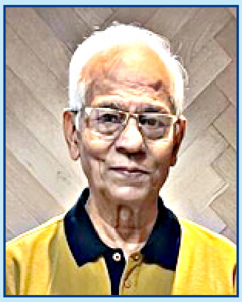
ISSN: 0379-5462
IPPTA: Quarterly Journal of Indian Pulp and Paper Technical Association
Vol. 36, E1, 2024, p. 179-181

VALORIZATION OF PULP AND PAPER MILL BIO-RESIDUES TO BIOCHAR FOR ENVIRONMENTAL AND BUSINESS SUSTAINABILITY IN TOTALITY

Rupam Kataki*

Bikram Borkotoki**

Neelam Bora*



Subhash Maheshwari***

**Biofuel Laboratory, Department of Energy, Tezpur University, Tezpur – 784028, Assam, India*
***Biswanath College of Agriculture, Assam Agriculture University, Biswanath – 784176, Assam, India*
****Tanjungenim Lestari Pulp and Paper Company, Indonesia*

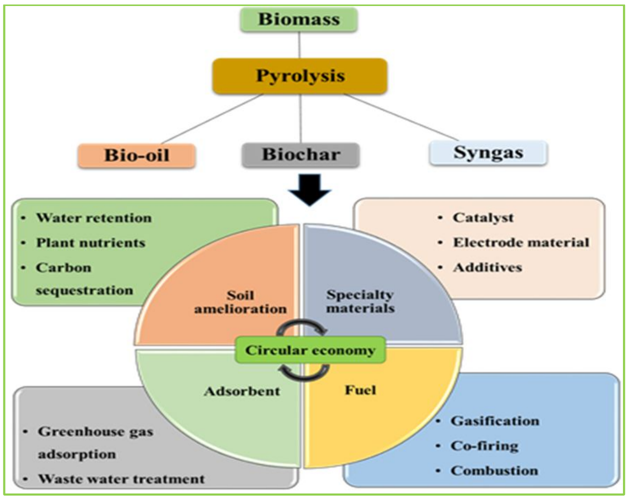
Abstract:

Pulp and Paper Industry is one of the key global and sustainable industries which handles a huge amount of biomass and its processing at various stages of the operations. This starts from plantation of suitable species, its management till its maturity, harvesting and processing, conversion to pulp and paper, green energy and bio-residues management. This makes the role of biomass management quite sensitive towards cost of production, energy and environmental impacts and sustainability issues of Pulp and Paper Industry, and it warrants continuous efforts to improve the performance at each stage of operation in the industry.

During the processing of biomass in the Pulp and Paper Industry, bio-residues are generated including plantation foliage, bark, wood dust, screen rejects and effluent sludge. These residues need specific management practices for improved sustainability of the industry. The present work discusses the conversion of market pulp mill's bio-residues i.e. wood dust, bark and effluent rejects/sludge to biochar. Biochar is a carbon rich solid material obtained from the thermochemical conversion of biomass in an oxygen-limited environment. It has a well-maintained porous structure with diverse functional groups, different inorganic nutrients, with a host of stable and recalcitrant form of carbon components which makes them suitable for diverse applications including sustainable soil management. The current works reports characterization of bio-residues and their pyrolytic conversion to produce biochar. Detailed biochar characterization is reported in the paper and based on the characterization of the biochar from different bio-residues, the potential of their uses is recommended for further investigations and field trials.

It is concluded that conversion of Pulp and Paper Mill bio-residues to biochar will be a potential way to reduce overall adverse environmental impacts along with enhanced business sustainability in totality to supply value added products for bioenergy and other industry applications through a circular economy.

Introduction:



In the wake of escalating environmental concerns and the urgent need for sustainable energy sources, the utilization of waste biomass has emerged as a pivotal area of research and development. Waste biomass, a broad category including agricultural residues, forestry byproducts, municipal solid waste, and various organic materials, has attracted significant attention due to its potential to address critical global challenges, including energy security, waste management, and greenhouse gas emissions reduction

To counteract the issues related to waste management, alternative waste valorization methods have come up in recent times. Biochar production from waste biomass represents one such approach of biomass waste valorization.. Pyrolysis is a thermochemical conversion method, where biomass yields three by-products viz. liquid bio-oil, solid biochar, and pyrolytic gas Fig below sows the potential of Biochar.

Materials and Methods

Three types of waste biomass material ;Eucalyptus pellita Wood Chip (EPWC), Eucalyptus pellita Bark (EPB) and Effluent solid waste Sludge (ESW). were used in this study from PT. Tanjungenim Lestari Pulp and Paper (PT. TeL), Indonesia. The collected biomass was subjected to pre-treatment to make it suitable for the characterization process. Waste biomasses were oven-dried at 110°C to remove the associated moisture. Dry biomass was then ground and sieved to obtain a uniform particle size of 2 mm and was stored in air-tight containers. The uniformly ground particle was taken for different analysis for their characterization.

Characterization of waste biomass

The proximate and ultimate analyses of the three waste biomass viz. EPWC, EPB and ESW were performed in accordance to ASTM standard procedures and laboratory analytical tools . Key data are given below:

Parameters	UoM	Euca wood chip (EPWC)	Euca bark (EPB)	Effluent sludge (ESW)
Moisture	%	8.7	6.8	11.8
Ash	%	4	6.4	19.9
Volatile matter	%	83.9	79.8	67.5
Fixed Carbon	%	3.2	7.0	0.67
C	%	47.2	42.1	28.5
H	%	6.9	6.1	4.0
N	%	0.02	0.37	0.59
S	%	0.09	0.09	1.67
O	%	45.9	51.3	67.3

Synthesis of Biochars

The grounded and sieved EPWC, EFB, EPB and ESW samples were pyrolysed in a batch-type pyrolyser). Pyrolysis of the samples were performed at two temperatures i.e. 350°C and 450°C, applying a heating rate of 20°C/min for 60 min of residence time in an inert atmosphere. Nitrogen was employed as the inert gas

Characterization of biochars

The proximate, ultimate analyses and calorific value of the biochars were determined in accordance to ASTM and other standard procedures

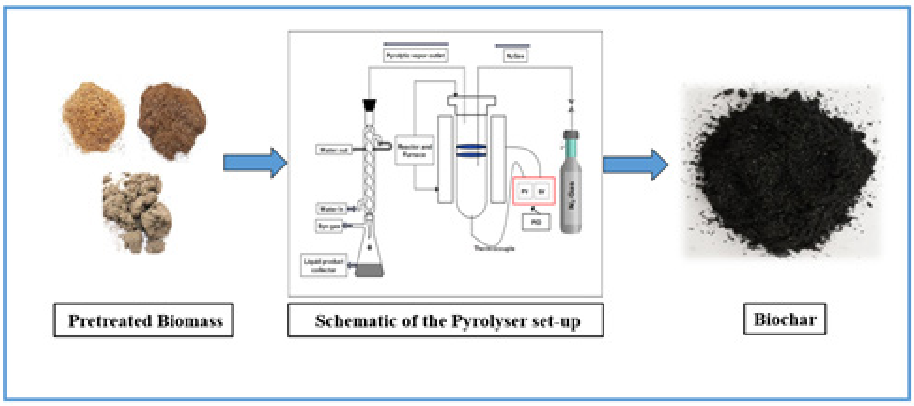
Observation and discussion

Biomass : Key observations of study are give below

- Biomass characterization is the process of determining the physical and chemical properties of biomass. Key data are summarized given below
- In pulp mills biomass residues quantity and quality vary with the mill and its operating situation including solid waste management.
- Biomass residues pulp mills are from agri-wastes or planation based these have some similarities in chemical constituents .
- Ash content as contaminant / as process chemical plays key role in biochar production and quality including fixed carbon/quality values.
- High volatile matter content biomass tends to undergo more extensive decomposition during pyrolysis, leading to a higher yield of fixed carbon in the biochar.
- Fixed carbon is the most stable component of biochar and contributes to its recalcitrance and long-term stability in soil .

Biochar : Key observations of study and data as reported above are give below

- Biochar yield is dependent on biomass constituents and much influence by ash, pyrolysis temperature (PT) and conditions. At higher PT: 450 °C reduces mass yield and volatile matter significantly .
- High fixed carbon content suggests that biochar probably still contain a certain amount of original organic plant residues such as cellulose and lignin. Highest fixed carbon was shown by EPWC (79 %) at 450 °C
- Calorific value(CV) of biochar vary depending on ash contents of input biomass/ residues.
- Increase in CV at higher PT is attributed to the rise in fixed carbon within the biochar, and volatile matter.
- Energy yield decreases at higher PT, due to the severe decomposition resulting in loss of more carbon compounds with high energy content.
- Energy density of biochar increases with increasing PT, which is attributed to the release of more aromatic compounds and increase in carbon content at higher PT.



Schematic procedure of pyrolysis process

- Calorific value(CV) of biochar vary depending on ash contents of input biomass/ residues.
- Increase in CV at higher PT is attributed to the rise in fixed carbon within the biochar, and volatile matter.
- Energy yield decreases at higher PT, due to the severe decomposition resulting in loss of more carbon compounds with high energy content.
- Energy density of biochar increases with increasing PT, which is attributed to the release of more aromatic compounds and increase in carbon content at higher PT.

Parameter	UoM	R-Temp-350°C			R.Temp=450°C		
		Euca wood chip (EPWC)	Euca bark (EPB)	Effluent sludge (ESW)	Euca wood chip (EPWC)	Euca bark (EPB)	Effluent sludge (ESW)
Mass Yield	%	49.5	54.4	56.3	23	31.1	48.9
Proximate analysis							
- Moisture	%	5.8	6.4	2.7	2.9	2.4	1.5
- Ash	%	0.5	12.5	43	0.8	18.2	60.3
- Volatile	%	41.4	30.7	21.3	17.2	7.1	15.9
- Fixed carbon	%	52.2	50.4	32.9	79	72.2	22.2
Calorific value	Mj/kg	30.4	23.1	10.3	32.4	26.6	9.2
Energy densification		2	1.6	1.8	2.1	1.9	1.6
Energy Yield	%	97.3	87.9	98.8	48.4	58.1	76.1
pH	-	7.2	7.3	9.2	7.5	7.5	9.5
Electrical conductivity (EC)	(ds/m)at 25°C	0.4	0.6	0.9	0.8	0.9	0.5
Total Salts	(mg/L)	256	364.8	588.8	524.8	569.6	332.8
Cation exchange capacity (CEC)	(cmol/kg)	19.2	35.6	30	25.1	39.9	40.9
Bulk density	(Mg/m3)	0.4	0.3	0.7	0.3	0.2	0.6
Particle density	(Mg/m3)	1.6	1.3	1.7	1.6	1.2	1.6
Total porosity	(%)	75	76.1	56.9	79.6	82.1	59.6
Water Holding Capacity (WHC)	(%)	84.2	89.4	68.8	88.6	98.8	70.2
Volume expansion	(%)	5.6	7	0.2	6.6	7.4	0.8
Total P	(%)	0.1	0	0.3	0.1	0	0.3
Total K	(%)	0.1	2.6	1.3	0.1	1.5	0.6
Total N	(%)	0.3	0.2	1.2	0.2	0.1	0.8
Total C	(%)	62.6	61.3	52.9	75.3	64.1	54.4
C:N ratio		240.6	266.6	44.1	327.5	493.2	68.0
Oxidizable Organic C (OOC)	(g/kg)	84.6	104.8	157.2	78.6	92.7	126.9
Exchangeable K	(Cmol/kg)	1.4	1.5	1.9	2.4	2.9	2.7
Exchangeable Ca	(Cmol/kg)	3.9	4.2	2.7	4	4.9	3.2
Exchangeable Mg	(Cmol/kg)	3	3.5	6.3	3.3	3.8	6.9
Base Saturation	(%)	44.8	30.9	44.1	45.9	36	37.5
Recalcitrance Index	(R50)	0.62	0.58	0.57	0.65	0.6	0.58

- Bulk density of biochar decreases with increasing PT due to loss of volatile matter, formation of pores, and decomposition of dense components, resulting in a more porous and less dense biochar structure.
- Particle density decreases with increasing PT due to loss of volatile matter, formation of pores, and decomposition of denser components, resulting in a more porous and less dense biochar structure.
- These quality parameters and their customization of biochar are very important for agro-industrial applications.
- PKN contents and so as the ratio of C:N play key role in soil/ plantation improvement applications . These values vary with input bio residues and PT and others conditions .
- At higher PT and retention time, P and N contents decreased indicating for soil application we should try milder condition of pyrolysis .
- Total carbon values higher at 450°C due to higher decomposition of volatile matter in biochar, during soil application it is quite beneficial.
- There is need to balance the biochar contents as per requirements
- Exchangeable K, Ca, Mg and Na of different Biochar is influenced by PT.
- Biochar with high base extraction capacity when added in soil can be beneficial for plant growth, as these bases are essential nutrients for plants.
- Recalcitrance index (R50)of all the biochar were found within the range of 0.5 – 0.6, so were rated as Class 2-minimal degradable.

Conclusions

The current work was undertaken to address multiple issues: management of various waste biomasses through their conversion to value-added material for its utilization as a soil amendment.

- The basic characterization of pulp mill Bio residues, which go to landfill, understudy has shown potential to convert these to biochar with efficient collection practices.
- The biochar from the bio residues have shown varying characteristics in terms of heat values, physical properties like porosity, surface area, water holding capacities etc and chemical compositions etc. These have great and positive influence on their potential for uses for different applications.
- Varying pyrolysis conditions specially temperature greatly influence the biochar characteristics. The customization of properties can be done, based on Biochar applications, through input preparations and setting pyrolysis conditions.
- The biochar so produced are also quite suitable as specific reference for soil and plantation productivity improvements and under further investigation apart from other industrial applications.
- Finally it can be concluded that valorisation of bio residues to Biochar in integration with mill operations and waste management has great potential to improve Carbon footprint and productivity of Pulp and Paper mills.

Acknowledgement

The first author gratefully acknowledges the financial assistance received from PT. TEL, Indonesia for carrying out the current investigation.