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Abstract

The synthesis of mineral-carbon composites from fruit pomace waste as a carbon precursor, and mined halloysite, halloysite nanotubes and kaolinite as mineral templates was described. The synthesis was carried out at mass ratios fruit pomace waste to mineral carrier 9:1 and 18:1, and with heating temperatures 500°C and 800°C in nitrogen atmosphere.

The mineral-carbon composites were characterized using the following methods: low-temperature nitrogen adsorption, X-ray photoelectron spectroscopy (XPS), Inverse gas chromatography (IGC), scanning electron microscopy with energy dispersion spectroscopy (SEM/EDS analysis), Fourier transform infrared spectroscopy (FTIR), Raman spectroscopy, determination of the point of zero charge (pH_{PZC}), determination of oxygen functional groups by the Boehm method, determination of carbon concentration.

Based on nitrogen adsorption/desorption isotherms, it was demonstrated that the specific surface areas of the resulting mineral-carbon composites were higher than those of the unmodified minerals. The SEM/EDS analysis confirmed carbon presence on the composite surface. Fourier transform infrared spectroscopy (FT-IR) allowed confirmation of changes in the surface of the resulting composites compared to the unmodified minerals. Raman spectroscopy confirmed the presence of crystalline carbon in the mineral-carbon composites. The Boehm method revealed the presence of both acidic and basic groups on the surface of the composites. The pH_{PZC} value for the CHS1a composite was 6.45. The inverse gas chromatography method showed that the dispersive component of surface energy for CHS1a was 252.2 mJ/m^2.

The mineral-carbon composites obtained were used as adsorbents for tetracycline, doxycycline, ciprofloxacin and sulfamethoxazole in water. The effect of the type of adsorbent on the adsorption process was investigated. Based on the studies conducted, the CHS1a halloysite-carbon adsorbent was identified as the best for the adsorption of selected antibiotics from water. Therefore, the CHS1a adsorbent was selected for further studies on adsorption from water. The effect of adsorbent mass, initial pH, contact time, initial concentration and temperature on the adsorption process was investigated.

It has also been demonstrated that it is possible to correlate the removal efficiency of the adsorbates under investigation with parameters such as specific surface area, pore volume and

the dispersion component of surface energy, as well as with the donor-acceptor properties of these adsorbents.

Measurements of adsorption kinetics on the CHS1a adsorbent showed that adsorption follows a pseudo-second-order kinetic model for all the antibiotics studied. The rate constants increased in the following order: ciprofloxacin < doxycycline < tetracycline < sulfamethoxazole.

Measurements of adsorption isotherms showed that the best fit to the experimental data was obtained using the multicentre Langmuir adsorption model. The values of the adsorption constants decreased with increasing temperature, suggesting an exothermic nature of the adsorption process. The adsorption equilibrium constants increased in the order: sulfamethoxazole < ciprofloxacin < doxycycline < tetracycline.

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