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Exposure assessment for swimmers in bathing waters and swimming pools

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ABSTRACT

Bathing water compliant with bathing water legislation may nevertheless contain pathogens to such a level that they pose unacceptable health risks for swimmers. Quantitative Microbiological Risk Assessment (QMRA) can provide a proper basis for protective measures, but the required data on swimmer exposure are currently limited or lacking. The objective of this study was to collect exposure data for swimmers in fresh water, seawater and swimming pools, *i.e.* volume of water swallowed and frequency and duration of swimming events.

The study related to swimming in 2007, but since the summer of 2007 was wet and this might have biased the results regarding surface water exposure, the study was repeated relating to swimming in 2009, which had a dry and sunny summer. Exposure data were collected through questionnaires administered to approximately 19 000 persons representing the general Dutch population.

Questionnaires were completed by 8000 adults of whom 1924 additionally answered the questions for their eldest child (<15 years). The collected data did not differ significantly between 2007 and 2009. The frequency of swimming and the duration of swimming were different for men, women and children and between water types. Differences between men and women were small, but children behaved differently: they swam more often, stayed in the water longer, submerged their heads more often and swallowed more water.

Swimming pools were visited most frequently (on average 13–24 times/year) with longest duration of swimming (on average 67–81 min). On average, fresh and seawater sites were visited 6–8 times/year and visits lasted 41–79 min. Dependent on the water type, men swallowed on average 27–34 ml per swimming event, women 18–23 ml, and children 31–51 ml.

Data on exposure of swimmers to recreational waters could be obtained by using a questionnaire approach in combination with a test to measure mouthfuls of water for transformation of categorical data to numerical data of swallowed volumes of water. Previous assumptions on swimmer exposure were replaced with estimates of exposure parameters, thus reducing uncertainty in assessing the risk of infection with waterborne pathogens and enabling identification of risk groups. QMRA for *Cryptosporidium* and *Giardia* was demonstrated based on data from previous studies on the occurrence of these pathogens in recreational lakes and a swimming pool.

Abbreviations: CI, Confidence Interval; QMRA, Quantitative Microbiological Risk Assessment.

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1. Introduction

As a result of poor microbiological water quality, exposure to bathing waters may pose health risks for swimmers. They may contract illnesses such as gastro-enteritis from infections with bacteria, viruses or parasites of fecal origin (WHO, 2003), but also skin disorders like cercarial dermatitis as a result of contact with the larvae of the parasite *Trichobilharzia* (Horák and Kolářová, 2001), or otitis externa due to an infection with *Pseudomonas aeruginosa* (Van Asperen et al., 1995). Bathing water legislation is in place to protect swimmers from fecal contaminants, although guideline values are not based on pathogen concentrations but on fecal indicator levels (Anonymous, 2006). Previous studies have demonstrated that bathing water that complies with bathing water guideline values may contain pathogens (Graczyk et al., 2007; Schets et al., 2008), whether of fecal origin or not, and thus still pose an unacceptable health risk for swimmers. Management actions solely triggered by non-compliance with fecal indicator standards may therefore not effectively protect bathers. A Quantitative Microbiological Risk Assessment (QMRA) of bathing in surface water may provide insights that can be translated into effective protective measures (Ashbolt et al., 2010). QMRA requires information on the concentration of pathogens in the water, swimmer exposure to these pathogens and dose-response relations for different pathogens. In this regard, there is little information available on swimmer exposure, *i.e.* the amount of swallowed water and how much skin contact there is with water. WHO guidelines assume that 20–50 ml of water is swallowed per hour of swimming activity (WHO, 2003); however, these values are not supported by studies on water ingestion. Schijven and de Roda Husman (2006) estimated the exposure of occupational and sport divers and found that both groups swallowed about the same volume per dive in marine waters (9.8 *vs.* 9.0 ml), whereas sport divers swallowed more than occupational divers in fresh (recreational) waters (13.0 *vs.* 5.7 ml). Sport divers diving in swimming pools swallowed a mean volume of 20 ml per dive. A study of water ingestion during active swimming in a swimming pool showed that non-adult swimmers (≤18 years) swallowed far more water than adult swimmers during the 45 min of their exposure (37 *vs.* 16 ml) (Dufour et al., 2006). The authors suggested that these swallowed volumes of water may also apply to fresh water swimmers due to similar frequencies of head submersions and time spent in the water, but not to marine water swimmers because of different behavior. The study does, however, not provide data on exposure of swimmers to fresh and marine water to substantiate this suggestion. Recently, Stone et al. (2008) estimated water ingestion and exposure among surfers and reported an average of 171 ml swallowed per day.

These studies provided valuable information, but data on water ingestion among swimmers in fresh and seawater are lacking and also, information on the duration and frequency of swimming events in recreational waters, sea or swimming pools is not available.

The objective of this study was to collect data on exposure of swimmers to fresh water, seawater and swimming pools; exposure data encompass the volume of swallowed water and the frequency and duration of swimming events. In the Netherlands, swimming in surface water typically occurs during the official bathing season (May 1st–October 1st), but mostly during the summer holidays (July–August). Water temperature in the North Sea ranges between approximately 10 and 20 °C, with an average of 18 °C; water temperatures in recreational lakes are highly variable depending on size and depth, but grossly range between 15 and 25 °C. Public swimming pools, both indoor and outdoor, use drinking water as source water and are chlorine disinfected, as required by law (Anonymous, 2009). In indoor swimming pools the water temperature is 25–28 °C, but in outdoor pools it is around 22–24 °C. Many outdoor pools close during the winter season.

The exposure data were used to estimate infection risks resulting from exposure to recreational waters and a swimming pool. To the latter, concentration data on *Cryptosporidium* oocysts and *Giardia* cysts in recreational waters (Schets et al., 2008) and a swimming pool (Schets et al., 2004) were used. In the two cited studies, infection risks were estimated in scenario's using a range of set swallowed water volumes. In the current study, exposure data were collected by means of questionnaires. To evaluate the impact of different years characterized by different weather conditions, particularly during summer, exposure data were collected in 2007 and 2009. The hypothesis that 2009 responders would report more frequent and longer bathing in fresh and marine water than 2007 responders due to more favorable weather conditions during summer was tested.

2. Materials and methods

2.1. Data collection

Data on bathing water exposure were collected through administration of questionnaires to a group of approximately 60 000 to 75 000 inhabitants of the Netherlands representing the general Dutch population, hereafter referred to as the E-panel (Research institute Synovate BV, Amsterdam, the Netherlands). Members of the E-panel have given their consent for responding to questionnaires about various topics, in return for a small consideration. The questionnaires were administered via the internet and the respondents had access to the questions through a secured web link. E-panel members have also provided information on basic demographic characteristics such as age, gender, postal code, socioeconomic status and composition of family.

The questionnaire on bathing water exposure included questions about frequency of bathing, duration of bathing, the amount of water swallowed during bathing, head submersion while bathing, whether or not bathing took place at sites that were designated as official European bathing sites, and general health and health complaints after bathing. The E-panel members were asked to provide answers for exposure to swimming pool water, fresh water and seawater separately. A questionnaire referring to bathing in 2007 was administered in December 2007–January 2008, and a questionnaire referring to bathing in 2009 was administered in December 2009–January 2010. Descriptive characteristics of the summers (June–August) of 2007 and 2009 were obtained from