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A survey of domestic wells and pit latrines in rural settlements of Mali: Implications of on-site sanitation on the quality of water supplies

P. Martínez-Santos[a,*], M. Martín-Loeches[b], N. García-Castro[b], D. Solera[c], S. Díaz-Alcaide[a], E. Montero[a], J. García-Rincón[b]

[a] Departamento de Geodinámica, Facultad de Ciencias Geológicas, Universidad Complutense de Madrid, C/José Antonio Novais 12, 28040, Madrid, Spain
[b] Departamento de Geología, Geografía y Medio Ambiente, Facultad de Ciencias Ambientales, Universidad de Alcalá de Henares, Campus Universitario, Ctra, Madrid-Barcelona, Km 33,600, Alcalá de Henares, 28801, Madrid, Spain
[c] Geólogos Sin Fronteras, C/El Bosque 5, Pozuelo de Alarcón, 28224, Madrid, Spain

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ABSTRACT

On-site sanitation is generally advocated as a means to eradicate the health hazards associated with open defecation. While this has provided a welcome upgrade to the livelihoods of millions of people in low-income countries, improved sanitation facilities are increasingly becoming a threat to domestic groundwater-based supplies. Within this context, a survey of pit latrines, domestic wells and improved water sources was carried out in a large rural village of southern Mali. All households were surveyed for water, sanitation and hygiene habits. Domestic wells and improved water sources were georeferenced and sampled for water quality (pH, electric conductivity, temperature, turbidity, total dissolved solids, thermotolerant coliforms, chloride and nitrate) and groundwater level, while all latrines were inspected and georeferenced. A GIS database was then used to evaluate the proportion of water points within the influence area of latrines, as well as to underpin multiple regression models to establish the determinants for fecal contamination in drinking supplies. Moreover, an appraisal of domestic water treatment practices was carried out. This revealed that nearly two-thirds of the population uses bleach to purify drinking supplies, but also that domestic-scale treatment as currently implemented by the population is far from effective. It is thus concluded that existing habits could be enhanced as a means to make water supplies safer. Furthermore, population, well and latrine density were all identified as statistically significant predictors for fecal pollution at different spatial scales. These findings are policy-relevant in the context of groundwater-dependent human settlements, since many countries in the developing world currently pursue the objective of eliminating open defecation.

1. Introduction

Adequate access to water and sanitation is essential for human dignity and wellbeing. Water is not only required for basic daily activities such as hydrating, cooking, washing or hygiene, but is also a key input for food security (United Nations, 2015a). On the other hand, sanitation systems are needed to guarantee the quality of water resources, thus protecting the environment and our very own drinking supplies. Sanitation also provides an essential service for living in human dignity and contributes to prevent disease in a number of ways. Despite these facts, official estimates suggest that 663 million people still lack sustainable access to safe drinking water (UNICEF/WHO, 2015), a figure which is most likely an underestimate (Martinez-Santos, 2017). Furthermore, just 68% of the world's population uses improved sanitation facilities. It is thus no wonder that "ensuring access to water and sanitation for all" has been listed as a core target of the Sustainable Development Goals for the year 2030 (United Nations, 2015b).

Groundwater resources are widely relied upon in sub Saharan Africa, particularly in those regions where rainfall is absent for several months each year. Areas where groundwater supplies are scarce or non-existent often have the greatest problems with health and poverty (MacDonald et al., 2008). It is estimated that Africa's shallow aquifers (< 80 m depth) currently underpin the daily life of 200 million people (Foster and Garduño, 2013). Groundwater is often extracted from boreholes, most of which are owned and operated by communities. Water is then supplied to the public by means of hand pumps or standpipes. Though more vulnerable to drying up periodically and to contamination, shallow domestic wells are also popular in many countries (Mkandawire, 2008; Pritchard et al., 2008; Wanke et al., 2014; Machado and Bordalo, 2014; Okotto et al., 2015; Liddle et al.,

* Corresponding author.
E-mail address: pemartin@ucm.es (P. Martínez-Santos).

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2015). This is largely because digging provides an affordable means to own a private water source, which in turn prevents people from walking the distance and queuing at community water points.

In the last decades, the advent of on-site sanitation has provided a welcome upgrade to the livelihoods of millions of people. However, improved sanitation facilities have also become a threat to domestic water supplies in many low-income regions (Dzwairo et al., 2006; Kiptum and Ndambuki, 2012; Nyenje et al., 2013; Shivendra and Ramaraju, 2015; Sorensen et al., 2016). Pit latrines are frequently constructed in close proximity to wells and boreholes, often based on ad hoc considerations such as space constrains or simple convenience (Islam et al., 2016). Moreover, pits are frequently unlined. Since latrine effluents contain harmful pathogens, including bacteria, viruses, protozoa or helminths (WHO, 2011), their very presence poses a direct risk to shallow groundwater and endangers human health. Fecal contamination in groundwater supplies usually translates into widespread gastro-intestinal disease among groundwater-dependent populations. Diarrheas may result in dehydration and malnutrition, poor intellectual development or even death (WHO, 2017a). It is estimated that about three quarters of child deaths due to diarrhea occur in just fifteen countries, most of which are located in Asia and sub Saharan Africa. One of these is the Republic of Mali, where diarrheas account for nearly 21,000 children deaths every year (UNICEF/WHO, 2009).

Open defecation has long-since been known to be a major public health issue, as it spreads diseases such as diarrhea, intestinal worms, typhoid or cholera (WHO, 2017b). Thus, its elimination has increasingly been recognized as a top priority for improving health, nutrition and productivity (UNICEF/WHO, 2015). The flipside of the coin is that latrine pressure on groundwater supplies can only be expected to grow, as on-site sanitation has been promoted throughout the African continent as an alternative to defecation in the open. In the context of the Millennium Development Goals, Mali has embraced different initiatives to prioritize improved sanitation facilities in rural communities. While this is a welcome step towards improving the living conditions of the population (70% of which inhabits rural settlements), this research argues that the inherent dangers are yet to be fully accounted for. Based on a field survey carried out in the southern part of the country, this paper presents three objectives. The first one is to establish how uncontrolled on-site sanitation poses a risk to domestic water supplies in villages of low-income countries. The second goal is to evaluate whether decentralized water treatment practices as currently implemented by the population in the study area are sufficient to cope with the threat of fecal pollution. Finally, the third objective is to explore potential correlations between fecal contamination markers in groundwater with spatially-distributed variables such as population, well or latrine density so as to be able to determine the key factors behind groundwater contamination and delineate the riskier areas.

2. Geographical setting

Field data was collected in Beleko-Soba, the chief village within the rural commune of Djedougou, during January 2017 (Fig. 1A). This study focuses on the three westernmost neighborhoods of the village (Diawarrala, Dougouyala Ouest and Fyenkala), whose joint population is 1500.

The area presents a hot tropical climate. Temperatures are high throughout the year, the average standing at 26 °C. Rainfall amounts to 800 mm/yr and takes place almost exclusively between June and September. There are no major streams or rivers in the immediate vicinity of the study site. Thus, the population relies exclusively on groundwater.

From the hydrogeological standpoint, the study area is located within the Infracambrian Metasedimentary aquifer of southern Mali. The relatively small size of the site (about 0.5 km^2), coupled with the available borehole information, suggests a relatively monotonous geological profile (Fig. 2). Thus, the uppermost layer is made up of a hard laterite crust whose thickness can exceed five meters in some areas. Immediately beneath, there is an unconsolidated layer made up of clays with intercalations of fine sand. This formation, which typically ranges between 10–15 m, lies on top of the regional sandstone aquifer, whose depth exceeds one-hundred meters and which is underlain by a gneiss basement.

Regional groundwater flow is ultimately controlled by rivers Bani and Banifling (García-Castro and García-Rincón, 2017), both of which are tributaries to river Niger. At the village scale, groundwater is observed to flow from the southwest to the northeast (Fig. 1B). The water table depth ranges between five and fifteen meters at the end of the dry season, and remains closer to the surface, i.e. one to three meters, during the rainy months. Groundwater is accessed either through improved water sources or through domestic wells. An improved water source is defined as one that, by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with fecal matter (UNICEF, 2014). This definition encompasses household connections, public standpipes, boreholes, protected dug wells, protected springs and rainwater collection. It leaves out unimproved sources such as unprotected wells and springs or surface waters. Public improved water sources include three boreholes equipped with hand pumps and one additional borehole serving two public standpipes (Figs. 3 and 4). The standpipes are connected to an elevated tank located approximately 500 m to the west of the study area. This means that there is approximately one public water point per every 235 people. On paper, this is an adequate ratio, since a hand pump or a standpipe can be expected to serve 300–500 people. Additionally, there are some improved sources which are privately-owned and operated. These include one hand pump and two standpipes, and could not be surveyed.

Domestic wells are shallow pits excavated by means of picks and shovels. In the study area these are typically less than 15 m deep and their diameter usually ranges between one and two meters. Despite the relative abundance of improved sources, our field survey reveals that over 80% of the households own a shallow well. As explained earlier, these are preferred by many people because they are cheaper than boreholes and allow users to avoid potentially long trips to public water sources.

There is no public sanitation system. Direct inspection shows that close to 85% of the households own pit latrines. These are built much like domestic wells, but are shallower (typically 2–6 m) and wider (1 × 1 to 2 × 2 m). Also, latrines are typically sheltered and covered with a concrete slab. In the vast majority of cases, latrines are unlined, meaning that feces may come directly in contact with groundwater. This is particularly true of the rainy season, when the water table rises close to the ground level.

Groundwater contamination from latrines must be understood in the light of the geological setting (Fig. 2). The laterite crust can be considered nearly-impervious for practical purposes. Clay also presents a very low permeability, which implies that the upper geological units provide some protection against contamination associated with the infiltration of surface runoff. However, contamination due to lateral groundwater flow can still be expected because domestic wells and pit latrines often break through both layers. Even when they do not, the sandy lenses embedded in the clay matrix are permeable. This implies that wells and latrines may come in contact through them.

3. Materials and methods

3.1. Field survey

A survey of all water and sanitation facilities was carried out in the three neighborhoods towards the end of the dry season 2017. A total of 119 domestic wells were characterized and surveyed for water table depth and water quality (pH, EC, temperature, turbidity, thermotolerant coliforms). All five public water points were also checked for