Biochar Hands-On Education

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Abstract. *Biochar topic integrates natural, environmental and social sciences and it is an ideal topic for integrating school subjects at all grades. Several schools worldwide have been reported to perform biochar hands-on projects. Pupils don't just learn what has been discovered a long time ago. They actually become scientists doing their own research and have a chance to contribute to common open-source knowledge. In this paper we present several hands-on activities related to biochar.*

Keywords. biochar, education, hands-on science

1. Introduction

Biochar (carbonized biomass) has been a subject of booming scientific research for the period of past decade. Specialists of many different fields became interested in biochar research mainly because of its potential for: 1. climate change mitigation through carbon sequestration, 2. soil amendment and 3. energy source.

As shown in the graph below number of scientific articles on biochar has been growing exponentially in the last decade.

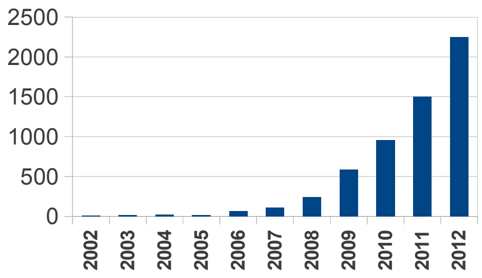

Figure 1. Number of scientific articles containing keyword "biochar" in the abstract (Source of data: Google Scholar)

We claim that science education ought to reflect advances in scientific research and keep the state of knowledge communicated at public schools up-to-date.

2. Biochar educational potential

Educators all around the world have been discovering biochar as a great learning topic suitable for all levels of schools. During biochar activities pupils learn scientific research methods and they actually work almost like real scientists. Biochar topic is ideal for integration of natural science subjects and can be used to teach about global environmental issues.

International Biochar Initiative (IBI) presents examples of successful biochar school projects on their websites (http://goo.gl/dVnLI). Up to our knowledge we have been the first ones in the Czech Republic engaged in development of biochar educational activities. In this paper we present several educational hands-on activities that were performed by pupils of upper primary school and at the Faculty of Education by pre-service physics teachers. From our own teaching experience and from reports of other schools presenting their biochar projects we summarize the following findings:

1. Biochar hands-on activities can be performed as laboratory experiments or as field trials. For outdoor field experiments we recommend to follow IBI methodology available online as a pdf document named "A Guide to Conducting Biochar Trials" (http://goo.gl/FfVda).

2. Biochar hands-on activities can be performed as individual projects of pupils (students) or as small team, class and whole school project.

3. Biochar hands-on activities can be performed as a single lesson or long time projects. For most of existing activities longer period is required, specially for activities based on comparing growth of plants in ordinary soil and in soil containing biochar.

4. Areas to investigate and examples of activities:

- biochar production (source of biomass, pyrolysis process, biochar yield...)
- stove design (improving gasifier stove design, determining thermal efficiency of stove by Water Boiling Test)

- biochar properties (pH, fraction, composition, density...)
- soil amendment (plants growth, pH change, water retention capacity...)

3. Sample activities

In this chapter, sample hands-on science learning activities are presented.

3.1. Gasifier stove made of cans

School willing to engage in biochar hands-on learning activities need a source of biochar. The easiest way is to get it is buying a bag of charcoal for grilling and crash it to powder. This us useful when you need large amount of biochar for field trials. Small amount of biochar for classrooms experiments can be produced in TLUD (Top-Lit Updraft) gasifier stoves. TLUD pyrolysis system was invented in the 80's and it has been handled as open source technology. Than means TLUD design is not patent protected and is free to use and innovate. Currently there is only one type of TLUD stove commercially produced by Spenton LLC (http://www.spenton.com). Their Campstove was designed for use in camping sites. It uses battery powered fan to sustain updraft and regulate stove's power.

Simplest TLUD stove can be made of just one tin can (named “iCan”). It works well under calm conditions. A more reliable and efficient design uses 3 cans, for chimney, inner and outer wall. Scheme of such a stove is on a Figure 2.

Biomass placed inside the smaller can is lit at the top layer. When it gets hot, flaming pyrolysis starts to move downward while air enriched by wood gas moves upward. Combustible gases (CO, CO4, H2) mix with preheated air sucked through hollow metal wall and burn. Flames come from holes at the top of inner can. After flames extinguish the stove contains hot char which must be immediately moved to airtight container in order to prevent char oxidation. When char cools down, it is ready to use for any school experiment.

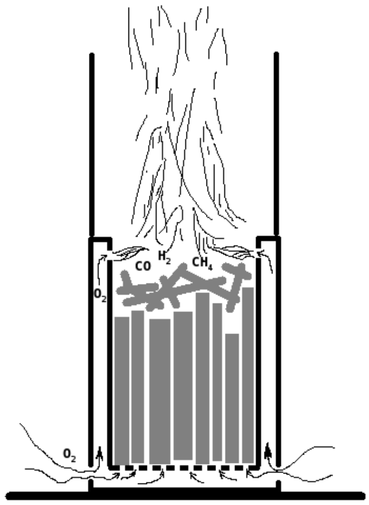

Figure 2. Scheme of TLUD stove made of three cans.

Making and operating the stove is a great learning activity itself. Pupils can try to improve the stove design and can do lots of measurements (temperature of flame or pyrolysis zone, duration of burning of different fuels, factors affecting biochar yields, thermal efficiency of stove etc.).

For safety reasons, the stove should be operated outdoors or in a ventilated fume hood, as woodgas contains carbon monoxide which is very toxic. Pupils should be well instructed how to safely handle the stove because its surface gets very hot and they could burn their fingers. Fire protection measures should also be considered.

3.2. Soil properties measurement

Biochar is usually recommended to be mixed with soil in order to improve its physical properties. There are many interesting questions that can be investigated by pupils through laboratory experiments. Below we present our sample measurement of three soil properties: water retention capacity, pH and conductivity. We tested, how biochar changes these properties for three kinds of soil: peat (as offered to gardeners), agricultural soil (collected on a field) and sand. Mixture ratio of soil and biochar was 1:1.

Equipment: laboratory glass, filtration papers, Vernier LabQuest and deterctors: electronic scale, pH meter, conductivity meter

Procedure:
1. Weigh 10 g of air-dried soil sample.
2. Measure 40 ml of distilled (or tap) water.
3. Place the soil sample onto filtration paper (see figure below) and let all 40 ml of water drop on the surface of the sample.

Figure 3. Collecting drops of water passing through the soil

4. Collect water passing through the sample until no more filtered water flows or drops.
5. Gently move the filtration paper with the wet sample to the scale and measure its weight. From that weight, subtract 10 g (dry sample) and 2 g (wet filtration paper). The final number is the weight of water retained by the sample.
6. Measure pH and conductivity.
7. Wash the sensors and glass in clean water every time.

Standardized procedure of determining soil pH (its suspension in water) is specified in ISO 10390:2005. According to that standard, water solution should contain potassium chloride (KCl) or calcium chloride (CaCl2). For school experiments we used simplified method which is sufficient to determine change of soil pH after mixing with biochar (not exact soil pH).

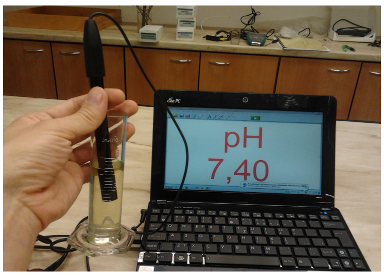

Figure 4. Measuring pH of a soil suspension in water using Vernier sensor.

Results of our measurements are shown at Figure 5. We found that peat has the highest retention capacity for water and sand the lowest. Biochar addition increased retention capacity of sand but for the given agricultural soil, retention capacity was reduced. That explains why biochar is recommended for sandy soils mostly. More experiments can be done to investigate how fast can water pass through the samples or how fast will a given agricultural soil lose water compared to soil+biochar mixture (using Vernier soil moisture sensors). That might be importatnt for understanding of soil behavior during rains or droughts.

Our measurements also revealed that biochar increased pH (decreased acidity) of all our samples – peat, soil and sand. Agricultural soils affected by long time use of mineral fertilizers are often acidic and biochar can help farmers to improve soil pH.

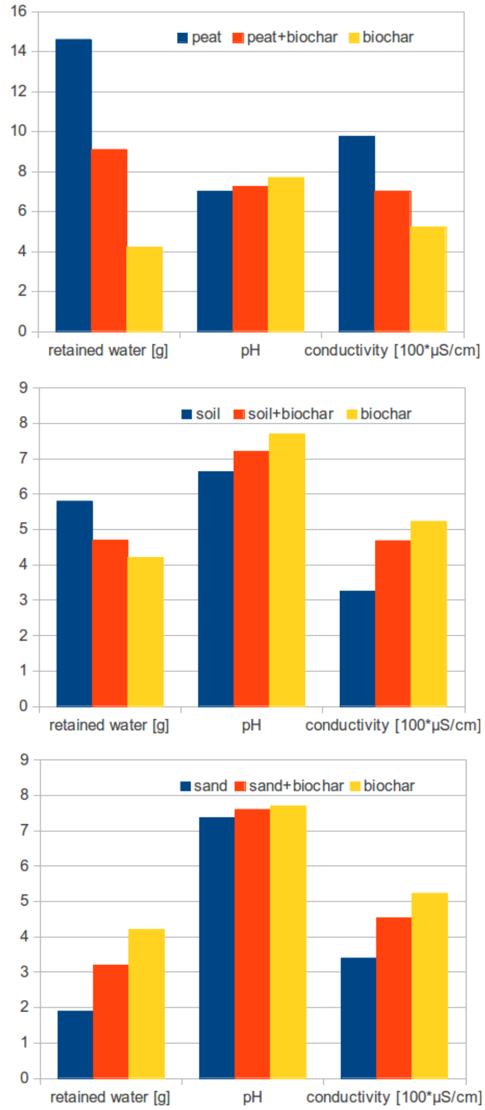

Figure 5. Sample measurements of three soil properties: 1. water retained in 10 g of substance, 2. soil pH, 3. conductivity.

The highest electrical conductivity was achieved for peat alone. Addition of biochar to sand and to agricultural soil increased their conductivity. That finding might have application in building industry for decreasing ground resistance of electrical installations and lightning rods.

Pupils can investigate even more properties of soil depending on their interest and school laboratory equipment available.

3.3. Czech school biochar project

The Czech republic has participated in the international GLOBE Program (The Global Learning and Observations to Benefit the Environment, http://globe.gov) since its beginning in 1995. Czech Republic is among 111 participating countries with 142 primary and secondary schools currently engaged. Every year, pupils from over 30 schools meet at GLOBE Games (www.globegames.cz/english.html).

In 2010 pupils of the primary school ZS Křídlovická explored biochar and prepared its presentation for the GLOBE Games in Svitavy. Pupils made a TLUD stove from cans and experimented with microgasification. They carbonized 10 different biomass samples (spruce wood, beech wood, pine cone, larch cone, hazelnut, walnut, corn cob, apricot pit, peach pit, cork stopper). At the GLOBE Games festival in a city park they demonstrated TLUD stove to the event participants and townspeople.

Figure 6. Demonstration of TLUD stove made of cans by 8th grade pupil.

Pupils of the Czech school also prepared a task for the visitors coming to their stand. On the table they arranged 10 samples of carbonized biomass. The visitors were asked to identify original source of biomass for each sample choosing from a given list. The samples were mostly easy to recognize, because by carbonization biomass reduces its size but the shape remains the same. Even small children were able to complete the task with a little help of their parents.

Figure 7. Presentation of carbonized biomass samples.

More photos from the event are available online at the address: http://goo.gl/RlqGm

4. Conclusion

Biochar is a brand new area of interdisciplinary science research. Educators have been seeking ways how to implement this topic into current education system. For many reasons, biochar appears to be a unique educational tool. In the paper we presented several hands-on science activities on biochar that can be utilized in primary, secondary or university science education.

5. Acknowledgements

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