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Estimated human health risks from exposure to recreational waters impacted by human and non-human sources of faecal contamination☆

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ABSTRACT

This work was conducted to determine whether estimated risks following exposure to recreational waters impacted by gull, chicken, pig, or cattle faecal contamination are substantially different than those associated with waters impacted by human sources such as treated wastewater. Previously published Quantitative Microbial Risk Assessment (QMRA) methods were employed and extended to meet these objectives. Health outcomes used in the analyses were infection from reference waterborne pathogens via ingestion during recreation and subsequent gastrointestinal (GI) illness. Illness risks from these pathogens were calculated for exposure to faecally contaminated recreational water at the U.S. regulatory limits of 35 cfu 100 mL^{-1} enterococci and 126 cfu 100 mL^{-1} *Escherichia coli*. The probabilities of GI illness were calculated using pathogen dose-response relationships from the literature and Monte Carlo simulations. Three scenarios were simulated, representing a range of feasible interpretations of the available data. The primary findings are that: 1) GI illness risks associated with exposure to recreational waters impacted by fresh cattle faeces may not be substantially different from waters impacted by human sources; and 2) the risks associated with exposure to recreational waters impacted by fresh gull, chicken, or pig faeces appear substantially lower than waters impacted by human sources. These results suggest that careful consideration may be needed in the future for the management of recreational waters not impacted by human sources.

1. Introduction

Since the 1950s, numerous epidemiology studies have been conducted worldwide to evaluate the association between recreational water quality and adverse health outcomes including gastrointestinal (GI) symptoms; eye infections; skin irritations; ear, nose, and throat infections; and respiratory illness (Prüss, 1998; Wade et al., 2006; Zmirou et al., 2003).

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Together these studies indicate that the rates of some adverse health outcomes are higher in swimmers compared with non-swimmers and that faecal indicator bacteria (faecal streptococci/enterococci and *Escherichia coli*, in particular) can be used to predict GI and in some cases, respiratory illnesses from exposure to recreational waters (Prüss, 1998; Wade et al., 2006; Zmirou et al., 2003).

Most bathing water epidemiology studies have investigated municipal wastewater effluent-impacted waters, and thus, the relative human health risks from exposure to recreational waters impacted by non-human sources are not as well understood. Sinton et al. (1998) reviewed available data to differentiate the relative health risks associated with human and animal faecal material and reported that reliable epidemiologic evidence was lacking for non-human impacted waters. More recently, the few studies undertaken provide mixed views. On one hand, Colford et al. (2007) reported that the incidence of swimmer illness was not associated with any of the traditional bacterial indicators at a marine beach with likely avian contamination. Fleisher et al. (2010) found no relationship between GI illness and increasing levels of enterococci at a subtropical marine water without known sources of sewage. Calderon et al. (1991) found no statistically significant association between swimmers' illness risk and animal faecal contamination in a freshwater pond. However, McBride (1993) suggested that if more swimmers had been included in the Calderon et al. (1991) study, achieving statistically significant results would have been possible. Finally, Dwight et al. (2004) demonstrated that surfers exposed to Southern California urban run-off had higher illness rates than surfers exposed to Northern California rural runoff, but detailed source characterizations were not provided. On the other hand, a marine bathing study in New Zealand (McBride et al., 1998) indicated that illness risks posed by animal versus human faecal material were not substantially different. In a study conducted in waters impacted by urban runoff, Haile et al. (1999) reported rates of illnesses in Southern California similar to those conducted in waters contaminated with municipal wastewater. However, the urban runoff source was known to have human sources of faecal contamination (Colford et al., 2007). The results from a marine water study in Hong Kong (Cheung et al., 1990) and a German freshwater study (Wiedenmann et al., 2006) are more difficult to interpret regarding risks from human versus non-human sources because in both studies, the analyses combined the results from sites with different predominant contamination sources. Taken together, these studies indicate that the health risks associated with swimming in non-sewage impacted waters remain equivocal.

The U.S. Environmental Protection Agency's (EPA) recreational water quality criteria do not differentiate between faecal sources (U.S. EPA, 1986). While new EPA recreational water criteria will be issued in 2012, the current situation is that waters impacted by non-human faecal contamination sources are considered as hazardous as human-derived sources. The World Health Organization's (WHO) recommended approach for classifying the water quality of recreational waters is based on the premise that the measure of bacterial (intestinal enterococci) indicators of faecal contamination should be interpreted in combination with evidence of the presence or absence of human faecal contamination (i.e. sanitary significance). The WHO approach assumes that in general, sources other than human faecal contamination are less of a risk to human health (WHO, 2003). In fact, WHO indicates that "due to the species barrier, the density of pathogens of public health importance is generally assumed to be less in aggregate in animal excreta than in human excreta and may therefore represent a significantly lower risk to human health" (WHO, 1999). From a regulatory and management perspective, it is important to understand whether exposure to recreational waters impacted by non-human sources corresponds to significantly different illness risks than human impacted waters.

In previous work, we presented a QMRA approach for comparing the potential health risk from exposure to recreational waters impacted by two sources of faecal contamination (Schoen and Ashbolt, 2010). Seagull faeces and primary sewage effluent were compared at the same density of faecal indicator bacteria (FIB) with the result of a lower predicted illness risk from seagull impacted waters (Schoen and Ashbolt, 2010). We also used QMRA to understand more fully the reported results from the 2003–2004 Great Lakes epidemiologic studies (Soller et al., submitted for publication). Those QMRA results indicate that human enteric viruses were the etiologic agents of primary concern during the epidemiologic studies and that using *Norovirus* as a reference pathogen likely accounted for the vast majority of gastrointestinal (GI) illness risk. The present study builds upon the previous work summarized above and was undertaken as an initial step to determine whether the relative risks from exposure to recreational waters impacted by gulls, chickens, pig, and/or cattle are substantially different than those associated with human impacted waters.

2. Methods

A QMRA-based approach was employed to predict estimated risks of infection and illness from ingestion of recreational water that is assumed to be contaminated with faeces from a range of human and non-human sources (secondary disinfected wastewater effluent, primary wastewater effluent, cattle, pig, chicken and gull faeces). The estimated risks were calculated for a hypothetical waterbody that contains sufficient contamination from each source so that the geometric mean FIB densities are at the U.S. recommended criteria for recreational marine and freshwaters (35 cfu 100 mL^{-1} enterococci and 126 cfu 100 mL^{-1} *E. coli* respectively). Epidemiology studies indicate that these indicator densities would result in highly credible gastrointestinal illness (HCGI) rates of approximately 0.01–0.02 (1–2 illnesses per hundred recreation events) for waters impacted by treated effluent (U.S. EPA, 1986). A recent redefinition of HCGI that excludes the need for fever (Colford et al., 2007; Wade et al., 2006, 2008) would result in an equivalent benchmark risk of approximately 0.03–0.04. Although undisinfected primary effluent is rarely discharged to recreational waters in the USA, this faecal contamination source was included here to evaluate the potential health implications of poorly treated effluent, leaking sewerage infrastructure, bather shedding, and/or poorly operating septic systems.