*Preprints* (www.preprints.org) | NOT PEER-REVIEWED | Posted: 18 January 2019 doi:10.20944/preprints201901.0182.v1

Peer-reviewed version available at *Asian Journal of Applied Chemistry Research* **2019**, *3*, AJACR.48785; doi:10.9734/ajacr/2019/v3i130085

# Potential of *Sorghum bicolor* L. (Moench) and the Effect of Enhancements in Remediation of Petroleum-Vitiated Soils of an Automobile Repair Workshop in Urbanite Kampala

**Timothy Omara[1,2,3,4]*, Raymond Kalukusu[3,4], Eddie Adupa[3,5], Tom Owori [5,6], David Mawanda Kizza[3,6], Jimmy Obonge[2,7]**

[1]Department of Health Sciences, Unicaf University, Longacres, Lusaka, Zambia
[2]Department of Quality Control, Quality Assurance and Product Development, AgroWays Uganda Limited, Jinja, Uganda
[3]Department of Quality Control and Quality Assurance, Leading Distillers Uganda Limited, Kampala, Uganda
[4] Department of Chemistry, Faculty of Science, Kyambogo University, Kampala, Uganda
[5]Department of Quality control and Quality Assurance, Abacus Parenteral Drugs Limited, Mukono, Uganda
[6]College of Agriculture and Environmental Sciences, Makerere University, Kampala, Uganda
[7]Department of Agroprocessing Engineering, Faculty of Engineering, Busitema University, Tororo, Uganda

## Email address:

prof.timo2018@gmail.com (T. Omara), kalukusur@gmail.com (R. Kalukusu), adupaeddie39@gmail.com (E. Adupa), oworitom@gmail.com (T. Owori), kizzadavid5@gmail.com (D.M. Kizza), jimmyobonge@gmail.com (J. Obonge)

*Corresponding author (prof.timo2018@gmail.com)

**Abstract:** The potential of S*orghum bicolor* L. (Moench) (*Epuripur 1995*) to phytoremediate petroleum oil-adulterated soils from an automobile repair workshop and the effect of enhancement factors: NPK fertilizer, cow dung and sewage sludge in *in situ* phytoremediation of the soil by the plant were assessed in this study. 50kg of petroleum oil-contaminated soil was collected from the workshop and divided into five equal portions. Four portions were potted with four sorghum plants with three subjected to equal amounts of enhancements (5%w/w) under normal growth conditions for 72 days. Representative soil samples were collected from spots at depths of 0-10cm and 10-20cm from the potted soils and subjected to Soxhlet oil extraction after 72 days. Experimental results revealed that *S. bicolor* survived in the petroleum oil-contaminated soils. Amendment of the petroleum oil-vitiated soils with cow dung, sewage sludge and NPK fertilizer augmented the remediation capacity of *Epuripur 1995* by 12.5%, 6.3% and 9.1%. Addition of cow dung to crude oil contaminated soils could make such soils fully reestablished for agricultural activities. Further research aimed at determination of the phytoremediation potential of cereals such as corn, barley, rye, millet should be done.

**Keywords:** Enhancement Factors, *Epuripur 1995*, Resource Curse, Urbanite Kampala.

## 1. Introduction

There has been a peak energy demand globally for diverse domestic and industrial purposes, especially following the invention of internal combustion engines. In Uganda, petroleum and its products utilized entirely for automobiles and thermal plants factor 9.7% to the gross national energy [1]. Uganda is a third world nation, growing steadily with lucrative commercial ties with the Western world. Despite its estimated 800million barrels of oil discovered in the Albertine Graben in 2006 [2], it is still a “resource curse”

Peer-reviewed version available at Asian Journal of Applied Chemistry Research 2019, 3, AJACR.48785; doi:10.9734/ajacr/2019/v3i130085



that it imports petroleum and petroleum products, used cars and second-hand machines from Japan, United Kingdom, United Arab Emirates, Singapore and South Africa [3,4]. Some of these imports are in compromised mechanical conditions, often requiring maintenance and servicing to enhance their intended performance. This calls for the establishment of automobile repair workshops (garages), which in turn aggravates the risk of oil contamination of the soils from spillages of petroleum and petroleum products. Petroleum (hydrocarbon) based products vitiate soil quality as the oil that infiltrates the soil persist for long periods of time [5]. Worse still, the oil suppresses nutrient availability [6,7] and retards water and nutrient absorption by plants [8]. In some cases, the oils accelerate toxic trace metal accumulation in the target soils [9].

The integrity of these petroleum oil-vitiated soils could be reestablished using locally available plants. Several approaches for elimination of petroleum oil in vitiated soil matrices include bioventing, soil washing, excavation, landfilling, incineration and land farming but usually carry prohibitive costs rendering bioremediation a feasible strategy [10]. Phytoremediation is a nascent eco-friendly and economically credited green environmental strategy for elimination of trace metals [11-13] and other soil contaminants in soils of vitiated qualities [14,15]. Plants utilized in remediation produce hazardous biomass with elevated levels of toxins, restricting their utilization as food and feed. Thus, the choice of plants with demonstrated remediation potential is key in effective phytoremediation.

*Sorghum bicolor* L. (Moench) (*Epuripur)* is a widely cultivated cereal in Uganda (third after maize and millet) and ranks among the top cultivated and consumed cereals worldwide [16]. It flourishes in nearly all environmental conditions and have excellent phytoremediation potential in adulterated soils [17]. Wastewater contaminated with Cadmium, Lead and Arsenic was used in an experimental irrigation of *S. bicolor* (L.) Moench by Shafiei and associates [18]**.** They reported that bioconcentration potential of *S. bicolor* is relegated to the priority trace metals and their corresponding concentrations; phytoremediation of the trace metals in the investigation followed the chemical sequence: Cadmium = Lead > Arsenic whereas tissue accumulation based on dry ash weight was equal for Cadmium and Lead with ions significantly differing in accumulation on dry weight basis. The plant potential to concentrate the trace metals followed a chemical sequence: Cadmium >Lead > Arsenic.

Phytoremediation of Lead contaminated soils by *S. bicolor* was investigated by Gandhi, Sirisha and Asthana [19]. Their results berwayed that *S. bicolor* L. (Moench) is a suited phytoextractor with a translocation factor (TF) less than 1, well higher than the bioaccumulation factor (BCF). At low concentrations, *S. bicolor* remediation was efficient though this diminished at elevated Lead concentrations; chelated assisted techniques employed comparatively in the investigation registered success in reducing the trace metal toxicity, with the physicochemical properties of the soils reducing drastically to WHO permissible limits [19].

Oh *et al* [20] assessed the remediation capability of *S. bicolor* and the enhancement effects with microbial inoculation in trace metal contaminated soil. Results pointed that sorghum survived the priority trace metals toxicity, and Lead-tolerant fungus inoculation enhanced the growth and phytoremediation of Lead, Nickel and Copper. The phytoextraction potential (evaluated in µg/plant) were respectively 73 for Copper, 410 for Lead and 74 for Nickel whereas 93 (Copper), 590 (Lead) and 120 µg/plant (Nickel) were recorded with inoculation. They recommended sorghum as a promising cereal for phytoremediation of adulterated soils.

Phytoremediation of Chromium metal polluted soils of Ranipet Tanneries was assessed utilizing *S. bicolor* plant as a phytoremediator by Revathi *et al* [21]. The impact of the trace metals on the biomass, chlorophyll content and the enhancement effect of vermicompost biosolids on *S. bicolor* bioaccumulation efficacy were evaluated. The findings revealed that a significant biomass decrement of the plant was noted with increased trace metal dosing meanwhile inclusion of vermicompost enhanced *S. bicolor* biomass.

Morphophysiological characterization of sweet Sorghum 'M-81E' by Jai *et al* [22] revealed that the plant effectively phytoremediated Cadmium metal without any negative growth consequences of the trace metal contamination in the growth media. Hydroponic assessments reported that the biomass of 'M-81E' had no detectable change at 10µM trace metal dosage. Trace metal concentration was elevated in the roots of both germinating and matured plants. Probing histochemical assays with dithizone staining showed that the trace metal was stored primarily in the root stele and haphazardly distributed in the intercellular spaces of the

*Preprints* (www.preprints.org) | NOT PEER-REVIEWED | Posted: 18 January 2019 doi:10.20944/preprints201901.0182.v1

Peer-reviewed version available at *Asian Journal of Applied Chemistry Research* **2019**, *3*, AJACR.48785; doi:10.9734/ajacr/2019/v3i130085

caulicles. Further analytical correlation studies in the caulicles and the leaves revealed that the trace metal exhibited a marked negative correlation with other trace metals: Zinc, Manganese and Iron and a positive correlation with Iron in the plant roots. They concluded that sorghum is a promising candidate for the remediation of Cadmium-adulterated soils.

Cesium (Cs) bioaccumulation properties by two cultivars of *S. bicolor*: Cowly and Nengsi 2 was assessed hydroponically at 50-1000µmol/L concentration and in soil with spiked metal concentrations of 100 and 400mg/kg soil by Wang *et al* [23]. The plants potted for the experimental 100 days had no significant differences in their heights, dry weight and metal bioconcentration. The *S. bicolor* varieties exhibited marked phytoextraction potential of Cs from the adulterated soils with the bioaccumulation and translocation factors greater than 1 in the soil and hydroponic systems respectively. The shoot of *S. bicolor* removed upto 92% of Cs. The metal at 100µmol/L in solution had the highest BCF and TF indices whereas Cs at lower concentrations were translocated to the plant shoot. Cs at higher concentrations had reduced transfer tendencies from the root to the aerial parts. Plant growth was considerably retarded at concentrations of 400 mg/kg soil and above. The metal was reported in the soil system at 1147, 2473 and 2939 mg/kg in the roots, stems and leaves respectively. On the other hand, the hydroponic system recorded an average metal concentration of 5270 and 4513 mg/kg in the roots and shoots respectively [23].

This study reported the potential of *S. bicolor*, locally known as *Epuripur* in phytoremediation of soils adulterated with petroleum-based oils in an automobile repair workshop. Akin to other nascent technologies in Uganda, plant remediation will be welcomed if and only if its success has been demonstrated with documentation to Environmental authorities like Uganda National Environmental Management Authority (NEMA), Ministry of Energy and Mineral Development (MEMD), Ministry of Finance, Planning and Economic Development (MoFPED) and Economic Policy Research Center (EPRC) for immediate emphasis as a green strategy for reclamation of petroleum oil-contaminated soils. The Upstream Act (cited in [2]) required NEMA to formulate guidelines for extraction, production, transit, storage, treatment and disposal of waste from the petroleum exploitation activities by the end of the year 2017. The results of this study is therefore a resource to the stakeholders involved in the drilling, extraction, transit and storage of the Ugandan crude oil in the Albertine Graben.

## 2. Materials and methods

### *2.1. Sampling site*

Petroleum oil contaminated soils were obtained from New Katanga Boys Automobile Repair Workshop (garage) on Akii Bua road, Wandegeya-Kampala (Figure 1).


***Figure 1.*** *Location of the area under study [24] (indicated by the arrow)*

### *2.2. Sample size, collection and preparation*

50kg of petroleum oil contaminated soils were collected and divided into five equal portions (5kg each in duplicate). NPK fertilizer was procured from Vap Chemicals Limited, 4 Entebbe Road, Kamu Kamu Plaza 7357, Kampala. Sewage sludge was obtained from Bugolobi sewage treatment plant, Bugolobi, Kampala. Prior to filling into pots, the soil was air dried, ground and homogenized. The samples were loaded into pots and given the treatments in Table 1. Four sorghum grains (purchased from a local store in Kampala and other grains in the lot previously tested for viability) were potted, watered accordingly and monitored for 72days under natural conditions before harvesting.

***Table 1***. *Experimental set up*

| Pot Number | Potted Soil Condition | Enhancement (5%w/w) |
|---|---|---|
| 01 | Contaminated | NPK fertilizer |
| 02 | Contaminated | Sewage sludge |
| 03 | Contaminated | Cow dung |
| 04 (Control) | Contaminated | None |

*Preprints* (www.preprints.org) | NOT PEER-REVIEWED | Posted: 18 January 2019 doi:10.20944/preprints201901.0182.v1

Peer-reviewed version available at *Asian Journal of Applied Chemistry Research* **2019**, *3*, AJACR.48785; doi:10.9734/ajacr/2019/v3i130085

| | | |
|---|---|---|
| 05 (Blank) | Normal | None |

### *2.3. Determination of percentage of phytoremediated oil*

After 72 days, the plants from all the experimental pots were harvested and the oil in the soils were extracted. A hand auger was used to collect the soil samples from each pot by taking 6 to 10 borings at depths of 0-10cm and 10-20cm. Prior to extraction of oil left in the soil samples, the samples were homogenized in a motor to obtain fine mixtures and to remove sticks, pebbles and rock particles. An aliquot (2±0.5g) of the homogenized samples were extracted using the Soxhlet method as per the Brinkman procedures outlined in the US EPA method 3540C [25] with slight modifications in the choice of the solvent, volume, extraction time and size of the extraction flask. The percentage of oil phytoremediated from the soils were computed from the numerical ratio of oil remediated from the soil sample to that in the original soil sample using equation (1).

$$\textit{Phytoremediated oil} = \frac{Mo - Me}{Mo} \times 100\% \qquad (1)$$

From which *Mo* = mass of oil in the original petroleum-oil vitiated soil sample, *Me* = mass of oil still entrained in the soil sample.

***Figure 2.*** *Measurement of vitiated soil weight prior to extraction*

### *2.4. Determination of the best enhancement factor*

Growth parameters: leaf length and width (leaf surface area), mass of roots and heads of the harvested plants were measured and averaged for all the four plants in each pot on the same day of harvesting to minimize errors due to withering. The sorghum plants were harvested by digging out with care not to break the root branching within the soil. This was made more effective by watering each pot the night before harvest to soften the soil. All the growth parameters from each plant was obtained on the same day.

## 3. Results

### *3.1. Germination*

All the sorghum grains germinated (Figure 3).

*(a)*

*(b)*

*(c)*

***Figure 3.*** *Experimental potted sorghum plants enhanced with (a) Cow dung, (b) NPK fertilizer, (c) Sewage sludge*

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 18 January 2019 doi:10.20944/preprints201901.0182.v1

Peer-reviewed version available at *Asian Journal of Applied Chemistry Research* **2019**, *3*, AJACR.48785; doi:10.9734/ajacr/2019/v3i130085

### *3.2. Phytoremediated oil from the vitiated soil*

The percentage of phytoremediated oil from the vitiated soils is given in Table 2. The original soil sample had 0.1700g of oil per gram of the contaminated soil.

***Table 2****. Phytoremediated oil from the contaminated soil samples*

| Factor | Oil in soil (g)$^+$ | Oil entrained (%) | Oil removed (%) |
|---|---|---|---|
| NPK | 0.01632 | 9.60 | 90.40 |
| Cow dung | 0.01054 | 6.20 | 93.80 |
| Sludge | 0.02110 | 12.41 | 87.59 |
| Control | 0.03179 | 18.70 | 81.30 |

$^+$ Mass is presented as mean mass of oil per gram of two soil samples previously potted with four sorghum plants.

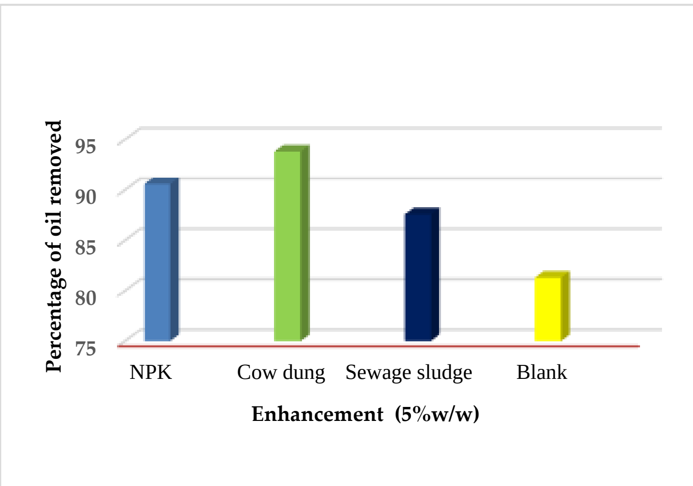


***Figure 4.*** *Phytoremediation of oil by the experimental sorghum plants*

### *3.3. Determination of the best enhancement factor*

Growth parameters: leaf length, width (surface area), root mass and the mass of the heads of the harvested plants were measured (Table 3 and Table 4) in order to determine the best amendment factor.

***Table 3.*** *Mass of S. bicolor heads and roots*

| Factor | Mass of head (g) | Mass of root (g) |
|---|---|---|
| NPK fertilizer | 10.61 | 13.60 |
| Sludge | 5.88 | 13.02 |
| Cow dung | 6.07 | 15.21 |
| Blank | 7.3 | 5.37 |
| Control | NA$^+$ | 10.63 |

+The control did not flower

***Table 4.*** *Mean lengths, widths and surface areas of the S. bicolor leaves*

| Factor | Leaf side | L (cm)$^+$ | W(cm)$^+$ | S.A (cm$^2$) |
|---|---|---|---|---|
| NPK fertilizer | Upper | 28.2 | 4.0 | 112.8 |
| | Middle | 47.4 | 4.0 | 189.6 |
| | Lower | 55.6 | 4.0 | 222.4 |
| Sludge | Upper | 21.0 | 3.2 | 67.2 |
| | Middle | 41.2 | 4.0 | 164.8 |
| | Lower | 58.0 | 4.0 | 232.0 |
| Cow dung | Upper | 25.0 | 4.2 | 105.0 |
| | Middle | 50.6 | 5.4 | 273.2 |
| | Lower | 59.0 | 4.8 | 283.2 |
| Control | Upper | 24.0 | 1.2 | 28.8 |
| | Middle | 30.0 | 2.4 | 72.0 |
| | Lower | 34.0 | 3.0 | 102.0 |
| Blank | Upper | 26.0 | 1.6 | 41.6 |
| | Middle | 32.3 | 2.7 | 87.2 |
| | Lower | 34.8 | 3.0 | 104.4 |

$^+$L= average length; W= average width and S.A= surface area of the leaves of eight potted plants

*(a)*

*(b)*

*(c)*

*(d)*

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 18 January 2019 doi:10.20944/preprints201901.0182.v1

Peer-reviewed version available at Asian Journal of Applied Chemistry Research 2019, 3, AJACR.48785; doi:10.9734/ajacr/2019/v3i130085


*(e)*

*(f)*

***Figure 5.*** *Sorghum roots and heads from pots of the investigated enhancement factors: (**a**) NPK fertilizer, (**b**) Sewage sludge, (**c**) Cow dung, (**d**) Sorghum grown in normal soil, (**e**) Cow dung,(**f**) Sorghum in normal soil.*

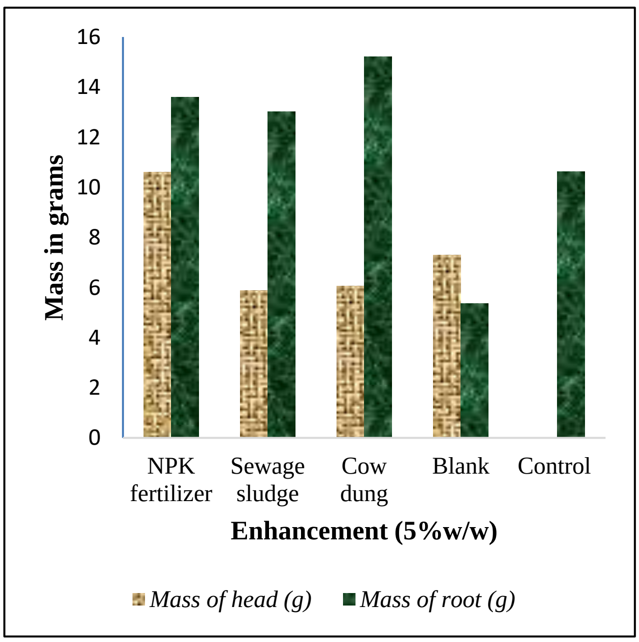


***Figure 6.*** *Mass of the heads and roots of the experimental sorghum plants*

## 4. Discussion

All the grains potted in this study grew normally. This implied that the growth of the plants are not directly affected by the petroleum contamination of the soil. However, the plants in the contaminated soil without any enhancement (control) did not flower. This could be due to growth retardation by the petroleum oil. It is empirically known that petroleum based oils suppress nutrient availability in soils [6,7] and retards water and nutrient absorption by plants [8]. All these are pivotal in plant growth, maturity and flowering.

Within 72 days, *S. bicolor* without any enhancement factor removed 81.3% of the original oil in the contaminated soil (Table 2; Figure 4). This demonstrated the potential of sorghum to revitalize the soil integrity after contamination. This is corroborated by other studies; *S. bicolor L.* and Ryegrass were used to remediate a crude oil spill site in Taxas by Gunther *et al* [26]. Various species of Kingdom plantae singly or in combination with other enhancement factors such as fertilizers and microorganisms have been reported to enhance replenishment of petroleum-contaminated soils [26-28]. Reynolds and Wolf [29] employed Ryegrass (*Lolum multitorum* Lam) to remediate diesel and crude oil-vitiated soils. Pradham *et al* [30] conducted a laboratory study with Alfalfa (*Medicago sativa*), switch grass (*Panicum virgatum*) and little bluestem grass (*Selizachyrium scoparium*) that demonstrated potential to remediate total polyaromatic hydrocarbon (PAHs) in vitiated soils at a gas plant.

The results obtained in this investigation showed that the ability of *S. bicolor* to remediate oil contaminated soils can be increased by the enhancement factors that were tested. However, all the factors tested have varying efficiencies in boosting phytoremediation potential of sorghum. The reason could be due to difference in their nutrient contents that affect the sorghum plant growth parameters in various ways. Cow dung, among all the tested enhancement factors had the highest amendment ability as reflected by the potential of cow dung amended soil sorghum plant to remove 93.8% of the oil. Probably, this could be because cow dung (an excreta of a primary consumer) has more nutrients it avails to the sorghum that increase the plants potential to absorb the oils from the soil. Cow dung contains about 3% Nitrogen, 2% phosphorous and 1% Potassium (3-2-1 NPK) [31] with generous amounts of organic matter and other nutrients. The extensive effect of cow dung was further observed from its effect on the growth parameters of the sorghum plants in comparison to the plants exposed to various enhancement factors. Sorghum plants potted in cow dung amended soil had the highest dry weight of plant roots (15.21g) (Table 3). This

Peer-reviewed version available at *Asian Journal of Applied Chemistry Research* **2019**, *3*, AJACR.48785; doi:10.9734/ajacr/2019/v3i130085

translated into increased surface area of the roots, which could have enhanced the absorption of the petroleum oil from the contaminated soil. More so, the leaf surface areas of cow dung were among the highest recorded (Table 4). Onwudike [32] in his findings pointed that the fertility of a degraded or highly leached soil can be improved by addition of cow dung singly or in combination with reduced quantity of NPK fertilizer. Further, Njoku and his co-workers [33] reported that there was a general improvement on the growth, dry weight, chlorophyll content, leaf area and pod production of *Glycine max* L. (Merrill) grown in cow dung amended crude oil-polluted soil.

On the other hand, NPK, an inorganic fertilizer used commonly for cereals was a better phytoremediation booster (90.6%) than sewage sludge (87.6%) (Table 2; Figure 4). This is because although sludge has more nutrients than NPK, the latter is majorly constituted by macronutrients (Nitrogen, Potassium and Phosphorous) which are released in a more direct form for easy and fast bioavailability to the plants than those nutrients from sludge that are indirect and not easily and immediately absorbed and metabolized.

The growth parameters of potted sorghum plants in normal soil (blank) were far better than the corresponding parameters of the sorghum grown in oil contaminated soils without any enhancement (control). This illustrates how oil contamination retards the *Sorghum bicolor* growth. The dry weights of root mass from normal soils (blank) were almost twice (10.6g) greater than those grown in the contaminated soil without any enhancement (control with root mass of 5.3g) (Table 3). Since plant root surface area affects rate of absorption, it greatly determines rate of nutrient uptake which influences the growth rate of the plants.

## Conclusion

This study revealed that *Sorghum bicolor* L. (Moench) (*Epuripur 1995*) grew normally and survived in the petroleum oil contaminated soils. However, the plant did not flower, thus it suffered the effect of petroleum oil-contamination. The enhancement of the soils with cow dung, sewage sludge and NPK fertilizer enhanced the phytoremediation potential of *S. bicolor* by 12.5%, 6.3% and 9.1% respectively. Other cereals such as maize, barley, millet that can flourish around the Albertine Graben should be assessed for their phytoremediation efficacy for possible future use in cleaning the soils in the region expected to be heavily polluted when the crude oil drilling commence in 2020.

## Acknowledgements

We owe much thanks to the Management of the College of Agriculture and Environmental Sciences (CAES), Makerere University for the laboratory services rendered that enabled us to finalize this research.

## References

[1] Ministry of Energy and Mineral Development (MEMD). Uganda's Sustainable Energy for All (SE4All) Initiative action agenda, Kampala, 2015.

https://www.seforall.org/sites/default/files/Uganda_AA_EN_Released.pdf.

[2] Avocats Sans Frontières (ASF). Business, Human Rights and Uganda's Oil and Gas Industry. *A Briefing of Existing Gaps in the Legal and Policy Framework*. July 2015, pp. 1-18.

http://www.asf.be/wp-content/uploads/2016/06/ASF_UG_GasOilIndustry_201507.pdf

[3] George Mugabi. Standards agency to inspect used vehicles imported into Uganda. Accessed August 13th, 2018. http://eagle.co.ug/2018/06/01/standards-agency-to-inspect-used-vehicles-imported-into-uganda.html.

[4] Japanese Used Cars. Accessed August 13th 2018. https://www.car-tana.com.

[5] Baker J.M., Guzman L.M., Bartlett P.D., Little D.I. and C.M. Wilson. Long-term fate and effects of untreated thick oil deposits on salt marshes. *Proceedings of 1993 International Oil Spill Conference*. American Petroleum Institute, Washington DC, 1993, pp. 395-99.

[6] Xu J.G. and R.L. Johnson. Nitrogen dynamics in soil with different hydrocarbon content planted to barley and field pea. *Canadian Journal of Soil Science*, vol. 77, pp. 453-58, 1997

[7] Tanee F.B.G. and L.A. Akonye. Phytoremediation Potential of *Vigna unguiculata* in a Crude Oil Polluted Tropical Soil of the Niger Delta. *Global Journal of Pure and Applied Sciences*, 2009, vol. 15, no. 1, pp. 1-4.

[8] A. J. Grummer. Investigation on sandy soil flooded by crude oil. In *Emsland Witsch Farsch*, 1965, vol. 17, pp. 229-43.

[9] Odu C.T.I. Degradation condition. The Petroleum Industry and the Nigeria Environment. *Proceedings of the 1981 International Seminar*. Lagos, 1982, pp. 143-53.

[10] Frankenberger W.T. Jr. The Need for a Laboratory Feasibility Study in Bioremediation of Petroleum Hydrocarbons. p. 237-293. In *P.T. Kostecki and E.J. Calabrese (ed.) Hydrocarbon Contaminated Soils and Groundwater*, vol. 2. Lewis Publ., Chelsea.

[11] Mustafa, H., Semin, S. Effects of lead and cadmium seed germination seedling growth and antioxidant enzyme activities of Mustard. *ARPN J Agri Biol Sci*, 2011, vol. 6, no. 1, pp. 44-47.

[12] Claudia P., Marian B., Maria-Magdalena Z., Ramona G., Lacramioara, I.; Constantin, G. Research regarding the germination process in *Ocimum basillicum* in an experimental environment, Studia Universitatis .Vasile Goldi, Seria tiinþeleVieþii 2010, vol. 20, no. 3, 55-57.

Peer-reviewed version available at *Asian Journal of Applied Chemistry Research* **2019**, *3*, AJACR.48785; doi:10.9734/ajacr/2019/v3i130085

[13] Moosavi S.A., Gharineh M.H., Afshari R.T., Ebrahimi A. Effects of some heavy metals on seed germination characteristics of canola (*Barassica napus*), Wheat (*Triticum aestivum*) and safflower (*Carthamus tinctorious*) to evaluate phytoremediation potential of these crops. J Agri Sci, 2012, vol. 4, no. 9, pp. 11-19.

[14] Oh K., Li T.; Cheng, H., Xie Y., Yonemochi S. Study on Tolerance and Accumulation Potential of Biofuel Crops for Phytoremediation of Heavy Metals. *Int J Environ Sci Dev* 2013, 4, 152-156.

[15] EPA. Introduction to Phytoremediation. 2000, EPA/600/R-99/107.

[16] Gnansounou E., Dauriat A., Wyman C.E. Refining sweet sorghum to ethanol and sugar: economic trade-offs in the context of North China. *Bioresour Technol*, 2005, vol. 96, pp. 985-1002.

[17] Galavi M., Jalali A., Ramroodi M., Mousavi S.R., Galavi H. Effects of treated municipal wastewater on soil chemical properties and heavy metal uptake by Sorghum (*Sorghum bicolor* L.). *J Agri Sci* 2010, vol. 2, pp. 235-241.

[18] Shafiei D.S.A., Almodares A., Ebrahimi M. Phytoremediation Efficiency of *Sorghum bicolor* (*L.)* Moench in Removing Cadmium, Lead and Arsenic. *Open J Environ Biol*, 2016, vol. 1, no. 1, pp. 001-006.

[19] Gandhi N., Sirisha D., Asthana S. Phytoremediation of lead contaminated soil by *Sorghum bicolor*. RPBS 2015, vol. 10, no. 9, pp. 333-342.

[20] Oh K., Cao T.H., Cheng H.Y., Liang X.H., Hu X.F., Yan L.J., Yonemochi S., Takahi S. Phytoremediation Potential of Sorghum as a Biofuel Crop and the Enhancement Effects with Microbe Inoculation in Heavy Metal Contaminated Soil. *J. Biosci Med*, 2015, vol. 3, pp. 9-14.

[21] Revathi K., Haribabu T.E., Sudha P.N. Phytoremediation of Chromium contaminated soils using sorghum plant. *Int J Environ Sci* 2011, vol. 2, no. 2, pp. 417-28.

[22] Jia W., Lv S., Feng J., Li J., Li Y., Li S. Morphophysiological characteristic analysis demonstrated the potential of sweet sorghum (*Sorghum bicolor* (L.) Moench) in the phytoremediation of cadmium-contaminated soils. *Environ Sci Pollut Res Int*, 2016, vol. 23, no. 18, pp.18823-31.

[23] Wang X., Chen C. & J. Wang. Cs phytoremediation by *Sorghum bicolor* cultivated in soil and in hydroponic system. *Int J Phytoremediation*. 2017, vol. 19, no.4, pp. 402-12.

[24] Google maps, 2018.

[25] US EPA Method 3540C. Soxhlet extraction. 1996.

[26] Gunther, T., Dornberger, U., and Fritsche, W. Effects of Ryegrass on biodegradation of hydrocarbons in soil. *Chemosphere*, 1996, vol. 33, no. 2, pp 203-15.

[27] Reilly K.A., Banks M.K. and A.P. Schwab. Organic Chemicals in the environment dissipation of polycyclic aromatic hydrocarbon in the rhizosphere. *Journal of Environmental Quality*, vol. 25, no. 212-19, 1996.

[28] Qiu X., Leland T.W., Shah S.I., Sorensen D.L. and Kendell E.W. Field Study: Grass Remediation for Clay Soil Contaminated with Polycyclic Aromatic Hydrocarbons. In Kruger E.L. et al. (eds). Phytoremediation of Soil and Water Contaminants. American Chemical Scociety, 1997, Chap. 14, vol. 664, pp. 186–99, *ACS Symposium Series*.

[29] Reynolds C.M. and Wolf D.C. Microbial based strategies for assessing rhizophere enhanced phytoremediation. *Proceedings of the Phytoremediation Technical Seminar* – May 31– June 1 1999, Calgary, AB. *Environmental Canada*, Ottawa, 1999, pp. 135-138.

[30] Pradham S.P., Conrad J.R., Paterrek J.R. and Srivastava V.J. Potential of phytoremediation for treatment of PAHs in soil at MGP sites. *Journal of Soil Contamination*, 1998, vol. 7, no. 4, pp. 467-80.

[31] Cow Dung Fertilizer: Learn The Benefits Of Cow Manure Compost. Accessed 18th November 2018. https://www.gardeningknowhow.com/composting/manures/cow-manure-compost.htm

[32] S.U. Onwudike. Effectiveness of Cow Dung and Mineral Fertilizer on Soil Properties, Nutrient Uptake and Yield of Sweet Potato (Ipomoea batatas) in South Eastern Nigeria. *Asian Journal of Agricultural Research*, vol. 4, pp.148-54, 2010.

[33] Njoku K.L., Akinola M.O., Oboh B.O. Growth and performance of *Glycine max* L. (Merrill) grown in crude oil contaminated soil augmented with cow dung. *Life Science Journal*, vol. 5, no. 3, pp. 89-93, 2008.