Aalto University

Bio-based activated carbon from locally available biomass: comparison of carbon activation methods on water treatment performance

the international water association

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INTRODUCTION

Problem: When problematic pollutants, such as nutrients or dyes appear in surface water, it requires additional methods of treatment, such as adsorption, to decrease their harmful impacts on human health and the environment. Conventional adsorption is usually performed with activated carbon (AC). However, AC cannot be considered an environmentally friendly material as usually it is made of coal, whose extraction and transportation to the end-users have a significant carbon footprint.
Our solution: Bio-based AC (BAC) produced from locally available biomass, so-called biochar, is attractive as a substitute for conventional AC. The production of such adsorbents is relatively easy and cost-effective. A considerable, underexplored advantage of BACs is the adjustability of their properties during production. The biomass type, production conditions, or activation method affect the final properties of BACs. Thus, we hypothesize that by controlling the pyrolysis temperature and activation method, it is possible to create specific carbons for improved removal of target pollutants. The illustrative presentation of the hypothesis is shown in Figure 1. As an example, we can assume that if we follow the green production line: with selecting bark biomass, pyrolyzing it at 350 °C, and activating it with steam under 800 °C, then such BAC will be a great adsorbent for the natural organic matter (NOM). We call this process "tailoring". Previously, we studied the effect of process temperature and different chemicals on the properties of the tailored BAC [1,2].
Objectives: here we aim to show how BAC's properties can be changed by different activation methods; to gain deeper knowledge on the process of tailoring by producing BACs from locally available biomass; and to explore the performance of the activated BACs for the removal of NOM or textile dye.

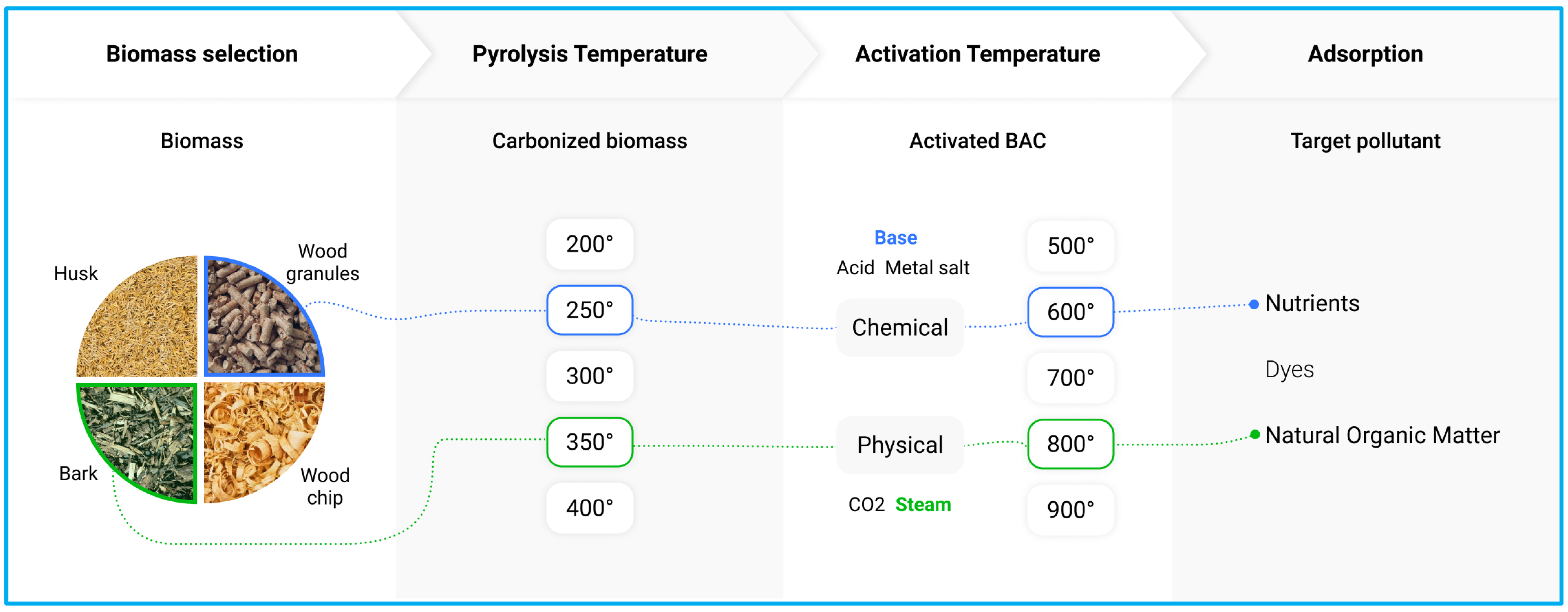

Figure 1 – The illustration of the hypothesis on tailoring BACs, the blue and green lines represent possible ways of production parameters selection and outcomes

METHODS

Three BACs were produced via two-step pyrolysis with chemical activation; a complete description was reported in our previous research [1]. The products were named iron-activated carbon (BAC-Fe), copper-activated carbon (BAC-Cu), and sodium-activated carbon (BAC-Na). Two types of BACs were produced from wood sawdust and food waste and named according to the used biomass as husk-activated carbon (HAC) and wood-activated carbon (WAC). Adsorption batch experiments were conducted with the solution of Direct Red 23 dye and lake water. The concentration of NOM was measured and represented with a collective parameter COD. To determine the concentration of NOM and dye, the UV absorbance measurement was performed, with further conversion of absorbance to concentration using the calibration curves.

RESULTS & DISCUSSION

As seen in Figure 2, BAC-Cu reaches 87 % removal already at 1 g/l, while BAC-Fe and BAC-Na show 97 and 80 % at 2 g/l, respectively. In the absence of competing ions, the BAC-Fe shows a considerable removal of NOM (97 %). Nevertheless, BAC-Fe can show selective adsorption for phosphorus and its performance may decrease significantly in a typical binary solution of NOM and phosphorus [2]. This indicates a monolayer adsorption that is a common characteristic of chemically modified adsorbents [2]. BAC-Na showed 84% removal with 3 g/l BAC, which is promising as it provides a better feasibility prospect for big-scale production.

Chemical activation can result in additional characteristics. For instance. BAC-Fe has magnetic properties (Figure 3), which facilitates the removal of carbon powder from water [2], and BAC-Cu has antimicrobial effect on E-coli bacteria (Figure 4).

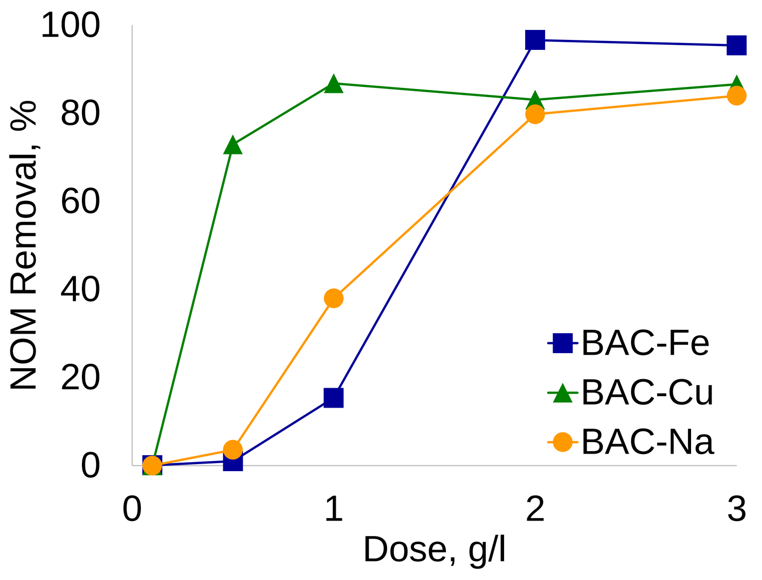

Figure 2 – The adsorption of NOM (initial COD = 16 mg/l)

Figure 3 – The magnetic properties of IAC

Figure 4 – The E-coli inactivation study

RESULTS & DISCUSSION

Chemical activation has its advantages over a physical one but for big-scale production, many chemical activators might be economically or environmentally unfeasible. The physical activation does not implicate chemicals, which makes it cheaper and poses fewer environmental risks. Based on this fact and previous research [3], for dye removal, it is reasonable to select physical activation during BAC production.

The removal of different dye concentrations with physically activated BACs displays a high 253 mg/g and 212 mg/g adsorption capacities for WAC and HAC, respectively (Figure 5). These results confirm that wood-derived adsorbents can rightfully occupy the first place among BACs, as apart from high-performance wood is a very accessible renewable biomass source. The decolorization of dye with WAC is shown in Figure 6. HAC shows slightly lower capacity than WAC, demonstrating that food waste such as fruit stones can be reused for BAC production and thus contribute to a circular economy.

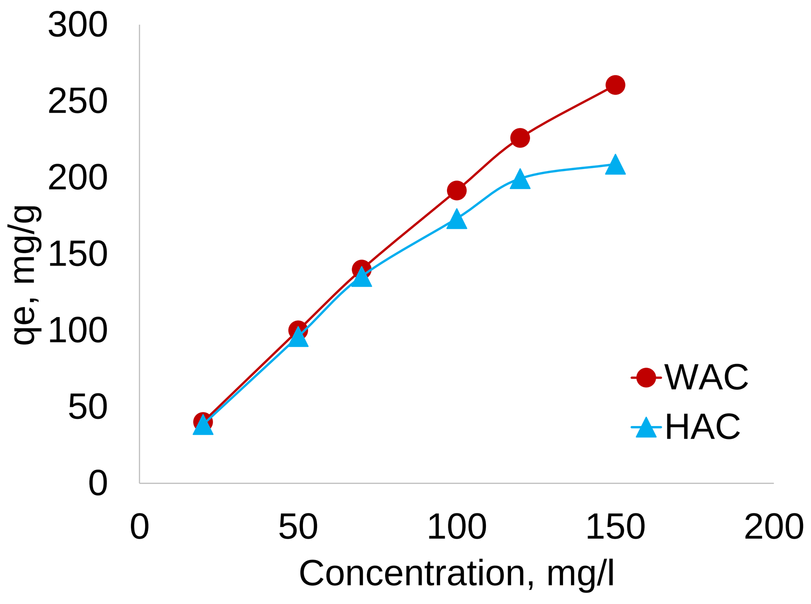

Figure 5 – The adsorption capacity of BACs (dosage 2 g/l, contact time 3 h, no pH adjustment, room temperature)

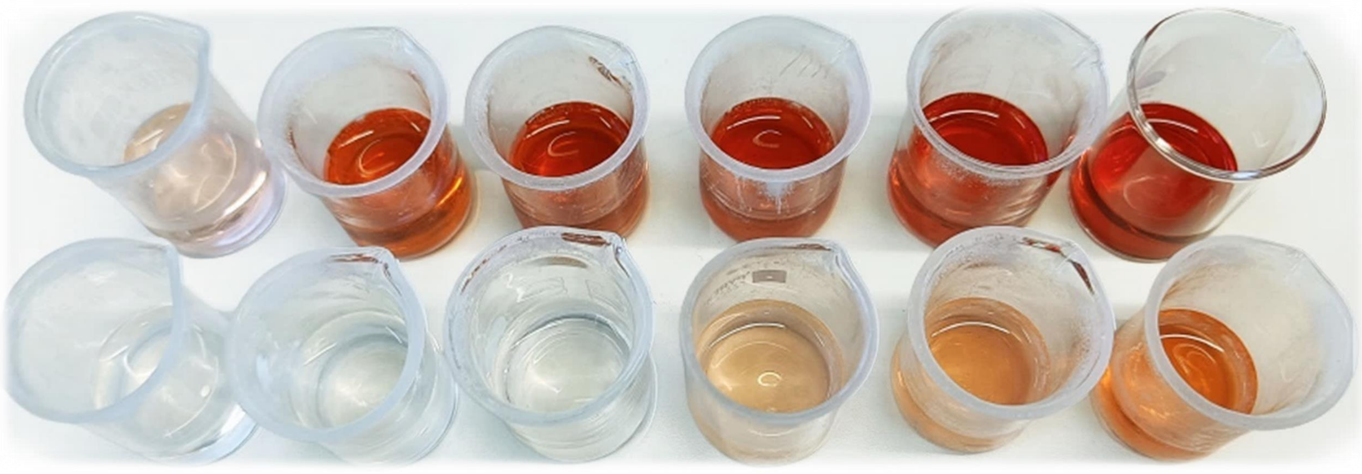

Figure 6 – Imaging of the dye removal process

CONCLUSIONS

This study aimed to show the adjustability of BAC's properties by different activation methods. The adsorption affinity of chemically activated BACs activated with copper oxide (BAC-Cu), iron oxide (BAC-Fe), and sodium hydroxide (BAC-Na), was tested on NOM adsorption, resulting in high removal of NOM: 87% with BAC-Cu, 97% with BAC-Fe and 80% with BAC-Na. The physically activated BACs were produced from locally available waste biomasses: wood sawdust and fruit stones with walnut shells. The physically activated BACs demonstrated high adsorption capacities for dye - 253 mg/g for WAC and 212 mg/g for HAC. This points towards a wide range of BAC production methods to create carbons from renewable sources and with desired properties.

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