Precipitation, Raw Water Quality, Drinking Water Treatment and Gastrointestinal Illness

Andreas Tornevi

Akademisk avhandling

som med vederbörligt tillstånd av Rektor vid Umeå universitet för avläggande av medicine doktorsexamen framläggs till offentligt försvar i Triple Helix, Samverkanshuset, fredagen den 9 oktober, kl 13.00
Avhandlingen kommer att försvaras på engelska.

Abstract

Background. On numerous occasions, outbreaks of acute gastrointestinal illnesses (AGI) have been linked to municipal drinking water in the industrialised world. Many of the reported outbreaks were observed after heavy rainfall events, which suggests that such events could result in a deterioration in the quality of drinking water. The observed drinking water-related outbreaks are, however, probably just the tip of the iceberg, and the extent to which public drinking water also influences the endemic level of gastroenteritis during non-outbreak periods is largely unknown. With climate change projected to increase the frequency of extreme weather events, data for preventive actions are needed now, to ensure safe drinking water today and in the future. The primary aim of this thesis is to increase the knowledge of the extent to which rainfall can still be a risk for insufficient drinking water quality, even with modern drinking water production methods. We aim to study if the incidence of gastroenteritis during normal endemic levels can be associated with water quality and the efficacy of pathogen elimination in different treatment processes. The thesis focuses first on AGI in the Gothenburg population and how precipitation affects its main fresh water supply (Papers I-III); this is followed by a broader comparison of AGI in 20 cities across Sweden (Paper IV).

Methods. Observational time series data was used for all papers to construct generalized additive regression models, using smooth functions to adjust for long-term trends. Delayed effects on the outcome were evaluated using distributed lag non-linear models. In Paper I, the raw water-quality data for the river Göta älv were analysed – this water is used to produce drinking water for the population living in the north part of City of Gothenburg. The short-term variation of daily mean turbidity measurements and samples of three different types of indicator bacteria were modelled with daily precipitation using seven years of data. In papers II and III, the analyses aimed to determine whether the daily incidence of AGI in the population which households received drinking water produced from the river water could be associated with precipitation. As a measure of AGI, we used four years of data on the daily number of phone calls to the nurse advice line about vomiting, diarrhoea or abdominal pain (Paper II), and six years of data of the daily number of visits to health care clinics, when individuals were diagnosed with gastrointestinal infections (Paper III). Paper IV analyses and compares the occurrence and seasonal patterns of nurse advice calls in twenty cities in Sweden, using seven years of data. The water treatment technique used by the public drinking water plants was obtained, and the processes theoretical efficacy of pathogen elimination was determined. The extent of AGI calls in relation to the pathogen elimination efficacy was analysed using a binomial regression design, adjusting for population size, age distribution and geographical area.

Results. We observed a strong relation between precipitation and the water quality in the Göta älv. A heavy rainfall event was related to increased concentrations of E. coli bacteria for several days, with the peak increase two days after the event. Precipitation was found to affect raw water quality parameters across all seasons. Heavy precipitation was also associated with a significant increase in the daily number of nurse advice calls due to AGI symptoms, with the number of calls peaking five days later. Consecutive wet weather periods were associated with both an increased number of AGI calls, as well as visits to clinics that led to diagnoses of AGI. Finally, we observed in Paper IV that cities with a higher pathogen elimination efficacy in their drinking water utility had a lower amount of AGI calls. The relations applied both to surface water and groundwater utilities, although the protective effect of better drinking water treatment on AGI was observed to be most significant in cities with surface water plants during the winter season.

Conclusions. The results suggest it is possible to reduce the occurrence of endemic gastroenteritis with a more advanced treatment process for drinking water. The delay between a heavy rainfall event (and the resulting decrease in raw water quality) and the increased number of nurse advice calls suggests viruses are the main cause, as the timing is consistent with viral incubation times. A viral transmission was also proposed when comparing different cities, as a more advanced water treatment process seems to be most beneficial during seasons where viruses are acknowledged as the main cause of AGI. Our research suggests that upgrades to drinking water treatment techniques, especially those aiming to better eliminate viruses, are warranted.