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Experimental Analysis of Heavy Metal Contaminated Electroplating Industrial Site Soil Using Tamarind Seed Biochar

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Abstract: Biochar application is a promising strategy for the rehabilitation of contaminated soil while ensuring suitable waste management. Biochar is a highly porous organic material derived from wood, manure, or plant-based biomass through pyrolysis in a low-oxygen environment. Pyrolysis is a technique that produces biochar by means of the thermal decomposition of the feedstock in an oxygen-free environment. In this work, tamarind seed was pyrolyzed in a muffle furnace 500 – 700^{o}C to prepare biochar. The soil is contaminated with the electroplating industrial effluent, which is rich in nickel (Ni), copper (Cu), and chromium (Cr) concentrations. In this study, the atomic absorption spectrophotometer (AAS) technique has been used to find the removal efficiency of heavy metals for a curing time of 7, 14 and 28 days soil samples The result obtained from the physicochemical analysis indicated that the contaminated soils recorded an acidic pH. Adding biochar to contaminated soil in different percentages (2%, 4%, 6%, 8%, and 10%) to increase the pH value and using direct shear test, the shear strength of the soil determined different percentage of biochar. The result obtained adding 8% of Biochar to get optimum Shear strength. The functional groups present in the raw biomass and pyrolyzed biochar are determined using fourier transform infrared spectroscopy (FTIR)
Keywords: Biochar, Chromium, Nickel, Copper, Direct shear test, AAS analysis, FTIR

I. INTRODUCTION

Biochar remediation of heavy metals (HM) contaminated soil primarily depends on the properties of the soil, biochar, HM. Biochar is a highly porous, organic material derived from wood, manure or plant based biomass through pyrolysis under limited oxygen environment. The cost of remediation using biochar will be several times cheaper than the conventional methods such as physical treatment, electro kinetic remediation, biological remediation and phytoremediation. The soil is contaminated with the electroplating industrial effluent were rich in Nickel (Ni), Copper (Cu) and Chromium (Cr) concentration. This may lead to the degradation of geotechnical as well as the mechanical properties of soil. This presentation focuses on the experimental analysis of the heavy metal contaminated electroplating industrial site soil using tamarind seed biochar. The word char is a common terminology used for the solid product of the combustion of carbonaceous material. Generally the product is rich in carbon content, an example is charcoal, which is almost the earliest invention of the humans from fire or heat creation. Another example char is biochar. In this case, the study is made from organic compounds such as forest, agriculture or animal products but in the absence supply of oxygen compared to charcoal. Therefore, biochar is derived from biomass combustion in the presence of a limited oxygen supply and at relatively low temperature below 700^{0}C.

II. MATERIALS AND METHODS

The soil sample used for this research work was collected from Elecroplating Industry near Kurumbapalayam, Coimbatore.The soil was slight ash in colour. A disturbed sample is collected from at a test pit at a depth below 0-15cm. The soil samples were kept in polythene bags and labelled.

Tamarind tree (Tamarindus indica) belongs to the botanical family Fabaceae. It is a leguminous tree and it produces fruits abundantly. The fruit contains around 55% edible pulp, 34% seed and 11% shell by weight. The edible pulp is used in several cuisines of the world. The hard, purple brown and shiny seed is composed of 20-30 % external cover and 70-75 % kernel . Though, tamarind seeds find several utilized commercially.

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The main objective to produce biochar by microwave pyrolysis of tamarind uses in textile, food, paper, paint, pharmaceutical, cosmetics and other industries, they are not yet seed and analyze the geotechnical and chemical properties of the Electroplating industrial site soil. It is Shiny polished black in color and rich in important minerals and nutrients like phosphorus, magnesium, potassium, calcium, amino acids, and vitamins, tamarind seeds offer you a range of health and nutritional benefits. The surface area of seeds was linearly related to weight per seed ($r \geq 0{\cdot}96$, $p \leq 0{\cdot}01$). The angle of friction of the whole seeds was determined on rough, smooth, and very smooth surfaces. The angle of repose for roasted kernel (34–39°) was higher than that of the raw whole seeds (31–35°).

A. *Tamarind seed biochar*

Biochar is a Carbon –rich material that is made from biomass through a thermochemical conversion process known as pyrolysis**.** Tamarind seed biochar to produce pyrolysis process. Pyrolysis is a technique that produces biochar by means of the thermal decomposition of the feedstock in an oxygen-free environment. Pyrolysis leaves most of the carbon in the original biomass trapped in a solid form. In this work, using muffle furnace tamarind seed was pyrolyzed for the production of biochar by a non-conventional microwave heating technique. The tamarind seed is hard, purple brown and shiny seed is composed external cover and kernel

Fig 1: Tamarind seed

Fig 2 : Tamarind seed biochar

III. PROPERTIES OF SOIL

The properties of the contaminated soil were determined by conducting various laboratory tests such as

Table 1: Geotechnical Properties of the Industrial Site Soil

S.NO	TEST CONDUCTED	PROPERTIES	RESULTS
1	Determination of Specific Gravity	Specific Gravity	2.69
2	Determination of Relative Density	Relative Density (%)	42.29
3	Grain Size Distribution	% Gravel (>4.75mm)	1.4
		% Sand (4.75 - .0075mm)	54.20
		%Silt and clay(<0.075mm)	44.40
4	Standard Proctor Compaction Test	Optimum Moisture Content(%)	16
		Maximum Dry Density (g/cc)	1.76
5	Direct Shear Test	Cohesion (kN/m2)	23.80
		Angle Of Internal Friction (°)	9

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Table 2: Chemical Properties of the Industrial Site Soil

S.NO	TEST CONDUCTED	PROPERTIES	RESULTS
1	Determination of the pH	pH	5.2
2	Determination of the Electrical Conductivity Test	Electrical Conductivity	13.74

IV. RESULT AND DISCUSSION

A. *Standard proctor Compaction Test*

Standard proctor Compaction tests were done on both contaminated as well as biochar amended soil. The compaction curves are shown in Fig. 3 and Fig. 4 shows the variation in Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) with the biochar content respectively. The effect of soil sample treated with Biochar is studied. For various proportions (2%, 4%, 6%, 8%, 10%) of Biochar OMC and MDD is found. From the figures it is clear that 2%- 4 % biochar, OMC is increasing and MDD is decreasing and after 8% biochar, OMC is increasing and MDD also increasing. Adding biochar to the soil will change the porosity and density of the soil. Biochar being a highly porous additive will increase the porosity of the soil hence there will be an increase in the OMC of the biochar amended soil. The decrease in MDD of the biochar amended soil is because of the addition of the biochar which has got very low density. The Maximum Dry Density is obtained 8% of Biochar. Further increases biochar content the MDD of the Soil decreased. The increase in OMC upto 8% due to change in surface area and the decrease in MDD upto 6% is due to the addition of less dense biochar and due to a change in soil structure.

Table 3 : Standard proctor test for Biochar treated soil

SOIL + % OF BIOCHAR	OPTIMUM MOISTURE CONTENT (%)	MAXIMUM DRY DENSITY (G/CC)
Untreated soil	16	1.76
Soil +2% biochar	16	1.74
Soil +2% biochar	18	1.73
Soil +2% biochar	18	1.76
Soil +2% biochar	20	1.82
Soil +2% biochar	18	1.78

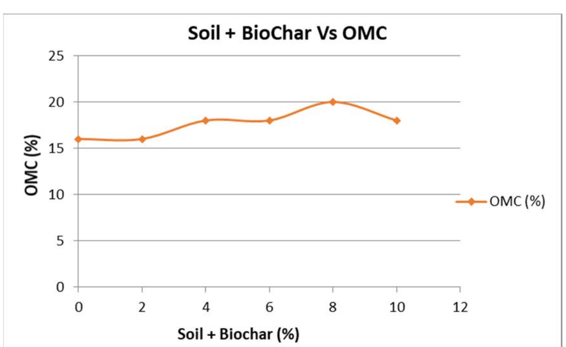

Fig 3 :SPCT _ OMC Comparison for biochar treated soil

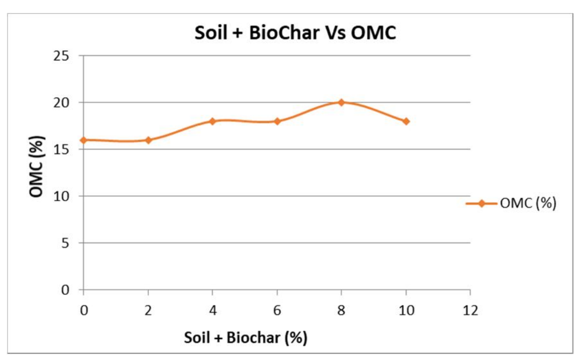

Fig 4 : SPCT _ MDD Comparison for biochar treated soil

B. Direct shear test

The contaminated soil was mixed with various percentages of biochar at 2%, 4%, 6%, 8% and 10% at OMC. Direct shear test results are shown in Fig. 3. The variation of cohesion values with biochar content and the variation of angle of internal friction are shown in Fig. 6 and Fig. 7 respectively. From the results, it is clear that the shear parameters such as cohesion and angle of internal friction increase with an increase in percentage of biochar upto 8%. The increase in cohesion could be because of the fact that the highly porous biochar underwent extensive particle re-arrangement under the applied vertical loads, which resulted in better interlocking and settlement of smaller particles within the void spaces, thereby resulting in better interparticle bonding. Biochar is a material with very low density, hence it can be easily subjected to particle rearrangement which in turn results in the filling of the interparticle void spaces upon the application of vertical loads. This will result in a lesser probability of slippage. As the biochar percentage increases from 2-8%, the Cohesion has been increased from 34.40 – 63.40 kN/m2. In addition of 10% of biochar the Cohesion of the soil decreased. When biochar added to the soil 4 – 8%, the angle of internal friction increases 110 - 220 . In 10% of biochar the internal Friction decreased by 10%. The valueof cohesion and angle of internal friction were found to be the highest at 8% biochar content, hence 8% can be taken as the optimum biochar content.

Table 4 : Direct Shear Test for Biochar treated soil

SOIL + % OF BIOCHAR	COHESION (KN/M2)	ANGLE OF INTERNAL FRICTION (°)
Untreated Soil	23.8	9
Soil + 2% Biochar	34.40	11
Soil + 4% Biochar	37.40	13
Soil + 6% Biochar	47.60	18
Soil + 8% Biochar	63.40	22
Soil + 10% Biochar	50.20	20

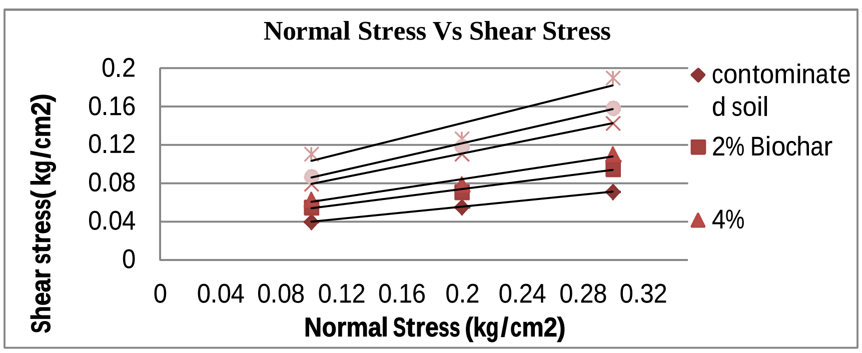

Fig 5: Normal stress Vs. shear stress

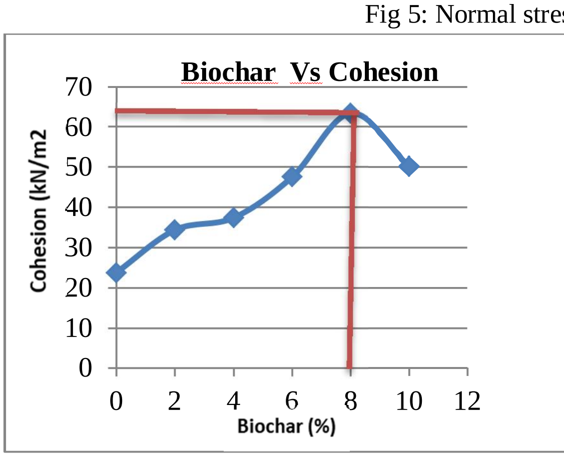

Fig 6: Effect of biochar on Cohesion of soil

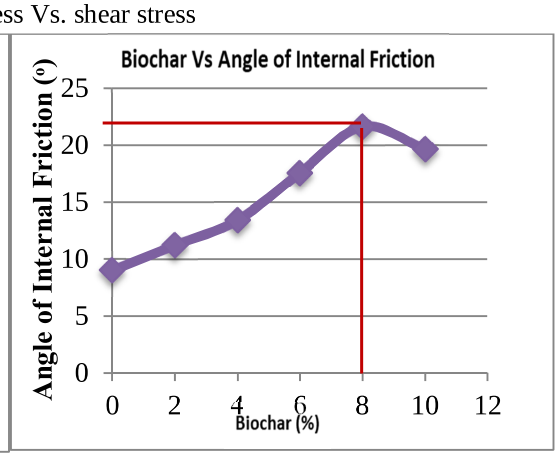

Fig 7: Effect of biochar on Internal Friction of soil

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V. CHEMICAL ANALYSIS

A. pH TEST

The pH value of untreated soil is Acidic in nature. The effect of soil sample treated with Biochar is studied. For various proportions (2%, 4%, 6%, 8%, 10%) of Biochar pH is found. By adding different proportions of biochar pH value increases. May be due to the high carbon content of the Biochar. By adding 6% of Biochar pH value becomes Neutral 7.25. When adding 8 -10% of Biochar the pH values changes from Neutral to Alkaline nature 7.25 – 8.05. Addition of % of Biochar is increases simultaneously pH value also increased.

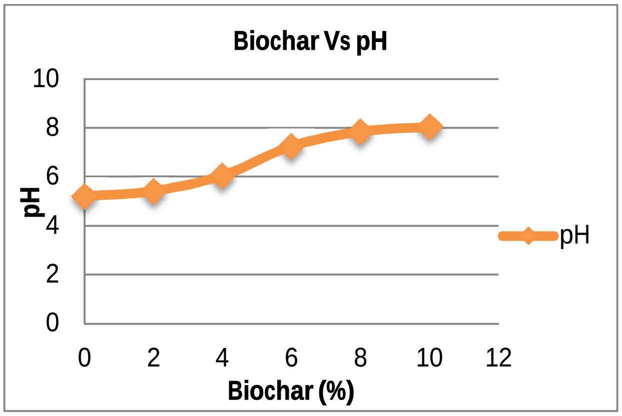

Fig 8: Effect of biochar on pH of soil

VI. ATOMIC ABSORPTION SPECTROMETER TEST

The sample was collected from the sample location using clean shovel. The soil sample was collected at 15cm depth around the sample area; it was thoroughly mixed and transferred into clean and labelled polythene bag for onward analysis. The sample was mix, gently homogenized and sieved through 2-mm-mesh sieve. The samples were first air dried, then placed in electric oven at a temperature of 40 °C approximately for 30 minutes. The resulting fine powder will kept at room temperature for digestion. 1g of the oven dried sample was weighed using a top loading balance and placed in a 250 ml Beakers separately to which 15 ml of aqueregia (35% HCL and 70% high purity HNO_3, in 3:1 ratio) will be added. The mixture was then digest at 70°C till the solution became transparent.

The resulting solution was filtered through whatman filter paper no. 42 and into a 50ml dilute to 50 ml volumetric flask and diluted to mark volume using deionised water and the sample solution was analyze for concentrations of Cu, Cr and Ni using an atomic absorption spectrophotometer.

AAS analysis used in determining the content of heavy metals in the previously digested soil samples. The nitrous oxide, acetylene gas and compressor were fixed and compressor turned on and the liquid trap blown to rid of any liquid trapped. The Extractor and the AAS control were turned on.

The slender tube and nebulizer piece were cleaned with purifying wire and opening of the burner cleaned with an arrangement card. The worksheet of the AAS programming on the joined PC was opened and the empty cathode light embedded in the light holder. The light was turned on, beam from cathode adjusted to hit target zone of the arrangement card for ideal light throughput, at that point the machine was touched off. The fine was set in a 10 ml graduated chamber containing deionized water and yearning rate estimated.

The analytical blank was prepared, and a series of calibration solutions of known amounts of analyte element (standards) were made. The blank and standards were atomized in turn and their responses measured. A calibration graph was plotted for each of the solutions, after which the sample solutions were atomized and measured. The various metal concentrations from the sample solution were determined from the calibration, based on the absorbance obtained for the unknown sample.

Using AAS analysis, the heavy metals present in the soil and its concentration are determined. Curing done in 7days, 14days and 28days. Again AAS analysis is done to determine the removal efficiency. From the experiment it is obtained percentage of removal of chromium, nickel and copper.

The results of the study revealed that Ni and Cu present in the soil sample are in higher concentrations. Cr is lower than that of Ni and Cu. The removal efficiency of Ni and Cu are higher. The removal efficiency of Cr is lower than that of Ni and Cu.

Table 5 : Concentration and efficiency of heavy metals

S.NO	DESCRIPTION	CONCENTRATION (PPB)	EFFICIENCY (%)
1	Nickel (Ni)		
	Soil sample	11.79	
	7 days	6.81	39.2
	14 days	4.92	65.4
	28 days	3.46	72.7
2	Chromium (Cr)		
	Soil sample	0.23	
	7 days	0.19	45.9
	14 days	0.068	70.5
	28 days	0.019	88.6
3	Copper (Cu)		
	Soil sample	14.16	
	7 days	9.50	33.8
	14 days	6.21	59.6
	28 days	2.94	80.4

VII. FTIR

The prepared tamarind seeds powder was analyzed using FTIR spectroscopy to identify the surface functional group present in the tamarind seed particularly, the functional groups that can improve the mechanisms of coagulation process. The observation of spectra for dried tamarind seed is illustrated in Figure 1 shows a range of frequency between 400 cm−1 and 4000 cm−1. The broad absorption band at 3349.17 indicates the presence of -OH functional group.

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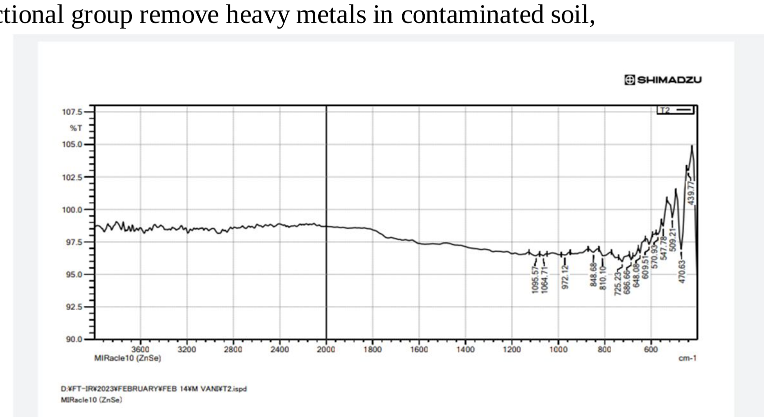

Fig 9: Raw tamarind seed

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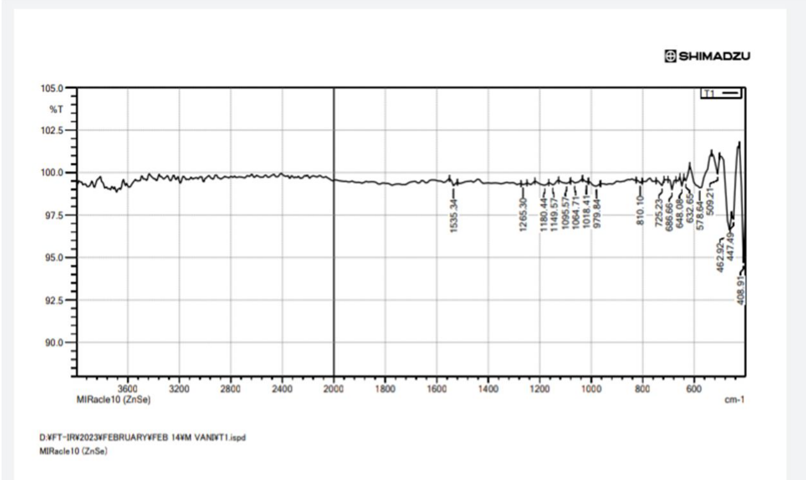

Fig 10 : pyrolyzed biochar

VIII. DISCUSSION

Results of experimental tests shows that the soil is classified as C –Ø soil. The optimum moisture content gradually increases by adding different percentage of biochar. The OMC is obtained by adding 8% of Biochar. Further increase in Biochar more than 8% of biochar the OMC decreases, because of absence of air voids. Another factor that varies with biochar content is the density of the biochar treated soil. Due to the surface area, porosity of the biochar adding biochar to decrease the dry density. The optimum MDD is obtained adding 8% of biochar. Adding different percentage of biochar gradually increases Cohesion and Angle of internal friction values. The optimum Cohesion (63.40kN/m2)and Angle of Internal Friction (22^o) is obtained by adding 8% of biochar. When adding additional % of biochar the Cohesion 13kN/m2 and internal friction 2^o value decreases. May be due to the filling of porous and the shape of biochar particles which may influence the inter-locking mechanism. The pH value of untreated soil is Acidic in nature. By adding biochar in different percentage neutral pH obtained at 6%. Further adding of biochar the pH value changes from Neutral to Alkaline nature.

In AAS analysis the results shows that Ni and Cu present in the soil sample are in higher concentrations. Cr is lower than that of Ni and Cu. The removal efficiency of Ni and Cu are higher. The removal efficiency of Cr is lower than that of Ni and Cu. FTIR analysis indicates -OH functional group present in the tamarind seed.

IX. CONCLUSION

Tamarind seed biochar added to clayey sand soil. Based on the study, the following Conclusions are drawn based on the experimental results.

1) As the Biochar percentage increases from 2 -8 % , the Optimum Moisture Content increases 20%. When Biochar content increased from 2 -4%, the Maximum Dry Density decreased. This may be the due to the surface area and porosity of the Biochar. The Maximum Dry Density is obtained 8% of Biochar. Further increases biochar content the MDD of the Soil decreased to 2.2%.
2) As the biochar percentage increases from 2-8%, the Cohesion has been increased from 34.40 – 63.40 kN/$m^{2.}$ In addition of 10% of biochar the Cohesion of the soil decreased by 26.3%. This may be due to the filling of porous and shape of biochar particles.
3) When biochar added to the soil 4 – 8% , the angle of internal friction increases 11^0 - $22^{0\,\cdot}$ Because of shape of the biochar particle. In 10% of biochar the internal Friction decreased by 10%.
4) The pH value of untreated soil is Acidic in nature. By adding different proportions of Biochar pH value increases. May be due to the high carbon content of the Biochar. By adding 6% of Biochar pH value becomes Neutral 7.25. when adding 8 -10% of Biochar the pH values changes from Neutral to Alkaline nature 7.25 – 8.05.
5) In AAS analysis the results shows that Ni and Cu present in the soil sample are in higher concentrations. Cr is lower than that of Ni and Cu. The removal efficiency of Ni and Cu are higher. The removal efficiency of Cr is lower than that of Ni and Cu.
6) FTIR analysis the band at 1535.34 cm-1 indicates -OH functional group present in the tamarind seed. The –OH functional group remove heavy metals in contaminated soil.

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