Sustainable decentralized water treatment for rural and developing communities using locally generated biochar adsorbents

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Aqueous Solutions
Advancing the Science of Self-reliance
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synthetic chemical water contaminants
an often overlooked challenge in sustainable community development

“In S/SE Asia, ~ 75% of the pesticides used are banned or heavily restricted in the West due to ecological and human health effects.”

“Small-scale, household-based removal techniques are often the only possible mitigation strategy due to the lack of a centralized infrastructure...”

Call for the development of “reliable, affordable, and simple systems that local inhabitants could use with little training.”

Charcoal/Biochar Filtration
an appropriate, low-cost and sustainable option for decentralized water treatment?

a note on terminology:

**charcoal** = biomass char
produced from traditional kilns
for use as a fuel (e.g. cooking)

**biochar** = biomass char
produced from a variety of
techniques (e.g. gasification)
for use as an agricultural soil
amendment and/or CO₂
sequestration strategy
I. char generation devices
   • traditional kiln, laboratory furnace, TLUD gasifiers

II. char characterization and sorption testing
   • herbicide sorption

I. incorporation of char filters into low-cost, decentralized, locally operated water treatment trains
   • long-term field monitoring study
traditional charcoal generation (Thailand)

200 L steel drum/adobe kiln

brick-and-mud “beehive” kiln
mud beehive kiln
Royal Thai Forestry Department
Wood Energy Research Centre
Saraburi Province, Thailand
brick beehive kiln
Royal Thai Forestry Department
Wood Energy Research Centre
Saraburi Province, Thailand
experimental kiln

illustrations by N. Reents
II. Laboratory Furnace Pyrolyzer

- high, medium, and low temperature programs
- placed in steel pyrolyzer, covered with sand to prevent combustion
- four feedstocks: bamboo, eucalyptus, longan, pine
- feedstocks cut to uniform dimensions – 1 cm thick planks
biomass gasifier char generation
(cookstove scale)

- 1-gal paint can reactor body (holes in bottom)
- thermocouple probes
- small electric fan

primary air draft

secondary air in for combustion of pyrolysis gases

chimney effect alone: “natural draft” (ND)
fan-enhanced draft: “forced draft” (FD)
200 L Top-Lit Up-Draft (TLUD) Biomass Gasifier
For Generating Enhanced Water Filter Biochar

- 120 cm
- 20 cm
- 10 cm
- 15 cm
- 20 cm
- chimney
- crown
- reactor body
- temperature probe housing (optional)
- 13 cm
- 25 cm
- handle
- lid, 55 cm
- sturdy support
- 5 cm lip in top of reactor body
- ~ 300 holes in bottom of reactor body 95 mm (3/8")

Illustration by Nathan Reents

combustion zone
second air intake
char
heating (gasification) zone
feedstock
primary air intake
video on theory, construction, and operation of this unit at aqsolutions.org
JRO ("Jolly Roger Oven")

design adapted from Hugh McLaughlin
combustion zone

wood gases exiting retort and combusting in combustion zone
char production factors that can influence sorption

- (peak) temperature
- heating duration
- gas sweep rate
- feedstock identity
- feedstock form
Kiln & Furnace Char Production Temperature Series

degrees Celsius

hours

- Kiln: eucalyptus
- Kiln: pine
- Kiln: bamboo
- Kiln: longan
lab experiments with chars and pesticide

batch sorption experiments:

100 μg/L 2,4-D herbicide (EPA MCL: 70 μg/L, WHO Guideline: 30 μg/L)

background dissolved organic matter (4 mg/L TOC)

20 mM buffer pH 7

composite char samples ground and sieved to pass #200

char doses 20 - 200 mg/L

2 weeks agitation
traditional kiln charcoals (composite samples)

- furnace chars
- longan
- bamboo
- pine
- eucalyptus

$2,4-D$ remaining vs. carbon dose (mg/L)
brick beehive kiln
Royal Thai Forestry Department
Wood Energy Research Centre
Saraburi Province, Thailand

![Graph showing the effect of temperature on 2,4-D remaining with different carbon doses and times.]
biomass gasifier char generation
(cookstove scale)

- 1-gal paint can reactor body (holes in bottom)
- thermocouple probes
- small electric fan
- chimney effect alone: “natural draft” (ND)
- fan-enhanced draft: “forced draft” (FD)

secondary air in for combustion of pyrolysis gases
primary air draft
Kiln & Furnace Char Production Temperature Series

- "high" program
- "standard" program
- "low" program

TLUD Biochar Manufacture Temperature Series

- Natural Draft (ND)
- Forced Draft (FD)

1-gal TLUD gasifier
200 L Top-Lit Up-Draft (TLUD) Biomass Gasifier
For Generating Enhanced Water Filter Biochar

- 5 cm lip in top of reactor body
- ~300 holes in bottom of reactor body 95 mm (3/8”)
- handle
- lid, 55 cm
- sturdy support
- chimney
- crown
- reactor body
- temperature probe housing (optional)
- combustion zone
- secondary air intake
- char
- heating (gasification) zone
- feedstock
- primary air intake

Illustration by Nathan Reents
200 L (55-gal) gasifier stats

- Mass loss consistently ~ 85%
- Mass yield 7-9 kg / drum batch
- Volume yield ⅓ - ½ drum (70-100 L)
- Peak temperatures consistently 800-900+ °C
- Run time 50 min – 2 hrs depending on feedstock
- 14 batches ≈ 100 kg ≈ 1 m³ char
other dimensions of water treatment using biochar

• dechlorination (objectionable taste & odor)
• removal of disinfection by-products (DBPs) and DBP precursors
• removal of natural T&O compounds
• removal of antibiotics
• nutrient recovery in WW treatment; eco-sanitation
• watershed protection
I. char generation devices
   • traditional kiln, laboratory furnace, TLUD gasifiers

II. char characterization and sorption testing
   • herbicide sorption

I. incorporation of char filters into low-cost, decentralized, locally operated water treatment trains
   • long-term field monitoring study
Wah Klu Koh village
Umphang District
Pun Pun Farm
Pun Pun Farm
Water Treatment System

- serves a varying population of 5-100 (average ~ 40) people, depending upon season and farm programming
- treats all water used on the farm except showering, toilets, and irrigation
  - drinking water
  - kitchen uses – food and drink preparation, washing produce
  - washing dishes
  - café
- max throughput 3000 L/day (800 gpd)
- common local materials, < US$400
- passive (gravity flow)
- installed Spring 2008...continuous use, even through rainy seasons
- minimal maintenance
water system monitoring rationale:
breakthrough curves from column studies using GAC

**FIGURE 1** RSSCT breakthrough curves for MIB, DOC, and 15 probe compounds (divided into two parts for clarity)

Source: Corwin and Summers, Controlling trace organic contaminants with GAC adsorption. JAWWA, January 2012.
Acknowledgements...

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In-kind donation from Hach

Practical, accurate and affordable. From wastewater to high purity water, we have a monitoring solution that’s right for you.

For over 7 years, our Real UV254 ‘P’ series portable meters have been redefining expectations for organic analysis in the field. With our patented Split-Sense technology, we offer hands down the world’s most advanced, accurate and affordable portable UV254 organic testing meter.

With an unprecedented 1 minute warm-up time, extreme accuracy of better than ±0.5% UV(T) (UV254T), and a price point anyone can include in their budget, the Real UV254 ‘P’ series portable meters can’t be beat.

Designed to cope with the harsh conditions encountered in the field, the ‘P’ series meters are very rugged yet have an accuracy that surpasses most laboratory instrumentation. Our meters can also provide testing in both units of UV transmittance (UV(T)) and UV absorbance (UV(A)), and any of the meters can be equipped with our optional battery pack feature, allowing the ‘P’ series meters to truly go anywhere, anytime.

In addition, our patented Split-Sense technology also allows for the precise ability to...
Data collection assistance by Sheena Niamjan and Ramphai Noikaew.
Pun Pun Farm

Wah Klu Koh village

map source: Thailand Burma Border Consortium, tbbc.org
 Portable Drinking Water Treatment Plant

• produces up to 300 L/day (80 gpd) ... enough to meet minimum daily DW requirements of 100 people

• surplus 200 L (55 gal) HDPE drums (BPA-free) + PVC connections ... cost < US$125

• can be assembled with only a Leatherman multi-tool

• media acquired / generated on-site

• passive (gravity flow)
Open-source handbooks (and videos) available at aqsolutions.org
Thai, Burmese, Spanish translations too! Karen, Khmer, etc. translations coming soon...

Also: See Oct. 2012 Water Conditioning & Purification International magazine, wcponline.com
Questions?

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