

QUANTIFYING *ESCHERICHIA COLI* RELEASE FROM SOIL UNDER HIGH-INTENSITY RAINFALL

T. Y. Ling, H. J. Jong, K. Apun, W. H. Wan Sulaiman

ABSTRACT. Bacterial loading in surface runoff can only be reasonably assessed or predicted with quantitative knowledge of the release of bacteria from the soil under different rainfall conditions. Most studies of bacterial movement were conducted under rainfall intensities of less than 44 mm h^{-1} . However, in the tropics, intensities higher than 44 mm h^{-1} are frequent. In this study, *Escherichia coli* release from the soil into surface runoff and its distribution in the soil under the impact of heavy rainfall (95 mm h^{-1}) of different durations were investigated. Results of simulated heavy rainfall of different durations on gently sloping grass plots with spray-applied *E. coli* indicated that *E. coli* was released with relative ease, resulting in contaminated runoff. Runoff *E. coli* concentrations ranged from $2.09 \log(\text{CFU mL}^{-1})$ in 5 min simulated rainfall events to $4.45 \log(\text{CFU mL}^{-1})$ in 15 min simulated rainfall events. The first simulated rainfall events after spray applications produced the highest concentration of *E. coli* in the runoff. Runoff loss accounted for 0.001% of the total applied *E. coli* in 5 min rainfall events and 2.1% in 15 min rainfall events. Total solids explained 28% of the variation in the concentrations and 14% of the total loadings. *E. coli* concentration in the surface centimeter of the soil explained 80% to 89% of the variations in runoff concentrations and loadings with regression slope of less than unity. Such quantitative relationships have the potential to predict runoff *E. coli* concentrations under high-intensity rainfall events.

Keywords. *E. coli* concentration, *E. coli* loading, Fecal bacteria, Simulated rainfall, Surface runoff.

Fecal contamination of soil and surface water is a concern to the public, as livestock can be infected with numerous bacterial, viral, protozoan, and helminthic pathogens that are also infectious to humans (Pell, 1997; Hill, 2003). Runoff from farm sites and manure-applied fields was suspected to be a source of several human disease outbreaks (Smith and Perdek, 2004). Bacterial loading from agricultural waste is identified as the main cause of impairment of rivers in the U.S. (USEPA, 2000). Agricultural practices that potentially contribute to bacterial contamination of surface water include waste deposited by grazing animals in the fields and in the streams, animal waste from concentrated animal feeding operations applied as fertilizer or disposed of on land, and effluent from lagoons (Hooda et al., 2000). Ling et al. (2006a) found the tributary of Serin River that received lagoon effluent and the river downstream of animal farms to have elevated *Escherichia coli* concentrations (0.6 to $4.0 \log(\text{CFU mL}^{-1})$). To reduce bacterial pollution of rivers, there is a need for further treatment of lagoon wastewater. An alternative could be a soil-based or land-treatment system, which is a natural treatment method with the advantage of microorganism removal through die-off, straining, sedimentation, entrapment, predation, radiation,

desiccation, and adsorption (Metcalf and Eddy, 1991). The above would require knowledge of the extent or quantity of bacteria transported to surface water during rainfall events before any recommendation can be made to farm operators.

Bacteria from animal farm wastewater or lagoon effluent are transferred directly to the soil system, whereas those in slurry and solid waste are transferred to the soil system predominantly during rainfall events (Ogden et al., 2001; Joy et al., 1998). Once in the soil, further movement of the bacteria to water bodies depends on the hydrologic conditions (McDowell et al., 2006) through pathways of surface runoff and leaching (Reddy et al., 1981). Ogden et al. (2001) reported that leaching losses accounted for 0.2% to 10% of the total *E. coli* applied to plots and were dependent on natural rainfall. According to Hattori (1970) and Ling et al. (2002a), *E. coli* adsorb onto soil particles and the extent of adsorption depends on clay content. Rain can, thus, transport the bacteria by way of eroded soil particles. Tyrrel and Quinton (2003) postulated that the concentration of microorganisms on the soil surface and the kinetic energy of the rainfall are two of the factors that contribute to the quantity of microorganisms detached from the soil. Therefore, quantitative knowledge of the release of *E. coli* from the soil to the runoff for rainfalls of different intensities and durations is important in assessing or making predictions about the quantity of bacteria transported in the surface runoff pathway. In an attempt to develop a model to continuously simulate *E. coli* density on land and concentration in surface runoff, our previous study (Ling et al., 2006b) indicated the need for a quantitative relationship between *E. coli* concentrations in surface runoff and the concentration in the soil during rainfall-runoff events for predicting the movement of *E. coli*.

A number of rainfall simulation studies with rainfall intensities of 16 to 44 mm h^{-1} have been conducted to investigate

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The authors are Teck Yee Ling, Associate Professor, Hse J. Jong, Graduate Student, Kasing Apun, Associate Professor, and Wan Harun Wan Sulaiman, Professor, Faculty of Resource Science and Technology, University Malaysia Sarawak, Sarawak, Malaysia. Corresponding author: Teck Y. Ling, Faculty of Resource Science and Technology, University Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia; phone: +6082-583040; fax: +6082-583160; e-mail: tyling@frst.unimas.my.