Title	**Managing greywater with microbial risk assessment.**
Keywords	Viruses, Campylobacter, (oo)cysts, greywater treatment, water re-use
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Short CV for Introduction Purposes (100 words max)	Jakob Ottoson, Fil. Lic. Royal Institute of Technology, Sweden. Next week he will defend his doctoral thesis, "Comparative pathogen occurrence in wastewater and management strategies for barrier function and microbial control "(2nd June). Enjoys playing with his kids and football.
Photograph attached (jpg)	No photograph available

Aims

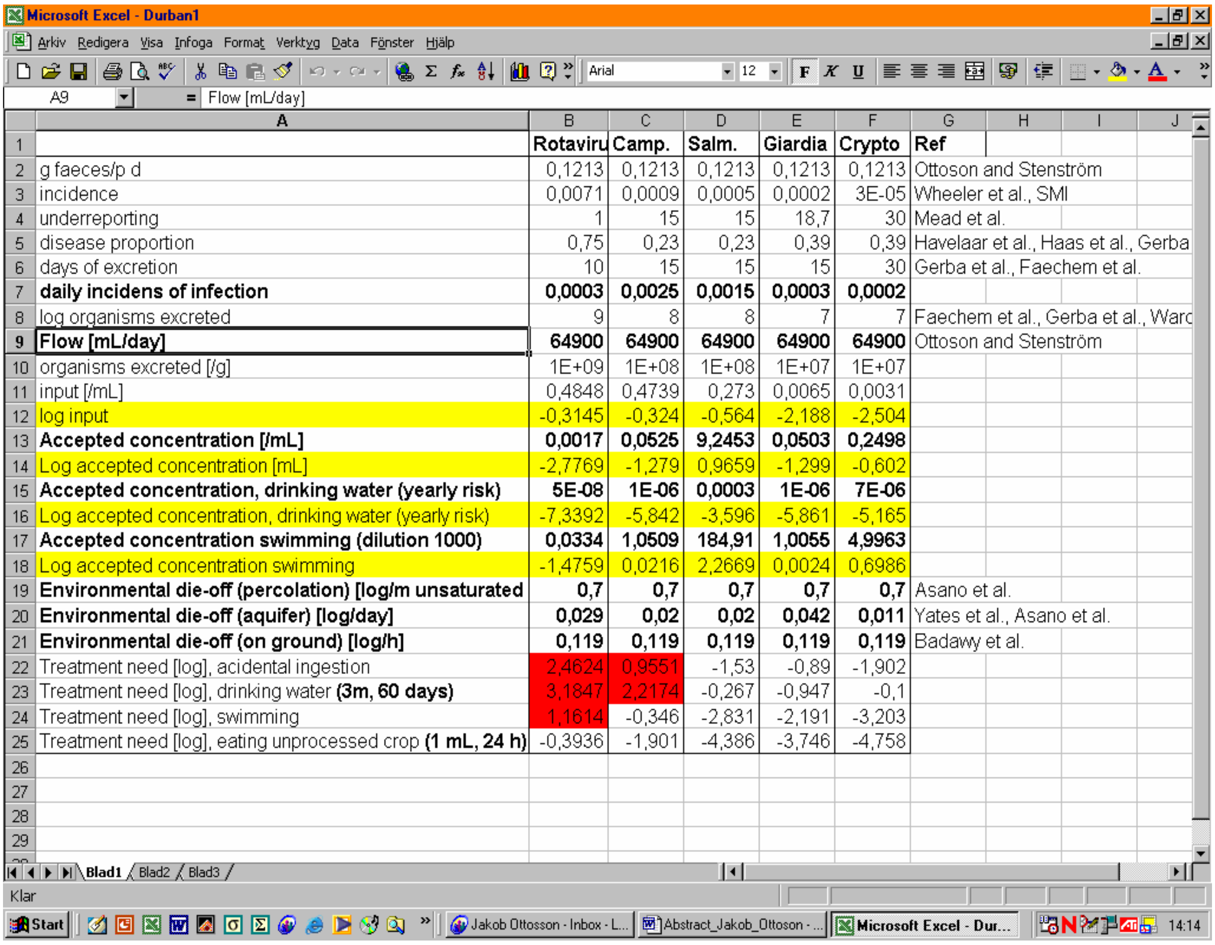
Attention has been paid to the possibility of re-using greywater. The potential risks with such a re-use needs to be systematically addressed. The aim with this study was to show how microbial risk assessment, MRA, could be a tool to manage potential health risks with greywater and greywater re-use.

Methods and Results

Faecal load in greywater and epidemiological data gave the input of selected pathogens in greywater (Figure 1). The accepted dose was calculated from dose-response curves (Teunis et al., 1999) setting the P_{inf} to 0.001 (1/1000) (Haas, 1996). Accepted doses gave accepted pathogen concentrations in the water for different exposures. Finally the environmental die-off was estimated. Substracting the figures log accepted concentration and log environmental removal from the log input value (Figure 1) gave the sum of the log removal needed in greywater treatment to be inside the specified accepted risk.

In figure 1, a Swedish scenario is shown where the treatment need for four different exposures - 1) accidental ingestion of greywater, for example from a pond, 2) drinking superficial groundwater produced from greywater, 3) swimming in a lake where greywater has been discharged and 4) eating crops irrigated with greywater – was assessed. The daily incidences of infections were calculated from reported yearly incidences, adjusted for underreporting and mean number of excretion days (Figure 1). For drinking superficial groundwater 1/1000 represented a yearly risk, expecting consumption to be 1 L/day of which 100 mL is recharged greywater.

Treatment was needed for rotavirus and Campylobacter in some exposures, shaded (superficial groundwater and accidental ingestion), whereas no treatment was needed to manage Salmonella or parasitic (oo)cyst exposure (Figure 1).



	A	B	C	D	E	F	G
1		**Rotaviru**	**Camp.**	**Salm.**	**Giardia**	**Crypto**	**Ref**
2	g faeces/p d	0,1213	0,1213	0,1213	0,1213	0,1213	Ottoson and Stenström
3	incidence	0,0071	0,0009	0,0005	0,0002	3E-05	Wheeler et al., SMI
4	underreporting	1	15	15	18,7	30	Mead et al.
5	disease proportion	0,75	0,23	0,23	0,39	0,39	Havelaar et al., Haas et al., Gerba
6	days of excretion	10	15	15	15	30	Gerba et al., Faechem et al.
7	**daily incidens of infection**	**0,0003**	**0,0025**	**0,0015**	**0,0003**	**0,0002**	
8	log organisms excreted	9	8	8	7	7	Faechem et al., Gerba et al., Warc
9	**Flow [mL/day]**	**64900**	**64900**	**64900**	**64900**	**64900**	Ottoson and Stenström
10	organisms excreted [/g]	1E+09	1E+08	1E+08	1E+07	1E+07	
11	input [/mL]	0,4848	0,4739	0,273	0,0065	0,0031	
12	log input	-0,3145	-0,324	-0,564	-2,188	-2,504	
13	**Accepted concentration [/mL]**	**0,0017**	**0,0525**	**9,2453**	**0,0503**	**0,2498**	
14	Log accepted concentration [mL]	-2,7769	-1,279	0,9659	-1,299	-0,602	
15	**Accepted concentration, drinking water (yearly risk)**	**5E-08**	**1E-06**	**0,0003**	**1E-06**	**7E-06**	
16	Log accepted concentration, drinking water (yearly risk)	-7,3392	-5,842	-3,596	-5,861	-5,165	
17	**Accepted concentration swimming (dilution 1000)**	**0,0334**	**1,0509**	**184,91**	**1,0055**	**4,9963**	
18	Log accepted concentration swimming	-1,4759	0,0216	2,2669	0,0024	0,6986	
19	**Environmental die-off (percolation) [log/m unsaturated**	**0,7**	**0,7**	**0,7**	**0,7**	**0,7**	Asano et al.
20	**Environmental die-off (aquifer) [log/day]**	**0,029**	**0,02**	**0,02**	**0,042**	**0,011**	Yates et al., Asano et al.
21	**Environmental die-off (on ground) [log/h]**	**0,119**	**0,119**	**0,119**	**0,119**	**0,119**	Badawy et al.
22	Treatment need [log], acidental ingestion	2,4624	0,9551	-1,53	-0,89	-1,902	
23	Treatment need [log], drinking water **(3m, 60 days)**	3,1847	2,2174	-0,267	-0,947	-0,1	
24	Treatment need [log], swimming	1,1614	-0,346	-2,831	-2,191	-3,203	
25	Treatment need [log], eating unprocessed crop **(1 mL, 24 h)**	-0,3936	-1,901	-4,386	-3,746	-4,758	

Figure 1. Excel spreadsheet showing a microbial risk assessment for treatment need of greywater in a Swedish scenario. Literature data taken from (Ottoson and Stenström, 2003, Yates et al., 1985, Badawy et al., 1990, Faechem et al., 1983, Gerba et al., 1996, Ward et al., 1986, Mead et al., 1999, Havelaar et al., 2000)

Discussion

In this exercise it was shown that greywater treatment in Sweden should be directed to remove viruses. Unless diluted, extensive treatment is needed for the production of superficial groundwater. Removing viruses will also remove Campylobacter, which was the other index organism of concern in the Swedish scenario. The background data are taken from references applicable for Sweden (groundwater 4° C, 1 litre/day drinking water, incidences of infection etc.) Further we have used 1/1000 as an acceptable limit. In many parts of the world that figure could be higher leading to less treatment need. Other variables that would lead to less treatment are higher die-off rates in warmer countries and a higher flow (more dilution) whereas higher incidences of infections and lower flow give a need for more extensive treatment. All figures could be changed, but figures in bold are those that might vary the most between regions. It may also be more interesting to look at other exposure scenarios than the ones presented here. What we wanted to show however was that microbial risk assessment does not have to be complicated or expensive in terms of computer power and need for software, but could be computed with a simple calculator giving a lot of communicable information. Information that could be useful to have as a background when planning new systems. The treatment performance targets that have been calculated can be also be used within a water management approach such as HACCP, hazard analysis critical control point. The next step then is to find suitable process indicators to be able to measure the performance target. But that´s another story.

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