Relationship between rainfall and microbiological contamination of shallow groundwater in Northern Mozambique

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Abstract

Outbreaks of contamination events in many developing countries occur during periods of peak rainfall. This study presents evidence of direct pulse response of shallow groundwater contamination events to rainfall in Northern Mozambique. The objective of the paper is to establish both a statistical relationship between rainfall and contamination and to analyse the pathways through which runoff resulted in contamination. To achieve this, data from 25 wells were monitored over a 12-month period in Lichinga, Northern Mozambique, and then compared to historical rainfall from the previous 8 years. Categorical (soil survey) and parametric (water quality, rainfall, depth-to-water-table) data were further collected before, during and after the 4-month monomodal rains. Using logistic regression statistics, three distinct conclusions were drawn from the study. Firstly, the study demonstrated a direct pulse response between increased numbers of presumptive thermotolerant coliforms and enterococci bacteria. Secondly, the study observed high risk of contamination through localised, as opposed to aquifer pathways, and thirdly, the study noted a higher survival function and stability of presumptive enterococci bacteria as compared to presumptive thermotolerant coliforms in the environment and at depth.

Keywords: rainfall/runoff, contamination, groundwater monitoring, microbiological processes

Introduction

Studies of shallow groundwater contamination in developing countries have demonstrated a direct pulse-response between trends of rainfall and microbiological contamination (Barrel, 1979; Lewis et al.., 1980; Lewis et al.,1984; Wright, 1986). A recent study of springs in the weathered crystalline aquifers of Kampala, Uganda by Barret (2000) and Howard et al. (2003) demonstrated a significant deterioration in microbiological groundwater quality within 12 hours of a rainfall event (Barret et al., 2000; Howard et al., 2003). This study is supported by further evidence from studies undertaken in Peru, Gambia, Sierra Leone and Zambia regarding the seasonality of groundwater quality (Barrel, 1979; Wright, 1986; Utkilen et al., 1989; Bartram, 1996). For example, in a study of wells in rural villages in the Gambia, Barrel (1979) noted an increase of approximately 10 orders of magnitude of faecal contamination following the onset of the rains over a period of 6 days (Barrel, 1979). Further studies by Utkilen et al. (1989) in Zambia concluded that peaks in faecal contamination of wells were associated with rainfall as a result of surface flushing of faecal material (Utkilen et al., 1989).

However, in contrast to these views, studies of the seasonality of water quality in Sierra Leone noted decreasing rates of contamination during the wet season (Wright, 1986). The study examined levels of selected faecal indicator bacteria and incidence of *Salmonella* spp. over a one-year period. The study concluded that counts were generally increasing during the dry season culminating in peaks at the transition from dry to wet season. This increase was attributed to a lack of sanitation development and the sporadic nature of rainfall patterns in the study area. Consequently, the human and animal waste was deposited at the soil surface and flushed into the water sources during the rains. Additionally, due to the water sources diminishing in the dry season, a lower level of dilution or concentration effect of faecal contamination was observed in the dry season resulting in higher detection levels (Wright, 1986).

Studies by Howard et al. (2003), although solely focused on spring contamination, provide a significant background to the development of the study presented in this paper. Their study highlights the importance of contamination of shallow springs by short-circuiting of sanitary headworks through "localised pathways" (Howard et al., 2003) It explores this alternative localised pathway by examining the microbiological contamination levels in springs with varied levels of sanitary protection during periods of high and low rainfall.

This paper widens the Howard et al. (2003) research to investigate microbiological contamination of 25 shallow wells over 12 months (November 2003 to October 2004) in Lichinga, Northern Mozambique. The aim of the study outlined in this paper was to identify the influence of rainfall and localised pathways on groundwater contamination. Based on the source-pathway-receptor model of groundwater contamination, "localised" and "aquifer" pathways of contamination are defined as follows;

- Localised pathways – a rapid bypass mechanism where pathogens enter the intake of the water supply due to poor design and/or construction, the microbes having limited residence time in the saturated zone as a consequence.
- Aquifer pathways – where pathogens migrate through the subsoil from a faecal source to the water table (ARGOSS, 2002).

Field workers report that localised pathways are considered of high significance in Mozambique, where poor quality materials, limited quality control in construction and high levels of

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