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Predicting nitrate contamination in recently recharged groundwater: High Plains regional aquifer

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The High Plains regional aquifer, a nationally important groundwater resource, has widespread elevated nitrate concentrations in recently recharged groundwater. This condition has created a potential health concern for nearly 2 million people who rely on the aquifer for drinking water. Concentrations and spatial distribution of nitrate are influenced by anthropogenic activity, particularly from non-point source contamination. A novel groundwater vulnerability assessment encompassing the entire High Plains aquifer is presented that predicts areas of the aquifer where nitrate concentrations are expected to exceed a background value of 4 mg/L as N in recently recharged groundwater, defined as less than 50-years old. This model couples particle-tracking simulations and multivariate logistic regression analysis within a GIS framework, thereby incorporating site-specific hydrogeologic parameters and the groundwater flow regime. Contributing areas, delineated by a 90-degree sector, represented the capture zone up gradient from the well location and defined the area for GIS-based extraction of explanatory variables for statistical modeling. Particle-tracking simulations identified the appropriate radial length for the sector and well screen depths corresponding to recently recharged groundwater. Horizontal and vertical particle movements were most sensitive to hydraulic conductivity and estimates of recharge, respectively. The final multivariate logistic regression model demonstrated statistical significance ($p < 0.001$), produced an excellent model fit ($R^2 = 0.912$), and was validated with an independent nitrate data set ($R^2 = 0.856$). Statistically significant explanatory variables in the contributing areas included percent agricultural land ($p < 0.001$), depth to water table ($p = 0.001$), soil infiltration score ($p = 0.013$), nitrogen applied as fertilizer on irrigated agricultural land ($p = 0.050$), and percent clay in the unsaturated zone ($p = 0.040$). Predicted groundwater vulnerability corroborated our conceptual model that nitrate concentrations are directly related to nitrogen loading at land surface and infiltration in the soil zone, and inversely related to impedances to downward advective chemical movement through the unsaturated zone. The nitrate vulnerability model and map offer a predictive tool for water resource managers to identify likely areas of non-point source contamination and evaluate the impact of anthropogenic activity on nitrate distribution in groundwater.