. While the height of Bermuda grass irrigated with waste water from the 1^{st}, 2^{nd}, 3^{rd} and 4^{th} week were 4.7, 4.75, 4.85 and 5.10 cm respectively. However, time and space would not permit to evaluate the actual heavy metals elements that were more responsible of reduction in plant height. It was suggested more elaborate or further studies should work out on elemental basis between the heavy metals to know exactly which of the heavy metals are truly responsible for the retarded growth.

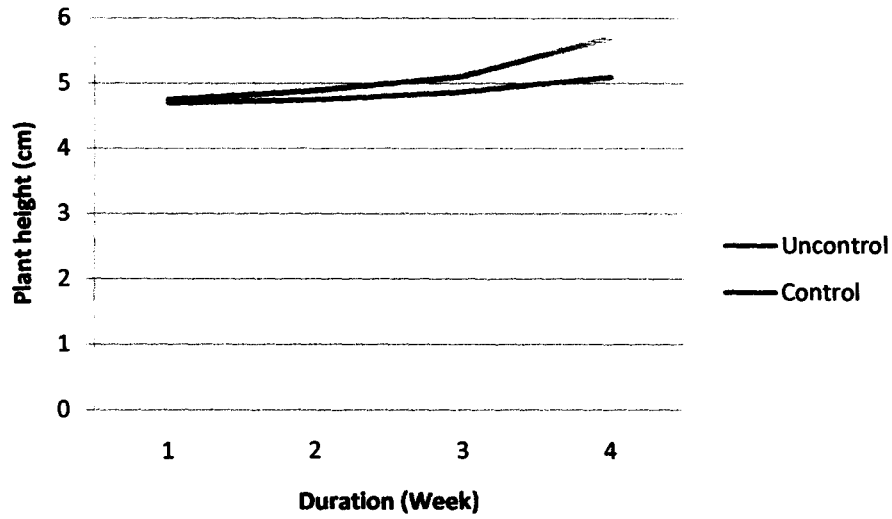


Fig.4.3: Plant growth showing plant height against duration

Analysis of Variance test was done using an XPSS software to produce the regression graph for both soil and plant analysis. The pre and post soil analysis result between the Bermuda grass irrigated with waste water and the other irrigated with tap water (control) showed a significant regression coefficient of 0.991 and 1.00 respectively, which indicates that there is a high concentration of metals in the soil for Bermuda grass irrigated with waste water to that of the control (tap water irrigated Bermuda grass). The pre and post plant analysis result between Bermuda grass irrigated with waste water and the other irrigated with tap water (control) showed a significant regression coefficient of 0.711 and 0.744 respctively, which indicates that the translocation of metals from the root to the shoot was high for Bermuda grass irrigated with waste water to that of the control (tap water irrigated Bermuda grass).

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Analysis were carried out on the industrial waste water, soil area and plant samples to determine the concentration of heavy metals. These heavy metals represent an important group of soil contaminants; many of these contaminants are very toxic to plant and animals. The concentration of Zinc was found to be the highest for both soil and plant analysis while Lead, Mercury and Arsenic were found to be below determination level for pre and post soil analysis. The concentration of chlorine in the control plant was higher than the uncontrolled due to the chlorination of urban water used for cleansing and reduction of contaminants. The method of Phyto-extraction using dilute hydrochloric acid and the use of Atomic Absoption Spectrophotomter in this research is useful in investigating the concentration of different heavy metals in the soil in order to determine possibility of plants growing effectively on that soil area and also *Cynodon dactylon* can be used for long term reclamation of a particular soil area by reducing the concentration of some metals that may retard plant growth.

5.2 RECOMMENDATIONS

i More research work on this study should be carried out by government, research and tertiary institution on appropriate methods used to check for heavy metal concentration in the soil

ii Regulatory agencies should be established to periodically investigate the heavy metal concentration on some existing cultivable land area.

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APPENDICES

A1: ANALYSIS OF VARIANNCE FOR PRE AND POST SOIL ANALYSIS (UNCONTROLLED)

A 1.1: Linear Regression Tables

Table A1: Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.991	.981	.972	.961

The independent variable is VAR00001.

Table A2: Analysis of Variance

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	97.385	1	97.385	105.412	.009
Residual	1.848	2	.924		
Total	99.233	3			

The independent variable is VAR00001.

Table A3: Linear Coefficients

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
VAR00001	.971	.095	.991	10.267	.009
(Const.)	.675	.858		.787	.514

Linear curve estimation

$Y = ax + C$

$Y = 0.971x + 0.675$

Linear regression (R) = 0.991

A 1.2: Quadratic Regression Tables

Table A4: Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.994	.989	.967	1.052

The independent variable is VAR00001.

Table A5: Analysis of Variance

	Sum of Squares	df	Mean Square	F	Sig.
Regression	98.127	2	49.063	44.349	.106
Residual	1.106	1	1.106		
Total	99.233	3			

The independent variable is VAR00001.

Table A6: Quadratic Coefficients

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
VAR00001	1.292	.406	1.318	3.185	.194
VAR00001 ** 2	-.022	.027	-.339	-.819	.563
(Constant)	.069	1.196		.057	.963

Quadratic curve estimation

Regression (R) = 0.994

$Y= ax^2 + bx + c$

$Y= -0.022x^2 + 1.292 + 0.69$

A 1.3: Cubic

Table A7: Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
1.000	1.000	.	.

The independent variable is VAR00001.

Table A8: Analysis of Variance

	Sum of Squares	df	Mean Square	F	Sig.
Regression	99.233	3	33.078	.	.
Residual	.000	0	.		
Total	99.233	3			

The independent variable is VAR00001.

Table A9: Cubic Coefficients

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
VAR00001	2.284	.000	2.330	.	.
VAR00001 ** 2	-.203	.000	-3.127	.	.
VAR00001 ** 3	.008	.000	1.831	.	.
(Constant)	-.689	.000		.	.

Cubic curve estimation = 1.000

Y= ax3+bx2+c2+D

$Y=0.08x^3-0.203x^2+2.284x-0.689$

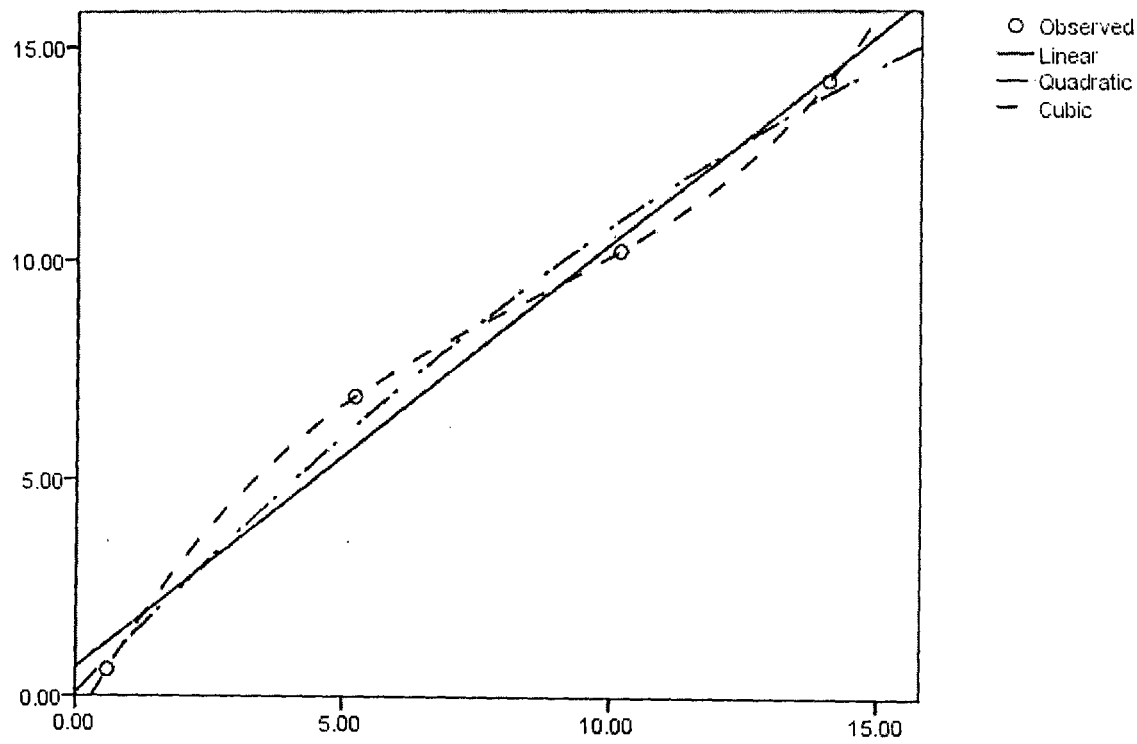

fig.A1: ANOVA graph of soil for uncontrolled Bermuda grass

A2: ANALYSIS OF VARIANCE FOR PRE AND POST PLANT ANALYSIS

A 2.1: Linear Regression Tables

Table A10: Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.711	.505	.258	.323

The independent variable is VAR00001.

Table A11: Analysis of Variance

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	.213	1	.213	2.043	.289
Residual	.208	2	.104		
Total	.421	3			

The independent variable is VAR00001.

Table A12: Linear Coefficients

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
VAR00001	.218	.153	.711	1.429	.289
(Const)	.438	.297		1.476	.278

Linear curve estimation

R= 0.711

Y= ax+c

Y= 0.218x + 0.438

A 2.2: Quadratic Regression Tables

Table A13: Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.797	.635	-.096	.392

The independent variable is VAR00001.

Table A14: Analysis of Variance

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.267	2	.134	.869	.604
Residual	.154	1	.154		
Total	.421	3			

The independent variable is VAR00001.

Table A15: Quadratic Coefficients

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
	-1.285	2.533	-4.189	-.507	.701
VAR00001					
VAR00001 ** 2	.340	.571	4.913	.595	.658
(Constant)	1.608	1.999		.805	.569

Quadratic estimation

R= 0.797

$Y= ax^2+bx +c$

A 2.3: Cubic

Table A16: Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.811	.658	-.025	.379

The independent variable is VAR00001.

Table A17: Analysis of Variance

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.277	2	.139	.964	.584
Residual	.144	1	.144		
Total	.421	3			

The independent variable is VAR00001.

Table A18: Cubic Coefficients

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
VAR00001 ** 2	-.613	1.131	-8.861	-.542	.684
VAR00001 ** 3	.180	.307	9.603	.587	.662
(Constant)	1.108	.896		1.237	.433

Cubic estimation

R= 0.811

$Y= ax3+bx^2+cx+D$

$Y=0.18x^3-0.613x^2+1.108$

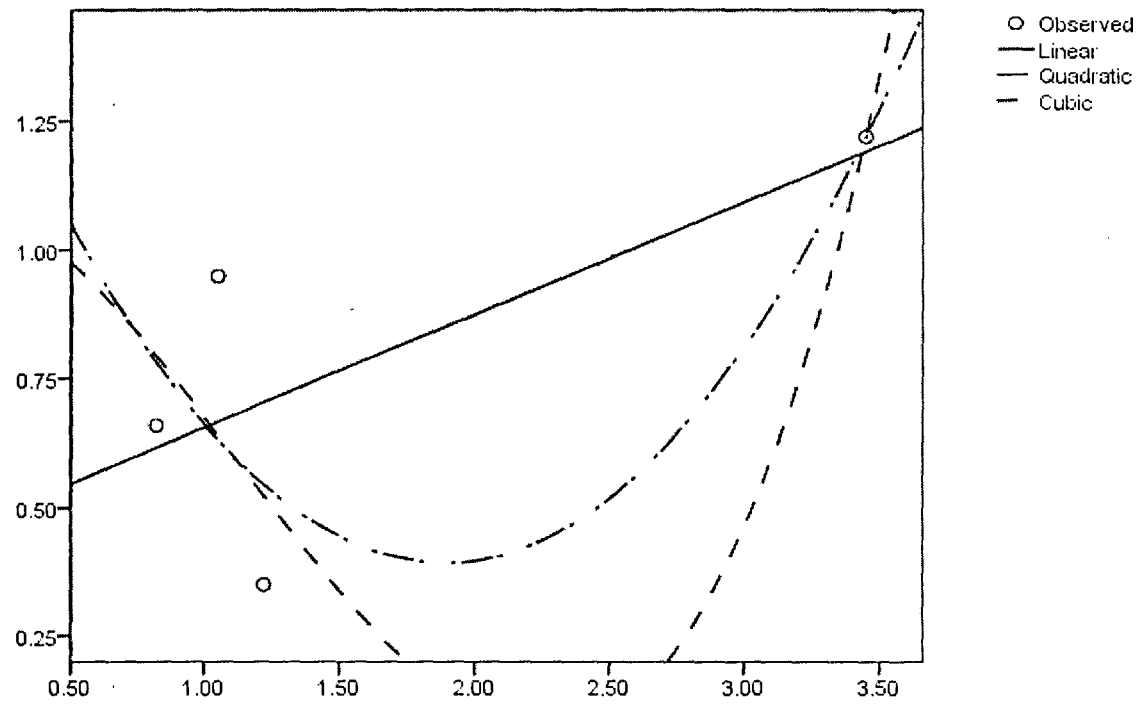

Fig.A5: ANOVA graph for uncontrolled Bermuda grass

A3: ANALYSIS OF VARIANCE FOR PRE AND POST ANALYSIS OF CONTROL SOIL

A 3.1 Linear Regression Tables

Table A19: Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
1.000	1.000	1.000	.091

The independent variable is VAR00001.

Table A20: Analysis of Variance

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	97.649	1	97.649	1.173	.0004
Residual	.017	2	.008		
Total	97.665	3			

The independent variable is VAR00001.

Table A21: Linear Coefficients

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
VAR00001	1.024	.009	1.000	108.327	.000
(Const)	-.250	.087		-2.863	.103

Linear curve estimation

Y= 1.000

Y= ax+c

Y= 1.024x-0.25

A 3.2: Quadratic Regression Tables

Table A22: Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
1.000	1.000	1.000	.044

The independent variable is VAR00001.

Table A23: Analysis of Variance

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	97.663	2	48.832	2.5434	.004
Residual	.002	1	.002		
Total	97.665	3			

The independent variable is VAR00001.

Table A24: Quadratic Coefficients

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
VAR00001	1.069	.017	1.043	64.402	.010
VAR00001 ** 2	-.003	.001	-.045	-2.769	.221
(Constant)	-.328	.051		-6.492	.097

Quadratic curve estimation

R= 1.000

$Y= ax^2+bx+c$

$Y= -0.03x^2+1.069x-0.328$

A 3.3: Cubic Regression Tables

Table A25: Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
1.000	1.000	.	.

The independent variable is VAR00001.

Table A26: Analysis of Variance

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	97.665	3	32.555	.	.
Residual	.000	0	.		
Total	97.665	3			

The independent variable is VAR00001.

Table A27: Cubic Coefficients

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
VAR00001	1.133	.000	1.106	.	.
VAR00001 ** 2	-.015	.000	-.208	.	.
VAR00001 ** 3	.001	.000	.104	.	.
(Constant)	-.369	.000		.	.

R= 1.000

Y= ax3+bx2+cx+D

Y=0.01x3-0.015x2+1.33x-0.369

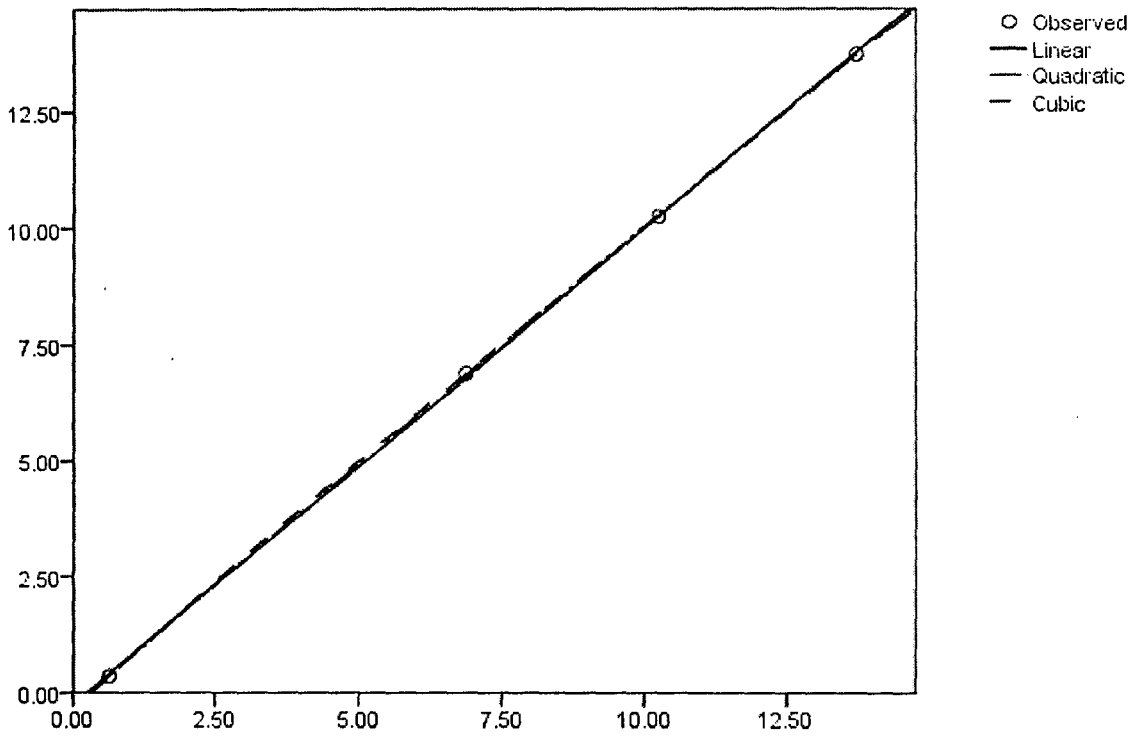

Fig.A6: ANOVA graph of soil for Bermuda grass (control)

A4: ANALYSIS OF VARIANCE FOR PRE AND POST PLANT ANALYSIS OF CONTROL

A 4.1: Linear Regression Tables

Table A28: Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.744	.554	.331	.326

The independent variable is VAR00001.

Table A29: Analysis of Variance

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	.264	1	.264	2.482	.256
Residual	.213	2	.107		
Total	.478	3			

The independent variable is VAR00001.

Table A30: Linear Coefficients

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
VAR00001	.298	.189	.744	1.575	.256
(Const.)	.350	.325		1.077	.394

Linear curve estimation

R= 0.744

Y= ax2+c

Y=0.298x+0.350

A 4.2: Quadratic Regression Tables

Table A31: Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.764	.584	-.249	.446

The independent variable is VAR00001.

Table A32: Analysis of Variance

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	.279	2	.139	.701	.645
Residual	.199	1	.199		
Total	.478	3			

The independent variable is VAR00001.

Table A33: Quadratic Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	T	Sig.
VAR00001	-.531	3.104	-1.326	-.171	.892
VAR00001 ** 2	.213	.796	2.078	.268	.833
(Constant)	.952	2.291		.416	.749

R=0.744

Y=ax2+bx+c

Y=0.213x2 -0.531x+0.952

A 4.3: Cubic Regression Tables

Table A34: Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.766	.587	-.238	.444

The independent variable is VAR00001.

Table A35: Analysis of Variance

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	.281	2	.140	.711	.642
Residual	.197	1	.197		
Total	.478	3			

The independent variable is VAR00001.

Table A36: Cubic Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	T	Sig.
VAR00001 ** 2	-.223	1.541	-2.175	-.145	.908
VAR00001 ** 3	.094	.481	2.934	.195	.877
(Constant)	.767	1.083		.709	.608

R= 0.766

Y= ax3+bx2+cx+D

Y= 0.094x3-0.223x2+0.767

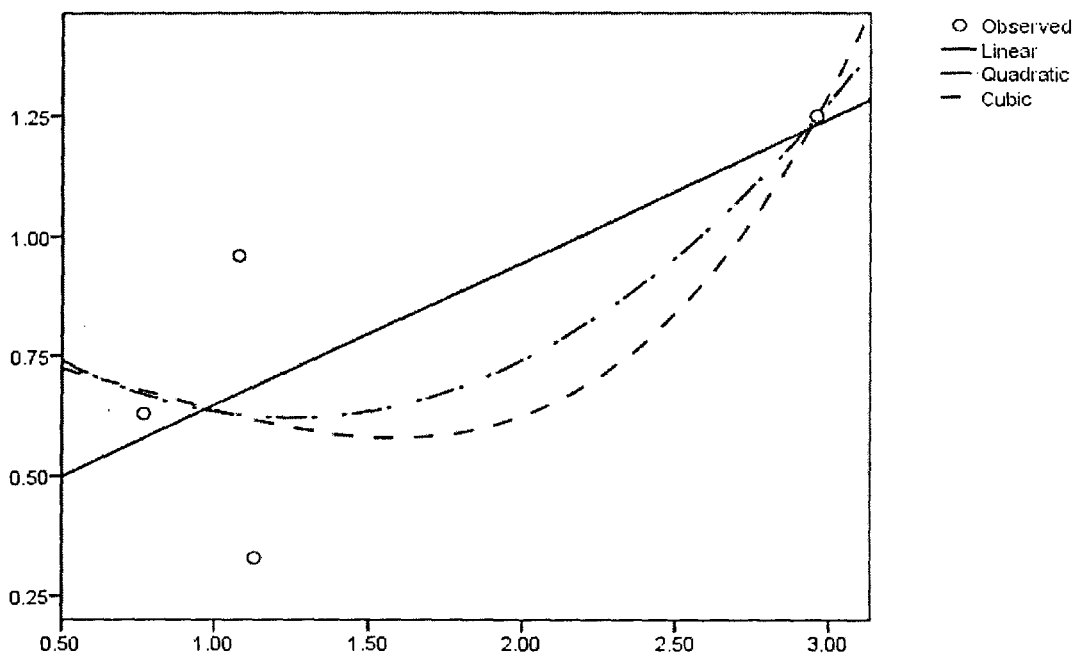

Fig.A7: ANOVA graph for Bermuda grass (control)

Plate A1: Bermuda grass (*Cynodon dactylon*)