Valorization of Pulp and Paper Mill bio-residues to biochar for environmental and business sustainability in totality

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Opening statement

The pulp and paper industry, is biomass based, in its total life cycle.

The development and efficient generation, processing & use of biomass/Bio residues to improve business sustainability and reduce global adverse environmental impacts are the need of the day.

This project and presentation on **Valorization of Pulp and Paper Mill bio-residues to biochar** is focused towards the same direction.

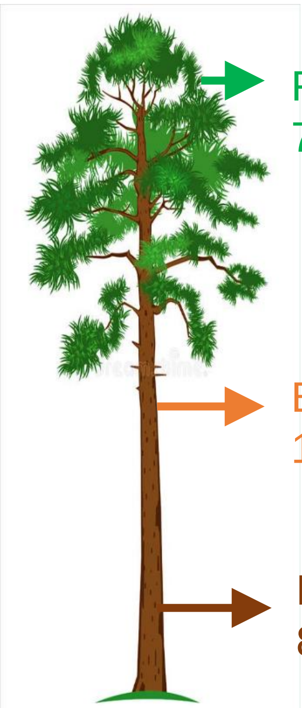
This project is the part of PhD study along with target for direct business/industrial applications .

Presentation Content

- Introduction – Bio mass/residues and Biochar
- Present management bio residues in Pulp and Paper industry
- Characterization of Bio residues
- Valorisation-Pyrolysis of Bio residues to Biochar
- Characterization and potential of Biochar applications.
- Sustainability impact of conversion Bio residue to Biochar
- Concluding remarks

Biomass/Fiber resources : Versatile potential

TREE | **PULP MILL** | **BIO PRODUCTs** | **BIO FIBRE RESIDUES**



Folliage
7%

Bark
11%

Logs
82%

Converting
Operation

Cellulose

- **Pulp – paper**
- **Mech Pulp**
- **Dissolving Pulp**
- **MCCell – Nano Cell**

Lignin/Derivatives

Biochemical

- **Furfurals**
- **Acetic Acid**
- **Medicinal Oil**
- **Methanol**

Xylose Derivatives

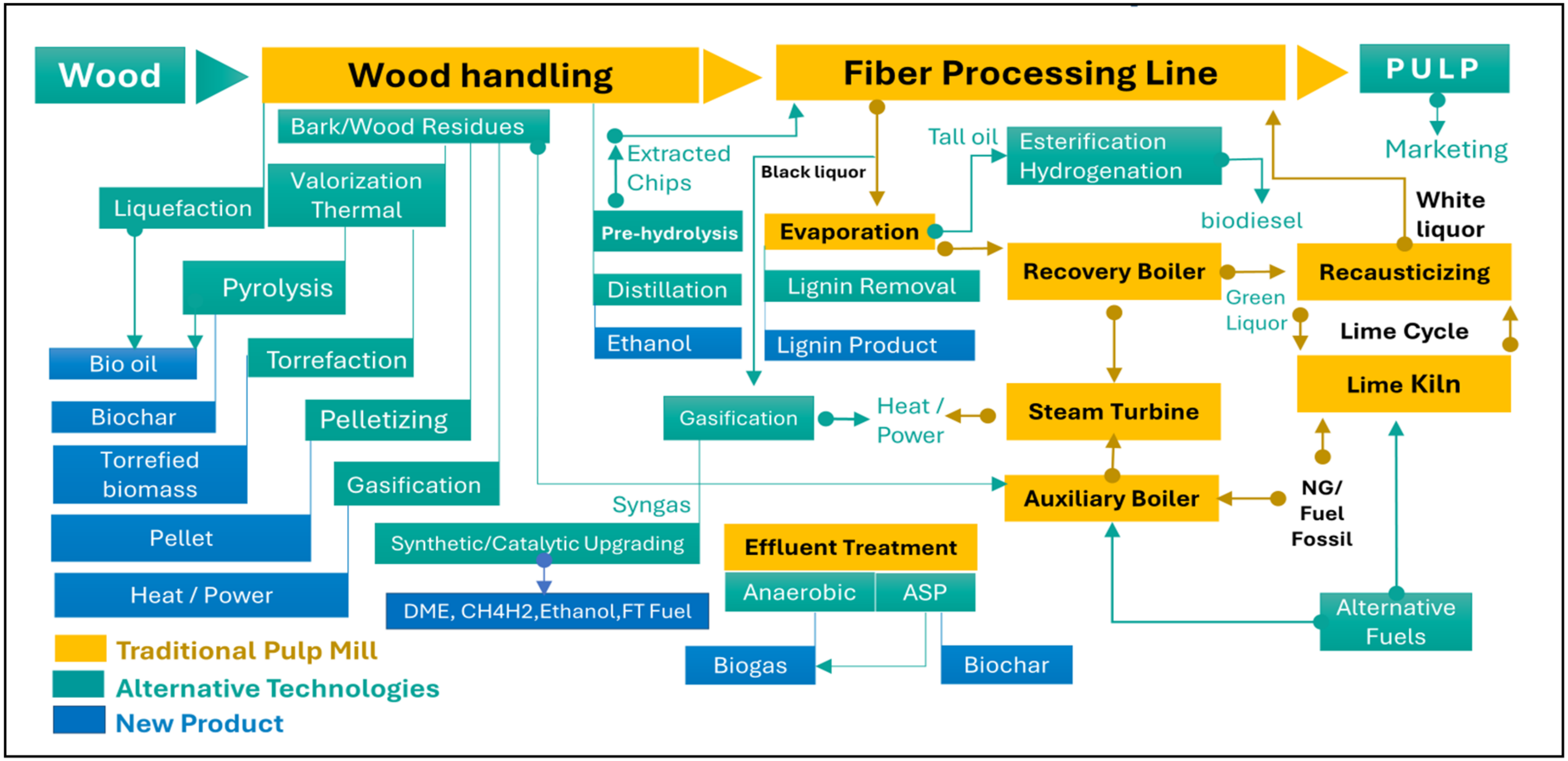
Tree stumps
Tree Foliage

Chips–oversize
Wood Bark and debris
Wood dust

Pulp screen rejects
Effluent sludge

Ref: ***Eucalyptus pellita***

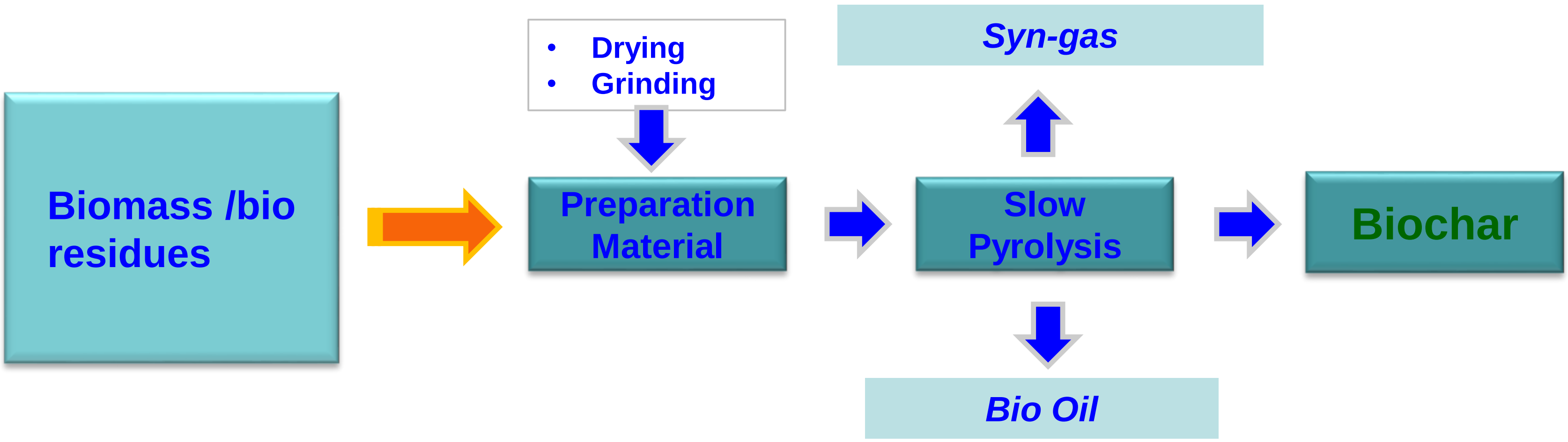
Pulp mill – Biomass based Development and Sustainability Opportunities



Biochar : It is stable carbon rich solid material obtained from the thermochemical conversion-Pyrolysis of biomass in an oxygen-limited environment.

Biomass Biochar Process description

- Biochar is produced by thermochemical conversions of biomass under anaerobic conditions and at elevated temperatures thru Pyrolysis.
- Pyrolysis of biomass results in different products consisting of solid biochar, liquid bio-oil, and pyrolytic gas.
- Based on biomass quality and operational conditions, physical and chemical properties of biochar and potential for its use will be decided.
- Biochar quality improvement and modification would be also the feature of the proposed total plan

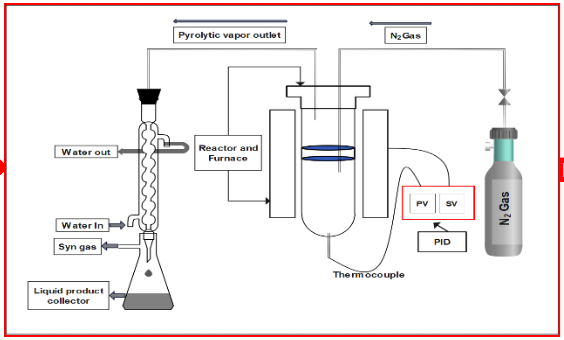


Note : Syn gas and Bio oil properties are not included in this presentation

Laboratory and Typical Biochar pilot reactor

Schematic of Pyrolysis process

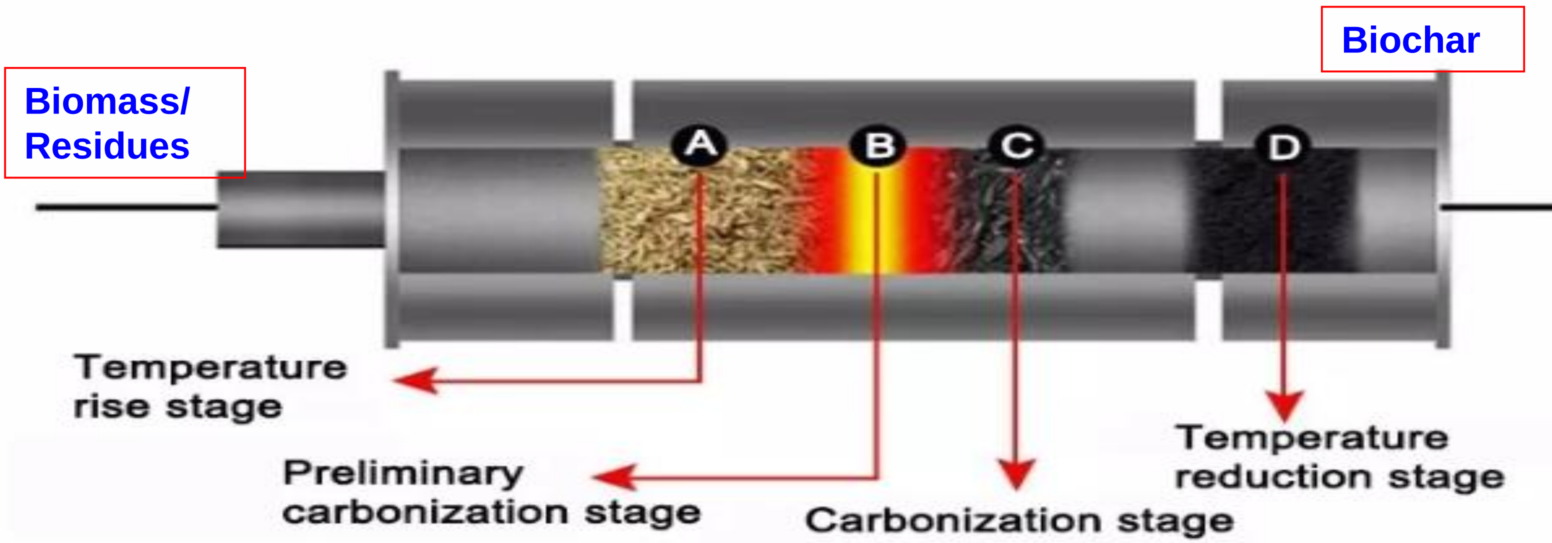
Pretreated Biomass



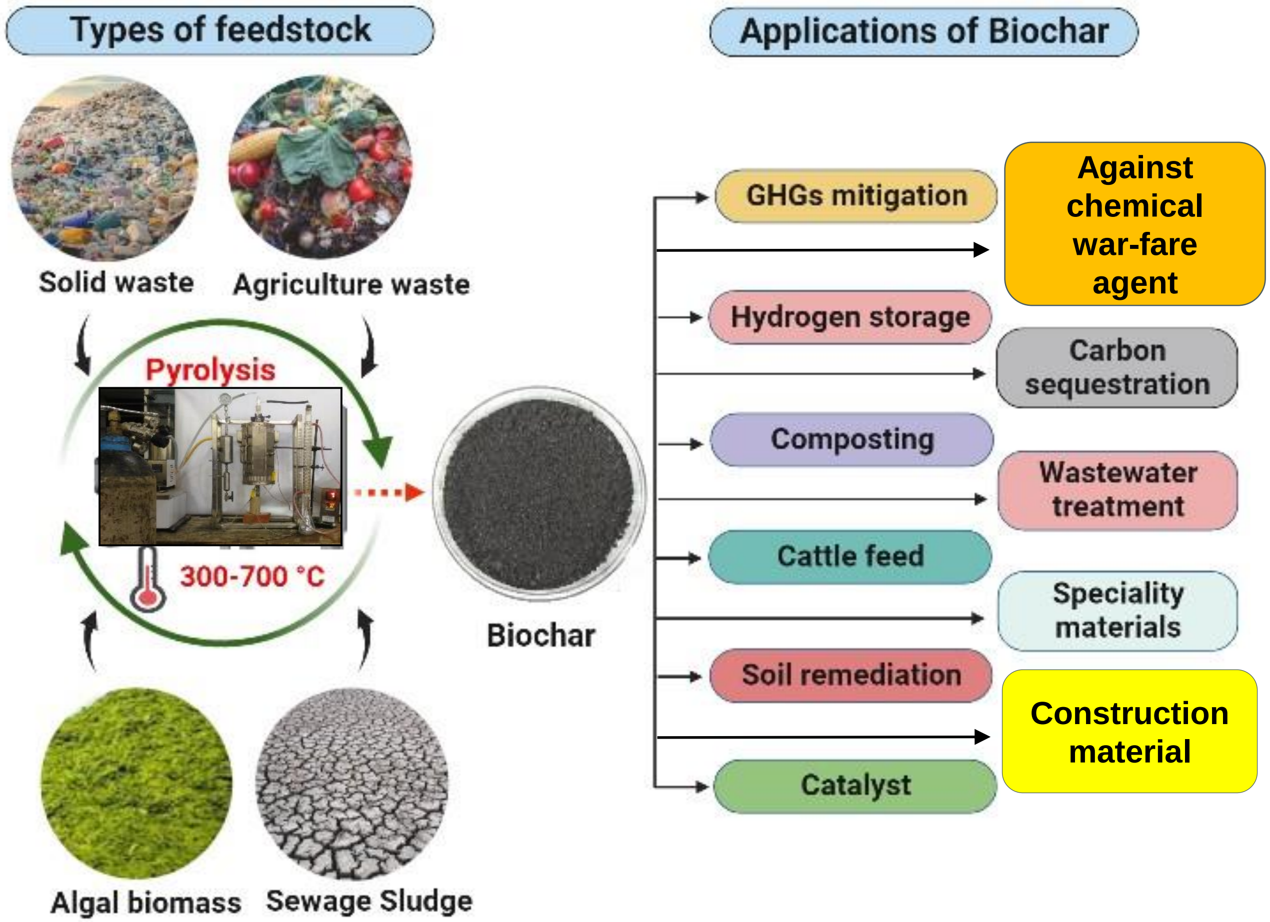
Schematic of the pyrolyser set-up

Biochar

Typical Biochar pilot reactor

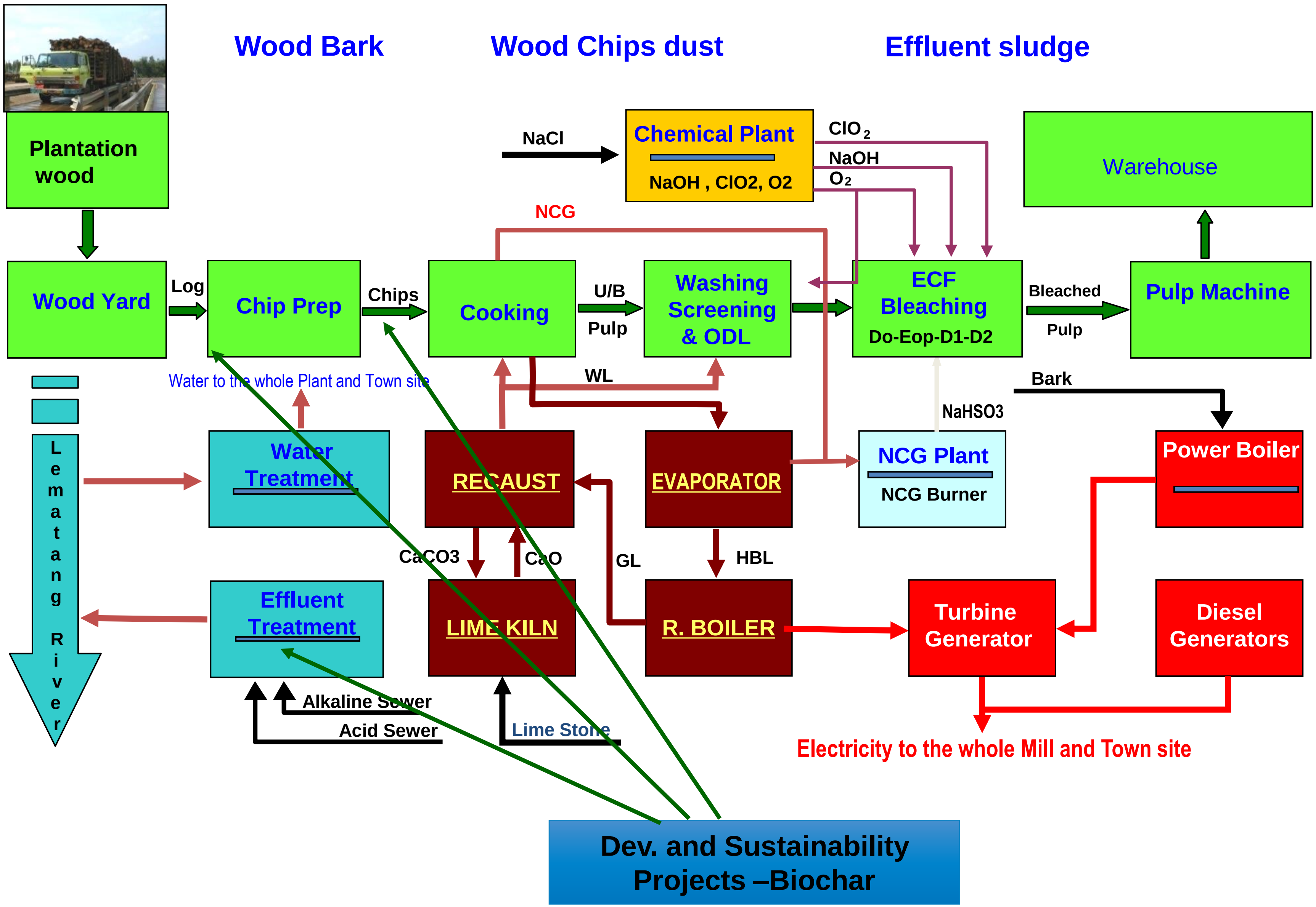


Different Applications of biochar



A thermo-chemical based biomass conversion system yielding products for varied applications

Market Pulp mill –Biomass/bio residues for Biochar study



Pulp mill –Biomass/bio residues under present study

Biomass /bio residues tested at Tezpur University, India Laboratory scale

I.Eucalyptus pellita Wood chips/dust (EPWC)
II.Eucalyptus pellita Bark- EPB
III.Effluent rejects /sludge -ESW

Eucalyptus pellita Wood Chip (**EPWC**)

Eucalyptus pellita Bark (**EPB**)

Effluent Sludge (**ESW**)

Bioresidues- Biochar Project

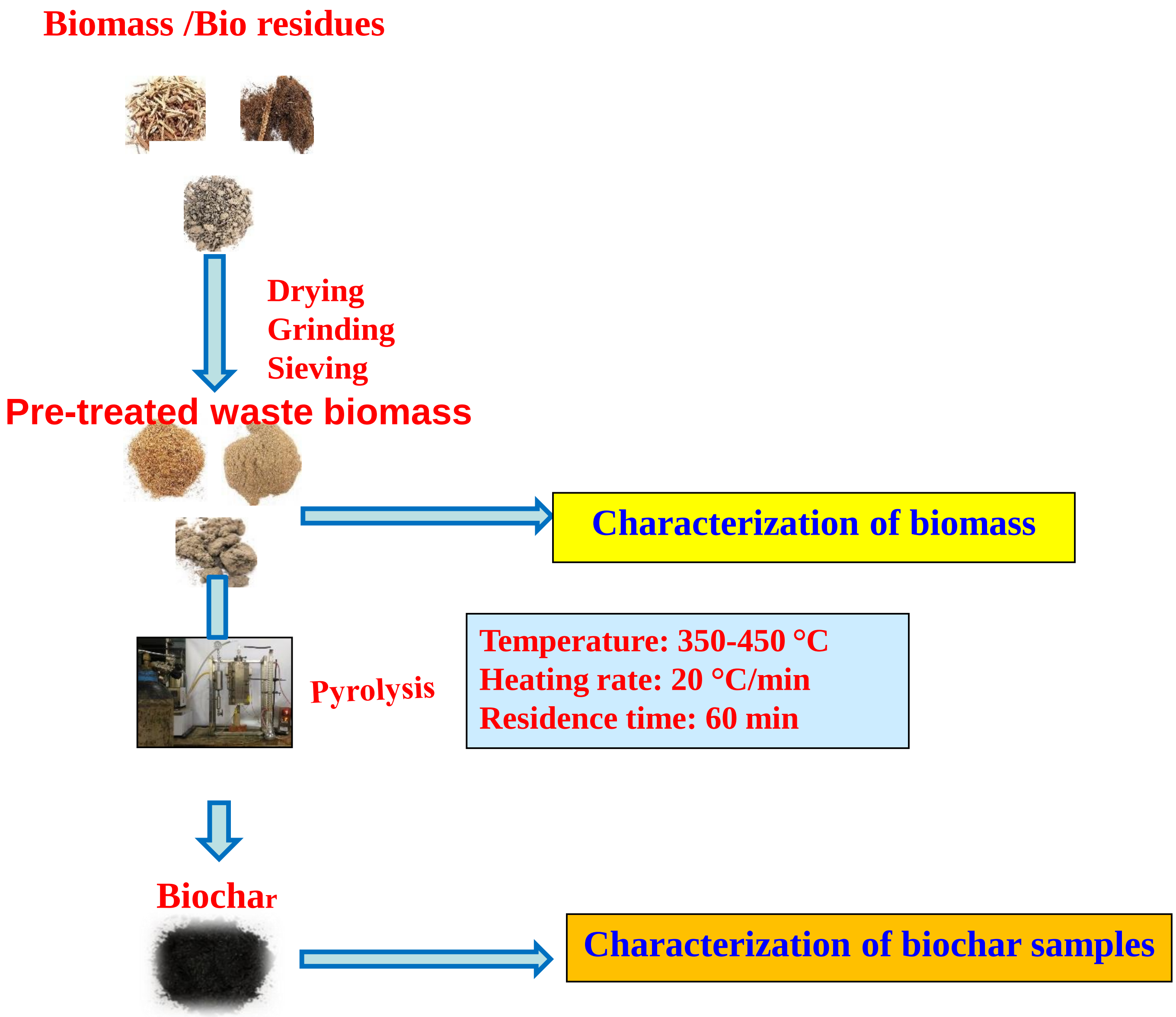
Overall Objective :

- Economical use/disposal of pulp mill bio residues thru Biochar production.
- Reduce CO_2 emission and sustainability in pulp production and
- Evaluate total management of Biochar production; process, products and marketing exploration.

Present status:

- Presently at Plantation and pulp mills some portion of residual biomasses are left infield, burnt and dumped in open causing the emission of Green House Gases
- Pulp mill under reference has also such underutilized biomass - wood bark, top portions of trees, effluent sludge, etc.
- Research studies are being carried out also are under progress to establish the process and pilot plant design etc .
- Biochar properties enhancement and utilization plan are under active considerations .
- Role of Biochar for Carbon Footprint and trading are getting importance ref to sustainability is also under consideration .

Biomass/bio residues - Biochar evaluation plan



Biomass/residues and Biochar key analysis data and observations

Data covered in discussion

- **Biomass /residues analysis data**
- **Biomass /residues biochar properties data**
- **Biomass /residues biochar comparative properties data matrix**

Note :

- Discussion covers briefly on Biochar application potential key ref soil/ forestry .
- As fixed conditions were tried based on earlier experience so impact of varying pyrolysis conditions not covered .
- Discussion in this presentation does not cover Environmental and Financial aspects

Biochar –Application Impact and properties

Sl No	Application	Impact	BioChar Properties
A	Plantation /Agriculture		
i	Soil improvement:	Soil's physical, chemical, and enzyme activities and biological properties,to increased crop productivity.	pH, EC, FC, El data, NPK, CEC, RGer
ii	Fertilizer:	As a fertilizer and with Fertilizer loaded	pH, EC, FC, El data, NPK, CEC
iii	Livestock Farming:	Feed additive to enhance immunity and feed efficiency.	FC, Vol Ex. Total salt
iv	Soil filter:	Hold and remove toxic substance in the soil.	Porosity, Pore size , EC , pH
B	Industrial		
i	Wastewater Treatment:	As absorbent to remove pollutants from water such as pesticides, antibiotics, oils, heavy metals.	EC, CEC, FC, Pore size, Porosity
ii	Biogas:	Effective substrate for biogas generation	HV, Density, Porosity
iii	Cement:	Used as an alternative material of cement. Strength differ a lot based on raw materials of the char.	Metals, FC
iv	Energy	Source of energy	Density, HHV
v	Other		

Bio Mass/Residues analysis data

Parameters	UoM	Euca wood chip (EPWC)	Euca bark (EPB)	Effluent sludge (ESW)
Moisture	%	8.7	4.0	11.8
Ash	%	4	5.9	19.9
Volatile matter	%	83.9	79.0	67.5
Fixed Carbon	%	3.2	10.9	0.67

- In pulp mills biomass residues quantity and quality vary with the miil 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/heating 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 .

Bio Mass/Residues analysis data

Parameters	UoM	Euca wood chip (EPWC)	Euca bark (EPB)	Effluent sludge (ESW)
C	%	47.1	43.1	28.5
H	%	6.9	6.3	4.0
N	%	0.02	0.1	0.59
S	%	0.09	0	1.67
O	%	45.9	50.44	67.3

- **High carbon content** in the biomass lead to production of biochar with high carbon content in the biochar, which would be valuable for sequestering carbon in the soil.
- **High hydrogen content** increases the energy consumption during pyrolysis and affect the yield and properties of the biochar.
- **Nitrogen content** in biomass influences the biochar; low C:N ratio is desirable for soil application.

Biomass -Biochar material balance

Parameter	UoM	Euca wood chip (EPWC)	Euca bark (EPB)	Effluent sludge (ESW)
Input Biomass/residues				
Fixed carbon	%	3.2	11.0	0.7
Volatile	%	84.0	79.1	67.5
Ash (550°C)	%	4.1	5.9	19.9
Moisture	%	8.8	4.1	11.9
Output Biochar (350°C)				
Fixed carbon	%	52.3	50.4	33.0
Volatile		41.4	30.8	21.3
Ash (550°C)	%	0.5	12.5	43.0
Moisture	%	5.8	6.4	2.7

- This is typical input-output material balance during this study at 350°C pyrolysis temperature .
- The total energy requirement to convert biomass is quite dependent on its ash, volatile constituents, pyrolysis temperature (PT) and final product quality requirement.

Biomass/Residues Biochar analysis data - 01

Parameter	UoM	P. Temp: 350°C			P. 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 matter	%	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

P.T. : Pyrolysis Temperature

- 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.

Bio Mass/Residues Biochar analysis data - 02

Parameter	UoM	P.Temp: 350°C			P.Temp: 450°C		
		Euca wood chip (EPWC)	Euca bark (EPB)	Effluent sludge (ESW)	Euca wood chip (EPWC)	Euca bark (EPB)	Effluent sludge (ESW)
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

- 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.

Bio Mass/Residues Biochar analysis data - 03

Parameter	UoM	P.Temp: 350°C			P.Temp: 450°C		
		Euca wood chip (EPWC)	Euca bark (EPB)	Effluent sludge (ESW)	Euca wood chip (EPWC)	Euca bark (EPB)	Effluent sludge (ESW)
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)	($cmol_c$ /kg)	19.2	35.6	30	25.1	39.9	40.9

- Biochar produced at lower PT tends to be lower alkaline due to incomplete degradation and conservation of acidic functional groups.
- Electrical conductivity of biochar increases with increasing PT, due to the formation of a more graphitic structure, which is highly conductive. This would influence on soil salinity
- Total salt content in these biochar increases in accordance with EC value with the increase in PT.
- With the increase in surface area of bio char at higher PT, the minerals such as K, Ca, Mg, Na, and P help in the formation of O-containing groups on biochar surfaces during pyrolysis, resulting in higher CEC which could improve soil quality by reducing leaching of nutrients and hence enhances nutrient cycling.

Bio Mass/Residues Biochar analysis data - 04

Parameter	UoM	P.Temp: 350°C			P.Temp: 450°C		
		Euca wood chip (EPWC)	Euca bark (EPB)	Effluent sludge (ESW)	Euca wood chip (EPWC)	Euca bark (EPB)	Effluent sludge (ESW)
Bulk density	(Mg/m^3)	0.4	0.3	0.7	0.3	0.2	0.6
Particle density	(Mg/m^3)	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

- 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.

Bio Mass/Residues Biochar analysis data - 05

Parameter	UoM	P.Temp: 350°C			P.Temp: 450°C		
		Euca wood chip (EPWC)	Euca bark (EPB)	Effluent sludge (ESW)	Euca wood chip (EPWC)	Euca bark (EPB)	Effluent sludge (ESW)
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

- 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 .

Bio Mass/Residues Biochar analysis data - 06

Parameter	UoM	P.Temp: 350°C			P.Temp: 450°C		
		Euca wood chip (EPWC)	Euca bark (EPB)	Effluent sludge (ESW)	Euca wood chip (EPWC)	Euca bark (EPB)	Effluent sludge (ESW)
Exchangeable K	$(cmol_c/kg)$	1.4	1.5	1.9	2.4	2.9	2.7
Exchangeable Ca	$(cmol_c/kg)$	3.9	4.2	2.7	4	4.9	3.2
Exchangeable Mg	$(cmol_c/kg)$	3	3.5	6.3	3.3	3.8	6.9
Exchangeable Na	$(cmol_c/kg)$	0.3	1.78	2.2	1.8	2.7	2.5
Base Saturation	(%)	44.8	30.9	44.1	45.9	36	37.5
Recalcitrance Index	(R_{50})	0.62	0.58	0.57	0.65	0.6	0.58

- 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 $(R_{50})$of all the biochar were found within the range of 0.5 – 0.6, so were rated as Class 2-minimal degradable.

Biochar properties –Comparative impact related to plantation

Fixed C:	**EPWC > EPB > ESW**
Total C:	**EPWC > EPB > ESW**
C : N Ratio:	**EPB > EPWC > ESW**
pH:	**ESW > EPB > EPWC**
Elect Cond.:	**ESW > EPB > EPWC**
Bulk Density:	**ESW > EPWC > EPB**
Particle density:	**ESW > EPWC > EPB**
Total Porosity:	**EPB > EPWC > ESW**
Volume Expansion:	**EPB > EPWC > ESW**
Total P:	**ESW > EPWC > EPB**
Total K:	**EPB > ESW > EPWC**
Total N:	**ESW > EPWC > EPB**
Carbon Sequestration Potential (CSP) and Recalcitrance:	**EPWC > EPB > ESW**

- Overall comparative evaluation as presented, needs to be carefully understood before deciding/exploring the application
- Each property has its own importance with reference to uses

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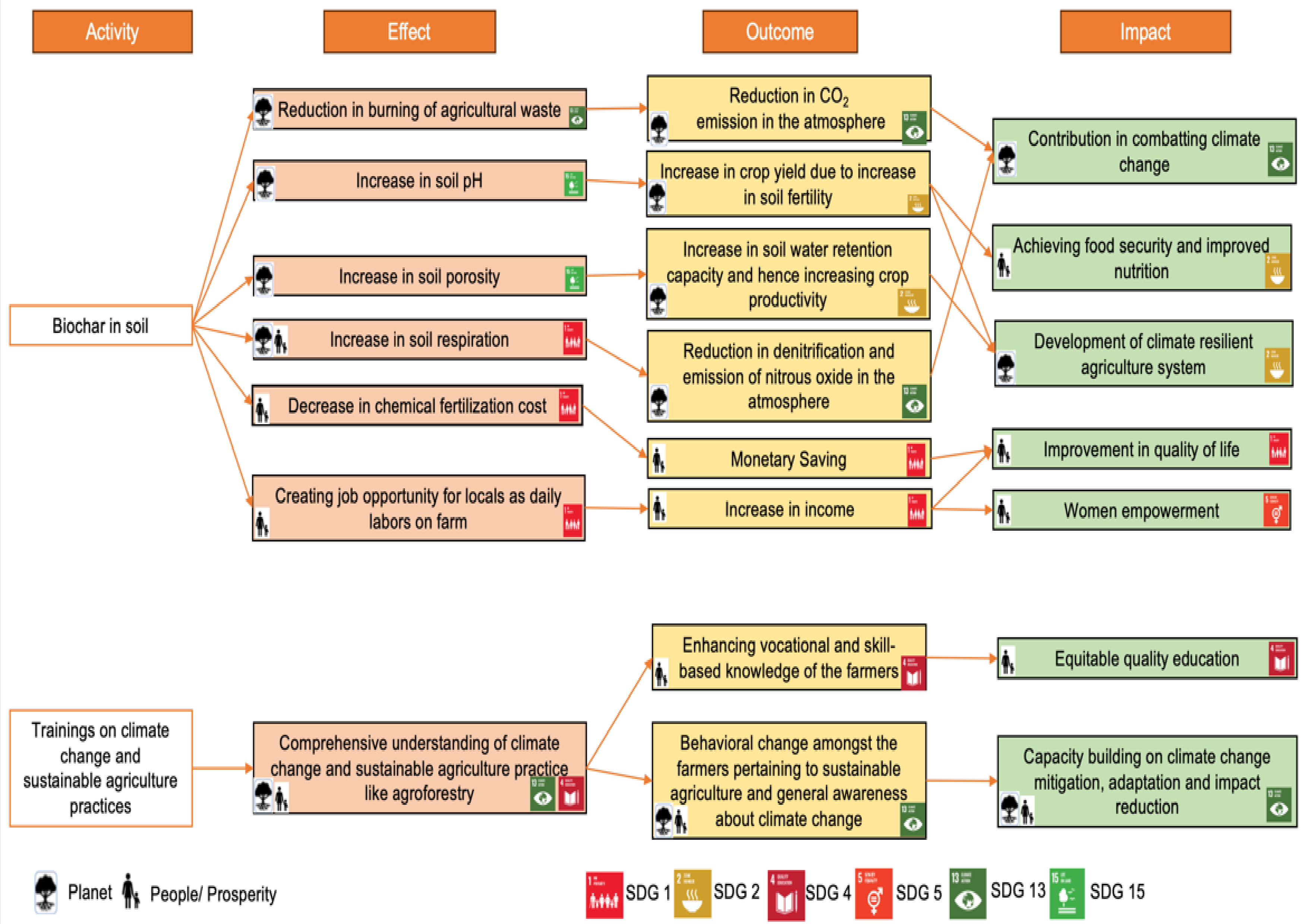
- **Detailed overall investigations are in progress/planned keeping in view of different application requirements and pulp /paper mills biomass/residues quality and quantity.**

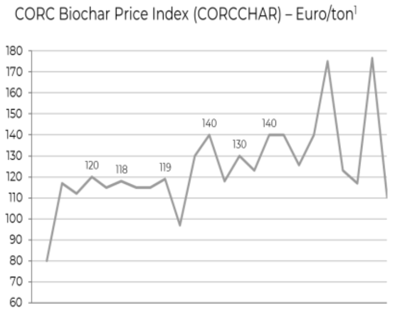


Activity
Effect
Outcome
Impact
Biochar in soil
Reduction in burning of agricultural waste
Increase in soil pH
Increase in soil porosity
Increase in soil respiration
Decrease in chemical fertilization cost
Creating job opportunity for locals as daily labors on farm
Reduction in CO_2 emission in the atmosphere
Increase in crop yield due to increase in soil fertility
Increase in soil water retention capacity and hence increasing crop productivity
Reduction in denitrification and emission of nitrous oxide in the atmosphere
Monetary Saving
Increase in income
Contribution in combatting climate change
Achieving food security and improved nutrition
Development of climate resilient agriculture system
Improvement in quality of life
Women empowerment
Trainings on climate change and sustainable agriculture practices
Comprehensive understanding of climate change and sustainable agriculture practice like agroforestry
Enhancing vocational and skill-based knowledge of the farmers
Behavioral change amongst the farmers pertaining to sustainable agriculture and general awareness about climate change
Equitable quality education
Capacity building on climate change mitigation, adaptation and impact reduction
Planet
People/ Prosperity
SDG 1
SDG 2
SDG 4
SDG 5
SDG 13
SDG 15

Biochar methodologies

Puro is currently the leading methodology with high prices - but takes a different accounting and monitoring approach, that is unproven with larger volumes and corporate buyers with easier to abate emissions profile.

Parameters	VM0044	Puro
Latest release	Jul/23 v1.1	Jan/2022 – V2
Retired volume	0	197kton
Pipeline volume	0	11,037kton
# listed projects	No listed projects under any version of the meth	27 projects
Issued volume	0	228kton
Eligibility Criteria	• Low or high technology production facilities allowed to produce biochar produced from eligible waste biomass through a thermochemical process (pyrolysis, gasification, and biomass boilers). •The biochar is subsequently applied to an end-use (soil - other than wetlands. or non-soil applications) •Biochar made from a single or mixed eligible feedstock types must comply with the latest version of the IBI Biochar Testing Guidelines or the EBC Production Guidelines • Limitation of 200km for transport of waste biomass and resulting biochar for application for non-road transportation: Road transportation for distances more than 200 km, defined under CDM Tool 12: Project and leakage emissions from transportation of freight	•The pyrolysis (heating of an organic material, such as biomass, in the absence of oxygen) gases must undergo engineered emissions control to decrease methane to negligible levels •Biochar must be used in applications that preserve its carbon storage property. •Biochar must not be used in applications that destroy its carbon storage •The producer must demonstrate net-negativity in GHG emissions through a life cycle assessment (LCA) •The biochar produced must have a molar $H/Corg$ ratio (Hydrogen to organic carbon molar ratio. lower than 0.7. •The end use of the biochar product needs to be proven to be other than energy use
Baseline	The methodology defines the default net baseline emission avoidance as zero following a conservative scenario (ERSS,y)	•The default baseline emission scenario for the project activity feedstock is zero, which is a conservative assumption since it does not takie into account methane emissions derived from decay of manure or combustion of waste biomass. •If input for biochar production is living biomass (not waste biomass), then emission from the living biomass needs to be considered
Additionality	1. Regulatory Surplus- not mandated by any law or regulation 2. Positive List	Project must convincingly demonstrate that the CO2 removals are a result of carbon finance.
Monitoring	•Life-cycle Assessment • Flux of CH4, N2O, and CO2 and are defined and quantified in terms of tCO2e/yr • Leakage is to be considered	•Life-cycle Assessment •Only CO2 •No Leakage



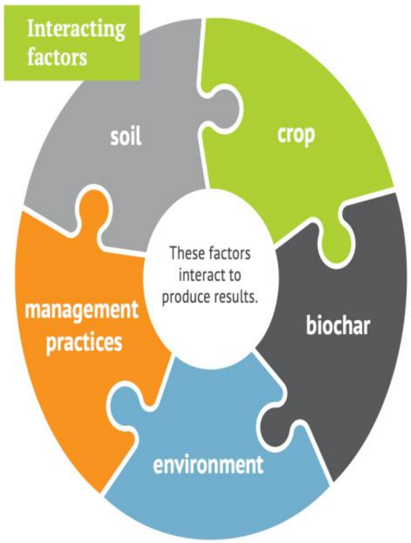
Reflects price and volume from actual carbon removals contract trades in the different Methods reported into the CORC registry managed by Puro.earth, where prices and corresponding volumes have been traded during the Reporting Period. Eligible trade types are spot and pre-purchase agreement transactions.

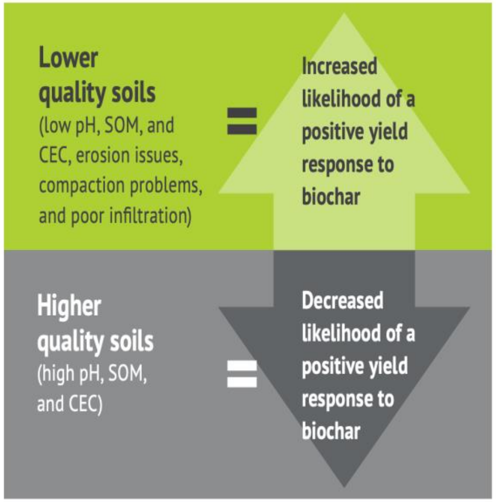
Source: https://www.nasdaq.com/solutions/carbon-removal-platform; Puro Earth Registry

About Puro.earth

- The Puro Standard is the first carbon removal standard for engineered carbon removal methods in the voluntary carbon market.
- Aligned with the IPCC definition for carbon removal, the Puro Standard brings integrity to the market with high-quality carbon removal methodologies, including the first methodology for biochar.
- The Puro.earth methodology for biochar was developed in 2019 and was updated in 2022 to include the latest research.

Parameters	Data/Information
Version of the methodology	2 (latest update on 2022)
Number of biochar projects registered till date	28
Tonnes of CO_2 removed from biochar projects till date	62,167
Permanence of the carbon stored	100+ years
Listing prices	60-125 eur





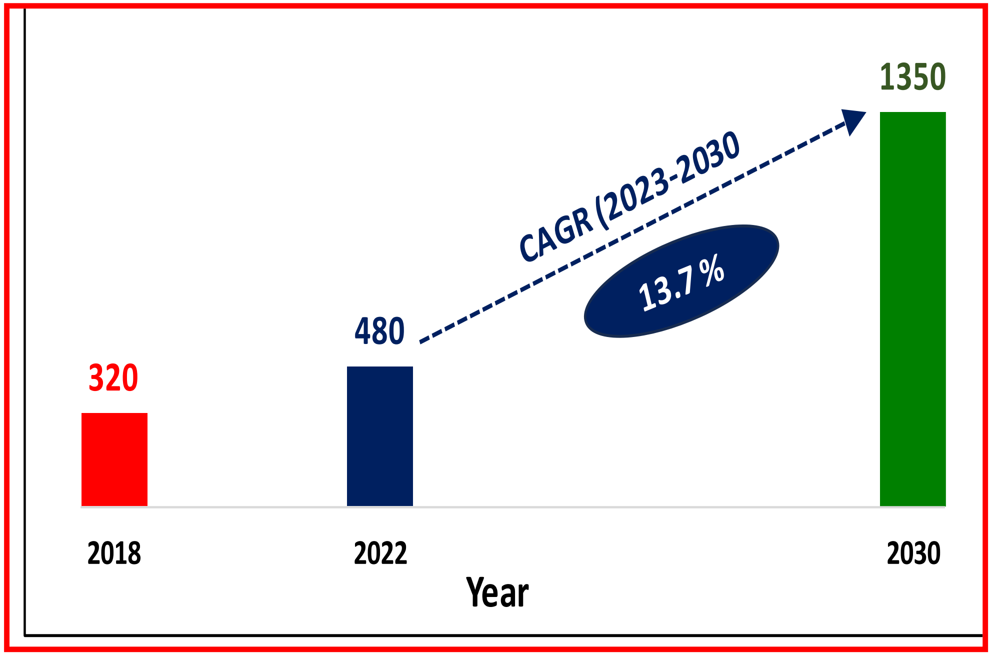
SOM = soil organic matter, CEC = cation exchange capacity

Biochar Application

- In-eligible for carbon credits if applied for energy purpose; application in soil and non-soil such as construction etc.
- Biochar application to soils requires a similar strategy as the 4Rs of nutrient stewardship: **right source, right place, right rate, and right timing**.
- When biochar is used appropriately it can help farmers achieve maximum crop productivity and improve soil health, while minimizing environmental impacts

Global Biochar market

Typical biochar projected Cumulative Annual Growth Rate (CAGR) -



1. Multiple market studies are reported.
2. Market is uniformly growing in all continents
3. Market growth is significantly being influenced
    - Biomass and Energy concerns
    - Global CO_2 emission
    - Individual commitment
    - Expanding potential for applications

TU results Biochar –Quality related to plantation

- The basic characterization of pulp mill bio-residues understudy, which otherwise may land up in the landfill, has shown potential to convert these to biochar.
- 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 varying influence on their potential 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 manipulating pyrolysis process parameters.

TU results Biochar –Quality related to plantation

- The biochar so produced are also quite suitable as specific reference for soil and plantation productivity improvements and are 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 can great benefit Pulp and Paper Industry to fulfil**

1. **responsible biowaste/sludge management**
2. **help the Industry to achieve CSR/Environmental Responsibility**
3. **reduce overall Carbon footprint and productivity of Pulp and paper mills**
4. **earn revenue from Carbon credit**

Recent publication on "Biochar application as construction material"

KEY FINDINGS

- Aims to prepare bio-based pozzolans from East-Indian lemon grass (*Cymbopogon flexuosus*) and poultry litter and to investigate the mechanical properties of concrete through their utilization as SCMs.

Energy, Ecology and Environment
https://doi.org/10.1007/s40974-024-00320-0

Check for updates

ORIGINAL ARTICLE

Optimization of biogenic supplementary cementitious materials in concrete prepared from East-Indian Lemon Grass (*Cymbopogon flexuosus*) and poultry litter using response surface methodology

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Abstract Developing construction materials from biomass and biowaste as a substitute for conventional cement has been receiving immense global interest in recent times, due to issues like greenhouse gas (GHG) emissions (e.g. CO_2), rapid depletion of non-renewable resources, and extensive energy consumption during cement production. Supplementary cementitious materials (SCMs) like fly ash, slag, and natural pozzolans can substitute conventional cement partially and can contribute to reducing GHG emissions and the environmental footprint of cement production. This study aims to prepare bio-based pozzolans from East- ... exhibited enhanced durability properties compared to traditional ones. The findings also demonstrate the robustness of RSM as a significant tool for optimization of concrete performance. Moreover, the characterization results of pyrolytic lemon grass bio-oil (LG-BO) confirm its bioenergy potential, thereby suggesting its diverse utilization in various applications.

Keywords Calcined lemon grass biochar · Poultry litter ash · Supplementary cementitious material · Biochar ash · Curing period · Water–cement ratio

- Based on RSM analysis, concrete prepared by substituting **17.57% of ordinary Portland cement with SCM** (which was **cured for 25.82 days** with a **water–cement ratio of 0.54**) yielded the optimum compressive, flexural and split tensile strengths of **33.94 ± 0.12, 8.78 ± 0.02 and 3.06 ± 0.02 N/mm2**,respectively.

Publication on "Biochar application as energy storage material"

Journal of Nano- and Electronic Physics

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Investigation of the Capacitive Properties of Chemically Activated Sugarcane Bagasse Biochar for Supercapacitor Application

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DOI	https://doi.org/10.21272/jnep.13(3).03025
PACS Number(s)	88.20.D, 81.05.U

KEY FINDINGS

- The **resultant activated carbon** displays high specific surface area with moderate mesoporous pore distribution, thus demonstrating **excellent electrochemical performances in aqueous electrolyte**.
- The study indicates that sugarcane bagasse has the potential to use it as raw material for the preparation of **activated biochar carbon for its application in supercapacitor**.

Publications on "Biochar application as soil amendment"

Original Article | Published: 13 March 2022

Role of pyrolysis temperature on application dose of rice straw biochar as soil amendment

Subham C. Mondal, Banashree Sarma, Rumi Narzari, Lina Gogoi, Rupam Kataki, Ankit Garg & Nirmali Gogoi

Environmental Sustainability **5**, 119–128 (2022) | Cite this article

KEY FINDINGS

- The study suggests that rice straw biochar prepared under low (350 °C) pyrolysis temperature should be applied at a lesser rate (5%) to obtain higher agronomic and environmental benefits.
- Whereas, a higher rate of application (10%) is suitable if the pyrolysis is performed at a higher temperature (550 °C).

Table 1 Proximate and ultimate analysis of rice straw biochars after 90 days of incubation

From: Role of pyrolysis temperature on application dose of rice straw biochar as soil amendment

Treatments	C%	H%	N%	O%	H/C	O/C	M%	Ash%	VM%	FC%
C1	$54.15^{f} \pm 0.09$	$3.85^{b} \pm 0.03$	$2.92^{b} \pm 0.01$	$39.08^{c} \pm 0.05$	0.85	0.54	10.31	$22.55^{h} \pm 0.03$	$19.5^{a} \pm 0.03$	$47.64^{c} \pm 0.02$
C2	$58.33^{d} \pm 0.06$	$2.62^{f} \pm 0.00$	$3.83^{a} \pm 0.02$	$35.22^{f} \pm 0.01$	0.54	0.45	6.92	$28.09^{g} \pm 0.02$	$15.8^{d} \pm 0.03$	$49.19^{b} \pm 0.01$
C1										
T1	$62.75^{b} \pm 0.09$	$2.53^{g} \pm 0.02$	$1.57^{e} \pm 0.02$	$33.15^{g} \pm 0.09$	0.48	0.40	6.79	$34.26^{d} \pm 0.06$	$15.3^{e} \pm 0.17$	$43.64^{e} \pm 0.06$
T2	$46.25^{g} \pm 0.06$	$2.29^{h} \pm 0.03$	$0.65^{g} \pm 0.00$	$50.81^{b} \pm 0.06$	0.59	0.82	6.72	$39.62^{a} \pm 0.02$	$18.8^{b} \pm 0.03$	$34.86^{h} \pm 0.01$
T3	$26.58^{h} \pm 0.12$	$3.46^{c} \pm 0.03$	$1.57^{e} \pm 0.02$	$68.39^{a} \pm 0.06$	1.56	1.93	7.17	$36.05^{b} \pm 0.02$	$16.6^{c} \pm 0.17$	$40.18^{g} \pm 0.02$
C2										
T1	$57.47^{e} \pm 0.03$	$4.35^{a} \pm 0.03$	$2.66^{d} \pm 0.02$	$35.52^{e} \pm 0.02$	0.91	0.46	6.78	$35.31^{c} \pm 0.06$	$15.8^{d} \pm 0.07$	$42.11^{f} \pm 0.06$
T2	$58.67^{c} \pm 0.12$	$3.30^{d} \pm 0.02$	$1.75^{d} \pm 0.02$	$36.28^{d} \pm 0.02$	0.67	0.46	7.05	$29.41^{f} \pm 0.02$	$11.4^{g} \pm 0.23$	$52.14^{a} \pm 0.06$
T3	$65.55^{a} \pm 0.12$	$3.01^{e} \pm 0.02$	$0.96^{f} \pm 0.01$	$30.48^{h} \pm 0.03$	0.55	0.35	7.97	$32.71^{e} \pm 0.06$	$12.9^{f} \pm 0.03$	$46.42^{d} \pm 0.03$

C1 = Biochar produced at 350 °C; C2 = Biochar produced at 550 °C; T1 = 5% biochar application; T2 = 10% biochar application; T3 = 20% biochar application; VM = volatile matter; FC = Fixed carbon

FORESTS, TREES AND LIVELIHOODS
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Efficacy of biochar application on seed germination and early growth of forest tree species in semi-evergreen, moist deciduous forest

Lina Gogoi[a], Nirmali Gogoi[b], Bikram Borkotoki[c], and Rupam Kataki[a]

[a]Department of Energy, Tezpur University, Tezpur, Assam, India; [b]Department of Environmental Science, Tezpur University, Tezpur, Assam, India; [c]AICRPDA, Biswanath College of Agriculture, AAU, Biswanath Chariali, Assam, India

Table 2. Results of proximate and ultimate analysis of the applied biochar.

Parameter	Value (±SE)
Moisture content (%)	6.43 ± 0.32
Ash content (%)	9.78 ± 0.48
Volatile matter content (%)	32.68 ± 1.6
Fixed carbon (%)	51.11 ± 2.5
pH	9.57 ± 0.47
EC (dsm^{-1})	1.08 ± 0.05
Carbon (%)	64.99 ± 3.24
Hydrogen (%)	2.13 ± 0.11
Nitrogen (%)	1.12 ± 0.056
Oxygen (%)	31.76 ± 1.59
H/C	0.39 ± 0.019
O/C	0.37 ± 0.018

Table 3. Variation of soil parameters, before the experiment, and after 2 years of tree growth with biochar treatments.

Treatment*	S_b	T1	T2	T3	T4	T5	T6	T7
pH	5.71	5.4 ± 0.05 c	5.4 ± 0.05 c	5.5 ± 0.05 c	5.5 ± 0.05bc	5.6 ± 0.05 b	5.6 ± 0.05b	5.8 ± 0.05 a
EC (dsm^{-1})	0.071	0.062 ± 0.001 c	0.067 ± 0.0005a	0.065 ± 0.001b	0.044 ± 0.001 f	0.046 ± 0.0005e	0.062 ± 0.001 c	0.059 ± 0.0005d
Organic Carbon (%)	1.69	1.68 ± 0.005 g	1.78 ± 0.001 f	1.79 ± 0.001e	1.80 ± 0.005d	1.81 ± 0.005 c	1.86 ± 0.005b	1.93 ± 0.002a
Available N (kg ha^{-1})	342.1	340.33 ± 0.57d	340.63 ± 0.55 cd	340.66 ± 0.57 cd	341.66 ± 0.57bc	342.5 ± 0.45b	342.56 ± 0.51b	625.93 ± 1a
S (mg kg^{-1})	3.412	2.75 ± 0.03 g	2.86 ± 0.003 f	2.96 ± 0.001e	3.02 ± 0.01d	3.14 ± 0.001 c	3.21 ± 0.001b	3.35 ± 0.19a
Na(kg ha^{-1})	6.24	1.37 ± 0.04e	1.66 ± 0.05de	1.94 ± 0.06d	3.44 ± 0.39 c	3.76 ± 0.49 c	5.67 ± 0.19b	7.62 ± 0.39a
K (kg ha^{-1})	40.56	40.28 ± 0.62d	40.96 ± 1.05d	42.8 ± 1.3d	56.41 ± 0.77 c	59.4 ± 0.7 c	68.53 ± 2.7b	137.73 ± 5.4a
P (kg ha^{-1})	14.5	12.5 ± 0.45d	12.9 ± 0.1d	13.93 ± 0.83 c	14.66 ± 0.25 c	15.8 ± 0.17b	16.13 ± 0.4b	21.03 ± 0.3a
Zn (mg kg^{-1})	1.4	3.82 ± 0.06a	1.93 ± 0.32b	1.88 ± 0.29b	1.38 ± 0.17 c	1.37 ± 0.01 c	1.33 ± 0.06 c	1.27 ± 0.17 c
Mn (mg kg^{-1})	13.06	38.93 ± 0.01a	34.66 ± 0.01b	34.64 ± 0.01 c	28.52 ± 0.01d	27.43 ± 0.01e	24.08 ± 0.01 f	21.46 ± 0.01 g
Fe (mg kg^{-1})	42.52	59.77 ± 0.01a	59.67 ± 0.01b	58.67 ± 0.01 c	58.59 ± 0.06 c	57.2 ± 0.1d	55.12 ± 0.01e	51.13 ± 0.01 f
WHC (%)	68.02	68.02 ± 0.01d	68.09 ± 0.01d	69 ± 1 cd	69.87 ± 0.06bc	71 ± 1b	71 ± 1b	73.5 ± 1.9a
Bulk density (%)	1.24	1.24 ± 0.01a	1.1 ± 0.1b	1.1 ± 0.1b	0.96 ± 0.01 c	0.71 ± 0.01d	0.65 ± 0.01de	0.56 ± 0.05e

*: S_b = Soil before experiment; T_1 = 0 biochar added (control), T_2 = 1 t ha^{-1}, T_3 = 2 t ha^{-1}, T_4 = 3 t ha^{-1}, T_5 = 4 t ha^{-1}, T_6 = 5 t ha^{-1} and T_7 = 6 t ha^{-1}

KEY FINDINGS:

- Biochar was produced from *Trewia nudiflora* and *Lagerstroemia speciosa*.
- Biochar applications significantly increased germination percentage, germination index, vigor index, and dry weight of 30 days old seedlings for both species.
- Highest increases were obtained when biochar was added at the highest rate (6 t ha−1).

Original Paper | Published: 03 June 2020

Effect of Biochar on Soil Respiration from a Semi-evergreen, Moist Deciduous Forest Soil

Lina Gogoi, Rumi Narzari, Nirmali Gogoi, Bikram Borkotoki & Rupam Kataki

International Journal of Geosynthetics and Ground Engineering 6, Article number: 26 (2020) | Cite this article

Biochar Characterization:

•The biochar had high carbon content (64.99%), while the contents of N, H and O were relatively low.

•The recorded BET surface area was 98.726 m2 g^{-1}.

•pH and EC of the selected biochar were recorded 9.57 and 1.08 dsm−1, respectively.

•It was observed that atomic H: C and O: C ratios of biochar were 0.39 and 0.37 which reflects the aromatic structure of the biochar.

KEY FINDINGS

- The results indicated the prospect of carbon sequestration with the amendment of biochar in soil.
- The documented negative priming efects with biochar treatment support the reduction in CO_2 emission from the soil in our study.
- A decrease in total CO_2 respired was found with the addition of biochar in the soil where 6 t ha^{-1} of biochar treatment (T_7) produced the lowest amount of CO_2 for both the temperature regimes.

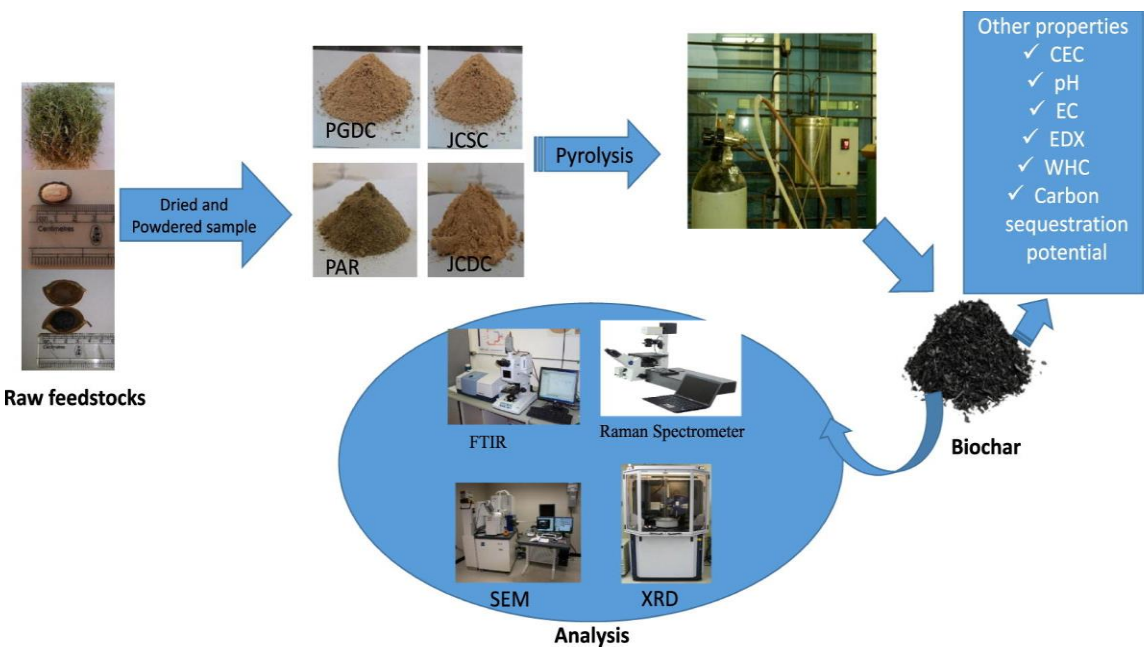
> Bioresour Technol. 2017 Oct;242:324-328. doi: 10.1016/j.biortech.2017.04.050. Epub 2017 Apr 16.

Fabrication of biochars obtained from valorization of biowaste and evaluation of its physicochemical properties

Rumi Narzari [1], Neonjyoti Bordoloi [1], Banashree Sarma [2], Lina Gogoi [1], Nirmali Gogoi [2], Bikram Borkotoki [3], Rupam Kataki [4]

Affiliations + expand

PMID: 28501382 DOI: 10.1016/j.biortech.2017.04.050



KEY FINDINGS

- Production temperature influence biochar characteristic.
- High energy, pH and inorganic nutrient in biochar produced at high temperature.
- High recalcitrance and CEC in biochar produced at higher temperature.
- Biochar produced at low temperature are highly hydrophobic in nature.

Impact of charcoal production activities on selected soil properties in Mizoram.

Author(s) : Lalmuankima, H. T. ; Upadhyaya, K. ; Kataki, R.

KEY FINDINGS

•The study area comprises of the **whole** of Mizoram state, covering all the 8 (eight) district headquarters viz., Aizawl, Kolasib, Serchhip, Champhai, Mamit, Lawngtlai and Siaha, and randomly selected villages representing each district to investigate the production and use pattern of charcoal.

•The charcoal of *L. polystachyus* shows highest calorific value as compared to other species. charcoal moisture content is positively correlated with calorific value and ash content, but negatively correlated with friability.

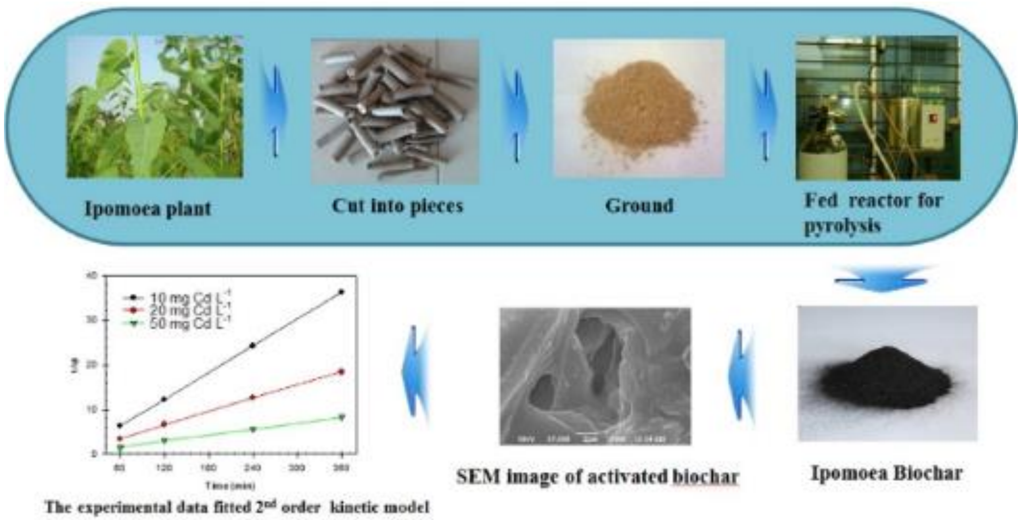
Publications on “Biochar application for waste-water treatment”

ELSEVIER

Ecological Engineering
Volume 97, December 2016, Pages 444-451

Characterization of cadmium removal from aqueous solution by biochar produced from *Ipomoea fistulosa* at different pyrolytic temperatures

Ritusmita Goswami [a], Jaehong Shim [b], Shantanu Deka [c], Deepa Kumari [d], Rupam Kataki [c], Manish Kumar [a]



KEY FINDINGS:

- ***Ipomoea fistulosa*** biochar was employed as a low cost, novel adsorbent to **remove Cd** from aqueous solution with minimum contact time period and adsorbent dose.
- The efficiency of Cd removal has been considerably improved by **activation** of biochar using KOH which subsequently enhanced the porous structure resulting in more adsorption sites being exposed to Cd.

ELSEVIER

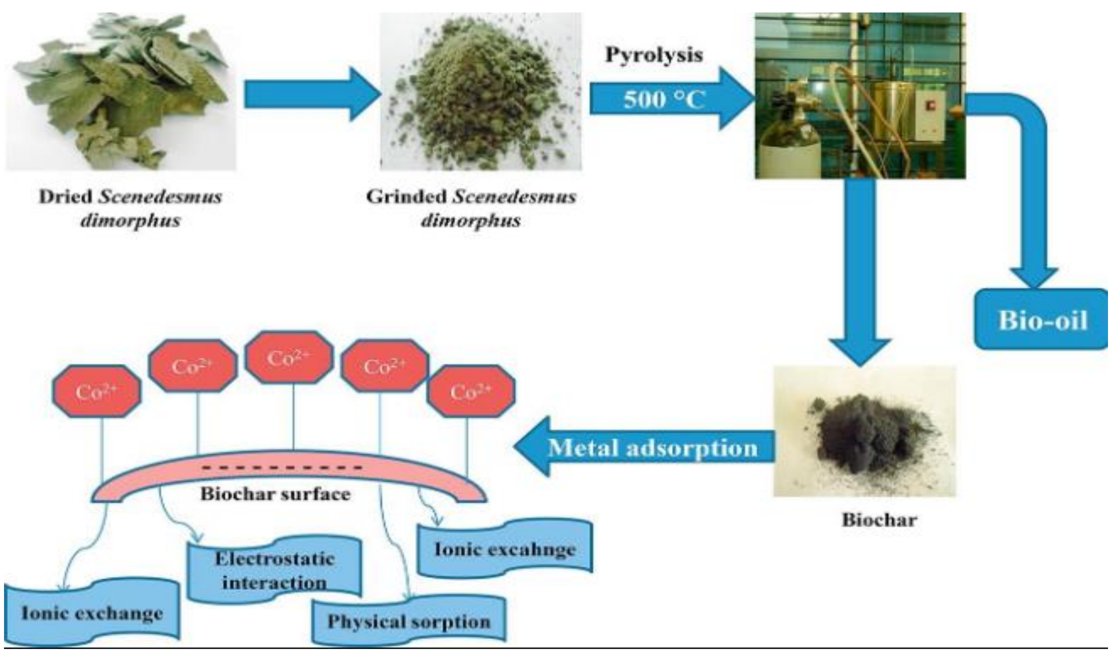
Bioresource Technology

Volume 244, Part 2, November 2017, Pages 1465-1469

Short Communication

Biosorption of Co (II) from aqueous solution using algal biochar: Kinetics and isotherm studies

Neonjyoti Bordoloi [a], Ritusmita Goswami [b], Manish Kumar [b], Rupam Kataki [a]



KEY FINDINGS

- Microalgae derived bio-char was used as an adsorbent.
- Effect of contact time for adsorption of Co (II) on bio-char was investigated.
- Adsorption equilibrium data was fitted for different isotherms.
- Kinetic study was described by using Pseudo-first and second order reaction model.

› Water Sci Technol. 2018 Feb;77(3-4):638-646. doi: 10.2166/wst.2017.579.

Adsorption of Methylene blue and Rhodamine B by using biochar derived from Pongamia glabra seed cover

Neonjyoti Bordoloi [1], Manash Deep Dey [2], Rupak Mukhopadhyay [2], Rupam Kataki [1]

KEY FINDINGS

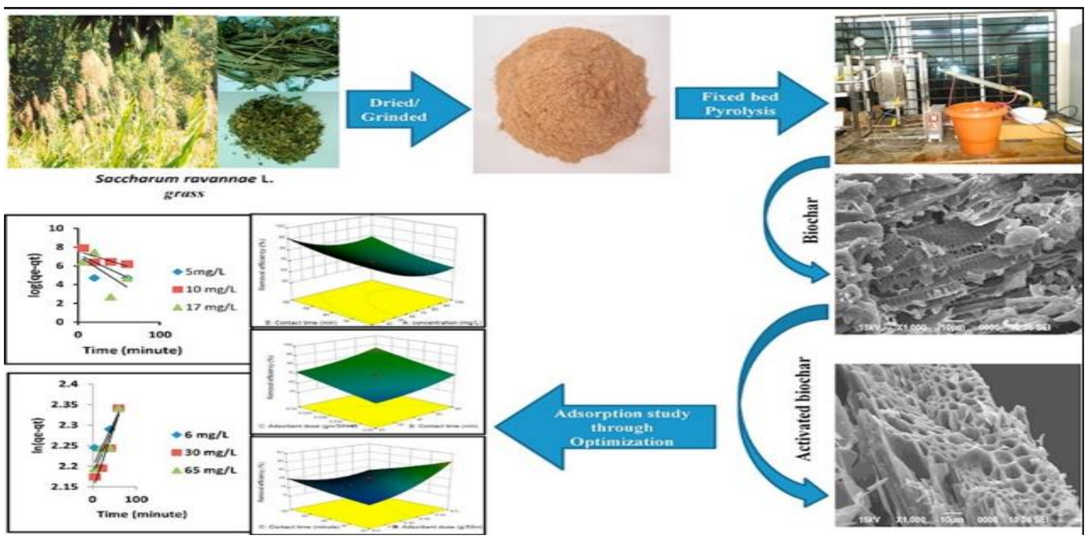
- Biochar obtained through the pyrolysis of *Pongamia glabra* seed cover (PGSC) at 550 °C with a heating rate of 40 °C/min was characterized and its ability to adsorb the dyes Methylene blue (MB) and Rhodamine B (RB) from aqueous solutions
- PGSC biochar could be used as a highly efficient adsorbent for the removal of synthetic dyes.

Journal of Environmental Chemical Engineering
Volume 5, Issue 6, December 2017, Pages 5528-5539

Research paper

Removal of arsenic and fluoride from aqueous solution by biomass based activated biochar: Optimization through response surface methodology

Ruprekha Saikia [a], Ritusmita Goswami [b], Neonjyoti Bordoloi [a], Kula K Senapati [c], Kamal K Pant [d], Manish Kumar [b e], Rupam Kataki [a]



KEY FINDINGS

- Perennial grass (*Saccharum ravannae* L.) based activated biochar was synthesized for possible application in both arsenic (As) and fluoride (F^-) removal from aqueous solution
- The activated biochar showed much larger specific surface area and a greater number of active adsorption sites as compared to raw biochar.