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Water quality and public health risks associated with roof rainwater harvesting systems for potable supply: Review and perspectives

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ABSTRACT

Knowledge of rainwater quality is critical for safeguarding public health. The review investigated rainwater quality, and public health risks associated with its consumption. Land use practices, roof material, weather patterns and their interactions influence rainwater quality. Contrary to the notion that roof water is safe, data point to physico-chemical and microbial contamination of rainwater via atmospheric deposition, leaching and weathering of roof materials, storage/conveyance utilities and faecal contamination. However, epidemiological studies linking consumption of rainwater to public health risks are scarce especially in developing countries. This reflects the lack of epidemiological research and confounding factors such as high disease burden. To minimize the public health risks, we recommend the implementation of risk assessment framework integrating laboratory analytical results and sanitary inspection risk analysis. Such a framework will enable proper prioritization and targeting of engineering/technological interventions, public education and housekeeping programmes.

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1. Introduction

In most developing regions including sub-Saharan Africa, water availability plays a critical role in supporting livelihoods, food security and public health (Baguma et al., 2010). The bulk of countries in sub-Saharan Africa (SSA) lie in water-scarce river basins, while for those countries with available fresh water resources, poor distribution of portable water has resulted in water shortages. Rapid population and industrial growth, coupled with declining and highly variable rainfall induced by climate change exert pressure on water demand for domestic, agricultural and industrial uses especially in sub-Saharan Africa (Barron, 2009). Current efforts to improve water supplies for domestic and industrial uses have largely focused on exploitation of surface water and groundwater resources even in countries such as Zimbabwe where principles of integrated water resources management are being promoted. On the other hand, water balance analysis suggest that rainwater from impermeable roof surfaces in both urban and rural areas represents an under-utilized resource currently excluded in existing water policies in SSA (Gwenzi and Nyamadzawo, 2014). Consequently, compared to surface water and groundwater resources, there is relatively limited research on the quality and public health risks posed by water harvested from roofs.

Rainwater harvesting (RWH) involves the collection, storage and subsequent use of rainwater for domestic, industrial and livelihood activities where and when it falls (Ngigi et al., 2005; Jebamalar and Ravikumar, 2011). In SSA, surface water in lakes, reservoirs and surface runoff are often contaminated with industrial/domestic wastes, pesticides, agrochemical released from agricultural land, roads and urban landscapes (Hranova, 2006; Gwenzi and Nyamadzawo, 2014). Attempts to harness rainwater harvesting have been limited to agriculture (Ngigi et al., 2005, 2007; Dile et al., 2013). At present, there are limited documented cases of RWH for domestic or industrial supply in SSA, but this trend is likely to change in the near future due to excessive demand for limited freshwater resources in the region. Moreover, RWH is also considered a key adaptation strategy to the impacts of climate change (Barron, 2009). Compared to centralized water supply systems, RWH systems have the potential to provide low-cost decentralized water to urban and rural households without access to treated water.

In principle, the collection of rainwater before it hits the ground mostly from roofs implies that is safer than surface water in lakes and rivers, and groundwater from shallow wells. However, several recent studies suggest that roof rainwater can be contaminated, thereby posing public health risk if consumed without treatment (Ahmed et al., 2010a,b, 2011a,b, 2012a,b, 2014; Lim and Jiang, 2013; Alves et al., 2014; Dobrowsky et al., 2014a,b; Jesmi et al., 2014; Lye, 2014). For example, consumption of untreated rainwater has been linked to bacterial diarrheas associated with *Salmonella* and *Campylobacter*, bacterial pneumonia due to *Legionella*, botulism due to *Clostridium*, tissue helminths, and protozoal diarrheas from *Giardia* and *Cryptosporidium* (Lye, 2002, 2014). A study in Australia also showed that untreated roof-harvested rainwater samples tested positive for *Salmonella, Giardia lamblia*, *Legionella pneumophila*, and *Campylobacter jejuni*, thereby posing public health risks to consumers (Ahmed et al., 2010b). These several studies challenge the anecdotal view that rainwater is safe for human consumption without treatment. Therefore, before the benefits of roof rainwater harvesting can be attained there is need to understand the public health risks associated with consumption of such water. This is particularly important in SSA and other developing countries, where water treatment facilities are unavailable for some poor urban and rural households. Moreover, even those who are connected often experience erratic water supplies due to demand exceeding supplies. Understanding the determinants of roof water quality and public health risks associated with consumption of roof water is critical for the design, operation and evaluation of roof water harvesting systems for potable water supply in developing regions such as sub-Saharan Africa, where such data are not available. For instance, such information is critical for devising public health measures to reduce the risks associated with consumption of roof rainwater.

Therefore, the current study reviews and synthesizes global literature drawn from journal articles, conference proceedings and research reports covering the period 1990s to present (2014). The specific objectives of the review were: (1) to identify possible contaminant pathways of rainwater from source to point of consumption, (2) to evaluate roof water quality and its determinants, (3) to determine potential public health risks associated with consumption of roof rainwater, and (4) to identify key research gaps on roof rainwater quality and associated public health risks.

2. The case of roof rainwater harvesting systems

Rainwater harvesting for domestic and agricultural uses is a very old practice dating back to 4500 BC in the Middle East and India (Sivanappan, 1997). The practice originated in arid and semi-arid areas, but increasing water demand for industrial and domestic uses is forcing most developing countries (Jebamalar and Ravikumar, 2011) including those in sub-Saharan Africa to consider RWH. Rainwater harvesting involves collection of rainwater from a catchment, storage and subsequent