Experimental Investigation of Entrainment Rates of Mixed Grain-size Particles in Turbidity Currents

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Turbidity currents in the ocean and lakes are driven by excess density originated from suspended sediment. The dynamics of turbidity currents are largely governed by suspended sediment that is entrained from the bed. Therefore, quantitative estimation of transport rates of suspended sediment is critical to predicting the behavior of turbidity currents. A key feature for the prediction of suspended load is the entrainment rate of basal sediment into suspension at the solid-fluid interface, which is the subject of this research. The previous research revealed that entrainment rates of basal sediment can be estimated from several flow parameters such as flow shear velocity on the basis of flume experiments and field observation. However, the empirical function of sediment entrainment rates established by previous research was mostly based on experiments using uniform particles, and very few research examined the entrainment function that can be applied to the mixed-grain size particles.

To this end, we conducted in total 17 flume experiments of turbidity currents especially focusing on differences between single and mixed grain-size cases. The lightweight plastic particles were used in our experiments in order to reproduce suspension in a relatively small-scale flume (4 m long and 15 cm wide). In this research, plastic particles with the specific gravity of 1.45 were chosen as the model sediment material. As the focus of the experiments reported here was centered on the dynamics of the current body, rather than the head, care was taken to measure only after the current front had passed and the flow had achieved a quasi-equilibrium state. At this condition, entrainment rate of basal sediment is balanced with the rate of sediment settling from suspended load in the flow, so that we measured basal concentration in the experimental flume by siphon tubes to estimate entrainment rates from basal sediment. Also, flow velocity profiles that were used for estimating flow shear velocity were measured by the acoustic Doppler velocity profiler. After the experiments were conducted, grain-size distribution of basal sediment was measured by a settling-tube grain size analyzer.

We examined the entrainment rate of basal sediment to suspension in turbidity currents and compared our measurements with the prediction using the empirical formulations that have been commonly used for numerical simulations of turbidity currents for these 20 years. In the uniform particle experiments, the prediction of entrainment of sediment matches with the measurement consistently. However, in the mixed grain-size particle experiments, it represents less consistent with anticipation. This implies that the new empirical formulation is needed for predicting entrainment rate of the mixed grain-size sediments into suspended load.

To obtain a new entrainment function, we examined our experimental results with compilation of existing data in previous research by using the multiple regression analysis. Adequacy to employ possible flow parameters to the entrainment function were examined by AIC and BIC, as well as PCA analysis with k-fold cross-validation. As a result, a new empirical function for sediment entrainment that is applicable to mixed-size particles was proposed in this research.

Keywords: entrainment rates, mixed-size grains, flume experiment, turbidity current

