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中文题名	长膜泥沙冲刷和淤积的实验研究
英文题名	Experiment of erosion and deposition for sediment colonized by biofilm
中文关键词	生物泥沙稳定性,粘性泥沙,粒子跟踪测速,推移质运动
英文关键词	biostabilization, cohesive sediment, PTV, bed load transport
中文文摘	粘性泥沙因其独特的性质，对周围颗粒具有一定的结合能力。而当有生物膜作用时，粘性泥沙又会呈现出新的特性。被生物膜包裹的粘性泥沙（简称“长膜泥沙”）的行为研究，有助于改善我们对泥沙输移过程的认识（如：推移质和悬移质运动等），而目前该领域尚缺乏大量的基础研究。本文以官厅水库和三峡水库的泥沙样品为例，借助生物膜培养试验，重点研究了粘性泥沙的生物稳定性。通过调查泥沙样品的物理、地球化学和形貌特性，以及相应的生物膜量和微生物群落等，发现官厅水库与三峡水库的长膜泥沙样品间在理化特性和生物特性上存在较强的相似性。试验结果表明：生物膜培养 5 天后，长膜泥沙的特性逐渐发生变化；而生物膜培养 10 天后，变化明显加快。生物膜在粘性泥沙表面的生长，一方面增加了粘性泥沙的抗冲刷强度和临界剪切应力，另一方面也减小了水槽中长膜泥沙的含沙量和床面的冲刷深度。采用烧失法研究以泥沙为基底的生物膜量的随时变化及受泥沙粒径的影响，结果表明生物膜量随时间呈增长的趋势（15 天内），基底泥沙粒径越小生物膜量越大。采用磷脂脂肪酸生物标记法研究样品的生物群落，表明革兰氏阳性和阴性菌种是研究床沙的优势菌种。上述结果与三峡水库细菌生物模量和种群中两类细菌占有很高的比例基本一致。 对比相同水流条件下水体中长膜沙与干净沙的最大悬沙浓度发现，培养 5 天、10 天和 15 天的长膜沙最大悬沙浓度分别比干净沙分别减小 1.5%、78%和 94.5%，但逐渐趋于稳定。可见生物膜培养时间越长，悬沙浓度越低，这是生物膜的粘结作用随生物膜量的增加而造成。此外，培养 5 天、10 天和 15 天的长膜沙起动剪切应力较干净沙分别增大了 1.82、2.92 和 4.56 倍。培养 5 天、10 天和 15 天的长膜沙的侵蚀率（冲刷总体积与原始总体积的比值）分别为干净沙的 92.5%、38.2%和 20%。采用粒子跟踪测速技术，对生物絮凝颗粒的床面运动进行可视化观测，得到了床面泥沙的跃移曲线。进而推导得到了长膜泥沙推移质运动的输沙律公式，结合垂向含沙量分布，该公式可用于推求床面附近的平衡含沙量浓度。
外文文摘	Cohesive sediment might have a binding effect for surrounding particles. When biofilm grows up at the surface of cohesive sediment, some new transport properties appear. To capture the law about how biofilm coated cohesive sediment, defined as bio-sediment, behavior vary, contribute to develop the application of sediment transport including bed load and suspended load in the practical engineering. This study focuses on biostabilization of bio-sediment in the Beijing Guanting Reservoir (BGR) and Three Gorges Reservoir (TGR). Physical, geochemical and morphological properties of such support particle as well as related biofilm mass and microbial community were investigated. Close similarity was found between mineralogy of BGR compared to TGR. Results showed that characteristics of biofilm-covered sediment gradually start to change after 5-days of biofilm growth and this change obviously accelerates after 10-days growth. On the one hand, constituted by bound sediment, growth of biofilm increased bed surface strength and critical shear stress and on the other decreased measured vertical sediment concentration and erosion depth of bed surface. Biomass analysis based on results of loss on ignition (LOI) showed an increase in biomass with either a decrease in support sediment size or an increase in cultivation period of biofilm. Microbial community analysis of TGR samples using phospholipid fatty acids (PLFA) technique deduced a high proportion of gram-positive bacteria and gram-negative bacteria. The results basically agree well with the biomass and microbial community of practical BGR and TGR. Comparison of maximum suspended concentrations between bio-sediment and primary sediment on the same flow condition showed that 1.5%, 78% and 94.5% decrease in values for 5, 10 and 15 days respectively, but decrease amplitude tends stabilization. It showed that longer biofilm growth periods have less sediment concentration in the flow due to more difficult erosions arising by biofilm binding bed surface sediment. Furthermore maximum shear stresses of bio-sediment,

	indicating bed biostabilization, for 5, 10 and 15 days increase 1.82, 2.92 and 4.56 times compared to primary sediment. Erodibility (ratio of eroded to initial sediment volumes) of bio-sediment for 5, 10 and 15 days was 92.5%, 38.2% and 20% respectively compared to primary sediment. Focusing on biofilm coated sediment, as the bed load transport, particle tracking velocimetry (PTV) technique was inferred for visualizing near bed motion of bio-sediment. Saltation curves based on PTV data were analyzed. Then a mathematical model describing near bed particle motion was modified to fit the properties of bio-sediment transport. Based on validation of calculated results of bed load transport rate and suspended load concentrations by experimental data, the relationship between the bed load transport rate of bio-sediment and flow function was proposed. By using the relationship and measured vertical suspended load concentration profiles for steady flow, the equilibrium sediment concentration formula at the surface of bed was then deduced.
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