Abstract

This thesis focuses on the investigation of sediment transport and distribution in suspension in open channel turbulent flow. Mathematical models are developed on concentration distribution in suspension for both uniform and non-uniform sediments through the traditional advection-diffusion equation (ADE) and fractional ADE, incorporating different turbulent features under non-equilibrium conditions. The developed models are solved numerically and semi-analytically, and are validated by comparing available analytical/semi-analytical solutions and existing experimental data under certain conditions.

Unsteady two-dimensional mathematical models for distribution of uniform and non-uniform sediments in suspension are developed, which incorporates concentration-dependent mixing length, hindered settling for uniform sediment case, stratification and hiding-hindering phenomena for non-uniform sediment case. The findings indicate that the suspension region experiences a decrease in concentration value farther from downstream as a result of the modified mixing length of sediment-laden flow and the opposite is the case for considering hindered settling velocity for all downstream distances. Overall, a reduction in concentration value occurs in the suspension due to the inclusion of these two effects in comparison to when the effects are excluded. For distribution of non-uniform sediments, the current findings reveal that the suspension concentration for all grain sizes at a smaller downstream distance increases due to concentration dependent mixing length and then the effect reverses for all grain sizes at a larger downstream distance. A similar trend is observed when both stratification and mixing length are considered.

Sediment particles can mix between any layers of fluid due to turbulent bursting and this process of mixing is known as non-local mixing. An unsteady one-dimensional (1D) model for distribution of non-uniform sediments is derived for erodible beds in open channels, considering non-local mixing due to turbulent bursting through variable β in the space-fractional ADE and hiding-hindering phenomena. The model is solved using the collocation method and shifted first kind Chebyshev polynomials. The temporal variation of concentration profiles for different particle sizes is studied by varying β and it is observed that the concentration magnitude decreases for each size as β increases.

When transporting particles in an open channel remain at rest for a longer time, the diffusion rate is slower than that of normal Fickian diffusion, a phenomenon referred to as subdiffusion/non-local due to the time memory effect. A semi-analytical solution based on Laplace and Fourier transform for a 1D mathematical model of sediment distribution, which incorporates this phenomenon through the time-fractional ADE with variable α, is proposed. Also, to address the non-local sediment transport caused by turbulent bursting and time memory together, a theoretical model is derived using the space-time fractional ADE. The findings reveal that as β increases, sediment concentration reduces in the main suspension region, while increasing α diminishes concentration in suspension after a certain time.

Keywords : Open channel turbulent flow, Concentration for uniform and non-uniform sediments, Mixing length, Hindered settling, Stratification effect, Hiding-hindering effect, Non-local mixing due to turbulent bursting and time-memory phenomena.