

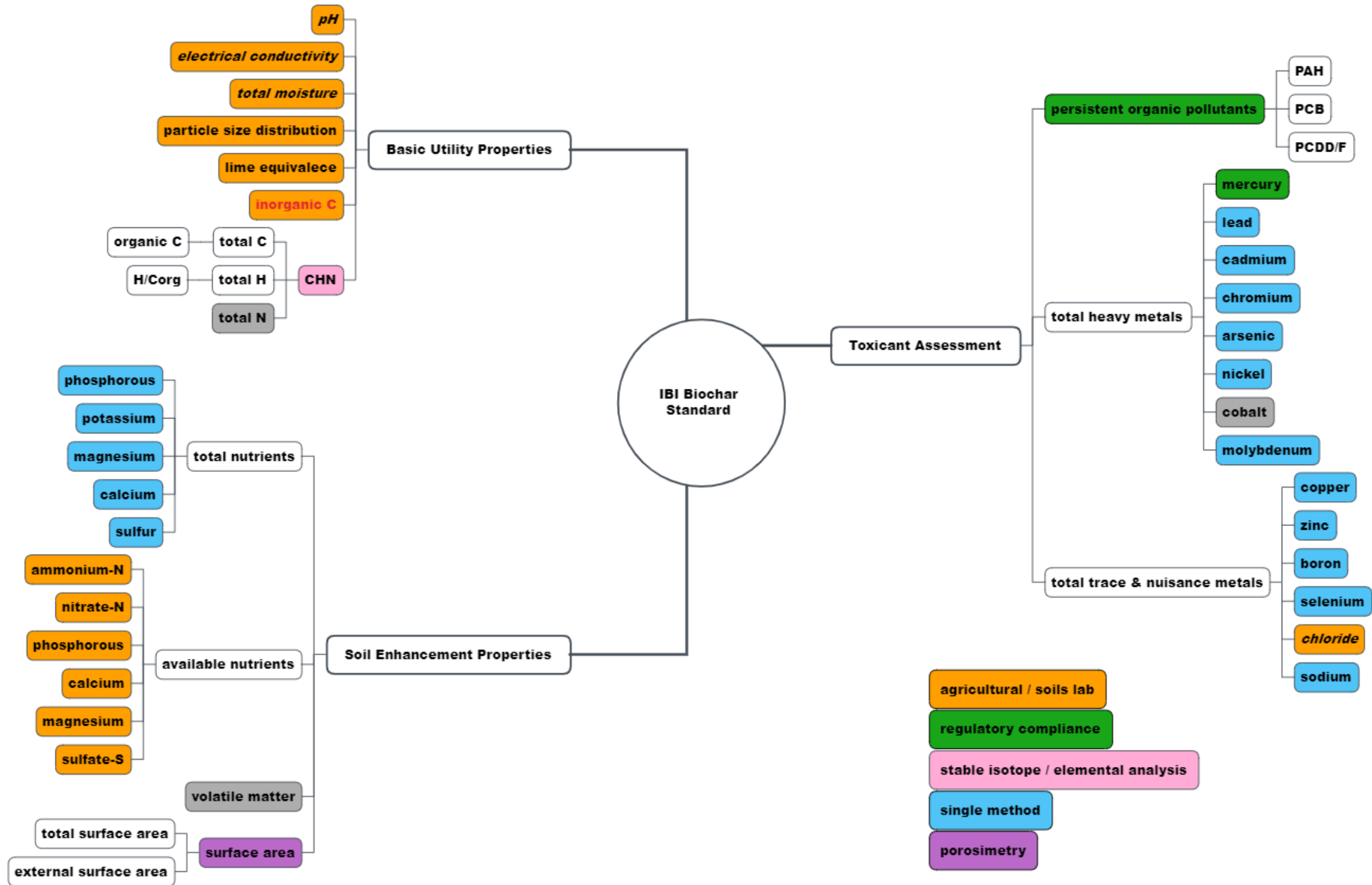


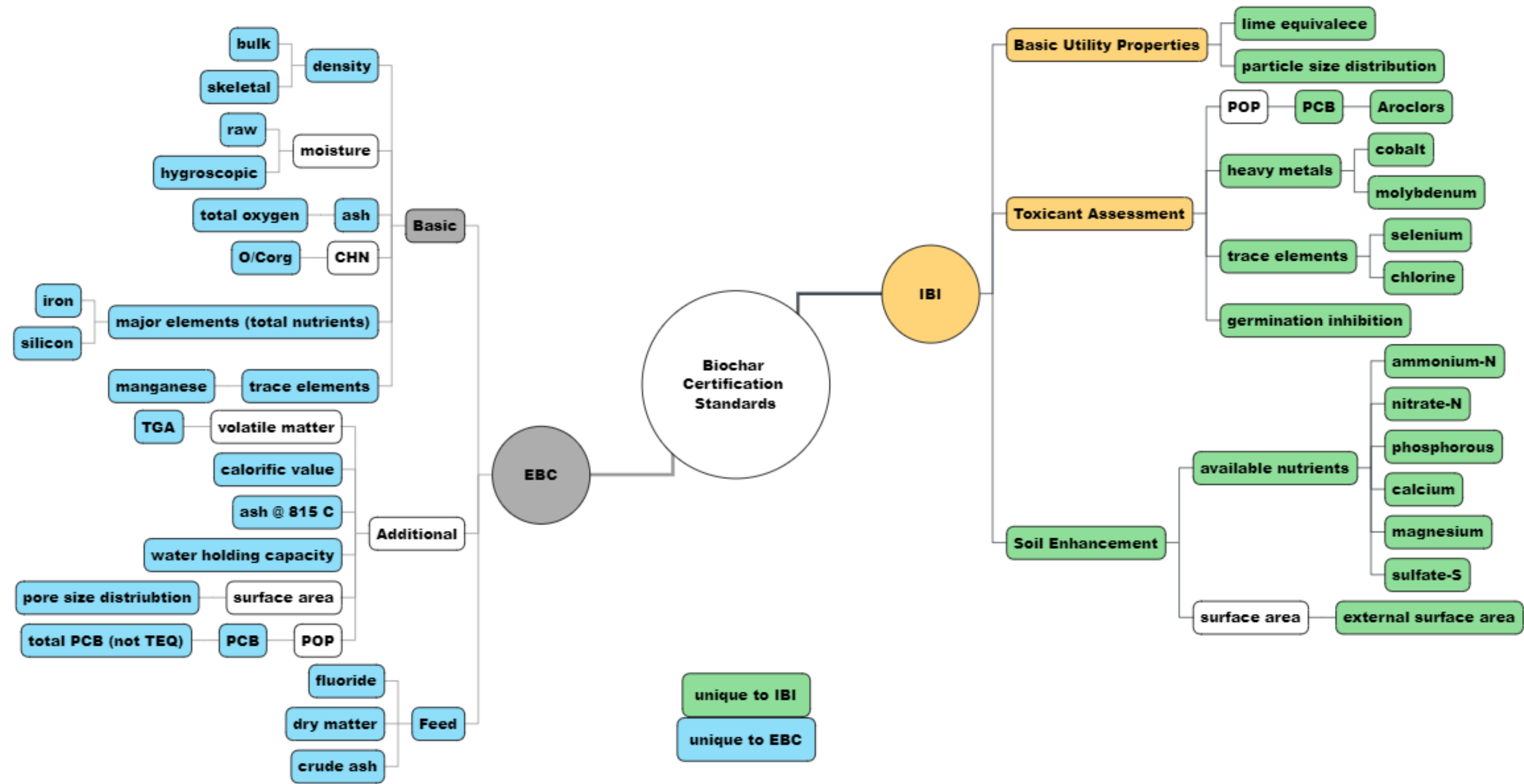
Biochar Analyses and
Certification

International Biochar Initiative



Photo credit- Johannes Lehmann





Biochar Certification Standards

EBC

IBI

Basic

Additional

Feed

Basic Utility Properties

Toxicant Assessment

Soil Enhancement

unique to IBI
unique to EBC

EBC -Certification Class	EBC-Feed	EBC-AgroOrganic	EBC-Agro	EBC-Urban	EBC-ConsumerMaterials	EBC-BasicMaterials	
Elemental analysis	Declaration of Ctot, Corg, H, N, O, S, ash						
	H/Corg	< 0.7					
Physical parameters	Water content, dry matter (@ < 3mm particle size), bulk density (TS), WHC, pH, salt content, electrical conductivity of the solid biochar						
TGA	Needs to be presented for the first production batch of a pyrolysis unit						
Nutrients	Declaration of N, P, K, Mg, Ca, Fe						
Heavy metals	Pb	10 g t ⁻¹ (88%DM)	45 g t ⁻¹ DM	120 g t ⁻¹ DM	120 g t ⁻¹ DM	120 g t ⁻¹ DM	declaration, no limit values for certification
	Cd	0.8 g t ⁻¹ (88% DM)	0.7 g t ⁻¹ DM	1.5 g t ⁻¹ DM	1.5 g t ⁻¹ DM	1.5 g t ⁻¹ DM	
	Cu	70 g t ⁻¹ DM	70 g t ⁻¹ DM	100 g t ⁻¹ DM	100 g t ⁻¹ DM	100 g t ⁻¹ DM	
	Ni	25 g t ⁻¹ DM	25 g t ⁻¹ DM	50 g t ⁻¹ DM	50 g t ⁻¹ DM	50 g t ⁻¹ DM	
	Hg	0.1 g t ⁻¹ (88% DM)	0.4 g t ⁻¹ DM	1 g t ⁻¹ DM	1 g t ⁻¹ DM	1 g t ⁻¹ DM	
	Zn	200 g t ⁻¹ DM	200 g t ⁻¹ DM	400 g t ⁻¹ DM	400 g t ⁻¹ DM	400 g t ⁻¹ DM	
	Cr	70 g t ⁻¹ DM	70 g t ⁻¹ DM	90 g t ⁻¹ DM	90 g t ⁻¹ DM	90 g t ⁻¹ DM	
	As	2 g t ⁻¹ (88% DM)	13 g t ⁻¹ DM	13 g t ⁻¹ DM	13 g t ⁻¹ DM	13 g t ⁻¹ DM	
Organic contaminants	16 EPA PAH	declaration	4±2 g t ⁻¹ DM	6.0+2.2 g t ⁻¹ DM	declaration	declaration	not required
	8 EFSA PAH	1.0 g t ⁻¹ DM				4 g t ⁻¹ DM	
	benzo[e]pyrene benzo[k]fluoranthene	< 1.0 g t ⁻¹ DM for each of both substances					
	PCB, PCDD/F	See chapter 10	Once per pyrolysis unit for the first production batch. For PCB: 0.2 mg kg ⁻¹ DM, for PCDD/F: 20 ng kg ⁻¹ (I-TEQ OMS), respectively				



Guidelines

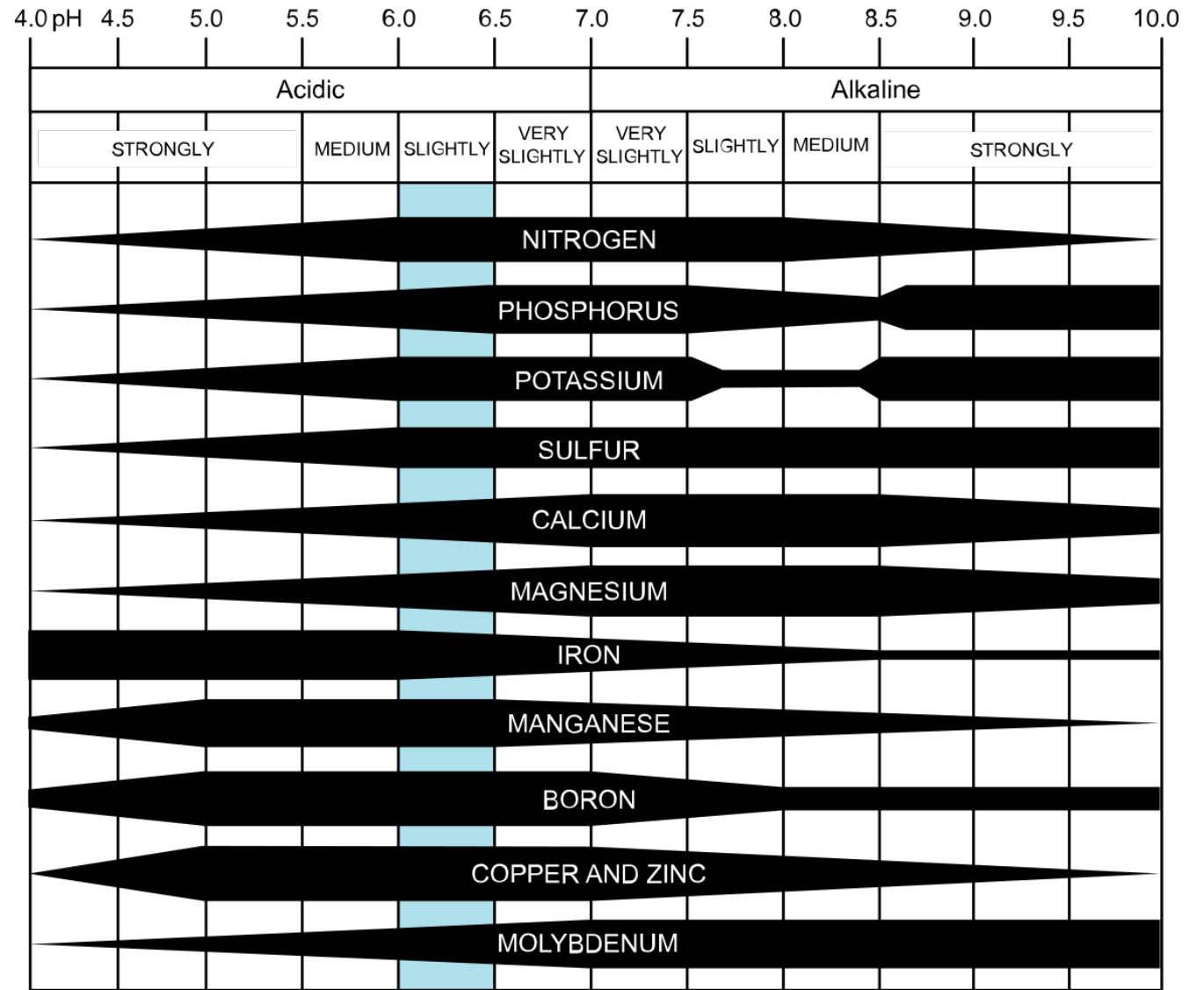
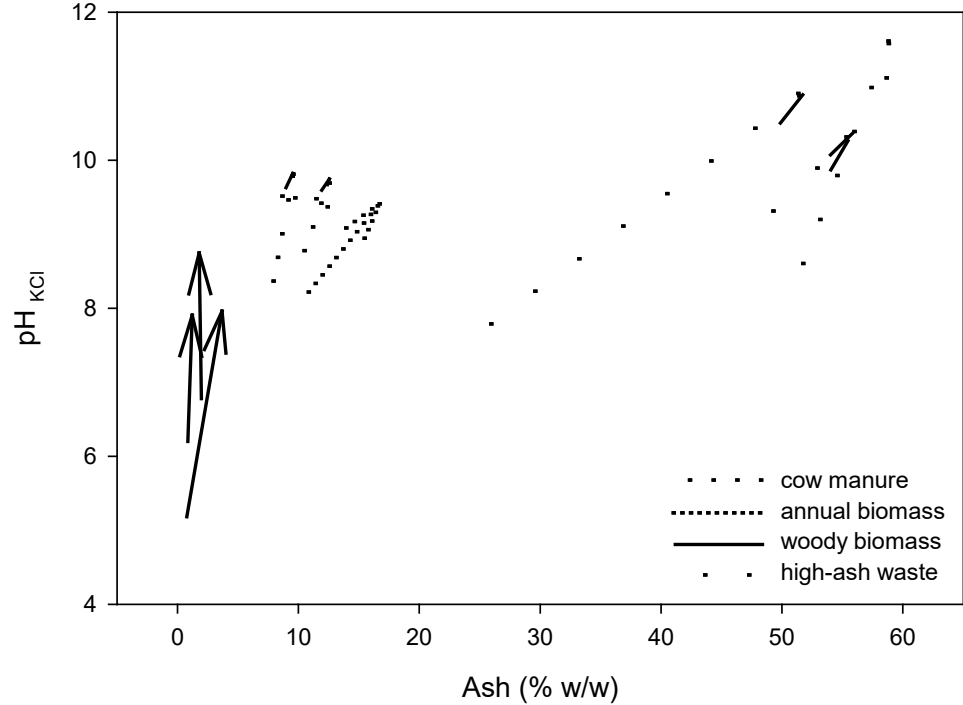
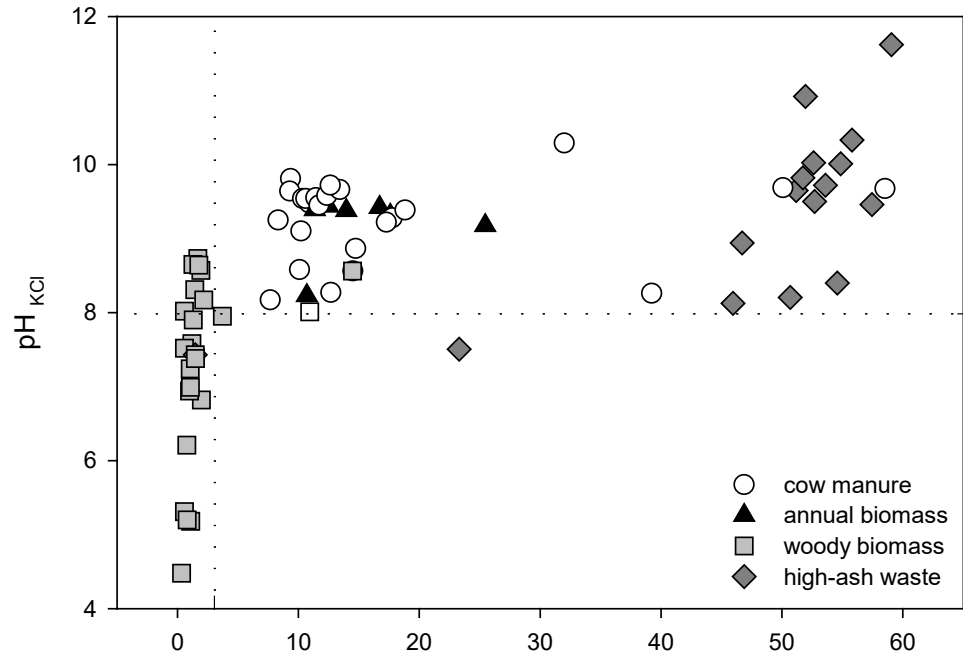
European Biochar Certificate



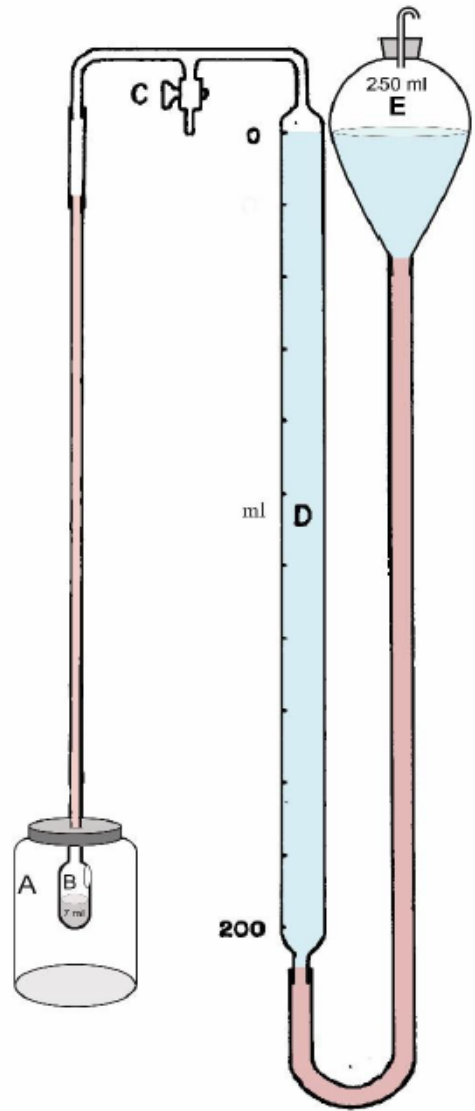
	OECD 1984	VanZwieten et al. 2010
species	1 from each of 3 categories (e.g. wheat, radish, lettuce)	Soybean, wheat, radish
mixture (% w/w)	0, 0.0001, 0.001, 0.01	1.5 & 2.0
container	'to allow unrestricted growth'	unspecified seedling tray
seeds / pot	5	1
replicates	4	110
pre-incubation	None described	22 days
water management	'suitable for normal growth'	mist 5 s every 45 min
temperature	'suitable for normal growth'	25 °C day, 15 °C night
day length	none described	none described
duration	14 d after 50 % emergence (control)	9 d after planting



Texture	Degree of salinity (salinity classes)					
	Nonsaline	Slightly saline	Moderately saline	Strongly saline	Very strongly saline	Ratio of EC _{1:1} to EC _e
EC _{1:1} method (dS/m)						
Coarse sand to loamy sand	0-1.1	1.2-2.4	2.5-4.4	4.5-8.9	9.0+	0.56
Loamy fine sand to loam	0-1.2	1.3-2.4	2.5-4.7	4.8-9.4	9.5+	0.59
Silt loam to clay loam	0-1.3	1.4-2.5	2.6-5.0	5.1-10.0	10.1+	0.63
Silty clay loam to clay	0-1.4	1.5-2.8	2.9-5.7	5.8-11.4	11.5+	0.71
EC _e method (dS/m)						
All textures	0-2.0	2.1-4.0	4.1-8.0	8.1-16.0	16.1+	N/A



Inorganic C via Manometric calcimetry



Volumetric calcimetry (Bernard)

$$C_{org} = C_{tot} - C_{inorg}$$
$$H:C_{org} \text{ (mol:mol)} < 0.7$$

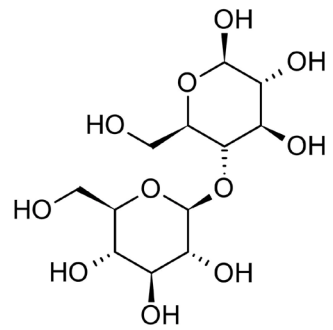


Photo credit- thoughtco.com

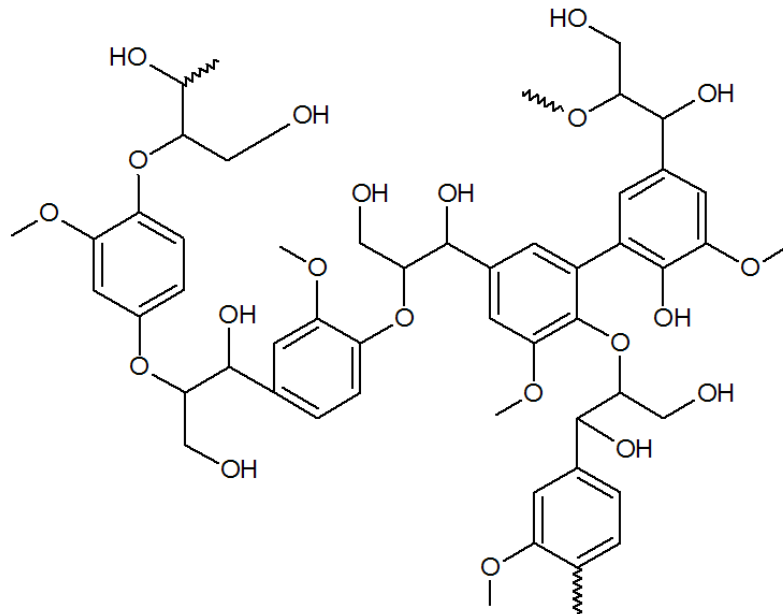
Carbon Stability- basis



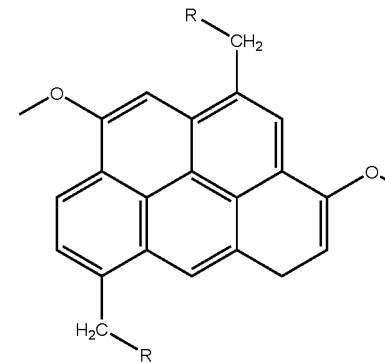
[cellulose]



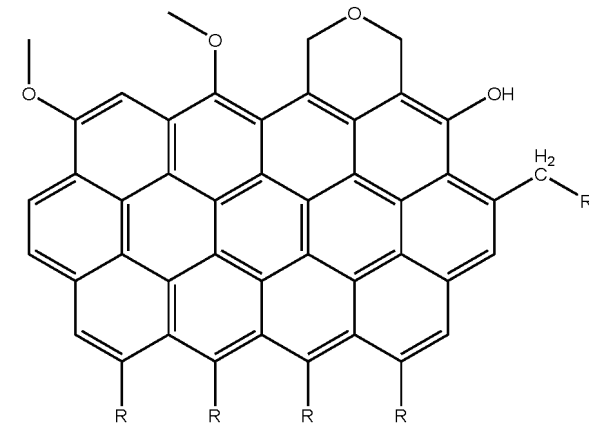
lignin



300 °C char



600 °C char



Carbon Stability- metrics

Volatile C = 100% - ash - fixed C

H/C_{org} = total H / organic C

total O = 100% - (C + H + N + S + ash)

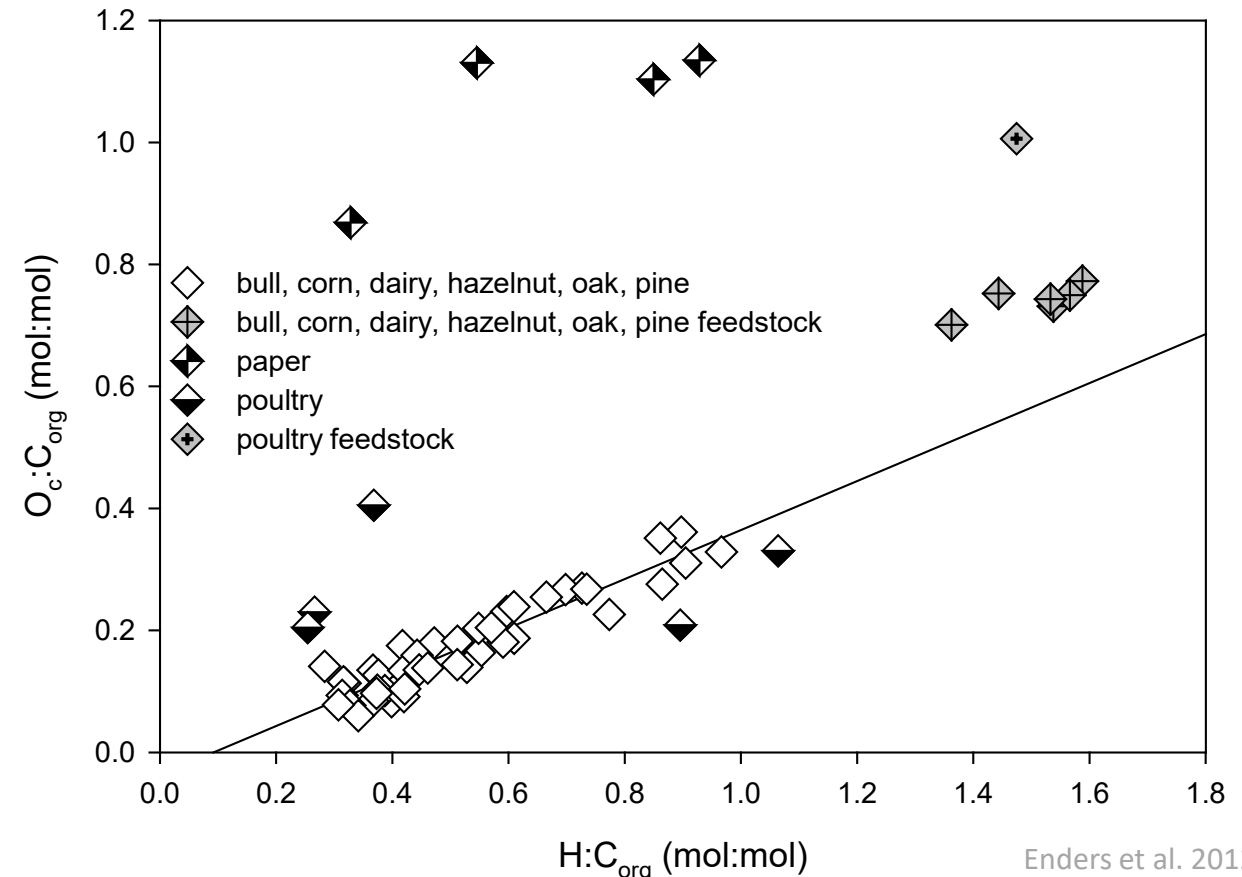
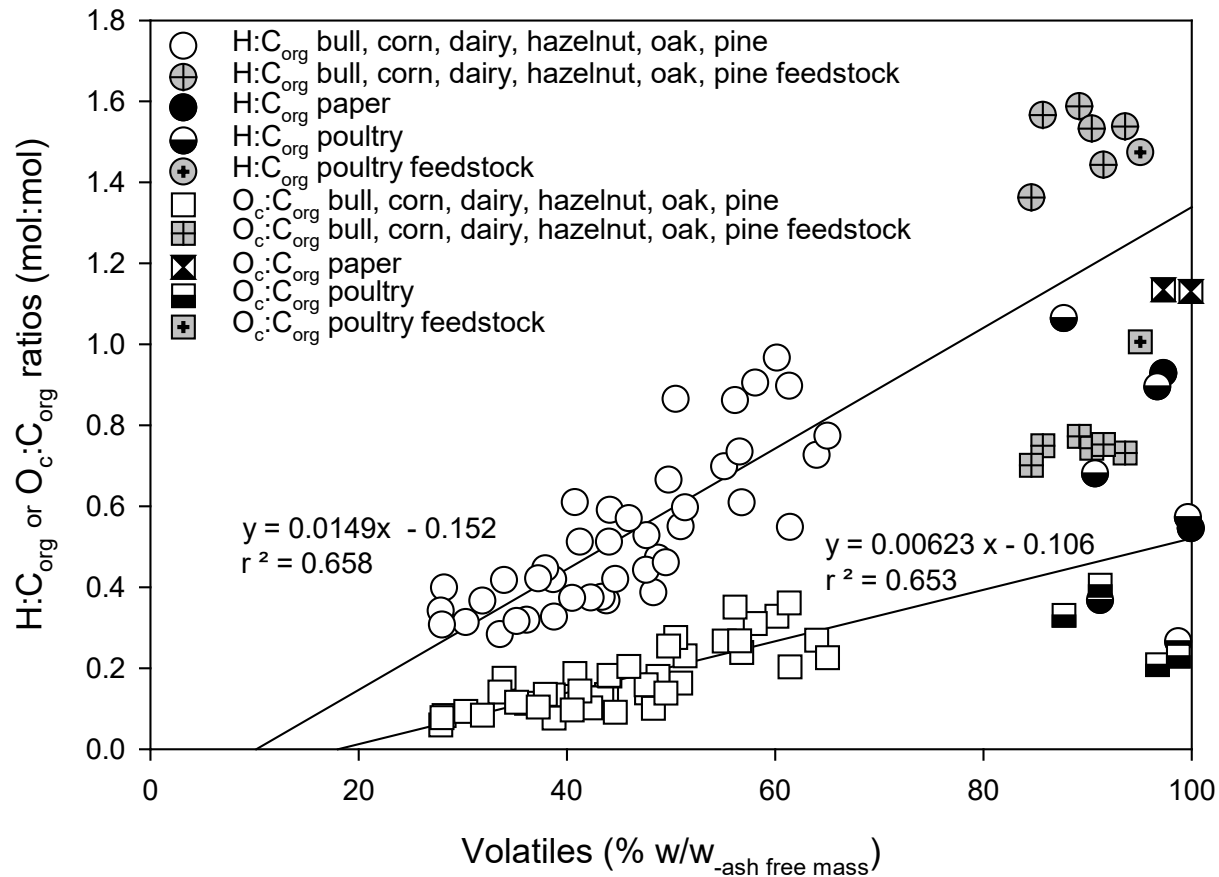
O_c = total O - inorganic O

O_c/C_{org} = organic O / organic C

mol = 6.022×10^{23} atoms

% H / 1.00784 molar wt = mol C

% C / 12.011 = mol C



Preparation for analysis of inorganic elements- includes heavy metals, trace, toxic, and nuisance elements, and plant nutrients

	IBI						EBC		
	microwave HNO3	HNO3 + H2O2	dry ash	water extraction	HNO3 + HCl	modified dry ash	microwave HNO3 + HF + H2O2	LiBO2 fusion	
	TMECC 04.12						Enders and Lehmann 2012	EPA 3052 / DIN EN ISO 17294-2	DIN 51729-11
	A (EPA 3051)	B (EPA 3050)	C (AOAC 985.01)	D	E				
Hg	X						X		
Pb	X	X			X		X		
Cd	X	X			X		X		
Cr	X	X			X		X		
As	X	X					X		
Ni	X	X			X		X		
Co	X	X	*1	*1	X		X		
Se	X	X					X		
Cl-				*1					
Na	X	X	*1	*1	X		X	X	
Cu	X	X	X	*1	X		X		
Mo	X	X		*1	X		X		
B	X	*1	X	*1			X		
Fe	X	X	X	*1	X	n/a	X	X	
Mn	X	X	X	*1	X	n/a	X		
Zn	X	X	X	*1	X		X		
Ca	X	X	X	*1	X	n/a	X	X	
Mg	X	X	X	*1	X	n/a	X	X	
S	*1	*1		*1		n/a		X	
P	*2		X		X	n/a	*3	X	
K	X	X	X		X	n/a	X	X	
Si								X	

	IBI
	EBC
	both IBI and EBC
	neither IBI nor EBC

- X approved by methods stated above in column
- *1 TMECC 04.05, not TMECC 04.12 or EPA
- *2 TMECC 04.12, not TMECC 04.05 or EPA 3051
- *3 DIN EN ISO 17294-2, but not by EPA 3052

Analysis of inorganic elements & EPA limits- includes heavy metals, trace, toxic, and nuisance elements, and plant nutrients

	EPA				cold vapor AA	IC / ISE	IBI limit (mg/kg)
	ICP-AES	FLAA	ICP-MS	GFAA			
	EPA 6010d DIN 22022-2	EPA 7000b	EPA 6020b / DIN 22022-7	EPA 7010			
Hg	X		X				17
Pb	X	X	X	X			300
Cd	X	X	X	X			39
Cr	X	X	X	X			1200
As	X		X	X			41
Ni	X	X	X	X			420
Co	X	X	X	X			n/a
Se	X		X				36
Cl-						X	declaration
Na	X	X	X				declaration
Cu	X	X	X	X			1500
Mo	X	X		X			75
B	*4						declaration
Fe	X	X	X	X			n/a
Mn	X	X	X	X			n/a
Zn	X	X	X	X			2800
Ca	X	X	X				no limit
Mg	X	X	X				no limit
S	*4						no limit
P	X						no limit
K	X	X	X				no limit
Si	SiO2						n/a

	IBI
	EBC
	both IBI and EBC
	neither IBI nor EBC

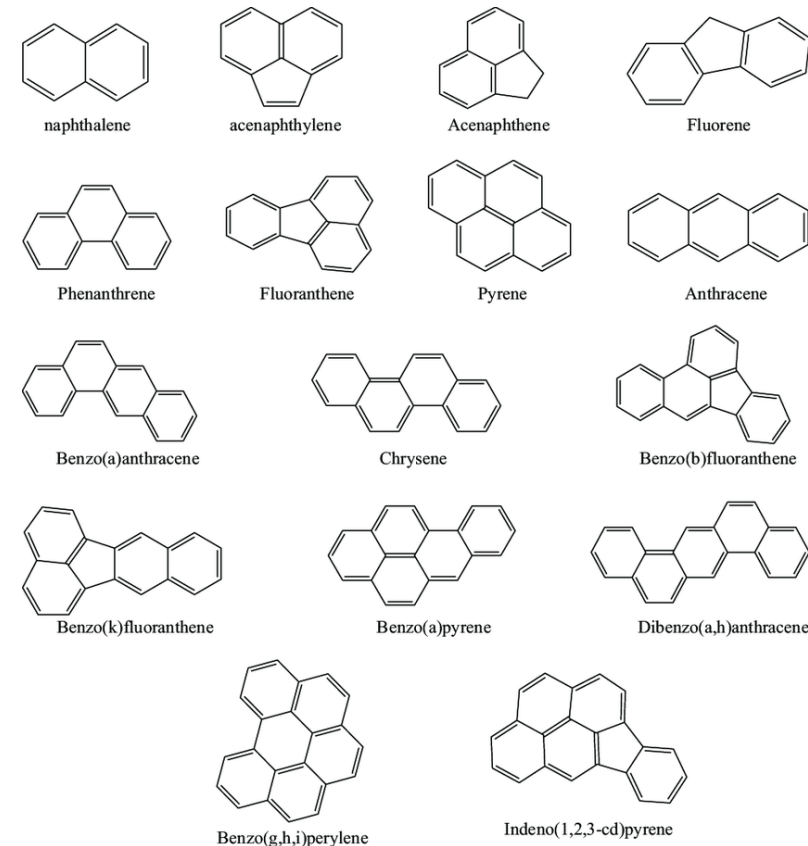
X approved by methods stated above in column

*4 TMECC 04.05, not TMECC 04.12 or EPA 6010d

Polyaromatic Hydrocarbon (PAH) TEQ = conc. * TEF

Total PAH < 6-300 mg/kg
sum for EPA 16 < 3 mg/kg

PAH compound	abbr. ^{*1}	abbr. ^{*2}	IARC ^{*3}	TEF ^{*4}	EPA 16	AU/EFSA 8 ^{*2}	SCF 15 ^{*5}
Benzo(a)pyrene	BaP	BaP	1	1	X	X	X
Cyclopenta(cd)pyrene	CPP	CPP	2A				X
Dibenz(a,h)anthracene	DhA	DBahA	2A	1	X	X	X
Dibenzo(a,l)pyrene	DIP	DBaIP	2A				X
Benz(a)anthracene	BaA	BaA	2B	0.1	X	X	X
Benzo(b)fluoranthene	BbF	BbFA	2B	0.1	X	X	X
Benzo(j)fluoranthene	BjF	BjFA	2B				X
Benzo(k)fluoranthene	BkF	BkFA	2B	0.1	X	X	X
Chrysene	CHR	CHR	2B	0.01	X	X	X
Dibenzo(a,h)pyrene	DhP	DBahP	2B				X
Dibenzo(a,i)pyrene	DiP	DBaiP	2B				X
Indeno(1,2,3-cd)pyrene	IP	IP	2B	0.1	X	X	X
5-Methylchrysene	5MC	MCH	2B				X
Naphthalene	-	-	2B	0.001	X		
Benzo(ghi)perylene	BgP	BghiP	3	0.01	X	X	X
Dibenzo(a,e)pyrene	DeP	DBaeP	3				X
Benzo(c)fluorene	BcL		3				EU 16 ^{*5}
Anthracene	-	-	3	0.01	X		
Acenaphthene	-	-	3	0.001	X		
Fluoranthene	-	-	3	0.001	X		
Fluorene	-	-	3	0.001	X		
Phenanthrene	-	-	3	0.001	X		
Pyrene	-	-	3	0.001	X		
Acenaphthylene	-	-	-	0.001	X		



*1 IUPAC nomenclature Moss 1998

*2 EFSA 2008, AU NEPM 2013

*3 International Agency for Research on Cancer classification

1- carcinogenic to humans

2A- probably carcinogenic to humans

2B- possibly carcinogenic to humans

3- carcinogenicity to humans not classifiable

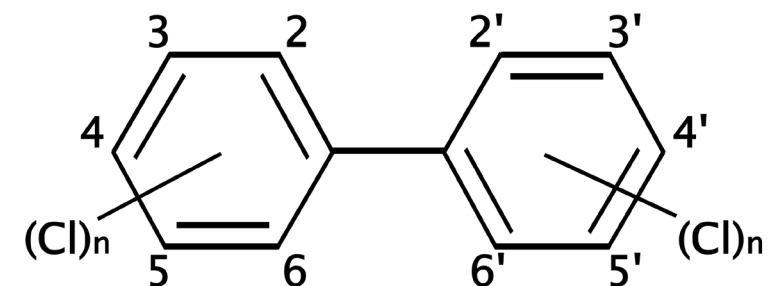
*4 Nisbet & LaGroy 1992

*5 Lerda 2011

Polychlorinated Biphenyls (PCBs) methods & TEF

name	CAS	EPA certified analytes			WHO TEF		
		IUPAC	8275a	8082a	1668c	1998	2005
Aroclor 1016	12674-11-2	n/a		X			n/a
Aroclor 1221	11104-28-2			X			
Aroclor 1232	11141-16-5			X			
Aroclor 1242	53469-21-9			X			
Aroclor 1248	12672-29-6			X			
Aroclor 1254	11097-69-1			X			
Aroclor 1260	11096-82-5			X			
3,3',4,4',5-PeCB3,6	57465-28-8	126			X	0.1	0.1
3,3',4,4',5,5'-HxCB3,6	32774-16-6	169			X	0.01	0.03
3,4,4',5-TeCB6	70362-50-4	81			X	0.0001	0.0003
3,3',4,4'-TeCB3,6	32598-13-3	77			X	0.0001	0.0001
2,3,3',4,4'-PeCB3,6	32598-14-4	105			X	0.0001	0.00003
2,3,4,4',5-PeCB6	74472-37-0	114			X	0.0005	0.00003
2,3',4,4',5-PeCB3,6	31508-00-6	118	X		X	0.0001	0.00003
2',3,4,4',5-PeCB6	65510-44-3	123			X	0.0001	0.00003
2,3,3',4,4',5-HxCB6	38380-08-4	156			X	0.0005	0.00003
2,3,3',4,4',5'-HxCB6	69782-90-7	157			X	0.0005	0.00003
2,3',4,4',5,5'-HxCB6	52663-72-6	167			X	0.00001	0.00003
2,3,3',4,4',5,5'-HpCB6	39635-31-9	189			X	0.0001	0.00003

Total Aroclor < 0.2-1 mg/kg

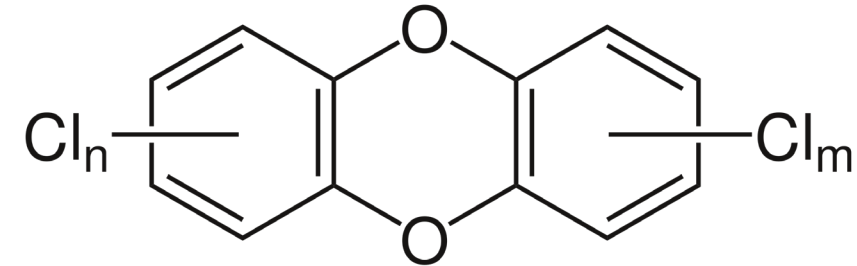


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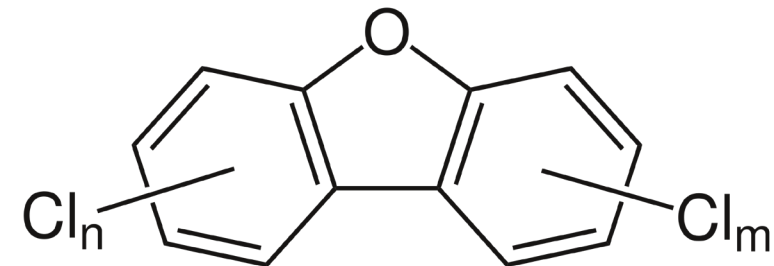
Polychlorinated Dibenzodioxins & Dibenzofurans (PCDD/PCDF) TEF

	WHO 2005 TEF
Chlorinated dibenzo- <i>p</i> -dioxins	
2,3,7,8-TCDD	1
1,2,3,7,8-PeCDD	1
1,2,3,4,7,8-HxCDD	0.1
1,2,3,6,7,8-HxCDD	0.1
1,2,3,7,8,9-HxCDD	0.1
1,2,3,4,6,7,8-HpCDD	0.01
OCDD	0.0003
Chlorinated dibenzofurans	
2,3,7,8-TCDF	0.1
1,2,3,7,8-PeCDF	0.03
2,3,4,7,8-PeCDF	0.3
1,2,3,4,7,8-HxCDF	0.1
1,2,3,6,7,8-HxCDF	0.1
1,2,3,7,8,9-HxCDF	0.1
2,3,4,6,7,8-HxCDF	0.1
1,2,3,4,6,7,8-HpCDF	0.01
1,2,3,4,7,8,9-HpCDF	0.01
OCDF	0.0003

Total PCDD/F < 17 ng/kg TEQ



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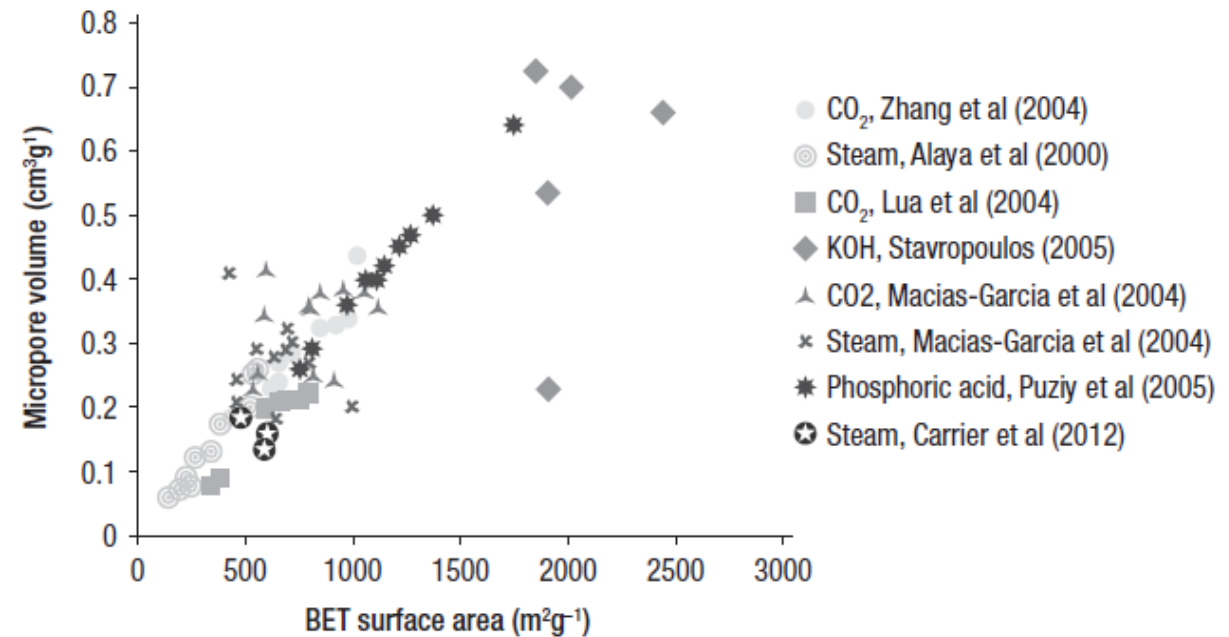
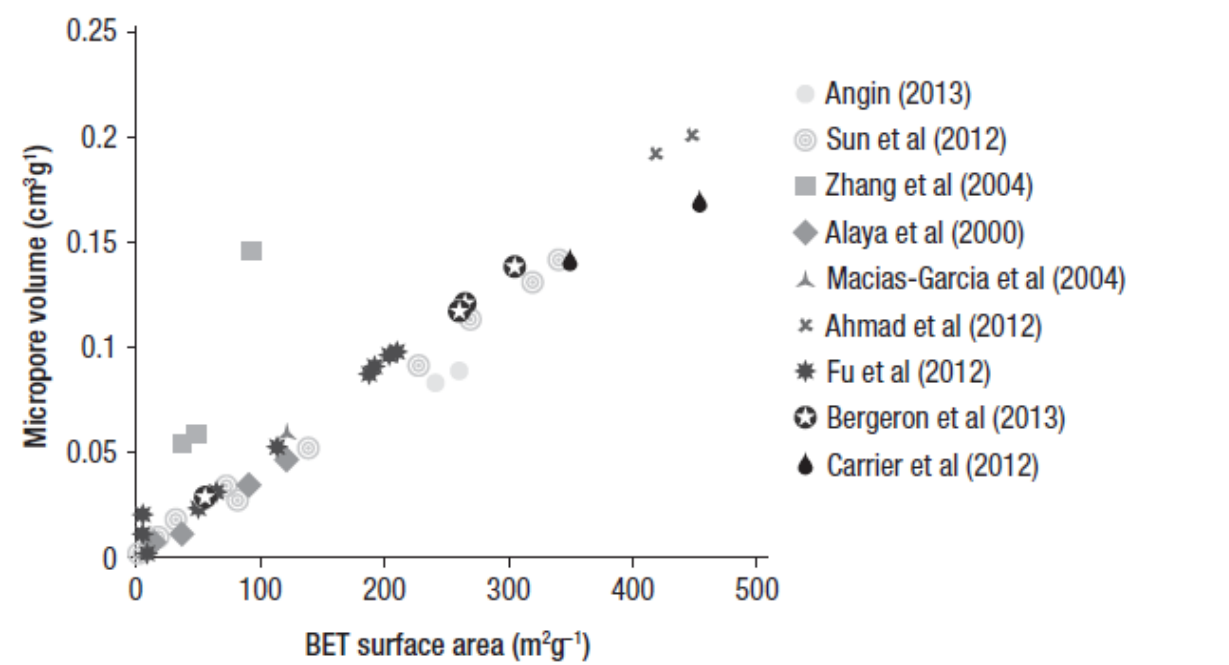
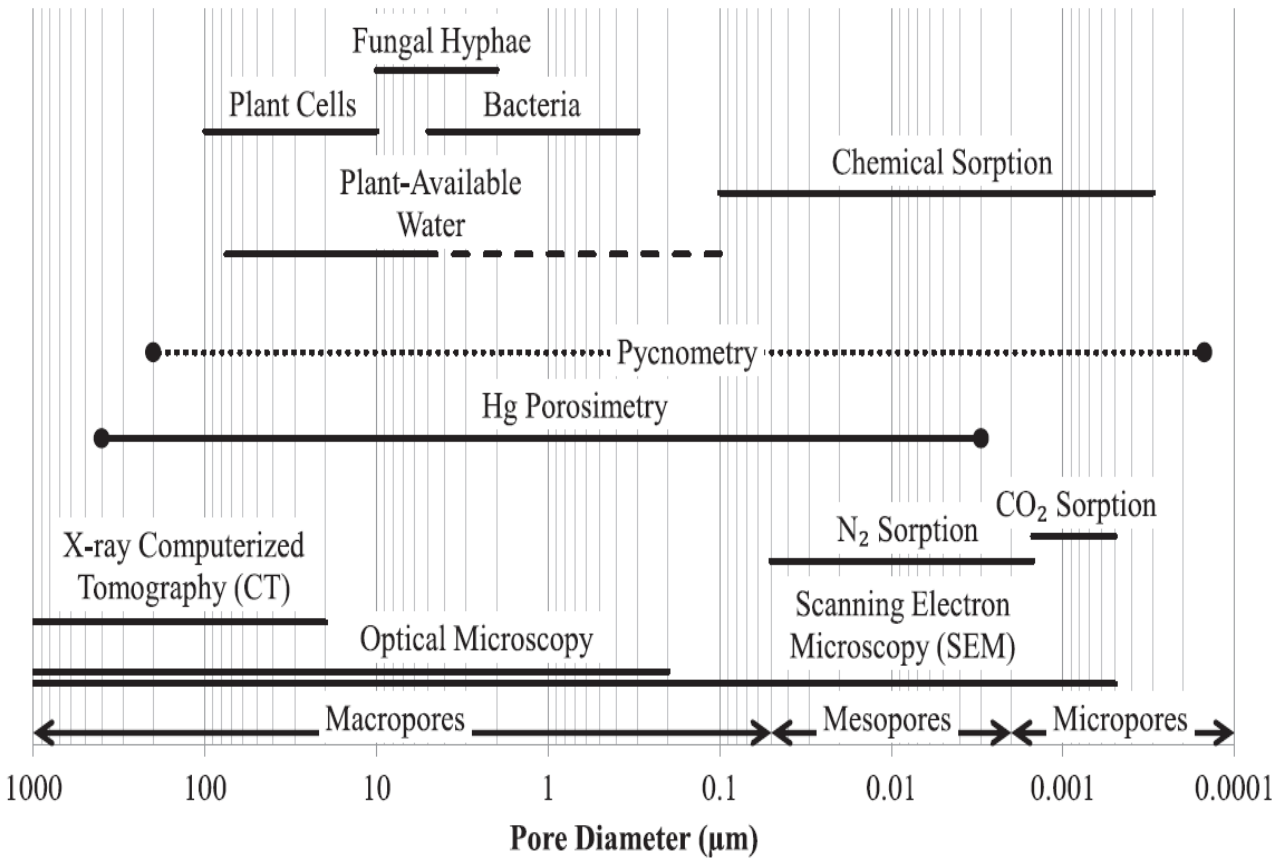


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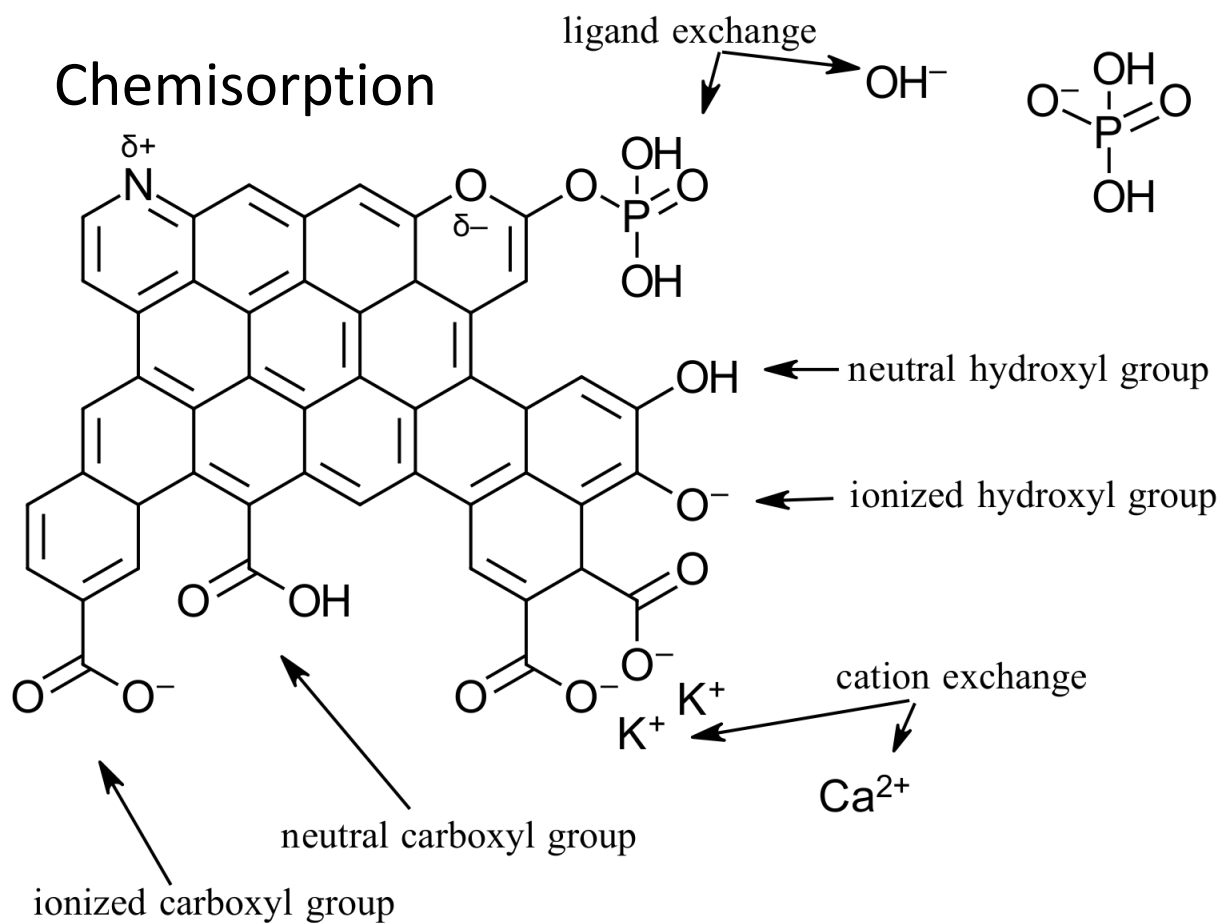
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Porosity and Surface Area



Adsorption Phenomena

Chemisorption



Physisorption

