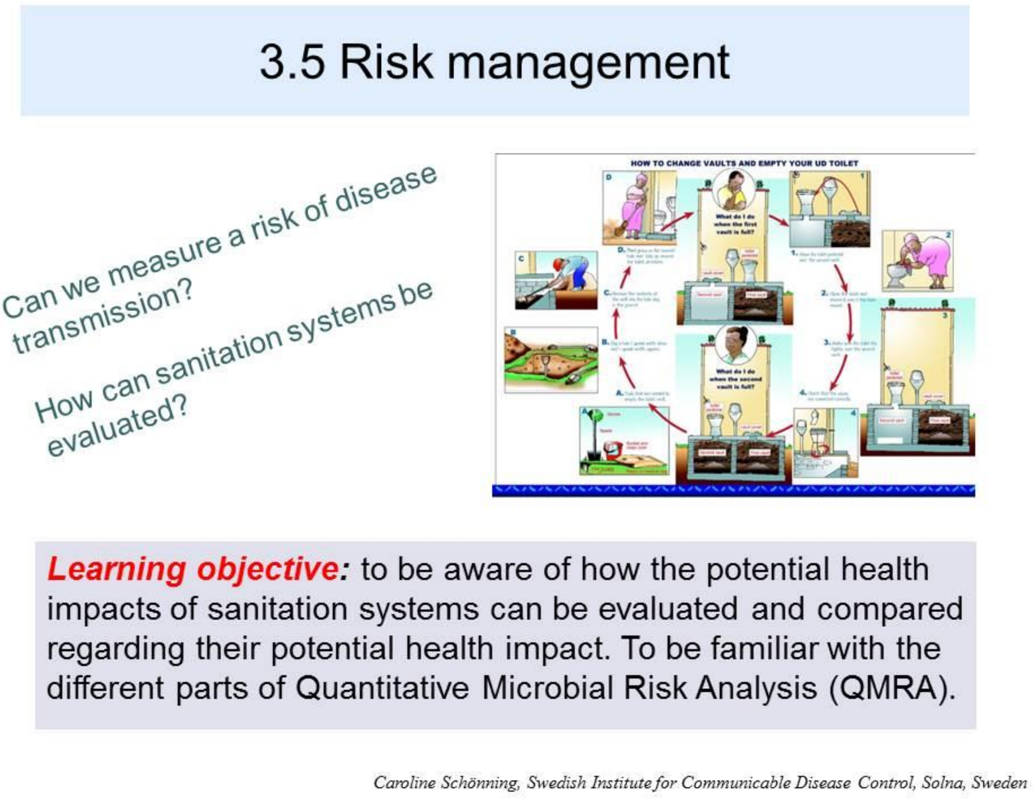
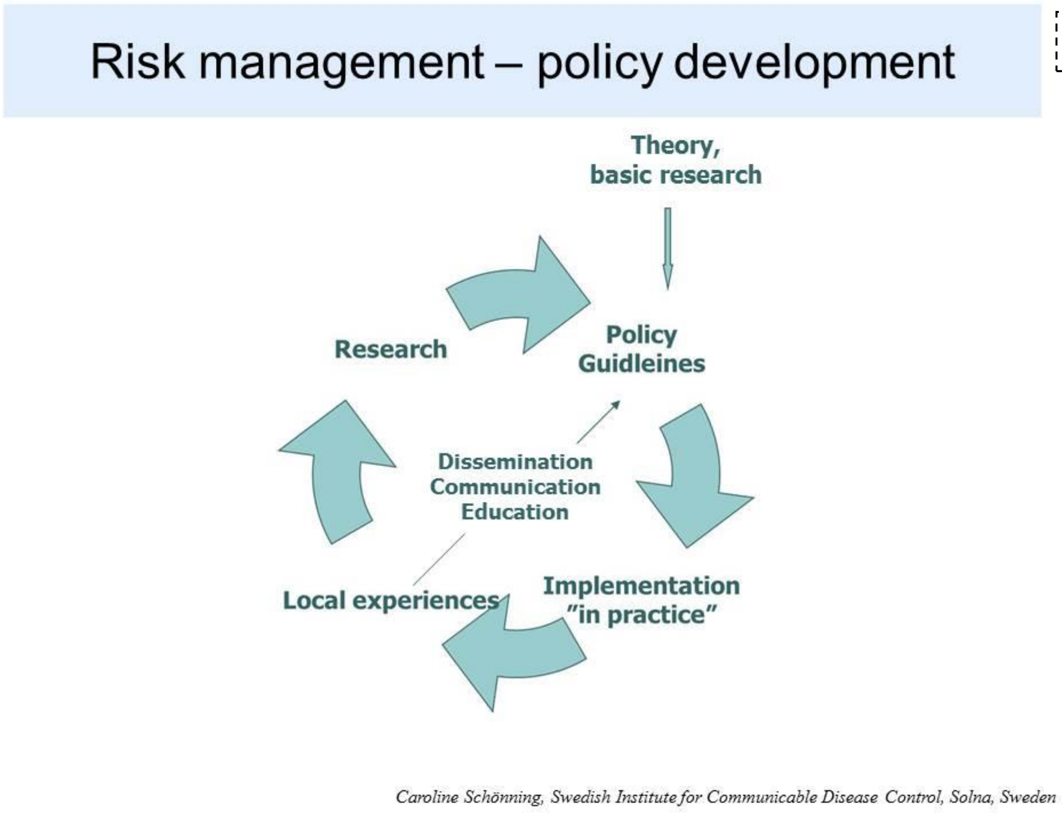


In this module microbial risk assessment is dealt with in more detail by giving some examples of QMRA studies that have been published in journals. They are related to developed areas (Sweden and Denmark) but the same approach has been applied in the epidemiological studies performed in developing areas with a worse background sanitary situation with a high incidence of parasitic infections. The studied interventions were implemented in order to improve the public health situation. However, as stated in Modules 3.3. and 3.4, risk management is crucial in any sanitation system and this module elaborates on the performance of barriers (health protection measures) in practice.

The scientific assessment of health risks related to water and sanitation can be conducted by microbial analysis of waste flows (that are either to be discharged or recycled), by epidemiological studies or by microbial risk assessments. Assessments can be either qualitative or quantitative. All approaches have drawbacks, but the cumulative knowledge that is used for creating guidelines can motivate that risk management strategies build on combined results, using all three methods.

The examples of studies in this module aim at giving a system overview, providing examples of exposure scenarios and results showing the common need for administering several barriers.

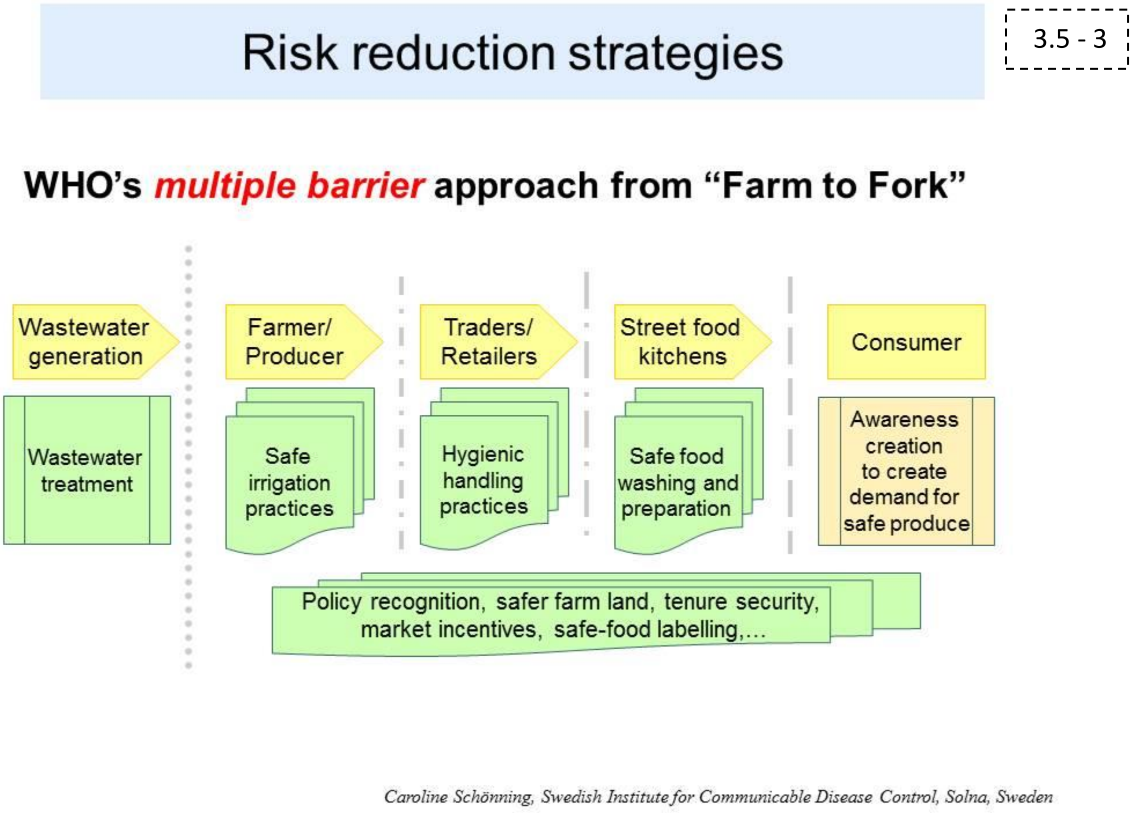
3.5 - 2



To address health issues in sanitation systems and to successfully contribute to improvements, the work plan shown in the above diagram could be followed. Policies and guidelines are often based on theory and basic research and oftentimes modified to suit general national conditions. Implementation and use of the policies in the local environment involves some adaptation to local conditions. Experiences gained from policy implementation may also generate additional general knowledge or identify areas which need further research. Policies are being developed in such loops which gradually integrates new facts and findings.

Dissemination, communication and education are crucial parts in any risk management system.

Regulations, policies and guidelines for reuse systems aim at reducing risks to acceptable levels and treatment is one important part of risk reduction. Treatment processes can be clustered into categories according to the level of safety that they provide. The hygienic standard of a waste product can be judged by testing for the presence of various microorganisms (both indicators and pathogens) or by measuring the reduction in the presence of these microorganisms, i.e. comparing the number of organisms present in the material before and after the treatment process. Restrictions on usage (e.g. crop restrictions) are other barriers, so is choice of irrigation or application method. Other regulations deals with how to transport and store the waste product and how to protect workers and residents. Procedures related to microbial analyses may also be introduced to raise the validity of results.



Module 3.2 introduced the idea of barriers to reduce exposure to pathogens. The F-diagram shows how good practices such as handwashing and careful handling of food constitute barriers. Treatment of excreta and other waste represents another kind of barrier both for reuse systems and for systems that do not recycle the waste as a resource.

Treatment is an important part of existing guidelines and regulations, e.g. in the WHO guidelines and in national EPAs (Environmental Protection Agency). Such rules and regulations build on both research and practical experiences. The WHO guidelines state that adaptation to local conditions is necessary, and a treatment system needs to be accepted and well managed in order to be a part of a sustainable sanitation system. Practical experiences leads to new challenges that demands additional research to further develop guidelines and advices for practical implementation. One research area to be developed is that of management of waste flows and recycling of resources e.g. nutrients and water to agriculture.

After treatment of excreta or wastewater there are a number of additional barriers or health protection measures that could be applied to further reduce risks. These include:

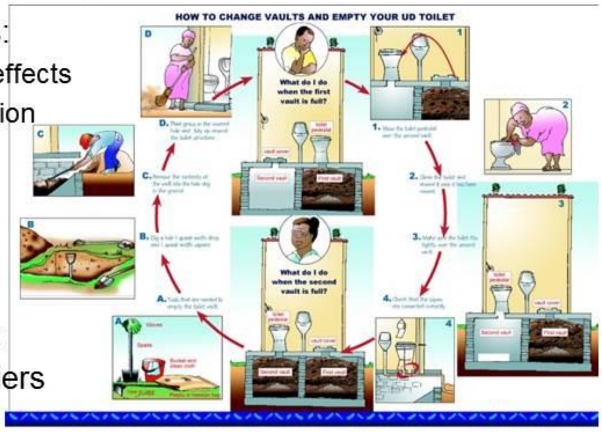
- Safe irrigation practices, which are the responsibility of farmers and food producers. Safe practices protect farmers and at the same time limit the exposure to surrounding humans and animals.
- Hygienic handling practices, which are the responsibility of traders and retailers.
- Safe washing and preparation of food, which are the responsibility of traders and retailers.

All these measures will in the end reduce the risk for the consumer, and such improvements can be driven by awareness which will increase the demand for safe produce.

Overview of risk management

3.5 - 4

- Different types of studies to understand the "real" situation:
  - Epidemiology – disease incidence, interviews, surveillance
  - Risk assessment – built on assumptions by professionals
  - Sampling and microbial analysis
- Range of interventions:
  - Hard to differentiate effects
  - Single or in combination
- Identifying need of risk management and barriers
  - Health protection measures



Caroline Schönning, Swedish Institute for Communicable Disease Control, Solna, Sweden

The studies presented in this module show that a sanitation system may introduce new transmission routes while removing others, resulting in higher or lower risks for infections. It is evident that implementation of sanitation systems can improve public health, for example, by reducing diarrhoea (e.g. 3.1–7). The degree of success depends to a large extent on the local situation – for example what the initial system (or lack of sanitation) was like, the local incidence of infections and how the waste produced within the system is handled (e.g. if it is recycled or not).

Epidemiological studies can be said to analyse the "real" situation (see 3.1-17; 3.2-2). Risk assessments evaluate situations and systems, using both estimates and known data, trying to calculate typical risks or risks related to worst-case scenarios. For example, the concentrations of protozoa and helminths that were measured in the faecal material in households in eThikwini (Trönnberg et al., 2010 on slides 19–20) were found to be lower than the calculated concentration for the same situation using literature data on excretion and duration as done in risk assessments. It is also known that collecting representative samples and analyzing for pathogens is a difficult task, and in Module 3.4 it is shown that faecal indicators cannot do the job for us in all situations.

In spite of the differences and the difficulties in obtaining hard facts, all the different types of studies help in identifying risks to be managed. In the final analysis, it is not exact data that is needed for introducing barriers and protection measures. These are successfully developed from reasonably representative data, practical experience, and expert valuation. Health protection measures include both technical measures and behavioral measures such as washing hands.

Comparison of sanitation systems

3.5 - 5

- Diverting systems:
  - Small volumes
  - Easier to treat (but not wastewater)
  - Suitable fertiliser products
  - Handling requires restrictions

- Mixed (conventional)
  - Large volumes of ”hazardous” waste
  - Extensive treatment
  - Reuse products: wastewater, sludge
  - Downstream pollution risk

Caroline Schönning, Swedish Institute for Communicable Disease Control, Solna, Sweden

A simple comparison can be made from a health point of view between diverting and mixed sanitation systems, i.e. systems where urine, faeces and greywater are kept separate and systems where these fractions are mixed in one flow. Properly managed, both systems can function well. However, how sustainable they are is intensely debated and depends on aspects such as the time frame and system boundaries.

The diverting system produces small volumes of homogenous and easy-to-treat faecal matter and urine, while polluted wastewater still needs to be handled. However, handling may be more labor intensive and require close contact with the waste. Mixed systems produce one large volume of non-homogenous liquid waste that is more challenging to treat.

Both systems generate waste products that can be recycled in agriculture, but their features vary. What is important in relation to health risks is that they can be properly managed; that is, it is possible to limit exposure and the number of pathogens can be reduced. Therefore health and hygiene issues do not need to be the considerations that decide which sanitation system is suitable in a particular situation. Again, local adaptation is a key to control risks of disease transmission.

The following pages deal with health protection measures concerning urine, faecal matter, and greywater.

Impacts of interventions on diarrhoeal disease

3.5 -6

Intervention area	Reduction in diarrhoea frequency
Hygiene	37%
Sanitation	32%
Water supply	25%
Water quality	31%
Multiple	33%

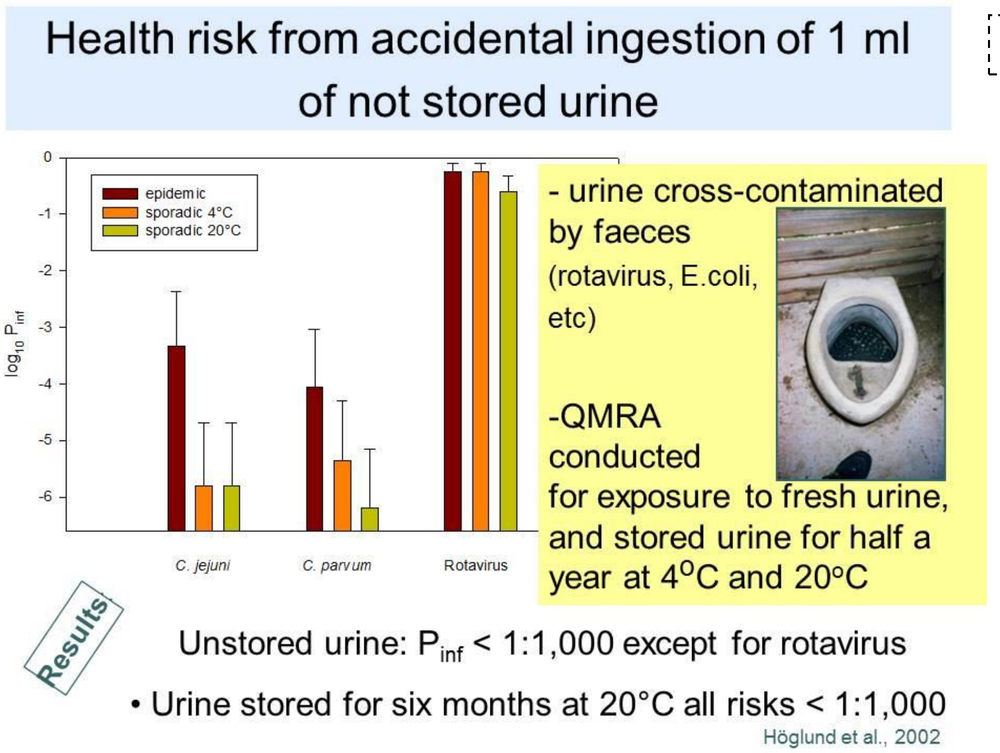
In WHO, 2008, adapted from Fewtrell et al., 2005

The effects of different interventions to reduce diarrhoea have been investigated in many studies. A systematic review, a so-called meta-analysis, was made by Fewtrell et al. (2005) in order to draw conclusions regarding interventions. In total, 2000 abstracts were screened and 38 studies were selected for the meta-analysis.

They found that most interventions reduced diarrhoea incidence by a quarter to one-third, and improved hygiene seems to be most important. It may be surprising that multiple interventions do not fare better. Even though it is not apparent from the results shown in the table above, water, sanitation and hygiene interventions interact, but the impact of each may vary widely according to local circumstances. Interventions to reduce vector-borne disease are even more related to local conditions since they are mostly related to the environmental situation.

The results from the studies from El Salvador (slide 3.5 – 17) and Durban (slide 3.5 – 19) should be seen in the light of these general impacts of various interventions.

3.5 - 7

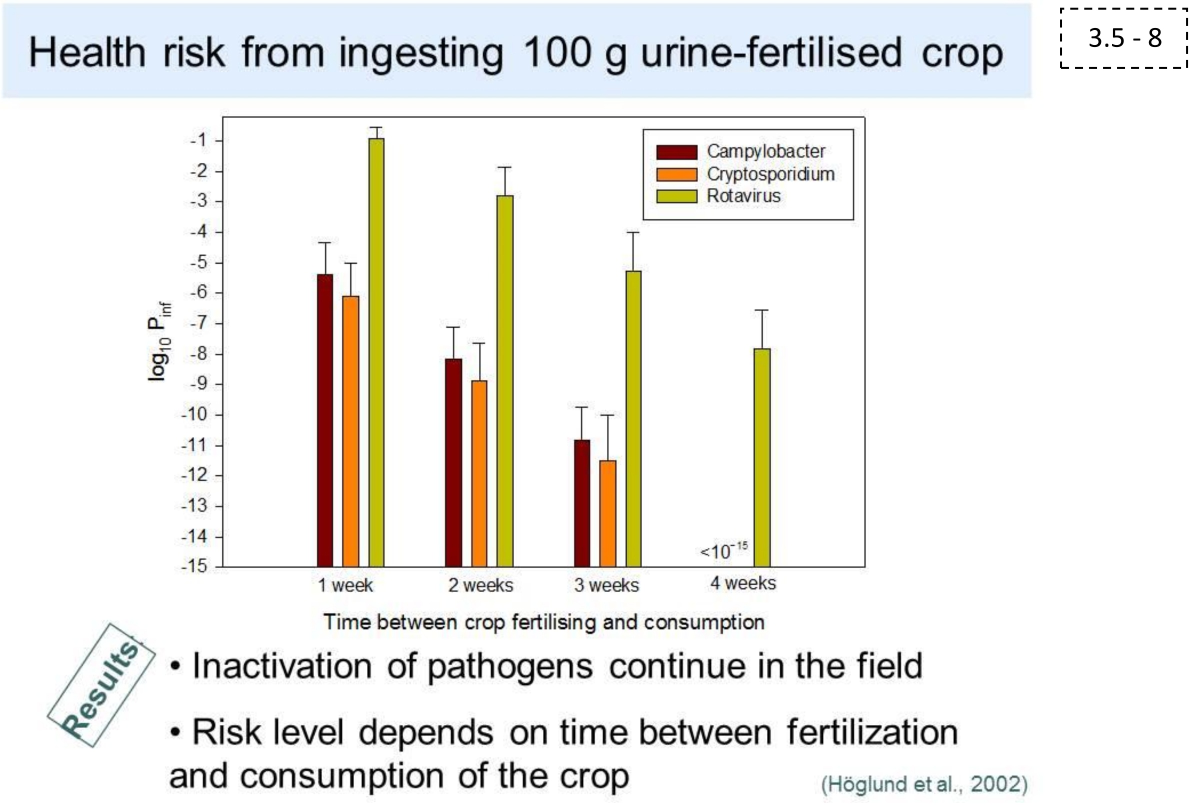


Module 3.1 provides information about pathogen content in urine and faeces which indicates that the concentration is very low in urine. Cross-contamination is common, however, and the picture shows how some faecal matter ends up in the urine. The urine in this case is assumed to contain faecal pathogens. Findings from Swedish QMRA studies on faecal contamination and survival of enteric microorganisms in urine-diverting system are being used here (Höglund et al., 2002; http://wmr.sagepub.com/content/20/2/150.full.pdf+html).

The concentration of faecal sterols (coprostanol) in the collected urine was measured and used to estimate the level of faecal contamination. Three pathogens, representing different organism groups, were examined more closely: *Campylobacter jejuni*, rotavirus, and *Crypto-sporidium parvum*. National surveillance data on incidence was used to calculate potential concentrations of these pathogens in the urine. The results from survival studies (Module 3.3) were used to calculate concentrations after storage and exposure scenarios were determined, i.e. theoretical scenarios and estimated amounts (volumes) of urine that could be ingested were determined.

The graph shows the risk for infection, P_{inf}, after ingesting 1 ml of fresh urine cross-contaminated by faecal matter, at different hypothetical levels of infection in the population. The worst case scenario is an epidemic event in which all the people connected to a urine-diverting system were infected right before the urine tank was emptied. The three left-hand bars for each pathogen (dark) present the number (in $\log_{10}$ values) of each pathogen. The other two bars represent a situation where all users of the urine collection tank are infected during the whole period in which the urine is collected. The storage temperature is 4°C (red bar) or 20°C (green bar).

Overall, risks were calculated using dose-response models and showed to be less than 1:1000 for one exposure at each event (scenario), except for the probability of rotavirus infection that was higher. If the urine mixture was stored for six months at 20°C the risks of infection from accidental and aerosol ingestion of rotavirus were also less than 1:1000. These results comply with the general rule that higher inactivation of the organism is achieved in higher temperature and thus represents a lower risk.



The previous page illustrated the health risks of ingesting 1 ml of contaminated urine, and it showed the positive impact of the barrier of storing urine. Slide 3.3 - 5 shows that a further die-off takes place when (stored) urine has been sprinkled on crops which are not eaten immediately.

The bar chart above shows another example on health risks of ingesting urine-fertilized crops. The inactivation of microorganisms will continue in the field and the risk will thus vary depending on the time that passes between sprinkling the leaves and harvest or consumption. Even if the urine has not been stored, the risk simulations show that the risk for bacterial and protozoan infections is already low after one week. After three weeks the risk for viral infections was also low and on that same level (this specific case corresponds to eating a fresh crop that holds as much water as lettuce). Storage is an effective barrier.

'Rules of thumb' for handling of faecal matter

3.5 - 9

- The risk of infection is too high (>1:10 000) when faeces is used without treatment
  - The highest risk from exposure to not-stored material was attributable to rotavirus
- 12 months storage – sufficient reduction of most pathogens (compared to a risk level 1:10 000)
  - The highest risk from exposure to stored faeces is attributable to *Ascaris*
  - the protozoa *Giardia* and *Cryptosporidium* are of greater concern in the European population
- The risks of infection can be reduced by simple measures such as longer storage, or treatment with a pH-elevating compounds such as ashes and lime

(Schönning et al., 2004)

There is a high level of uncertainty regarding inactivation of pathogens in faecal material (See module 3.2), and further studies are recommended. The risks of infection can be reduced by measures such as longer storage, adding a pH-elevating substance, or heating. The variations in the risk of infection depend on the pathogen in question and were up to 12 orders of magnitude in a specific scenario. If the material was stored for 12 months the typical risk (50^{th}-percentile) in general decreased with 3–7 orders of magnitude when compared with no storage. The risk from EHEC is eliminated if the material is stored for 12 months and the typical risk of being infected by *Salmonella* is also very low. Viruses and parasites generally survive longer in the environment, and require lower infectious doses, which result in higher risks for rotavirus, the protozoa and *Ascaris*. The following storage options were evaluated by WHO:

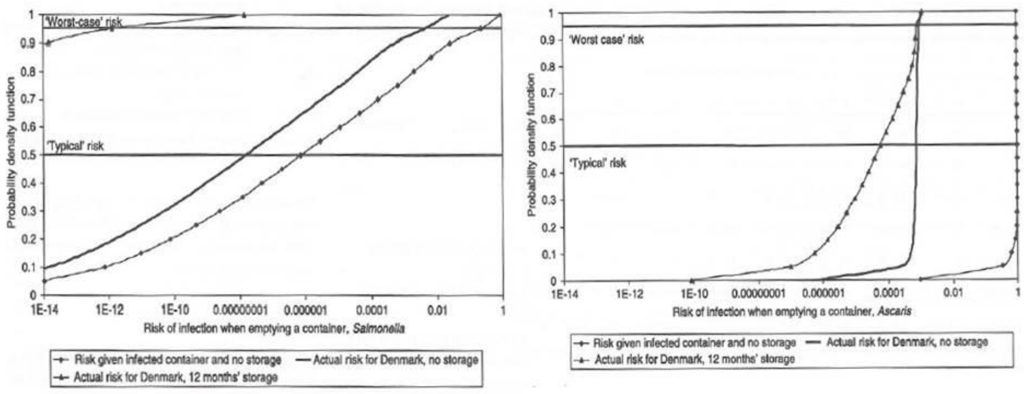
1. Application of the material after storage for 0 months
2. Application of the material after storage for 6 months
3. Application of the material after storage for 12 months
4. Application and incorporation of the material in soil after storage for 6 months
5. Application and incorporation of the material in soil after storage for 12 months

Results showed that 12-months' storage before use was sufficient for the inactivation of most pathogens to acceptable levels. When working or spending time in the garden the annual risk of infection by Ascaris was still slightly above 1:10 000 in these scenarios, although the incidence rate for Ascaris is very low in the targeted population. Measures to further reduce the hygienic risks include longer storage or treatment of the faeces. The results can easily be extended to other regions with different incidence rates.

Even if a thermophilic (high-temperature) composting process was aimed for in the previously investigated systems, temperatures never rose above 20°C and were, at most, 7°C higher than the ambient temperature. The faeces could thus be said only to be treated by means of storage prior to application in the garden. The pH of the faeces varied from 6.7 to 8.4 and the dry substance content was 22–39% (J. Møller, Royal Veterinary and Agricultural University, Denmark, personal communication).

Infection risk when emptying faecal container

3.5 - 10



Salmonella Ascaris

Risk of infection presented as probability functions.

- the typical risk is shown to be in the 50th percentile
- the worst case risk is shown by the 95th percentile.

(Schönning et al., 2004)

A quantitative risk assessment was performed for urine-diverting toilets in Denmark (http://www.iwaponline.com/jwh/005/0117/0050117.pdf). The aim was to evaluate the risk of transmitting infectious diseases when recycling of faeces as a fertilizer. Pathogenic micro-organisms (bacteria, viruses, protozoa and helminths) capable of being transmitted to humans via the faecal-oral route were selected for study. And among these, those were selected which:

- were relatively common in Denmark
- were persistent
- required low infectious dose
- severe consequence of the disease
- had reasonably large amount of background information available.

The following assumptions were made for human exposure scenarios:

- faeces-soil intake (Larsen,1998) for children was around 200 mg (max of 5-10 g).
- adults ingest 15–50% of this amount, with a maximum of 100 mg.
- the container is emptied once a year and only adults were exposed during this process.
- the median number of exposures through recreation was 3.5 times per week (during June-August).
- 50% of the households were exposed through gardening once a week (during May-September).
- one exposure corresponded to two hours of gardening that occurred a maximum two times per day.

The evaluated human exposures included accidental ingestion of small amounts of faeces, or a mixture of faeces and soil, while emptying the storage container and while applying the material in the garden, during recreational stays in the garden, and while gardening. The four QMRA steps were applied for the selected pathogens. The probability that the faeces in the storage container from a typical household contained at least one type of pathogen was calculated to be 11.6%. The probability that a typical container would contain at least two types of pathogens was 0.5%. Rotavirus and Giardia were found to be the most prevalent pathogens. They were present in 4.7% and 4.3% of the containers respectively.

The risk of infection is greatest when emptying the container, since the material at this stage is partly fresh and not yet mixed with soil, and no reduction of pathogens has occurred. To remedy the situation, a urine-diverting toilet should have two faecal chambers or two collection bins, one of which is in use while the other is resting.

The two graphs illustrate the calculated risks when handling the content of faecal containers. The highest risk was attributed to rotavirus (3 x 10^{-2}), whereas *Ascaris* constituted the highest risk after 6 or 12 months' storage, although this infection is quite uncommon in the Danish population. The study suggests that local handling of faeces may open a new route of infection for *Ascaris* in a population where this helminth is rare.

For *Salmonella*, the health risk depends more on storage time as a barrier than on incidence rate. The risk levels over time differ by several orders of magnitude. For other pathogens (e.g. *Ascaris*) the storage has limited importance because of 1) the high persistence of eggs/pathogens, and 2) is instead dominated by the low prevalence of Ascaris eggs/pathogen in the population in question.

The typical risk is defined by the 50th-percentile and worst case is defined by the 95th percentile. The large differences between the typical risk and the worst-case risk indicate that, in general, viruses, protozoa and helminths may constitute a problem due to the substantial level of uncertainty. Furthermore, the risk increases significantly if the material is stored for less than 12 months. The importance of the estimated incidence rates differs greatly between pathogen species. The incidence rate of the region is less important when the decay of the pathogen is rapid, whereas the overall risk is dominated by the initial incidence rate of the pathogen when the decay rate is low.

In approximately nine out of ten gardens, the use of stored faeces as a fertilizer will not result in a risk of infection in Denmark. This is because no family member in these households was infected, and thus no pathogens were excreted into the container. In the remaining 11.6% of the gardens there was a risk of infection; however, most exposures will not lead to infection as too few pathogenic organisms will be ingested. If one judges the risks according to previously identified acceptable levels (10^{-4} per year), the practice of using faeces that has been stored for one year, but is otherwise untreated, should be regarded as unacceptable, since the risk for infection is too high. The risk of infection is due mainly to the helminth *Ascaris*. Furthermore, the risk level is very sensitive to changes in the incidence rate.

Without storage, the material in the containers was highly infectious for all the pathogens involved except bacteria. After 12 months of storage the typical risk associated with emptying the container was less than 10^{-4} for all of the pathogens. When considering typical risks associated with gardening and recreational activities in the garden, the yearly risk of infection was only higher than 10^{-4} for *Ascaris*. As such, the risks were just below the acceptable level suggested by Regli et al. (1991).

Wastewater and sludge – hazards & exposure

3.5 - 11

In another study conducted at a 12,500 m^3/day treatment plant utilizing tertiary wastewater treatment and mesophilic sludge digestion, a Hazard Analysis and Critical Control Points (HACCP) was applied (where QMRA was one step) to identify and control exposure to pathogenic microorganisms encountered during normal sludge and wastewater handling (http://www.iwaponline.com/wst/05002/0023/050020023.pdf). The treated sludge was assumed to be applied to vegetables.

The quantitative microbial risk assessment (QMRA) included assessment of the risk from rotavirus, adenovirus, hemorrhagic *E. coli*, *Salmonella*, *Giardia* and *Cryptosporidium* was conducted in order to prioritize barriers for pathogen hazards. The exposure scenarios considered were identified in collaboration with staff at the wastewater treatment plant (WWTP).

Data from the literature was used for most of the information that was needed to calculate the concentrations of pathogens in the various waste flows. Site-specific data on removal of indicators in the treatment plant was used to calculate their concentration in the outgoing wastewater. Human exposures were treated as individual risks, but were also related to the endemic situation in the general population.

The hazardous scenarios considered were human exposure during treatment of wastewater (the eight pictures above):

(1) during pre-aeration; (2) at the belt press, exposure via water at the wetland-area; (3) someone falling in; (4) child playing and recreational swimming; (5) exposure during treatment, handling and soil application of sludge; (6) child playing at storage site; (7) contractor/farmer spreading sludge; and (8) exposure from crop consumption.

The following two slides present the details from this exposure study.

3.5 - 12

Exposure scenarios for the Danish wastewater treatment study

Type of exposure	Volume ingested (mL or g)	Frequency (times*year^{-1})	Number of persons affected
1. WWTP worker at pre-aeration	1	52	2
2. WWTP worker at belt press	5	208	1
3. (Un)intentional immersion at wetland inlet	30	1	2
4. Child playing at wetland inlet	1	2	30
5. Recreational swimming	50	10	300
6. Child playing at sludge storage	5	1	2
7. Contractor spreading sludge	2	30	2
8. Consumption of raw vegetables	1	2	500

Westrell et al., 2004

The table shows, for each of the eight scenarios, the estimated volume possibly ingested, and the number of times per year that this occurred (all in theory). In the site-specific investigation the numbers of persons that could be exposed and affected were also estimated.

The highest individual health risk per single exposure was through exposure to droplets and aerosols for workers at the treatment plant (exposures 1 and 2), particularly at the belt press for sludge dewatering, and through contact with digested sludge (exposures 6 and 7) with a risk of viral infection equal to 1 or nearly 1. The lowest risk was from swimming in the lake (exposure 5). In this case, the wastewater treatment followed by polishing in a wetland and dilution in the receiving lake water reduces the number of pathogen to a great extent. However, if currents in the lake transport undiluted wetland discharge to the bathing area, the risk could increase a thousand times.

The viruses constitute the highest risk for a single exposure due to high influent concentrations, low infectious doses and lower removal rates than for bacteria and protozoa. *Giardia* is more infectious than *Cryptosporidium*, and this is reflected in the risk calculations. The higher risk for EHEC than for *Salmonella* was due mainly to the difference in dose-response equations and the median infectious doses. Haas et al. (2000) have however reported a median infectious dose for EHEC 500 times higher than the one used here.

3.5 - 13

Number of yearly infections in Danish study

Exposure		EHEC	*Salmonella*	*Giardia*	*Cryptosporidium*	Rotavirus	Adenovirus
1						1.98 (1.69-2.00)	1.99 (1.30-2.00)
2				0.57 (0.05-0.99)		1.00 (0.99-1.00)	1.00 (0.97-1.00)
3							0.21 (0.02-1.87)
4							0.23 (0.02-5.21)
5							0.18 (0.01-4.26)
6						0.76 (0.23-1.28)	1.87 (0.22-2.00)
7				0.52 (0.04-1.75)	0.13 (0.006-1.25)	2.00 (1.64-2.00)	2.00 (1.49-2.00)
8							0.41 (0.01-20.51)

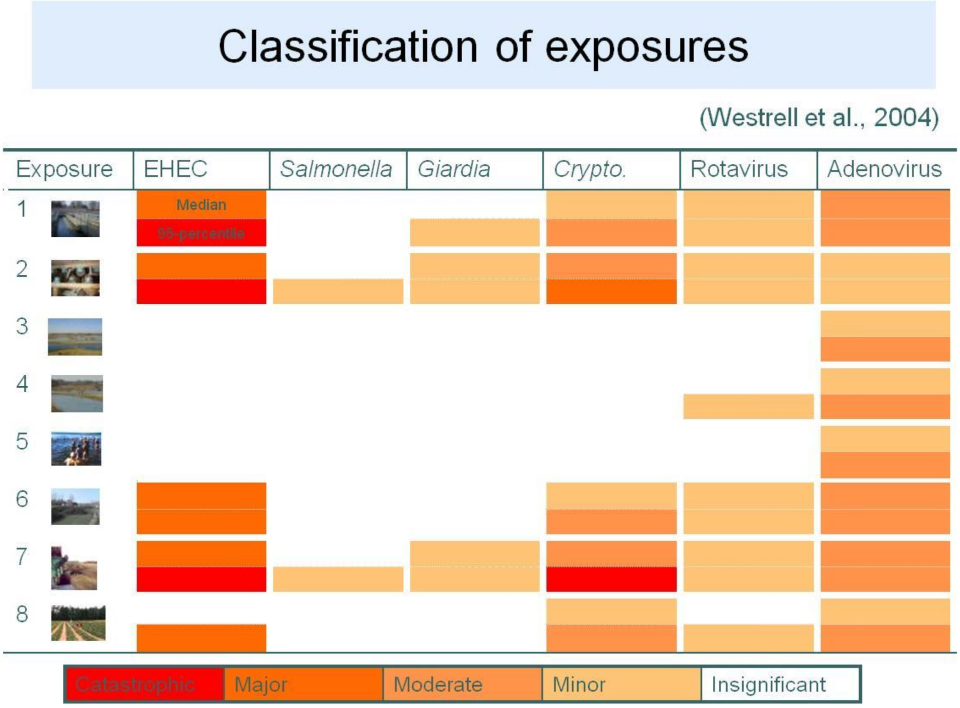
The absence of a reading indicates <0.0001 infections

Westrell et al., 2004

The annual number of infections estimated to occur per hazardous exposure was generally very low for non-viral pathogens (<<1). The number of cases should, however, be compared to the number of exposed individuals. Viruses constitute the major risk in exposure scenarios 2 and 7, and nearly reached 1 in scenario 1, with the maximum number of infections, for both adenovirus and rotavirus. This means that the workers at the treatment plant and the entrepreneurs handling and spreading sludge were quite certain to become infected at least once during one year of performance, unless already immune or protected. Antibodies against enteric viruses, e.g. adenovirus, have been reported among wastewater treatment plant workers with higher prevalence among those subjected to high aerosol exposure (Clark, 1987).

The consumption of vegetables grown in sludge-amended soil constituted a lower risk and a lower number of yearly infections than expected. A significantly higher risk would, however, result if the organisms occurred in higher concentrations in lumps of sludge rather than being homogeneously distributed as assumed. In the current Swedish legislation ten months must pass between sludge fertilization and the harvest of crops that are eaten raw, but in this study a worst-case scenario assuming a waiting period of one month was applied.

3.5 - 14



In order to rank the hazardous exposures according to severity of consequences, a comparison was made to the endemic level of these diseases in the community. An increase in the number of EHEC infections is considered more serious than an increase in the incidence of any of the other infections, since EHEC is associated with symptoms other than diarrhoea (e.g. renal failure) and often requires hospitalization.

Item	Definition
Catastrophic	Major increase in diarrhoeal disease >25% or >5% increase in more severe disease or large community outbreak (100 cases) or death
Major	Increase in more severe diseases* (0.1-5%) or large increase in diarrhoeal disease (5-<25%)
Moderate	Increase in diarrhoeal disease (1-<5%)
Minor	Slight increase in diarrhoeal diseases (0.1-<1%)
Insignificant	No increase in disease incidence (<0.1%)

* In this study represented by EHEC

Although several of the exposures only resulted in much fewer infections they had a large impact on the community as a whole. This was due to anticipated low prevailing numbers of infection. The largest impact on the community would arise if children ingested sludge at the unprotected storage site, although in the worst-case situation the largest number of infections would arise from vegetables fertilized with sludge and eaten raw (see slide above Number of yearly infections, up to 20 cases for adenovirus).

Viruses generally posed the highest risks and resulted in the largest number of potential cases, while EHEC and *Cryptosporidium*, with only a few cases constituting the endemic level, were identified as having the largest impact on the community, with above 5% (major) and 25% (catastrophic) increase in disease rates, respectively.

3.5 - 15

Barriers or control measures for exposures

- **Exposure 1**

  Easy to control with:
  - Personal Protective Equipment (PPE)
  - Covering of basins

- **Exposure 2**

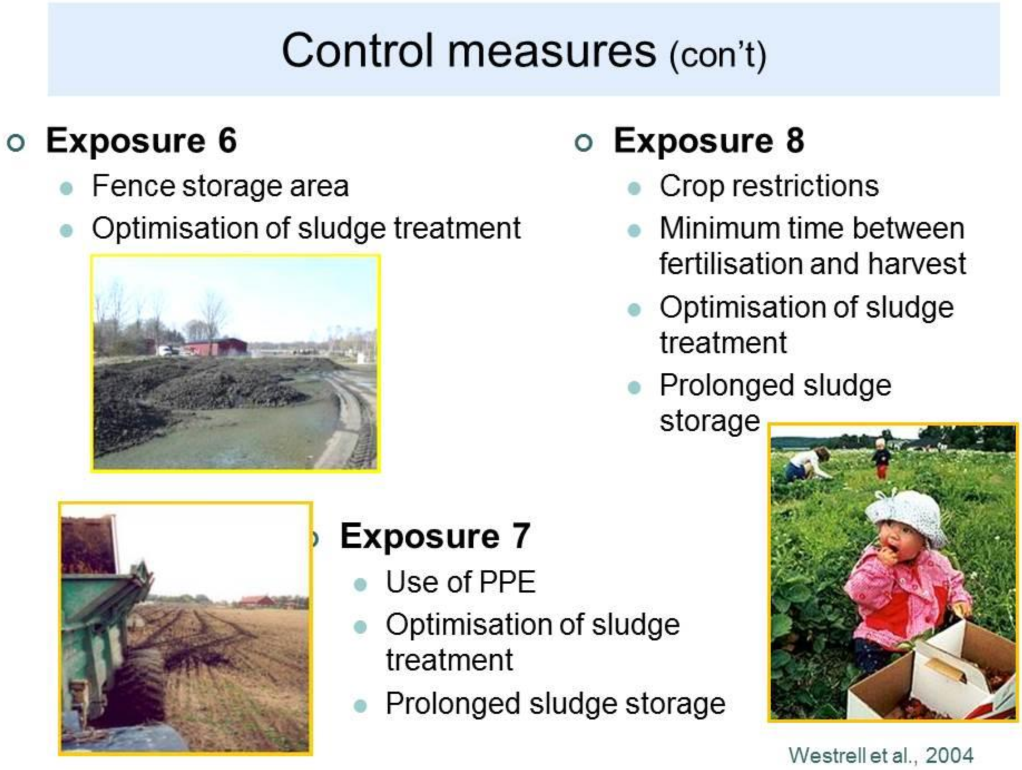
  Easy to control with:
  - PPE
  - Optimisation of sludge treatment (baffles against short-circuiting, thermophilic digestion etc.)

Westrell et al., 2004

Wastewater treatment does normally not achieve anything like complete barriers since the treatment processes are not optimized for pathogen removal, although each process generally inactivates or removes some of the pathogens. The most hazardous exposures identified in this case study included some of the early processes in the treatment and handling of sludge. From the society's perspective it is most important to control exposures 1, 2, 6 and 7 at this sewage treatment plant.

Exposures at the treatment plant could be controlled by the use of personal protection equipment (PEE), covering the basins to reduce aerosols, and improving treatment of the sludge.

3.5 - 16



An easy control measure to prevent children from getting access to the sludge storage (exposure 6) would be to fence the area. Other improvements that would also increase the safety in the subsequent exposures of handling sludge or eating vegetables grown in sludge amended soil would be to change from mesophilic to thermophilic digestion or prolong the storage times.

Epidemiological study in rural El Salvador

3.5 - 17

- Study **prevalence of parasitic infections** in 109 rural households with 449 residents
- **Types of toilets** (UD = urine-diverting):
  - UD solar desiccating toilet (single vault)
  - UD double-vault desiccating toilet(LASF)
  - Pit latrine toilet
  - No toilet
- In El Salvador, the **solar toiletis recommended**
  - Includes urine diversion
  - Better results than pit latrine
- **Limitations of the study**
  - Different communities compared
  - Small sample size

Corrales et al., 2006

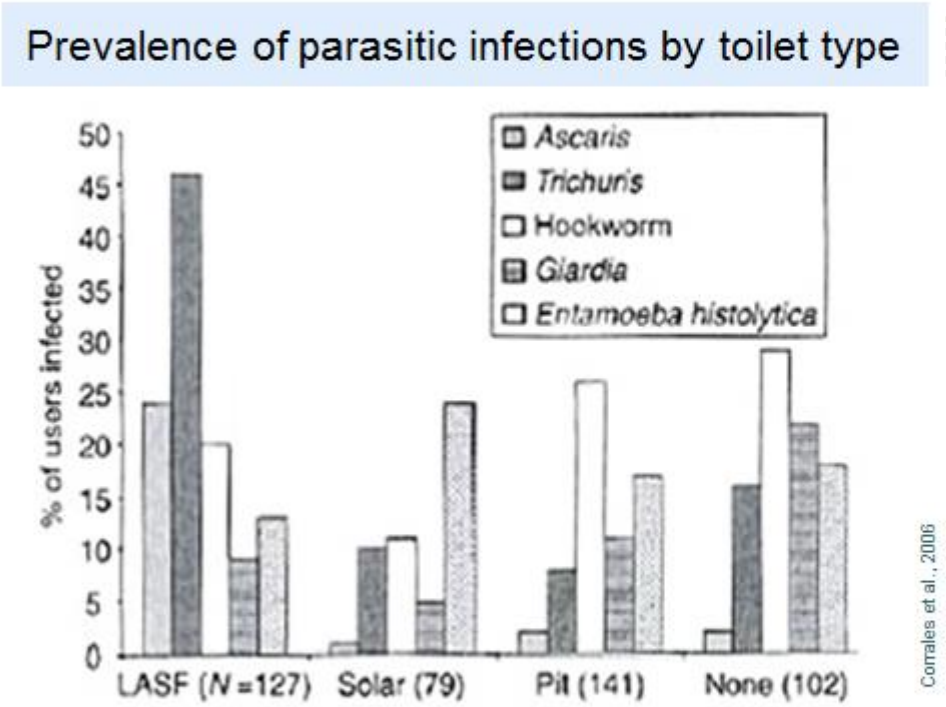
Epidemiological studies are often difficult and expensive to conduct. Such studies conducted on sanitation systems are therefore considered particularly valuable, and have the potential to give credibility to both interventions and policies. Reviews of epidemiological studies related to sanitation are included in several publications, among them the WHO *Guidelines on Safe use of excreta and greywater in agriculture* (2006) (See slide 3.5-24).

A study of the prevalence of parasitic infections was conducted in El Salvador in a community with 109 households (449 people). The purpose of this study was to examine the impact of various dry sanitation systems on the prevalence of helminths and protozoa infections while accounting for other individual and household risk factors. Therefore, the selection of households was done to include various sanitation arrangements: pit-latrine toilets (147), Urine-diverting toilets (UD) solar desiccating single (127) and double vault (79), and households with no toilet (102).
http://www.watersanitationhygiene.org/References/EH_KEY_REFERENCES/SANITATION/General%20Sanitation%20References/Parasites%20and%20Sanitation%20(Tropical%20Medecine).pdf

In El Salvador, the solar toilet is recommended since it allows to recycle urine and it gave better results than pit latrines in this study (i.e. lower prevalence of a majority of the infections). When published, the results were somewhat unexpected and caused heated debate on the possible health impacts of the types of toilets that had been promoted in the country.

The authors identified some limitations of the study: it is not possible to compare households with different latrine types in the same community because latrine interventions were carried out as community-wide programs, and the small sample sizes limited analyses for certain variables.

3.5 - 18



The table above shows a high prevalence of five parasites among users of all kinds of toilets. More than half of the users were infected with at least one type of intestinal parasite, indicating that these pathogens represent a significant health problem.

The pit latrine toilet users fare well in comparison with users of other kinds except for hookworm infection. This shows the great importance of containing faecal matter in the pit and wearing shoes, since hookworms are spread via feet on top of the slab. The higher prevalence of Ascaris and Trichuris infections among LASF users when compared with persons using solar toilets, pit latrine toilets or no sanitation suggests that LASFs may pose an increased risk for transmission of these helminths.

A comparison should always take into account how persistent the pathogens are, since this impacts the measures to reduce risks. For example, users of UD-toilets (both solar and LASF) display lower prevalence of the less environmentally persistent pathogens (hookworm, *Giardia*, *Entamoeba*), suggesting that such eco-san toilets can reduce transmission of these pathogens.

The users of LASF had a higher prevalence of more environmentally persistent pathogens (*Ascaris*, *Trichuris*). Based on the patterns of infection observed here and in previously obtained data on ova viability, it is likely that these toilet vaults do not consistently achieve the conditions necessary for more or less complete inactivation of these organisms in the faecal material (called “biosolids” by the authors).

The authors (Corrales et al.) had previously examined ova recovery and viability in stored samples collected from LASF and solar latrines in the same studied communities. Viable *Ascaris* and *Trichuris* ova were detected in LASF samples that had been stored for up to 2 years, while no viable ova were recovered from solar latrines. Solar latrines generally achieved higher internal temperatures than LASFs, the key determinant of *Ascaris* destruction, and produced a safer end product than the LASFs (Moe et al., 2001). The results of this study indicate that LASF and solar latrines protected against hookworm and *Giardia*, suggesting effective containment and destruction of these less environmentally persistent pathogens.

Using “biosolids” (faecal matter) as fertilizers resulted in a higher prevalence of infections (*Trichuris* and protozoan infections) compared to households that buried the material. This indicates a risk associated with the dispersal of biosolids around the home. If the biosolids are buried, human exposure and the potential for parasitic transmission are reduced. However, emptying and transferring contents from the toilet vault to a pit introduces an additional opportunity for parasitic transmission if the biosolids still contain infective pathogens. This may explain the higher prevalence of the more persistent helminths (*Ascaris* and *Trichuris*) among users of eco-san latrines who buried biosolids when compared with pit latrine users. Although most *Ascaris* and *Trichuris* infection was observed among children under 12 years, the prevalence of infection for members of households where biosolids were buried was much higher among adults than among children (57% in adults >31 years, vs. 14% in children <12 years). This finding lends further support to the hypothesis that transmission is more likely to occur during emptying of the latrine (a task performed by adults), than from contact with the biosolids after they have been buried (see 3.5-10).

High prevalence of some infectious agents in urine-diverting toilets highlights the need for further work on better designs, better use and maintenance and better information for users as well as further evaluation under different local environments and cultures.

Epidemiological study in rural Durban, SA

3.5 - 19

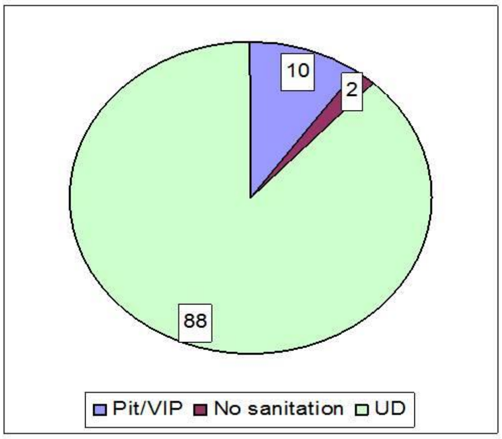
- Peri-urban area, eThekweni municipality, in Durban
  - 1337 households incl. in study
- Intervention
  - Sanitation – dry UD-toilets
  - Safe water (200 L per day)
  - Health and hygiene education
- Purpose and method
  - Measure reduction in diarrhoea associated with the interventions
  - Prospective cohort study
  - Disease incidence questionnaire (6 visits)

Picture provided by Teddy Gounden

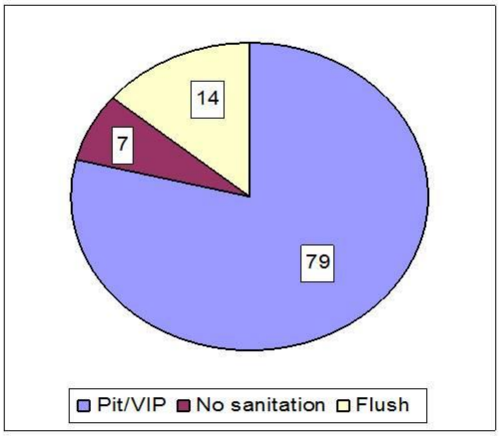
(Knight et al., manuscript)

The Durban city council embarked on a major upgrading of provision to 63 000 households in rural parts of the municipality (picture on next slide). By the end of 2007 the households had been provided with urine diversion (UD) toilets and free supply of 200 litres of safe water per day, complemented with health and hygiene education.

An epidemiological study was undertaken among 1337 households to investigate the effects of the combined intervention comprising new toilets, provision of safe water, and health and hygiene education. The circular diagrams below tell what toilet systems were available in the two areas. A prospective observational cohort study design was utilized including a disease incidence questionnaire. Each household was visited every two weeks, and in total six visits were made to reduce information bias (Knight et al. manuscript).



Intervention area with 660 households



Unexposed area with 667 households

Results from the Durban epi-study

3.5 - 20

41% reduction in diarrhoea

- Benefits 3 times greater for children <5 years
- Fewer acute water-related health incidences
- Duration of diarrhoea episodes decreased (54% fewer days reported)

Picture provided by Teddy Gounden

Not possible to disaggregate the separate effect of each intervention

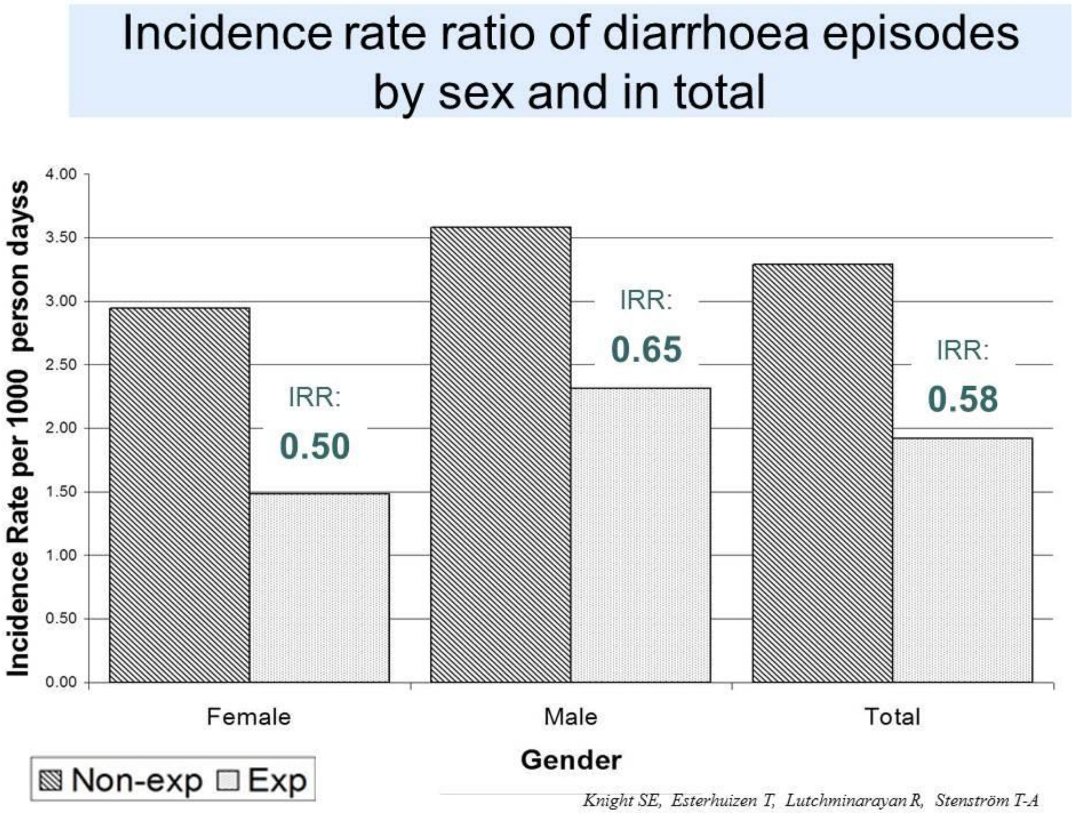
Knight et al., manuscript

The overall conclusion in the study is that the intervention resulted in a 41% reduction of diarrhoea compared to unexposed areas. The incidence rate for diarrhoea was 0.71 episodes per person per year in exposed areas compared to 1.23 episodes per person per year in unexposed areas. For children, the number of diarrhoea episodes was higher, especially for those under the age of 5. However, this group benefitted the most of the intervention and the number of episodes was reduced to one-third of that of the unexposed group.

Furthermore, the duration of diarrhoea episodes was shorter in the intervention areas than in the unexposed areas: 5.6 days compared to 9.9 days which resulted in 54% fewer days of diarrhoea in total.

The study design did not allow for disaggregation of the effect of each separate intervention. (Knight et al. manuscript). The general perception from many studies is that improved sanitation has a greater positive impact than improved water quality (See Module 3.1).

3.5 - 21



The table shows the incidence rate per thousand person-days for men and women is between 3 - 3.5 or about once a year. Two significant differences are found: females have a lower rate of diarrhea than males, and the intervention halved the diarrhoea episodes for females while that of men is reduced by 30% only. One possible explanation for this could be that women stay at home more often than men and thus receive a greater benefit from the interventions (Knight et al. manuscript).