International Association of Hydrogeologists

# Strategic Overview Series

# SANITATION & GROUNDWATER

## KEY MESSAGES

- all sanitation technologies have a close (but often obscure) relationship with groundwater
- on-site sanitation systems invariably affect both the quantity and quality of groundwater resources, often causing pollution of shallow aquifers
- in villages the much lower density of sanitation units means that groundwater interaction can be dealt with by sensible separation criteria between sanitation units and waterwells
- the interactions of main sewerage systems with groundwater varies markedly with urban topography
- in more elevated urban areas point leakage and line seepage from sewers can act as a significant source of groundwater pollution
- in lower-lying urban areas poor maintenance of main collector sewers often results in groundwater inflows and marked increases in the volume for wastewater treatment for which no revenue has been collected
- the reuse of inadequately-treated wastewater for irrigation can result in significant groundwater pollution, especially in more arid regions

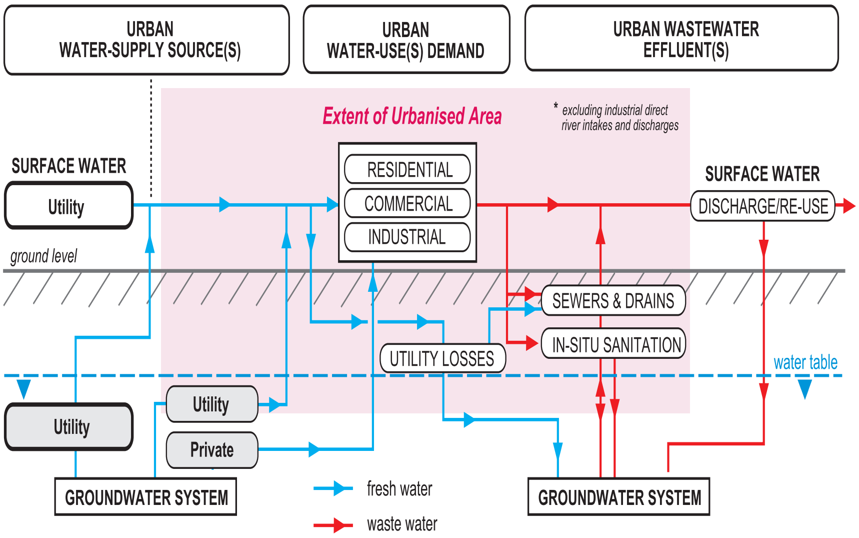
## What are the range of sanitation options under consideration here ?

The evacuation, disposal and/or reuse of urban wastewater is commonly achieved by one of two essentially-different types of technology : on-site sanitation units or (much more expensive) main sewer systems (including pipe network and centralised treatment).

The interaction of these two different technologies with groundwater needs to be approached individually but on an integrated basis. Both have a close, but often obscure, relationship with groundwater, which operates in two different directions :

- on-site sanitation practices impacting to a varying degree the quantity and quality of groundwater resources
- groundwater conditions exerting influences on, and increasing the cost of, sewered sanitation systems.

Today over 3,000 billion of the global population are estimated still to be without access to safely-managed sanitation, which is the cause of widespread health and environmental problems.




GENERALISED RELATIONSHIPS OF URBAN SANITATION TO WATER-SUPPLY SYSTEM

*This Series is designed both to inform professionals in other sectors of key interactions with groundwater resources and hydrogeological science, and to guide IAH members in their outreach to related sectors.*

The way this deficit is managed will exert a major influence on underlying groundwater, which is also often a critical resource for the same people. In particular the heavy pollution of shallow waterwells is of great concern because the poorer parts of the population are often more highly dependent on this resource.

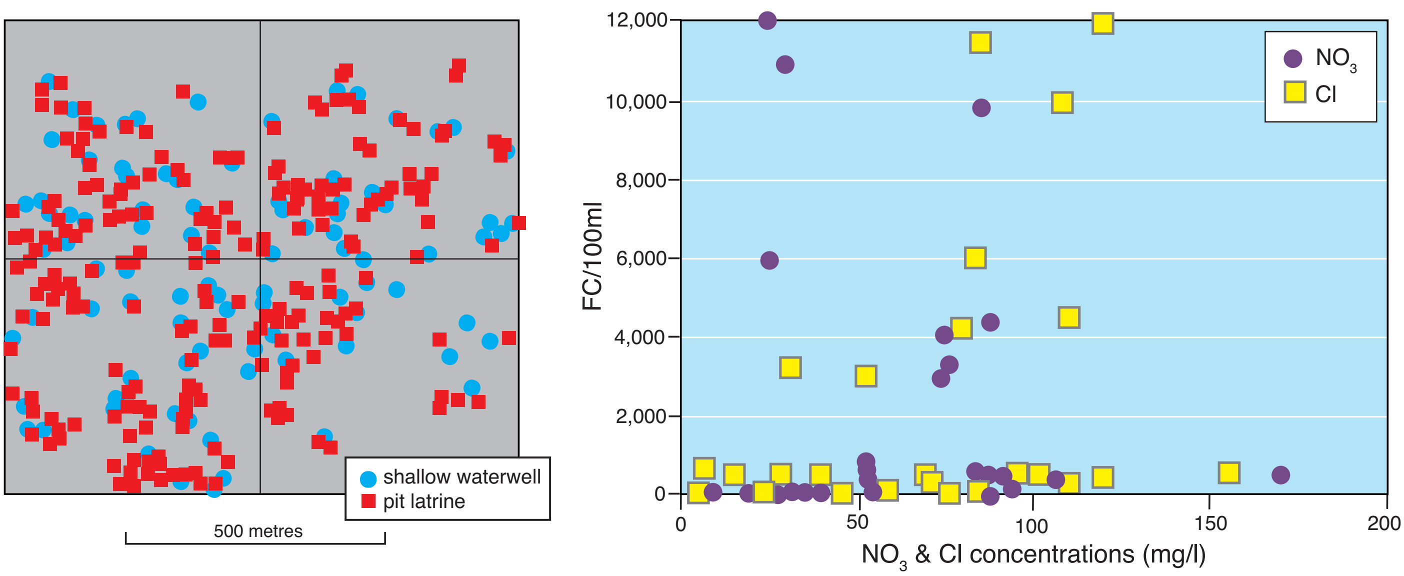
Groundwater is a critical resource for human life, accounting for almost 60% of global drinking water supplies, with even higher dependence in regions of more arid climate. It has a comparatively low development cost and generally high quality for which only simple water treatment is necessary, and is thus an excellent source for supplying small distribution systems and for private self-supply from waterwells. In Brasilian cities, for example, more than 80% of the extracted groundwater is destined for private self-supply.

## How does urban on-site sanitation impact underlying groundwater systems and can these interactions be managed ?

In urban areas the use of on-site sanitation enhances groundwater resources (by returning water-supplies to the ground), but can also be a major source of shallow groundwater pollution. This fact has long been known, but effective examples of how to control and manage the related risk have been slow to appear. Private self-supply waterwells are especially susceptible to pollution from the intensive urban use of on-site sanitation, especially where these are of very shallow depth.

The level of pollution will depend on the relative vulnerability of the underlying aquifer and equally on the design, operation and maintenance of the on-site sanitation units themselves (in particular practices of faecal sludge handing). Under favourable conditions,with clear construction protocols and reliable faecal sludge evacuation servicing, the pollution can be manageable. But where unfavourable the impacts can be very serious, including elevated concentrations of nitrate, DOC compounds, micro-pollutants and pathogens entering groundwater. This constitutes a major hazard, especially if shallow aquifers are used for drinking water-supply — an issue that is clearly illustrated by data from the karst dolomitic aquifer underlying Lusaka-Zambia.

*LOCATION OF SHALLOW WATERWELLS WITH RESPECT TO ON-SITE SANITATION UNITS AND THEIR GROUNDWATER QUALITY IN LUSAKA (data from Sorensen et al, 2015)*



A major challenge facing sanitary engineers is how can human urine (in addition to faecal sludge) be recycled from on-site sanitation units to reduce the impact on groundwater quality.

### How does the sanitation-groundwater relation differ in rural village settings ?

In villages there is a very much lower density of on-site units and smaller volume of effluent involved, and this can generally be treated through unsaturated zone percolation.  Sensible separation criteria need to be employed between in-situ sanitation units and potable waterwells to minimise the risk of their pollution and the temptation of reducing physical separation for use convenience needs to be forcefully and consistently resisted.

### How do urban sewers interact with groundwater and affect their operation ?

Water companies face various problems when in the process of managing and extending urban mains sewer systems to cope with population growth and increasing energy costs, including potential sewer overflows and mixed sewerage/ land drainage systems, and increased rainfall intensity and managing climatic uncertainty.

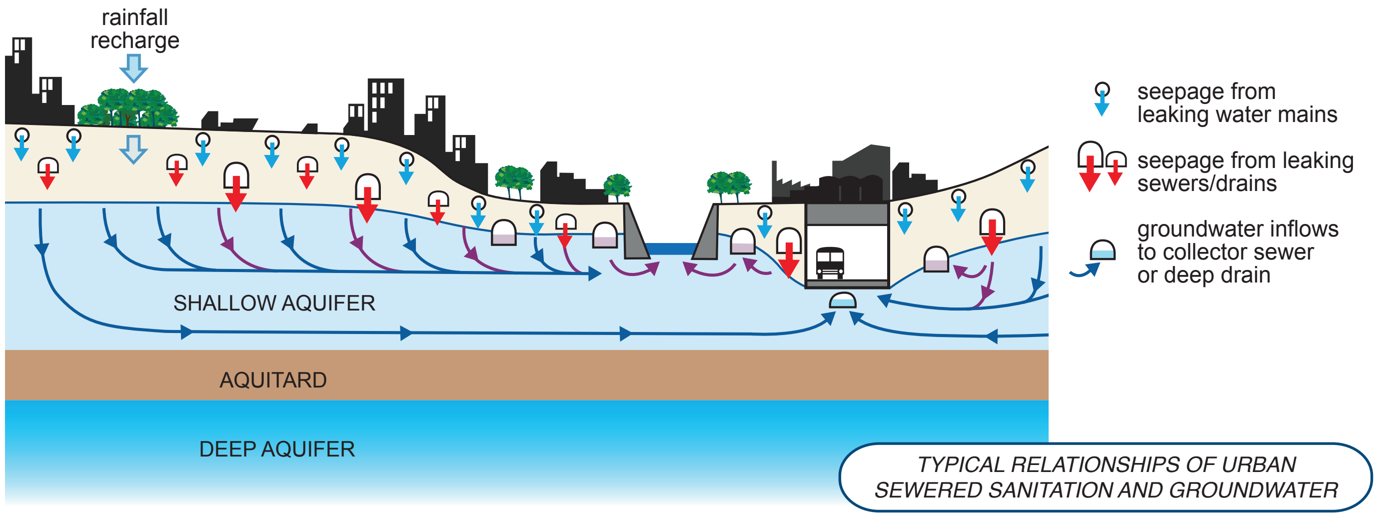
But the design, construction and management of sewered sanitation also requires sound understanding of groundwater conditions to avoid excessive pressure on sewer pipes (beyond that from ground burden, traffic loads and seismic events) and to minimise leaks in the interest of groundwater quality protection.

In the past PVC or cement was widely used for sewer-pipe construction, but in more recent years trenchless sewer-pipe installation using glass-reinforced polyester and vitrified ceramic pipes (of 300-600mm diameter) has generally become the preference, since this greatly reduces the need for soil extraction and reduces the potential routes of sewer leakage.

The potential impacts of groundwater on sewered sanitation systems requiring careful evaluation are :

- pollution of shallow groundwater by sewer leakage in areas where groundwater is used for drinking-water supply
- major excess sewer flows arising from the ingress of shallow groundwater in lower-lying areas
- pollution of shallow groundwater where partially-treated wastewater is used for agricultural irrigation.

In more elevated urban areas point leakage and line seepage from sewers can act as sources of




*TYPICAL RELATIONSHIPS OF URBAN SEWERED SANITATION AND GROUNDWATER* pollution to shallow groundwater, and this can become a hazard where groundwater is used as a source of potable water-supply. This phenomena requires investigation and control on a site-by-site basis, and in some cases will require the closure of polluted waterwells. In some cities in Sao Paulo State-Brasil sewer leakage to groundwater has been estimated to be more than 10% of their total flow.

In the lower-lying parts of urban areas main collector sewers usually drain the groundwater system and (despite losses described above in more elevated areas) the overall balance will often amount to a considerable excess flow to the mains sewer. This represents a substantial additional wastewater treatment burden for which no revenue has been collected directly from water-supply users.

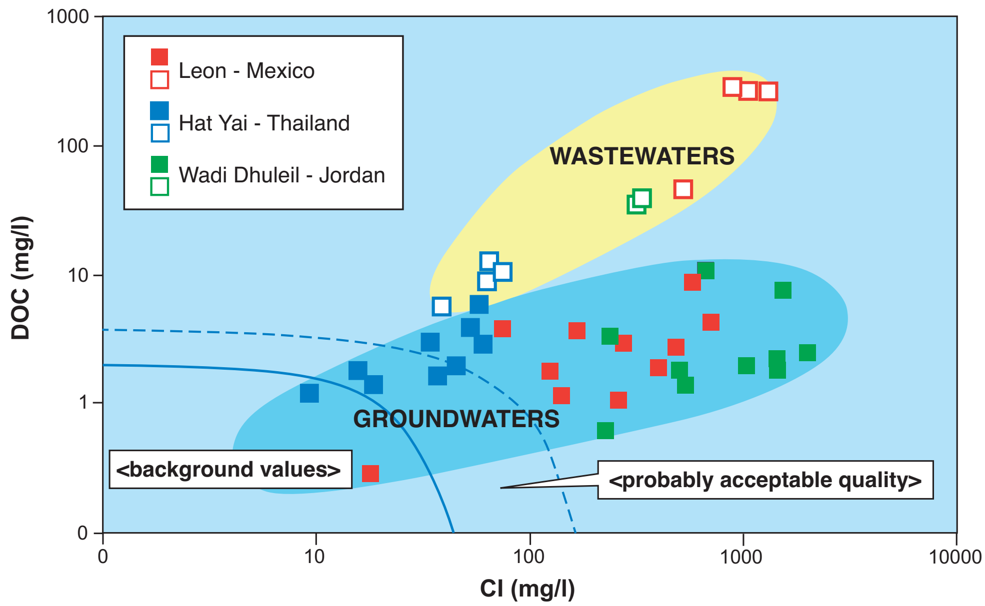
This issue is clearly illustrated by the well-researched case of Bucharest-Romania, where more than 20% of the sewerage system is submerged in groundwater, and sewer pipe restoration triggers an increase in groundwater levels. A net gain of about 1m$^3$/sec has been measured.

If sections of the main collector sewer are renewed to eliminate groundwater inflows, the water-table will normally rise significantly and threaten flooding of subsurface structures – a common problem in the older cities of The Netherlands. There is also a widespread need to improve the management of urban run-off through :

- progressively reducing inflows of rainfall run-off to the sewage system
- enhancing infiltration rates to groundwater to cope with increasing rainfall intensity through permeable pavements and infiltration trenches, so-called SuDS (Sustainable Drainage Structures)
- increasing the effectiveness of green infrastructure to reduce contaminant concentrations in rainfall run-off
- reducing urban per capita water use substantially to decrease wastewater volumes requiring treatment.

There is also concern that climate-change will adversely affect the performance of existing sewerage systems, as a result of increased rainfall intensity and changing groundwater levels, but the potential impacts are still poorly understood.

*GROUNDWATER QUALITY IN WASTEWATER IRRIGATION ZONES DOWNSTREAM OF SELECTED CITIES*
*(data from Foster & Chilton, 2004)*



Especially in more arid regions, there is pressure to reuse wastewater for a variety of purposes, including agricultural or amenity irrigation and artificial aquifer recharge. A major hazard that often has to be confronted is the quality impact on shallow groundwater of re-using wastewater for agricultural irrigation, which is especially severe where wastewater treatment is inadequate and/or where it includes a highly-contaminated industrial effluent component. This issue is well illustrated by groundwater quality data down-stream of Leon-Mexico, Hat Yai-Thailand and Amman-Jordan.

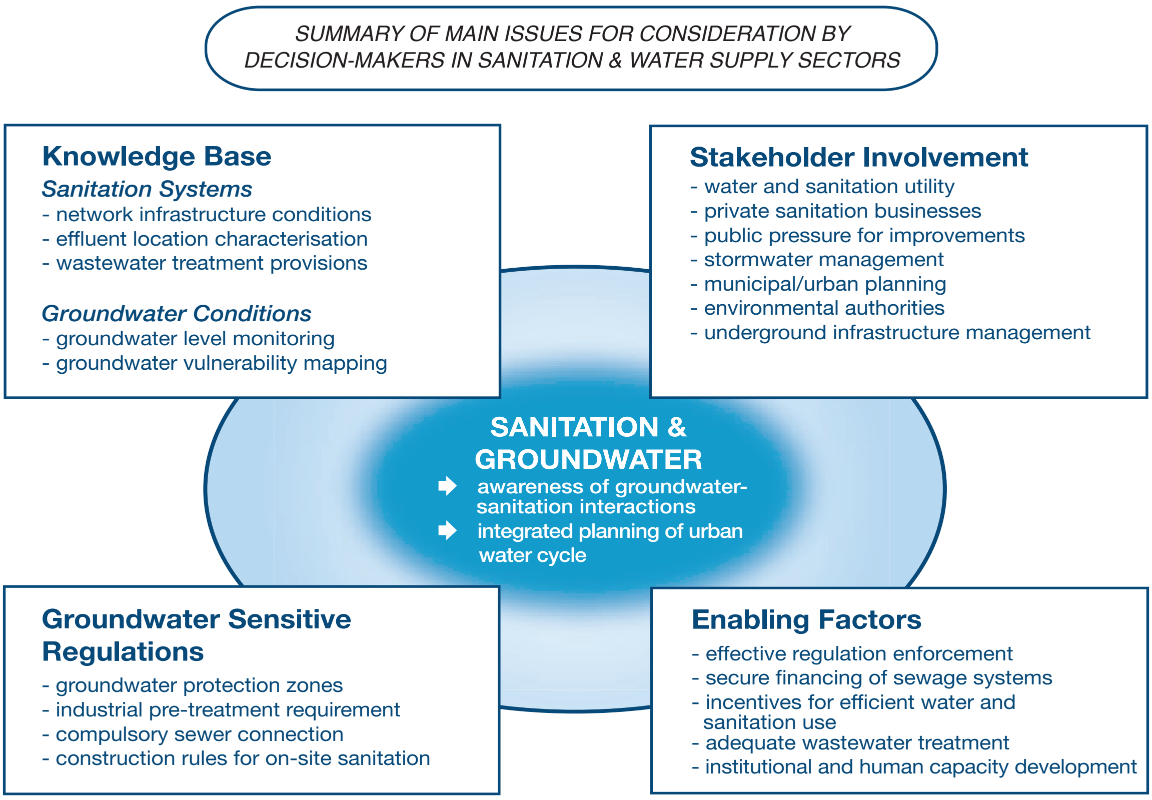
## What are the main recommendations for decision-makers in the sanitation and water-supply sectors ?

In conclusion is it recommended that the planners of urban mains sewage systems (and their waste-water irrigation areas) and of on-site sanitation systems need to be aware of :

- the location of waterwells used for drinking water-supply, even where these structures are private or informal
- urban areas with thick accumulations of silt and clay sediments that will provide additional protection of underlying groundwater
- urban areas of high groundwater pollution vulnerability (eg : karst aquifers) which afford very little protection to their groundwater
- the distance separating the base of their sanitation systems from the groundwater table
- available data on groundwater use and flow conditions.

In order to minimise groundwater inflow to sewers,water utilities need a thorough under-standing of their sewer network condition (in-cluding sewerage, construction, repair and flow measurements) together with monitoring of local groundwater levels.

The water-supply sector need to improve con-struction of deep waterwells, sealing them off more effectively from shallow aquifer systems to reduce or eliminate chances of their pollution.



# SANITATION & GROUNDWATER

*In collaboration with Sustainable Sanitation Alliance (SuSanA)*

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## PRIORITY ACTIONS

- **urban planners using both on-site sanitation units and mains sewerage systems need to be more aware of groundwater vulnerability and potential interactions, and incorporate them into their work**
- **a major effort is needed to collect all data relevant to sanitation/groundwater inter-actions, including most notably the mapping and monitoring of groundwater levels/quality/abstraction and pertinent details of the sanitation infrastructure**
- **the main challenge facing sanitary engineers is how can human urine, as well as faecal sludge, be recycled and reused to minimise impact on ground-water resources**
- **urban water utilities need a thorough understanding of their sewer network condition and its potential relation (losing or gaining) to underlying groundwater**
- **the urban water-supply sector needs to improve the construction of waterwells, such they are either sited appropriately or sealed effectively to prevent the ingress of shallow polluted groundwater**
- **the dynamics of sanitation/groundwater interactions need to be more effectively communicated among all relevant stakeholders and sectors**

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