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Experimental study on the impact of NaCl concentration on the flocculating settling of fine sediment in static water

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Abstract

NaCl concentration can increase the flocculation of the fine-grained sediments in suspension. However, the impact of NaCl concentration on the process of flocculation and settling is unclear. This paper investigated the effect of NaCl concentration on the settling velocity of fine sediments, which kaolin is the constituent mineral of the sediment sample (D_{10}=0.9μm; D_{50}=2.7μm; D_{90}=10.3μm). The experiments were conducted in a 1.2 meter high settling column. Experimental cases were set for different initial concentration of sediment (0.2, 0.5, 1.0 g·l^{-1}) and different NaCl concentration (0, 0.2, 0.5, 1.0, 2.0 g·l^{-1}). With respect to each case, water samples were collected and measured at 11 different times from 0 min to 300 min during the process of experiment .Settling velocities were calculated based on the time evolution of suspended sediment concentrations. The experimental results show the time evolution of the relative sediment concentration, which is the ratio of the concentration to the initial concentration, follows a hyperbolic dynamic model under the low initial sediment concentration conditions. The settling velocity increases with the NaCl concentration and sediment concentration. An empirical formula among the settling velocity of sediment, salinity and sediment concentration have been established by means of the multiple linear regression analysis.

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Keywords: Settling velocity; Fine sediments; Flocculation; Nacl concentration

1. Introduction

The settlement characteristics of fine sediment play an important role on the sedimentation control of reservoirs, environmental protection in coastal or estuary regions. It is also a fundamental parameter in numerical modelling, and critical for the conceptual understanding of fine sediment dynamics [1]. Different with the settling velocity of

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the sand with larger sizes that can be obtained by using Stokes' law, the settling velocity of fine sediment is affected by many factors, such as salinity [2, 3, 4], suspended sediment concentration [5], grain size [6], temperature of water [7], and so on. Fine suspended sediments are prone to aggregation and form flocculation network structures (flocs) as a result of Brownian motion, turbulence shear, and differential settling, which makes their behavior different from that of non-cohesive sands [8].

Salinity is known to increase the cohesion of clay minerals, and the flocculation follows the double-layer theory [9]. Due to the adsorption of salt ions in the water, the surface potential of suspended sediment particles can be reduced. The variation of ion concentration in water will change the surface double-layer thickness of sediment particles. As a consequence, the decrease of the interaction force between the sediment particles will result in the adhesive sediment particles to form flocs [10].

Many researchers have proposed that the response of settling velocity to salinity was not in a monotony trend, whereas there is a maximum-flocculation salinity or optimum responding range. Chen [11] reported the maximum-flocculation salinities of the fine sediments in the north passage of Yangtze River estuary are 10~12 $g{\cdot}l^{-1}$ in flood season. In high salinity situation, settling particles are more easily to form flocs while it is hard in lower salinity [12].

Some relationships between settling velocity and salinity have been established in the previous studies [2, 3]. However, the relationship involving the sediment concentration and salinity was rarely reported. Besides the sediment samples in the previous research were collected from the specific estuaries or rivers, which limits the applicability in more extensive scales.

2. Materials and methods

2.1. Sediment

According the previous research [13], the fine-grained sediments collected from the natural rivers or estuaries are mixtures coexisted by fine sediment parts and organic and biological aggregation parts. For this reason, the flocculation of the fine-grained sediments are affected by organic and biological aggregation parts in a great extent. In order to remove the effect of the organic parts and explore the universal characteristics of the influence of salinity on the flocculation and settling process of fine sediment, industrial Kaolinite were selected as sample sediment to use in this paper. The constituent and physical properties were listed in **Table 1**. The sediment sample consists of clay-size particles, with diameters D_{10}, D_{50} and D_{90} of 0.9μm, 2.7μm and 10.3μm measured by Malvern Mastersize Micro, listed as **Figure 1**.

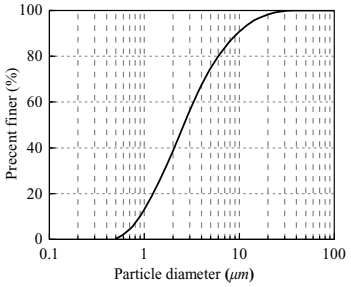

Fig. 1. Grain-size distribution of the sediment sample.

Table 1. Physical-chemical properties of the kaolinite.

Constituent	(%)	Physical property	
Al_2O_3	44	Specific gravity ($g{\cdot}l^{-1}$)	2650
SiO_2	51	Shape	platelets
K_2O	3.3	Cohesiveness	low
Fe_2O_3 and CaO	<1.3	Swelling capacity	low