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Numerical Modelling of Natural Flood Management and its Associated Microbial Risks in the United Kingdom

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Abstract

This paper reviews and discusses the recent studies of natural flood management (NFM) and its associated microbial risks in the UK and suggests set of numerical modelling approaches for their respective investigation. This study details the importance of precise numerical representation of the NFM to flood inundations and microbial risks caused by NFM measures. Possible future numerical advancements of the numerical modelling for the NFM and microbial activities are also discussed here.

Keywords: Natural Flood Management; Microbial Risks; Flash-Flood; Numerical Modelling

Introduction

In recent studies, natural flood management (NFM) has proven to be able to play crucial role in alleviating the devastation caused by flooding, in particular flash-floods that occur at UK and worldwide [18]. To understand NFM effectively, the use of accurate flood numerical modelling tool is crucial; however, in modelling of flash-flood's multiple inundations interaction, numerical spurious oscillations often happen in common hydraulic models that do not consider turbulence (i.e. caused by inundation through buildings/ housings within catchment) and sediment transport effects [2,3]. To add on to the modelling complexity, the microbacteria-related health risks to society that brought alone with flood water has to be predicted precisely to achieve good NFM planning.

Numerically, flood risks are commonly assessed by simplified hydraulic modelling strategies due to the high computational cost and demand of complicated models. Such simplified strategies are only appropriate in catchments with non-movable sediment, and relatively mild-slope and simple terrain [6]. In catchments with complicated landscape, this can result in significant computational errors. Due to the heavy rainfall pattern UK has recently recorded, most urban and rural catchments are subjected to flash-flooding. Thus, it is critical to incorporate accurate shock-capturing computational algorithms in the hydraulic modelling procedure in order to provide more precise estimation to flash-flood's complicated inundation system [7].

It has been found that the use of standard flood risk estimation tools in flash-flood catchments have tendency to underestimate flood's intensity, in particular the peak-flood levels. In small steep catchments such as those in south-west England, Wales and Scotland, there is a need for more advanced hydraulic modelling tools to accurately assess the effectiveness of NFM in reducing flood risk [8]. Viewing the afore-mentioned reasoning, this study will discuss the current technologies crucial for efficient hydraulic modelling to predict flooding in the UK.

Modelling Methodology of NFM

From previous findings, it is crucial for numerical model to employ a good strategy to integrate the global hydrodynamic system within a catchment to the local hydraulic model in order to ensure the accuracy of flood simulation. This coupled approach is also vital for effective NFM planning, as its strategy is tightly depending on the hydrodynamic features within the catchment and flow characteristics through the deployed NFM measures. To computationally represent the complicated impacts of NFM within catchment is challenging, due to:

a) The huge variation of frequency and intensity of flash-flood events, and

b) The uncertainty in climate change projection. Due to these complexities, the numerical prediction needs to be robust to anticipate different kind of hydraulic modelling challenges.

For the first and foremost challenge, due to the ever-changing flood frequency and intensity at the UK, it is hard to accurately model the flood-inundation as the drought (numerical dry) and flood-waves interaction (shock) coupling causes model degradation and inaccuracy. The designed model should couple flood-inundation, flow turbulence and sediment transport modelling to fully simulate flow through buildings/housings within catchment with watercourse/river erosion impact. For the turbulence modelling, an efficient Kolmogorov k-ε approach has been proposed [4]. In the model, the shock-capturing technique has been used as it is crucial for accurate flow representation at the shock-shock or dry-shock encountering flow areas. Tests in Pu [4] revealed that this method can sufficiently represent flow turbulence in shallow flow similar to flooding in urban domain, besides retaining time-saving characteristic in simulation. In the tested condition showing in Figure 1, the turbulent flow condition showed by the flow velocity vectors through various blocks positioned at different locations (can be used to represent housing/building blocks) was simulated with good accuracy. The flow was tested under the velocity of 0.24m/s and the Reynolds number of 6000. In [4], the simulated flow has also compared to experimental data by [9], which proved the accuracy of the numerical Kolmogorov k-ε approach in representing real-world flow turbulence, i.e. for flood flow.

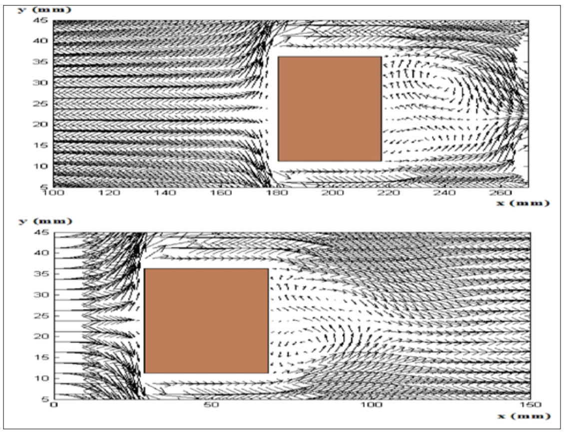

Figure 1: Flow tests of Kolmogorov k-ε numerical model (adapted from [4])

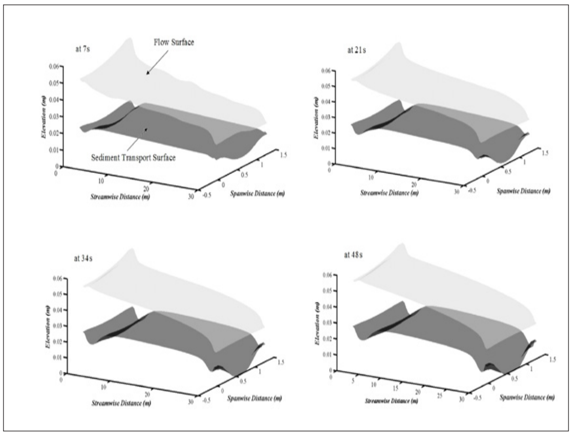

Figure 2: Change to 'Flow tests of time-varying sediment adaptation model (adapted from [2]).

In terms of modelling sedimentation within flood inundation, various studies have proposed time-effective models to represent the transport phenomenon accompanied in turbulence flow and flooding [1,4,10] and further study at Pu and Lim [5] suggested an effective sediment transport modelling system to simulate turbulent flow sedimentation, e.g. in concentrated sediment flashing and in fast scouring flow, suitable to be deployed in flash-flood modelling. The validation outcomes by [2] on a flow test with velocity of 0.53m/s and high sediment initial depth suggested that using time-varying sediment adaptation scheme can more effectively and accurately simulate the sedimentation with multiple inundation sources. The validation tests at Figure 2 shows that the time-varying sediment adaptation model simulated the flow depth and sediment bed-load with good accuracy when compared to measured data by [12] in study of [2].

Afore-studies demonstrates the recent numerical modelling developments that approach adequate capability to realistically simulate the turbulence and sediment transport within flood flow domain. However, for NFM planning, there are still individual modelling strategies needed for each NFM flood defence mechanism. As described by Working with Natural Processes (WWNP) framework by UK's Environment Agency (EA), there are numerous NFM key strategies such as wetlands, leaky-wood dams and flood-storage in fields [11]. In computational representation, this study suggests wetlands to be represented by numerical porous-medium, leaky-wood dams by obstructed-flow and flood-storage by extra spatial computation-domain for flow. By these ways, the numerical models discussed above could convert the complicated NFM strategies into simplified numerical functions, hence to produce comprehensible computational solutions. In addition, through these separate representations in different local flow domains, the performance of NFM measures could also be computed in both single and combination of computer clusters which could improve the computational effectiveness.

Potential Microbial Risks

Even though NFM carries good potential for flood mitigation, there are limited studies into the microbial risks that could be brought by the NFM measures. When we look at the three key strategies of NFM, all the wetlands, leaky-wood dams and field-storages could potential causing health hazards to flood communities by their own mechanism. One of the key risks comes from the pathogen contamination which is a waterborne process [13]. According to a key report by Historic England [14], the contamination risks from flood water is increasing year-by-year due to the worsen pollution and anthropogenic activities. The sources of such contamination are also complicated to trace due to the complexity of mixed environment, such as residential areas close to hills, urban rivers or natural green-fields.

Pathogens-induced risks from flood water is hard to be understood quantitatively [19] as its species can travelled with random flood propagation and reached a wide area even beyond the flood catchment. Besides, the flooding also impacts the local soil microbial communities and acts as medium for their interaction with residential homes/buildings, which this can impact negatively on the community's health in long-lasting manner [15]. For each key NFM measure, wetlands can promote soil and plant-related microbial risk; leaky-wood dams can feed into the microbial communities; and field-storages can act as breeding-ground to spread the microbacteria-related diseases, which their utilisations have to be carefully planned to avoid long-term impacts. In terms of numerical modelling, the microbial risks are hard to be computed due to the complicated flood inundating processes. The current strategy is usually coupling the hydrodynamic model and microbial risk spreading map to compare against the residential map [16,17]. However, this approach has to be revisited for reaching a representative modelling method due to the uncertainty of microbacteria interaction with inundation waves [18,19]. Also, the existing of different green, brown and grey-fields could also influence the microbial activities, which can add on to the modelling complexity.

Conclusion

This paper discusses the research efforts in natural flood management (NFM) modelling and its associated microbial risks. From various studies, it could be observed that the hydraulic modelling, including hydrodynamics, turbulence and sediment transport, are in advance stage to represent the real-world flooding. The microbial risks have been found to be complicated to represent due to its complex interaction with flood inundations and catchment environment. This further suggests that more researches are needed to refine current studies into NFM and its related microbial risks.

References

1. Boudet L, Sabatier F, Radakovitch O (2017) Modelling of sediment transport pattern in the mouth of the Rhone delta: Role of storm and flood events. Estuarine Coastal and Shelf Science 198: 568-582.
2. Pu JH, Hussain K, Shao S, Huang Y (2014a) Shallow sediment transport flow computation using time-varying sediment adaptation length. International Journal of Sediment Research 29(2): 171-183.
3. Pu JH, Shao S. Huang Y (2014b) Numerical and experimental turbulence studies on shallow open channel flows. Journal of Hydro-environment Research 8: 9-19.
4. Pu JH (2015) Turbulence modelling of shallow water flows using Kolmogorov approach. Computers and Fluids 115: 66-74.
5. Pu JH, Lim SY (2014) Efficient numerical computation and experimental study of temporally long equilibrium scour development around abutment. Environmental Fluid Mechanics 14: 69-86.
6. Hunter NM, Bates P, Neelz S, Pender G, Villanueva I, et al. (2008) Benchmarking 2D hydraulic models for urban flooding. Proceedings of the Institution of Civil Engineers: Water Management 161(WM1): 13-30.
7. Leandro J, Chen A, Djordjevic S, Savic, DA (2009) Comparison of 1D/1D and 1D/2D coupled (sewer/surface) hydraulic models for urban flood simulation. Journal of Hydraulic Engineering 135(6): 495-504.
8. Kvocka D, Ahmadian R, Falconer RA (2017) Flood Inundation Modelling of Flash Floods in Steep River Basins and Catchments. Water 9: 705.
9. Kabir MA, Khan MMK, Bhuiyan MA (2004) Flow phenomena in a channel with different shaped obstructions at the entrance. Fluid Dynamics Research 35: 391-408.
10. Guan M, Wright NG, Sleigh A (2015) Multiple effects of sediment transport and geomorphic processes within flood events: modelling and understanding. International Journal of Sediment Research 30: 371-381.
11. Burgess-Gamble L, Ngai R, Wilkinson M, Nisbet T, Pontee N, et al. (2017) Working with Natural Processes – Evidence Directory. Environmental Agency, Report No. SC150005.
12. Wren D, Kuhnle R, Chambers J (2005) Measurement of suspended-sediment concentration and particle size in laboratory flumes. Proceedings of Sediment Monitoring Instrument and Analysis Research Workshop pp: 1–8. Flagstaff, Arizona, USA.
13. Ramirez-Castillo FY, Loera-Muro A, Jacques M, Garneau P, Avelar-Gonzalez F,J et al. (2014) Waterborne pathogens: detection methods and challenges. Pathogens 4: 307-334.
14. Ridout B (2017) The health risks from contaminated flood water in the UK. Historic England, Report No. 39-2017.
15. Unger IM, Kennedy AC, Muzika RM (2009) Flooding effects on soil microbial communities. Applied Soil Ecology 42: 1-8.
16. Jorgensen C, Erichsen A, Mark O, Domingo NS, Heinicke G, et al. (2016) Dynamic modelling of health risks during wastewater influenced urban flooding. Proceedings of Novatech p: 1-4.
17. Taylor J (2012) Predicting the microbial risk in flooded London dwellings using microbial, hygrothermal, and GIS modelling. PhD Thesis, University College London, UK.
18. Lane S (2017) Natural flood management. Wires Water 4(3): e1211.
19. Ten Veldhuis JAE, Clemens FHLR, Sterk G, Berends BR (2010) Microbial risks associated with exposure to pathogens in contaminated urban flood water. Water Research 44: 2910-2918.