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## Characterization and physicochemical properties of wood sawdust in Niger area, Nigeria

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### ABSTRACT

Investigation was carried out to examine the characterization and physicochemical properties of some wood sawdust obtained from Niger Delta Area of Nigeria limited for the purpose of usage as an adsorbent for remediation of contaminant in soil environment. Experimental examination was conducted on value, moisture content, bulk density and porosity, iodine number and ash content for the various wood sawdust samples from Obuba and Abura, Opepe/mahogany. The result obtained revealed that the pH value of Obuba red (soft wood) is 5.48, Abura (hard wood) 6.18, opepe/mahogany (hard wood) 5.75 and iroko (soft wood) 5.29, whereas the moisture content value opepe/mahogany and iroko. The result further revealed that the bulk density and the porosity value are as presented, grain volume value are 2.910, 2.475, 1.931, and 2.959, bulk density value are 1.0317, 0.884, 0.2190, 0.4306, 0.5490, and 0.3499 for obuba red, abura, opepe/mahogany and iroko. The iodine number tested demonstrates the following value of 10.20, 6.90, 13.90 and 5.9 and 6.6 for obuba red, abura, opepe/mahogany and iroko. Finally, it was demonstrated that the usefulness of characterization and examination of physicochemical properties of functional components that control and improve the monitoring, predicting and determination of the kinetics values.

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**Capsule Summary:** The research work demonstrates the examination of some wood sawdust characteristics and properties as well as their usefulness in the application of crude oil remediation. The significance of different wood sawdust defined in terms of porosity, bulk density, moisture content and the degree of adsorption was attributed to the characteristics and properties of the various species sampled.

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### INTRODUCTION

Oil spill is a challenge that is common to oil producing areas; as a result several clean-up methods have been suggested by many researchers to curb this menace. This work is therefore

focused on exploring the suitability of applying natural adsorbent(sawdust) for oil clean up to achieve an effective environmental recovery. The predominantly used adsorbents are expensive hence the use of readily available materials that are inexpensive and renewable will be advantageous. This research seeks to study the adsorption capability of

sawdust from selected local woods. Sawdust is a waste generated from various sawmills across the country, it is mostly disposed of in the environment thereby causing pollution (Braz et al., 2019; Chen et al., 2019; Kebibeche et al., 2019; Raheem and Ige, 2019; Tiuc et al., 2019; Wang et al., 2019). Hence using sawdust as an adsorbent for hydrocarbon clean up could enhance the eradication of the menace associated with saw dust waste in the long run and help to sustain the ecosystem (Mohsen, 2007; Idris et al., 2014., Ikenyiri and Ukpaka, 2014).

It is of great importance to explore the capability of natural adsorbent (sawdust) for the adsorption process in clean - up operations of oil spilled environment. A better understanding of the mechanism of adsorption of crude oil on this adsorbent( sawdust materials) will require investigation into the particle size of the adsorbent and the critical factors that affect its rate of adsorption in terms of adsorbent characteristics (adsorption capacity) will be valuable in ascertaining the suitability or otherwise of these materials for oil spill cleanup. It will also involve the determination of the physical and chemical properties of the sawdust. These will entail carrying out experimental works to determine the rate of adsorption (Gatoki et al., 2002., Jiang et al., 2002., Hussein et al., 2011., Kingston, 2002). This work shall explore different kinds of locally available wood sawdust for the purpose adsorbents and examine the challenges associated with their use for any given process. The study will include examining their characteristics, evaluating their effectiveness and feasibility for application as remediation materials (Hussein et al., 2009). Suggestions will be made based on findings from experimental results and appropriate characterization as well as the physicochemical properties was examined to describe the rate of adsorption (Leiviska 2014; John, 2007; Ikenyiri and Ukpaka, 2016; Hussein et al., 2008)

Oil introduced into environment can cause gross biological damage, physiological effects on the biotic and a broad range of ecological changes. All aquatic biota are permeable to oil constituents and accumulate them from their environment either directly from the water column, or through their food. Oil can affect and cause changes in many organisms at all levels: cellular, organismic and ecosystem (Karan et al., 2011; Horisawa et al., 1999; Garg et al., 2004). Crude oil exposure, even at very low concentrations can cause deleterious effect, whether lethal or sub lethal, to an organism, population or community. It can also enhance genetic effects and a wide range of deleterious effects on metabolism Haussard et al. (2003). The effects of oil on aquatic life can be considered as being caused by either its physical nature or by the chemical components of the oil. Aquatic life may also be affected by clean-up operations or indirectly through physical damage to the habitat in which they live. Populations of plants and animals in the sea are subject to considerable natural fluctuations in numbers brought by changes in climatic and hydrographic conditions and availability of food. Thus, the species composition and age structure of the various populations within a particular

aquatic habitat are far from constant but instead are in a state of dynamic. In view of this, it is usually extremely difficult to assess the effects of an oil spill and to distinguish changes by the oil from those due to natural variability (Karan et al., 2011).

The different life stages of a species may show widely different tolerance and reaction of oil pollution. Usually, the egg, larval and juvenile stages will be more susceptible than the adults. However, many aquatic species produce very large number of eggs and larval stages to overcome natural losses. This will normally result in less than one in 100,000 eggs or larval surviving to maturity but the extreme losses due to adverse local conditions. These facts make it unlikely that any localized losses of eggs or larva caused by an oil spill will a discernible effect on the size or health of future adult populations (Ho et al., 2005). The ability of animal and plant populations to recover from an oil spill and the time taken for normal balance in the habitat to be re-established depends upon the severity and the duration of the disturbance and recovery potential of the individual species. Abundant organisms with highly mobile young stages produced regularly in large numbers may repopulate an area rapidly when pre spill conditions are restored, whereas populations of long-lived, slowly maturing species with low reproductive rates may take several years to recover their numbers and age structure (Garg et al., 2004).

Whilst it may be possible to restore the physical characteristics of an oiled habitat to near its pre-spill conditions, the extent to which its biological recovery can be enhanced is severely limited. Although the cleaning of mangroves and salt marshes, and replanting with seedlings, may be feasible in some situations, care needs to be taken to ensure that the area is not physically damaged since this may be more destructive in the longer term than the loss of the vegetation (Horisawa et al., 1999). Present investigation was carried out to examine the physicochemical properties of some wood sawdust obtained from Niger Delta Area of Nigeria limited for the purpose of usage as an adsorbent for remediation of contaminant in soil environment.

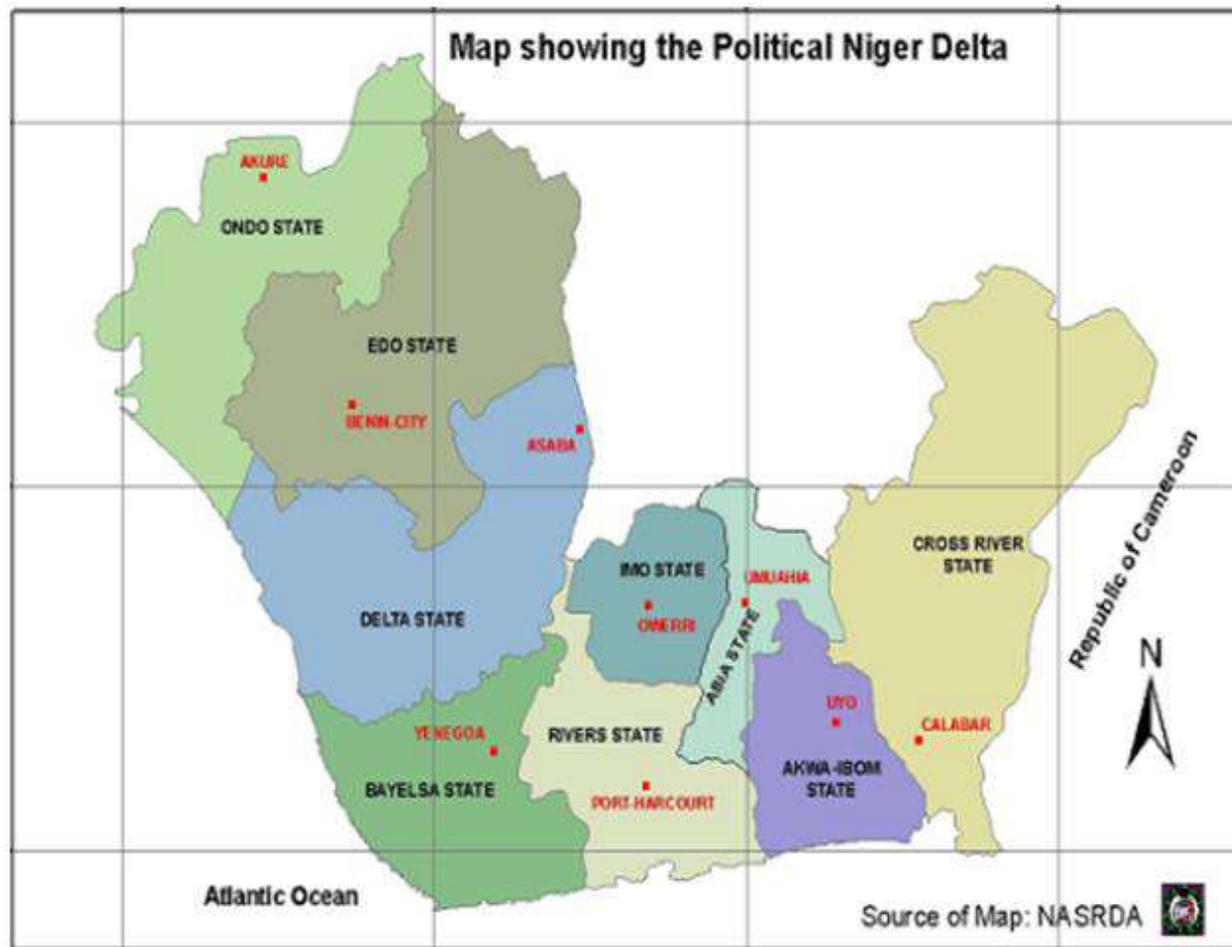
## MATERIAL AND METHODS

### Materials and equipment used for the investigation

The material and equipment used in this study are: Adsorbent (sawdust), crude oil, beakers, cylindrical flask, sampling containers(cans), pH meter, electronic balance, reagents ,filter paper, funnels, water (fresh and saline), digital water and soil analysis kit, desiccators, oven, sieves mechanical shaker, UV spectrophotometer.

### Sample collection and characterization

The sawdust used for this investigation was collected from a sawmill located in Mile 3 Diobu, Port Harcourt, Rivers State, Nigeria (Fig. 1). The fresh water was obtained from the chemical/petrochemical laboratory environment.



**Fig. 1:** Showing map of Niger Delta

The Salt water used for this experiment was gotten from the Eagle Island water source Port Harcourt, Rivers State, Nigeria. The various samples (opepe, abura, mahogany, cedar, iroko) collected were transported to the Department of Chemical/Petrochemical Engineering laboratory for analysis, and determination of the following physicochemical parameters: moisture content, pH, porosity, bulk density, kjedahl nitrogen, potassium, phosphorus, carbon and others. Similarly, some of the samples were taken to the Department of Microbiology laboratory for the purpose of isolation, identification and characterization of the possible microorganism present in each sample of the soft, semi hard, and hardwood of small particle size (sawdust). Crude oil samples were collected from three different oil wells in OML 58 of Total E&P Nigeria limited location in Ogba/Egbema/Ndoni Local Government Area of Rivers State of Niger Delta Area of Nigeria. The various samples collected were taken to the Department of Chemical /Petrochemical Engineering laboratory for physicochemical analysis. The laboratory adsorption experiment was carried out for two water samples (fresh and seawater)

### Moisture content

The moisture content was obtained by measuring the weight reduction of the sample when the samples were subjected to drying. The initial weights of the samples were measured and thereafter, experimental investigation were made on the samples when it was subjected to drying at environmental temperature ranging from 15°C-37 °C. The difference in samples weight before and after drying gives exact information on the moisture content ASTM D2016-74 (1983) and ASTM D 4442-07 (2007). The moisture content was thereafter calculated on dry basis using this expression:

Moisture content =

$$\text{Moisture content \%} = \frac{\text{initial weight} - \text{Dry weight}}{\text{Dry weight}} \times 100$$

$$\text{Moisture content \%} = \frac{W_w - W_d}{W_w - W_c} \times 100$$

$W_c$  = Weight of container (g)  
 Weight of container plus wet sample (g)  
 Weight of container plus sample after drying (g)

$W_w$  =  
 $W_d$  =  
 had been displaced, the sample was superficially dried and weighed again. The increase in weight divided by the density of water gives the pore volume.

### Sieve analysis

The selected sawdust samples were weighed using the electronic balance. The samples were screened with the mechanical shaker to obtain various particle sizes. The particle sizes are presented in this work. (ASTM C136/C136M-14 and ASTM D 2862-10).

### pH determination

The pH of the Sawdust sample was measured using a microprocessor pH meter. 20gm of sawdust was sieved through a 2mm sieve and transferred into 100ml beaker and 5ml of distilled water was added and stirred for 30 minutes with a glass rod. The electrode of a standardized pH meter was inserted into it and the sawdust pH in water was measured when the digital display reading was stable. Thereafter, the pH of the sawdust water mixture were recorded. APHA 4500H(1992)(2).

### Bulk density

After sieving with a 5mm sieve. A known weight of sawdust samples of 5g each were prepared. The bulk density was determined using the core sampler method. The finest sawdust samples of 0.40mm particle size was then weighed and kept in a core. In this case, the core was prepared with a nickel foil and stainless mesh made in a cylindrical shape. Alternatively, the core sample can be taken by driving the metal core, that is the cylindrical material into the sawdust sample at the desired depth and horizon. The bulk density is the mass of the sample divided by the total volume of the sample (BS 1377-2(1990))

$$p_b = M_s / V_t$$

$M_s$  = mass of oven dried sawdust (g)

$V_t$  = total sawdust volume (cm<sup>3</sup>) assumed to be equal to volume of a cylinder

### Porosity determination

The porosity was determined by first measuring these quantities: bulk volume, pore volume and grain volume of the selected woody samples. These quantities which are related to porosity as expressed in the equation.

$$\% \text{ Porosity} = \frac{\text{Pore volume}}{\text{Bulk volume}} = \frac{\text{Bulk volume} - \text{Grain volume}}{\text{Bulk volume}}$$

The pore volume of the core samples were measured using the gravimetric method. A 5g of each sample was taken and saturated with water. After the air in the pore of the material

$$\text{Pore volume} = \frac{\text{Increase in weight}}{\text{Density of water}}$$

The grain volume was measured by crushing a dry and clean core sample. The volume of the crushed sample was determined by immersing in water. Also the bulk volume was measured by observing the volume of fluid displaced by the sample. The fluid displaced can be measured volumetrically or gravimetrically. Though the gravimetric determination of bulk volume was employed, the sample was immersed in a fluid and the loss in weight of the sample was noted. Thereafter, % porosity was determined by calculation, by substituting the values of bulk volume, pore volume or grain volume. ASTM D7263-09(2018)e2.

### Carbon contents

Sawdust samples were weighed 5g each and sieved with 0.5mm mesh. This was done in duplicate before being transferred to 25ml Erlenmeyer flask. 10ml of 1N(K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>) solution was pipetted into each flask and was stirred gently to disperse the sawdust sample. This was followed by the addition of 20 ml concentrated H<sub>2</sub>SO<sub>4</sub> using a graduated cylinder, taking a few seconds only in the operation. The flask was stirred gently until sawdust sample and reagents were mixed, then vigorously for one minute, to effect more complete oxidation and it was allowed to stand for 30 minutes. The contents were diluted with water at about 250ml. Thereafter, 25ml of 0.5N ferrous ammonium sulphate was then added and titrated with 0.4N potassium permanganate under a strong light. ASTM D5373-16 (2016)

### Iodine number

Sawdust sample was measured (5g) and placed in a 250ml beaker. 20ml of carbon tetrachloride (CCl<sub>4</sub>) and 25 ml of Wiji's reagent were also added. Then 9g of iodine in 1 litre of glacial acetic acid was pipetted into beaker and 10 ml of C<sub>3</sub> was added into the 250 ml beaker. It was shaken vigorously for 1 minute. The mixture was allowed to stand for 30 minutes in a dark locker. Thereafter, 20ml of potassium iodide (KI) solution and 100 ml of distilled water into the solution was added. The solution was titrated against 0.1 N Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>. Furthermore 0.5 ml of starch solution was added at end point of the titration. Titration was continued again with 0.1N Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>. The procedure was repeated for blank with only distilled water. The test method adopted was the A.O.C.S and ASTM D4607-14 method. The Iodine number was calculated using the formula.

$$I_{\text{number}}(\%) = \frac{(\text{Blank} - \text{Sample}) \times \text{Normality} \times 12.69}{\text{Weight of sample}}$$

**Table 1:** Wood sample and coding

S/N	Name of the Wood (Botanical Name)	Wood code
1	Abura wood (Halleaciliata)	A
2	Iroko wood (Chlorophora/miliciaexcela)	B
3	Obuba red wood (Berlinagrandiflora)	C
4	Opepe/Mahogany wood (Naucleadiderrichi/mellaceae)	D

## RESULTS AND DISCUSSION

### Characterization and physicochemical properties of sawdust

Results obtained from the research work are presented in Tables 1-5. Figure 1 illustrates the relationship between pH value and the various wood samples. Increase in pH values were observed in the order of magnitude as: Abura > Opepe/MA > Obuba > Iroko. The variation in the pH values can be attributed to the variation in the wood specie sampled. Table 4 demonstrates the relationship between the porosity with respect to the identity of the various wood sawdust. The variation in the porosity can be attributed to the variation in the wood specie. Increase in porosity was observed in the following order of magnitude Opepe/Ma > Abura > Iroko > Obuba. Porosity and bulk density has been reported to play an important role in assessing the adsorptive capability of an adsorbent. One of the parameters determined on characterization of the material is porosity. The result presented shows high percent porosity of 55% for Opepe sawdust (naucleadiderrichii) while Obuba (Berlinagrandiflora) has 22% porosity, Abura (HalleaLedermannii) has 43% and Iroko(chlorophora) with 35% porosity. The porosity values are displayed in Table 4. The wood sample and coding procedure is represented in Table 1.

### Grain volume

Also the grain volume of the selected samples falls within the range 1.931cm<sup>3</sup> to 2.959cm<sup>3</sup>. The grain volume of Opepe (naucleadiderrichii) was the lowest at 1.9cm<sup>3</sup>. Table 4 shows the various samples with respect to their grain volumes. It is shown that the grain volume varies with different species of the wood. Increase in the grain volume for the different sawdust were observed to follow the order of magnitude Iroko > Obuba > Abura > opepe/Ma. The variation in the grain volume can be attributed to the variation in the sampled specie.

### Bulk density

Bulk density is one of the properties of Adsorbents. The bulk densities of these sawdust samples are: Abura sawdust sample (HalleaLedermannii), Opepe (naucleadiderrichii)

and Iroko (chlorophora/miliciaexcela) obtained are: 0.88g/cm<sup>3</sup>, 0.90g/cm<sup>3</sup> and 0.84g/cm<sup>3</sup> respectively. The result shows that the Obuba red (Berlinagrandiflora) has high bulk density value of 1g/cm<sup>3</sup>. The bulk density of the sawdust samples are presented in Table 4. The variation in the bulk density can be attributed to the variation in the physicochemical properties of the wood. The magnitude of the bulk density is in this sequence Obuba > Opepe/Ma > Abura > Iroko.

**Table 2:** pH of sawdust samples

Sample (Sawdust)	pH value
A - Obuba red (soft wood)	5.48
B - Abura (hard wood)	6.18
C - Opepe/Mahogany (hard wood)	5.75
D -Iroko (soft wood)	5.29

**Table 3:** Moisture content of sawdust sample

Samples (Sawdust)	Moisture content	
	%	Dry weight (mass) %
A - Obuba red	14.74	85.26
B - Abura	9.82	90.18
C - Opepe/Mahogany	8.25	91.76
D - Iroko	9.25	90.76

### Moisture content

The moisture content feature for the various wood sawdust samples are shown in Table 3. The moisture content analysis reveals that the Obuba red sawdust sample (Berlinagrandiflora) has the highest moisture content of 14.7%. The results also indicated the moisture content for Abura (HalleaLedermannii) with 9.82%, Iroko (Chlorophora/miliciaexcela) has 9.25% and Opepe (naucleadiderrichii) has 8.25%. Increase in the moisture content was observed in this sequence Obuba > Abura > Iroko > opepe/Ma wood sawdust.

**Table 4:** Bulk density, grain volume and porosity of sawdust samples

Samples sawdust	Grain volume	Bulk density	Porosity
A – Obuba Red	2.91	1.0317	0.219
B – Abura	2.475	0.884	0.4306
C – Opepe/Mahogany	1.931	0.8978	0.549
D – Iroko	2.959	0.8445	0.3499

**Table 5:** Iodine number value and ash contents of the sawdust samples

Samples sawdust	Iodine number	Ash contents
A – Obuba Red	10.2	4.2
B – Abura	6.9	6.1
C – Opepe/Mahogany	13.9	5.9
D – Iroko	14.2	6.6

Results indicates that the softwood contains more moisture content than the hard and semi soft wood as demonstrated in Table 3.

#### Iodine number

The Iodine number of different wood sawdust is presented in Table 5. Result demonstrates the level of the iodine number with respect to wood type. The variation in the iodine number can be attributed to the variation in the physicochemical property of the wood specie. Table 5 illustrates the iodine number of various samples (obuba red, Abura, Opepe/Mahogany and Iroko). Results revealed that the iodine number is higher in the order of magnitude Iroko > opepe/Mahogany > Obuba > Abura. The result obtained indicates that the hard wood contains high iodine number than the softwood samples.

#### Ash content

Table 5 illustrates the ash content of various samples (obuba red, Abura, Opepe/Mahogany and Iroko). Results revealed that the ash content is higher in the order of magnitude Iroko > Abura > opepe/Mahogany > Obuba. It is observed that the hard wood sawdust possesses high level of ash content concentration compared to the semi and soft wood sawdust. It also indicates that the ash content of the hardwood will be more effective if used as activated carbon in water treatment mechanism.

#### pH values

The pH value of wood sawdust samples is determined as follows: A-obuba red (soft wood) is 5.48, B-Abura (hardwood) is 6.18, C-opepe/mahogany (hardwood) is 5.75 and D-iroko (softwood) is 5.29. From the result presented

in Table 2 revealed that iroko is more acidic than other and the magnitude order of acidity is D > A > C > B. The results of present study revealed that the characterization and examination of physicochemical properties of functional components that control is helpful in monitoring, predicting and determination quality of respected area (Chen et al., 2019; Cipullo et al., 2019; Frick et al., 2019; He et al., 2019; Kalhor et al., 2019; López-Vizcaíno et al., 2019; Mobbs et al., 2019; Rocha et al., 2019; Sivagami et al., 2019; Song et al., 2019; Wang et al., 2019; Ye et al., 2019), for the improvement of unwanted condition of contaminant in soil environment.

#### CONCLUSIONS

The following conclusion was drawn; the research work revealed that wood sawdust obtained from softwood is more acidic in nature than the ones obtained from the hard wood. It is obtained that the softwood species obtained high moisture content retainable than the hardwood species. The grain volume is observed to be high in softwood sawdust than the hard wood sawdust. It is seen that the bulk density of the soft wood sawdust is higher than hardwood sawdust. The research work also revealed that the hardwood sawdust is more porous than the softwood sawdust. The research work demonstrates the iodine number of the various species of wood sawdust samples which indicates that the magnitude of the iodine number is as stated iroko > opepe/mahogany > obuba red > abura.

#### REFERENCES

APHA., 1992. Standard Test method for the Examination of Water and Waste Water, American Public Health Association.

- APHA., 1992. Standard Test method for the Examination of Water and Waste Water, American Public Health Association.
- APHA., 1992. Standard Test method for the Examination of Water and Waste Water, American Public Health Association.
- APHA., 1992. Standard Test method for the Examination of Water and Waste Water, American Public Health Association.
- ASTM., 1983. Standard Test Methods for Moisture Content of wood. ASTM International, West Conshohocken, PA.
- ASTM., 1998. Standard Test Method for Water and Sediment in Crude Oil by the Centrifuge Method, in: Annual Book of American Society for Testing and Materials standards. ASTM committee on standards, West Conshohocken, PA.
- ASTM., 2007. Standard Test Methods for Direct Moisture Content Measurement of Wood and Wood -Based Material, ASTM International, West Conshohocken, PA.
- ASTM., 2014. Standard Test Method for Determination of Iodine Number of activated carbon, ASTM International, West Conshohocken, PA.
- ASTM., 2016. Standard Test Methods for Determination of Carbon, Hydrogen and Nitrogen in Analysis Samples of Coal and Carbon in Analysis Samples of Coal and Coke, ASTM International, West Conshohocken, PA.
- ASTM., 2018. Standard Test Methods for Laboratory Determination of Density (Unit Weight) of Soil Specimens, ASTM International, West Conshohocken, PA.
- Braz, A., Mateus, M.M., Santos, R.G.d., Machado, R., Bordado, J.M., Correia, M.J.N., 2019. Modelling of pine wood sawdust thermochemical liquefaction. *Biomass and Bioenergy* 120, 200-210.
- Chen, B., Fang, L., Yan, X., Zhang, A., Chen, P., Luan, T., Hu, L., Jiang, G., 2019. A unique Pb-binding flagellin as an effective remediation tool for Pb contamination in aquatic environment. *Journal of Hazardous Materials* 363, 34-40.
- Chen, L., Yu, Z., Xu, H., Wan, K., Liao, Y., Ma, X., 2019. Microwave-assisted co-pyrolysis of *Chlorella vulgaris* and wood sawdust using different additives. *Bioresource technology* 273, 34-39.
- Cipullo, S., Negrin, I., Claveau, L., Snapir, B., Tardif, S., Pulleyblank, C., Prpich, G., Campo, P., Coulon, F., 2019. Linking bioavailability and toxicity changes of complex chemicals mixture to support decision making for remediation endpoint of contaminated soils. *Science of the Total Environment* 650, 2150-2163.
- Fatoki, O.S., Lujizan, O., Ogunfowokan, A.O., 2002. Trace metal pollution in Umata River water. *Safety and Aquatic Journal*, 28(2), 183-189.
- Frick, H., Tardif, S., Kandeler, E., Holm, P.E., Brandt, K.K., 2019. Assessment of biochar and zero-valent iron for in-situ remediation of chromated copper arsenate contaminated soil. *Science of the Total Environment* 655, 414-422.
- Garg, V. K., Moirangthem, A., Kumar, R., Gupta, R., 2004. Basic Dye (Methylene Blue) Removal from Simulated Wastewater by Adsorption Using Indian Rosewood Sawdust: Timber Industry Waste. *Dyes Pigments* 63 (3), 243-250.
- Haussard, M., Gaballah, I., Kanari, N., De Donato, P., Barre's O., Villieras, F., 2003. Separation of Hydrocarbons and Lipid From Water Using Treated Bark, *Water Research* 37 (2), 362-374.
- He, M., Shen, H., Li, Z., Wang, L., Wang, F., Zhao, K., Liu, X., Wendroth, O., Xu, J., 2019. Ten-year regional monitoring of soil-rice grain contamination by heavy metals with implications for target remediation and food safety. *Environmental Pollution* 244, 431-439.
- Ho, Y.S., Chang, T.H., Hsueh, Y.M., 2005. Removal of basic dye from aqueous solution using tree fern as bioadsorbent. *Process Biochemical* 40, 119-124.
- Horisawa, S.M. Sunagawa, Y., Tamai, Y. Matsuoka, T. Miura, M., Terazawa, C., (1999). Biodegradation of non-lignocellulosic substance II: Physical and Chemical properties of sawdust before and after use as artificial soil. *Journal of Wood Science* 45(6), 492-497
- Husseien, M, Amer, A.A., EI-maghraby, A., Taha, N.A., 2009. Availability of bailey straw application on oil spill cleanup. *International Journal of Environmental science and Technology* 6(1), 123-130
- Hussein, M. Amer A.A., Sawsan, I.I., 2008. Oil spill sorption using carbonized pith bagasse. Trial for practical application. *International Journal of Environmental Science and Technology* 5(2), 233-242.
- Hussein, M., Amer, A.A., Sawsan, I.I., 2011. Heavy oil spill cleanup using low grade raw cotton fibers: Trial for practical application. *Journal of petroleum Technology and alternative fuels* 2(8), 132-140.
- Idris, J., Eyu, G.D., Mansor, A.M., Ahmad, Z. & Chukwuekezie, C.S., 2014. A preliminary study of biodegradable waste as sorbent material for oil spill cleanup. *The Scientific World Journal* 2(9), 140-150.
- Ikenyiri, P.N., Ukpaka C.P., 2014. Mathematical model to monitor the inhibiting effect of pH on the adsorption of crude oil in bioremediation. *Scholars research library, Archives of Applied Science Research* 6(6), 100-110.
- Ikenyiri, P.N., Ukpaka C.P., 2016. Overview on the effect of particle size on the performance of wood based adsorbent. *Journal of Chemical Engineering and Process Technology* 7(5), 7-14.
- Jiang, J.Q., Cooper C., Ouki, S., 2002. Comparison of modified montmorillonite adsorbents: part 1: preparation, characterization and phenol adsorption. *Chemosphere* 47, 711-716
- John, M.H., 2007. Uses for sawdust, shavings and waste chips. *Chemist forest products laboratory, forest service U.S Department of Agriculture*, 45.
- Kalhor, K., Ghasemizadeh, R., Rajic, L., Alshawabkeh, A., 2019. Assessment of groundwater quality and remediation in karst aquifers: A review. *Groundwater for Sustainable Development* 8, 104-121.
- Karan, P.C., Rengasamy R.S., Das D., 2011. Oil spill cleanup by structured fibre assembly. *Indian Journal of Fibre and Textile Research* 36, 190-200.

- Kebibeche, H., Khelil, O., Kacem, M., Kaid Harche, M., 2019. Addition of wood sawdust during the co-composting of sewage sludge and wheat straw influences seeds germination. *Ecotoxicology and environmental safety* 168, 423-430.
- Kingston, P.F., 2002. Long-term Environmental Impact of Oil Spills, *Spill Science. Technology and Biotechnology* 7(1-2), 53-61.
- Leiviska, T., 2014. Sawdust for wastewater treatment. *Journal of Bioremediation, Biodegradation* 5, 159.
- López-Vizcaíno, R., dos Santos, E.V., Yustres, A., Rodrigo, M.A., Navarro, V., Martínez-Huitle, C.A., 2019. Calcite buffer effects in electrokinetic remediation of clopyralid-polluted soils. *Separation and Purification Technology* 212, 376-387.
- Mobbs, S., Orr, P., Weber, I., 2019. Strategic considerations for the sustainable remediation of nuclear installations. *Journal of Environmental Radioactivity* 196, 153-163.
- Mohsen, .A. H., 2007. Adsorption of lead ions from aqueous solution by okra wastes. *International Journal of Physical Sciences* 2(7), 178-184.
- Raheem, A.A., Ige, A.I., 2019. Chemical composition and physicochemical characteristics of sawdust ash blended cement. *Journal of Building Engineering* 21, 404-408.
- Rocha, I.M.V., Silva, K.N.O., Silva, D.R., Martínez-Huitle, C.A., Santos, E.V., 2019. Coupling electrokinetic remediation with phytoremediation for depolluting soil with petroleum and the use of electrochemical technologies for treating the effluent generated. *Separation and Purification Technology* 208, 194-200.
- Sivagami, K., Padmanabhan, K., Joy, A.C., Nambi, I.M., 2019. Microwave (MW) remediation of hydrocarbon contaminated soil using spent graphite – An approach for waste as a resource. *Journal of Environmental Management* 230, 151-158.
- Song, Y., Fang, G., Zhu, C., Zhu, F., Wu, S., Chen, N., Wu, T., Wang, Y., Gao, J., Zhou, D., 2019. Zero-valent iron activated persulfate remediation of polycyclic aromatic hydrocarbon-contaminated soils: An in situ pilot-scale study. *Chemical Engineering Journal* 355, 65-75.
- Tiuc, A.E., Nemeş, O., Vermeşan, H., Toma, A.C., 2019. New sound absorbent composite materials based on sawdust and polyurethane foam. *Composites Part B: Engineering* 165, 120-130.
- Wang, J., Zhong, Z., Ding, K., Li, M., Hao, N., Meng, X., Ruan, R., Ragauskas, A.J., 2019. Catalytic fast co-pyrolysis of bamboo sawdust and waste tire using a tandem reactor with cascade bubbling fluidized bed and fixed bed system. *Energy Conversion and Management* 180, 60-71.
- Wang, T., Liu, Y., Wang, J., Wang, X., Liu, B., Wang, Y., 2019. In-situ remediation of hexavalent chromium contaminated groundwater and saturated soil using stabilized iron sulfide nanoparticles. *Journal of Environmental Management* 231, 679-686.
- Ye, S., Zeng, G., Wu, H., Liang, J., Zhang, C., Dai, J., Xiong, W., Song, B., Wu, S., Yu, J., 2019. The effects of activated

biochar addition on remediation efficiency of co-composting with contaminated wetland soil. *Resources, Conservation and Recycling* 140, 278-285.

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