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

1. QMRA-MC_Unrestricted irrigation_2

Open the program file and click on 'enable macros'.[1]

There are two sheets:

      i. QMRABetaPoisson
    ii. QMRAExp

Sheets i uses the β-Poisson dose-response equation for viral and bacterial pathogens, and sheet ii the exponential dose-response equation for protozoan pathogens.

Determination of risks of infection

1.1. The program calculates the median and 95-percentile pathogen annual infection or disease risk from consuming every n days a variable quantity 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.

1.2. In the yellow boxes in columns 3 and 4 of either sheet i or sheet ii enter your chosen range of values for:
- *E. coli* numbers per 100 ml (usually, but not necessarily, a single log range[2]);
- Pathogen numbers per 10^5 *E. coli* [see note 1.5 below];
- The volume of wastewater remaining on 100 g lettuce after irrigation (ml);
- The quantity of lettuce consumed on each occasion (g per day);
- 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 any value <1) in both boxes.
- ►Click on any empty cell to confirm your choices.

1.3. Select the pathogen of interest (columns 5) and in column 3 enter the variation (i.e., ± x%) you wish to use for the 'pathogen coefficients' − α and N_{50} in the β-Poisson equation and r in

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[1]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'.
[2]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., $y \times 10^n$).

the exponential equation. ►Click on any empty cell to confirm your choices.

1.4. Click the box "Do Monte Carlo Simulation", wait a minute or two, then read the median (50-percentile) 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).

1.5. The basic approach in this program follows that developed by Professor Hillel Shuval and colleagues[3] 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 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.

1.6. This program uses the **Benke and Hamilton** method for calculating the annual risk of infection.[4] This method firstly determines an annual risk of infection by doing a Monte Carlo simulation with the number of simulations set equal to the number of days of exposure per year (this is rounded down to an integral value), and it then repeats this 1000 (or 10,000) times and determines the 50- and 95-percentile annual risks.

2. QMRA-MC_Restricted irrigation_2

Determination of risks of infection

2.1. This program calculates the median (50-percentile) 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.[5]

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** (*not* per 100 g) 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 10^5 *E. coli*;
   • Fieldworker exposure − i.e., the number of days worked in wastewater-irrigated fields per year;

[3]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

[4]Benke, K. K. and Hamilton, A. J. (2008). Quantitative microbial risk assessment: uncertainty and measures of central tendency for skewed distributions. *Stochastic Environmental Research and Risk Assessment* **22**, 533−539. Abstract available at:
http://www.springerlink.com/content/v30566l223171504/?p=9168f2f5b6c14d00b98dfe744acd1d0a&pi=9

[5]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**, 39−50. Available at: http://www.personal.leeds.ac.uk/~cen6ddm/pdf's%202006+/0701.pdf

- 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., ± *x* %) you wish to use for the 'pathogen coefficients' − α 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 minute 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 1.5 and 1.6 above.

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Prepared by Duncan Mara, December 2008