Abstract

The disposal of coal discards (CD) and sewage sludge (SS) is a substantial problem to waste management in coal beneficiation and wastewater treatment plants (WWT). This work investigates essential aspects for contributing to the reduction of environmental effects, with a particular emphasis on the hydrothermal carbonization (HTC) technology for the synergetic treatment of CD and SS to produce value-added carbonaceous materials (CM). When compared to the individual treatment of CD and SS, the Co-hydrothermal carbonization (Co-HTC) method improved the physicochemical attributes of the produced hydrochars (HCs). The produced HCs could be suitable for a wide range of potential applications i.e., soil amendment, WWT, production of activated carbon (AC). The findings of this thesis indicate that profitable commodities may be made from the aforementioned waste materials, lowering the cost of waste disposal and ecological damage while also providing new green jobs. South Africa, as one of the world's top coal producers, creates approximately 60 million tons of coal waste each year, which is typically stockpiled in the form of a discard dump and slurry ponds. The environmental risk and public health risk posed by the presence of these wastes represent a significant impediment to the socioeconomic growth of the coal mining sector. As a result, waste coal management is advised to devise innovative approaches for the reuse and recovery of coal waste. In this thesis, the HTC and co-HTC of CD and CD-SS blend respectively has been experimentally performed for the upgrading of the fuel properties and adsorbent characteristics of the raw material utilized proving the ability of HTC to produce high-quality HCs from CD alone or in conjunction with SS as precursors for decontamination of polluted waters and energy storage.

The absorbent properties of the obtained HCs were evaluated in this study on the removal of nonbiodegradable pharmaceutical products dissolved in recycled water. The Co-HTC-derived hydrochar (HCB) had a high SBET of 20.35 m^2/g and pore volume of 0.38 cm^3/g, leading to significant adsorptive reductions of nevirapine (NEV) and lamivudine (LAM) (97.19% and 93.32%, respectively). The HC from coal tailing (HCT) and HC from coal slurry (HCS) displayed high NEV and LAM adsorption

capacities (50 mg g^{-1}, 42 mg g^{-1} and 52 mg g^{-1}, 41 mg g^{-1}) respectively despite being less effective than HCB (53.8 mg g^{-1}, 42.8 mg g^{-1}). In addition, the use of spent adsorption residues for energy storage applications was investigated further. The results revealed that the textural structure of the produced ACs electrode from the spent residues has a significant impact on the electric conductivity qualities. The produced ACs exhibited roughly rectangular cyclic voltammetry shape, good reversibility and stability as observed from the ideal electrical double-layer capacitors (EDLCs). These findings showed that spent adsorption residues are an effective CM precursor for the production of excellent EDLCs for current densities ranging from 1 A/g to 5 A/g in energy storage applications.

Furthermore, the synthesis of AC from the obtained HCs for adsorptive hydrogen storage was conducted. The hydrogen adsorption characteristics of the produced ACs were evaluated at 77 K and 293 K and 40 bars. The results indicate that the values of hydrogen adsorbed onto the ACs were approximatively 6.12wt%, 6.8wt% and 6.57 wt% for AC-HCT, AC-HCS and AC-HCB respectively at 35 bars implying that they could be used for hydrogen storage, sustainable carbon emissions management and provide viable pathways for cost-effective energy and material circular economies for both WWTPSs and the mining industry.