

# NOTES ON THE USE OF THE QMRA – MONTE CARLO PROGRAMS FOR WASTEWATER USE IN AGRICULTURE



## 1. QMRA-MC\_Unrestricted irrigation\_1

Open the program file and click on 'enable macros'.<sup>1</sup> There are four sheets:

- i. QMRABetaPoisson – see 1A below
- ii. QMRABetaPoissonReverse – see 1B below
- iii. QMRAExp – see 1A below
- iv. QMRAExpReverse – see 1B below

Sheets i and ii use the  $\beta$ -Poisson dose-response equation for viral and bacterial pathogens, and sheets iii and iv use the exponential dose-response equation for protozoan pathogens.

### 1A. Determination of risks of infection

#### ► Sheets i and iii

1A.1. The program calculates the median and 95-percentile pathogen annual infection or disease risk from consuming every  $n$  days 100 g of lettuce irrigated with wastewater of a quality specified as a single log range of *E. coli* numbers – e.g.,  $10^x - 10^{x+1}$  per 100 ml.

1A.2. In the yellow boxes in columns 3 and 4 of either sheet i or sheet iii enter your chosen range of values for:

- *E. coli* numbers per 100 ml (usually, but not necessarily, a single log range<sup>2</sup>);
  - Pathogen numbers per  $10^5$  *E. coli* [see note 1A.5 below];
  - The volume of wastewater remaining on 100 g lettuce after irrigation (ml);
  - The pathogen die-off between last irrigation and consumption, if any (log units);
  - Consumer exposure – i.e., the consumption of wastewater-irrigated crops every  $n$  days (enter your value of  $n$  in both boxes); and
  - The proportion of exposed consumers who become ill (if this is set to 1, then the program effectively determines the infection risk; if set to  $<1$ , then it calculates the disease risk) – enter your value, 1 or other value  $<1$ , in both boxes.
- Click on any empty cell to confirm your choices.

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<sup>1</sup>In Excel 2007 click on 'Options ...' to the right of 'Security warning. Some active content has been disabled'; then select 'Enable the content' and click on 'OK'

<sup>2</sup>You can specify a larger range if you wish – e.g.,  $10^x - 10^{x+n}$  per 100 ml; alternatively you could set a single fixed value in both boxes – e.g.,  $y \times 10^n$ ).

1A.3. Select the pathogen of interest (columns 5) and in column 3 enter the variation (i.e.,  $\pm x\%$ ) you wish to use for the 'pathogen coefficients' –  $\alpha$  and  $N_{50}$  in the  $\beta$ -Poisson equation and  $r$  in the exponential equation. ► Click on any empty cell to confirm your choices.

1A.4. Click the box "Do Monte Carlo Simulation", wait a second or two, then read the median and 95-percentile risks of infection per person per year under "PI Annual" in column 3 (the maximum and minimum risks determined in the MC simulation are also given).

1A.5. The basic approach in this program follows that developed by Professor Hillel Shuval and colleagues<sup>3</sup> which assumed a constant ratio of pathogen numbers to *E. coli* numbers (1 rotavirus per  $10^5$  *E. coli*). As described above, a range of pathogen numbers per  $10^5$  *E. coli* is used in this program (e.g., 0.1–1 rotavirus per  $10^5$  *E. coli*). However, you can set the pathogen number per  $10^5$  *E. coli* in both yellow boxes (see 4 above) to  $10^5$ , so that you are equating pathogen and *E. coli* numbers and thus effectively determining the risks resulting from a wastewater quality of  $10^x$ – $10^{x+1}$  (or  $10^x$ – $10^{x+n}$ ) pathogens per 100 ml.

1A.6. You can check the values we used – see Mara et al. (2007).<sup>4</sup>

## 1B. Determination of required pathogen reduction(s)

### ► Sheets ii and iv

1B.1. The program is essentially the reverse of that used in sheets i and iii as, for any specified median tolerable infection risk ( $10^{-x}$  per person per year), it calculates the total log unit pathogen reduction(s) (to be achieved by wastewater treatment and post-treatment health protection control measures) required to ensure that this specified level of risk is not exceeded.

1B.2. In the yellow boxes in columns 3 and 4 of the either of these sheets you now enter your chosen tolerable infection risk ( $10^{-x}$  per person per year), the raw wastewater quality (commonly, but not necessarily, as the range  $10^7$ – $10^8$  *E. coli* per 100 ml), the ranges of values for all the other parameters, your choice of pathogen and the variation (i.e.,  $\pm x\%$ ) of either  $\alpha$  and  $N_{50}$  or  $r$  (as described in 1A.2 and 1A.3 above).

1B.3. Click the box "Do Monte Carlo Simulation", wait a second or two, then read under "Required Total Log Reductions" in column 3 the log reductions required for 50-percentile and 95-percentile compliance with your specified level of tolerable infection risk per person per year (the maximum and minimum log reductions determined in the MC simulation are also given).

1B.4. See Notes 1A.5 and A1.6 above.

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<sup>3</sup>Shuval, H. I., Lampert, Y. & Fattal, B. (1997). Development of a risk assessment approach for evaluating wastewater reuse standards for agriculture. *Water Science and Technology* **35** (11–12), 15–20. Abstract available at: <http://www.iwaponline.com/wst/03511/wst035110015.htm>

<sup>4</sup>Mara, D. D., Sleigh, P. A., Blumenthal, U. J. & Carr, R. M. (2007). Health risks in wastewater irrigation: comparing estimates from quantitative microbial risk analyses and epidemiological studies. *Journal of Water and Health* **5** (1), 39–50. Available at: <http://www.personal.leeds.ac.uk/~cen6ddm/pdf%27s%202006+/0701.pdf>

## 2. QMRA-MC\_Restricted irrigation\_1

### Determination of risks of infection

2.1. This program calculates the median and 95-percentile infection risks per person per year from working in a wastewater-irrigated field, based on the exposure scenario of involuntary soil ingestion.<sup>2</sup>

2.2. Open the program file and click 'enable macros'. There are two sheets, QMRABetaP (for bacterial and viral pathogens) and QMRAExp (for protozoan pathogens).

2.3. In the yellow boxes in columns 3 and 4 of either of these sheets you now enter your chosen range of values for:

- *E. coli* numbers per **gram** of soil (usually, but not necessarily, a single log range) – note that this is assumed (as a worst case scenario) to be the same as the wastewater quality expressed as *E. coli* numbers per **ml** (*not* per 100 ml);
  - Pathogen numbers per 10<sup>5</sup> *E. coli*;
  - Fieldworker exposure – i.e., the number of days worked in wastewater-irrigated fields per year;
  - The quantity of soil (in **grams**, *not* mg) ingested per day of exposure; and
  - The proportion of exposed fieldworkers who become ill (if this is set to 1, then the program effectively determines the infection risk; if set to <1, then it calculates the disease risk) (enter your value, 1 or other value <1, in both boxes).
- Click on any empty cell to confirm your choices.

2.4. Select the pathogen of interest (column 5) and in column 3 enter the variation (i.e.,  $\pm x\%$ ) you wish to use for the 'pathogen coefficients' –  $\alpha$  and  $N_{50}$ , or  $r$ .

► Click on any empty cell to confirm your choice.

2.5. Click the box "Do Monte Carlo Simulation", wait a second or two, then read the median and 95-percentile risks of infection per person per year under "PI Annual" in column 3 (the maximum and minimum risks determined in the MC simulation are also given).

2.6. See Notes 1A.5 and 1A.6 above.



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*Prepared by Duncan Mara, October 2008*