Project Report 2024

Performance and characterization of two activated carbons of biogas treatment applications

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Objectives: short, medium and long term

The aim of the project is the study of sulfur removal through adsorption systems, investigating the behavior and adsorption capacity of some commercial adsorbent materials. In particular, two impregnated activated carbons, AC Airpel Ultra DS (treated with KOH-KI) supplied by Desotec and AC RGM1 (impregnated with Cu-Cr salts) supplied by Norit, have been tested using different matrices, including biogas ones, in dry and wet conditions and also in presence of small percentages of oxygen in the gas carrier. Moreover, the characterization of the adsorbent materials before and after their use is done through nitrogen adsorption-desorption measurements (B.E.T. method), to verify modifications in terms of specific surface area and/or micropore volume.

Brief summary of work carried out

The adsorption runs were carried out using a fixed-bed flow reactor made of quartz with temperature control. The outlet H2S concentration was detected using an electrochemical sensor, able to operate a continuous measurement. The used gas matrices consist on different mixtures of N2/CO2/CH4/O2/H2O, to identify the effect of single components. The tested activated carbons, RGM1 and Airpel Ultra DS, were ground and sieved to obtain homogeneous powders in the range 250-350 μm. The adsorption runs consist on breakthrough tests needed to identify the breakthrough point (connected to the tolerance limit of high temperature fuel cells), then used to calculate the H2S adsorption capacity of the filter. The experimental results highlighted a different behavior of the two carbons related to inlet gas composition. In particular, for Airpel Ultra DS, the presence of CO2 caused a strong decrease of H2S adsorption capacity, occurring both in dry and wet condition, due to the competition in adsorption between CO2 and H2S on the basic sites of this carbon. Moreover, the experimental data showed an enhancement of filter performance using CH4 as gas matrix instead of N2. This phenomenon can be ascribed to the different polarizability of the two molecules, due to the isotropic and non-isotropic nature of CH4 and N2 respectively. On the contrary, RGM1 adsorption capacity was not influenced by the change of gas matrix, revealing a different mechanism of interaction. In wet conditions (R.H. 90%), higher values of adsorption capacity were obtained, due to the dissolution of H2S molecules in the water film that cover the pores. In the case of Airpel Ultra DS, the presence of water promotes also the acid-base neutralization processes. The use of small amounts of oxygen (2%) in the gas matrix led to an increase of H2S adsorption capacity, because of the realization of oxidation reactions beside adsorption phenomena, able to

partially counterbalance the negative effect of CO2. The comparison between B.E.T. measurements on the virgin and spent samples revealed a diminution of both specific surface area and micropore volume, that indicated the presence of adsorbed H2S molecule in the solid frame of the carbons, not desorbed during the degassing phase.

Main achievements intended for publication

The work studied the synergetic effect of some operating parameters, in terms of gas composition (gas matrix, humidity and presence of oxygen), on H2S adsorption capacity of two commercial activated carbons characterized by different treatments (KOH and Cu-Cr salts respectively). This investigation started from the results of previous works, where a systematic study of the individual effects of the above mentioned parameters had been studied on the same activated carbons. In particular, the different behavior of the two carbons towards gas matrices constituted by various concentrations of N2/CO2/CH4/O2/H2O gases was demonstrated and the results were explained in terms of physical and chemical characteristics of the adsorbent materials.
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Difficulties encountered

The use of high percentages of humidity required an accurate temperature management in the different sections of the test bench, from the injection to the detection points, to avoid water vapor condensation.

Further comments

Additional activity could be done to better explain the role of CH4/N2 matrices on H2S adsorption. Moreover, the co-presence of different pollutants, such as H2S and mercaptans, in the gas stream could be further investigated.