A stoichiometric equation and kinetic model were developed and validated using experimental data from batch respirometer studies on the biodegradation of 2,4-dinitrotoluene (DNT). The stoichiometric equation integrates bacterial energetics and is revised from that in a previous study by including the mass balance of phosphorus (P) in the biomass. Stoichiometric results on O2 consumption, CO2 evolution, and nitrite evolution are in good agreement with respirometer data. However, the optimal P requirement is significantly higher than the stoichiometrically derived P, implying potentially limited bioavailability of P and the need for buffering capacity in the media to mitigate the adverse pH effect for optimal growth of DNT-degrading bacteria. An array of models was evaluated to fit the O2/CO2 data acquired experimentally and the DNT depletion data calculated from derived stoichiometric coefficients and cell yield. The deterministic, integrated Monod model provides the goodness of fit to the test data on DNT depletion, and the Monod model parameters (Ks, X0, mumax, and Y) were estimated by nonlinear regression. Further analyses with an equilibrium model (MINTEQ) indicate the interrelated nature of medium chemical compositions in controlling the rate and extent of DNT biodegradation. Results from the present batch respirometer study help to unravel some key factors in controlling DNT biodegradation in complex remediation systems, in particular the interactions between acidogenic DNT bacteria and various parameters, including pH and P, the latter of which could serve as a nutrient, a buffer, and a controlling factor on the bioavailable fractions of minerals (Ca, Fe, Zn, and Mo) in the medium.