Potential health risk associated with exposure to microorganisms in urban floods

Risques sanitaires potentiels au contact de micro-organismes présents dans les eaux d’inondation urbaine

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RÉSUMÉ

Avec le changement climatique, le nombre de journées avec de fortes pluies augmente. Par conséquent, y a plus d’inondations dans les zones urbaines. L’exposition à cette eau peut provoquer des problèmes de santé car elle est contaminée par des agents pathogènes d’origine humaine et animale. En 2011 et 2012, 23 prélèvements ont été effectués dans des zones urbaines aux Pays-Bas où il y avait eu des inondations. Ces prélèvements ont été analysés et testés pour voir l’éventuelle présence de la bactérie E. coli ou l’entérocoque intestinal ou certains agents pathogènes d’origine entériques (agents pathogènes dans les intestins). Cette recherche a démontré qu’il existe un risque que l’eau provenant des inondations soit contaminée par des matières fécales, ce qui a été démontré par des concentrations élevées de la bactérie E. coli et de l’entérocoque intestinal. L’eau était contaminée également par des agents pathogènes entériques, à savoir Campylobacter, Giardia, Cryptosporidium, norovirus et les entérovirus. L’exposition à ces agents pathogènes peut provoquer des problèmes de santé. En supposant qu’une personne avale 0,1 ml, il y a un risque d’infection de 36% pour ce qui est de l’eau provenant des égouts unitaires. Pour ce qui est de l’eau provenant des égouts pluvieux ce risque d’infection est de 3,4% et pour ce qui est de l’eau coulant dans les rues inondées ce risque d’infection est de 1,1%. Bien que cette recherche ait été effectuée aux Pays-Bas, les données quantitatives sur les agents pathogènes peuvent être utilisées pour les analyses quantitatives des risques microbien dans d’autres pays.

ABSTRACT

One of the major global concerns with a potential change in climate is the increased frequency of intensive rainfall, which may result in flooding. Exposure to floodwater may have negative health effects because the water is contaminated with micro-organisms from human and animal origin. From 2011 to 2012, 23 samples were taken of urban floods in the Netherlands and analyzed for fecal indicator bacteria E. coli and intestinal enterococci and some waterborne enteric pathogens. Urban floodwater was fecally contaminated, which was demonstrated by elevated concentrations fecal indicator bacteria. The floodwater contained waterborne enteric pathogens, namely Campylobacter, Giardia, Cryptosporidium, norovirus and enterovirus. Exposure to these pathogens may pose a health risk. Assuming that an exposed individual ingested 1 ml resulted in a risk of infection of 20% for floodwater originating from combined sewers, compared to 10% for floodwater originating from storm sewers and 1% for floodwater originating from rainfall generated surface runoff. Although this research was performed in the Netherlands, the generated quantitative pathogen data for urban floodwater may be useful to inform quantitative microbial risk assessments in other countries.

KEYWORDS

Climate change, Combined sewer, Indicator bacteria, Pathogens, Public health risk, Storm drain, Surface runoff, Urban floods
1 INTRODUCTION

One of the major global concerns with a potential change in climate is the increased frequency of extreme events (Easterling, Meehl et al. 2000). Observational studies suggest that in several areas changes in total precipitation are amplified at the extremes and changes in temperature extremes have been observed. Global climate scenarios for the future show that flooding will occur more often, which is amplified by ongoing urbanization and increased imperviousness of urban areas (ten Veldhuis, Clemens et al. 2010).

People who are exposed to flooding may run health risks, because the water might be contaminated with pathogens from human and animal origin (Communicable Disease Surveillance Centre Public Health Wales 2011). Floodwater originating from rainfall generated surface runoff might be contaminated by pathogens originating from runoff dirt from paved surfaces (including dog feces and bird droppings). Floodwater originating from flooded storm sewers might be contaminated by pathogens originating from these sources, but also by human pathogens originating from illicit household connections. Floodwater originating from backflow from a combined sewer system is definitely contaminated with pathogens originating from (diluted) wastewater.

Citizens may be exposed to pathogens in floodwaters and sediments during the flood itself and throughout clean-up procedures (Fewtrell, Smith 2007). They might be exposed through ingestion, inhalation and/or dermal contact, which can result in outbreaks. For example, an outbreak of norovirus infection in American tourists in Salzburg revealed a link with direct exposure to floodwater contaminated with raw sewage (Schmid, Lederer et al. 2005). Following heavy exposure to the floodwaters during the clean up, 49 of 64 people in the party (77%) succumbed to a gastrointestinal illness later diagnosed as norovirus infection.

Epidemiological studies focus primarily on the investigation of outbreaks that have already occurred, offering little insight into how to prevent such outbreaks. Instead of that, a quantitative microbial risk assessment (QMRA) can quantify health risks for exposed people and such an assessment may be used to get insight into measures that can prevent outbreaks. Such an assessment requires information on the concentration of pathogens in the water, the exposure of people to these pathogens, and dose-response relations for different pathogens. However, there is no information about the concentration of pathogens in urban floodwater.

In this study, the fecal contamination of urban floodwater is investigated by measuring indicator bacteria Escherichia Coli and intestinal enterococci. The prevalence of human enteric pathogens is determined by measuring Campylobacter, Giardia, Cryptosporidium, norovirus and enterovirus. Based on these data, a QMRA was performed to determine the risk of infection for exposure to urban floodwater.

2 MATERIAL AND METHODS

Flood incidents in the Netherlands were sampled from June 2011 until May 2012 by a sample team that drove to locations where flooding was expected according to a Dutch meteorological website (www.weerplaza.nl). When the sample team arrived at such a location, they checked for emergency calls about flooding on their smartphone (www.112meldingen.nl) and went to that address. Samples were taken at locations where at least 100 m² of the street was flooded, where buildings were flooded or where infiltration fields were filled up.

Twenty-three samples were analysed for the presence of bacteria E.coli and intestinal enterococci, which indicate a recent fecal contamination and suggest that human pathogens are possibly present. Furthermore, the concentrations of the pathogens Campylobacter, Giardia, Cryptosporidium, norovirus and enterovirus were analysed according to ISO 17995, ISO 15553 and (Schets, Van Wijnen et al. 2008). These pathogens are representative of the fate and transport of other pathogens potentially of concern from the waterborne route of exposure (Ferguson, De Roda Husman et al. 2003) and together these pathogens make up a large portion of all gastrointestinal illnesses from known pathogens in the Netherlands and US (De Wit, Koopmans et al. 2001, Mead, Slutsker et al. 1999).

To determine to which extent exposure to these pathogens in water of urban floods poses a health risk for people was quantified by means of a quantitative microbial risk assessment (QMRA). The risk of infection was estimated using dose-response models (Schijven, Teunis et al. 2011) and was calculated as a function of the consumption of water in litres. The risk of infection was distinguished for, respectively, flooding originating from rainfall generated surface runoff, storm sewers and combined sewers.
3 RESULTS AND DISCUSSION

Urban floodwater was found to be fecally contaminated, which was demonstrated by elevated concentrations fecal indicator bacteria ($10^5$-$10^7$ Colony Forming Units per litre). See table 1. The prevalence of waterborne enteric pathogens in urban floodwater ranged from approximately 30% for norovirus and Cryptosporidium up to almost 90% for Campylobacter. Depending on the method applied to detect pathogens (PCR, plating, microscopy) pathogen concentrations ranged from $0.1 - 10^3$ per liter. These enteric pathogens originated from human (norovirus and enterovirus) and animal reservoirs.

Floodwater originating from combined sewers contained more different pathogens compared to floodwater that originating from storm sewers or floodwater originating from rainfall generated surface runoff. Furthermore the concentration of pathogens in floodwater originating from combined sewers was higher than floodwater originating from from storm sewers or from rainfall generated surface runoff.

Table 1 Concentrations of fecal indicator bacteria in samples of urban flood water that originated from combined sewers, stormdrains and rainfall generated surface runoff.

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Floodwater that originated from combined sewers</th>
<th>Floodwater that originated from storm sewers</th>
<th>Floodwater that originated from rainfall generated surface runoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.coli</td>
<td>$10^7$-$10^8$ CFU/l</td>
<td>$10^3$-$10^6$ CFU/l</td>
<td>$10^4$-$10^5$ CFU/l</td>
</tr>
<tr>
<td>Intestinal enterococci</td>
<td>$10^4$-$10^6$ CFU/l</td>
<td>$10^3$-$10^6$ CFU/l</td>
<td>$10^4$-$10^5$ CFU/l</td>
</tr>
</tbody>
</table>

Quantitative microbial risk assessment shows that the risk of infection for exposure to floodwater originating from combined sewers was higher than the risk of infection for exposure to floodwater originating from storm sewers or rainfall generated surface runoff. See figure 1. Assuming that an exposed individual ingests $10^{-3}$ liter of water resulted in a risk of infection of 20% for floodwater originating from combined sewers, compared to 10% for floodwater originating from storm sewers and 1% for rainfall generated surface runoff. However, the risk that an exposed individual became ill after infection is dependent on his susceptibility.

Figure 1 Results of quantitative microbial risk assessment for floodwater that originated from combined sewers, from storm sewers and from rainfall generated surface runoff.
4 CONCLUSION

The results of this study demonstrated that floodwater can be fecally contaminated and that enteric pathogens are present in urban floodwater. Exposure to these pathogens may pose a health risk, to which extent however is also dependent on the magnitude of exposure (i.e. the volume of ingestion) and the susceptibility of the host. Quantitative microbial risk assessment showed that flooding originating from sewage causes higher risks of infections compared to flooding originating from storm sewers or from rainfall generated surface runoff. However, the extent to which people are exposed to urban floodwater was not yet included and has to be investigated to quantify infection risks more closely. The generated quantitative pathogen data may be useful to inform risk assessments in other EU member states.

LIST OF REFERENCES

COMMUNICABLE DISEASE SURVEILLANCE CENTRE PUBLIC HEALTH WALES, 2011. Systematic review of waterborne disease outbreaks following extreme water events.


