Abstract

In modern times, due to rapid urbanization, the quantity of waste water going into the urban sewer systems has been increased significantly. The urban waste water includes construction debris, industrial wastes, natural sediments, urban solid wastes, wastes from roads etc. Sediment entrainment into the sewers or storm water drainage channels from the adjoining catchment areas, subsequently their movement and deposition in the channel reduce the flow area, and as a result the hydraulic efficiency of the channels gets reduced. Sediments get deposited on the invert (bottom) along the reach of the drainage channels during the period of dry weather due to non-availability of sufficient flow velocity which leads to the sedimentation and reduction in the carrying capacity of the channel. The water containing sediments creates environmental pollution and hinders the operation of pumps in Sewage Treatment Plants (STP) and turbines in Hydro Power Plants. It also adversely affects the aquatic and plant life in a river. Continuous efforts had been made by the mankind to understand the mechanics of movement of the sediments in running water. To solve the sediment problem in a flowing channel, sediment ejectors, excluders, extractors and a number of sediment trapping devices have been developed and are being used at suitable places along the reach of the channel to minimize the sediment content in the channel to ensure smooth and optimum functioning of the drainage system. Invert trap is one of the trapping device to trap the sediments flowing into a sewer or storm water drainage channel. As the name itself indicates, it is a chamber provided at the invert of the channel in which the sediment falls and gets trapped. Among sediment trapping structures, invert traps are very effective method of reducing the amount of sediment flowing in a drainage system and irrigation channels (Gupta et al. 2005).
Experimentation is required to analyze the effect of variable parameters of flow, trap geometry and sediments on the trap efficiency of an invert trap for its design and performance purpose. As experimentation is always not possible, time consuming or becomes a costly affair, Computational Fluid Dynamics (CFD) has now become an excellent and economically less expensive tool for the study of flow in sewers or storm water drainage systems. For the CFD modeling of invert traps in open channels, earlier investigators used Fixed Lid Model (FLM), i.e. assuming open channel flow as closed conduit flow with top wall as shear free wall, with stochastic Discrete Phase Model (DPM). This approximate model was poorly validated with their experimental data. In the present study, experimentation has shown that the free water surface rises above the central slot (opening) of the invert trap which cannot be modelled using FLM because water surface fluctuations/profiles are not possible in closed conduits. Therefore, in the present study without making such assumptions, the appropriate Computational Fluid Dynamics (CFD) model for open channel flow i.e. Volume of Fluid (VOF) model along with stochastic DPM has been used. This VOF model has been extensively validated with the experimental results in which only natural sediments including actual sewer solids have been used. 2D & 3D CFD analysis show that 2D predicts a little lower trap efficiencies than 3D which is theoretically as well as experimentally justified because in 3D modeling, more sediments fall into the trap due to their low velocity near the walls (which has also been observed experimentally) and subsequently giving higher values of trap efficiency which is contrary to the presumption of Buxton et al. (2002) that the 3D may predict low values. The CFD predicted Water Surface Profile (WSP) above the central opening (slot) of the invert trap has also been compared and validated with the experimentally measured WSP. In addition, the CFD predicted flow field has been satisfactorily compared with the experimentally measured velocities using Laser Particle Image Velocimetry (PIV). On the basis of the present study, it can be concluded VOF model along with stochastic DPM is the appropriate CFD model in comparison to FLM
for the numerical performance and design analysis of invert traps. It has also been established that 2D predicts the same qualitative results as 3D but quantitatively, 3D model predicts the best results in comparison to the experimental results.

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