Water Treatment by Adsorption on Sage-Based Adsorbents: Removal of Pollutants and Phytotoxicity

Authors

Marwa Rammal (marwa.rammal.1@ul.edu.lb) * 1 Lebanon
Akram Hijazi (akram.hijazi@ul.edu.lb) * 2 Lebanon
Dalia Massoud (Dalia.Massoud@st.ul.edu.lb) * 3 Lebanon
Salem Darwich (Salem.darwich@ul.edu.lb) 4 Lebanon
Heba Hellany (he115@aub.edu.lb) * 5 Lebanon

Affiliations

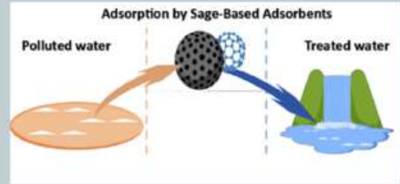
1 Department of Food and Technology Studies, Lebanese University, Beirut, P.O. Box 146404, Lebanon
2 Lebanese University Platform de recherche et d'analyse en sciences de l'environnement (ESDT-PRASE), Beirut P.O Box 6573/14, Lebanon
3 Lebanese university, Beirut, laboratory Sciences , Faculty of public health , Lebanese university, Hadath , Lebanon.
4 Lebanese University Faculty of Agronomy
5 Biology, American University of Beirut, Beirut P.O. Box 11-0236, Lebanon

Introduction

Water pollution from nitrates, phosphates, bacteria, and dyes poses major health and environmental risks. To address this, sustainable and low-cost purification methods are essential. This study investigates Salvia officinalis (sage) as a natural source for activated charcoal, evaluating its adsorption efficiency and phytotoxicity as an eco-friendly approach to water treatment."

Objective

The study evaluates sage-derived adsorbents for sustainable water purification, focusing on pollutant removal, activation effects, and environmental safety assessed via phytotoxicity tests on both the filtrate and solid adsorbents.



Methodology

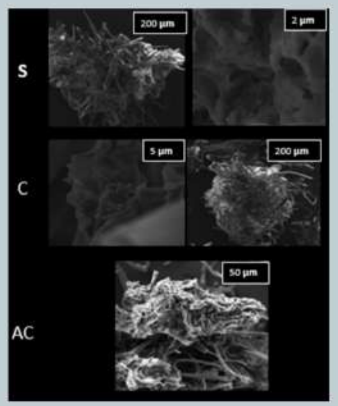
This study employed an experimental approach to evaluate the adsorption performance and environmental safety of Salvia officinalis (sage)-derived adsorbents for water treatment. Three materials were prepared from sage biomass—sage powder (S), charcoal (C), and activated charcoal (AC)—through washing, drying, pyrolysis, and chemical activation processes.

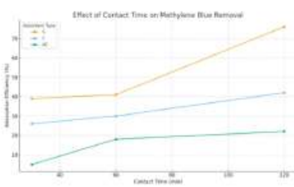
Laboratory experiments were conducted to assess the removal of methylene blue, nitrate, and phosphate using batch adsorption tests under controlled conditions. The antibacterial activity of the adsorbents was also evaluated against Streptococcus sp, total coliforms, and E. coli using selective culture media.

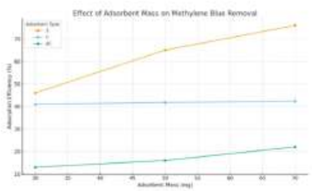
Adsorbents were characterized by pH, conductivity, and Scanning Electron Microscopy (SEM) to observe surface modifications. Phytotoxicity assays on Lepidium sativum and Eruca vesicaria were performed to ensure environmental compatibility.

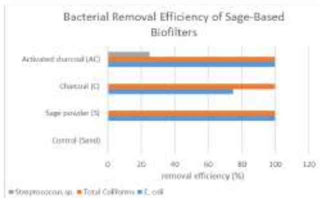
Results

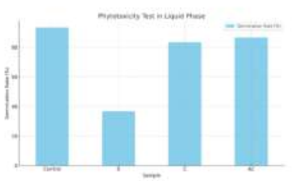
Three adsorbents derived from Salvia officinalis—sage powder (S), charcoal (C), and activated charcoal (AC)—were tested for water treatment. pH and conductivity varied with treatment: AC was the most acidic and least conductive, while C showed the highest conductivity. SEM images revealed increased porosity after pyrolysis and activation. In antibacterial tests, S and AC fully removed E. coli and total coliforms; C partially removed E. coli; only AC showed slight (25%) inhibition of Streptococcus sp. Dye adsorption increased with contact time and adsorbent mass, reaching 76% removal with S. AC showed better performance for nitrate (34%) and phosphate (49%) adsorption. In liquid tests, S caused high phytotoxicity, while C and AC showed moderate to low effects. In solid phase, all samples achieved 100% germination; S showed the highest shoot length (4.3 cm), confirming no phytotoxicity and a potential growth-promoting effect.

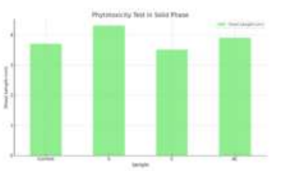


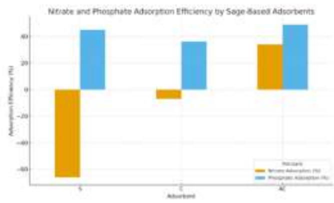












Analysis

The findings highlight the strong influence of treatment conditions on adsorption performance. Increased porosity and surface functionalization improved pollutant removal efficiency, especially for AC. The antibacterial effect of S and AC reflects the presence of phenolic compounds and enhanced surface reactivity. The solid-phase phytotoxicity results confirm the environmental safety of the materials, suggesting that sage-derived adsorbents—particularly activated charcoal—offer a sustainable and effective approach for water treatment.

Conclusion

This study investigated sage-derived materials—raw powder, charcoal, and activated charcoal—for the removal of organic, inorganic, and microbiological pollutants from water. Sage powder showed the highest removal of methylene blue (76%), while activated charcoal was more efficient for nitrate and phosphate adsorption. All materials exhibited antibacterial properties, with activated charcoal being the most effective. Phytotoxicity tests revealed minimal impact of AC in water and growth promotion by sage powder in soil. Overall, these findings demonstrate the potential of Salvia officinalis biomass as a sustainable adsorbent, highlighting how processing methods influence its adsorption and environmental performance.