A multicompartment Taylor-Couette flow hemofilter was designed to remove toxins from a patient's bloodstream via immunoadsorption. This device (Vortex Flow Plasmapheretic Reactor, VFPR) treats blood plasma with a fluidized-bed of small ($45-165 \times 10^{-6}$ m diameter) particles, while protecting fragile blood cells from lysis. The potential application for the VFPR is dialysis-related amyloidosis, a disease associated with the systemic accumulation of beta-2-microglobulin in patients with long-term kidney failure. The equilibrium behavior of immunoadsorptive gel beads is characterized experimentally and theoretically using confocal microscopy and the Langmuir adsorption isotherm. The importance of external mass-transfer resistance within the active compartment is assessed through dissolution studies conducted with benzoic acid particles. These results are combined with mass-transfer fundamentals to develop a dynamic immunoadsorption model. The modeling results, without the use of adjustable parameters, agree with the experimental data and provide a foundation for further development and eventual application.