Release of Pollutants From Particles and Pore Water due to Sediment Resuspension

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Summary Experiments were conducted in order to characterize the relative roles of resuspended particles and pore water under different hydrodynamic conditions and sediment feature. Conservative tracer (NaCl) and reactive tracer (phosphate) were respectively used as the contaminant in bed sediment in a laboratory flume. The mixing between overlying water and pore water occurred in a short time while the desorption of contaminant from resuspended fine-grained particles would last relatively long.

INTRODUCTION

Recently, the effect of sediment on the water environment has been recognized by many researchers. Sediment-water interactions in lakes and rivers may become very important with time, since bed sediments have become large repositories of contaminants as shown in Fig.1. At certain velocity of flow, the sediment can be eroded and re-suspended, resulting in the pollutant release into overlying water column, in which both re-suspended solid particles and pore water enter water body. Since the problem relate to hydrodynamics conditions and sediment feature, the mechanism of sediment environment effect is very complex. Previous studies of the sediment pollutant release focused on two mechanisms: sediment-water interface and re-suspended release. The role of pore water and the sediment particle feature were often ignored in releasing contaminants.

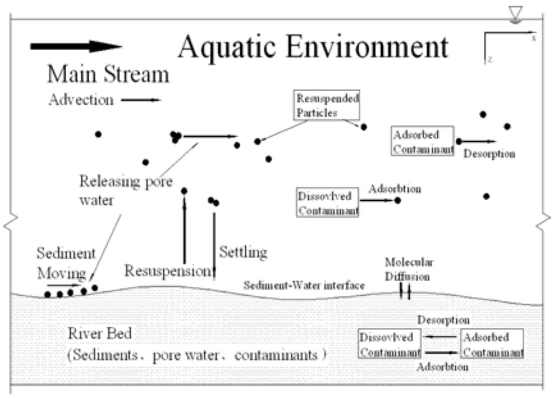

Fig. 1: Schematic of the sediment-water interactions in aquatic environment

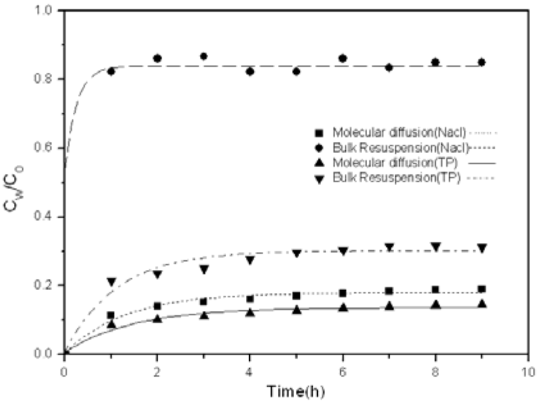

Fig. 2: Non-dimensional concentration of compared Nacl and TP in steady and suspended state

Present experiments were carried out in order to characterize the relative roles of resuspended particles and pore water in pollutant release. A conservation tracer and a reactive tracer (NaCl and phosphate) were respectively used as the contaminant in bed sediment in a laboratory flume to distinguish between resuspended particles releasing and pore water releasing. When the sediment was static, only molecular diffusion on sediment-water interface was considered. When the sediment resuspention occurred, if the tracer is conservative, all the pollutants released were from pore water; else if reactive tracer was used solely, pore water played a dominant role at the early stage of pollutant releasing, then the adsorbed tracer was desorbed from resuspended particles, which controlled successor pollution releasing. The mixing between overlying water and pore water occurred in a short time while the desorption of contaminant from resuspended particles would last relatively long.

EXPERIMENTAL APPARATUS

A recirculating flume consisting of a rectangular test section with 6m in length, 0.2m in width, 0.45m in depth was used to determine the bottom sediments response over a range of flow velocities. Surface water flow was controlled by a variable rotating speed pump and a tail valve. The water flow velocity was varied from 0.1m/s to 0.3m/s. Maximum design water depth could reach 0.4m. A micro-propeller velocimeter was used to measure the flow velocity. A layer of sediment containing pollution tracer about 5cm thick was gently and uniformly laid on the bottom of the flume.Three vertical horizontal arrays of sampling ports, with 0.5m intervals between neighboring ports, were installed through the sides of the flume for average trace concentrate sampling.

RESULTS AND DISCUSSION

Some results can be obtained from the experimental studies including the environment water flume test and refined measurements.

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Contributions from suspended particles and Pore water

There were particles in the overlying water as soon as the critical water flow velocity or shear stress was exceeded, and the NaCl concentration in water body increased immediately. The pollutant release flux may be due to the liquid phase stored in the surficial sediment, i.e. the pore water contribution. Pore water may dominate the release flux at the first resuspension. The phosphate concentration also got an increment at the early stage, but the percentage according its initial quantity is less than the NaCl. Phosphate exits both in solid and liquid phases in bottom sediment, only those stored in pore water were released into the overlying water, others were still adsorbed in resuspended particles. It needs time for the adsorption-desorption process to reach equilibrium. As can be seen from Fig.2, when bulk sediments resuspension occurred, the Nacl concentration did not increase any more after 1 hour while the phosphate (TP) concentration was as twice as that 2 hours ago.

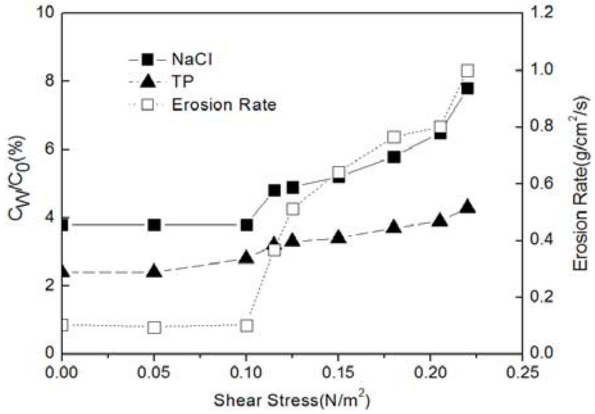

Fig. 3: Non-dimensional concentration of Nacl and phosphate at each shear stress level

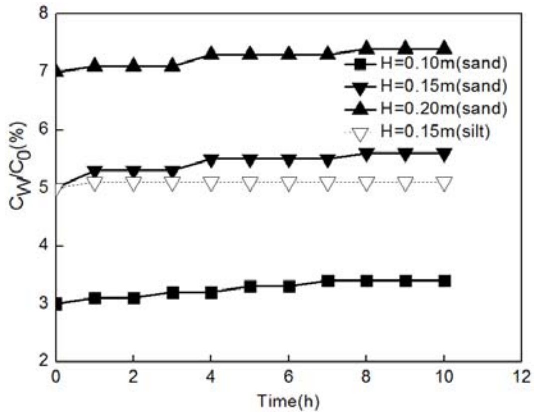

Fig 4: Non-dimensional concentration of phosphate over time at each depth of water

Long-term release from suspended particles

A range of typical flow velocity was applied to the fine-grained sediment. At each step, the tracer concentration was measured. As can be seen from Fig.3, when the bottom shear stress increased, more particles and pore water would enter into the overlying water. The concentration of the NaCl and Phosphate are depended on the shear stress. The response of Nacl release was faster than the Phosphate. It also can be seen from Fig.4, flux from pore water is flash once. The release of solutes due to the resuspension of coarse-grained and fine-grained sediments has shown two different ways of release from sediment. Coarse-grained sediment may have many times of resuspension, considering the properties of the bottom sediment do not change with time. For cohesive, fine-grained sediment, it takes into the distribution of sediment particle sizes with depth and the time-changed conhesivity. The resuspension of fine-grained sediment is in large quantities initially, and reach a const value. The deposition of fine-grained sediment is negligible, the desorption reaction occurs at a limit time.

CONCLUSIONS

Through the experimental studies and theoretic analyse, the mechanism of the bottom sediment pollution release was understood deeply. Main conclusions were summarized as follows: When the sediment was static, only molecular diffusion on sediment-water interface was considered. When the sediment resuspention occurred, all the conservative pollutants released were from pore water in the sediment; else when reactive tracer was used solely, pore water played a dominant role at the early stage of pollutant releasing, then the adsorbed tracer was desorbed from resuspended particles, which controlled successor pollution release. The mixing between overlying water and pore water occurred in a short time while the adsorption and desorption of contaminant from resuspended particles would last relatively long. The different effects of coarse-grained and fine-grained sediment on the pollutant releasing flux were also studied, flux from coarse-grained sediment is smaller than that from fine-grained sediment, but the duration of release from coarse-grained sediment last longer.

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