THE VALUE OF BIOCHAR FOR IMPROVED SOIL & WATER QUALITY HEALTH

CENTER FOR WATERSHED PROTECTION - WEBCAST 2

FEBRUARY 15, 2023

DOMINIQUE LUECKENHOFF

SENIOR VICE-PRESIDENT FOR CORPORATE AFFAIRS, EHS & SUSTAINABILITY HUGO NEU

THE VALUE OF BIOCHAR FOR IMPROVED SOIL & WATER QUALITY HEALTH

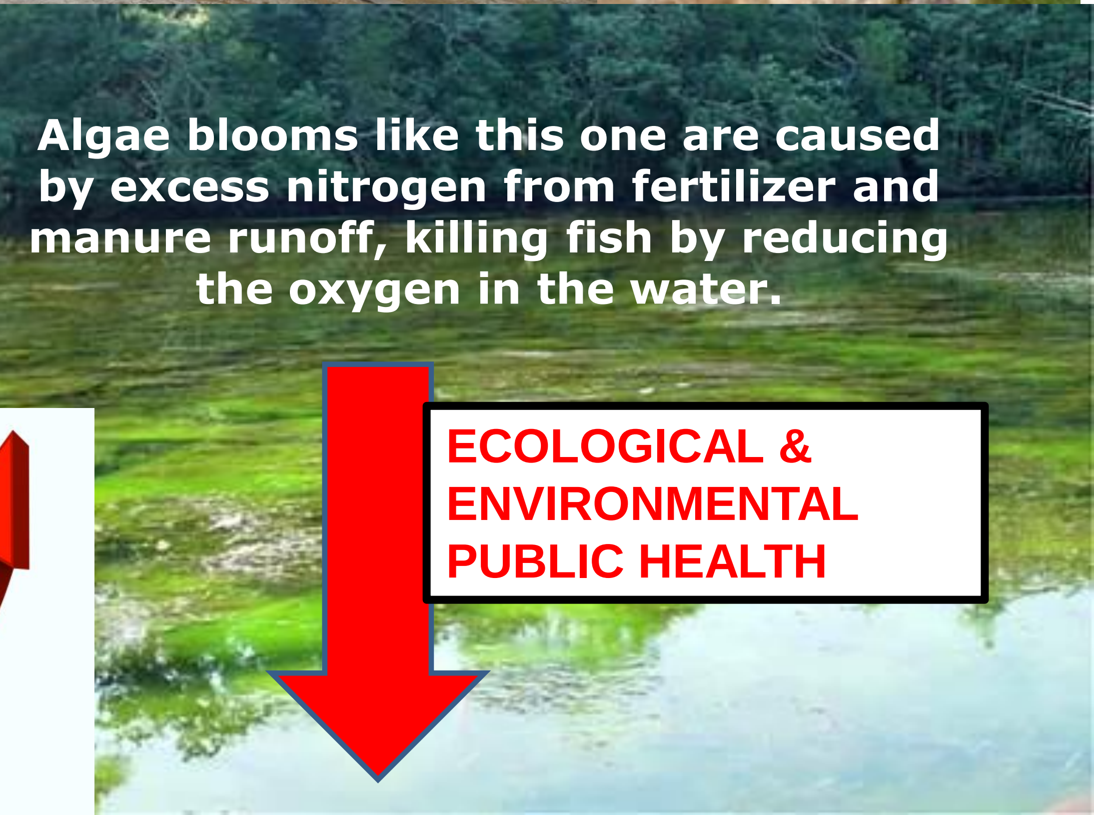
OVERVIEW

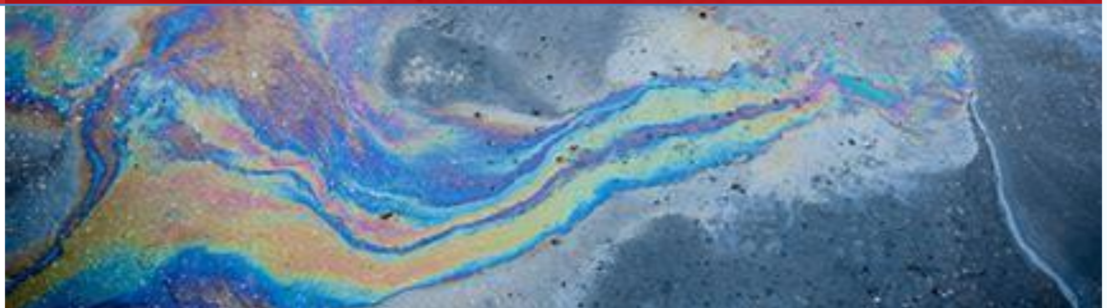
- WHY BIOCHAR?
- CHARACTERIZATION & BENEFITS OF BIOCHAR
- BIOCHAR'S POTENTIAL TO IMPROVE WATER AND SOIL QUALITY HEALTH IN THE CHESAPEAKE BAY AND BEYOND
- BIOCHAR AS A HIGH-PERFORMANCE NET-ZERO (CARBON NEGATIVE) GREEN INFRASTRUCTURE AMENDMENT

t

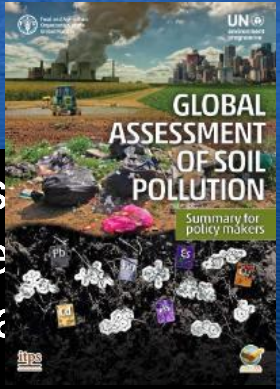
NPS Stormwater Pollutant Challenges to Soil & Water Quality –
Areas of Increasing Concern!

- Pathogens
- Algae/HABs
- Perfluorinated Compounds
- Nutrients
- Pesticides – Arsenic, e.g.
- Lead & Heavy Metals from Contaminated Sites
- Manure Land Applications
- Biosolids & Landfill Leachates
- Air Deposition
- Endocrine Disruptors
- Plastics





GLOBAL COST OF WATER CONTAMINATION - $100'S OF BILLIONS!



The same report estimates the Englis agricultural sector as an example, the estimated cost of removing soil conta (nitrates, phosphates, pesticides and pathogens) to meet drinking water standards and ecological restoration of watercourses affected by eutrophication amounted to GBP 230 million (about USD 315 million), as calculated in 1996 (Pretty et al., 2000).

More recent estimates attribute a cost of up to **USD 340 billion** to the American population from nitrogen pollution alone (Sobota et al., 2015). The global cost of water pollution could be billions of USD annually (FAO and IWMI, 2018).

US Economic Impacts

Clean-Up of Contaminated U.S. Groundwater Sites - Cost $110 Billion

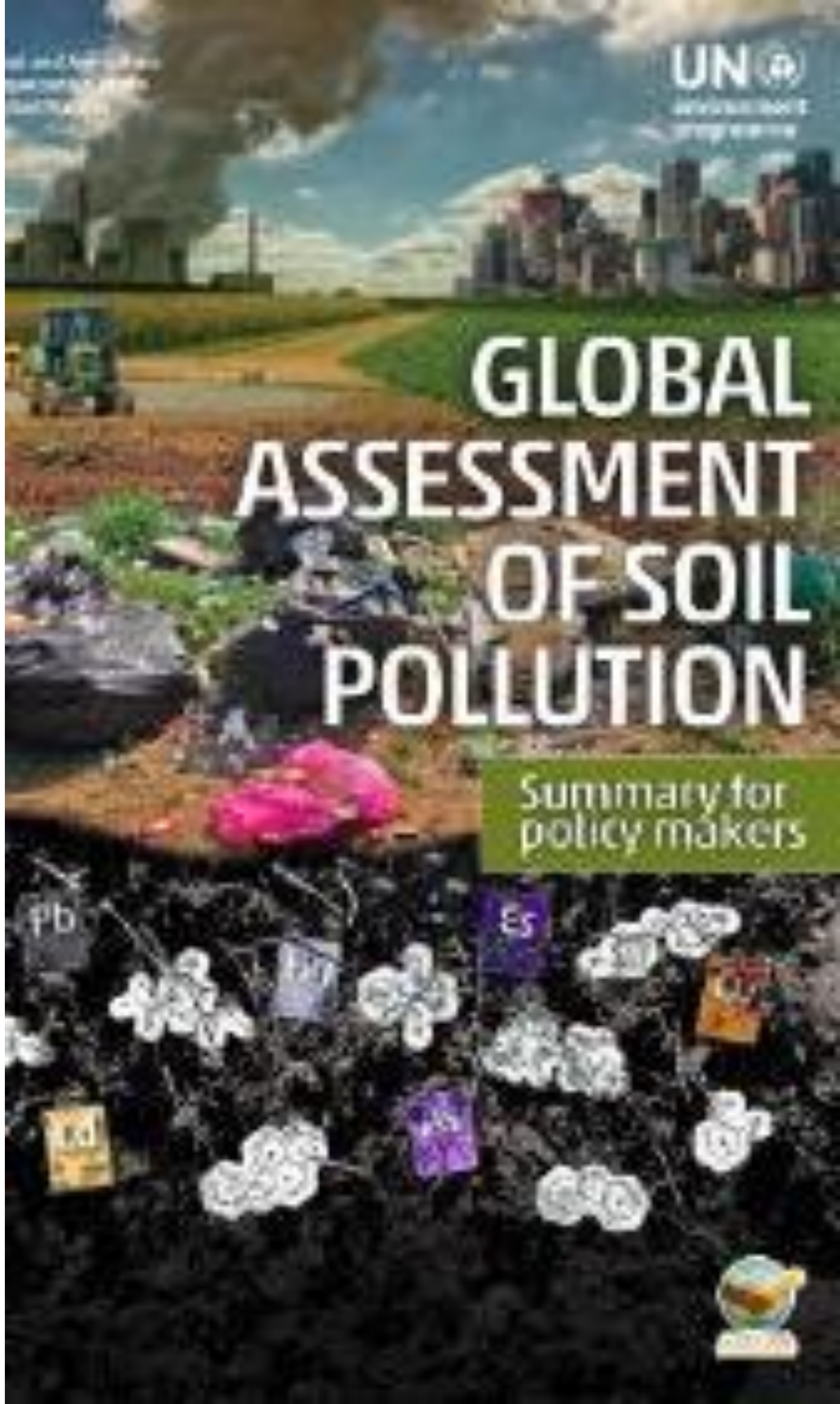
Fresh Water Pollution Costs > $3.4 B/Year

Global cost of soil contamination - $100's of Billions!

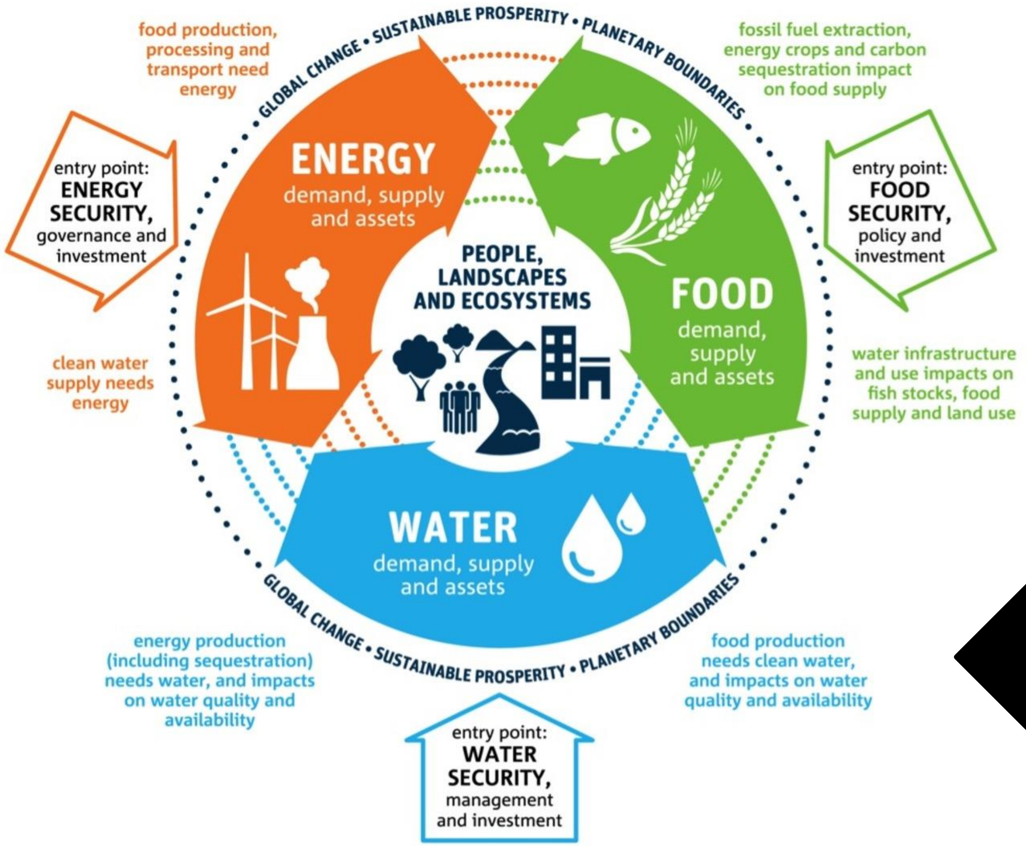
- THE WORLD'S SOILS, WHICH PROVIDE 95% OF HUMANITY'S FOOD, ARE "UNDER GREAT PRESSURE", ACCORDING TO A UN REPORT ON SOIL POLLUTION.

- SOILS ARE ALSO THE LARGEST ACTIVE STORE OF CARBON, AFTER THE OCEANS, AND THEREFORE CRUCIAL IN FIGHTING THE CLIMATE CRISIS. BUT THE REPORT SAID INDUSTRIAL POLLUTION, MINING, FARMING AND POOR WASTE MANAGEMENT ARE POISONING SOILS, WITH THE "POLLUTER PAYS" PRINCIPLE ABSENT IN MANY COUNTRIES.

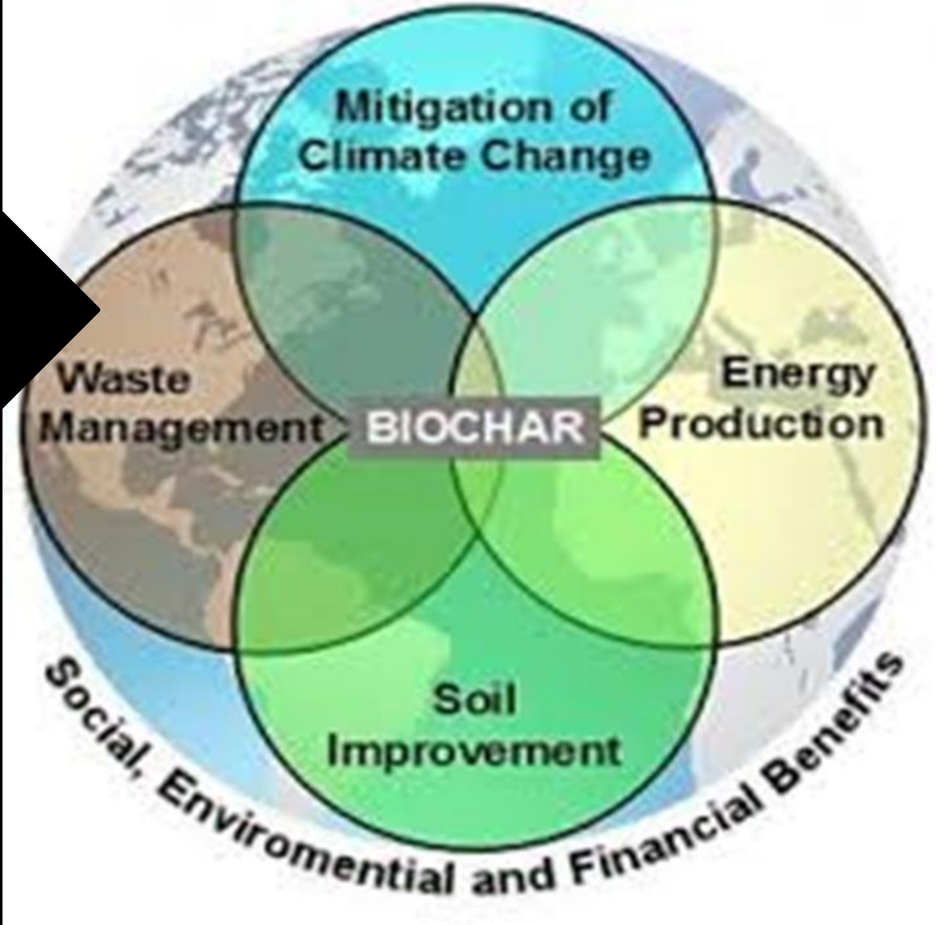
- IN CHINA, SOIL POLLUTION IS ESTIMATED TO CAUSE ANNUAL AGRICULTURAL ECONOMIC LOSSES WORTH USD 20 BILLION DUE TO LOST PRODUCTIVITY AND FOOD CONTAMINATION (ZHOU ET AL., 2020). REMEDIATION OF CONTAMINATED SOIL WOULD BE 100'S OF BILLIONS OF DOLLARS (US).



BIOCHAR-BASED SOLUTIONS CAN SUPPORT THE W.E.F. NEXUS & REGENERATIVE ECOSYSYTEMS & COMMUNITIES!



SYNERGY!



What is Biochar?

- Carbon-rich solid produced by thermochemical processes - heating biomass in the absence of oxygen via pyrolysis or gasification. Optimum range 500-800 ºC.

- Residual product of bio-energy production

- Porous solid with a number of beneficial properties

- Properties depend upon feedstock, pyrolysis conditions and possibly modifications

- The approach is **carbon-negative** because carbon is sequestered in the soil in the form of biochar, thus releasing less carbon than do carbon-neutral technologies.

- By contrast, conventional carbon capture and storage reduces the carbon dioxide concentrations from exhaust fumes, therefore at best preventing atmospheric carbon dioxide levels from rising further.

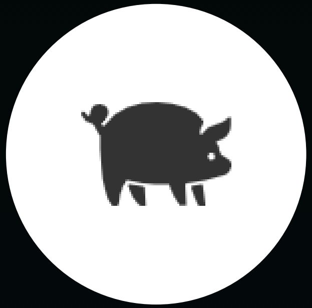
BIOMASS WASTE

FOR EVERY BIOMASS, THERE'S A CARBON NEGATIVE BENEFICIAL BIOCHAR

BIOMASS = CARBON-BASED BIOLOGICAL MATERIAL;
SOURCE OF RENEWABLE ENERGY FROM PLANTS & ANIMALS

WOOD & WOOD PROCESSING WASTES

CROPS



ANIMAL MANURE

GARBAGE/LANDFILL

FOOD

GREEN/YARD

CLIMATE-CHANGE/GHG PROBLEM SOLVER

Biochar & Carbon Sequestration

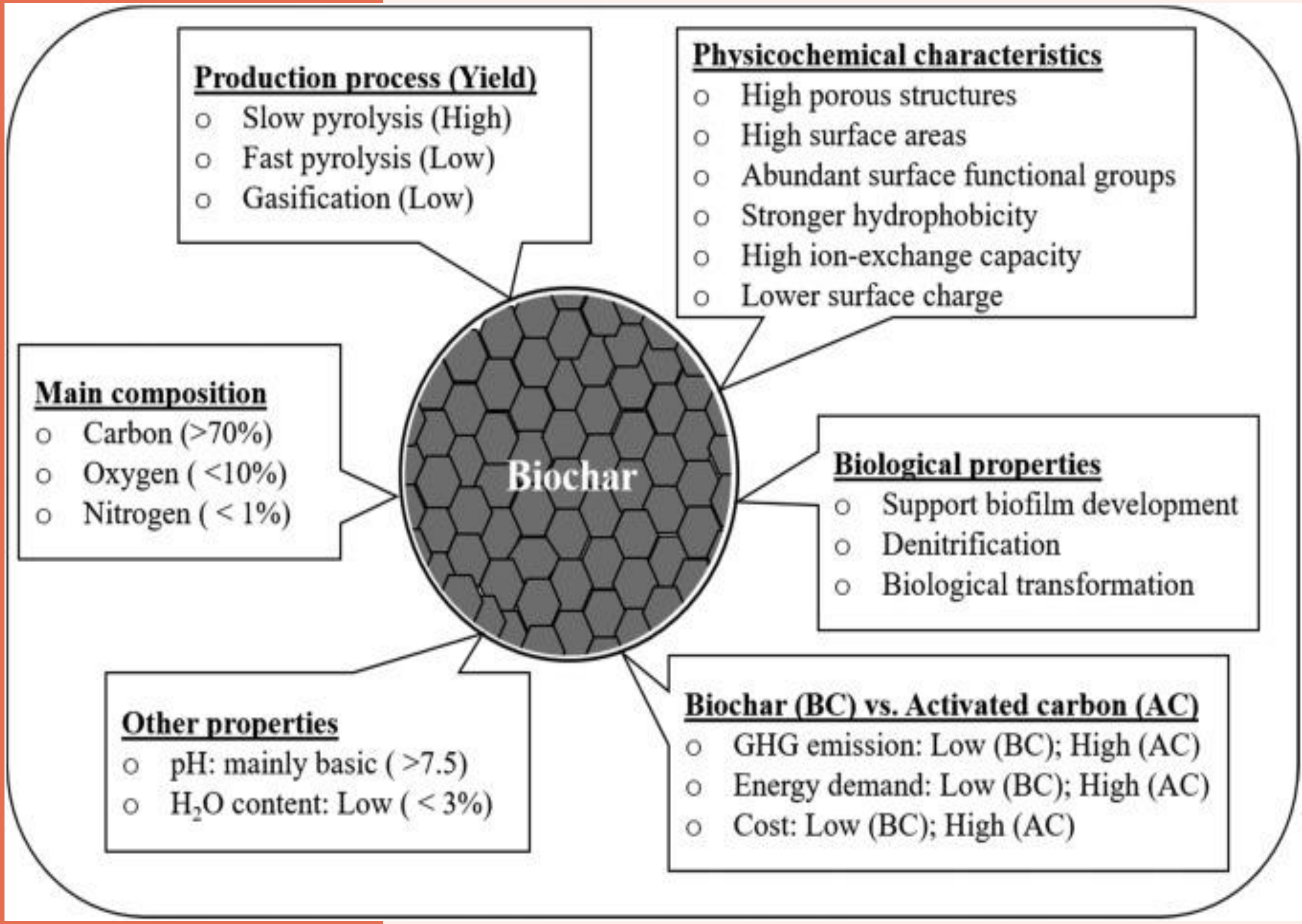
- **Cornell University estimates that producing biochar from biomass could sequester carbon equivalent to 12% of global CO_2 emissions - on par with emissions from the global transport sector.**
- Biochar sequesters carbon by converting it into a stable element of the soil that can stay in the ground for millennia.
- Land degradation is a driver of climate change through emission of greenhouse gases and reduced rates of carbon uptake. Biochar can restore land, helping to regenerate healthy soil and plant carbon sinks to reduce emissions and enhance carbon sequestration.

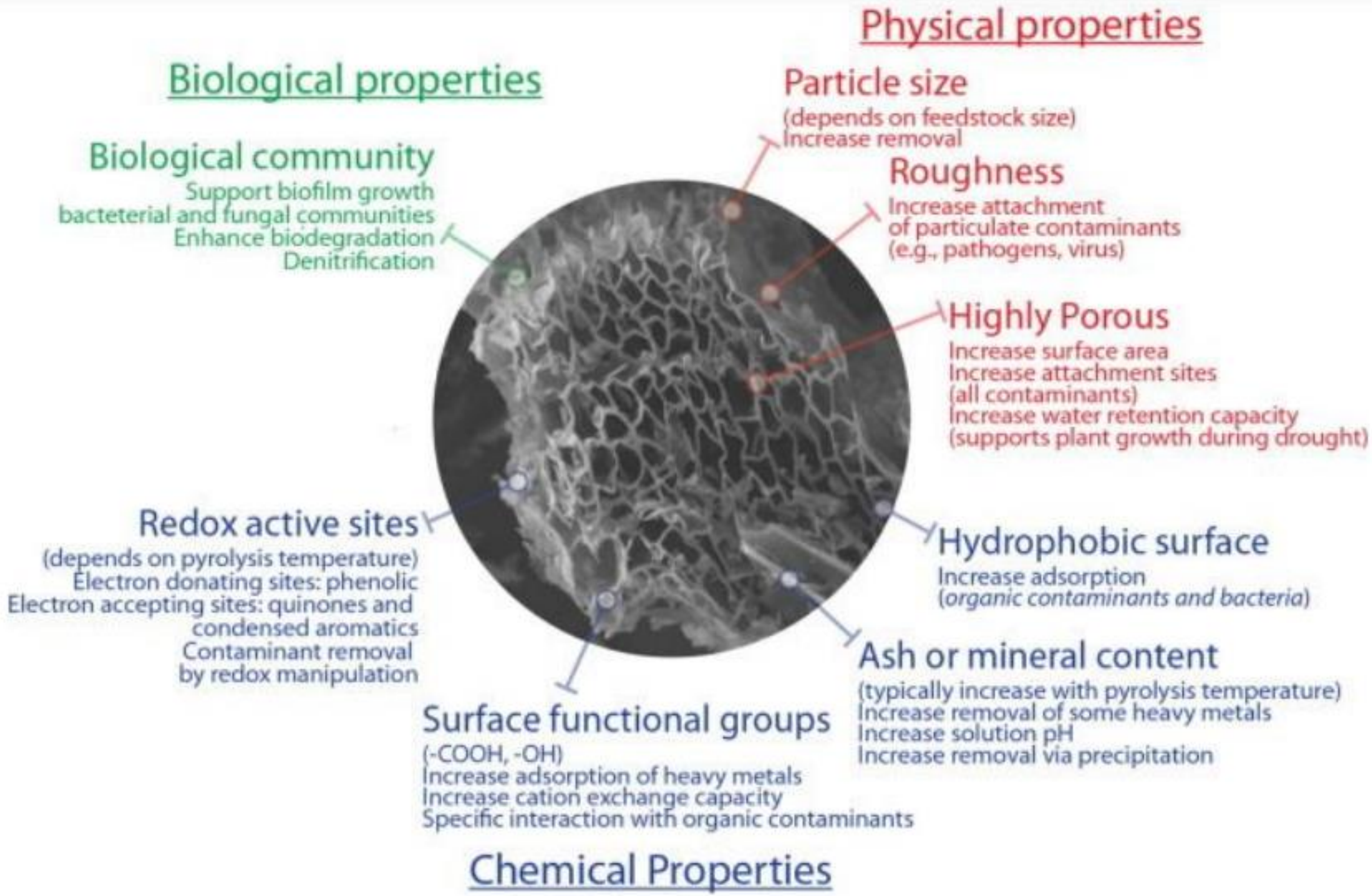
BIOCHAR PROPERTIES

- PHYSICAL
- CHEMICAL

Properties of biochar are affected by technological parameters such as pyrolysis or gasification temperature, feedstock, and activation.

Resultant differentiation can lead to products with a wide range of pH values, surface area sizes, pore volumes, Cationic Exchange Capacity (CEC), volatile matter, ash and carbon contents.





Variation of biochar properties according to their method of production and how they can help in removal of pollutants.
From Mohanty et al., 2018

BIOCHAR – NOW SUBSIDIZED FOR REGENERATIVE SOIL & CLIMATE BENEFITS!

- UPCYCLING A WASTE BIOMASS WHILE NEGATIVELY SEQUESTERING GHGS
- ADDITION OF NEGATIVELY SEQUESTERED CARBON TO REGENERATE SOIL HEALTH
- BIOCHAR CARBON MARKET!
- REGENERATING SOIL AS A CARBON SINK!

USDA NOW PAYING TO ADD BIOCHAR TO AG AND FORESTED LANDS FOR ENHANCED SOIL CARBON!

"Valorizing what might otherwise be a waste product, what would otherwise be releasing CO_2 and other greenhouse gasses."

Biochar Vs. Activated Carbon

GAC - TOXICS TREATMENT OF CHOICE, BUT NOT CLIMATE FRIENDLY

- **Biochar** - shares adsorption properties with activated carbon.
- **Biochar has a significant amount of ion exchange capacity,** a property that is minimal or absent in traditional activated carbons.
- **Biochar is low density** – as compared to higher density of AC.
- As soil amendment – provides **greater voidage, aeration, significant cation exchange capacity, and the ability to increase both nutrient uptake and soil fertility, while increasing water holding capacity by 20-30+%.**

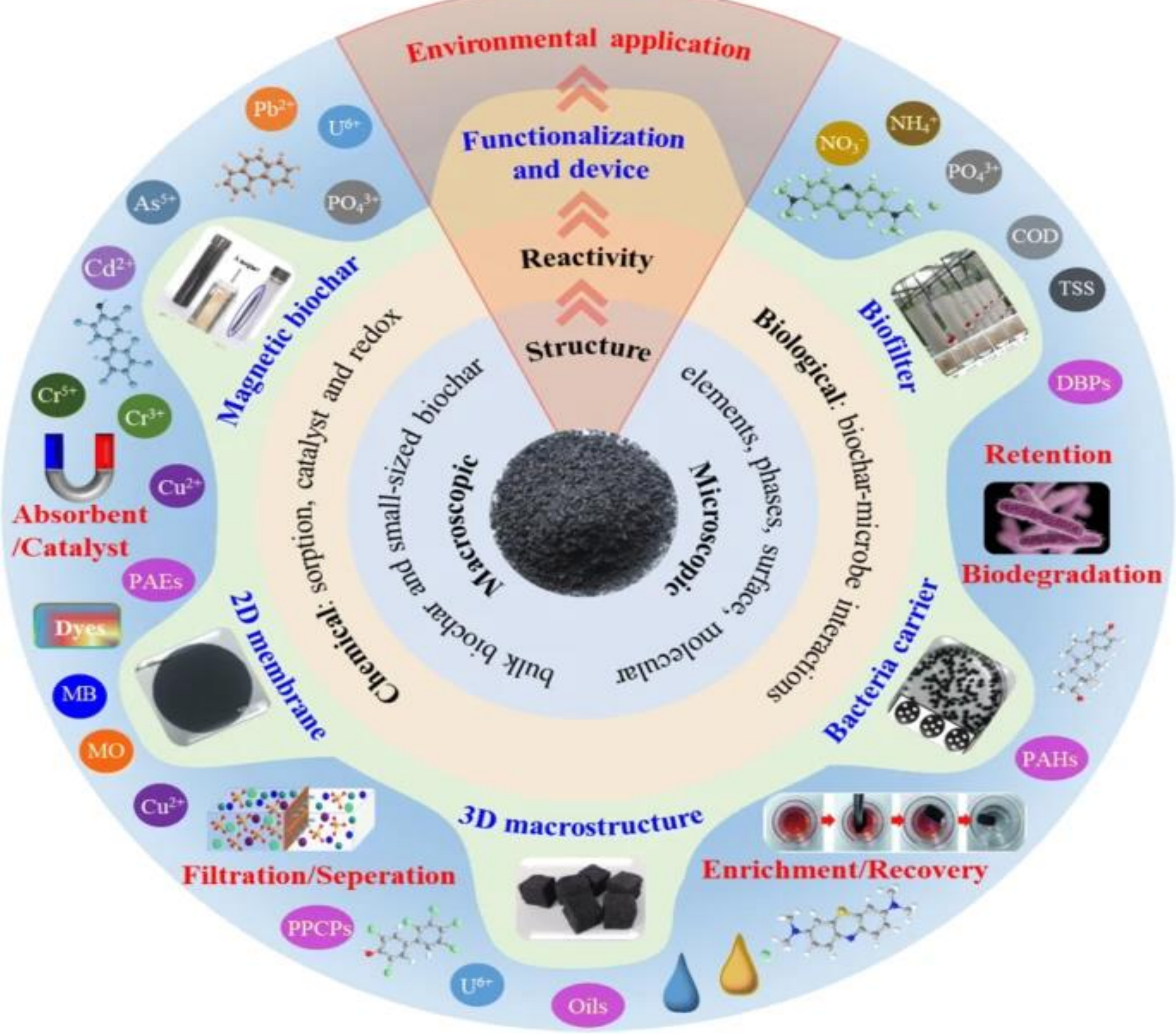
Biochar needs 90% less energy to be produced than Activated Carbon! Biochar is also less expensive!

	Biochar	Activated Carbon
Energy Demand	6.1 MJ/kg	97 MJ/kg
GHG emissions	- 0.9 Kg Co2e/kg	- 6.6 Kg Co2e/kg
Price	< $1.00/kg - $ 5.00/kg	$5.50/kg

Activated Carbon Market worth 8.12 Billion USD by 2021 - ***Exclusive Report by MarketsandMarkets™***

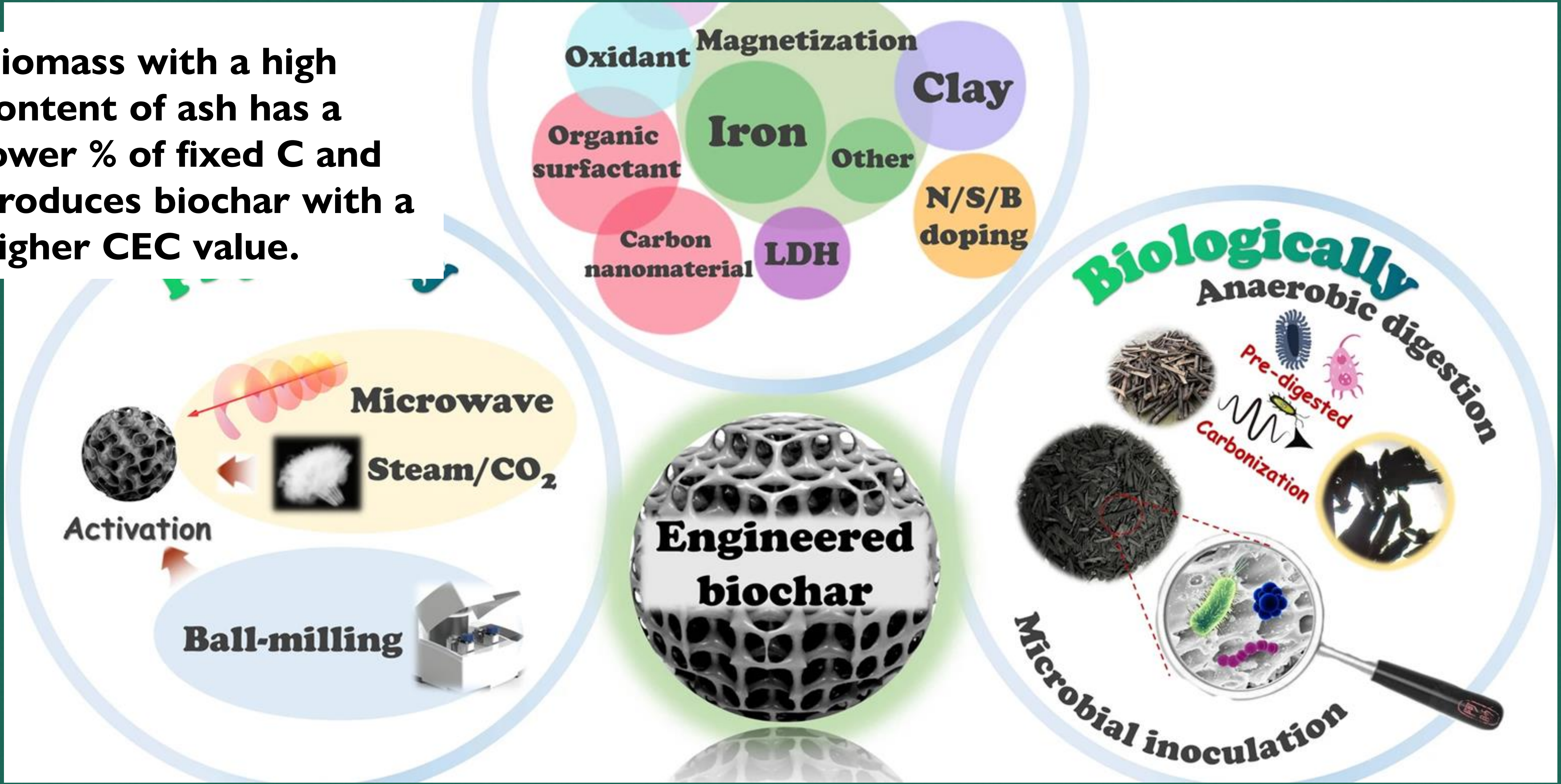
ENVIRONMENTAL TREATMENT BENEFITS OF BIOCHAR

- **BIOFILTER**
- **RETENTION/BIODEGRADATION**
- **BACTERIA/PATHOGEN INHIBITOR**
- **ENRICHMENT/RECOVERY**
- **FILTRATION/SEPARATION**
- **2D MEMBRANE**
- **CHEMICAL ABSORBENT/CATALYST/REDOX**



Lu, L., Yu, W., Wang, Y. *et al. Biochar* **2,** 1–31 (2020)

Biomass with a high content of ash has a lower % of fixed C and produces biochar with a higher CEC value.

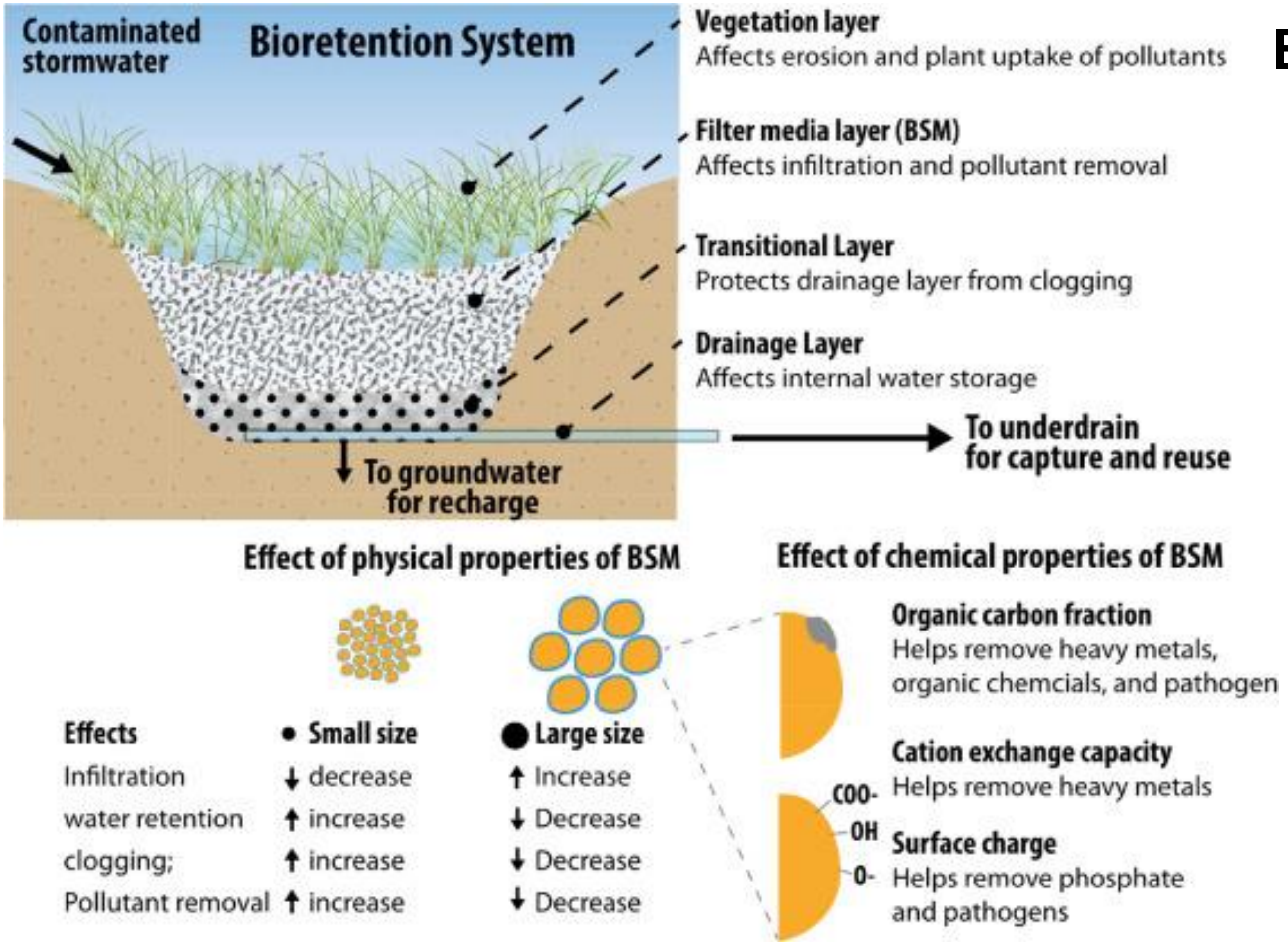


Chen, H., Gao, Y., Li, J. *et al., June 2022*

BIOCHAR AS AMENDMENT FOR IMPROVING GREEN INFRASTRUCTURE

Biochar can be applied to green infrastructure systems to improve soil & water quality.

BIOCHAR FOR HIGH-PERFORMANCE GI



Tirpak et al.,Water Research, Volume 189, 2021

- GREEN INFRASTRUCTURE BIORETENTION SYSTEM PERFORMANCE VARIES BY DESIGN, REQUIREMENTS, BIORETENTION SOIL MEDIA (BSM) AND POLLUTANTS
- POLLUTANT REMOVAL CAPACITY OF TRADITIONAL BSM IS LOW, PARTICULARLY FOR DISSOLVED POLLUTANTS, AND THEY MAY LEACH POLLUTANTS INTO THE STORMWATER.
- THERE'S A GROWING NEED TO ADD AMENDMENTS TO IMPROVE THE CONTAMINANT REMOVAL CAPACITY OF TRADITIONALLY DESIGNED BSM

BIOCHAR CAN BE ADDED, ACTIVATED, BLENDED, AND/OR AMENDED AS A KEY BSM TO SIGNIFICANTLY IMPROVE TREATMENT PERFORMANCE.

BIOCHAR - POLLUTANT REMOVAL EFFECTIVENESS

Biochar-amended biofiltration systems efficiently remove diverse pollutants such as total & dissolved nitrogen (32 – 61%), total & dissolved phosphorus: (45 – 94%), total & dissolved heavy metals (27 – 100%), organics (54 – 100%) and microbial pollutants (log10 removal: 0.78 – 4.23) from urban runoff.

The variation of biofiltration performance is due to changes in biochar characteristics, the abundance of dissolved organic matter and/or stormwater chemistry. The dominant mechanisms responsible for removal of chemical pollutants are sorption, ion exchange and/or biotransformation, whereas filtration/straining is the major mechanism for bacteria removal

TOTAL & DISSOLVED NITROGEN

- Total & Dissolved nitrogen (32 – 94%)

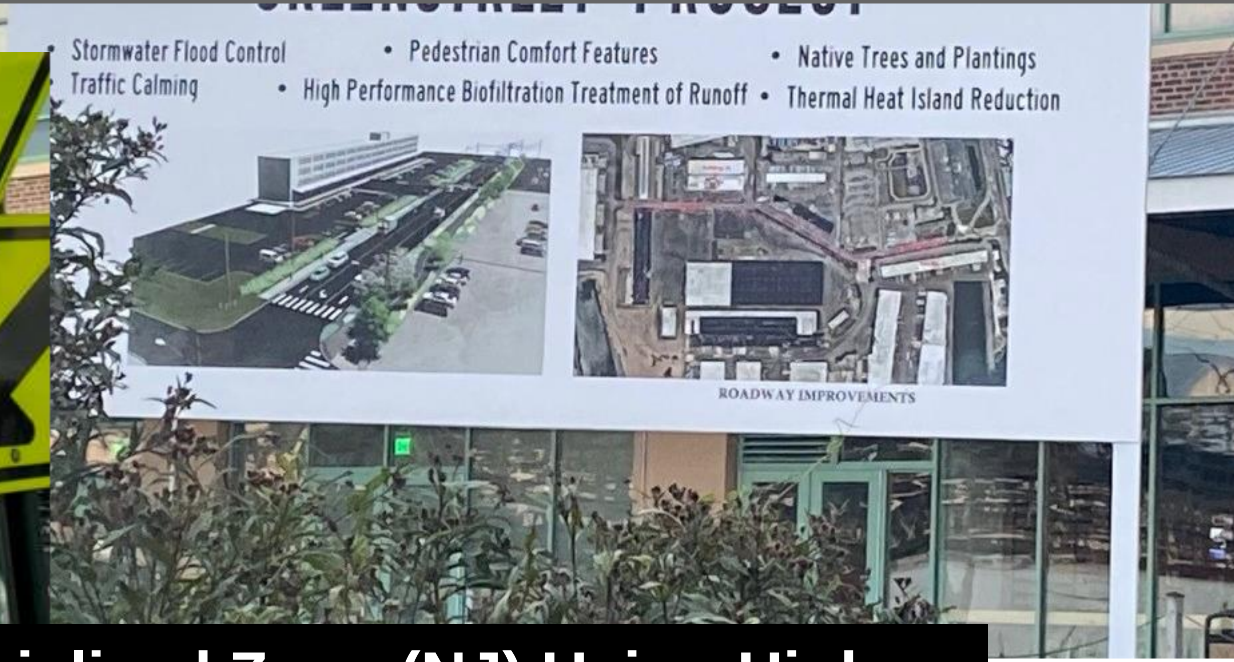
TOTAL & DISSOLVED PHOSPHORUS

- Total & Dissolved phosphorus (45 – 99%)

TOTAL & DISSOLVED HEAVY METALS

- Total & Dissolved Heavy metals (27 – 100%)

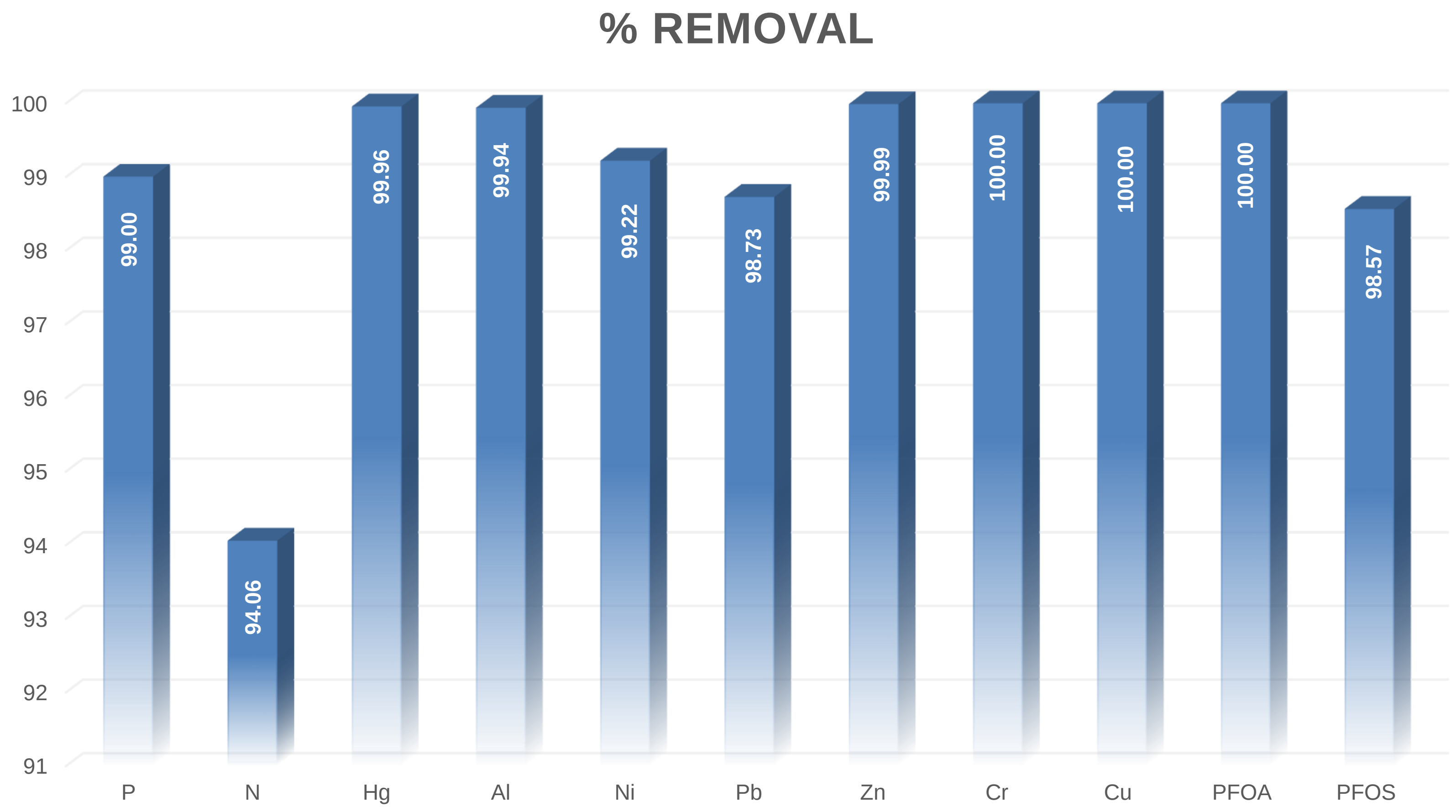
Biochar	Pinewood Biochar pyrolysed at 550℃.
Results	Compiled from 123 rain events, biochar amended strip land reduced runoff flow rate and stormwater runoff volume by 56% and 69% respectively.



Complete Green Street in Heavy Industrialized Zone (NJ) Using Higher Ash Biochar Amendments to Also Treat Heavy Metals in Stormwater Runoff

Pictures Courtesy of Hugo Neu

Hydraulics & Kinetics Testing Results Using Various Ecochars (Biochars) to Treat a Range of Heavy Metal & PFAS Pollutants
Flow Rates =110-118 in/hr; Avg. Contact Time ~ 2 min.

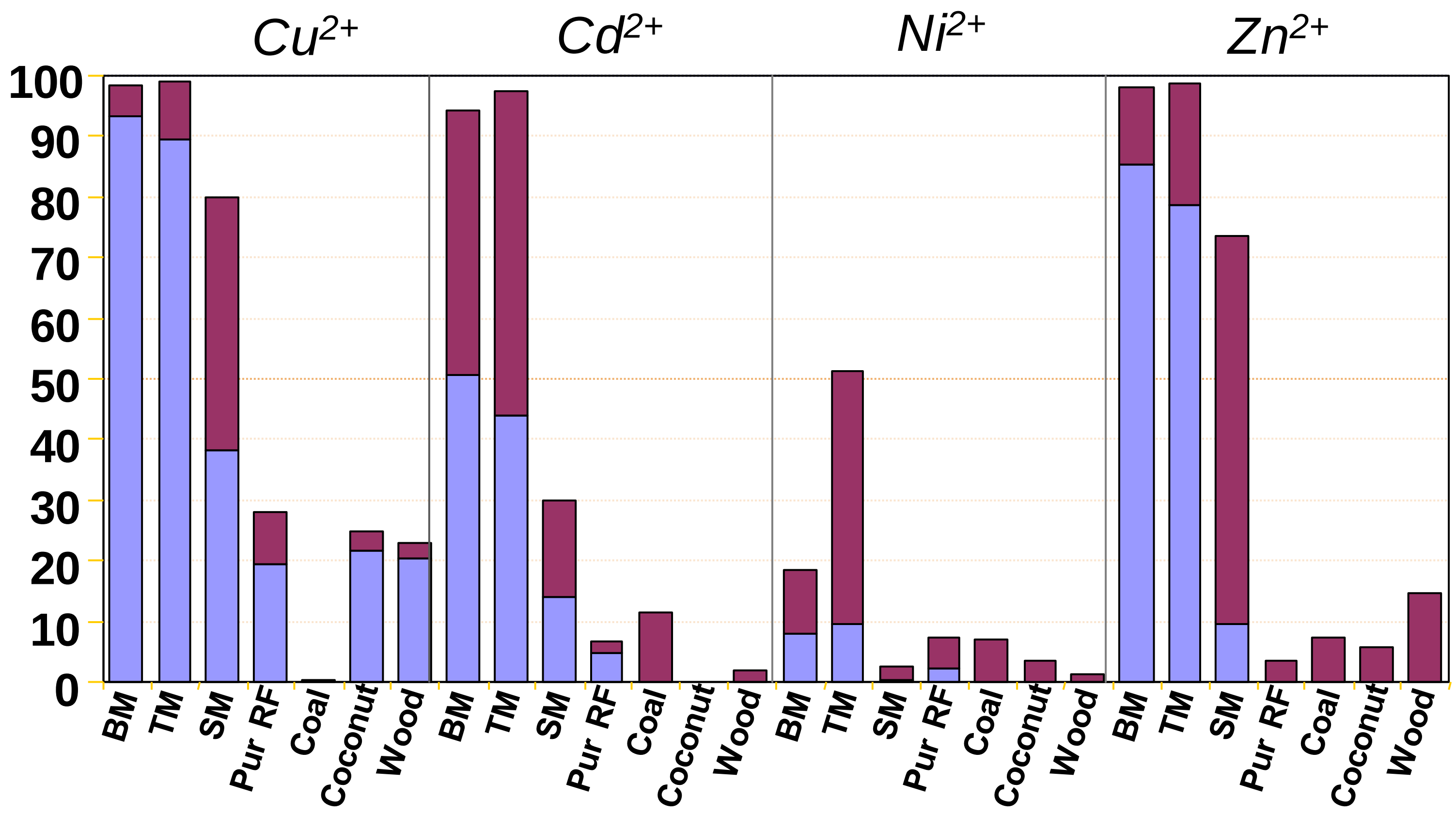


ECOCHAR
ENVIRONMENTAL SOLUTIONS

Source: D. Lueckenhoff

Heavy Metal Adsorption (%)

	Sample	Cu^{2+}	Cd^{2+}	Ni^{2+}	Zn^{2+}
Single	Broiler manure	95.4	83.2	6.6	89.8
	Broiler litter	95.0	82.3	5.1	90.9
	Coal	0.0	12.8	0.5	2.6
	Coconut shell	3.1	13.5	0.0	0.5
	Wood	6.3	13.3	0.0	1.8
Competition	Broiler manure	71.1	18.8	3.8	23.7
	Broiler litter	66.1	18.1	3.6	25.2
	Coal	0.6	0.3	0.7	1.0
	Coconut shell	0.2	0.9	0.7	3.8
	Wood	4.0	0.0	0.0	2.4



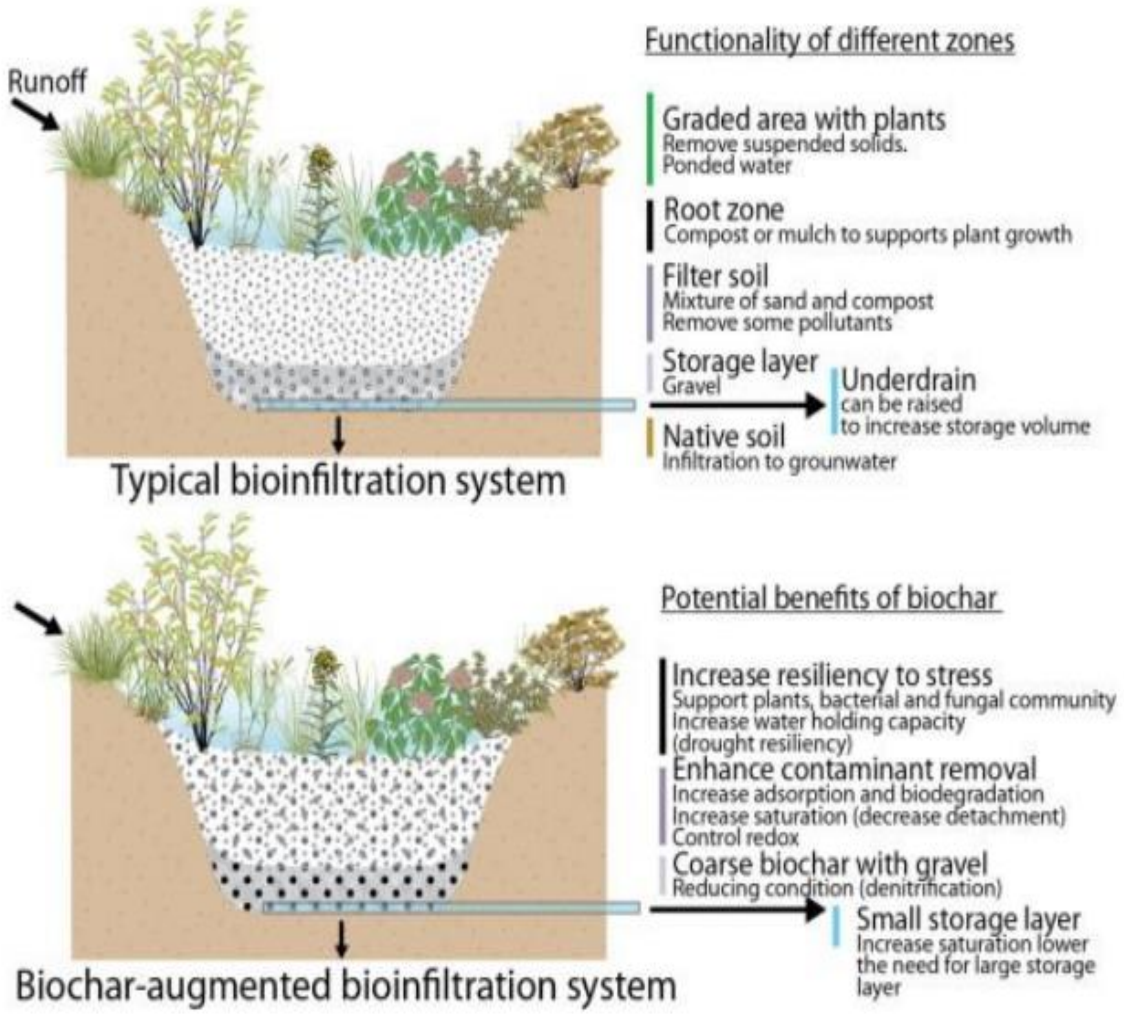
Source: Dr. Isabel Lima, USDA ARS

Single

Competition

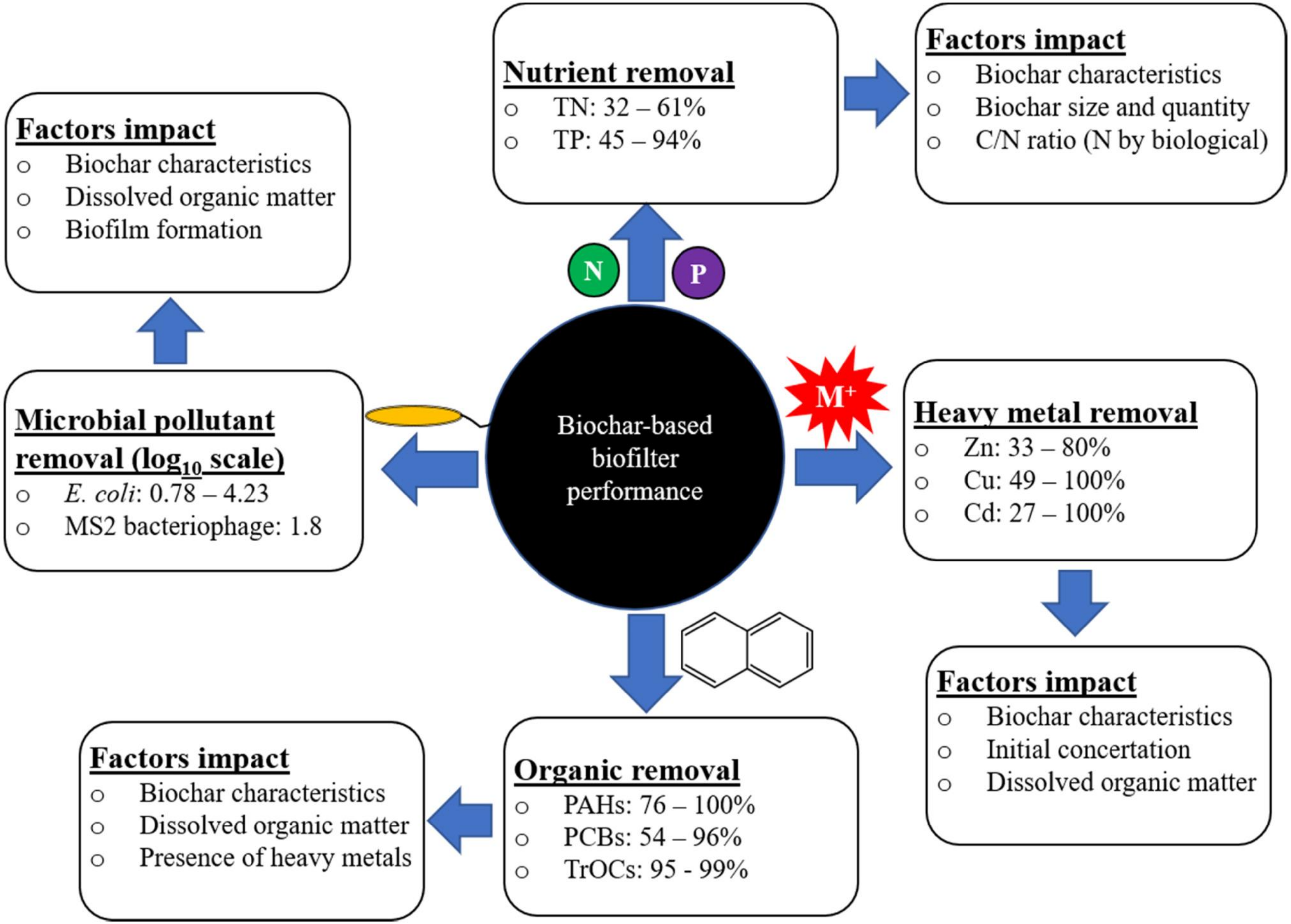
Legend: BC: broiler manure carbon; TC: turkey manure carbon, SM: swine manure carbon

BIOFILTRATION DESIGN CONSIDERATIONS



Advantages of amended bioinfiltration systems using biochar (Mohanty et al., 2018)

Key design considerations for successful
implementation of a biofiltration system with biochars.



Biochar-based biofilter performance and important factors affecting the removal of chemical and microbial pollutants from stormwater.

IN SUMMARY - BIOCHAR CAN GROW THE GREEN, SOAK THE RAIN, SINK THE CARBON AND SAVE THE PLANET!

II

IT IS KEY TO RESILIENT, REGENERATIVE HEALTH & ECONOMY IN THE CHESAPEAKE BAY & BEYOND!

THE VALUE OF BIOCHAR FOR IMPROVED SOIL & WATER QUALITY HEALTH

CENTER FOR WATERSHED PROTECTION - WEBCAST 2

FEBRUARY 15, 2023

DOMINIQUE LUECKENHOFF

SENIOR VICE-PRESIDENT FOR CORPORATE AFFAIRS, EHS & SUSTAINABILITY HUGO NEU

THANK YOU!