BIOSYSTEMS ENGINEERING 105 (2010) 71–81

Available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/issn/15375110

Research Paper

Sensitivity analysis of agroenvironmental indicators of the hygienic pressure from livestock production on population health

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ARTICLE INFO

Article history:
Received 24 July 2008
Received in revised form
14 August 2009
Accepted 22 September 2009
Published online 31 October 2009

Two Agroenvironmental hygienic pressure indicators (AHPIs) were developed to evaluate the effects of livestock production on water contamination and the risk for human health by expressing a complex public health risk *via* simple quantifiable figures. The first of the two AHPIs is addressing the aspect of surface water contamination while the second one is dealing with groundwater contamination. Each of the two AHPIs is built from a multiplicative model based on 25 parameters related to the transmission of bacteria through excretion by animals, survival in manure, and by run-off or infiltration water produced by rainfall. A global sensitivity approach was used to identify the most significant parameters in regard to the AHPIs output results. This analysis found that bacterial survival on the soil after manure spreading or grazing of animals (K_s), the proportion of bacteria able to reach surface water with run-off from manure on the soil ($B_{run\text{-}off}$), bacteria concentration in faeces B_{conc}, within-herd proportion of animals shedding the pathogenic bacteria targeted (B_{prev}) and the area used for pasture (A) – on bovine farms – are the most influential parameters with respect to the estimation of the AHPIs. With the exception of the latter element, these factors are all directly related to bacterial characteristics and parameters for which obtaining high quality data is most challenging. The identification of these most influential parameters will guide further research to enhance both the precision application of the AHPIs, and their use in managing public health risks.

1. Introduction

Several studies have linked animal grazing and manure spreading to the microbiological contamination of surface and groundwater (Faust, 1982; Patni, 1991; Rudolph *et al.*, 1998). Waterborne outbreaks such as the one in Walkerton, Ontario, where thousands inhabitants were infected by verotoxigenic *Escherichia coli* and *Campylobacter* (O'Connor, 2002), clearly demonstrate that the hygienic pressure exerted by livestock farms on the environment creates a risk to the health of the surrounding populations. At present, we are not able to easily measure and control the multiple factors influencing the

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doi:10.1016/j.biosystemseng.2009.09.016

Nomenclature

A_m	Area of field used for manure spreading for the farm targeted, ha
A_p	Area of field used for grazing for the farm targeted, ha
B_{conc}	Bacteria concentration in faeces, bacteria g^{-1} [faeces]
$B_{infiltration,m}$	Proportion of bacteria able to reach groundwater through infiltration of rain water from manure on the soil, %
$B_{infiltration,p}$	Proportion of bacteria able to reach groundwater through infiltration of rain water from faecal pats deposited on the soil, %
$B_{run\text{-}off,m}$	Proportion of bacteria able to reach surface water with run-off from manure on the soil, %
$B_{run\text{-}off,p}$	Proportion of bacteria able to reach surface water with run-off from faecal pats deposited on the soil, %
$B_{prev,m}$	Within-herd proportion (prevalence) of animals shedding the pathogenic bacteria targeted while they are confined into barns, %
$B_{prev,p}$	Within-herd proportion (prevalence) of animals shedding the pathogenic bacteria targeted while on pasture, %
D_m	Water drainage coefficient in field receiving manure, dimensionless
D_p	Water drainage coefficient of pasture, dimensionless
F	Annual frequency of farrowing per year per sow, $year^{-1}$ sow^{-1}
K_m	Coefficient of bacterial survival in stored manure for spring and autumn season (subscripts sp or au) or in faecal pats of grazing animals (subscript p), day^{-1}
K_s	Coefficient of bacterial survival on the soil in either manure spread or manure pat (for pasture only), day^{-1}
I	Practice of incorporating or injecting manure into soil (yes or no)
N_m	Number of animals contributing to manure production
N_p	Number of animals contributing to faecal pats on pasture
P	Practice of ploughing prior to manure spread (yes or no)
$R_{accu,m}$	Total accumulated rain during one major rain event during either spring or autumn manure-spreading season, mm
$R_{accu,p}$	Total accumulated rain during one major rain event during pasture grazing, mm
$R_{duration,m}$	Average duration of rain event during manure-spreading season, day
$R_{duration,p}$	Average duration of rain event during pasture season, day
$R_{interval}$	Median interval between two rain events for the geographical location, day
S_m	Average slope of field receiving manure spreading for the farm targeted, %
S_p	Average slope of pasture for the farm targeted, %
T_m	Average annual time animals spend in barn, day
T_{manure}	Average duration of manure accumulation time period, day
T_p	Average annual time spent grazing on pasture, day
W_{faeces}	Daily amount of faeces produced per animal type (see indices), kg/day
$\rho_{Spearman}$	Spearman non-parametric correlation coefficient

Subscripts

sp	Spring
au	Autumn
m	Related to manure production by confined animals
mp	Related to herds of animals both confined and grazing on pasture part of the year when performing sensitivity analysis.
p	Related to grazing on pasture

presence, the survival and the transmission of these pathogens in the environment. To cope with the complexity of the bacterial contamination of water by food animal production two Agroenvironmental Hygienic Pressure Indicators (AHPIs) were developed (De Andrade Lima, 2001; Bigras-Poulin *et al.*, 2004). These model-based indicators were proposed as a decision support tool to aid those stakeholders who are responsible for managing the potential risk of human exposure to water contaminated by bacteria of agricultural origin.

The waterborne zoonotic transmission of pathogenic bacteria is a complex phenomenon to study, and scientists and decision-makers are confronted with the additional challenge of translating this complex reality into manageable and practical information that can be used to assess risk and prevent disease. By producing a single value, an indicator summarizes the situation to one dimension, one point on a single metric. The decision maker can therefore concentrate on weighting the importance of this information against other criteria. The two AHPIs are model-based indicators (see typology presented by Bockstaller *et al.*, 2008) and have been proposed as a means of managing the scope and complexity of surface water and groundwater contamination by enteropathogens from agroenvironmental sources (De Andrade Lima 2001; Bigras-Poulin *et al.*, 2004). Five significant mechanisms were included on a conceptual basis in the AHPIs and formalised by the use of five specific equations (attributes). The five attributes were: a) *Animal1*: the load of the targeted bacteria produced by the animals on a targeted farm, b) *Animal2*: the survival of these bacteria in the storage facility when present, c) *Animal3*: the survival in the soil surface of the bacteria population originating from the animal manure or faecal pats prior to its transport with water run-off or water infiltration, d) *Surface*: the transport of the bacteria with water run-off to a nearby stream, and e) *Ground*: the transport of the