sustainable sanitation alliance

SuSanA document

# How to keep your groundwater drinkable: Safer siting of sanitation systems

VERSION January 2015

## 1. Objectives

This document serves as an introduction to the criteria for siting sanitation systems in order to reduce the risk of adversely affecting groundwater quality. Pathogens that contaminate groundwater are a serious contamination risk and can lead to fatal faecal-oral transmission diseases (e.g. cholera, diarrhoea). Adequate water, sanitation and hygiene (WASH) are essential to prevent such transmission which account for considerable disease burden (Wolf et al., 2014). In a poll of health professionals in the British Medical Journal, sanitation was voted as the most important medical advance since 1840. But good sanitation should not contaminate the groundwater resources it may come into contact with. A prominent documented example from a developed country is Walkerton, Canada, with more than seven deaths from poor groundwater protection strategies which allowed E. coli from manure to enter the drinking water supply well after heavy rainfall (Ontario Ministry of the Attorney General, 2002; Hrudey et al., 2003). There are undoubtedly many Walkertons happening on a daily basis in developing countries but go undocumented.

This important transmission route still remains poorly understood. The passage of water through the subsurface provides a reliable natural barrier to contamination but one that only works under favorable conditions. Once pathogens have infiltrated into the groundwater, e.g. through open defecation, manure heaps, pit latrines, leaking sewerage systems or over-irrigation with untreated wastewater, it may take varying amounts of time for the different types of pathogens to die off, during which they will have been transported in the natural water system, perhaps to a water source.

This document provides a simplified checklist of the criteria for siting and planning small scale sanitation systems, such as pit latrines or septic tanks (all onsite sanitation systems have been documented by Tillich et al., 2014). The suitable application of the criteria aims to minimize the risk of subsurface pathogen transmission to a water source, and thus to increase protection of valuable drinking water resources.

The present document aims at providing a broad initial overview **to engineering and geological professionals, planning officials, government officials** who **are involved in the planning and construction of sanitation systems** or developing water safety plans (WHO, 2005) or sanitation safety plans.

The presented list of criteria is a starting point and should be followed by a more detailed risk assessment for the individual case. For further reading we recommend the “Guidelines for assessing risk from on-site sanitation for groundwater resources” (ARGOSS, 2001) or the “Guidelines for separation distances based on virus transport between on-site domestic wastewater systems and wells” (Moore et al, 2010), or a recent review on the siting of pit latrines (Graham et al., 2013). In any case, detailed geological and hydrogeological understanding is recommended.

Pathogens are not the only harmful substances in wastewater which pose a risk to groundwater (Nick et al. 2012). Nitrate pollution, for example, is frequent and even though the relative public health risk is lower than microbial contamination, high nitrate levels should be checked for and avoided.

## 2. Criteria

### 2.1 Horizontal distance between the drinking water source and the sanitation system

The horizontal distance, also called separation distance, is an obvious criteria which can be checked with relative ease. Larger separation distances generally imply a longer time which pathogens need to travel to the well (see Figure 1). During such a longer travel time, more pathogens will die off or will be filtered out by the soil and constitute a lower risk. In Germany, for example, among other precautions, a groundwater protection zone with a minimum of 50 days travel time is placed around public water supply wells to provide a barrier for pathogens. This assessment requires knowledge about the location of the drinking water supply wells or springs used and the associated geology and hydrogeology.

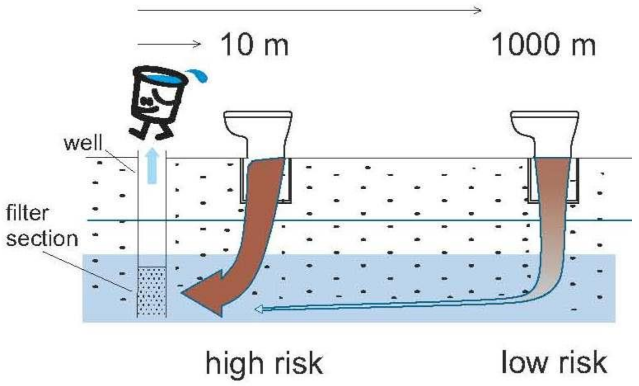



Figure 1: Example for high and low risk due to different horizontal separation distances.

It might be necessary to take a more detailed look at the surface water bodies in areas where surface water infiltrates into the groundwater. In these situations the transport of pathogens to the drinking water occurs first via surface water and second via groundwater.

Table 1: Horizontal separation distance recommendations vary widely. The different recommendations were developed on different hydrogeological settings (which result in very different travel times). Also, the recommendations on separation distances should be understood as a "rule of thumb" that very much simplify a complex matter.

| Minimum Horizontal Separation Distances [m] | Reference |
|---|---|
| 30 | Sphere Project (2011); Robens Institute (1996) |
| 40 | NZ-Guidelines – best case – (Moore et al. 2010) |
| 50 | WaterAid (2011) |
| 75 | South Africa (DWAF 1997) |
| 300 | NZ-Guidelines – worst case – (Moore et al. 2010) |

The following sections present the factors other than horizontal distance that are of major relevance.

### 2.2 Vertical distance between drinking water well and sanitation system

Deeper groundwater supply wells are perceived as being significantly less vulnerable to pollution than shallow wells (e.g. shallow handpump wells, dugwells), again due to longer travel time (Figure 2). It is necessary not just to know the total depth of a borehole, but to know in which depth interval the screens are placed, through which groundwater enters the well (Figure 3).

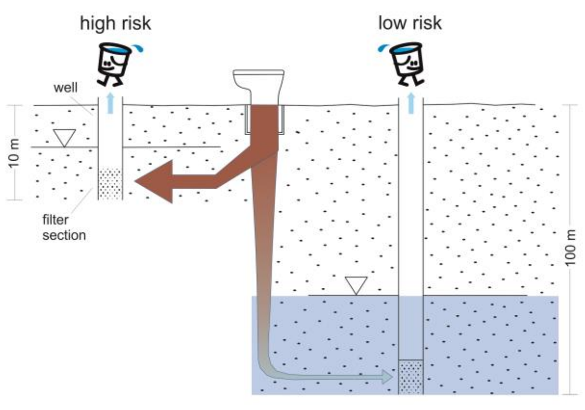



Figure 2: Lower risk with greater depth: A) Example for significant increase in risk: Dugwell with less than 10 m depth in permeable aquifers. B) Example for significant decrease in risk: Well with screened depths of more than 100 m below surface and appropriate sealing of the annular space (see also Figure 7).

Also the well needs to be properly constructed and sealed with clay or similar material against contamination from the surface running down the side of the well via the annular space (Figure 3). Manuals on well construction are readily available (e.g. Ball, 2002; IGI, 2007; Adikele, 2014).

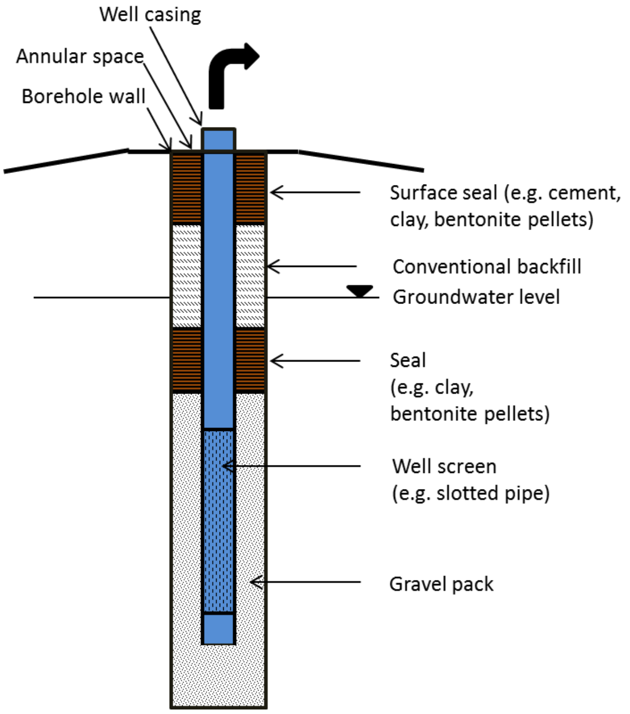



Figure 3: Example for placement of sealings.

## 2.3 Aquifer type

An aquifer is an underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, or silt) from which groundwater can be extracted using a water well.

The water in the aquifer may flow through the pores (e.g. through the pore voids of a sedimentary sand aquifer), or through fractures (e.g. fractured hard rock) or through fractures and voids which are widened by dissolution processes in karstified limestone (see Figure 4).

The fastest water flow typically occurs in the widened fractures of a karstified limestone, but also hard rock, e.g. granite will be able to transport water quite fast if fractures are present. Also coarse gravel sediments will transport water quickly, but flow through fine sand will already be slower by a factor of 10-1000 times compared to gravel.

The New Zealand guidelines for instance suggest that more than 300 m of separation distance is required to achieve satisfactory removal of viruses in a karst system, provided that a minimum of 10m sand cover is available over the karst. On the other hand, the same guidelines recommend that in a sandy aquifer with a cover of a 20 m unsaturated sand, a separation distance of 50 m will achieve an adequate reduction of viruses. The New Zealand guidelines focus on viruses instead of bacteria. While Escherichia Coli is a standard parameter to test for pathogens, we have to consider that viruses (e.g. rotavirus and enterovirus) can pass through smaller pores and survive longer periods.

For further reading on basic geology and hydrogeology, excellent and illustrative textbooks are available (Moore, 2012; Fetter, 2001; Hiscock & Bense, 2014).

*A) Unconsolidated sand & gravel* *B) Fractured hard rock* *C) Karstified limestone*

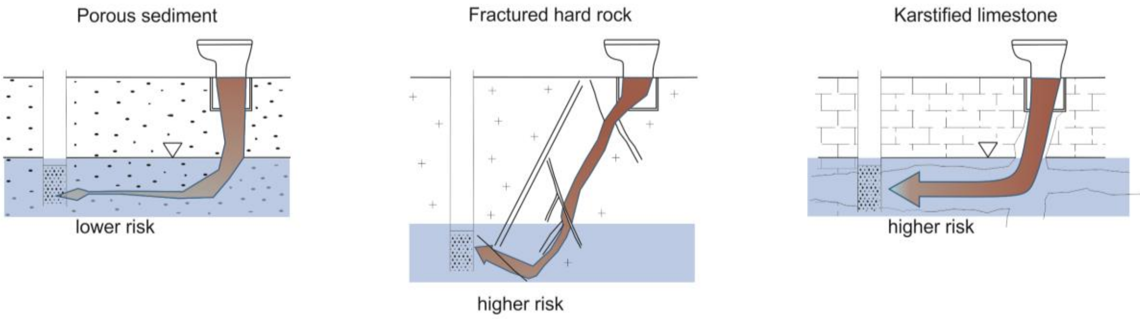
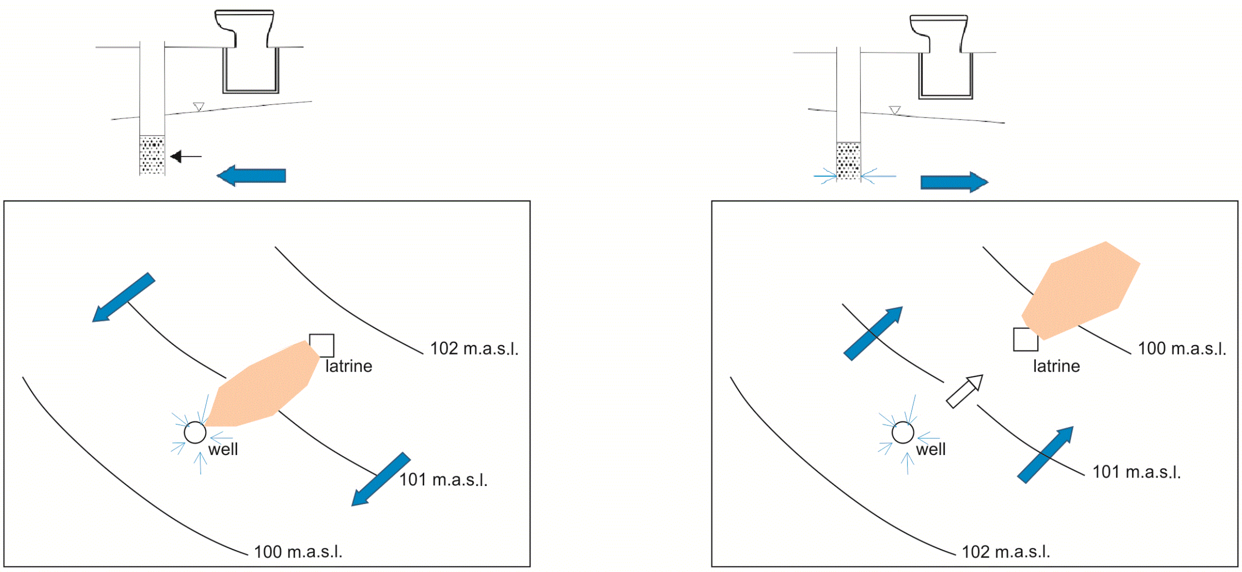



Figure 4: Different aquifer types leading to different risk levels. A) Example for lower risk: unconsolidated sand and gravel aquifer. B) Example for higher risk: fractured hard rock, C) Example for highest risk: karstified limestone. (Photographs by Kai Hahne, BGR)

## 2.4 Groundwater flow direction

If the local groundwater flow is not connecting the contamination source to the well, this can aid the very effectiveprotection of the well or spring against contamination from this source (Figure 5). The assessment of groundwater flow direction requires sound knowledge of the groundwater table at a number of measurement spots. These measurements can be performed at low cost if a number of wells and observation bores are available. Later, expert advice is required as to the continuity of the groundwater flow. For example, natural groundwater flow directions might reverse if strong pumping activities set in.




high risk low risk

Figure 5: Example: These map examples show the contours for groundwater head above an agreed standard – here in meter above sea level (m.a.s.l.). The blue arrows show the direction of groundwater flow (from high to low head). To decrease the risk to the well, the sanitation system should be located down-gradient of the groundwater supply system (right figure) . This should be proven by repeated measurements at several wells during several years.

## 2.5 Impermeable layers

Even if the aquifer itself is highly permeable or has very fast preferential flow paths, just like a karstified limestone, the groundwater may still be quite safe from pollution. This can be due to the presence of impermeable layers (see Fig. 6). The term impermeable layers refers to covering layers such as soil or overburden that don't let much water and contaminants easily pass through; a layer of clay would be quite impermeable for example. For the latter to be effective in protecting the groundwater, the sanitation system must be built on top of the ground, not deep into the ground and hence below the protective layer (e.g. Figure 6c).

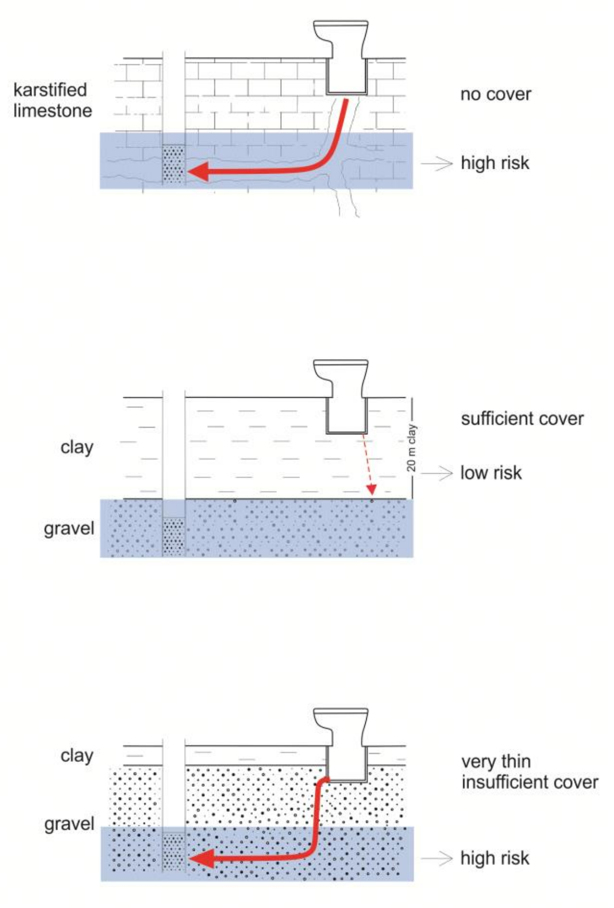



Figure 6: (a) high risk setting due to lack of cover sediments (b): low risk setting due to thick clay sequence acting as barrier (c) high risk setting due to insufficient depth of cover sediments (e.g. clay).

## 2.6 Slope and surface drainage

If the surface in the vicinity of the well or spring is sloped, there may be a significant risk of wastewater from uphill sanitary systems entering the water supply via surface runoff (see Figure 7).

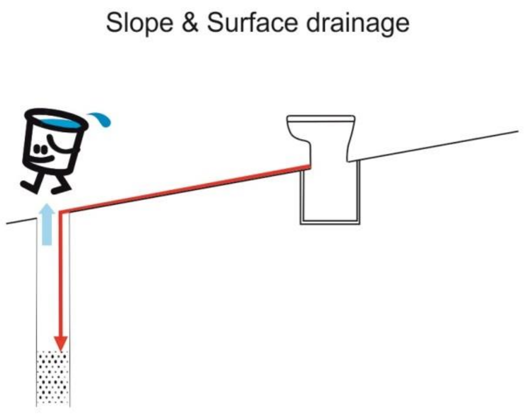



Figure 7: Example for strong increase in risk: septic tank 20 m uphill of the water supply well which does not have a properly constructed sanitary sealing /defect headworks.

This is especially dangerous if the construction standards of the borehole/well are poor and/or annular sealing is absent. Unfortunately this latter scenario is surprisingly common with many regions failing to have proper systems in place to check if this critically important seal (see Figure 3) is present and adequate before commissioning and approving wells.

## 2.7 Volume of leaking wastewater

Small amounts of wastewater entering the soil might take a long time until they are transported downwards through the unsaturated zone. However, if the unsaturated zone is sufficiently wet, the transport will be several times faster (and the die-off of microbes lower) and so the contamination risk will increase. Therefore the size of the facility and the volume of wastewater potentially entering the soil are important to consider. Large facilities pose a significantly higher risk, especially if no household water treatment takes place.

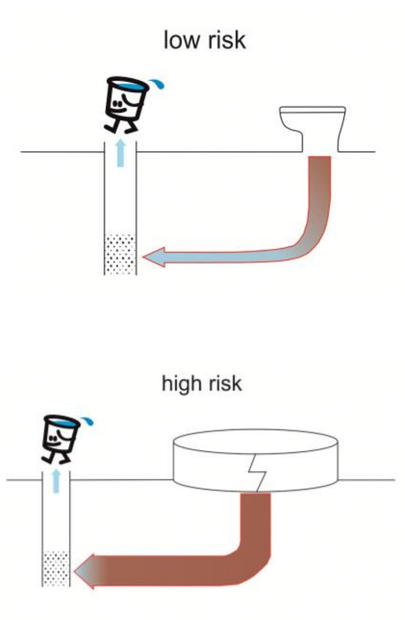



Figure 8: Example for an increase in risk: a large unsealed septic tank which collects wastewater from several houses and which constantly seeps wastewater to the ground.

## 2.8 Superposition

In densely populated environments (e.g. urban areas) it may often be the latrine from the neighbour which is causing the major health risk. Due to limitations of plot size, it will be practically impossible to ensure sufficient separation distance (Fig. 9). It is therefore recommened to consider not only one pair of latrine and well, but to consider a larger planning area and to develop an action strategy within the bigger picture. In some areas, it may be more suitable to stop using local boreholes for drinking water supply and rather source the water from unaffected parts of the aquifer outside the settlement or from deeper aquifers.

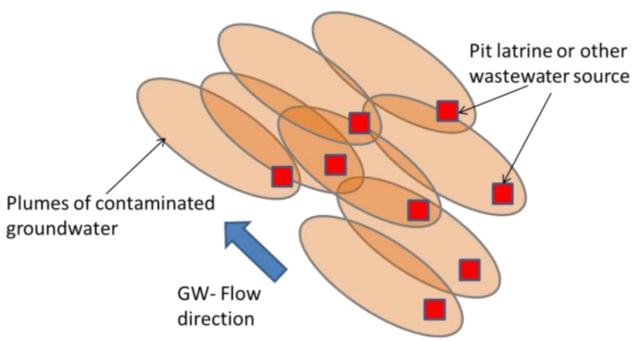



Figure 9: Example for the superposition problem.

## 3 Conclusions

Poor siting of sanitation can impact negatively on groundwater quality. The criteria listed above provide an introduction to better groundwater protection from sanitation systems. The siting criteria are simple enough to be applied in a semi-automated analysis to a larger number of sanitation systems with the help of a geographic information system (GIS). Detailed guidelines with explanation of terminology and criteria (also with a decision tree and a risk matrix) are provided for example by the British Geological Survey (ARGOSS, 2001). On the general topic of sustainable sanitation and groundwater protection, SuSanA collated a specific factsheet for public download (Nick et al., 2012).

Guideline values for separation distances between on-site sanitation systems and water sources vary widely (e.g. between 15 to 100 m between pit latrine and groundwater wells, see also Graham & Polizotto, 2013) because the guidelines are simplified and account differently for the 8 criteria listed above. Any quantitative information on separation distances provided within this document should be seen as general examples only. For application to your site or setting, it is strongly recommended to consult groundwater professionals to elaborate specific guidelines which are adapted to the regional setting. Further research on this topic has also been called for (Wright et al., 2013).

If larger groundwater based water supply structures are present, it might be appropriate to establish groundwater protection zones around the major wellfields to inform land use planning. Typically, for large-scale drinking water supply, classification of these areas involves three levels of restrictive use, allowing fewer human activities with increasing proximity to the groundwater extraction site. In Germany, for example, the zones are defined as follows (DVGW 2006):

The first and immediate zone is to protect the production wells or springs and their immediate environment from any contamination and interference. The second zone is delineated at the line from which groundwater travels 50 days until it reaches the production well or spring. Within this zone, input of pathogens such as bacteria, viruses, parasites, protozoa and worm eggs must be avoided and no facilities which pose any risk of contaminants entering the aquifer are allowed. Within the third, outmost protection zone, the use of contaminants which do not degrade within 50 days are strongly regulated, e.g. using pesticides, radioactive substances or non-degradable chemicals.

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