Adsorption of Polyquaternium-10 Polymers by Activated Sludge Mixed Liquor Solids

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Abstract:

Adsorption isotherms of four Polyquaternium-10 polymers (PQ-10) (quaternary ammonium derivatives of hydroxyethyl cellulose) by activated sludge mixed liquor solids (MLS) were obtained using phenol method with matrix-matched calibration standards (low molecular mass JR-125 and LR-400 and high molecular mass JR-30M and LR-30M). Solution concentrations of all PQ-10 polymers at low dosing were negligible, within the limitation of the analytical method used. At some level of dosing, subsequent increase in polymer dosage resulted in a quantifiable increase of solution concentration ("solution concentration rising" region). Adsorption isotherms were non-linear. Below some "threshold value" solution concentration of the polymer was close to zero and above this value it increased linearly with increase of the dosage. The "threshold values" for all tested polymers are much higher than the loadings expected to be present in domestic sewage. Therefore, PQ-10 polymers discarded in domestic sewage are likely strongly adsorbed by activated sludge and removed from the wastewaters by commonly used wastewater treatment process.

Project Focus:

Polyquaternium-10 polymers are extensively used as components of personal and home care products, as conditioners, humectants, viscosity control agents, and deposition aids. Therefore, they are released into wastewaters. Like other cationic polymers, PQ-10 are considered toxic to aquatic organisms and should be removed by wastewater treatment process. Adsorption by activated sludge solids is assumed as the most significant pathway for removal of cationic polyelectrolytes from the wastewater. However, little supporting data is available. The goal of this project was to assess adsorption isotherms of 4 widely used PQ-10 polymers of varying molecular weight (MW) and charge densities to activated sludge MLS.

Experimental Design:

- Freshly collected, washed with aqueous mineral medium, activated sludge MLS were placed in the test vessels and test medium was added to make total suspended solids (TSS) concentration 3 g/L.
- Vessels were dosed with the polymer dosing solutions to provide initial concentrations of the polymers from 10-30 to 500-700 µg activate ingredient/mL (corrected for ash and volatiles).
- To obtain adsorption isotherms, the test systems were equilibrated for 2 hours at 20±2 °C. After this, the vessels were centrifuged, and the supernatants were analyzed using phenol method with matrix-matched calibration standards.

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Results

- Calibrations (relationships between nominal concentration of the polymer and light absorbance of analytical mixtures at wavelength of 487 nm) for all four polymers within a concentration range of 0 to 100 µg activate ingredient/mL were close to linear and did not change with the period of 1, 2, 3, and 4 hours.
- Adsorption of each polymer by MLS reached a plateau after approximately 2 hours of equilibration.
- Dose-response curves (Figure 1.) calculated as amounts dosed per gram of oven-dry mass of activated sludge solids versus equilibrium concentrations in the aqueous phase were non-linear.
- Solution concentrations at relatively low dosing were negligible or apparently negative (apparent "total adsorption" region of dose-response curve). At some level of dosing, a subsequent increase in polymer dosage resulted in an increase of solution concentration ("solution concentration rising" region).
- The apparent adsorption isotherms (relationships between concentration of adsorbed polymers and concentration of the polymers in the aqueous phase) (Figure 2.) were non-linear.

Figure 1. Dose - Response Curves

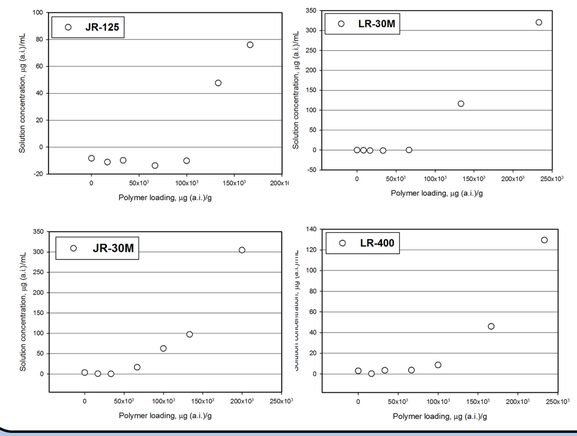
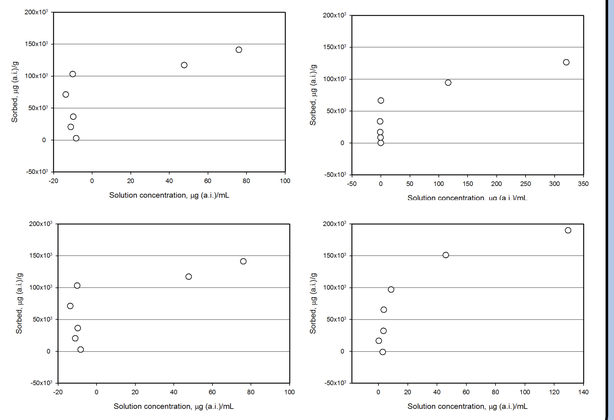


Figure 2. Apparent Adsorption Isotherms



Discussion:

1. Negligible aqueous concentrations of all tested polymers at low dosages were likely caused by the retention of the polymers by the activated sludge MLS. After some portion of polymer was strongly bound, the subsequent amounts of polymer were bound less strongly or not bound.
2. The ability of MLS to bind polymers may be characterized by apparent "binding regions" of the MLS with respect to each polymer. The "threshold value" (binding capacity providing apparently zero solution concentration) was approximately 100 mg activate ingredient /g for relatively low molecular mass JR-125 and LR-400 and approximately 70 mg activate ingredient/g for relatively high molecular mass JR-30M and LR-30M.
3. The approach based on the assumption that concentration of adsorbed chemical is proportional to the concentration in the aqueous phase with adsorption distribution coefficient Kd remaining constant is not applicable over the range of concentration tested.
4. The "threshold values" for all tested polymers are much higher than the loadings expected to be present in domestic sewage commonly processed by wastewater treatment plants.