THREE-DIMENSIONAL NUMERICAL MODELING OF SALINE INTRUSION AND PURGING IN SEA OUTFALLS

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Saline intrusion into sea outfalls during periods of low discharge greatly decreased the efficiency of sewage disposal (Wilkinson, D.L. 1984, 1985). Numerical simulation for this phenomenon was investigated from 1980s. Early research (Wilkinson, D.L. 1984 & Burrows, R. & Davies, P. A. 1996) addressed the fundamental processes of saline intrusion. Subsequent work by Mort (Mort, R.B. 1989) provided the basis for numerical model. Later, Larsens and Guo and Sharp (Guo Z. R. & Sharp J. J. 1996) refined Mort's model. The refined model was integrally one-dimensional and locally two-dimensional that buoyant effect and interfacial mixing in stratified flow were partially taken into consideration. Researchers in The Queens University of Belfast built two-dimensional model and recreated the intrusion process to a certain degree (Shannon, N.R., Mackinnon P.A. & Hamill G.A. 2001, Shannon, N. R., 2000). However, the flow in outfalls has intensive three-dimensional characteristic in fact, these one or two-dimensional modeling had great discrepancy with the nature of the flow.

So in this paper the flow was modeled in three dimensions under turbulent conditions with $k-\varepsilon$ turbulence model. The interacting of two fluids was modeled with species model and VOF model. The species model was used to calculate the mixing of the two fluids and the VOF model was used to calculate the location of the interface of the two fluids. Meshes of different density were applied in different flow field to improve calculating efficiency. The first order up-wind differencing scheme and PISO algorithm were used to solve the transport equations.

With this three-dimensional modeling, the process of saline intrusion was simulated in detail. In the initial stage of sewage flowing into the outfall pipe, stratified flow was formed in the outfall due to the buoyancy caused by density difference. The profile of sewage was wedge shaped. The mixing and entrainment were in evidence in the density transition region. During this stage, the flow directions in three risers were all upward that indicated saline was expelled out of the system. Furthermore, the discharges and velocities in three risers were almost uniform.

But this duration was not long. After a short while the discharge in the bankward riser began to increase rapidly to a large value and then almost kept constant. But the discharges in the other two risers began to decrease at this time. The discharge in the middle riser firstly decreased and a little while later it began to increase. In the seaward riser, the discharge decreased all the time until to a constant.

After a period of time the discharge in the seaward riser decreased to a negative value. This indicated that saline intrusion occurred in this seaward riser. Along with the time, the intruding discharge increased. During this period, saline intruded into the seaward riser and flowed to the bankward and then discharged through the bankward riser. Such process was called saline circulation. After a period of time, this circulation of intrusion and discharge became stable and would persisted for a very long time. Such saline circulation was common when outfall systems were intruded.

With the three-dimensional numerical modeling the flow mechanisms of saline intrusion and purging in a simplified outfall with three risers under turbulent conditions have been recreated. The variations of densities and velocities were described in detail. During the course of this flow, stratification and mixing and entrainment due to buoyancy and turbulence were incorporated with each other. These mechanisms were modeled reasonably to a considerable degree. However, the flow was so complicated transient flow with intensive turbulence that the solution parameters and boundary conditions of the model should be demonstrated and improved by further experimental data. This is currently under way.

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