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The synthesis and characterization of activated carbon from sewage sludge as low cost bio-adsorbent for nitrate and cationic dye pollution remediation

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ABSTRACT

Sewage sludge is an inevitable waste from wastewater treatment plant. in South Africa, landfilling of sewage sludge remains the principal route of management. This study aims to synthetise bio-adsorbent from sewage sludge and discard coal.

This study plan to synthetise bio-adsorbent from sewage sludge and discard coal as precursor. To achieve this purpose: two types of municipal wastewater sewage sludge were collected from the ERWAT wastewater treatment plant in the Mid-Vaal district (South Africa). The secondary sludge, which was a dissolved air flotation stage outlet, was labeled as (D), while the digested and dewatered (with filter belt) sludge (primary and secondary) ready for disposal was labelled as (D) (S). The activating reagent concentration (Potassium Hydroxide: KOH), temperature, and mixture with discard coal were chosen as variables to consider in the sewage preparation based on literature. Precursors sludge TGA curves with temperatures varying from 30 °C to 900 °C in nitrogen (N_2) atmosphere were used to determine the minimum pyrolyzed temperature (minimal weight variance located about 600 °C). Two numerical variables (pyrolysis temperature and KOH concentration) and two categorical variables (types of sewage sludge samples blended with/without discard coal) were used to synthesize activated carbon from sludge. The effect of the synthesis variables on the low cost activated carbon derived properties in comparison to commercial activated carbon was investigated using response surface methodology (RSM) with eight responses. R1 (Specific surface area: m^2/g), R2 (micropore surface area/total surface area*100: %), R3 (Cations Exchange Capacity (CEC): meq/100g), R4 (pH_{pzc}), R5 (Acidity: mmol/g), R6 (Basicity: mmol/g), R7 (N/C ratio), R8 (H/C ratio) were the eight responses considered.

In contrast to the precursors, FT-IR (Fourier Transform Infrared Spectroscopy), SEM/EDS (Scanning Electron Microscopy-Energy Dispersive Spectroscopy), BET (Brunauer–Emmett–Teller), and XRD (X-Ray Diffraction) study reveal evidence of surface functionalities, morphology, texture, and crystalline structures transformation after activation. Furthermore, the Toxicity Characteristic Leaching Procedure (TCLP) test revealed that after activation, the concentrations of Cu, Zn, Pb, Ni, Co, Cr, Fe, and Mn decreased significantly, indicating that the metals had stabilized. The effect of

sludge type was also examined, and two types of bio-adsorbents with the best surface areas were chosen for oxidation ammonium persulfate: SC-3-600 (281,72 m^2/g) and SC-5-900 (422,09 m^2/g) from S sludge, and DC-5-750 (312,72 m^2/g) and DC-7-900 (247,57 m^2/g) from D sludge. After triggering precursors synthesized with sewage and waste coal, the bio-absorbent was obtained. FT-IR analysis revealed the introduction of an acidic surface functional group after oxidation with ammonium persulfate in all cases, although Raman spectroscopy revealed a minor graphitization advancement over disordered carbon structure. However, after oxidation with a 2M ammonium persulfate dissolved in 1M H_2SO_4 solution, the texture of SC-3-600 and SC-5-900 was seriously affected, dropping from 281,72 m^2/g and 422,09 m^2/g, respectively, to 46,57 m^2/g and 313,05 m^2/g after oxidation. The differences were less significant in the case of DC-5-750 and DC-7-900, which started with a surface area of 312,72 m^2/g and 247,57 m^2/g, respectively, and ended up with 282,22 m^2/g and 295,31 m^2/g after oxidation. The highest nitrate adsorption capacity was found in an acidic solution (pH 2), while the highest methyl red adsorption capacity was found in a mild acidity solution (pH4).

For both nitrate and methyl red, the adsorption process using synthesized adsorptions was primarily represented by the pseudo kinetic model rather than the pseudo first-order kinetic model, and the intraparticle model diffusion was not found to be the sole controlling mechanism in both cases. For nitrate, the Langmuir isotherm model suits the adsorption process better in the following order: For methyl red, DC-5-750 (26,735 mg/g) > Com-AC (20,618 mg/g) > DC-7-750 M1 (17,064 mg/g) DC-5-750M2 (175, 438 mg/g) > DC-7-750 (147,058 mg/g) > Com-AC (196,07 mg/g). The adsorption was favorable in all cases because R_L (Langmuir constant) was between 0 and 1. Thermodynamic data analysis revealed that nitrate uptake was exothermic, spontaneous at lower temperatures, and had an S value of < 0, while adsorptive methyl red (MR) removal was endothermic, feasible, and spontaneous with an S value of >0.