A WELL FACTSHEET

The microbiological contamination of water supplies from pit latrines

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Edited and produced as a PDF document: May 2020

Introduction

The contamination of boreholes and shallow wells from on-site latrines is an issue that is generally poorly understood and irrationally assessed by organisations implementing water supply and sanitation programmes. This should not be the case as the health risks are often lower than popularly anticipated. The method of risk assessment outlined in this fact sheet is within the technical capacity of a competent engineer and should be regarded as being the first step in gaining a better understanding of the problem. This fact sheet provides background information on the factors that lead to microbiological contamination, the basic principles of risk assessment, and points those requiring more guidance in the right direction. It does not contain any information about assessing nitrate or chemical contamination from latrines, which can be a problem in some areas.

Pathogens characteristics and water point contamination

The majority of disease organisms (pathogens) lack the capacity to propel themselves through the environment in which they live, and those that can are not capable of travelling very great distances. Instead, pathogens are carried from one point to another within the medium in which they live and in the case of water point contamination from latrines, this is in the liquid that accumulates within the pit. Pathogens, therefore do not travel further or faster than the water in which they are suspended and this is an important fact to remember when trying to understand water point contamination.

There are two other important attributes of pathogens that effect their ability to contaminate a water point; their size and their die-off rate.

Size

Helminth (worm) eggs and Protozoa are relatively large and are efficiently removed through the physical filtration process in the soil (Lewis, Foster et al 1980). Bacteria and viruses are much smaller and are much more able to travel unrestricted through the subsoil. The bacteria and viruses in the table below are some of the greatest causes of concern.

Viral disease	**Pathogen**
Infectious hepatitis	Hepatitis A virus
Poliomyelitis	Poliovirus
Diarrhoeal diseases	Rotavirus, Norwalk agent, other virus
Bacterial disease	
Cholera	Vibrio cholerae
Typhoid	Salmonella typhi
Paratyphoid	Salmonella paratyphi
Bacillary dysentery	Shigella spp
Diarrhoeal diseases	Enterotoxigenic E coli, Salmonella spp, Campylobacter spp

Die-off rate

Faecal micro-organisms, like all life forms, have a limited life span in the environment and die off exponentially at rates which vary enormously from a few hours to several months. In ground water, some viruses are known to survive for up to 150 days. In the case of E. coli indicator bacteria, an estimated half life (ie the time taken for 50% reduction in numbers) in temperate ground water has been noted as being as high 10 to 12 days, with survival of high numbers up to 32 days. Some salmonella species have been shown to persist for up to 42 days (ARGOSS). If the time taken for pathogens to be transferred to the water point is large, the pathogens will have died off and the water will no longer present a threat to public health.

The figure below shows six different factors which can effect pathogen transmission from a latrine to a nearby water point. These are discussed in turn.

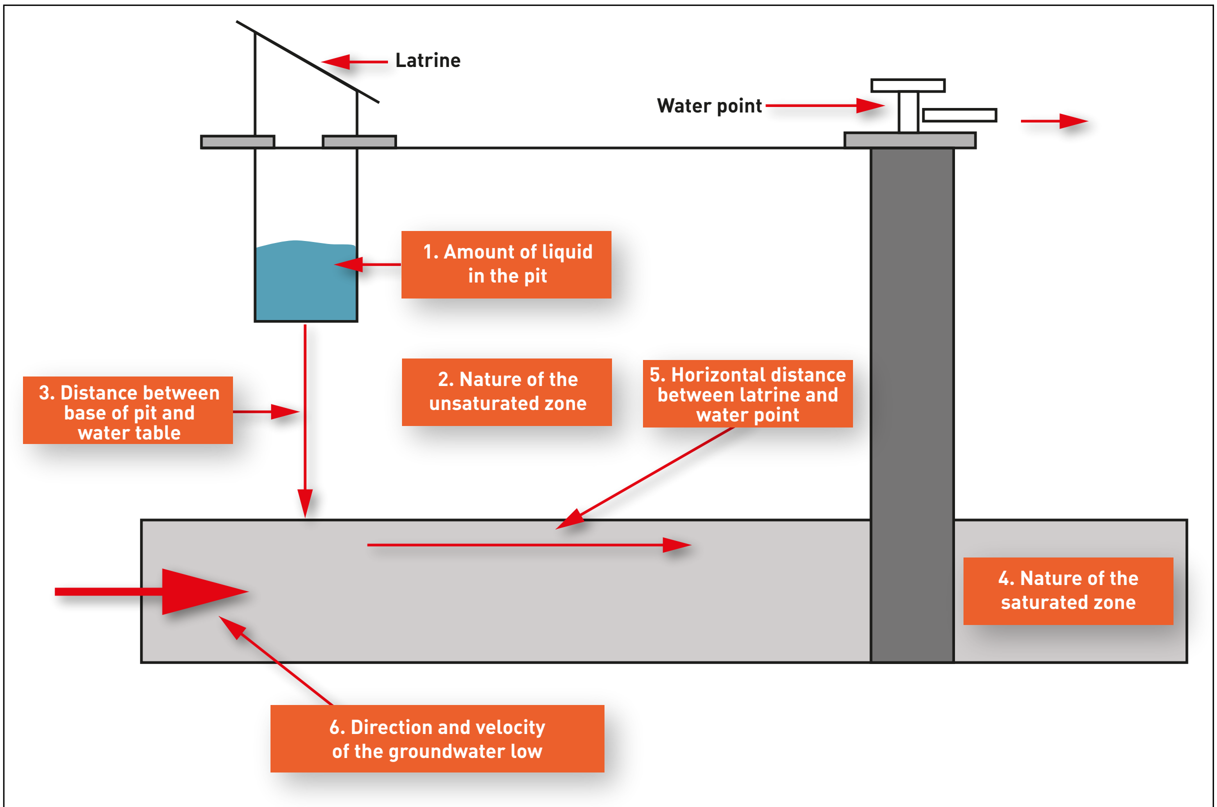

Figure 1. Six different factors which can effect pathogen transmission from a latrine to a nearby water point

1. Amount of liquid in the pit

Any liquid in the pit is certain to be grossly contaminated. The amount of this liquid depends on the type of latrine and the method of anal cleansing. If the pit (or tank) is full of liquid a large static head is created within the pit and the liquid forced under pressure into the unsaturated zone of the subsoil (i.e. the zone above the ground water table, which is not saturated with water). If the pit is dry, there is no liquid to create a static head, no pressure is exerted, and there is no flow into the unsaturated zone. With dry latrine systems the pathogens remain within the pit and water point contamination does not occur. This puts the dry systems used in ecological sanitation among the safest options from the perspective of ground water contamination.

General rule: The smaller the amount of liquid in the pit, the lower the risk of water point contamination.

2. Nature of the unsaturated zone

The spaces between the grains in some types of sub-soil are so small that they physically prevent the passage of a pathogen. In effect the sub-soil acts as a filter. This filtering process is enhanced in established latrines when an organic film of micro-organisms develops on the surface of the soil particles (as in a slow sand filter) and this effectively further restricts the passage of the pathogen.

Sediment	Silt and clay	Fine sand	Medium sand	Coarse sand	Gravel
Grain size	<0.06mm	0.06mm to 0.2mm	0.02mm to 0.6mm	0.6mm to 2mm	>2mm

Some clay soils also have the capacity to absorb viruses and prevent their passage to the saturated zone.

General rule: The smaller the sediment grain size the lower the risk of contamination.

3. Distance between the base of the pit and water table

The further water containing the pathogen has to travel to the water table, the more tortuous its route and the longer it is retained. This additional time allows for greater numbers of pathogens to die off naturally. Care is needed when assessing this factor to consider the higher water table level in the wet season and not just the dry season water levels.

General rule: The greater the distance between the base of the pit and the water table, the lower the risk of contamination.

4. Nature of the saturated zone (aquifer)

The ease at which water can flow through a rock is known as its permeability (measured in metres per day (m/d)) and is dependent on both the size of the spaces (or pores) and how well they are connected with each other. Sands and gravels have large well connected pore spaces between their grains and allow water to flow relatively easily. As a result they have permeability ranging between 10 to 100 m/d. Clays have a high porosity, but are poorly connected and water has difficulty in passing through them easily; as a result clay has permeability ranging from only 0.01 to 0.1 m/d.

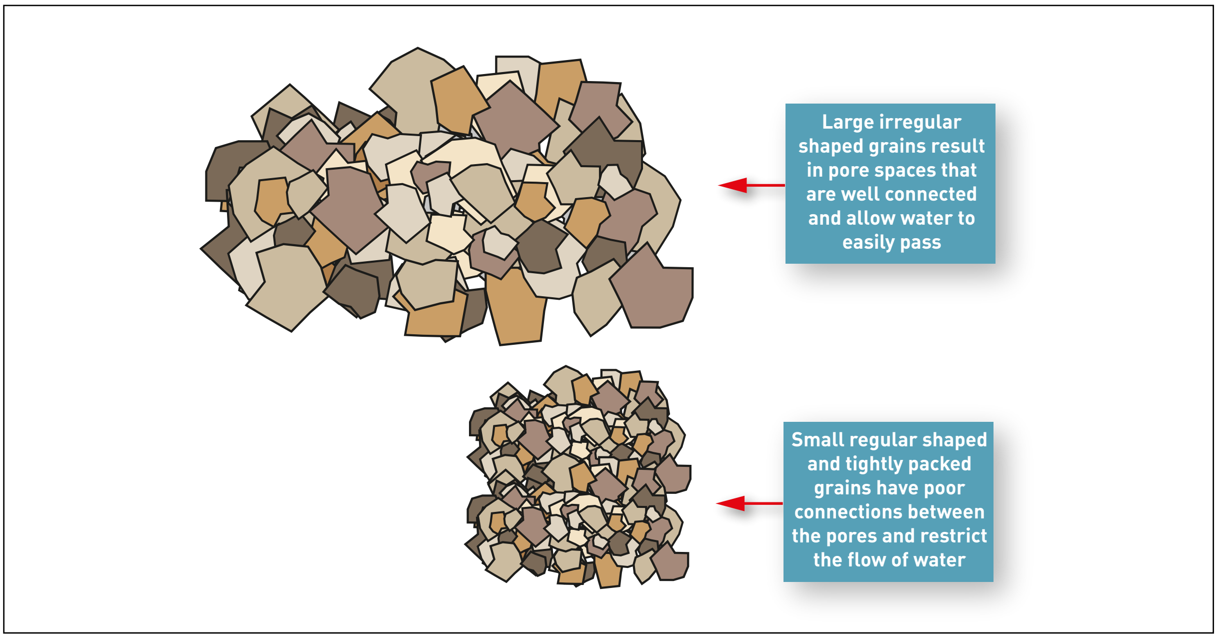

Figure 2. Volume of the spaces (or pores) between the grains

The ability of an aquifer to store water depends on the volume of the spaces (or pores) between the grains. Sands can have a porosity of 0.3 (i.e. 30% of their volume is air space), whilst consolidated rock porosities rarely exceed 0.01.

General rule: The greater an aquifer's permeability, the higher the risk of water point contamination.

5. Horizontal distance between latrine and water point

The further the horizontal distance the pathogen has to travel from the point of entry into the water table to the water point, the longer it is retained and the more likely the pathogen is to die.

General rule: The greater the distance between the latrine and the water point, the lower the risk of contamination.

6. Direction and velocity of the groundwater flow

The rule that water flows downhill holds true for the vast majority of ground water, although there are exceptions. It would be more accurate to say that water always travels down a hydraulic gradient from areas of high water pressure to areas of low pressure. Groundwater will generally follow the slope of a hill and flow towards a river, sea or lake. The steeper the hydraulic gradient the faster the groundwater (and the pathogen it contains) will travel towards the water point.

If the latrine is located physically lower than the water point it is highly unlikely that contamination from the latrine will be a problem. However, many rural villages, and the latrines they contain, are sited on the highest points in an area whilst water points are usually found in the valleys where it is easier to find and access ground water.

General rule: The greater the hydraulic gradient towards the water point, the higher the risk of water point contamination.

With an understanding of these 6 general rules it is possible to undertake a rudimentary risk assessment.

Assessing the risk of water point contamination

Assessing the risk of water point contamination from latrines is based on gaining an understanding of the amount of time it would take the water, and the pathogens it contains, to travel from the pit to the water point. The longer it takes, the greater the reduction in the number of pathogens through natural die-off. The overall aim in either siting a latrine or water point is to ensure that the pathogen die-off has been sufficient to reduce the risk to a level where it is not a public health concern.

The time taken can be used as a proxy indicator for risk of contamination. The Guidelines for Assessing the Risk to Groundwater from On-Site Sanitation (ARGOSS) produced by the British Geological Survey (BGS) states that the following times are applicable to assessing risk from microbiological contaminates.

Significant risk	Time taken is less than 25 days
Low risk	Time taken is more than 25 days
Very low risk	Time taken is more than 50 days

(BGS - ARGOSS 2001)

AGROSS takes care to stress that the 'low risk' category should provide confidence, but no guarantees, that the travel time would result in levels of micro-organisms which are unlikely to represent a major risk to health. The 'very low risk' category provides a further margin of safety and therefore greater confidence that the water will meet WHO guidelines and that the more persistent pathogens will have been removed.

Assessment stage one – Is the unsaturated zone sufficiently reducing the pathogen levels?

Because of the very low velocities of unsaturated flow, the unsaturated zone is the most important line of defence against faecal pollution of the aquifers (Cave & Kolsky 1999). If the rate of transmission to the aquifer is slow, by the time the water from the pit reaches the aquifer, the pathogens in it will have died off and the risk to public health will be minimal.
The capacity of the latrine design and the unsaturated zone to reduce the risk of contamination can be estimated by using a combination of the following tables.

Table 1. Reduction through latrine design	
Risk category	**Latrine type**
Very low	Dry composting ecological latrines
Low	VIP, traditional pit latrine, low usage pour flush latrines
High	Septic tank, Aqua privy, high usage pour flush latrines, pit used to drain water from bathroom

Table 2. Reduction in the unsaturated zone			
Geology of unsaturated zone	**Water table less than 5m below ground level**	**Water table less than 5m and 10m below ground level**	**Water table greater than 10m below ground level**
Fine sand, silt and clay			
Weathered basement			
Medium clean sand			
Course sand and gravels			
Solid rock			
Key: Significant risk that micro-organisms may reach water table at unacceptable levels			
Low to very low risk that micro-organisms may reach water table at unacceptable levels			

If these do not sufficiently reduced the pathogens to 'low risk' levels, it will be necessary to estimate the effect of the aquifer has on pathogen reduction.

Assessment step two – The effect of the saturated zone on pathogen levels

This is based on the number of days the pathogen remains in the aquifer before it enters the water point. It is calculated using the following formula,

$$\text{Number of travel days} = \frac{\text{Porosity x Horizontal distance}}{\text{Permeability x Hydraulic gradient}}$$

ARGOSS provides the following table to act as a guide when the exact figures are not known. It also suggests using a hydraulic gradient of 1/100 (0.01).

Table 3. ARGOSS guide when the exact figures are not known		
Type of aquifer	**Porosity**	**Permeability (m/d)**
Silt	0.1 - 0.2	0.01 - 0.1
Fine silty sand	0.1 - 0.2	0.1 - 10
Unconsolidated weathered basement	0.05 - 0.2	0.01 - 10
Clean sand	0.2 - 0.3	10 - 100
Gravel	0.2 - 0.3	100 - 1000
Fractured rock	0.01	Difficult to generalise - can be 1000's of metres per day

Example 1: In a clean sand aquifer where the latrine is situated 20m from a water point the number of days taken for a pathogen to travel to the water point is:

$$\text{Number of travel days} = \frac{0.25 \times 20\text{m}}{60\ \text{m/d} \times 0.01}$$

Number of travel days = 8.3 days = a significant risk of contamination

Example 2: In a fine silty sand aquifer where the latrine is situated 20m from a water point the number of days taken for pathogen to travel to the water point is:

$$\text{Number of travel days} = \frac{0.15 \times 20\text{m}}{6\ \text{m/d} \times 0.01}$$

Number of travel days = 50 days = a very low risk of contamination

If the actual figures for porosity and permeability are not known, it is worthwhile placing figures from the top, bottom and mid-way of the given ranges into the calculations for a specific situation This will provide a guide as to the maximum and minimum ability of the saturated zone to reduce the pathogens to a safe level and allow the designer to make a more considered assessment.

Other factors to consider

- In urban areas where there may be latrines in a relatively small area, the accumulative effect of pollution reaching the water table could be significant and extra care needs to be taken.
- Thin highly permeable horizontal layers may occur within the aquifer which provides a rapid pathway to the water point. How uniform is the aquifer?
- The presence of fractures in harder rock aquifers may allow the very rapid transfer of pathogens to the water point.
- High extraction rates (for example, from a borehole supplying a large community), will increase the hydraulic gradient in the area around the water point and hence reduce the time taken to reach the water point, increasing the risk of contamination.

Next steps

If the assessment clearly shows that the risk of contamination is very low, then no other action is necessary other than to monitor the situation to ensure distances are adhered too and the designs and quality of construction remain high.

If the assessment shows a low risk of contamination it may be worthwhile to confirm the result with a series of water quality checks of a representative sample of water points. If the results confirm some form contamination, it will be necessary to verify that the latrines are in fact the cause of the problem. Water point contamination can occur from many causes, including faulty or substandard water point construction which allows surface runoff to enter.

Be careful not to jump to conclusions. The methodology described is conservative and makes a number of assumptions based on approximate categories of soil type, conductivities, gradients etc. If the results show borderline risks it may be worthwhile employing the services of a hydrogeologist to undertake a more exact assessment.

It is important to keep the community informed and to discuss with them the implications of your findings. With community-owned water points the users should have the ultimate decision as to what action to take. Your role may be only to ensure that they base their decisions on sound knowledge and an awareness of the different options.

Methods of reducing the risk of contamination

- Increase horizontal separation distances between latrine and water point
- Move water point higher than latrines
- Change to a drier form of latrine
- Increase vertical separation between bottom of pit and water table by using shallower pits or vaults latrines
- If a borehole is being used, site the screens lower in the water table
- Treat water supplies or encourage use of home water treatment

Other issues to consider before taking action

- What are the alternative sources of water if the water point is closed? If the alternative is even more heavily contaminated, closing the water point may not be the most sensible option.
- What are the alternatives if pit latrines are banned? If the community are forced to return to open defecation the health risks may be greater than those from drinking contaminated water.
- If the option of building a sewer is being considered, it is worth remembering that it is generally a lot more expensive than providing a new off-site piped water supply system.
- If you have access to a water testing kit, why not test the water at different points of the drinking water chain. Test the water straight from the water point, from the container in which it is carried home, from the storage container in the home and from any cup or container used as a drinking vessel. Calculate how additional contamination could be entering the chain and take a more holistic view of the problem. Decide what action or change of behaviour would result in the largest reduction in the bacterial levels of the water finally consumed.

Some final points to ponder?

"Groundwater contamination is thus a matter of degree, and rather than basing all decisions on absolute water quality targets or guidelines, it may be more helpful to strive for the best practicable water quality which may be achieved with economic, financial, technical, and social constraints. Such an approach will vary with locally available alternatives of water supply"

"If however, one reviews the epidemiological evidence concerning the relationship between dose and response in drinking water, the evidence for the most commonly used indictor, (E coli), appears significant at doses greater than 1000 E.coli / 100ml... It would this appear unwise to forego the health benefits of affordable and sustainable sanitation to eliminate the risk of groundwater contamination of less than 1000 E.coli / 100ml"

Cave and Kolsky, Groundwater, latrines and health, WELL Task 163 1999.

Further information

The Guidelines for Assessing the Risk to Groundwater from On-Site Sanitation (ARGOSS), British Geological Survey (BGS) 1991.

Groundwater, latrines and health, WELL Task 163, Ben Cave and Pete Kolsky 1999.

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