# Pit latrines — a source of contamination in peri-urban Dhaka?

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**Increasing numbers of people in Dhaka rely on groundwater for domestic use, yet this source appears to be particularly susceptible to pollution. Are sanitation systems to blame?**

**Natural processes in the subsurface that can reduce numbers of micro-organisms**

***Die off***: Most non-indigenous pathogenic micro-organisms do not reproduce in groundwater and therefore numbers will reduce in time due to natural die-off.

***Dispersion and dilution***: This is the process of spreading that occurs as a result of the tortuous pathways that water (and contaminants) take during migration through an aquifer. This does not reduce numbers of micro-organisms but spreads them more widely through the aquifer.

***Filtration***: Micro-organisms, especially larger protozoans, may be filtered out of groundwater by the small pores in soil and rock.

***Adsorption***: Micro-organisms may become attached to the solid surfaces of soil and rock grains, reducing the numbers in groundwater. This is more effective when the soil and rock has a higher clay or organic material content.

Bangladesh's capital, Dhaka, has grown dramatically in recent years, both in population and area. Some 8.5 million people currently live in the city, and it has one of the most rapidly increasing urban populations in the developing world. This has meant an increase in the size and number of informal settlements, while the rate of population growth in many areas outstrips the capacity of the city authorities to install proper urban infrastructure. As a result, residents are often dependent on low-yielding boreholes (tube-wells) fitted with handpumps for water supply, and on pit latrines for the disposal of human sewage.

## On-site sanitation — the risks

As in many urban situations in the developing world,[1,2] the disposal of this sewage to the subsurface, from which groundwater is also pumped, has raised concerns in Dhaka about cross-contamination. These two activities will only be compatible provided the subsurface is effective in reducing contaminants to acceptable (or safe) levels. Processes that occur naturally in the subsurface help to reduce contaminant levels (see Box, left) — these are usually most effective in the unsaturated zone and, especially in fine-grained sediments, may be sufficient to eliminate most micro-organisms. However, although the aquifer beneath Dhaka is unconsolidated fine-grained alluvium, the high population density in peri-urban areas means there are severe space restrictions, leading to a reduced separation between on-site sanitation systems and water supply boreholes, and hence an increased risk of pollution. Under these circumstances, questions arise as to what the likelihood is for contamination of groundwater supplies from on-site sanitation?

An ongoing project, funded by the UK's Department for International Development (DFID), is addressing this issue. As part of the project, a number of case studies are being undertaken, one of which is looking at the problems in two areas of Dhaka — Dattapara and Keraniganj. Dhaka was chosen because of the importance of groundwater for drinking water supplies, and the apparent susceptibility of these supplies to contamination. This susceptibility arises because the depth to the water-table is seasonally very shallow; because the tube-wells fitted with handpumps are normally drilled by the manual 'sludger' method, which precludes the sealing of the annulus between the outside of the tube-well casing and the drilled borehole; and as a result of the small distance between wells and latrines. The specific objectives of the case study are to:

- discover whether seepage from the base of pit latrines produces wide-spread contamination of groundwater;
- rank those factors which increase the risk of contamination of the well; and
- assess the risk to groundwater of chemical contamination derived from pit latrine effluent.

The principal concern in situations where on-site sanitation and tube-wells are in close proximity is the contamination of well water by pathogenic micro-organisms which include bacteria, viruses and protozoa. Of less immediate concern, but potentially a more persistent problem, is the chemical contamination of ground-water by nitrate and chloride. High ground-water nitrate concentrations have been reported beneath many unsewered cities.[3]

1. van Ryneheld M.B. and A.B. Fourie, 1997 (see Resources Guide).
2. Foster, S.S.D, .A.R. Lawrence and B.L. Morris, *Groundwater in urban development assessing management needs and formulating policy strategies*, World Bank Technical Paper No. 390, 1998.

## Microbiological contamination

Analysis of water samples from the 100 wells selected for monitoring at the two sites has identified faecal coliform in 43 of the wells. Sanitary surveys carried out at the well sites (see Figure 1) show the potential for contamination from pit latrines: 95 out of 100 wells have a pit latrine within 15m, with 2 latrines within 15m as the average, and 38 of the wells have a pit latrine within 5m. However, contamination of a well does not necessarily mean that either the pit latrines are responsible or that the groundwater is widely contaminated — contamination may be the result of poor well design and/or construction. Figure 2 shows a number of other possible contaminant sources and pathways. Examination of sanitary surveys carried out at the 100 wells shows that 1 in 10 of the handpumps were loose at the point of attachment to the concrete base; that ponding occurs on or around the concrete surround at 6 out of 10 well sites; and that in all cases the cement surround is inadequate i.e. it extends less than 1m beyond the pump or is cracked. However, there does not appear to be any significant correlation between sanitary hazard scores and bacteriological water quality.

Results to date do not suggest that serious microbiological contamination of the groundwater is widespread; most wells sampled show bacteriological quality to be excellent or good, with wells showing intermittent contamination only. Significantly, samples of well water show levels of bacteriological contamination found in tube-wells at the Keraniganj site to be greater than at Dattapara, even though the tube-wells at Keraniganj are typically much deeper (54m on average, compared with 15m). It is unlikely that pathogens could survive for the time it would take to move through the aquifer from the pit latrine to the well (pathway 1 in Figure 2); more likely is that contamination has moved to the well-screen via more direct routes (pathways 2, 3, 4 or 5). This may be, for example, as a result of inadequate or deteriorated well-headworks, as mentioned above, or through the use of polluted water for pump-priming, a widespread practice. If breaks occur in the casing of the well at shallow depths, due to corrosion or inadequate joints, pit latrines could be a source of contamination through lateral movement of leachate at shallow depths, particularly where the unsaturated zone beneath the latrine is thin and the permeability of shallow layers is high. The very common hand-operated drilling method precludes the installation of a good cement seal behind the casing. Further work is planned to investigate possible pathways.

SANITARY SURVEY FORM
Deep and shallow tube-well with handpump

Location:
Well Ref. No:
Owner:
Date of visit:
Water sample collected?

RISK ASSESSMENT

1. Is there a latrine within 3m? Y/N
2. Is there any other source of pollution within 3m of the handpump? (e.g. animal excreta, rubbish, surface water) Y/N
3. Is drainage poor, causing stagnant water within 2m of the handpump? Y/N
4. Is the handpump drainage channel faulty — permitting ponding? Y/N
5. Is the cement floor less than 1m all around the handpump? Y/N
6. Is there any ponding on the cement floor around the handpump? Y/N
7. Is there a cement surround at all? Y/N
8. Is the cement surround cracked which might permit water to enter well? Y/N
9. Is the handpump loose at the point of attachment to the base? Y/N
10. Is there a slot on top of the handpump? Y/N
11. And is it used to prime the pump? Y/N
12. Are pit latrines used? Y/N
13. How many pit latrines are present within: 5m
10m
15m

Figure 1. Sample sanitary survey form.

## Chemical contamination

On-site sanitation is likely to be the major source of chemical contamination of groundwater in these areas. Typically a person excretes 2kg of chloride and 5kg of nitrogen per annum. Given population densities as high as 600 persons per

3. Morris, B.L., A.R. Lawrence and M.E. Stuart, 'The impact of urbanisation on groundwater quality', Project summary report. *BGS Technical Report* WC/94/56, 1994.

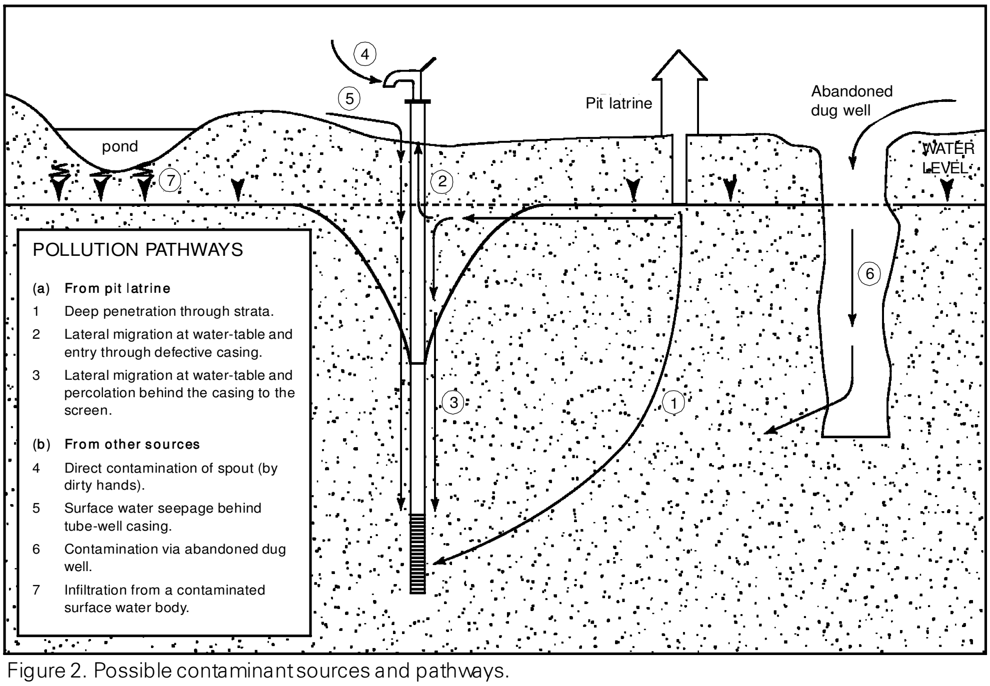
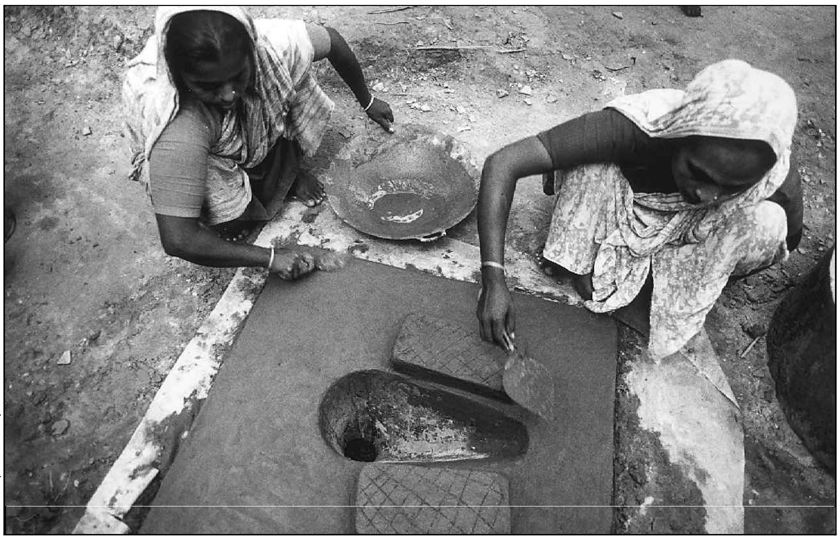



Figure 2. Possible contaminant sources and pathways.



Jeremy Hartley/Panos Pictures

Women finish work on a latrine. On-site sanitation is likely to be the major source of chemical contamination in the study areas.

hectare, and an annual recharge of 300mm, a 'back-of-the-envelope' calculation gives concentrations in leachate from pit latrines of 400mg/l chloride and 1000mg N/l nitrate. Analysis of samples from a range of depths indicates widespread chemical pollution of the aquifer at shallow depths, although not necessarily due solely to on-site sanitation.

### *Chloride*

Chloride concentrations in the shallow groundwater beneath Dattapara can exceed 250mg/l (the WHO guideline), this compares with typical chloride concentrations in water pumped from deep boreholes (> 50m) in Keraniganj and Dattapara of 10mg/l. It would appear that the 'front' of modern high chloride water has not reached the deeper aquifer at our two study sites but in time, as water demands grow and abstractions from these deeper aquifers increase, this situation is likely to change.

### *Nitrogen*

Organic nitrogen is oxidized to nitrate via ammonium; the absence of ammonium in groundwater suggests that this process is complete. Ammonium concentration in groundwater is noticeably low at our two sites, but the concentration of nitrate in groundwater is also noticeably low. In aerobic environments nitrate is stable, and where the contaminant loading is high, concentrations in groundwater would be expected to build up and exceed WHO drinking water guidelines. In anaerobic, or low-oxygen environments, however, the nitrate can be reduced naturally by micro-organisms present in the subsurface to produce eventually harmless nitrogen gas. This denitrification process would appear to be taking place in the aquifer underlying the two project study sites. Of the 100 wells sampled, all are within WHO guidelines for nitrate (50mg $NO_3$/l).

## Conclusion

The limited results we have to-date would appear to show there is no widespread bacteriological contamination of the aquifer beneath our two study sites. A few wells do show significant bacteriological contamination, and it is possible that this may be derived from pit latrines with contaminants entering tube-wells at shallow depths. It is thought that improved well construction could reduce this risk, for example by using better quality casing material to reduce the likelihood of defective casing. Although nitrate does not appear to be a problem, elevated chloride concentrations are widespread in the shallow groundwater beneath Dattapara and may, in the longer term, cause many potable supplies to exceed WHO guidelines in both our study areas. ■

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