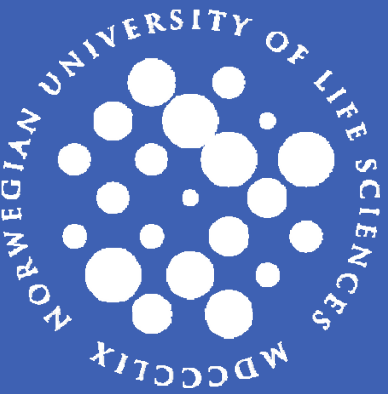
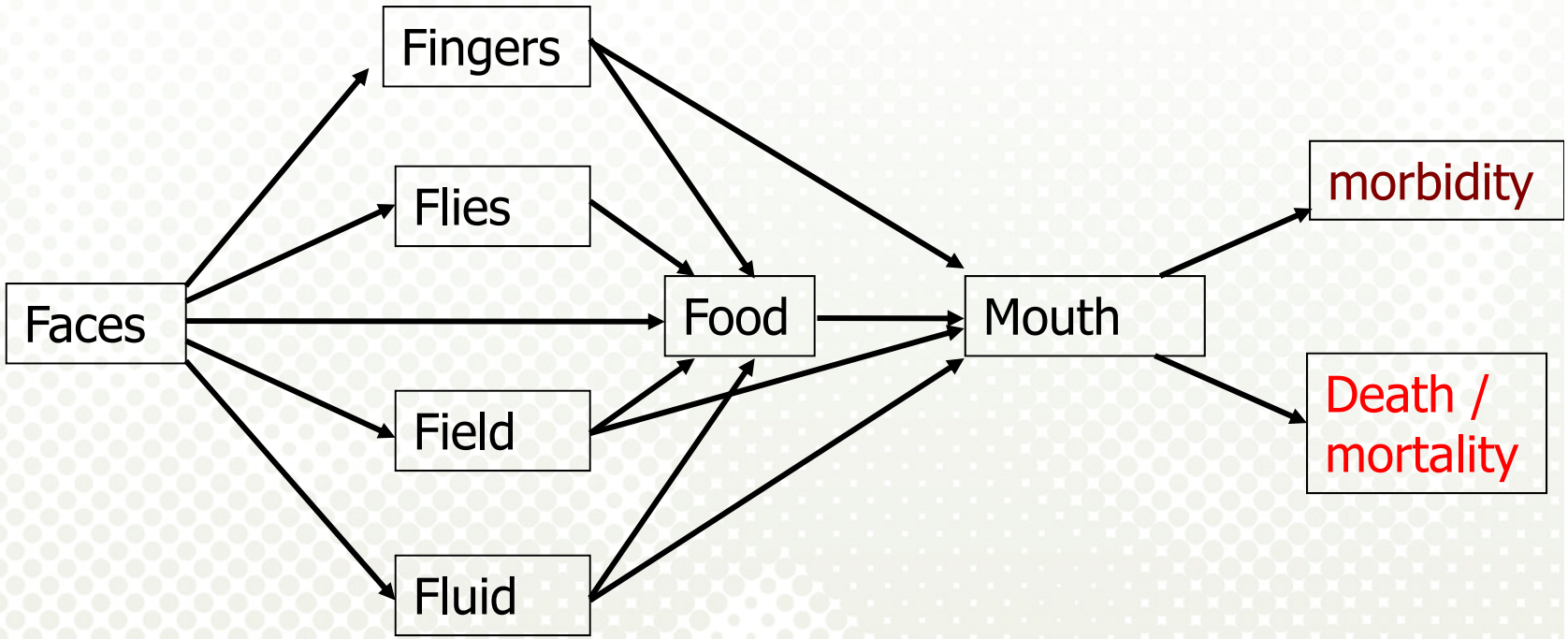
Health and risk assessment



Routes of disease transmission (F-diagram) (lucas, 1972)



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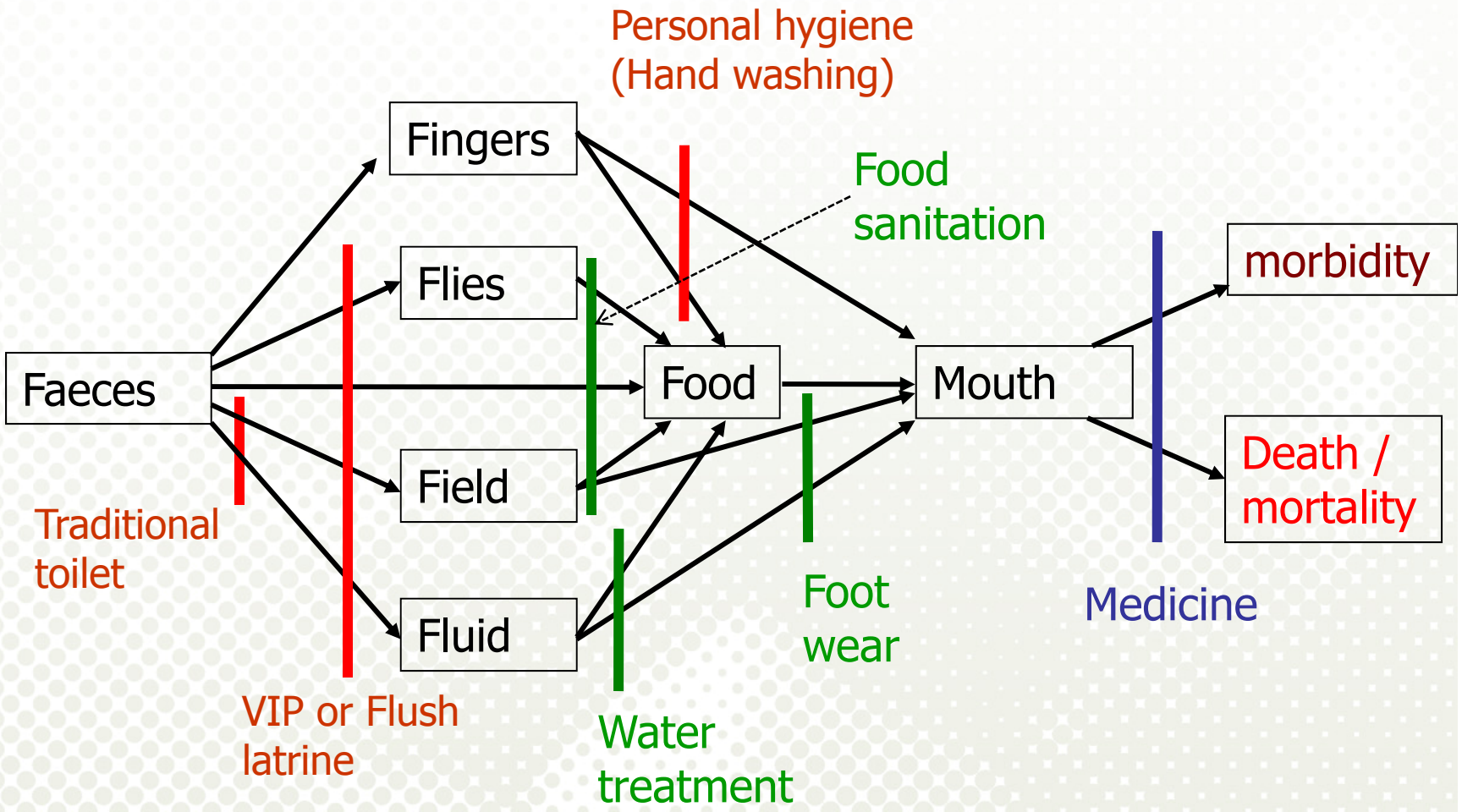
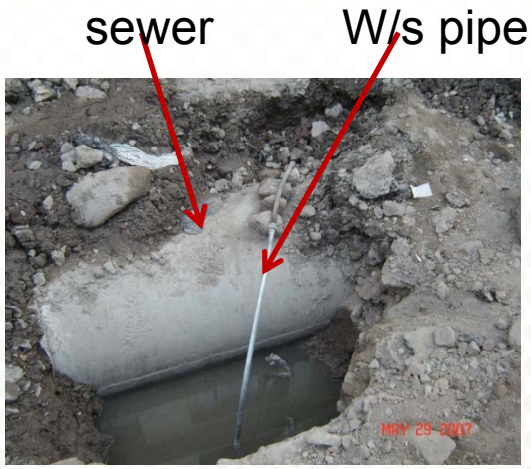
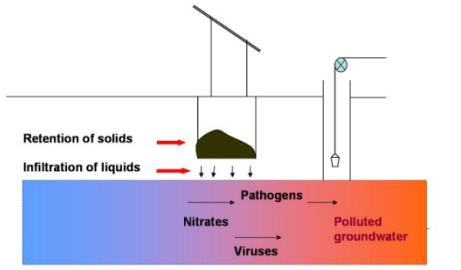


Health risk hazard in W/S and sanitation system



Faulty design and layout

Operational problem in treatment plant



Faulty design and layout

Inadequate source protection

Inadequate hyginization of faecal matter/compost

Compost

Photo: Bahadar (2009)

http://academics.vmi.edu/enviro

Who are at risk? people working in farm, childrens in field, consumers…

Digging a hole for urine application

Morgan (2007)

Urine application

Raw wastewater application in agriculture

Vegetable market

Quantitative Microbial Risk Assessment (QMRA)

- Risk assessment is the process of quantifying the probability of a harmful effect to individuals or populations from the exposure to the infectious agents.
- **Quantitative Microbial Risk Assessment (QMRA)**
- Four basic elements:
  - identification of hazards and hazardous events
  - exposure assessment
  - effect assessment (dose-response)
  - risk characterization

Quantitative Microbial Risk Assessment

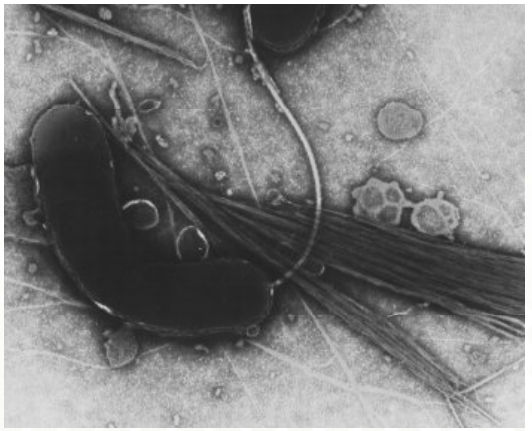
- **Hazard Identification**

- Hazard identification is both the identification of the microbial agent and the spectrum of human illness and disease associated with the microbial agent (Haas et al. 1999).

Diarrhoea

- The infectious agents responsible for causing diarrhoea are – Vibrio cholerae (bacteria), Cryptosporidium parvum (protozoa), Giardia (Protozoa) , rotavirus (virus) Norovirus (virus)
- Diarrhoea is a symptom of infection caused by a host of bacterial, viral and parasitic organisms most of which can be spread by contaminated water
- Kills around 2.2 million people globally each year, mostly children
  - In Southeast Asia and Africa, diarrhoea is responsible for as much as 8.5% and 7.7% of all deaths respectively (www.who.int/water_sanitation_health).

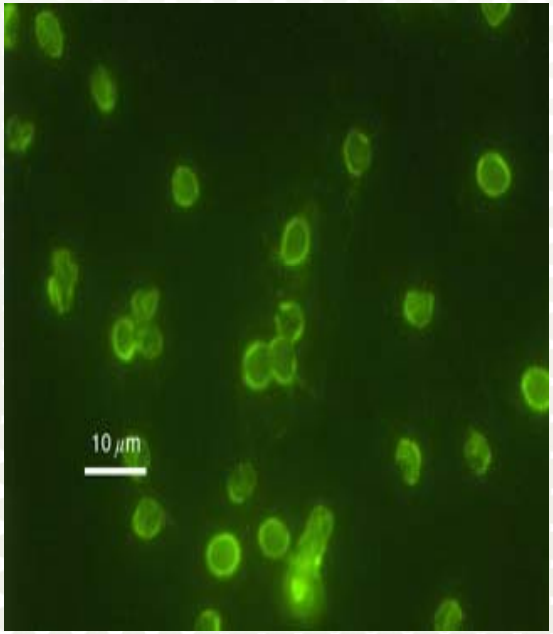
Vibrio cholerae (Pathogenic bacteria)



- Acute infection of intestine causing accute diarrhoea and vomiting
- Source- contaminated water and food, open defecation, faecal oral transmission
- There are an estimated 3–5 million cholera cases and 100 000–120 000 deaths due to cholera every year around the world (PAHO, 2010)

Cryptosporidium parvum (protozoan pathogens)

- most resistant to chemical disinfection and smallest in size (4-5 μ m), so most difficult to remove by filtration.
- *Cryptosporidium* Oocysts can remain viable for about 18 months in a cool, damp or wet environment.



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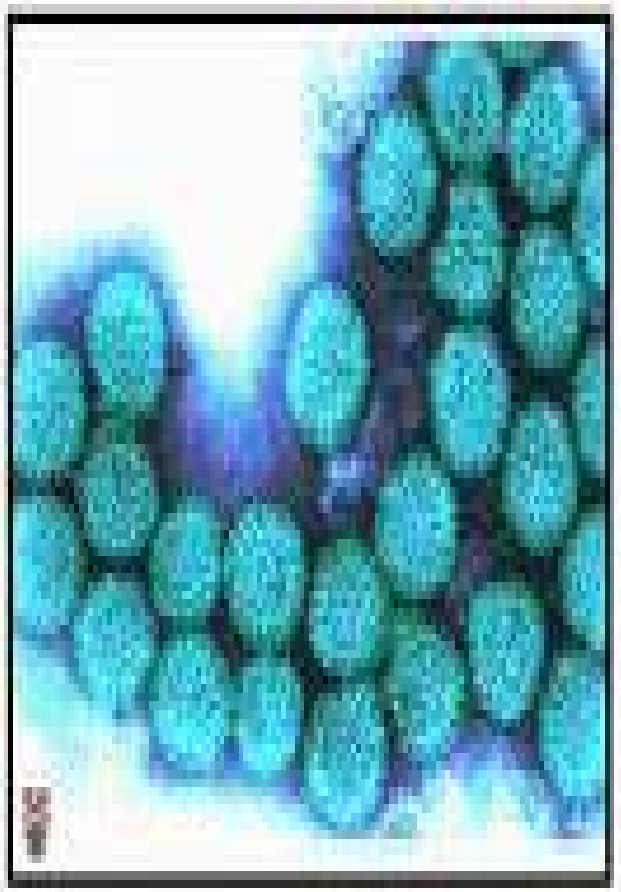
Giardia (protozoan pathogens)

- Prevalence in Developing Countries: **20-30%**
- Prevalence in Developed Countries: 2 - 5%
- Highly resistant to Chlorine disinfection
- without proper chemical pretreatment *Giardia cysts will pass the filtration* process.

Rotavirus

- Size- 60–80 nm in diameter and may pass through filter
- Difficult to deactivate by chlorine
- Rotavirus causes about 25% of all diarrhoeal illnesses in children under 5, and is a major cause of morbidity and mortality globally.
- They survive in surface waters for 8–32 days



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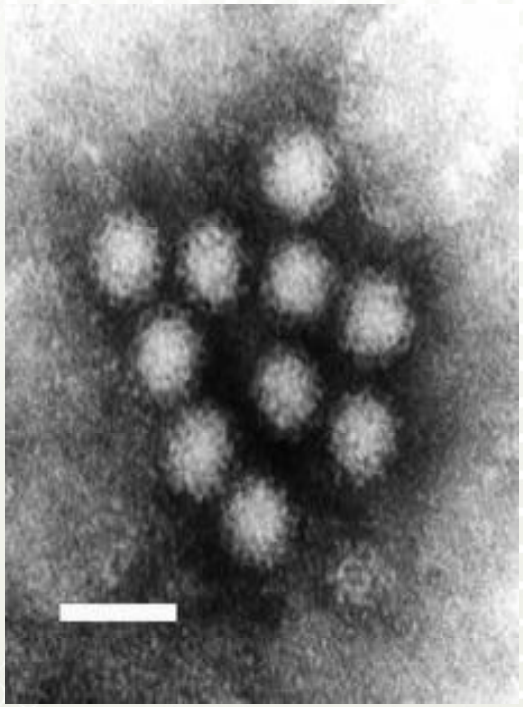
Norovirus

- The most infectious virus ever described

• NV is considered the leading cause of adult gastroenteritis outbreaks worldwide and is thought to be second only to Rotavirus in terms of all causes of gastroenteritis

•Average probability of infection of 50% for a single virus (Teunis et al.2008)



Parasites

- -*Ascaris*.

The most prevalent parasitic infection worldwide with an infection rate ranging from 40 – 98% in Africa (Freedman, 1992)

An estimate of worldwide prevalence is

1 273 million (AWWA, 1999)

Can survive several years in moist soils,

Pathogens	**Number in Wastewater (per litre)**
Bacteria	
Thermotolerant coliform	**$10^8 – 10^{10}$**
Vibrio Cholera	**10^2 - 10^4**
Helminths	
Ascaris lumbricoides	**10 - 10^3**
Protozoa	
Cryptosporidium parvum	**1 - 10^4**
Giardia intestinalis	**10^2 - 10^5**
Viruses	
Noro viruses	**10^5 - 10^6**
Rotavirus	**10^2 - 10^5**

Source : Westrell, 2004

Efficacy of Some Water Treatment Processes

Organism	Treatment Step (log removal)				
	Coagulation/ Flocculation	Rapid Sand filtration	Slow sand filtration	Chlorine dioxide disinfection	UV
Viruses	1.8 (0.2-4.3)	0.8 (0.1-3.8)	2.2 (0.6-4.0)	2.43 (2.21-2.77)	Rotavirus **4**
Bacteria *(indicator)'*	1.5 (0.6-3.7)	0.6 (0.1-1.5)	2.7 (1.2-4.8)	3.89 (3.77-4.08)	*Campylo* **4**
Cryptosporidium	1.9 (0.4-3.8)	2.0 (0.0-3.1)	3.8 (0.3->6.5)	**0.57 (0.41-0.9)**	**3**
Giardia	1.6 (0.0-2.9	1.7 (0.0-6.5)	3.3 (1.2-6)	**0.57 (0.41-0.9)**	**3**

Source: Hijnen et al., (2005); Thorwaldsdotter (2006); Hijnen et al., (in preparation)

Exposure assessment

- **Determines the size and nature of the exposed population and the pathways, amount and duration of exposure to the pathogenic organism**

Who?	Defines group at risk (children, adults etc)
How many ?	People directly and indirectly exposed to pathogens
Where ?	Where the exposure occurs (from user to potential reuse)
Which route?	Direct contact or indirect contact (eg. Inhalation, faecal-oral, dermal contact
How frequently?	How often exposure occurs eg. Daily, weekly, yearly etc
What dose of exposure?	Depends on prior treatment, type of system and may differ between individuals

Who are at risk? people working in farm, children in field, consumers…

Digging a hole for urine application

Morgan (2007)

Urine application

Child photo

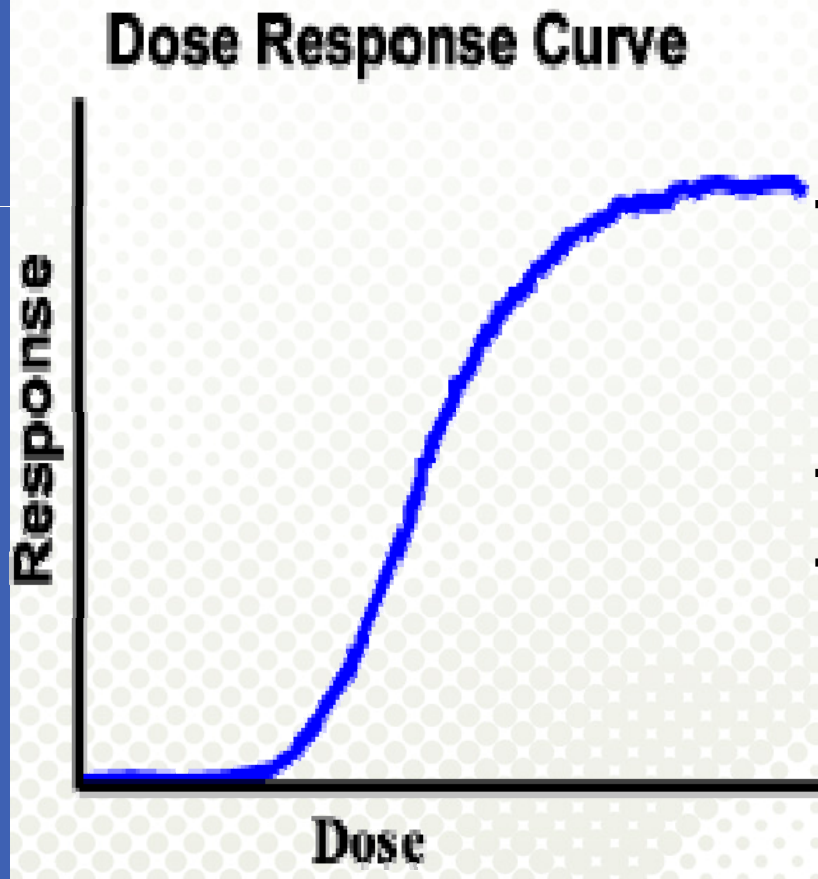
Raw wastewater application in agriculture

Vegetable market

Exposed Pop.	Pathway	Exposure Amount
Children	Accidental soil ingestion	150- 200mg/d(1-6yr) 100mg/d (>6yrs)
Adults	Working with contaminated soil	100mg
	Consumption of contaminated salad	100g
All	Inhalation of aerosol	$20m^3$/d (adult) 5-$10m^3$/d children
	Recreational Swimming	50mL
Adult	Spreading faecal sludge	2g
All	Water consumption	2 L/d
	Toilet flushing	1 – 2mL per flush

Effect Assessment

Dose Response Assessment



Describes the relationship between the dose of microbial hazard to which a human is exposed and the probability that there will be an infection.

Quantitative Microbial Risk Assessment

Dose-response Models

Two models of the infection process have been proposed:

The Exponential Model (used for **giardia** infection)

$$P_{inf} = 1 - e^{-r\mu}$$

Where: P_{inf} = probability of infection for a single dose

μ = pathogen dose, particle/ml

r = fraction of pathogen that survives to cause an infection

Quantitative Microbial Risk Assessment

- **Beta-Poisson Model (applicable for rotavirus,** Cryptosporidium)

$$P_{\text{inf}} \approx 1 - \left(1 + \frac{\mu}{\beta}\right)^{-\alpha}$$

Where: P_{inf} = Probability of Infection

μ = dose of pathogen

α and β = parameters used to describe variability in the beta distribution

Dose Response Parameters for Some Pathogenic Organisms

Organism	Dose Response Model	Parameters	Reference
Rotavirus	Beta-Poisson	α=0.253 β=0.42	Haas *et al.*, (1993)
Cryptosporidium	Beta-Poisson	α=0.115 β=0.176	Teunis et al., (2002)
Giardia	Exponential	r = 0.0199	Teunis et al., (1996)

- **Multiple Exposures**

- Given the infection per single exposure, the annual infection risk from multiple exposure ***n*** to pathogen dose μ is given as:

- $P_{annual} = 1 - [1 - P_{inf}]^n$

P_{annual} = annual risk of infection

P_{inf} = Probability of Infection from a single exposure

n = days of exposures per year

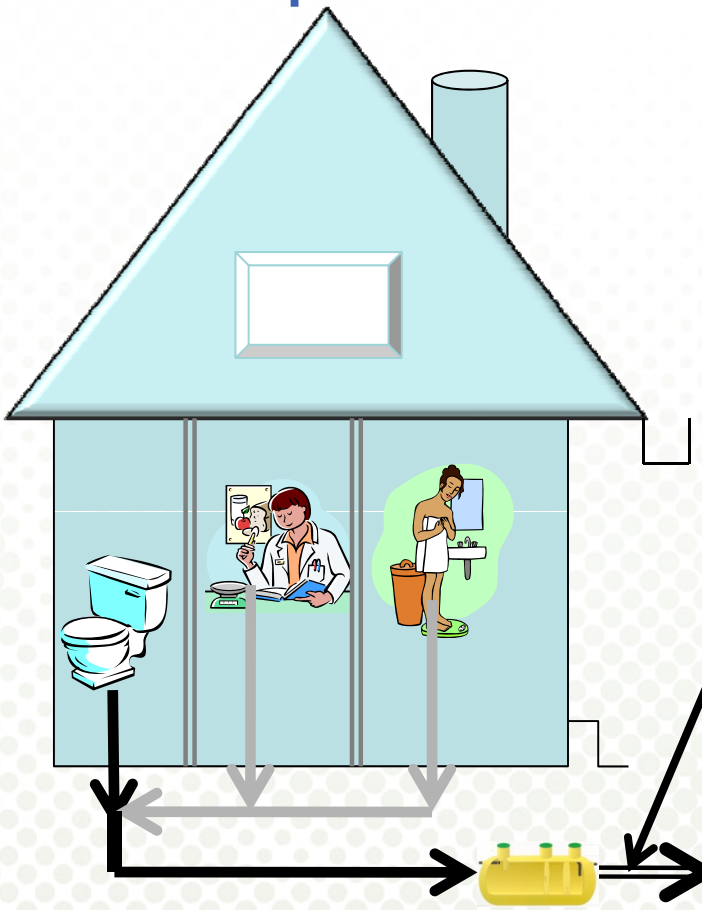
Risk Characterisation

- **Tolerable Infection Risk**

- With regards to microbiological risks from drinking water, the USEPA, using *Giardia* as a reference organism, required that the microbial risk is less than 1 infections per 10,000 people per year (Macler and Regli, 1993)

- An infection risk of 1 in 10,000 exposed persons per year is also applied in wastewater use related infections (WHO, 2006)
- TOLERABLE infection risk also expressed in terms of DALY

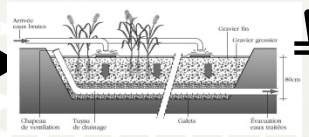
Example

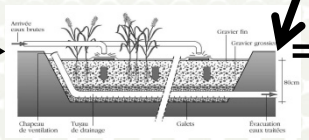


10^6 Rotavirus particles/ 100 ml in the influent of the first stage vertical flow constructed wetland

How much?

How much?





Septic tank (S.T)

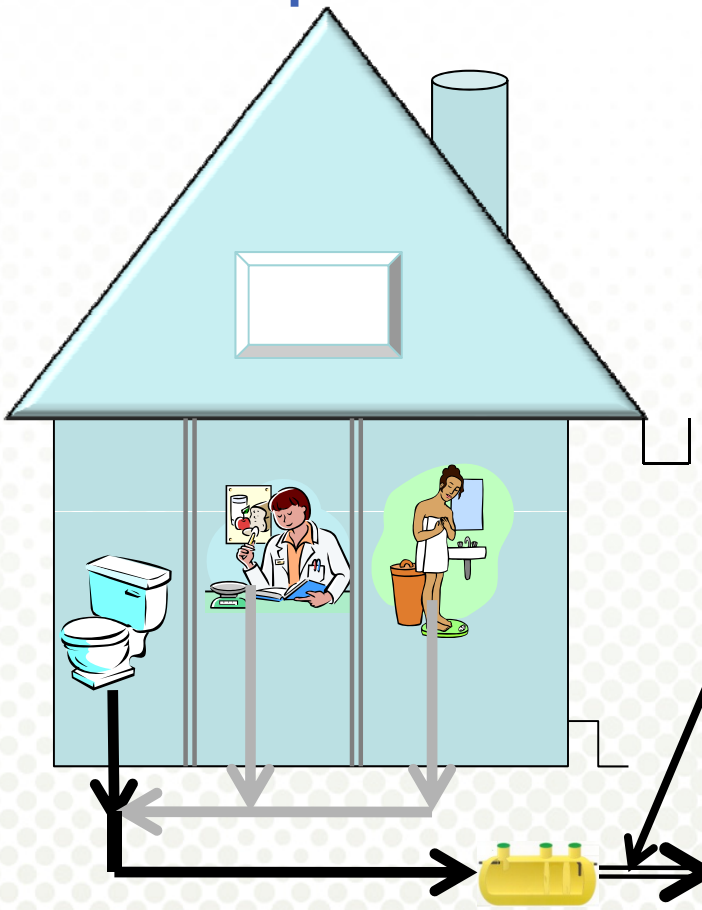
•Constructed wetland 1st stage

(Assume log Reduction 2)

•Constructed wetland 2st stage

(Assume log Reduction 2)

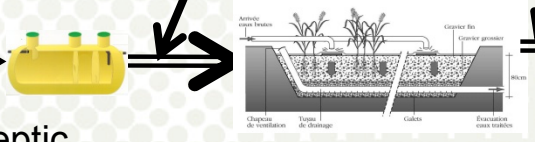
Example



10^6 Rotavirus particles/ in 100 ml in the influent of the first stage vertical flow constructed wetland

log 4

log 2



Septic tank (S.T)

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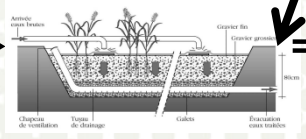
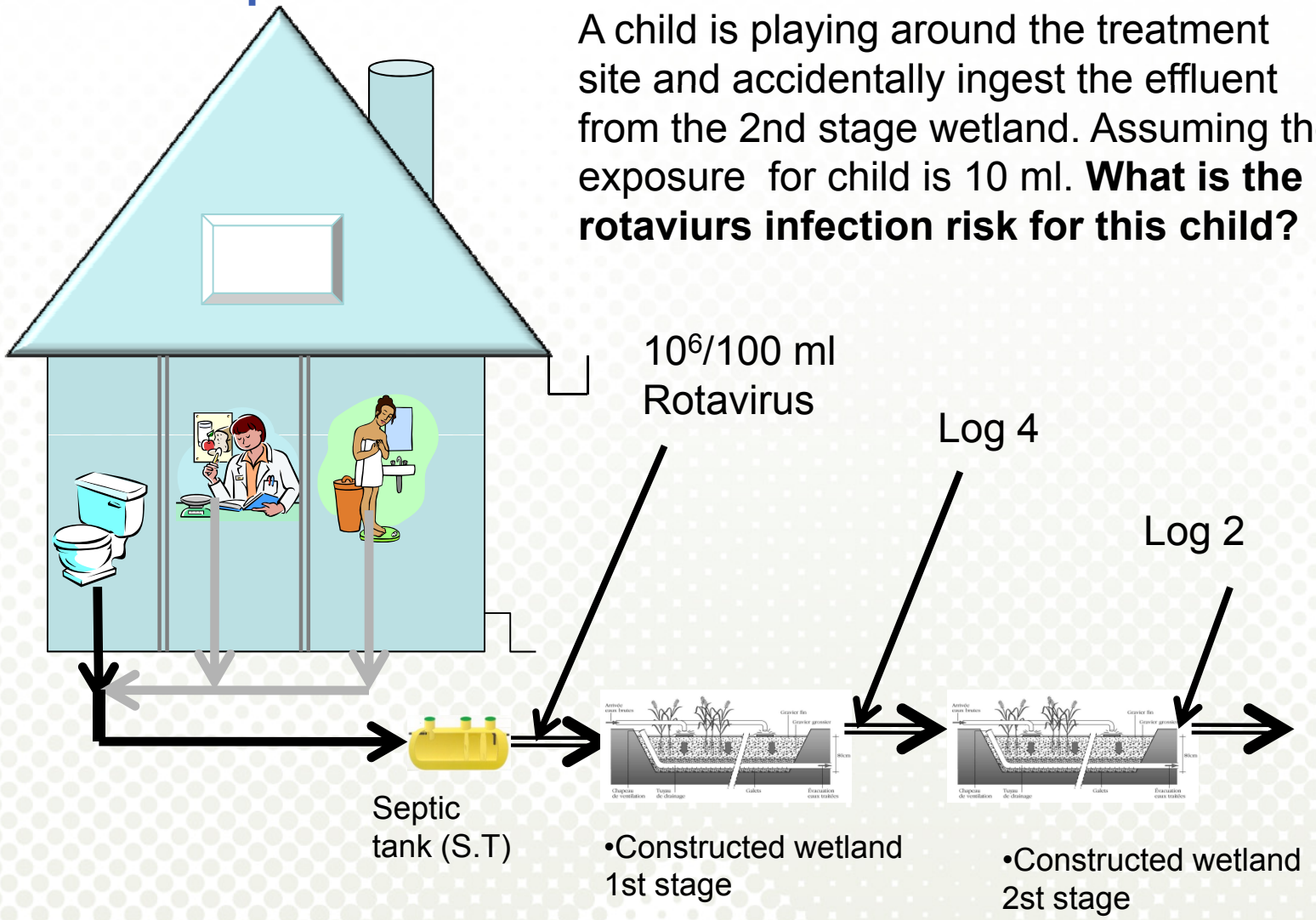


•Constructed wetland 2st stage

Example

A child is playing around the treatment site and accidentally ingest the effluent from the 2nd stage wetland. Assuming the exposure for child is 10 ml. **What is the rotaviurs infection risk for this child?**



Example calculation

$$P_{\text{inf}} \approx 1 - \left(1 + \frac{\mu}{\beta}\right)^{-\alpha}$$

For rota virus α = 0.253
B = 0.42

1. Calculate of μ (dose per single exposure)

Ingestion of wastewater = 10 ml

100 ml contains = 10^2 rotavirus

10 ml contains = $\frac{10^2}{100ml} \times 10ml = 10\ rotavirus$

$P_{inf} = 1 - (1 + 10/0.42)^{-0.253} \approx 0.55$

If the child is exposed 10 times in a year, what is the annual risk of infection?

$$P_{annual} = 1 - [1 - P_{inf}]^n$$

$$P_{annua\ risk}\ \text{of infection} = 1-(1-0.55)^1 = 0.55$$

$$P_{annua\ risk}\ \text{of infection} = 1-(1-0.55)^{10} = 0.99\ !!!!$$

We determined risk of infection for given wastewater qualities – First approach

Second Approach – Determine the required level of pathogen reduction in $\log_{10}$ units for a given levels of tolerable infection risk
TOLERABLE RISK FOR INSTANCE 10^{-6} DALY (Diseases burden arising from working in irrigated field)

What is DALY ?

- Disability Adjusted Life Year

Time lost because of disability or death from a diseases compared with a long free of disability in the absence of disease

DALY = years of life lost to premature death (YLL) + years lived with disability (YLD)

- We determined risk for given waste

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THANK YOU