Electronic Supplementary Material (ESI) for Environmental Science: Water Research & Technology.
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Supplementary Material

Separation of Pharmaceuticals and Nutrients in Synthetic Urine Using Biochar

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Submitted to Environmental Science: Water Research and Technology
August 24, 2014
Revised manuscript submitted January 23, 2017

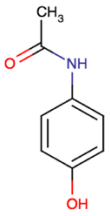
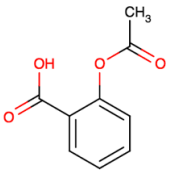
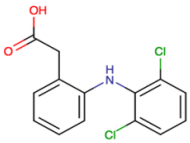
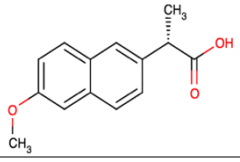
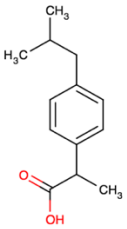
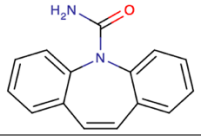
Table S1: Pharmaceutical loading (mg/g) on biochar at the 0.8 g/L dose.

Pharmaceutical	Bamboo	Activated Coconut	Southern Yellow Pine	Coconut Shell	Northern Hardwood
ASA	3.13	38.9	7.94	1.13	0.28
CBM	8.09	55.7	14.3	1.03	1.30
CTP	9.71	62.7	20.5	4.29	1.55
DCF	9.72	73.4	16.2	0.53	2.39
IBP	6.43	44.8	10.2	1.67	1.66
NPX	8.83	56.6	21.3	8.55	2.16
PCM	11.1	37.2	18.0	1.13	1.83

Table S2: Pharmaceutical loading (mg/g) on biochar at the 40 g/L dose.

Pharmaceutical	Bamboo	Activated Coconut	Southern Yellow Pine	Coconut Shell	Northern Hardwood
ASA	0.27	0.78	0.67	0.00	0.41
CBM	1.00	1.12	1.11	0.43	0.73
CTP	1.31	1.81	1.78	0.88	0.78
DCF	1.44	1.52	1.51	0.12	0.71
IBP	0.76	0.94	0.92	0.08	0.57
NPX	1.02	1.16	1.13	0.43	0.78
PCM	0.61	0.76	0.74	0.35	0.74

Table S3: Hydrogen bonding inclination for each pharmaceutical.[1]

Pharmaceutical	Chemical Structure	H-bonding acceptor count	H-Bonding donor count
Paracetamol CAS 103-90-2		2	2
Acetylsalicylic Acid CAS 50-78-2		3	1
Diclofenac CAS 15307-79-6		3	2
Naproxen CAS 26159-54-2		3	1
Ibuprofen CAS 31121-9304		2	1
Carbamazepine CAS 298-46-4		1	1

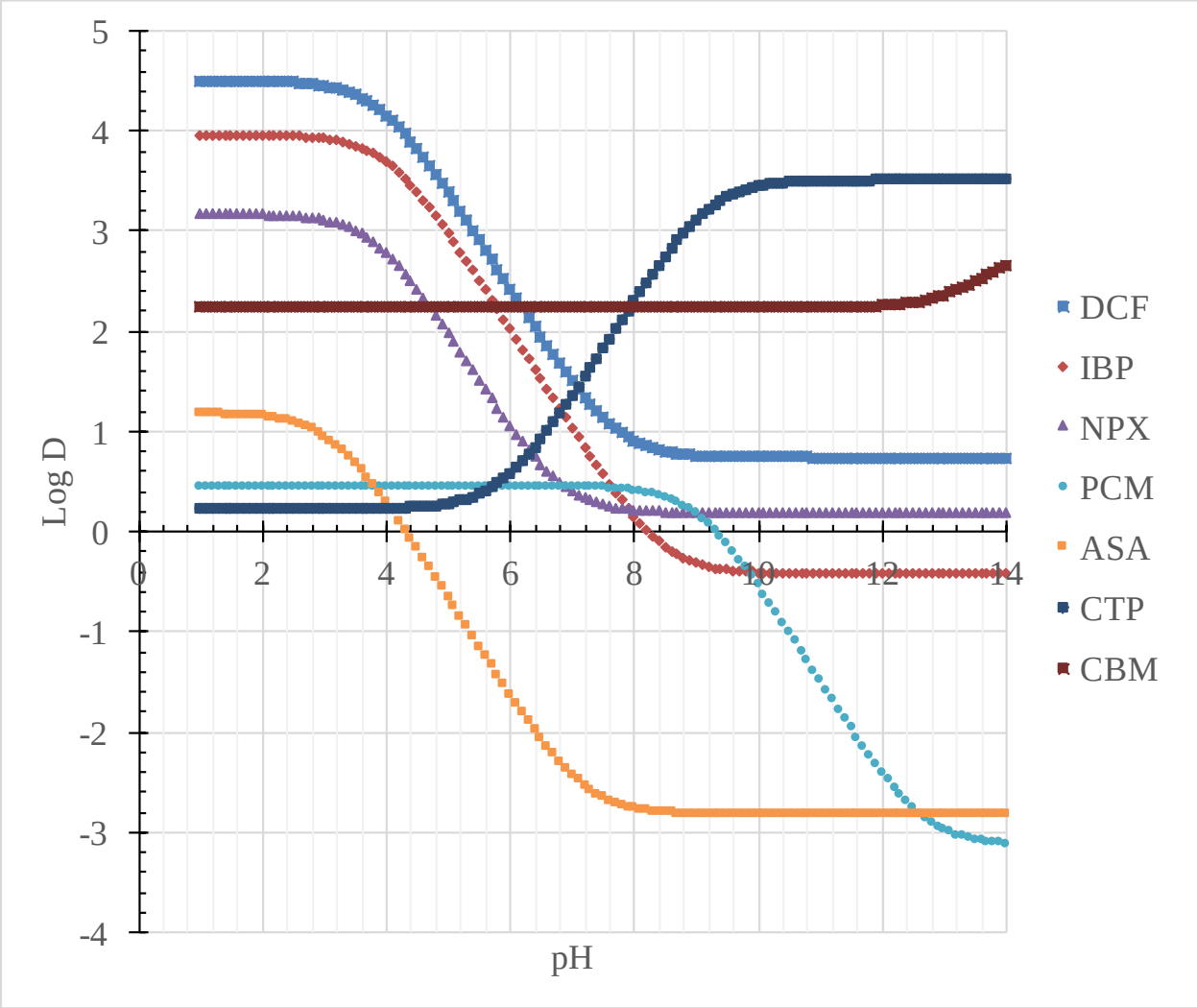


Figure S1: Octanol-water partition coefficient (log D) versus pH for seven pharmaceuticals tested following methods by Jafvert et al.[2]

Log D Calculation Method and Results:

The logD calculations were completed as prescribed in previous research[3] with values obtained from ChemAxon in Marvin Suite v6.3.0.[1] Figure S1 shows that DCF, IBP, NPX, PCM and ASA have decreasing log D values as pH increases. DCF and NPX have two aromatic rings which account for the higher hydrophobicity in comparison to IBP and NPX. In addition, DCF contains two chlorine groups that enhance the hydrophobicity of this compound due to the larger size of chlorine atoms. CBM displays consistent hydrophobic behavior due to the high pK_a value, presence of 2 aromatic rings and a heterocylic feature. CTP is the only positively charged pharmaceutical studied, as a result, CTP exhibits an opposite trend of increasing hydrophobicity as pH increases. The presence of one aromatic ring, heterocyclic feature, and halogen functional group generate the increased hydrophobicity. The logD results demonstrate that the refractive

index and logK_{ow} values alone are not suitable indicators of the hydrophobicity of a compound that has ionizable fractions.

Table S4: Two factor ANOVA statistical analysis ($\alpha = 0.05$)

Pharmaceutical	Biochar dose (g/L)	p-value factor i.[a]	p-value factor ii.[b]
ASA	0.8	5.13E-31	4.02E-10
ASA	40	1.88E-25	5.66E-10
CBM	0.8	1.46E-41	1.70E-12
CBM	40	1.24E-30	3.71E-10
CTP	0.8	7.77E-36	7.80E-10
CTP	40	7.37E-20	9.72E-02
DCF	0.8	4.10E-27	8.52E-03
DCF	40	6.47E-38	3.38E-05
IBP	0.8	5.20E-33	2.02E-07
IBP	40	8.86E-37	1.21E-02
NPX	0.8	3.82E-31	5.84E-13
NPX	40	1.67E-33	1.35E-18
PCM	0.8	1.17E-42	3.18E-04
PCM	40	2.78E-22	7.82E-07

[a]Factor i. conducted for statistical significance for pharmaceutical removal between biochars.
[b]Factor ii. conducted for statistical significance for waste water compositions

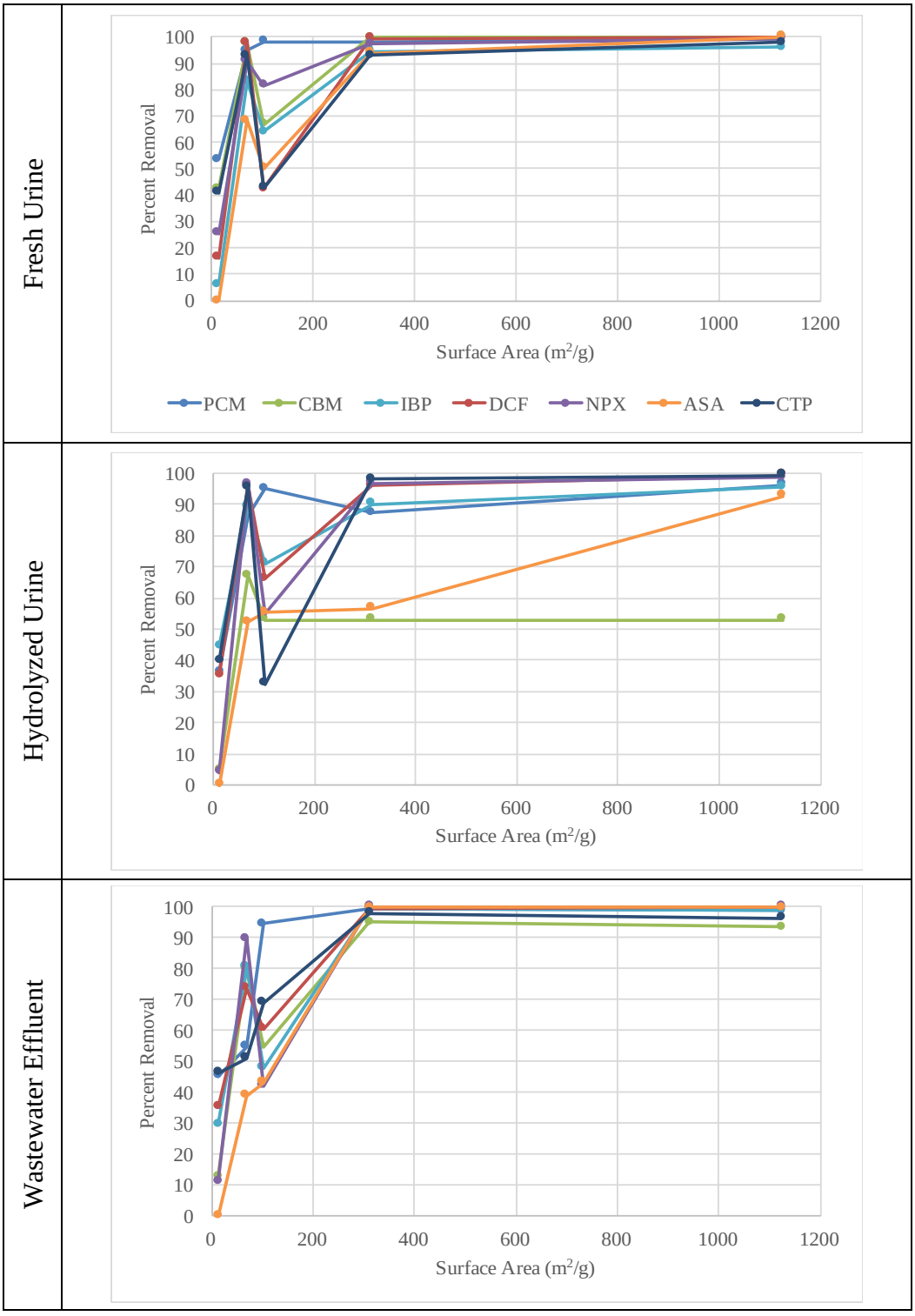


Figure S2: Surface area versus percent removal in fresh urine, hydrolyzed urine and wastewater effluent.

Table S5: Biopolymer make-up for each biochar [4-6]

Biochar	Source Material	Lignin (%)	Hemicellulose (%)	Cellulose (%)
BB	Bamboo	23	25	47
AC	Coconut	28	27	42
SW	Softwood	22	32	41
CS	Coconut Shell	50	35	15
HW	Hardwood	30	68	19

Table S6: Phosphate loading (mg/g) on biochar in fresh urine

	ASA	CBM	CTP	DCF	IBP	NPX	PCM
Bamboo	-0.20	0.14	0.89	6.36	1.28	7.67	1.93
Activated Coconut	7.23	4.59	7.57	16.2	6.24	14.7	8.18
Southern Yellow Pine	3.52	2.68	3.38	7.32	4.00	11.4	3.35
Coconut Shell	-0.61	0.14	-0.48	2.75	0.27	5.23	0.15
Northern Hardwood	5.51	3.96	7.33	6.52	6.35	11.2	7.90

Table S7: Phosphate loading (mg/g) on biochar in hydrolyzed urine.

	ASA	CBM	CTP	DCF	IBP	NPX	PCM
Bamboo	-0.12	-0.41	-0.15	1.33	-1.47	-0.95	-0.60
Activated Coconut	1.80	1.29	1.91	1.90	1.37	2.21	1.49
Southern Yellow Pine	3.05	1.74	2.78	-1.65	1.71	0.99	2.57

Coconut Shell	1.22	-0.04	1.28	-1.83	-0.07	-0.81	0.13
Northern Hardwood	0.88	1.14	0.05	0.32	0.17	0.27	0.06

Table S8: Phosphate loading (mg/g) on biochar in wastewater effluent.

	ASA	**CBM**	**CTP**	**DCF**	**IBP**	**NPX**	**PCM**
Bamboo	-0.51	-0.63	-0.51	-0.43	-0.37	-0.41	-0.51
Activated Coconut	0.04	0.04	0.03	0.03	0.04	0.03	0.04
Southern Yellow Pine	-0.06	-0.06	-0.06	-0.09	-0.07	-0.04	-0.06
Coconut Shell	-0.16	-0.13	-0.10	-0.12	-0.13	-0.09	-0.11
Northern Hardwood	0.02	0.01	0.02	0.01	0.01	0.01	0.01

Table S9: Nitrogen loading (mg/g) on biochar in fresh urine and hydrolyzed urine for representative batch

	Fresh	**Hydrolyzed**
Bamboo	18.9	20.4
Activated Coconut	17.34	27.5
Southern Yellow Pine	6.89	35.9
Coconut Shell	-1.82	28.3

Northern Hardwood	-6.83	24.7

Table S10: pH and conductivity values for ASA

Fresh Urine

	0.8 g/L dose		40 g/L dose	
Biochar	**pH**	**Conductivity (mS/cm)**	**pH**	**Conductivity (mS/cm)**
Bamboo	6.03	17.2	7.29	19.1
Activated Coconut	5.89	17.5	7.40	17.3
Southern Yellow Pine	5.94	17.4	6.31	17.2
Coconut Shell	6.01	17.7	6.17	17.6
Northern Hardwoods	5.99	17.5	6.99	17.7
Control	6.05	17.7	6.05	17.7

Hydrolyzed Urine

	0.8 g/L dose		40 g/L dose	
Biochar	**pH**	**Conductivity (mS/cm)**	**pH**	**Conductivity (mS/cm)**
Bamboo	9.25	39.2	9.25	38.1
Activated Coconut	9.24	37.6	9.23	37.7
Southern Yellow Pine	9.23	39.0	9.20	38.4
Coconut Shell	9.24	38.5	9.20	37.1
Northern Hardwoods	9.23	39.0	9.23	38.7
Control	9.23	39.0	9.23	39.0

Wastewater Effluent

	0.8 g/L dose		40 g/L dose	
Biochar	**pH**	**Conductivity (µS/cm)**	**pH**	**Conductivity (µS/cm)**
Bamboo	7.22	162	10.2	1690
Activated Coconut	7.60	119	8.75	317
Southern Yellow Pine	7.50	117	8.15	292
Coconut Shell	7.32	102	7.74	271
Northern Hardwoods	7.42	116	8.11	232
Control	7.25	100	7.25	100

Table S11: pH and conductivity values for CBM

Fresh Urine

	0.8 g/L dose		40 g/L dose	
Biochar	**pH**	**Conductivity (mS/cm)**	**pH**	**Conductivity (mS/cm)**
Bamboo	6.01	17.8	7.13	19.2

Activated Coconut	5.96	17.8	7.72	17.8
Southern Yellow Pine	6.01	17.8	6.33	17.5
Coconut Shell	5.93	17.7	6.20	18.1
Northern Hardwoods	5.94	17.8	6.72	17.9
Control	5.91	18.1	5.91	18.1

Hydrolyzed Urine

	0.8 g/L dose		40 g/L dose	
Biochar	**pH**	**Conductivity (mS/cm)**	**pH**	**Conductivity (mS/cm)**
Bamboo	9.49	47.0	9.49	47.4
Activated Coconut	9.50	46.7	9.49	46.9
Southern Yellow Pine	9.50	46.7	9.45	46.3
Coconut Shell	9.50	46.8	9.47	46.6
Northern Hardwoods	9.49	46.7	9.49	46.4
Control	9.49	46.2	9.49	46.2

Wastewater Effluent

	0.8 g/L dose		40 g/L dose	
Biochar	**pH**	**Conductivity (µS/cm)**	**pH**	**Conductivity (µS/cm)**
Bamboo	6.11	144	10.3	1630
Activated Coconut	6.20	124	10.4	359
Southern Yellow Pine	5.82	123	6.46	295
Coconut Shell	6.03	108	6.09	263
Northern Hardwoods	5.74	114	7.90	263
Control	7.78	225	7.78	225

Table S12: pH and conductivity values for CTP

Fresh Urine

	0.8 g/L dose		40 g/L dose	
Biochar	**pH**	**Conductivity (mS/cm)**	**pH**	**Conductivity (mS/cm)**
Bamboo	6.02	17.7	7.23	19.1
Activated Coconut	5.99	17.6	7.52	17.8
Southern Yellow Pine	6.00	17.4	6.30	17.5
Coconut Shell	6.14	17.4	6.10	17.4
Northern Hardwoods	5.96	17.1	6.70	17.6
Control	6.02	17.6	6.05	17.6

Hydrolyzed Urine

	0.8 g/L dose		40 g/L dose	

Biochar	pH	Conductivity (mS/cm)	pH	Conductivity (mS/cm)
Bamboo	9.22	41.3	9.25	42.5
Activated Coconut	9.21	40.2	9.23	39.9
Southern Yellow Pine	9.23	39.9	9.20	41.4
Coconut Shell	9.23	40.1	9.20	38.1
Northern Hardwoods	9.25	41.1	9.23	41.2
Control	9.23	40.8	9.23	40.8

Wastewater Effluent

	0.8 g/L dose		40 g/L dose	
Biochar	**pH**	**Conductivity (µS/cm)**	**pH**	**Conductivity (µS/cm)**
Bamboo	7.32	172	10.2	1616
Activated Coconut	7.81	166	8.75	380
Southern Yellow Pine	7.45	144	8.15	315
Coconut Shell	7.22	128	7.74	285
Northern Hardwoods	7.45	142	8.11	301
Control	7.28	127	7.28	127

Table S13: pH and conductivity values for DCF

Fresh Urine

	0.8 g/L dose		40 g/L dose	
Biochar	**pH**	**Conductivity (mS/cm)**	**pH**	**Conductivity (mS/cm)**
Bamboo	6.08	14.4	6.91	15.1
Activated Coconut	5.95	14.3	7.58	14.4
Southern Yellow Pine	5.98	14.2	6.41	14.1
Coconut Shell	5.92	14.2	6.14	14.5
Northern Hardwoods	5.98	14.3	6.58	14.3
Control	6.07	14.3	6.07	14.4

Hydrolyzed Urine

	0.8 g/L dose		40 g/L dose	
Biochar	**pH**	**Conductivity (mS/cm)**	**pH**	**Conductivity (mS/cm)**
Bamboo	9.28	36.1	9.28	36.6
Activated Coconut	9.33	36.4	9.33	36.5
Southern Yellow Pine	9.33	36.7	9.31	36.2
Coconut Shell	9.33	36.9	9.29	36.9
Northern Hardwoods	9.32	36.9	9.31	36.9
Control	9.32	36.9	9.32	36.9

Wastewater Effluent				
	0.8 g/L dose		40 g/L dose	
Biochar	pH	Conductivity (µS/cm)	pH	Conductivity (µS/cm)
Bamboo	7.50	145	10.2	1700
Activated Coconut	7.98	148	10.6	368
Southern Yellow Pine	7.92	153	8.04	313
Coconut Shell	7.76	130	7.96	281
Northern Hardwoods	7.19	142	10.2	298
Control	7.73	125	7.73	125

Table S14: pH and conductivity values for IBP

Fresh Urine				
	0.8 g/L dose		40 g/L dose	
Biochar	pH	Conductivity (mS/cm)	pH	Conductivity (mS/cm)
Bamboo	6.01	17.8	7.13	19.2
Activated Coconut	5.96	17.8	7.72	17.7
Southern Yellow Pine	6.01	17.8	6.33	17.5
Coconut Shell	5.93	17.7	6.20	18.1
Northern Hardwoods	5.94	17.8	6.72	17.9
Control	5.91	18.1	5.91	18.1

Hydrolyzed Urine				
	0.8 g/L dose		40 g/L dose	
Biochar	pH	Conductivity (mS/cm)	pH	Conductivity (mS/cm)
Bamboo	9.31	41.4	9.49	42.1
Activated Coconut	9.30	39.2	9.49	40.3
Southern Yellow Pine	9.25	40.4	9.45	41.0
Coconut Shell	9.35	38.9	9.47	39.4
Northern Hardwoods	9.37	40.3	9.49	40.2
Control	9.34	40.1	9.34	40.1

Wastewater Effluent				
	0.8 g/L dose		40 g/L dose	
Biochar	pH	Conductivity (µS/cm)	pH	Conductivity (µS/cm)
Bamboo	7.55	186	9.93	1210
Activated Coconut	8.02	199	10.1	382
Southern Yellow Pine	8.11	165	7.91	331
Coconut Shell	7.85	152	7.77	301
Northern Hardwoods	7.45	171	9.35	299

Control	8.18	154	8.18	154

Table S15: pH and conductivity values for NPX

Fresh Urine				
	0.8 g/L dose		40 g/L dose	
Biochar	**pH**	**Conductivity (mS/cm)**	**pH**	**Conductivity (mS/cm)**
Bamboo	5.06	13.7	6.87	15.1
Activated Coconut	5.27	13.8	7.32	13.6
Southern Yellow Pine	5.12	13.8	6.14	13.6
Coconut Shell	4.78	13.8	5.81	14.0
Northern Hardwoods	5.01	13.9	6.27	13.8
Control	5.04	13.8	5.04	13.7
Hydrolyzed Urine				
	0.8 g/L dose		40 g/L dose	
Biochar	**pH**	**Conductivity (mS/cm)**	**pH**	**Conductivity (mS/cm)**
Bamboo	9.25	38.3	9.26	39.3
Activated Coconut	9.26	38.3	9.25	37.8
Southern Yellow Pine	9.26	38.2	9.21	37.7
Coconut Shell	9.24	38.2	9.20	38.3
Northern Hardwoods	9.26	38.3	9.24	38.3
Control	9.26	38.6	9.26	38.6
Wastewater Effluent				
	0.8 g/L dose		40 g/L dose	
Biochar	**pH**	**Conductivity (µS/cm)**	**pH**	**Conductivity (µS/cm)**
Bamboo	7.01	170	10.19	1710
Activated Coconut	7.32	121	9.42	389
Southern Yellow Pine	6.99	147	7.40	312
Coconut Shell	7.12	167	7.39	287
Northern Hardwoods	7.09	155	8.10	230
Control	7.25	167	7.25	167

Table S16: pH and conductivity values for PCM

Fresh Urine				
	0.8 g/L dose		40 g/L dose	
Biochar	**pH**	**Conductivity (mS/cm)**	**pH**	**Conductivity (mS/cm)**
Bamboo	6.01	17.8	7.13	19.2
Activated Coconut	5.96	17.8	7.72	17.7
Southern Yellow Pine	6.01	17.8	6.33	17.5

Coconut Shell	5.93	17.7	6.20	18.1
Northern Hardwoods	5.94	17.8	6.72	17.9
Control	5.91	18.1	5.91	18.1

Hydrolyzed Urine

Biochar	0.8 g/L dose pH	0.8 g/L dose Conductivity (mS/cm)	40 g/L dose pH	40 g/L dose Conductivity (mS/cm)
Bamboo	9.49	47.0	9.49	47.3
Activated Coconut	9.50	46.6	9.49	46.9
Southern Yellow Pine	9.50	46.6	9.45	46.2
Coconut Shell	9.50	46.8	9.47	46.6
Northern Hardwoods	9.49	46.6	9.49	46.4
Control	9.49	46.1	9.49	46.1

Wastewater Effluent

Biochar	0.8 g/L dose pH	0.8 g/L dose Conductivity (µS/cm)	40 g/L dose pH	40 g/L dose Conductivity (µS/cm)
Bamboo	5.91	143	10.32	1670
Activated Coconut	6.21	124	10.31	356
Southern Yellow Pine	5.78	117	6.48	298
Coconut Shell	5.99	108	6.26	267
Northern Hardwoods	5.94	121	9.23	260
Control	6.58	106	6.58	106

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