Hydraulic Simulation of *Escherichia coli* Distribution in Chhnok Tru Floating Village, the Tonle Sap Great Lake

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Abstract

In order to get the fundamental information on the temporal and spatial distribution of pathogen in a floating village in the Tonle Sap Great Lake, transport and dilution of *Escherichia coli* (*E. coli*) was simulated by a three-dimensional hydraulic model. Chhnok Tru was selected as the study site. Before the simulation of transport of *E. coli*, in order to estimate the flowrate from the upstream channels that form a complex dendriform network, a two-dimensional hydraulic simulation was done for a wide area including both the village and the upstream channels. Then, the three-dimensional simulation was conducted for one week in the dry season. The transport of *E. coli* was calculated together with the water flow. The calculated result shows that the speed of reduction of *E. coli* concentration drastically changes according to location in the village.

Keywords: *Escherichia coli*; Tonle Sap Lake; Chhnok Tru; Floating village; 3D Flow Simulation

Introduction

Tonle Sap Great Lake (TSL) is the largest freshwater lake on Southeast Asia. More than one million people lives at the TSL's floodplain that is routinely flooded in the wet season (Keskinen, 2006). In order to cope with the seasonal fluctuation of water level, a large number of people are living in floating houses. The floating houses get together and form about ninety villages in the TSL (Johnstone, 2013). Although the houses floats on water, access to safe drinking water still remains difficult. According to a recent baseline survey using a questionnaire (In, 2017), in the floating villages, about a half of people have drunken the lakewater and about 30 percent of the drunken water has not been treated. While the people has been easily infected by drinking the unsafe lake water, there are scarcely sanitation facilities to prevent the pathogen from excreting to the lake water. In the typical toilet of floating house, a hole is made on the floor. Feaceses directly drop into the lake water through the hole and the lakewater is easily contaminated with the pathogen like the *Escherichia coli* (*E. coli*). To prevent the infection, a numerical simulation of water current must be useful. Because the *E. coli* spatial distribution and its temporal change can be grasped from the simulated water flow, the households enable to know where and when they can get non-contaminated safe water. In this work, as

a pilot application, we applied a 3D numerical flow model to Chhnok Tru floating village (Figure 1.1) and evaluated the temporal change of spatial distribution of *E. coli*.

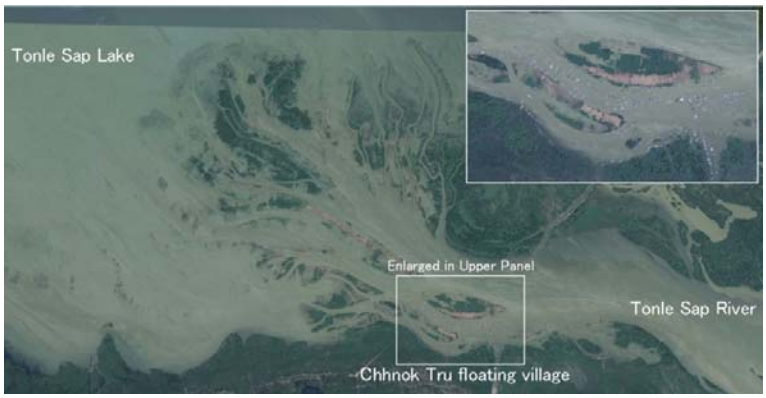

Figure 1.1 Chhnok Tru floating village (satellite image ©2019 CNES/Airbus)

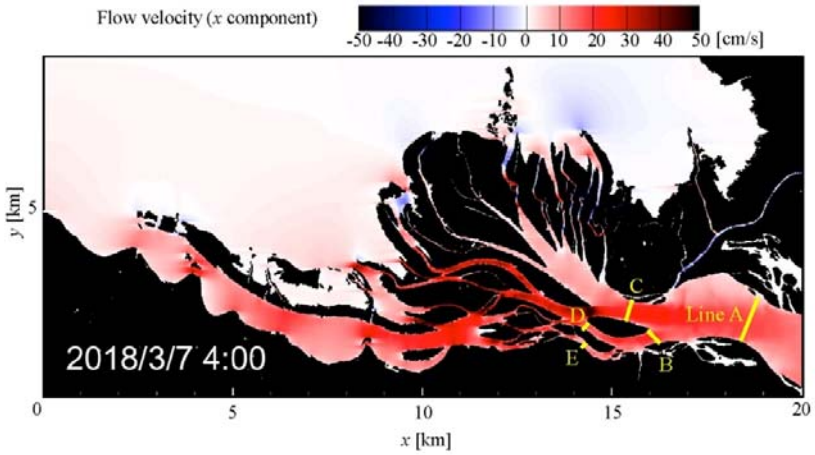

Figure 2.1 Calculated result of 2D flow simulation.

Table 2.1 Comparison of flowrate along the line A-E

	Line A	Line B	Line C	Line D	Line E
Observational Flowrate[m^3/s]	587	99	480	61	38
Calculated Flowrate [m^3/s]	583	102	437	82	30

Preparation of Computational Conditions

The Chhnok Tru floating village is placed around the upstream end of Tonle Sap River (TSR) and in a narrow sub-channel branching off from a main channel of TSR. In the upstream of the village, many small channels makes a complex network between the TSL and TSR (Figure 1.1). There is not sufficient information about the channels. A bathymetric map has already been published by Mekong River Commission (MRC, 1999). However, its spatial resolution does not seem enough fine to represent the narrow channels. Thus, a sounding survey was conducted around the village from 7th March to 9th March 2018. After positions of channel were detected by a satellite image analysis with Sentinel-2 data, elevation of river bed is interpolated from the result of sounding survey. Finally, a

new Digital Elevation Model (DEM) with a 10m spatial resolution was successfully created. To estimate the flowrate, a 2D shallow water simulation was applied to a wide area containing the Chhnok Tru floating village and the upstream channel network (Figure 2.1) (Nakamura, 2019). The simulation was conducted for one week (from 3rd to 10th March, 2018). The observed water level at Kompong Luong in the TSL was used as a boundary condition of upstream end. Along the line A-E, we mesured flowrate with an Acoustic Doppler Current Profiler. As shown in Table 2.1, it was confirmed that the calculated flowrate agrees very well with the observational data.

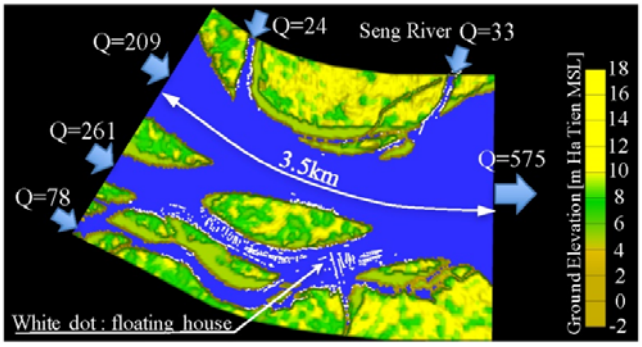

Figure 3.1 Computational domain and boudary conditions used in 3D flow simulation. Flowrates (Q [m^3/s]) are estimated from the 2D flow simulation.

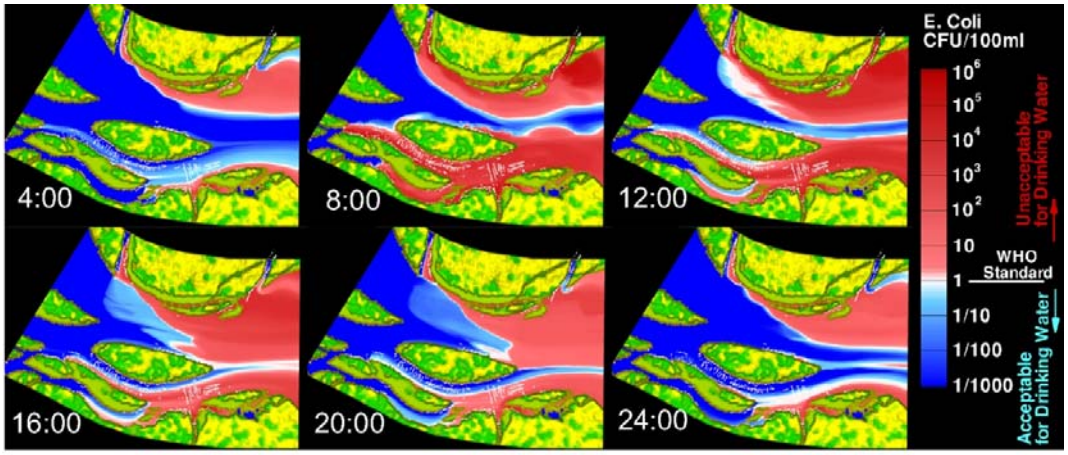

Figure 3.2 Daily change of *E coli.* concentration calculated by 3D transport simulation.

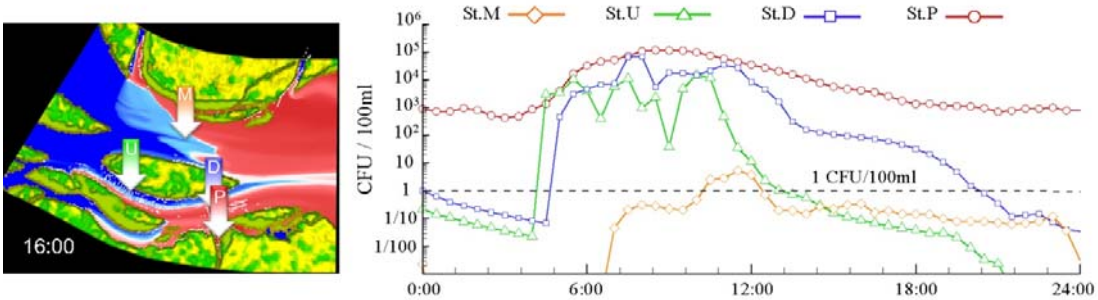

Figure 3.2 Temporal change of *E coli.* concentration at different location.

3D Simulation of *E. coli* Transport in Floating Village

The three-dimensional simulation was conducted for one week in the dry season (from 3rd to 10th March, 2018). As the 3D model, Tokyo Institute of Technology – WAter Reservoir Model (TITech-WARM) was used (Nakamura, 2013). TITech-WARM solves 3D water flow based on the Navier-Stokes equation with a k-ε turbulent model. Beside the flow, water temperature and transportation of substances can be calculated. A computational domain is set to a 3.5 km section of the Tonle Sap River (Figure 3.1). As boundary conditions, the flowrate at the edge of computational domain was estimated by integrating the flow velocity of the 2D simulation. The transport of *E. coli* was modeled as follows; 1) representing life span of *E. coli* is 10 hours, 2) *E. coli* are excreted from each house every morning, 3) time of the excreting are distributed randomly from 4 AM to 8 AM, 4) weight of feces excreted by each person is 105 g and 5) *E. coli* included in feces is 10^9 CFU/g. The position of each house was read from a satelite image. According to a demographics of Cambodia, we assume that five people lives in each house. Figure 3.2 shows the calculated daily-change of concentration of *E. coli* at water surface. The calculated result shows that the speed of reduction of *E. coli* concentration strongly depends on the topographic condition. As shown in Figure 3.3, in a channel where the many houses locate and water flow is relatively rapid, the concentration can reduce to the WHO standard for the drinking water (1CFU/100ml) before early afternoon (St.U). On the other hand, in a dead water area such as a clogged canal (St.P), the concentration is kept to be one thousand times denser than the WHO standard throughout the day.

Conclusion

3D flow simulation was applied for water current and *E. coli* transport in a floating village. The calculated results shown the following features of *E. coli* transport, which 1) the spreading/dilution process is influenced by the water current and topography, and 2) reduction rate of *E. coli* drastically changes according to location in the village. While *E. coli* concentration in the dead water area is kept to be larger than WHO standard, its concentration in the water channel can reduces to the level below the standard before early afternoon.

Acknowledgement

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ESTABLISHMENT OF ENVIRONMENTAL CONSERVATION PLATFORM OF TONLE SAP LAKE (SATREPS PROJECT)

THE 4TH INTERNATIONAL SYMPOSIUM ON CONSERVATION AND MANAGEMENT OF TROPICAL LAKES

Sokha Hotel

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PROCEEDINGS

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