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To swim or not to swim? A disagreement between microbial indicators on beach water quality assessment in Hong Kong

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ABSTRACT

The USEPA and the WHO now advocate the use of enterococci as indicators for marine water quality. This study investigated the outcomes for Hong Kong beach water quality assessment by comparing enterococcus measures with data from the HKEPD's monitoring programme. Six beaches were tested once every 2–3 months from November 2013 to June 2014 in order to identify the most contaminated sites, followed by intensive water sampling in sites found to have the highest enterococci densities (Clear Water Bay Second and Golden) every five to six days for six sampling events over a 30-day period in 2014. The geometric means of enterococci were found to be 124 and 41 cfu/100 mL at Clear Water Bay Second and Golden respectively, indicating that there may be higher risks of illness associated with swimming at both beaches than previously known. Moreover, beach sediments contained higher concentrations of enterococci than water, and warrant further study.

1. Introduction

In 2012, Hong Kong reached a population of about seven million. Human sewage is thus a major source of marine pollution in Hong Kong, with high concentrations of microbes posing a direct threat to human health. Over 2.7 million m^3 of treated sewage is discharged into Hong Kong coastal waters every day but over 80% of this volume receives only preliminary treatment or Chemically Enhanced Primary Treatment (CEPT) with disinfection (DSD, 2014). Moreover, 7% of the population (approximately 500,000) is not covered by public sewerage (DSD, 2014). Data from the Drainage Services Department (DSD) has shown that the effluents from Stonecutters Island Sewage Treatment Works (Fig. 1) contain a high concentration of *Escherichia coli* (*E. coli*) even with disinfection (chlorination). In September 2014 for example, the geometric mean (GM) of *E. coli* in treated effluent was approximately 50,000 cfu/100 mL with single measures sometimes exceeding 2 x 10^6 cfu/100 mL. Although the effluent is discharged through a deep tunnel, it is still believed to affect the water quality in beaches relatively close to the outfalls, such as the one in Silver Mine Bay (Fig. 1) (Thoe et al., 2012) and those in the Tsuen Wan area (Fig. 1) (EPD, 2005). The lack of high-level sewage treatment and direct discharge of untreated sewage may be compromising coastal water quality in certain areas of Hong Kong.

Despite known issues with sewage pollution, 41 gazetted beaches in Hong Kong have attracted nearly 10 million visitors in 2014 (EPD, 2014). Monitoring beach water quality in Hong Kong is therefore critical for the protection of public health, as swimming in sewage-contaminated waters increases the risk of diseases and infections, most commonly gastroenteritis, skin infections and respiratory diseases. In 1990, it was estimated that swimming in polluted water accounted for over 400,000 illness cases in Hong Kong and that swimmers were five times more likely to develop gastroenteritis than non-swimmers (Cheung et al., 1990). Therefore, a positive correlation between illness rate and bacterial load has to be established and appropriate indicator microbes must be monitored in order to accurately assess the health risk of swimming in contaminated waters. In an epidemiological research programme conducted during the 1970s, a linear relationship between enterococci density and swimming-associated highly credible gastrointestinal illness (HCGI) was reported (Cabelli et al., 1982). It was also observed in the same study that the frequency of gastroenteritis cases was associated with proximity to sewage sources. Fleisher et al. (1996) investigated the dose–response relationship in swimmers exposed to sewage-contaminated waters in the UK and also found a significant increase of acute febrile respiratory illnesses in bathers when the pollution level increased from 51 to 158 faecal streptococci per 100 mL. The correlation between illness rate and microbial indicators, such as enterococci and *E. coli*, thus facilitates the protection of public health by setting guideline values of these indicators.

The Hong Kong Environmental Protection Department (EPD) is responsible for monitoring beach water quality in Hong Kong. During the bathing season (March to October), the EPD collects water samples at least three times a month at each of Hong Kong's 41 gazetted beaches. The beaches are graded every year based on the GM of *E. coli* counts throughout the bathing season. The water quality criteria for Hong

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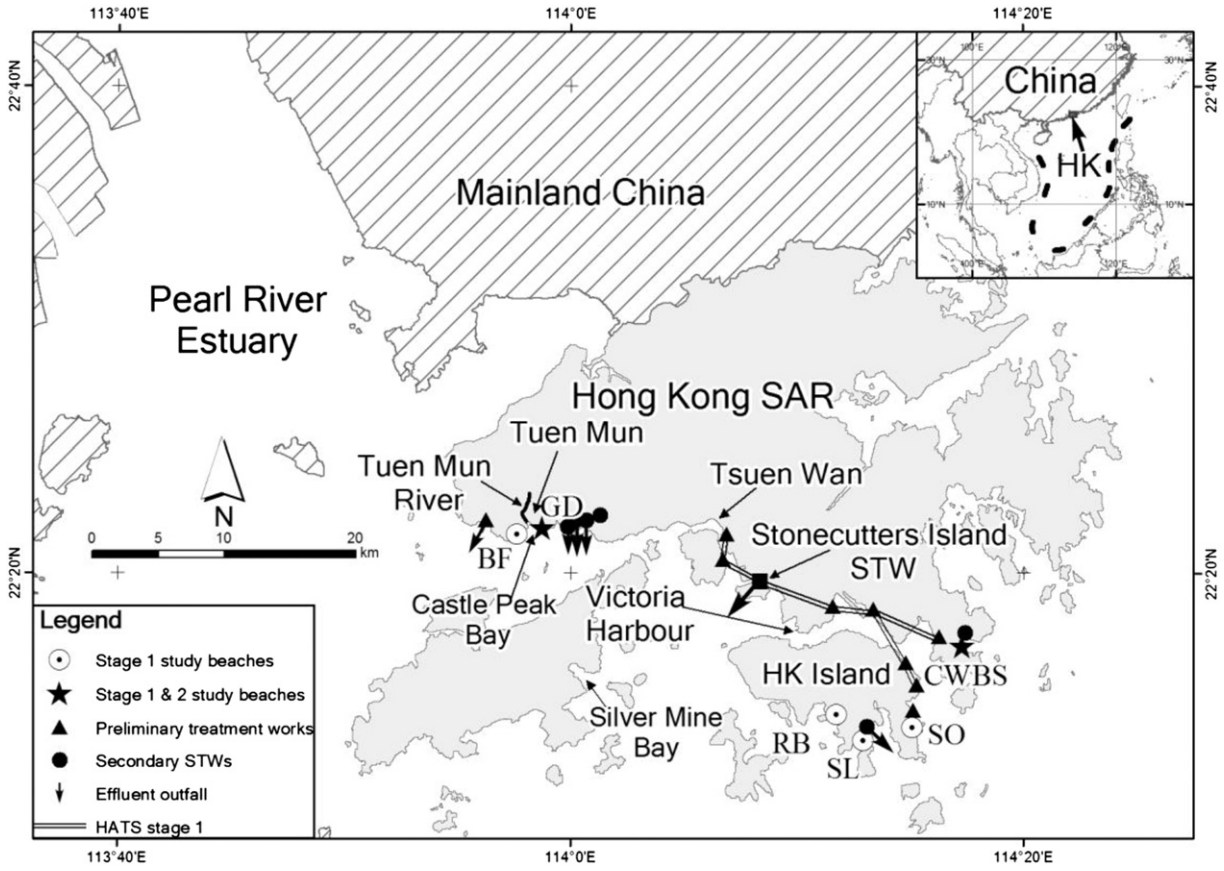

Fig. 1. The locations of the beaches under study and some of the sewages treatment works (STWs) with their effluent outfall directions. BF: Butterfly; CWBS: Clear Water Bay Second; GD: Golden; Repluse Bay; Stanley Main: SL; SO: Shek O. The lack of sewage outfall directions for some STWs means the outfalls are too short and are not significant in the map.

Kong (Water Quality Objectives or WQOs) set a limit on *E. coli* level at 180 counts/100 mL for bathing beaches, which corresponds to a swimming-associated illness rate of 10 cases/1000 swimmers. This level is based on an epidemiological study conducted in 1987 at nine beaches in Hong Kong (Cheung et al., 1990). The study found that *E. coli* density correlated best with combined skin symptom and HCGI, followed by faecal streptococci and enterococci (faecal streptococci and enterococci were later considered the same bacteria by WHO (2003)). However, if HCGI was considered alone, only *E. coli* had a statistically significant correlation. Unexpectedly, another local epidemiological study conducted in 1992 showed no statistically significant relationship between *E. coli* density and gastrointestinal (GI) or HCGI symptoms (Kueh et al., 1995), which challenges the utility of *E. coli* as a marine water quality indicator.

Yet, the use of *E. coli* as the sole indicator for beach water quality in Hong Kong has not been changed since the EPD was established in 1986. In 2001, the EPD initiated a feasibility study on the use of alternative faecal indicator bacteria, including faecal streptococci, enterococci and *Clostridium perfringens* (EPD, 2002). Thereafter, the EPD dismissed the use of alternative microbial indicators for the reason that *E. coli* were found to be most common in beach water samples and were in higher density than other three bacterial types (Lui et al., 2007). Soon after the EPD study was completed, the World Health Organization (WHO) published guidelines for recreational waters in 2003, which recommended using enterococci as the target indicator that measures and classifies existing levels of faecal contamination. This would be further supported by sanitary inspection in the beach hinterlands, which gauges the susceptibility to faecal contamination (WHO, 2003). The WHO microbial water quality classification was primarily based on two randomized trial studies conducted in the UK, namely Kay et al. (1994) and Fleisher et al. (1996).

The randomised trial study has three major merits over the more common retrospective case–control study and prospective cohort study (Kay et al., 1994): (1) accurate differentiation between swimmers and non-swimmers, (2) accurate measurement of the levels of exposure of each swimmer, (3) better control on disease risk factors other than exposure to contaminated water. The first study was conducted from 1989 to 1992 at four UK resorts, and recruited 1216 adults and examined the relationship between gastroenteritis and five faecal indicator bacteria, including total and faecal coliforms, faecal streptococci, total staphylococci and *Pseudomonas aeruginosa*. It was concluded that only faecal streptococci (i.e. enterococci) had a significant dose–response relationship with gastroenteritis and that 32 cfu/100 mL (Kay et al., 1994) was the threshold level at which significant health effects occurred. The second study also demonstrated that only enterococci had a significant relationship with acute febrile respiratory illness among the same five indicator bacteria (Fleisher et al., 1996). These two studies provide a strong basis for WHO to derive its guidelines for recreational water quality, as their study designs were superior to the traditional retrospective case–control study and prospective cohort study.

In 2008, given the international trend to follow WHO (2003) guidelines and adopt enterococci for marine water quality assessment, the EPD commissioned a technical review on local conditions and overseas practices, along with other aspects in marine water quality management. However, the final report only concluded that local environmental, economic and sociocultural factors had to be taken into account before making changes in beach water quality criteria for Hong Kong (EPD, 2009). In the case of the United States, EPA conducted five prospective cohort epidemiological studies between 2003 and 2007 to obtain more recent health and water quality data for the evaluation of water quality criteria. The five studies enrolled 54,250 people at the beach and followed the health conditions of both swimmers and non-