Analysis of the Impact of Anthropogenic Pollution on Shallow Groundwater in Peri-Urban Kampala

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Abstract

An investigation to assess the anthropogenic pollutant loads, transport and impact on shallow groundwater in one of Kampala's peri-urban areas (Bwaise III Parish) was undertaken. Bwaise III is a densely populated informal settlement with a high water table (<1.5 m below ground level) and inadequate basic social services infrastructure (e.g, sanitation, safe water supply, roads, etc).

Field surveys were undertaken to identify, locate and quantify various pollutant sources. Information on the usability and operational aspects of the excreta and solid waste management systems was obtained from consultations with the residents. Water from installed monitoring wells and one operational protected spring and wastewater (sullage) characteristics (quality, discharges for drains and spring, water levels for the wells) as well as soil characteristics (soil stratigraphy, physical and chemical) were determined through field and laboratory measurements. Laboratory batch experiments were undertaken to estimate phosphorus sorption potential of the soils.

The results reveal that excreta disposal systems, solid waste and sullage are the major contributors to shallow groundwater contamination. High contaminant loads from these sources accumulate within the area resulting in widespread contamination. The water table responds rapidly to short rains (48hr) due to the pervious and shallow (<1 m) vadose zone, which consists of mostly organic fill material. Rapid water quality deterioration (increased thermotolerant coliforms, organic content in the form of total kjedahl nitrogen, phosphorus) following rains potentially follows from leaching, desorption and macropore flow. Spatial variation of the water quality in the area is largely related to anthropogenic activities within the vicinity of the well sources. Animal rearing, solid waste dumps and latrines are seen to result in increased localised microbial and organic content during the rains. The spring discharge with high nitrate levels does not respond to short rains suggesting that this source is fed by regional base flow. The corresponding high microbial contamination in this case is a result of observed poor maintenance of the protection structure leading to direct ingress of contaminated surface runoff. Natural attenuation of contaminants is very limited. Estimated bacteria die-off rates are very low, about $0.01hr^{-1}$, suggesting a high risk for microbial contamination. The soils still have potential to retain additional phosphorus, whose sorption is largely a function of iron, available phosphorus and moisture content of the soils. This is also seen with the model results in which the phosphorus contaminant plume sticks to the surface irrespective of the rainfall infiltration rates. Simulation results show that continuous heavy intense rains (> 0.25mm/min) result in rapid flooding occurring within 1hr to 2 days. With lower rains, the water table does not rise to the surface, and no flooding takes place.

Protection of the shallow groundwater in the area requires socio-technical measures targeting reduction of pollutant loads within the area as well as a wider spring catchment. Re-protection of the spring, coupled with awareness creation, should be immediately addressed so as to reduce microbial contamination. Community participation in solid waste management should be encouraged. Resource recovery systems such as composting of the mostly organic waste and use of ecological sanitation toilet systems should be piloted in the area. Successful operation of the systems however depends on continuous sensitisation of the communities.

Key words: Shallow groundwater; Sanitation; Peri-urban; Vadose zone; Anthropogenic; Modelling

Licentiate Thesis in the Department of Land and Water Resources Engineering, Royal of Institute of Technology, Sweden, 2005 ISBN 91-7178-103-X.