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中文题名	细颗粒泥沙吸附规律及粘性絮团的絮凝与起动特性研究
英文题名	Properties of the Adsorption, Flocculation and Threshold Motion of the Fine-Grained Sediment
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中文文摘	细颗粒泥沙广泛存在于河流、湖泊等天然水体及床面。在表面电化学作用下，颗粒表面吸附效应显著、颗粒间存在粘结絮凝，影响水体中泥沙和污染物的存在形式以及迁移转化过程。传统研究中假定泥沙颗粒为均质光滑球体，而实际泥沙颗粒具有异质性，矿物组成复杂、表面具有非均匀形貌和电荷分布。已有研究缺少对泥沙表面异质特性的影响分析，本文将结合泥沙主要组成矿物，研究颗粒表面异质特性对颗粒吸附及粘结絮凝等过程的影响。 利用高分辨率的显微观测设备对颗粒表面微观形貌和电荷分布进行观测，提出基于泰勒展开的形貌表征方法，并对表面微形貌和电荷分布信息进行统计表征。结果显示，颗粒表面存在复杂形貌和不均匀的电荷分布；泰勒二阶展开项反映颗粒表面微凸起或凹陷形貌，对表面电荷分布影响显著。颗粒表面异质特性会影响表面吸附特征，不同矿物颗粒不同微形貌处吸附概率变化趋势不同，其吸附量分布近似为 Weibull 分布。Sips 模型可表征颗粒表面异质吸附特性，其异质吸附参数、最大吸附能力随表面异质形貌增大而增大；利用组分累加法，可通过纯矿物吸附特性对天然泥沙的吸附进行预测。研究中提出颗粒分配系数的定量表征，可计算不同颗粒性质及外界环境条件下分配系数的变化，简便地应用于水质模型中。 颗粒表面不均匀形貌和电荷分布影响颗粒间粘结特性。基于 DLVO 理论，计算表面异质的数学泥沙颗粒间相互作用，并建立颗粒间粘结力和粘结概率的定量表达。然后，基于连续的群体平衡方程，建构表面异质颗粒的水体絮凝数学模型：采用粒径区间离散方法得到群体平衡絮凝模型，采用粘结概率的理论计算值；采用矩方程和相似变换方法，理论推导拉格朗日型絮凝模型，表征颗粒表面异质性及外界环境条件对絮团平均粒径计算的影响。 颗粒间粘结力还会影响粘性床面的临界起动，综合颗粒粒径、表面异质性及床面矿物组分、堆积密度等因素，基于量纲分析建立粘性床面临界起动切应力及床面成团起动时絮团粒径大小表达式，结果显示床面成团起动粒径大小与水流条件及颗粒自身异质特性等因素密切相关。
外文文摘	Fine-grained sediment is a complex assemblage of various minerals and exists extensively in the river, lake and reservoir. Due to the strong electrochemical attraction, these fine-grained particles show a strong adsorption capacity for the nutrient element and pollutant, thus changing the transport and transformation of the corresponding adsorbate. Meanwhile, flocculation of these cohesive sediment occurs, and the resultant flocs significantly affect the particles’ existence, settling velocity and sediment transport. The effect of surface heterogeneities are usually ignored in traditional sediment research, while in this paper, the role of surface morphology and charge distribution in particles’ adsorption and flocculation is investigated with the micro and macro experiments and theoretical analysis. The surface micro-morphology and charge distribution are observed with the high-resolution microscopy, including the scanning electron microscope and the atomic force microscope. Then the Taylor expansion method is applied to quantitatively characterize the heterogeneity of surface morphology, and the statistic relation between the micro-morphology and surface charge distribution is also obtained. Results show that heterogeneous micro-morphology and charge distribution exist on particles’ surface. The second order term of Taylor expansion F2 can characterize the local concave or convex micro-morphology, and affect considerably the surface charge density and distribution. A weighted average morphology factor F2a is derived to characterize the overall surfa

	ce heterogeneity, based on the distribution of F2. The contribution of particles’ heterogeneities to P adsorption is investigated with adsorption experiments and microscopic examinations. Results reveal that the adsorption probability varied with the micro-morphology F2 and mineral species, and the adsorbed P at different F2 here fit to a Weibull distribution. The Sips model can successfully fit the experimental data of different minerals and the heterogeneity parameters and adsorption capacity are proved to be functions with the mineral properties, including the particle size, surface site density and surface heterogeneities as well. With the component additivity, the adsorption on natural sediment can be predicted by the adsorption properties of pure mineral. The paper also provides an expression for the distribution coefficient on the basis of dimension analysis, which characterize properly the role of intrinsic particle properties and environmental condition, and can be applied to the water quality model conveniently. The surface morphology and charge distribution can also affect the cohesive properties. Total interaction are calculated based on the DLVO theory, and the theoretical expression of cohesive force and attachment efficiency are derived. It shows that the surface heterogeneities can increase the repulsive electrostatic force considerably, thus decreasing the cohesive force and particles’ attachment. Based on which, two types of flocculation models are developed. The population balance model can be derived by separating the continuous floc size distribution into discrete size classes, in which the empirical attachment efficiency are replaced with the developed theoretical expression. The modified model can simulate the variation of average floc size and floc size distribution. Furthermore, a new Lagrangian type flocculation model is theoretically developed with similarity transform and moment methodology. The model introduces the role of surface heterogeneities and environmental condition in the variation of average floc size, and has a better performance than the traditional semi-empirical flocculation model. The cohesive properties would also affect the incipient motion condition of fine grain bed. In this paper, the expression of critical shear stress is developed integrating the influence of surface heterogeneities in cohesive force calculation, and also the bulk density, clay percentage. When the cohesive force is significant, the particles would tightly attach with each other and the bed would erode as flocs or aggregates of sedimentary particles. The size of flocs or aggregates are theoretically calculated based on the intrinsic particles’ properties and the bed condition.
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