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Fluoride removal by palm shell waste based powdered activated carbon vs. functionalized carbon with magnesium silicate: Implications for their application in water treatment

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HIGHLIGHTS

- $MgSiO_3$ impregnated on PSAC for fluoride removal was studied for the first time.
- MPSAC showed higher fluoride adsorption capacities compared to PSAC.
- Anions inhibited F^- adsorption with the following sequence: $Cl^- < NO_3^- < SO_4^{2-}$.
- PSAC had stable sequestration capacities of fluoride due to strong C–F bond formation.
- MPSAC had high regeneration capacities for ex-situ fluoride treatment using NaOH.

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ABSTRACT

In this study, palm shell activated carbon powder (PSAC) and magnesium silicate ($MgSiO_3$) modified PSAC (MPSAC) were thoroughly investigated for fluoride (F^-) adsorption. F^- adsorption isotherms showed that PSAC and MPSAC over-performed some other reported F^- adsorbents with adsorption capacities of 116 mg g^{-1} and 150 mg g^{-1}, respectively. Interestingly, the $MgSiO_3$ impregnated layer changed the adsorption behavior of F^- from monolayer to heterogeneous multilayer based on the Langmuir and Freundlich isotherm models verified by chi-square test (X^2). Thermodynamic parameters indicated that the F^- adsorption on PSAC and MPSAC was spontaneous and exothermic. PSAC and MPSAC were characterized using FESEM-EDX, XRD, FTIR and XPS to investigate the F^- adsorption mechanism. Based on the regeneration tests using NaOH (0.01 M), PSAC exhibited poor regeneration (<20%) while MPSAC had steady adsorption efficiencies (~70%) even after 5 regeneration cycles. This is due to highly polarized C–F bond was found on PSAC while Mg–F bond was distinguished on MPSAC, evidently denoting that the F^- adsorption is mainly resulted from the exchange of hydroxyl (-OH) group. It was concluded that PSAC would be a potential adsorbent for in-situ F^- groundwater remediation due to its capability to retain F^- without leaching out in a wide range pH. MPSAC would be an alternative adsorbent for ex-situ F^- water remediation because it can easily regenerate with NaOH solution. With the excellent F^- adsorption properties, both PSAC and MPSAC offer as promising adsorbents for F^- remediation in the aqueous phase.

1. Introduction

Fluoride (F^-) is one of the most abundant elements presents in water bodies and it is an important micronutrient for human beings to maintain healthy tooth and bones with an appropriate intake amount. The tolerable limit of F^- in drinking water suggested by

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