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Research

Surface modification of *Trema orientalis* wood biochar using natural coconut vinegar and its potential to remove aqueous calcium ions: column and batch studies

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ABSTRACT

Recent investigations have revealed the harmful health effects of elevated calcium levels in drinking water. Chemically activated biochar is the most popular option for low-cost cation adsorption. However, most of these chemicals are hardly available for rural communities, corrosive, and difficult to handle by unskilled personnel. This study aimed to determine the ability of natural coconut vinegar, a common mild acid, to activate *Trema orientalis* wood biochar pyrolyzed at 300°C (BC) as a facile, safe, and low-cost approach for aqueous calcium ion (Ca^{2+}) removal. Column tests showed a two-fold increase of Ca^{2+} adsorption capacity and a ten-fold increase of Ca^{2+} retaining capacity of BC after activation with vinegar. The isotherm results were well correlated with the Langmuir model. The maximum Langmuir adsorption of the activated biochar (BC-A) was 9.96 mg/g. Ca^{2+} amount was determined using flame photometry. EDX analysis showed that the O/C ratio of BC increased from 0.07 to 0.13 after activation. FTIR and wettability studies showed increased oxygenated functional groups on the BC-A surface. The authors suggest a possible acid-catalyzed hydration of the C-O-C bridges of the biochar, introducing new hydroxyl/carbonyl/ester/carboxylic/lactone groups to the biochar surface due to the vinegar activation, enhancing Ca^{2+} adsorption through chemisorption.

Keywords: Adsorption capacity, Adsorption isotherms, Biochar, Calcium, Coconut vinegar, *Trema orientalis*

1. Introduction

In most developing countries, untreated groundwater or surface water is the sole source of drinking water for many communities [1]. Higher Ca^{2+} levels are common in most untreated water sources worldwide [2]. Recent research has provided evidence that higher Ca^{2+} levels cause dangerous health effects when combined with other factors, such as fluorides in water. A detailed hydro-geochemical investigation revealed a significantly lower sodium to calcium ratio in areas with a prevalence of Chronic Kidney Disease of unknown etiology (CKDu) in Sri Lanka, suggesting that high Ca^{2+} activity aggravates the damage caused by fluoride, which results in possible lesions on tubular cells of the kidney tissue [3]. A recent study conducted using rats also supports this idea. In the latter study, hard water with high fluoride content resulted in acute tubular injury in the tested rats [4]. In addition, the number of CKDu patients recorded has had a marked positive relationship with the extent of ground water hardness in Sri Lanka [5]. A number of advanced technologies have been proposed to purify water with varying degrees of success, such as ion exchange, reverse osmosis, and electrochemical treatment [6, 7]. However, complicated procedures and high operational and maintenance costs restrict rural communities from benefitting from them. Hence, the need for a low-cost and facile domestic process to reduce Ca^{2+} in drinking water is identified to improve the health and living standards of low-income communities.

Over the last few decades, adsorption has emerged as one of the most popular, efficient, and convenient methods for low-cost water treatment. Carbonaceous adsorbents are commonly used for the removal of various pollutants from water because of their abundance and cost-effectiveness [8, 9]. Biochar characteristics depend

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