Anthropogenic pollution characteristics and impacts on shallow groundwater in a peri-urban settlement in Kampala, Uganda and solutions for prevention

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Introduction
Kampala, the capital city of Uganda like many cities in Sub-Saharan Africa has the majority of its population (80%) residing in peri-urban areas. These areas are densely populated, located in valleys with a high water table and lack basic social infrastructural services. The use of shallow groundwater for domestic consumption is a common practice in Kampala’s informal settlements. About 36% of the population in the peri-urban settlements and slums within the study area, draws shallow groundwater. The use of shallow groundwater for domestic consumption is a common practice in Kampala’s informal settlements. About 36% of the population in the peri-urban settlements and slums within the study area, draws shallow groundwater. The shallow groundwater has up to 779 mg/l of nitrates, 370 mg/l of total kjedahl nitrogen, 126E3 cfu/100ml of TTCs, 154E3 cfu/100ml of Streptococci and 13 mg/l of total phosphorus. Contamination of the shallow groundwater in the area is widespread and is linked to the multiple pollutant sources (Fig. 3).

Case Study Area
Bwaise III Parish is located in the northern part of Kampala approximately 4 km from the city centre. Fig 1 shows the location of the area. Fig 2 shows an overview of the area. Low-lying area with a high water table (>0.5-1.5m) in most of the areas. Largely unplanned with lack of basic services, poor road access and deplorable housing (Fig 2).

The highest population growth rates in Kampala District with an average annual growth rate of 9.6% (more than twice the city's average annual growth rate of 3.7%) and a population density of about 27,000 persons/km².

Materials and Methods
- Field surveys and consultations were undertaken to identify and locate pollution sources, and assess the environmental sanitation of the area.
- 16 monitoring wells (code named MWI 1 to MW16) were installed (up to 2m depth) in two zones of the study area. Water quality monitoring was carried out over a period of 19 months during 2003/2004 from these wells and one protected spring to ascertain the seasonal variation.
- Rainwater samples were collected near the Faculty of Technology, Makerere University (about 1.5km from the study area) to ascertain the quality. Wastewater samples were collected from three selected secondary drains within the area.
- Field-in-situ measurements of temperature, pH, electrical conductivity and dissolved oxygen using oxygen field meters and, wastewater flow and water level discharge gauges.
- Water and wastewater sample analysis is carried out at the Public Health and Environmental Engineering Laboratory (PHEEL) at the Faculty of Technology, Makerere University according to APHA/ AWWA standard methods for water and wastewater analysis.

Results and Discussion
Pollutant source characteristics
The identified anthropogenic pollution sources for shallow groundwater in the area are presented in Fig. 3.

Shallow groundwater quality - anthropogenic pollution impacts
- Shallow groundwater quality varies with season. During the rains, quality deteriorates in terms of the bacteriological and organic content (Fig. 8).
- The shallow groundwater has up to 779 mg/l of nitrates, 370 mg/l of Total kjedahl nitrogen, 126E3 cfu/100ml of TTCs, 154E3 cfu/100ml of Streptococci and 13 mg/l of total phosphorus.
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Solutions for prevention
- Excavation and disposal systems
  - Ecological sanitation toilets should be installed in the area especially at household level (Fig. 10). These have the advantage of:
  - *space economy
  - *resource recovery and
  - *minimal impact on the environment including groundwater protection

- Solid waste
  - Community participation should be encouraged so as to improve solid waste collection and disposal in the area.
  - With more than 80% of the solid waste generated in the area being organic, composting is a plausible solution to obtain manure that can be used in gardens (Fig. 11).
  - Direct use of fruit (bananas) peels as animal feed should be encouraged.

- Grey water and storm water harvesting
  - Lining of drains should be encouraged and dumping of garbage in all drains should be prohibited.
  - Natural wetlands receiving these wastewaters should be gazetted and encroachment restricted.
  - Rainwater harvesting should be encouraged.
  - Low cost decentralized wastewater treatment systems such as waste stabilisation ponds, constructed wetlands (reed bed filters) where land is available.
  - Direct application to a garden or container field (Fig. 12).

Conclusions
- There is widespread contamination of shallow groundwater in Bwaise III mainly from excreta disposal systems, solid waste dumps and grey water.
- The highly permeable and shallow vadose zone in the area offers limited attenuation of contaminants especially during the rains.
- The operational spring in the area should be protected to safe guard communities' health. In view of the high nitrate concentrations, consideration should be given to provision of piped water and encouraging communities to harvest rainwater.
- Proposed solutions necessitate community participation, institutional support and collaboration with existing non-governmental organisations (NGOs), Community based organisations (CBOs) and development partners.