## COMPARISON OF THE QUANTITATIVE MICROBIAL RISK ANALYSIS-MONTE CARLO METHOD USED IN THE 2006 WHO GUIDELINES FOR THE SAFE USE OF WASTEWATER IN AGRICULTURE AND THAT DEVELOPED BY BENKE & HAMILTON (2008)

The basic approach in both methods follows that developed by Professor Hillel Shuval and colleagues.<sup>1</sup> The fundamental equations are:<sup>2</sup>

(a) β-Poisson dose-response model:  $P_{I}(d) = 1 - [1 + (d/N_{50})(2^{1/\alpha} - 1)]^{-\alpha}$  (1)

(b) Annual risk of infection:  $P_{I(A)}(d) = 1 - [1 - P_I(d)]^n$  (3)

where  $P_{I}(d)$  is the risk of infection in an individual exposed to (here, following ingestion of) a single pathogen dose *d*;  $P_{I(A)}(d)$  is the annual risk of infection in an individual from *n* exposures per year to the single pathogen dose *d*;  $N_{50}$  is the median infective dose; and  $\alpha$  and *r* are pathogen 'infectivity constants' - for rotavirus  $N_{50} = 6.17$  and  $\alpha = 0.253$ .

In the method used in the 2006 WHO Guidelines<sup>3</sup> the QMRA-MC computer program does 10,000 simulations of annual infection risk and then determines the median annual risk. In the method developed by Benke and Hamilton<sup>4</sup> the program firstly determines an annual risk of infection by doing a single Monte Carlo simulation with the number of iterations equal to the number of days of exposure per year; it then repeats this 9,999 times and determines the median annual infection risk.

► The computer programs for the two methods are available at: http://www.personal.leeds.ac.uk/~cen6ddm/QMRA.html

The method used in the 2006 WHO Guidelines and that developed by Benke and Hamilton were used to compare the resulting median annual rotavirus infection risks for unrestricted irrigation and restricted irrigation. The results are shown in Tables 1 and 2, respectively.

http://www.personal.leeds.ac.uk/~cen6ddm/pdf%27s%202006+/0701.pdf.

<sup>&</sup>lt;sup>1</sup> Shuval HI, 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: <u>http://www.iwaponline.com/wst/03511/wst035110015.htm</u>.

<sup>&</sup>lt;sup>2</sup> Haas CN, Rose JB, Gerba CP (1999). *Quantitative Microbial Risk Assessment*. John Wiley & Sons, New York.

<sup>&</sup>lt;sup>3</sup> Chapter 3 of the Guidelines, available at:

http://www.who.int/water\_sanitation\_health/wastewater/wwuvol2chap3.pdf.

**See also:** Mara DD, Sleigh PA, Blumenthal UJ, Carr RM (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:

<sup>&</sup>lt;sup>4</sup> Benke KK, Hamilton AJ (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

Wastewater quality	Median rotavirus infection risk pppy	
( <i>E. coli</i> per 100 ml)	WHO	Benke & Hamilton
$10^{7}$ - $10^{8}$	1	1
$10^3 - 10^4$	0.29	0.36
100-1000	$3.4  imes 10^{-2}$	$4.5 imes10^{-2}$
10-100	$3.5  imes 10^{-3}$	$4.6 \times 10^{-3}$
1-10	$3.4  imes 10^{-4}$	$4.6 imes10^{-4}$

**Table 1.** Unrestricted irrigation: Median rotavirus infection risks per person per year (pppy) from the consumption of wastewater-irrigated lettuce estimated by 10,000-trial Monte Carlo simulations\*

\*Assumptions: 100 g lettuce eaten per person per 2 days; 10-15 ml wastewater remaining on 100 g lettuce after irrigation; 0.1-1 rotavirus per  $10^5 E$ . *coli*; **no pathogen die-off**; N<sub>50</sub> = 6.7 ± 25% and a = 0.253 ± 25%. Note: a wastewater quality of  $10^7$ - $10^8 E$ . *coli* per 100 ml indicates raw wastewater.

i.e., both methods result in a requirement for a 6-log unit reduction to achieve a tolerable rotavirus infection risk of  $\sim 10^{-3}$  per person per year.

**Table 2.** Restricted irrigation: Labour-intensive agriculture with exposure for 300 days per year: median rotavirus infection risks per person per year (pppy) from the ingestion of wastewater-contaminated soil estimated by 10,000-trial Monte Carlo simulations\*

Soil quality	Median rotavirus infection risk pppy	
( <i>E. coli</i> per 100 g)	WHO	Benke & Hamilton
$10^{7}$ - $10^{8}$	1	1
$10^{6}$ - $10^{7}$	0.88	0.96
$10^{5} - 10^{6}$	0.20	0.28
$10^4 - 10^5$	$2.1  imes 10^{-2}$	$3.3  imes 10^{-2}$
<b>10<sup>3</sup>-10<sup>4</sup></b>	$2.2 \times 10^{-3}$	$3.3 \times 10^{-3}$
100-1000	$2.2  imes 10^{-4}$	$3.3 imes10^{-4}$

\*Assumptions: 10- 100 mg soil ingested per person per day for 300 days per year; 0.1- 1 rotavirus per  $10^5 E. \ coli$ ; no pathogen die-off;  $N_{50} = 6.7 \pm 25\%$  and  $a = 0.253 \pm 25\%$ .

i.e., both methods result in a requirement for a 4-log unit reduction to achieve a tolerable rotavirus infection risk of  $\sim 10^{-3}$  per person per year.

## CONCLUSION

As shown in Tables 1 and 2, the results obtained by the two methods are very similar. It can therefore be concluded that the recommendations in the 2006 WHO Guidelines are still valid.