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EXTENDED ABSTRACT

Investigating the Effect of Wastewater Concentration on the Fall Velocity of Cohesive Sediments in Water Transfer Systems

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1. Introduction

Cohesive sediments are composed primarily of clay-sized material, which have strong interparticle forces due to their surface ionic charges. As particle size decreases, the interparticle forces dominate the gravitational force, and the settling velocity is no longer a function of only particle size. When, under certain conditions, the attractive forces exceed the repulsive ones, colliding particles stick together, forming agglomerations known as "flocs" with size and settling velocities much higher than those of the individual particles. This phenomenon is known as "flocculation" (Baldock et.al, 2004). In a flocculated cohesive sediment suspension, the settling unit is the floc rather than the individual particle. The settling velocity of cohesive sediment particles, also is called the fall velocity, is one of the key variables in the study of sediment transport and is important in understanding suspension, deposition, mixing and exchange processes (Partheniades, 2009). Adding a chemical solution in a mixture of water and sediment changes the physicochemical of the sediments and the flocculation of the clay particles may increase or decrease. Today, in many countries the wastewater is used for irrigation sector as an additional water resource. Wastewater in combination with other water resources change the physicochemical characteristics of the water and it causes changing in hydrodynamic behaviors which one of them is the effect of wastewater concentration on the fall velocity of cohesive sediments in channels and water transfer Systems (khastar-Boroujeni, 2018). Therefore this study focuses on the effect of urban wastewater on cohesive sediments transport to improve water quality and manage the irrigation systems. For this purpose, some experiments were carried out in an annular flume using a mixture of cohesive sediment and water with combination of three levels of wastewater for evaluating their effects on the fall velocity of cohesive sediments.

2. Methodology

In this work, all experiments were conducted in an annular flume located at the Hydraulics Laboratory of Shahrekord University, Iran. The flume is circular and is made of galvanized steel sheet with a Plexiglas window. The flume has a mean diameter of 1.6 m, is 0.30 m wide and 0.47 m deep, and rests on a rotating platform which is 1.9 m in diameter. Fine sediments used in the experiments were taken from sediment deposited in Pribalut dam reservoir. The dam is located in northern Karun Basin, in Iran. These fine sediments contain 63.2% silt and 36.8% clay with mean diameter of 0.0035 mm. Wastewater used in the experiments was taken from Shahrekord wastewater treatment plant outlet which is located south of Shahrekord city, Iran. The tests were carried out for five bed-shear stress conditions, three different initial sediment concentrations and three levels of wastewater concentrations. The shear stresses were chosen in a way that at minimum and maximum shear stresses which was defined depositing eighty and twenty percent of suspended sediments,

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respectively. Also in the experiments levels of wastewater was 0%, 30% and 60% of water used and initial sediment concentrations was 5, 10 and 20 g/l, respectively.

Acoustic Doppler Velocimeter (ADV) was used to measure velocity and shear stress distributions, and based on these measurements, the relationship between hydraulic parameters and the flume rotational speed was obtained. Then, sediment and water mixture with a given initial concentration was prepared and was transferred to the flume. In order to mix water and sediment completely, the flume and its ring were oppositely rotated at their maximum speeds of 14.8 and 16.2 rpm, respectively, for thirty minutes. Then, the speed of the flume and its ring was lowered to reach a rotation speed providing the desired bed shear stress. The time duration for all experiments was considered 240 minutes, and in the meanwhile, the test samples were collected in a sampling interval of 15 min during the first hour, and 30 minutes thereafter. The samples were taken from depths 5.5, 10.3 and 18.3 cm from the bottom and then, sample concentrations were measured by the drying and weighting method.

3. Results and discussion

The results showed that wastewater causes deposition rate of the sediments to be increased at a constant shear stress. This rate also increases much more by increasing initial sediment concentration. It was also found that the fall velocity of suspended sediment was increased with increasing of the concentration of wastewater. The fall velocity of the sediments was calculated by using the Krone (1962), Krone modify (1962), thorn (1981), Nicholson and O'Connor (1986), Burban et al (1990) and Lau and Krishnappan (1991) equations (Huange etal, 2006).

Based on the obtained results and using multiple regression technique, the following relationships were derived:

$$W_s(w_0) = 0.085\left(\frac{\tau}{\tau_{cd}}\right)^{0.102}\left(\frac{C_{eq}}{C_0}\right)^{1.056} \qquad R^2 = 0.87, \quad RMSE = 0.0001$$

$$W_s(w_{30}) = 0.048\left(\frac{\tau}{\tau_{cd}}\right)^{0.24}\left(\frac{C_{eq}}{C_0}\right)^{0.013} \qquad R^2 = 0.60 \ , \quad RMSE = 0.0002$$

$$W_s(w_{60}) = 0.041\left(\frac{\tau}{\tau_{cd}}\right)^{0.427}\left(\frac{C_{eq}}{C_0}\right)^{0.037} \qquad R^2 = 0.65 \ , RMSE = 0.00004$$

Where, W_S: fall velocity, w_i: concentration of westwater, τ: flow sher stress, τ_{cd}: critical shear stress for full deposition, C_0; initial concentration, C_{eq}: equilibrium concentration.

4. Conclusions

The result showed fall velocity of sediment particles depends on the amount of shear stress and suspended sediments concentration. It was also observed the wastewater increase sediment mass fall velocity. The Multiple regression analysis showed that by increasing concentration of wastewater, the effect of shear stress on the fall velocity of the cohesive sediment is strongly increased and the effect of initial sediment concentration is decreased.

5. References

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