



Distribution of faecal indicator bacteria in tropical waters of Peninsular Malaysia and their decay rates in tropical seawater

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ABSTRACT

We investigated the appropriateness of faecal indicator bacteria in tropical waters. We compared total coliform (undetectable to 7.2×10^5 cfu 100 mL⁻¹), faecal coliform (undetectable to 6.1×10^5 cfu 100 mL⁻¹) and enterococci (undetectable to 3.1×10^4 cfu 100 mL⁻¹) distribution in Peninsular Malaysia. Faecal indicator bacteria was highest in freshwater, and lowest in seawater ($q > 4.18$, $p < 0.01$). We also measured the decay rates of *Escherichia coli* and *Enterococcus faecium* in microcosms. In seawater, average decay rate for *E. coli* was 0.084 ± 0.029 h⁻¹, and higher than *E. faecium* (0.048 ± 0.024 h⁻¹) ($t = 2.527$, $p < 0.05$). Grazing accounted for 54 % of both *E. coli* and *E. faecium* decay. *E. coli* decayed in the < 0.02 μm seawater fraction (0.023 ± 0.012 h⁻¹) but *E. faecium* sometimes grew. Seawater warming further uncoupled the response from both *E. coli* and *E. faecium* as *E. faecium* grew and *E. coli* decayed with warming. Our results suggested that the prevalence of faecal indicator bacteria in tropical waters was not due to faecal pollution alone, and this will have serious implications towards the use of these faecal indicator bacteria.

1. Introduction

Faecal indicator bacteria such as total coliform (TC), faecal coliform (FC) and enterococci (ENT) have been used as faecal pollution indicators to assess the microbiological safety of recreational waters throughout the world (WHO, 1999). The effectiveness of faecal indicator bacteria is related to their link with enteric pathogens and disease (Cabelli, 1983; Jin et al., 2004; Boehm and Soller, 2011). However the occurrence of these faecal indicator bacteria in non-human sources, and their ability to grow in the environment have complicated their use as faecal pollution indicators (Anderson et al., 2005; Byappanahalli et al., 2012; Boehm and Sassoubre, 2014). Even though FC remains in use in many states in the USA and in other countries (Jin et al., 2004), *Escherichia coli* and ENT are now recommended for use as faecal indicator bacteria in freshwater,

whereas ENT is recommended for seawater (Kay et al., 2004; USEPA, 2012) (Appendix Table 1).

In Malaysia, TC and FC have been used in the microbiological assessment of recreational waters with the enactment of the Environmental Quality Act in 1974 (Appendix Table 2) (Department of Environment, 2008). With the recent National Standard for Natural Recreational Water Quality (RecrWQS), Malaysia has started using ENT in addition to FC to assess the microbiological safety of recreational waters (Appendix Table 3) (Ministry of Health, 2017). This RecrWQS is for both freshwater and seawater, and is based on guidelines from Association of Southeast Asian Nations (ASEAN), Australian and New Zealand Environment Conservation Council (ANZECC), World Health Organization (WHO), European Economic Community (ECC) and United States Environmental Protection Agency (USEPA) (Ministry of

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