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Comparative study of vetiver root (*Chrysopogon zizanioides*) and other biochars for water purification

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Abstract

A lab experiment was conducted at Vanavarayar Institute of Agriculture, Pollachi, Tamil Nadu, India, during 2018-2019 in a completely randomized design to study the effect of vetiver root (*Chrysopogon zizanioides*) and other biochars on water quality and water nutrient status in Bore well water and Well water. The experiment consisted of five main factors and two sub-factors. The samples like vetiver root, vetiver root biochar, sugarcane bagasse, palmyrah fruit and banana peel were shade dried and dried in a hot air oven at different temperatures for uniform drying. The pyrolysis process *i.e.* dried samples into biochar with the recommended temperatures, was carried out in Dr. Mahalingam College of Engineering and Technology, Pollachi. Water from bore well and well was filtered using vetiver root and different biochars. Water quality parameters such as pH, EC, TDS, potassium, and alkalinity were analyzed. The analysis concludes that vetiver root biochar-treated water showed the best results in pH, electrical conductivity, TDS, potassium and sodium concentrations.

Key words: Banana, biochar, nutrients, palmyrah, pyrolysis, sugarcane, vetiver, water purification.

Introduction

Biochar, a valuable carbon-rich product obtained from heating biomass in a closed container with limited air, serves multiple purposes in promoting environmental sustainability. Its primary use lies in soil conditioning, where its hygroscopic properties help retain moisture and enhance fertility. Beyond agriculture, biochar plays a crucial role in wastewater management. Sewage water contamination poses significant challenges to water bodies like dams, lakes, and the sea. Untreated sewage, mixed with rain and drainage water, carries harmful elements and disease-causing bacteria, resulting in considerable damage to aquatic ecosystems and coastal areas. However, incorporating biochar with wastewater treatment can effectively remove contaminants, mitigating the environmental impact of sewage pollution and preserving water quality.

The basic vetiver grass technology or vetiver system comprises a dense vetiver grass (*Chrysopogon zizanioides*) hedgerow planted across the land's slope or embankment. The hedgerow traps sediments, spreads out rainwater runoff, and provides through its roots significant reinforcement to the soil (Zheng Hao *et al.*, 2018).

Vetiver grass was effective in all its applications because it had an extensive, deep penetrating root system that could grow to about 4 meters. The tensile strength of vetiver grass is about one-eighth of mild steel, allowing it to resist environmental influences. Vetiver can be used in various ways to treat sub-standard water and effluent due to high rate of absorption. With these facts in mind, water recycling and sewage treatment processes could be explored using vetiver as an alternative or a solution (Zhihui Hu *et al.,* 2019).

Pyrolysis is a thermal decomposition process that occurs at moderate temperatures in which the biomass is rapidly heated in the absence of oxygen or air to produce a mixture of condensable liquids (bio-oil), gases and bio-char. It was one of the most recent renewable energy processes and promises high liquid yields with a minimum of gas and biochar if carefully controlled. The yields and compositions of end products of pyrolysis were highly dependent on types of biomass, chemical and structural compositions of biomass and other physical parameters such as temperature, heating rates, reactors, particle size, co- reactant and others.

The properties of the biochar obtained after biomass pyrolysis directly influence subsequent biochar oxidation step since the amount and type of pores determine the gas accessibility to the active surface sites. The properties of biochar were decisively affected, not only by parent material properties but also by operating conditions used, mainly the heating rate, the maximum temperature experienced and the residence time at this temperature. This is because these variables, together with biomass properties, influence the amount and nature of volatiles produced during pyrolysis, as well as their rate of release. These factors also determine both the macroscopic morphology and the microscopic porosity of the resultant biochar (Onay, 2012)

The conversion of biomass into valuable products, such as biofuel and biochar, has garnered significant research attention due to the increasing energy demands and growing concerns regarding greenhouse gas emissions and global soil degradation (Elham Amiri *et al.*, 2017). Thermal pyrolysis of carbon-rich biomass stands out as one of the most popular bioenergy conversion technologies, as it not only produces biofuel but also yields biochar (charcoal). Consequently, this study aims to investigate the impact of vetiver and other biochars on water quality and nutrient levels in bore well and well water.

Materials and methods

The research study was conducted at the Department of Horticulture, Vanavarayar Institute of Agriculture, Pollachi, Tamil Nadu and Dr. Mahalingam College of Engineering and Technology, Pollachi, Tamil Nadu during 2018-2019 with five main factors (Vetiver root, Vetiver Biochar, Sugarcane Biochar, Palmyrah Biochar and Banana peel) and two sub factors (Bore well water and well water). Geographically it was located at 11^0 02 N latitude, 77^0 03" E longitude and at an altitude of 426 .76 M above MSL.

The pyrolysis process *i.e.* dried samples into biochar with the recommended temperatures, was carried out in Dr.Mahalingam College of Engineering and Technology, Pollachi, Tamil Nadu. The samples were pyrolyzed at different temperatures with a defined time.

Vetiver root: Dried roots of vetiver (*Chrysopogon zizaniodes*) were used for the purification of water.

Vetiver biochar: 5 kg of vetiver root was used for biochar preparation. 500 g of vetiver biochar was obtained. Vetiver biochar derived from dried roots of vetiver was prepared by pyrolysis method at the temperature range of about 200-300 ^{0}C with a retention time of 7 hours.

Sugarcane biochar: Sugarcane bagasse was used for the preparation of biochar. Sugarcane biochar from sugarcane bagasse was obtained by pyrolysis process at the temperature range of 600-700 ^{o}C with the retention time of 6 hours.

Palmyrah biochar: Palmyrah Biochar was prepared from palmyrah fruit bunches by pyrolysis process at the temperature of about 800 ^{o}C with a retention time of 3 hours. The byproduct of palmyrah biochar was palmyrah biofuel.

Banana peel biochar: 4.25 kg of banana peel was used for biochar preparation. 500g of banana peel biochar was used for filtration. Banana peel biochar derived from dried banana peel was prepared by pyrolysis method at about 300^{0}C with a retention time of 4 hours.

Water samples from bore well and well were collected for the study. This study used the vacuum filtration method to separate a solid product from a liquid . Vacuum filtration was used as Buchner funnel and a side-arm flask. Vacuum filtration was faster than gravity filtration, because the solvent or solution and air are forced through the filter paper by applying reduced pressure. The mixture of solid and liquid was poured through a filter paper in a Buchner funnel. The solid was trapped by the filter and the liquid was drawn through the funnel into the flask below by a vacuum. Exhaust Filters-Vacuum cleaners operate using suction. As un-filtered air goes in, it must come out. The function of the exhaust filter was to pick up microscopic particles that are too small to be trapped inside the bag or dust cup (Mothe and Miranda, 2013).

Five samples in each treatment were utilized for recording observations on the characters like pH, Electrical conductivity, Total Dissolved Solids, Potassium content and Microbial load and the values were subjected to statistical analysis as per the method suggested by Chih-Chun Kung *et al.* (2015) and the critical difference was worked out for five % (0.05) probability.

Results and discussion

A Lab experiment was conducted to study the efficiency of vetiver root and other biochars for water purification by analyzing pH, electrical conductivity, total dissolved solids, potassium contents and microbial load in bore well water and well water samples.

pH: Vetiver root biochar positively gave a minimum pH value (9.08, 8.49) compared to control. The highest pH value was observed in sugarcane biochar (Table 1). The optimum pH varied in different supplies according to the composition of the water and the nature of the construction materials used in the distribution system but was often in the range of 6.5-9.5. Extreme pH values can result from accidental spills, treatment breakdowns and insufficiently cured cement mortar pipe linings.

Table 1. Analysis of pH in different samples

Treatments	Bore well water	Well water
Vetiver root	9.18	8.67
Vetiver root biochar	9.08	8.49
Sugarcane biochar	10.35	10.43
Palmyrah biochar	9.52	9.09
Banana peel	9.87	9.55
Control	10.16	9.93
SEd	0.47	0.68
CD (0.05)	1.32	2.39

Electrical conductivity: Table 3 displays the electrical conductivity (EC) results in dS/m for various treatments in bore well water and well water samples. Vetiver root and vetiver root biochar exhibit the lowest EC values, while sugarcane biochar shows the highest. The differences in EC values among treatments are statistically significant based. These results offer insights into water quality and treatment effectiveness. Earlier studies show that high-quality deionized water had a conductivity of about 0.55 dsm^{-1}, drinking water in the range of 5-50 ms/m, while seawater about 5 S/m (*i.e.*, seawater conductivity was one million times higher than that of deionized water (Dongning Wei *et al.*, 2018).

Table 2. Analysis of electrical conductivity (dsm^{-1}) in different samples

Treatments	Bore well water	Well water
Vetiver root	1.30	0.36
Vetiver root biochar	1.10	0.23
Sugarcane biochar	4.34	4.68
Palmyrah biochar	1.81	1.00
Banana peel	2.08	2.32
Control	3.76	2.47
SEd	1.22	1.53
CD (0.05)	3.42	5.37

Total dissolved solids: When compared to the control (2406.4 ppm, 1508.6 ppm), vetiver root biochar produced significantly lower TDS values (704, 147.2 ppm). The value of sugarcane biochar was greater than the average (2777.6, 2995.2 ppm). Table 3 provides a tabulation of these TDS values. While there have been reports of negative effects, early epidemiological studies suggest that even low concentrations of TDS in drinking water may have positive effects. Consumers were generally willing to drink water with TDS levels below 1000 mg/L, though this threshold could be pushed higher under certain conditions.

However, high TDS levels in water may be unappealing to consumers because of the taste and excessive scaling in water pipes, heaters, boilers, and other household appliances. In addition to being corrosive to water-supply systems, water with extremely low concentrations of TDS may be unpalatable to consumers due to its bland, tasteless nature (Willis Gwenzi *et al.*, 2017).

Table 3. Analysis of total dissolved solids (ppm) in different samples

Treatments	Bore well water	Well water
Vetiver root	832.0	230.4
Vetiver root biochar	704.0	147.2
Sugarcane biochar	2777.6	2995.2
Palmyrah biochar	1158.4	640.0
Banana peel	1689.0	1558.2
Control	2406.4	1580.6
SEd	778.0	988.0
CD (0.05)	2178.6	3458.2

Potassium content: Vetiver root biochar gave low potassium content (298, 1666 ppm) when compared to other treatments (Table 4). The potassium levels in drinking water were relatively low compared with those of water softeners using potassium chloride. When potassium permanganate was used in water treatment, concentrations of added potassium were up to a maximum of 10 mg/L, but usually, concentrations would be less than this (Ahmad *et al.*, 2014). Average K+ concentration in drinking water, based on the average potassium concentration in the Canadian province with the highest measured K+ concentrations based on Health Canada's drinking-water quality guideline for hardness. Assuming consumption of 2 liters of water per day by a 60 kg adult, vetiver root biochar had given lower concentrations of potassium (29.8, 1666 ppm) which was present within the limits of recommended concentration (Deng Jin Huan *et al.*, 2018).

Table 4. Analysis of potassium content (ppm) in different samples

Treatments	Bore well water	Well water
Vetiver root	2607.0	2504.0
Vetiver root biochar	298.0	1666.0
Sugarcane biochar	2875.0	2511.0
Palmyrah biochar	1713.0	3208.0
Banana peel	1825.0	1877.0
Control	101.8	302.0
SEd	1051.7	911.3
CD (0.05)	2103.5	2187.2

Sodium content: The lowest sodium content was found in the vetiver root biochar (19.2, 18.9 ppm), followed by the vetiver root (19.5, 20.4 ppm) (Table 5). Food and water were the main sources of daily exposure to sodium salts. The latter can be significantly higher than this in some countries, while the former typically has a sodium concentration of less than 20 mg/L (Barnes and Hart, 2009). Whether or not there is a connection between sodium in drinking water and the onset of hypertension cannot be determined at this time. As a result, it was suggested that there be no guidelines for health (Demirbas, 2010). However, sodium can change the flavour of drinking water at levels greater than 200 mg/L. Vegetable root biochar had a much lower sodium content (19.5, 20.4 ppm) than other biochars.

Table 5. Analysis of sodium content (ppm) in different samples

Treatments	Bore well water	Well water
Vetiver root	19.5	20.4
Vetiver root biochar	19.2	18.9
Sugarcane biochar	19.7	19.4
Palmyrah biochar	20.0	20.6
Banana peel	19.5	20.1
Control	23.0	21.4
SEd	1.3	0.8
CD (0.05)	3.6	2.9

Microbial load: Vetiver root biochar gave the lowest microbial load (2.0 cfu and 3.8 cfu) positively when compared to other treatments (Table 6). Microbiological water analysis was a method of analyzing water to estimate the number of microbes present and, if needed, to find out what sort of bacteria they were. It represents one aspect of water quality (Zirebwa *et al.*, 2012). It was a microbiological analytical procedure that used water samples and determined the concentration of microbes from them. It was then possible to draw inferences about the suitability of the water for use from these concentrations. This process was used, for example, to routinely confirm that water was safe for human consumption or that bathing and recreational waters are safe to use. Microbiological analysis of water samples was done using a nutrient agar medium by plate count method. The recommended drinking water limits were 100cfu/100mL to 10,000cfu/100mL.

Table 6. Analysis of microbial load in different samples

Treatments	Bore well water	Well water
Vetiver root	9.5	11.2
Vetiver root biochar	2.0	3.8
Sugarcane biochar	11.7	16.1
Palmyrah biochar	14.2	28.5
Banana peel	23.8	32.0
Control	378.0	410.6
SEd	136.5	146.0
CD (0.05)	273.0	350.5

Among the various treatments, vetiver root biochar-treated water performed the best regarding pH, electrical conductivity, TDS, potassium, and microbial load analysis. To conclude, the treated water from vetiver root biochar was suitable for drinking and human health.

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