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A new methodology for dynamic modelling of health risks arising from wastewater influenced urban flooding

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Indroduction

Urban flooding due to rainfall exceeding the design capacity of drainage systems is a global problem and it has significant economic and social consequences. While the cost of the direct flood damages of urban flooding is well understood, the indirect damages, like the water borne diseases is in general still poorly understood. Climate changes are expected to increase the frequency of urban flooding in many countries which is likely to increase water borne diseases.

Diarrheal diseases are most prevalent in developing countries, where poor sanitation, poor drinking water and poor surface water quality causes a high disease burden and mortality, especially during floods. The level of water borne diarrhea in countries with well-developed water and waste water infrastructure has been reduced to an acceptable level, and the population in general do not consider waste water as being a health risk.

Hence, exposure to wastewater influenced urban flood water still has the potential to cause transmission of diarrheal diseases.

When managing urban flooding and planning urban climate change adaptations, health risks are rarely taken into consideration. This paper outlines a novel methodology for linking dynamic urban flood modelling with Quantitative Microbial Risk Assessment (QMRA). This provides a unique possibility for understanding the interaction between urban flooding and the health risks caused by direct human contact with flood water and provides an option for reducing the burden of disease in the population through the use of intelligent urban flood risk management.

Methodology

We have linked hydrodynamic urban flood modelling with quantitative microbial risk assessment (QMRA) to determine the risk of infection caused by exposure to wastewater influenced urban flood water. The deterministic model MIKE Flood, which integrates the sewer network model in MIKE Urban and the 2D surface model MIKE21, was used to calculate the concentration of pathogens in the flood water, based on either measured waste water pathogen concentrations or on assumptions regarding the prevalence of infections in the population. The exposure (dosage) to pathogens was estimated by multiplying the concentration with literature values for the ingestion of water for different exposure groups (e.g. children, adults). The probability of infection was determined by applying dose response relations and MonteCarlo simulation.

The methodology is demonstrated on two cases, i.e one case from a developing country with poor sanitation and one case from a developed country, where climate adaptation is the main issue: The risk of cholera in the City of Dhaka, Bangladesh during a flood event 2004, and the risk of bacterial and viral infections of during a flood event in Copenhagen, Denmark in 2011.

Results

The historical flood events in Dhaka (2004) and Copenhagen (2011) were successfully modelled. The urban flood model was successfully coupled to QMRA. An example of the results of the quantitative microbial risk assessment given as the average estimated risk of cholera infection for children below 5 years living in slum areas in Dhaka is shown in the figure.

Similarly, the risk of infection during the flood event in Copenhagen will be presented in the article.

Conclusions

We have developed a methodology for the dynamic modeling of the risk of infection during waste water influenced urban flooding. The outcome of the modelling exercise indicates that direct contact with polluted flood water is a likely route of transmission of cholera in Dhaka, and bacterial and viral infectious diseases in Copenhagen. It demonstrates the applicability and the potential for linking urban flood models with QMRA in order to identify interventions to reduce the burden of disease on the population in Dhaka City and Copenhagen.