CURRENT STUDIES IN COMPARATIVE EDUCATION, SCIENCE AND TECHNOLOGY, VOLUME 2, NUMBER 2, 2015, PP. 179-196

Impact of Oilfield Wastewater on Soil Quality and Soils Planted with Various Crops

EMYLIA TAMUNODIARI JAJA & OMOKARO OBIRE
University of Science and Technology, Nigeria

ABSTRACT The effect of various concentrations (0%, 25%, 50%, 75% and 100%) of oilfield wastewater on soil quality and of soils planted with *Zea mays* (Maize) *Abelmoschus esculentus* (Okra) *Arachis hypogeal* (Groungnuts) and *Telfairia occidentalis* (Fluted pumpkin) commonly cultivated in the Niger Delta was investigated. This was achieved by the determination of the physico-chemical constituents including heavy metals (zinc, lead, nickel, and cadmium) of the oilfield wastewater, of the experimental soil, of soils treated with oilfield wastewater and planted with these plants using standard methods of APHA and ASTM. Results of the physicochemical constituents of the oilfield wastewater showed, the pH was in the alkaline range of 8.3, high electrical conductivity, Turbidity and Total Dissolved solids above the acceptable limit by FEPA. The values of the heavy metals ranged from <0.001 to 0.391mg/l. With the exception of pH, there was a progressive increase in the concentration of all the other constituents of the soil with increasing concentration of oilfield wastewater. There was a steady rise in values for the pH, EC, total hydrocarbon, Available P, and NO_3-N with increasing concentration in soils planted with *A. occidentalis*. However, there were variations in the trend of the other parameters. The treated soils planted with *Z. mays* showed that except in the Mg^{2+}, NH_4-H, NO_3-H, THC and EC all others parameters increased with increase in concentration of oilfield wastewater. The treated soils planted with *A. hypogea* showed that though there was a steady increase in pH, Organic Carbon, Total Nitrogen, and Available Phosphorus, all other parameters showed no regular pattern of variation. Treated soils planted with *A. esculentus* showed that uptake of nutrients by the plant did not follow any definite pattern. A comparison of the physico-chemical constituents of the soils after planting showed that each plant responded differently to the initial nutrient level of the soils. *A. esculentus* elicited the least effect on the soil. Heavy metals in treated soils with the various plants except *T. occidentalis* showed that generally, these soils exhibited increases in Zinc content between the control and 25%. Except at 50% concentration, soils planted with *A. hypogea* had Nickel values of <0.001 and in control soils for all the plants. *T. occidentalis* and *A. hypogea* had same values of Cadmium in all the 50% treatment. Values of Cadmium were the same at 100% in all the soils. Zinc values for all the treatment were highest in *A. esculentus.* However, the control of all the plants except *Z. mays* had the highest values. Absorption of total hydrocarbon and other hazardous constituents of the oilfield wastewater by the plants which serve as sources of food for humans pose a serious health hazard. The oilfield wastewater has been shown to have serious deleterious effect on soil and plants, leading to eco-toxicological and agro soil fertility problems that could create an artificial food scarcity.

Keywords: Oilfield wastewater, soil quality, plants, nutrient uptake, heavy metals, total hydrocarbon

Introduction

Soil quality is the sustainable capacity of the soil to produce a good yield of high quality on basis of chemical, physical and biological quality factors, maintain environmental quality and promote plant and animal health (Solomon *et al.,* 2008). Soil pollution has, in fact, been an issue for decades. The soil serves as a temporary or permanent sink for any chemical substance that hits its surface. The fate of the chemical is determined by the combination or relationships such as variations in sorption, desorption, transport and permeability of soil water and soil air, and the properties of the given chemical (Torstensson *et al.,* 1998).

Crude oil (including refined petroleum products) is not the only pollutant of the environment from petroleum exploration and productive activities. The oilfield wastewater resulting from crude oil exploration activities is one of the major pollutants of both terrestrial and aquatic environments (Wills, 2000; Obire and Amusan, 2003). Produced water discharged on terrestrial and or aquatic environments may be very devastating. The numerous inorganic and organic constituents dissolved in the produced water can be potentially or actually far more hazardous than the crude oil itself. All these components may act together to impact on soil properties (Wardley-Smith, 1979; Scott *et al.,* 2007). Perhaps the most ecologically damaging types of oilfield related spills are those which involve releases of oilfield brines from buried injection lines. Since there is often no petroleum-related sheen associated with spills of these highly saline fluids, they can go unnoticed initially, becoming evident much later when overlying vegetation begins to show signs of stress or dies (Bennmoussa and Achouch, 2005).

It has been noted that onshore oil operations discharge produced water onto the terrestrial environment usually within settlement ponds or pits as part of their normal activities (Wills, 2000). However, due to faulty construction or deterioration or absence of synthetic impermeable liners, a fault or crack could develop in the wastewater stabilization ponds leading to soil contamination (Ream, 1983). Oilfield wastewater discharged onto terrestrial is very devastating because this could lead to eco-toxicological and agro soil fertility problems that would create an artificial food scarcity due to damage to vegetation (Odeigah *et al.,* 1997).

The Niger Delta is home to several petroleum and petroleum related exploration activities and petroleum industries. The intense industrial activities have attracted a lot of research interest especially in petroleum hydrocarbons in soil and aquatic environments and in organisms. However, most of these researches are classified information and as a result, there is little or no literature on the impact of oilfield wastewater on the environment that is available to the general public.

The Objectives of this study were to determine the effect of various concentration (0%, 25%, 50%, 75% and 100%) of oilfield wastewater on soil quality (physicochemical parameters including heavy metals) of soils planted with *Arachis hypogeal* L (Groundnut), *Abelmoschus esculentus* L (Okra), *Telfairia occidentals* Hook F (Fluted pumpkin "Ugu") *and Zea mays* L (Maize). These plants were chosen because of their availability and the fact that they are commonly grown, cultivated and consumed in the Niger Delta region (FPDD, 1989; Akande *et al.,* 2006). The study will therefore help to unravel the retention properties of soils to chemical constituents of the oilfield wastewater; the impact of oilfield wastewater on soil fertility and on agricultural productivity and to ascertain the phyto-remediation potential of the various plants in oilfield wastewater polluted soils.

Materials and Methods

Collection of Oilfield Produced Water Samples

Freshly treated oilfield produced water samples were collected from the outlet of the separation/treatment plant of an oilfield flow station located at Kwale Community in Ndokwa East Local Government Area of Delta State. Sterile plastic Jerry cans were used to collect the produced water samples. Prior to collection of the produced water, the interior of the nozzle of the outlet valve was flushed by allowing the produced water to flow to waste for 2 to 3 minutes after which the Jerry cans were filled from a gentle stream of the produced water.

Collection of Soil Samples

Soil Samples were collected from a depth of 0 - 15cm with the aid of a brand new shovel sterilized with ethanol and bulked together to form a composite sample. The composite soil was sieved through a 2mm sieve as to remove debris that would otherwise absorb the treatment that will be experimentally performed on the soil and plants. Thereafter, one Kilogramme (1kg) of the sieved soil was weighed out using Analytical weighing balance (AL 2105 Germany) and put into a black polythene bag. A total of 120 polythene bags with sieved soil samples were prepared and kept in a Green house.

Collection of Plant Seeds and Viability Test

The plant seeds of *Arachis hypogeal* L, *Abelmoschus esculentus* L*, Telfairia occidentalis* L *and Zea mays* L were purchased from the Mile 3 market in Diobu, Port Harcourt. The seeds were collected in sterile polythene bags and transported to the laboratory. The viability test as described by Amakiri and Onofeghara (1984) was used to ascertain the viability of the various seeds before they were used for the study.

Preliminary Study on the Plants

A preliminary study of the effect of the different concentrations of oilfield produced water on the plants was carried out to determine the duration of study. The study showed that by the 10^{th} week, most of the plants treated with higher concentrations had died off. The 8^{th} week was therefore taken as the terminal age of plant at which collection and analysis were carried out.

Determination of Water Holding Capacity

The water-holding capacity of the soil was determined with reference to Bouyoucos (1951).
The volume of each concentration of oilfield formation water used for the treatment was 60% of the water holding capacity of the soil.

Experimental Design

The experimental design was the randomized complete block design (RCBD). Twenty (20) bags from the 120 bags of sieved soil were allotted to each of the four plant seeds making a total of 80 bags sowed with seeds. Plant seeds were not sowed into the remaining 40 bags of sieved soil. However, 20 bags were also treated with oilfield wastewater and these served as control soils without plant seeds while the remaining 20 bags of sieved soil were treated with the water used in the dilution of the oilfield wastewater and these served as a second set of control. The five different concentrations of the oilfield wastewater used as treatments for the study were [0% (control), 25%, 50%, 75%, and 100%]. The 0% treatment served as control for the treated plants. All the treatments for each plant seed was replicated four times (i.e. 5 × 4 = 20). Each experimental polythene bag was appropriately labeled with the concentration of oilfield wastewater to be used as treatment. Five (5) viable seeds were sown into each bag of soil and treatment with the different concentrations of oilfield wastewater commenced two (2) weeks after the seeds were sown. This was to allow the seeds to germinate before the treatment. Treatment volumes of 60% water holding capacity were repeated at weekly intervals until after 8 weeks during which the soils were collected at intervals for analysis.

Results

The mean values of physicochemical constituents of oilfield wastewater is as follows; pH (8.3), Electrical Conductivity (9500 µmhos/cm), Turbidity (139 NTU), Salinity (5.2‰), Temperature (30.4 ^{o}C), Total Dissolved Solids (6650.4 mg/l), Phosphate (0.06 mg/l), Nitrate (0.16 mg/l), Sulphate (24.26 mg/l), Chloride (2568.8 mg/l), Total Alkalinity [($CaCO_3$) 500 mg/l], Total Hardness [($CaCO_3$) 134.4 mg/l], Calcium (46.08 mg/l), Magnesium (4.68 mg/l), Lead (0.001 mg/l), Nickel (0.001 mg/l), Zinc (0.391 mg/l), and Cadmium (0.001 mg/l). On the other hand, the mean values of physicochemical constituents and textural class of the experimental control soil sample is as follows; pH (6.99), Electrical Conductivity (176µmhos/cm), Salinity (0.0‰), Total Hydrocarbon (4.74mg/kg), Organic Carbon (1.45%) Carbon/Nitrogen ratio [(C : N) 2:1], NH_4-N (21.0 mg/kg), NO_3-N (70.0 mg/kg), Available Phosphorus (42.11 mg/kg), K (0.22 mg/kg), Na (0.37 mg/kg), Ca (4.40 mg/kg), Mg (2.20 mg/kg), Pb (0.014 mg/kg), Ni (0.346 mg/kg), Zn (1.412 mg/kg), Cd (0.001 mg/kg), Sand 89.52%, Silt 6.00%, Clay 4.48%, Textural Class is Sand.

The Physico-chemical constituent of soils planted with the various crops and treated with different concentrations of oilfield wastewater is shown in Figure 1. The heavy metal content of soils planted with the various crops and treated with different concentrations of oilfield wastewater is shown in Figure 2.

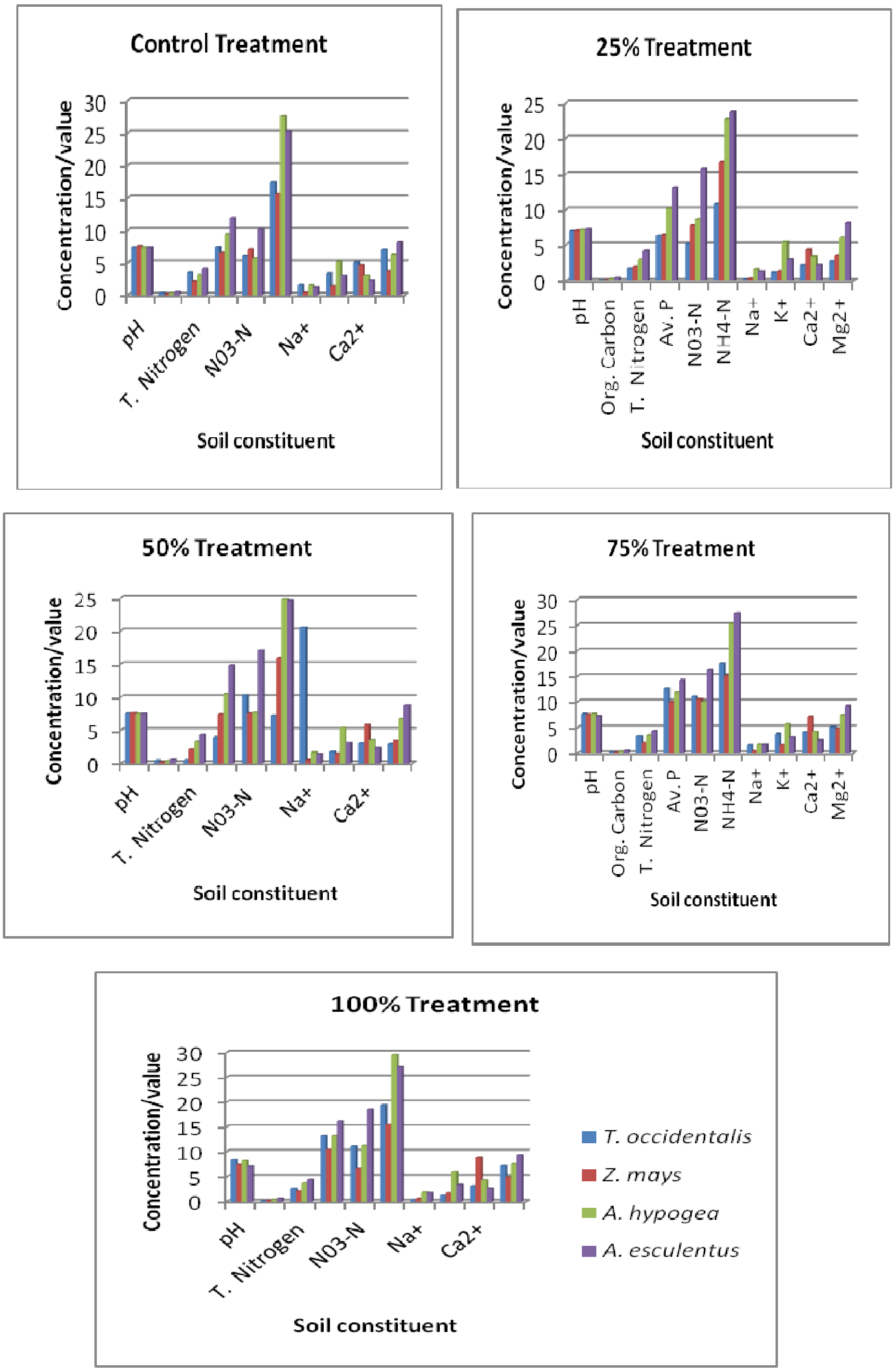

Fig.1: Constituent of soils planted with different crops and treated with oilfield wastewater

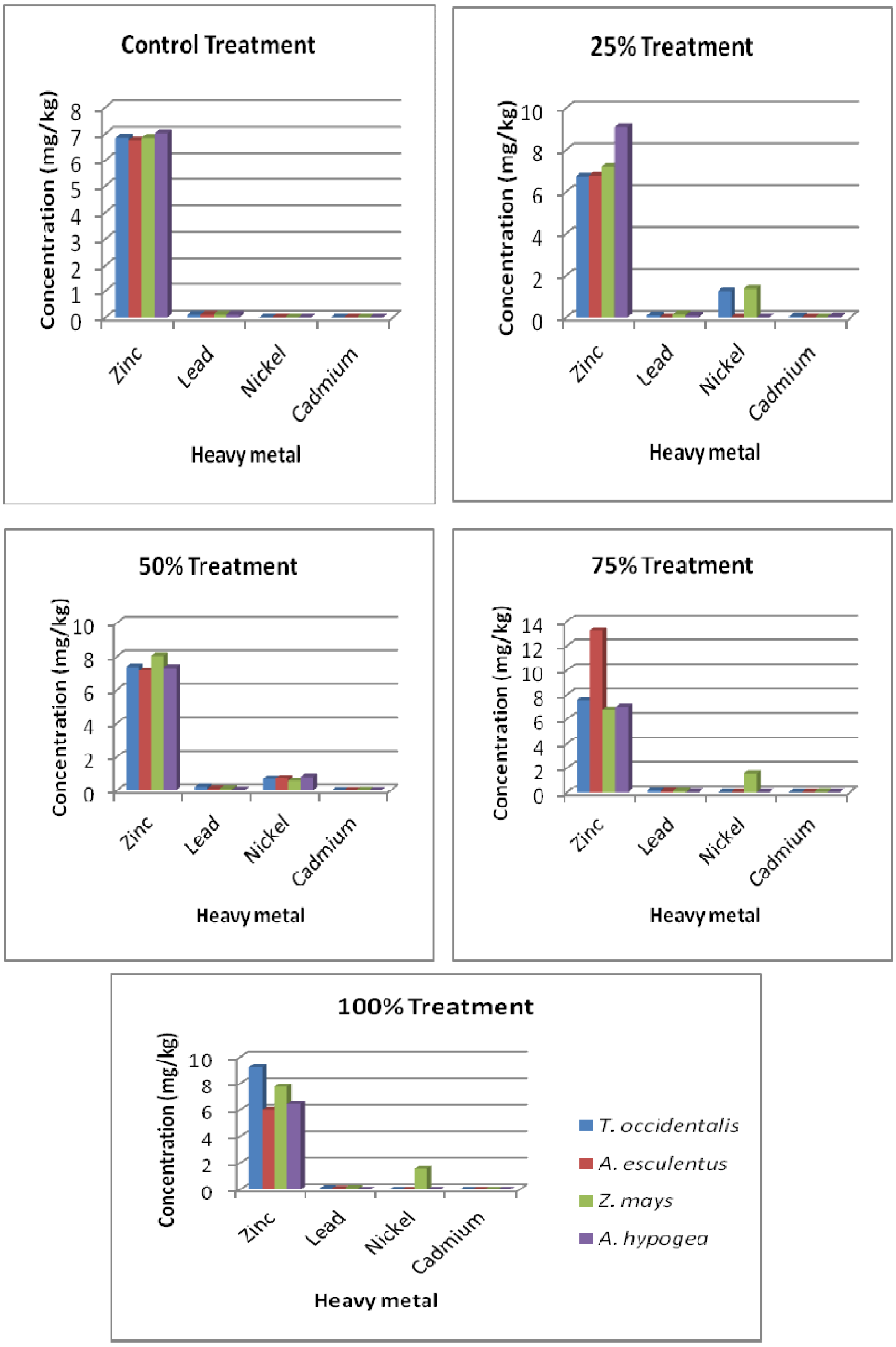

Fig.2: Heavy metals in soils planted with different crops and treated with oil-field wastewater

Discussion

The present study has unraveled the concentrations of the physicochemical constituents including heavy metals of oilfield wastewater and constituents and textural class of soils treated with various concentrations of oilfield wastewater. The study has also revealed the constituents of soils planted with various crops and treated with various concentrations of oilfield wastewater thereby unraveling the impact of the oilfield wastewater on the physicochemical constituents of the soils used in this study.

It was observed during this study that, on treatment of the control soils with oilfield wastewaters of varying concentrations, there was a complete change in the values of the physicochemical constituents of the soils.

Results of physicochemical constituents of the oilfield produced water showed that values recorded for electrical conductivity, turbidity, salinity, chloride, total alkalinity, total hardness and calcium were quite high when compared to their corresponding values in the control soil samples. This result alone is an indication that when such oilfield wastewater is introduced into the soil, the organisms (plants and animals) therein the soil will definitely be subjected to some form of stress conforming to the work of Amadi *et al.,* (1993). The concentration of zinc was higher than the concentration of the other heavy metals. The values of the heavy metals except those of zinc were within the permissible limit recommended for effluents before discharge (FEPA, 1991). However, heavy metal concentration was observed to increase with increasing concentration of oilfield wastewater.

The calcium and magnesium values of the produced water were lower than the permissible limit of 200mg/l allowed for effluent before discharge (DPR, 1991). It is known that calcium and magnesium may cause hardness in the produced water and this can cause undesirable effects (Onyeike and Oseyi, 2003) especially when discharged into soil. The high electrical conductivity (EC) levels, total dissolved solids (TDS), Total hardness and total alkalinity values are all indictors of the fact that the oilfield wastewater is not suitable for use in irrigation or for plant growth. High salinity affects plant growth either osmotically, by direct toxicity or by creating nutrient imbalance (Parrondo *et al*., 1978; Pezeshki *et al*., 1987) confirmed that a common grass in freshwaters marshes (*Panicum hemitomen*), will die within four days if exposed to one third the salinity of seawater .

The pH recorded for the oilfield produced water used in this study is in the alkaline range and within the permissible range of 6.5 and 8.5. The pH of 6.99 is within the range that is suitable for plant growth (DPR, 1991). The pH of the control soil is in the neutral range. However, the pH of the experimental soil that was within the neutral range became acidic following treatment with the various concentrations of the oilfield wastewater. The acidity was observed to increase with increasing concentration of the wastewater. This must have been due to the interaction of other constituents of the oilfield wastewater with some constituents of the experimental soil.

Generally, except for the values of pH, the values of all other constituents of treated soils were higher than those of the control soil. In addition values were also observed to increase with increasing concentration of the wastewater. These increased values of the constituents have been reported to have negative effects on plant growth (Clemente *et al*., 2003). The soil quality is known to reduce with oil pollution.

The physico-chemical constituents and textural class of treated soils planted with *Telfairia occidentalis* showed that there was a steady rise in values for the pH, EC, THC, Available P and NO_3-N with increasing concentration of oilfield wastewater. However, there were variations in the trend of the other parameters. Plant nutrients such as phosphorus, nitrate nitrogen, ammonia were higher in the treated soils planted. This is an indication that the plants in such soils were stressed in their uptake of these plant nutrients.

Soils planted with *Zea mays* showed that except with Mg^{2+}, NH_4-H, NO_3-H, THC and EC all others parameters analyzed in soils planted with *Z. mays* increased with increase in concentration of oilfield wastewater. However, plant nutrients such as nitrate nitrogen, ammonia in treated soils planted with *Zea mays* did not follow this trend with the 25% and 50% treated soils (Amadi *et al.*, 1993). This is an indication that *Zea mays* were not stressed in the uptake of these nutrients at these concentrations of oilfield wastewater. This is a proof that different plant species can respond differently to different concentrations of a particular pollutant or contaminant (Akande *et al.,* 2006).

The treated soils planted with *Arachis hypogea* showed that although there was a steady increase in parameters such as pH, Organic Carbon, Total Nitrogen, Available Phosphorus, all the other parameters showed no regular pattern of variation. The pH of the soils became more alkaline with increasing concentration of the wastewater. This can be attributed to the increasing concentration of total nitrogen, nitrate nitrogen and ammonia due to the inability of the plant to absorb these nutrients. This resulted in their accumulation in the soils which in turn resulted in the soils becoming more alkaline. The observed decrease in these nutrients at 25% is also attributed to the fact that *Arachis hypogea* was able to fix nitrogen which resulted in the decreased values observed for total nitrogen and nitrate nitrogen at the 25% concentration. This showed that *Arachis hypogea* were not stressed in the uptake of these nutrients and available phosphorus at the 25% concentration.

The treated soils planted with *Abelmoschus esculentus* showed that the uptake of nutrients by the plant did not follow any definite pattern. However, organic carbon and total nitrogen decreased at 25% concentration. An indication that their uptake was not stressed as the 25% concentration. A comparison of the physico-chemical constituents and textural class of control soils planted with the various plants showed that each plant responded differently to the initial nutrient level of the soils. *Abelmoschus esculentus* elicited the least effect on the soil. The soils planted with *Abelmoschus esculentus* also became more alkaline (7.30) than those of other plants.

A. hypogea showed increase in pH of the treated soil with increase in concentration of oilfield wastewater. An alkaline soil is detrimental to plant growth (Clemente *et al.,* 2003) and root establishment. Odeigah *et al.,* (1997) showed that root lengths decrease with increasing concentration of wastewater. Generally, there was an increase in Nitrogen constituents of the soil with *Arachis hypogea* which can be explained to be because of the leguminous nature of the plant (Fashina *et al.*, 2002).

Electrical conductivity values for treated soils with *A. hypogea* were higher than in the control. The values at 75% concentration were above all other concentration. This agrees with the work of Pezeshki *et al.,* (1987) that increase in salinity can affect the adsorption proportion of the roots. There was a general variation between the control and soil of the various concentrations in this study. Wardley-Smith (1979) reported that organic constituents dissolved in the produced water can be potentially or actually for more hazardous than the crude oil itself. Electrical conductivity value of less than 3,000µs/cm was reported during this study. This was also reported by (Mcfarlane *et al.,* 2002).

The values for the micronutrients of the treated soils varied from those of the control in this investigation. This could be as a result of the pollution with the oilfield wastewater which has been made unavailable for the plant uptake. A change in the textural class of the soil after treatment to increased clay proportions showed a decrease in soil fertility (Bernal *et al.,* 2007). Plant roots modified the chemical and physical properties of the soil around them by way of root exudates, ramification and physical presence and thus influence the bioavailability of some chemical elements (Tortennson *et al*., 1998). The control soil remained the most fertile with its silt constituent being the highest. Added to sandy soil, the waters holding capacity is increased (Isirimah *et al.,* 2003).

The pH values were consistently lower in the control soil planted with *A. esculentus* except at 50%. *A. esculentus* was able to reduce the EC values of lower than the control except at the 100% concentration of oilfield wastewater. *A. esculentus* was able to take up some of the toxic substances in soil thus increasing fertility of soil (Tedesco *et al*., 2003). The deviation in response at 25% oilfield concentration agrees with the works of Amakiri and Onofeghara (1984) which states that sub lethal doses of pollutant can sometimes elicit remarkable effects. *A. esculentus* was consistently, the plant that was least affected by the physicochemical constituents of the oilfield wastewater.

The physico-chemical constituents and textural class of 25% treated soils planted with the various plants showed that the pH values for soils of all the plants were 7.27 except that of *Z. mays* which was higher at 7.45. *T. occidentalis* had a high E.C value of 355 µs/cm while the THC of soils of *A. esculentus* was the highest at 536.73. Most of the constituents of soils planted with *A. esculentus* recorded higher values than soils of the other plants.

The Physico-chemical constituents of 75% treated soils planted with the various plants showed that soils planted with *Z. mays* had the lowest values for K^+. Available phosphorus was highest in soils planted with *A. esculentus.* Results gave an overall view of the nutrient requirement of each plant type.

The physico-chemical constituents and textural class of 100% treated soils planted with the various plants showed that they were all in the alkaline range (pH 7.15 – 8.37). The EC values were found to be between 401 – 572.00µs/cm. The total hydrocarbon (THC) content ranged from 111.37 – 285.54. The highest THC concentration was recorded in the soils planted with *Zea mays* while the lowest was recorded in soils planted with *Abelmoschus esculentus.* Fertility of the soil was also most affected by *A. esculentus* which eventually left the textural class of the soil as clay (Isirimah *et al.,* 2003).

The heavy metals in 50%, 75% and 100% treated soils planted with the various plants showed that Nickel ranged from 0.571–0.818mg/g and Cadmium <0.001 – 0.008mg/g. Zinc content of soils planted with *T. occidentalis* was high at 13.254 while values for the other plants ranged between 6.735 – 6.991mg/g in 75% soils planted with the various plants. Values of Lead in the various treated soils were within the range 0.008 – 0.091mg/g. Cadmium was present in trace levels in 100% soils planted with the various plants.

The concentrations of Zinc, Lead, Nickel and Cadmium in treated soils with the various plants showed that generally, all the treated soils exhibited increases in Zinc contents between the control and 25% except *T. occidentalis.* All treated soils for the various plants recorded lower lead values in the 100% concentration than the control. Except at 50% concentration, soils planted with *A. hypogea* had Nickel values less than 0.001; control soils for all the plants had Nickel <0.001. Treated soils planted with *T. occidentalis* and *A. hypogea* had same values of Cadmium in all the 50% levels of concentration. In all the treated soils, Cadmium values were the same at 100%.

The heavy metals in soils treated with different concentrations of oilfield wastewater planted with *Arachis hypogea* showed a reduction in zinc with increasing concentration of treatment ranging from 6.443 – 9.074. Lead followed almost same pattern. This reduction in zinc and lead with increasing concentration showed that there was an active uptake of these heavy metals which is detrimental to the plants and human health through bioaccumulation and ingestion (Alloway, 1995; Biran *et al.*, 2000 and Briuns *et al.*, 2000). Nickel was insignificant except at the 50% concentration where a value of

0.818 was recorded. The heavy metals in soils treated with different concentrations of oilfield wastewater planted with *Telfairia occidentalis* showed no regular pattern. Their concentration ranged from <0.001 – 13.254.

The heavy metals in Control soils and 25% treated soils planted with the various plants are as showed that the soils of *A. esculentus* extracted the more Zinc from the soil. Nickel and Cadmium had values of <0.001 for all the soils. While values for Nickel in all the soils with various plants ranged between <0.001 and 1.393 and Cadmium <0.002 and 0.004 in 25% soils planted with the various plants.

The values of Zinc, Lead, Nickel, and Cadmium in the leaf extracts of the various plants with the various treatments showed that Zinc was highest in *A. esculentus*. However, for all the plant except *Z. mays* the control had the highest values. Except in *A. esculentus,* lead was highest in the control. Nickel was found to be high at 100% concentration for *A. esculentus* with a value of 3.564. The values of nickel were the same at all levels of concentration and plant types except for *A. esculentus* at 100% and *A. hypogea* at 25%. However, there was generally no definite trend in the values of Cadmium in leaf extracts of the various plants for all treatment (Aletor *et al.*, 2002).

The heavy metals in leaf extracts from the treated soils planted with the various plants also showed that Zinc values were high for all the plants. The heavy metals were highest in *A. esculentus* than in any other plant. However, the values for Nickel were the same for all plant types except in *A. hypogea*. An overall view showed *A. esculentus* to have the highest values for heavy metal at 25% level of concentration and treatment. Generally, the value of Nickel was the same for all the plant types *Z. mays* had the lowest value of 0.036 for Cadmium in leaf extracts from 50% planted with the various plant. At 75% treatment of the plants, *T. occidentalis* has the lowest values for all the heavy metals. There was generally, heavy metal accumulation in leaf extract from 100% concentration

Heavy metals in leaf extracts of *Zea mays*, *Abelmoschus esculentus*, *Arachis hypogea*, and *Telfairia occidentalis* from soils treated with different concentrations of oilfield wastewater showed that Zinc levels was highest at the 100% concentration the control had the highest values for Lead and Cadmium (Kaschl *et al.,* 2002). The levels of Nickel were highest at the 100% concentration. The highest value was recorded for Zinc in the control for *Abelmoschus esculentus*. Lead and Zinc values were highest in the control except at the 25% concentration of oilfield wastewaters, the values of Nickel remained the same for all other concentrations for *Arachis hypogea*. The values of all the heavy metals under study were highest in the control (Ghosh and Singh, 2005). Values for Nickel were same for all the concentrations for *Telfairia occidentalis*. The heavy metals in soils treated with different concentration of oilfield wastewater and planted with various plants showed that the cadmium content of soils was quite low. Zinc and Nickel ranged as having the higher values of the four heavy metals under study. Generally there was an increase in uptake of the heavy metals with increase in concentration of oilfield wastewater. The values in the control soils were lower than those of all treated plants. This agrees with reports from the other workers that reported that heavy metal movement is small (Prasad *et al.,* 2001). The extent of toxicity of the heavy metal in the relation to the concentration and the time of exposure Lead values for the various plants soils recorded lower values at the 100% concentration than the control. This is because under extreme stress conditions and high concentration of heavy metals, the plants take up more of the heavy metals. The results of heavy metals have shown that different plants respond differently to the uptake of different heavy metals.

Conclusion

The oilfield wastewater used in the study has been proven to be a pollutant to the soil. The oilfield wastewater had a very high electrical conductivity which makes it unsuitable for plant growth. The amount of total dissolved solids, 6650.4mg/l found in the oilfield wastewater was above the acceptable limit by FEPA and detrimental to plants. Calcium level of 46.08mg/l was high. An indication of the hardness of the wastewater in which is bound to reduce plant growth. Bioavailability of the important plant nutrients, N_2, P and K were affected by treatment with oilfield wastewater. The textural class of the soil was also affected by treatment with oilfield wastewater thus reducing the fertility (soil quality) of the soils. Treatment with oilfield wastewater reduced the Total Nitrogen in soil while increasing the Ca^{2+} and Mg^{2+} ions and as a result, causing reduction in fertility of the soil. Through none of the plants could be recommended for serious phytoremediation processes, *A. hypogea and A. esculentus* were more effective in phytoremediation as they were observed to bioaccumulate more heavy metals (zinc, nickel, lead and cadmium) than the other plants. Absorption of total hydrocarbon content by the plants which serve as sources of food for humans poses a serious health hazard. The discharge of oilfield wastewater into the terrestrial environment has been shown to have serious deleterious effect on soil and plants, leading to eco-toxicological and agro soil fertility problems that could create an artificial food scarcity due to damage to vegetation and soil organisms. Oilfield wastewater is known to contain some carcinogenic chemicals. Pollution of agricultural soils with toxic substances such as oilfield wastewater is a frequent problem of oil exploration and exploitation. The hazardous components/constituents of the oilfield wastewater are taken up by the plants which in turn are eaten by humans. This poses a serious health hazard.

Recommendations

Based on the findings from the study, it is recommended that the Federal Government should acquire improved technology for on-site removal of oil from the oilfield wastewater for reduction of the concentrations of organic and inorganic constituents. To avoid bioaccumulation of the toxic constituents of the oilfield wastewater, there should be a continuous evaluation of the soils at the points of discharge. Oil companies must be consistently reminded of the potential eco-toxicological problems that may arise with persistent discharge of oilfield wastewater onto soil and aquatic environments. That phytoremediation of polluted soils be encouraged with use of appropriate and suitable plants; and that appropriate government agencies should put in place appropriate legislations to avoid the indiscriminate discharge of oilfield produced water onto terrestrial and into aquatic environment with the statutory responsibility of overall protection of the environment.

Correspondence
Omokaro Obire
Department of Applied and Environmental Biology, Rivers State
University of Science and Technology
P.M.B 5080, Port Harcourt, Nigeria
E-mail: omokaro515@yahoo.com

References

Akande, M. O., Oluwatoyinbo, F. I., Kayode C. O. and Olowokere, F. A. (2006). Response of maize (*Zea mays*) and Okra (*Abelmoschus esculentus*) intercrop Relayedmwith cowpea (*Vigna unguiculata*) to Different Levels of cow Dung amended Phosphate Rock. *World Journal of Agriculture sciences*. *2(1)*: 119-122.

Aletor, O., Oshodi, A. A. and Ipinmoroti, K. (2002). Chemical composition of common leafy vegetables and functional properties of their leaf protein concentrates. *Food Chemistry*. *78*: 63-68.

Alloway, B. J., (1995). *Heavy Metal in Soils* 2nd Ed Blackie Academy and Professional Gaslgow. 52-144.

Amadi, A., Dickson, A. A. and Maate, G. O. (1993). Remediation of Oil Polluted Soils 1. Effect of Organic and Inorganic Nutrient Supplements in the Performance of Maize (*Zea mays* L). *Water, Air and Soil Pollution*. *66*: 59-76.

Amakiri, J. O. and Onofeghara, F. A. (1984). Effect of Crude oil on the Germination of *Zea mays* and *Capsicum Frutescence*. *Environmental Pollute*. *35*:159-167.

American Public Health Association (APHA). (1998). *Standard methods for the examination of water and waste water*, 20th Ed. USA.

American Standard for Testing and materials (ASTM). (1999). "*Water and environment technology*. Philadelphia, USA.

AOAC (1984). *Association of Official Analytical Chemist.* 14th Ed. Wash ington D. C.

Benmoussa, Mebrouk and Achouch Abderrahmane (2005). Effect of water stress on yield and its composites of some cereals in Algeria. *Journal of Central European Agriculture*. *6(4)*: 427 - 434.

Bernal, M. P., Clement, R. and Walker, D. J. (2007). The role of Organic amendments in the bioremediation of heavy metal Polluted Soils. *Environment Research Journal*. *1/2*: 1-57.

Biran, I., Babia, R., Levcov, K., Rishpon, J. and Ron, E. Z. (2000). Online and Institution Monitoring of Environmental Pollutant: Electrochemical Biosensing of Cadmium. *Environmental Microbiology*. *2(3)*: 285-290.

Bouyoucos G. H (1951) A Recalibration of the Hydrometer for Making Mechanical Analysis of Soils. *Agron. Journ. 43:* 434 - 438.

Briums, M. R., Kapil, S. and Dehme, F.W. (2000). Microbial Resistance to Metals in the Environment. *Ecotoxicology and Environmental Safety, Environmental Research*. *45*: 198- 207.

Clemente, R., Walker, D. J., Roig, A., Bernal, M. P. (2003). Heavy metal Bioavailability sulphides contamination following the mine spillage at Aznalcollar (Spain). *Biodegradation*. *14*: 199-205

DRP - Department of Petroleum Resources. (1991). *Environmental Guidelines and Standards for the Petroleum industry in Nigeria.* Ministry of Petroleum Resources, Lagos, Pp 30-37.

Fashina, A. S., Olatunji, K. A. and Alasiri, K. A (2002). Effect of different plant populations and poultry manure on the yield of Ugu (*Telfairia occidentalis*) *in* Lagos State, Nigeria. In: *Proceedings of the Annual Conference of Horticultural Society of Nigeria (HORTSON),* 14th – 17th May 2002; NIHORT, Ibadan, Nigeria.

Federal Environmental Protection Agency FEPA. (1999). *Effluent Limitation and Pollution Abatement in Industries and Facilities Generating Wastes in Nigeria*. Abuja Nigeria.

FPDD., (1989). Fertilizer Use and Management Practices for Crops in Nigeria. Enwezor, W. O., Uoroh, E. J., Adeputu, J. A., Chude V. O. and Udegbe, C. I. (Eds.), FPDD Div. *Fed. Ministry of Agriculture and Water Resources and Rural Development Series*. *2*: 80 - 82.

Ghosh, M. and Singh, S. P. (2005). A review of Phytoremediation of heavy metals and utilization of it's by products. *Applied Ecology and Environment Research*. *3(1)*: 1 - 18.

Isirimah, N. O., Dickson, A. A. and Igwe, C. (2003). *Introductory Soil Chemistry and Biology for Agriculture and Biotechnology.* Osia Int'l Publishers Port Harcourt. 36-97.

Kaschl, A. V., Romheld and Chen, Y. (2002). Binding of Cadmium, Copper and Zinc to Humic Substances Originating from Municipal Solid Waste Compost. *Israel Journal of Chem. 291(1-3)*: 45 - 57.

McFarlane, J., Bostick, D. T. and Luo, H. (2002). Characterization and Modeling of Produced Water presented at the 2002 Ground Water Protection Council Produced Conference, Colorado Springs, CO, Oct. 16-17. (Paper available at: http://www.gwpc.org/Meetings/PW2002/Paper-Abstracts.htm.)

Obire, O. and Amusan, F. O. (2003). The Environmental Impact of Oilfield Formation Water on a Freshwater Stream in Nigeria. *J. Appl. Sci. and Environ. Mgt. 7(1)*: 61 - 66.

Odeigah, P., Nuruddeen, G. C. O. and Amund, O. O. (1997). Genotoxicity of oilfield waste water in Nigeria. *Hereditas*. *126*: 161 - 167.

Onyeike, E. N and Osuji, J. O. (2003). *Research Techniques in Biological and Chemical Sciences*. Springfield Publishers Ltd., 174 – 188.
Parrondo, R. T., Gooselink J. G. and Hopkinson C. S. (1978). Effects of Salinity and Drainage on the growth of three salt Marsh grasses *Bot. Gas*. *139*:102 - 107.

Pezeshki, S. R., Delaune, R. D. and Patrick, W. H. (1987a). Response of freshwater marsh species, *Panicum hemitomen* Schultz, to increased salinity. *Freshwater Biol*. 17:195-200.

Prasad, M. N. V., Malec, P., Waloszek, A., Bojko, M., Strazalka, K., (2001). Physiological responses of *Lemna trisulca* L. (duckweed) to Cadmium and Copper Bioaccumulation. *Plant Sci*. *161*: 881-889.

Ream, K. H. (1983). *Hazardous Waste Management.* American Chemical Society, Washington.

Scott, K. A., Yeats, P., Wohlgeschaffen, G., Dalziel, J., Niven, S. and Lee, K. (2007). Precipitation of heavy metals in produced water. Influence on contaminant transport and toxicity. *Marine Environ. Res. 63*: 143 - 167.

Solomon, M. G., Okon, P. B. and Umoetok (2008). Effects of Neem extracts on Soil properties, Microbial Populations and leaf Area of Fluted Pumpkin (*Telfairia occidentalis*). *Res. J. of Agron. 2(1)*: 12 - 17.

Tedesco, M. M., Ligo, Gianelo, C. and Simon, Z. (1988). Effect of Petroleum activated sludge on soil properties *Water Sci. Technol. 20(10)*: 63 - 74.

Torstensson, L., Pell. M. and Stenberg, B. (1998). Need of a Strategy for evaluation of arable soil quality. AMBIO: *A Journal of Human Environment*. *27(1)*:4 - 8.

Wardley-Smith, J. (1979). *The Prevention of Oil Pollution*. Graham and Tortman Ltd., London, 69 - 75.

Wills. J. (2000). A Survey of Offshore Oilfield Drilling Wastes and Disposal Techniques to reduce the ecological impact of Sea dumping: The effects of Discharged produced Waters. *Ekologickeaya Vahktaa Sackhalina (Sakhalina Environment Watch)* 25th May, Sakhalina. 1-5.