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ORIGINAL PAPER

Characterisation and optimisation of *M. oleifera* for the removal of humic substances from peat water

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Abstract
The application of peat water may be able to address the problem of water scarcity. This study used *Moringa oleifera* seed as a coagulant via jar tests in a series of coagulation-flocculation processes to remove humic substances (HS) from peat water. Characterisations were performed on the coagulant and peat water. GC–MS analysis showed that oleic acid and octadecanoic acid are two of the main parts of the seeds that help in the coagulation process. FTIR analysis revealed that the coagulant consists of hydroxyl, carboxyl, and amino groups that can be ionised. To attain the maximum HS removal of peat water, three parameters, namely coagulant dosage, pH value, and contact time, were varied and optimised by response surface methodology (RSM) via Box-Behnken Design. The quadratic model predicted that the ideal condition of 1.94 g/L of coagulant, pH 7.6, and a contact time of 86 min would result in 91.1% of HS removal, which was comparable with the experimental value of 88.4% removal. Antimicrobial study was performed using ethanolic and hexanic extracts of moringa powder. The largest inhibition zone was demonstrated by the ethanolic extracts against *S. aureus* (18.33 ± 0.58 mm), while the weakest activity was observed in hexanic extract against *E. coli* at 5.00 mm. This proves that the coagulants possess antibacterial properties against both types of microbes. By using a modified jar test, this study sheds new light on the possibility of using peat water as a source of water and *M. oleifera* as a possible natural coagulant.

Keywords *M. oleifera* · Coagulant · Peat water · Jar test · Response surface methodology · Antibacterial

Introduction

Poor sanitation, contaminated water, or a lack of access to clean water especially in low-income and developing countries have been associated with various diseases and illnesses (Clasen et al. 2014). The relentless pursuit of effective and low-cost water treatment techniques is therefore necessary. Coagulation-flocculation, which uses water coagulants to separate suspended particulates from water, is used in wastewater treatment plants (Koohestanian et al. 2008; Kurniawan et al. 2020). Commercial coagulants made of iron and aluminium salt are often used to treat wastewater. However, long-term health effects from using these coagulants to treat drinking water have been recorded which included neurodegenerative diseases, Parkinson's disease and others (Bondy and Campbell 2017; Inan-Eroglu and Ayaz 2018; Sieliechi et al. 2010). Thus, organic, non-hazardous, biodegradable, and potentially carbon–neutral plant-based coagulants are sought after (Hamad et al. 2016; Saleem and Bachmann 2019).

Moringa oleifera is a native Indian plant that thrives in tropical and subtropical climates worldwide (Abdull Razis et al. 2014; Gopalakrishnan et al. 2016). It is also referred to as the "miracle tree" because every part of the tree possesses beneficial properties that could benefit humanity (Ashfaq et al. 2012; Daba 2016). The powdered seed *M. oleifera* has coagulant properties that have been used to improve the clarity of various types of water which includes dye, synthetic turbid water (kaolin suspension), and municipal wastewater (Al-Kindi and Al-Haidri 2021; Ali et al. 2012; Mathivanan and Elumalai 2017; Taiwo et al. 2020).

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