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How do people's perceptions of water quality influence the life cycle environmental impacts of drinking water in Uganda?☆

Christine Prouty, Qiong Zhang*

University of South Florida, Department of Civil and Environmental Engineering, 4202 E. Fowler Ave., Tampa, FL 33620, USA

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ABSTRACT

Over the last two decades, more than 2 billion people have gained access to improved drinking water sources. The choices for water sources and treatment methods at the household level are influenced by people's perceptions of water quality. To ensure long-term sustainability, it is important to evaluate the environmental impacts of water provisions considering people's perceptions. In this study, the life cycle assessment (LCA) method and qualitative data collected from household interviews are used to determine the environmental impacts associated with water sources and household treatment methods. Results showed discrepancies between perceived and measured water qualities. In the case of tap water (i.e. low perceived water quality but high measured water quality), charcoal was used for boiling water at the household level that resulted in a high environmental impact due to a chronic over-treatment of water. In contrast, rainwater (i.e. high perceived water quality but low measured water quality) received under-treatment that resulted in a low environmental impact but potential health problems. This study highlights the need for an alignment in the perceptions of water quality with the actual, measured quality in order (1) to prevent public health outbreaks due to under-treatment, (2) to reduce the consumption of environmental resources as a result of over-treatment, and (3) to conserve household expenditures being used to purchase charcoal for boiling water.

1. Introduction

Over the last two decades more than 2 billion people have gained access to improved drinking water sources (WHO and UNICEF, 2013). While this progress has been applauded, the increasing population continues to drive the need to provide safe drinking water for all. It is important to consider the environmental impacts associated with water supply systems to assure that this basic necessity is being delivered in an environmentally responsible way (Bonton et al., 2012). Consequently, many studies have investigated the environmental impacts of water supply systems using the life cycle assessment (LCA) method (Sombekke et al., 1997; Mohapatra et al., 2002; Homäki, 2003; Lundie et al., 2004; Raluy et al., 2005; Stokes and Horvath, 2006; Friedrich et al., 2007, 2009; Barrios et al., 2008; Vince et al., 2008; Lyons et al., 2009; Venkatesh and Brattebø, 2012; Godskesen et al., 2013). LCA is an assessment framework used to determine the environmental burden of products, services, or processes across their life cycle stages (ISO 14040, 2006).

The LCA method has been employed in previous water supply studies for two purposes. The first type of application is to compare alternative supply options based upon their environmental performance (Lundie et al., 2004; Raluy et al., 2005; Tangsubkul et al., 2005; Friedrich et al., 2009; Lyons et al., 2009; Bonton et al., 2012; Godskesen et al., 2013; Jiang et al., 2013). For instance, Lyons et al. (2009) compared the environmental impact of water reclamation, importation, and desalination in Scottsdale, Arizona to determine a sustainable option to solve water scarcity issues. The second purpose for using the LCA method is to improve the environmental performance of a system by pinpointing hot spots that significantly contribute to the overall impact (Tangsubkul et al., 2005; Friedrich et al., 2007; Lemos et al., 2013). Lemos et al.'s (2013) study found that, in an urban water system, the electricity consumption for extracting and treating drinking water caused the greatest impact to the environment. As a result, efficiency improvements in the distribution network and alternative non-fossil based fuel sources were suggested to reduce the impact (Lemos et al., 2013). Furthermore, a South African study concluded similar results for the electricity consumed for pumping water during the collection,

☆ A life cycle assessment (LCA) study that incorporates qualitative data from household interviews to determine the environmental impacts associated with water sources and household treatment methods that are influenced by people's perceptions of water quality.

* Corresponding author.
E-mail addresses: cprouty@mail.usf.edu (C. Prouty), qiongzhang@usf.edu (Q. Zhang).

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treatment, distribution, and reuse phases. As a result, the study recommended that electricity consumption should be used as a basic environmental performance indicator to quickly compare the various pumping steps to determine the best area for improvement (Friedrich et al., 2007).

A majority of the previous studies have focused on the evaluation of centralized systems in industrialized, urban areas (Friedrich et al., 2007; Godskesen et al., 2013; Lemos et al., 2013), whereas only a few studies, primarily in developing regions, have evaluated the impacts of decentralized water supply or treatment schemes (Homäki, 2003; Held et al., 2013; Baird et al., 2013). In Vietnam, Homäki et al. (2003) assessed the impacts of a community's low quality water provision from a centralized public treatment plant that was being further treated at the household level. The study investigated three energy alternatives (coal briquettes, liquefied petroleum gas (LPG), and electricity) for household level treatment and found that boiling with a tank of LPG resulted in the least environmental impact associated with the decentralized treatment. However, the scope of the study was limited in terms of the water sources considered, environmental impact categories included, and preferences of the community for drinking water sources or treatment options. Another study (Held et al., 2013) investigated community and household level drinking water treatment and source protection in rural Mali based on their embodied energies. The study found that the human energy exerted for water collection and transport outweighed the fossil-based energy for water treatment. This highlights the difference between decentralized community or household level water treatment in developing countries and centralized drinking water treatment in developed countries. Previous studies have found that water provisions in developing countries have some unique characteristics, such as the diversity of source options (Mu et al., 1990; Howard et al., 2002) and the water source preferences based upon perceptions of water quality or cultural norms (Mu et al., 1990; Doria, 2010; Baird et al., 2013). For example, Mu et al.'s study revealed that certain water supply features like the time it takes to get to a source and its price had a significant impact on household choices whereas household income did not (Mu et al., 1990). Furthermore, the treatment approaches applied at the household level also depend on multiple factors such as cost, convenience and water quality (Prouty, 2013). People's perception of water quality has a significant impact on household level treatment choices (Rainey and Harding, 2005) that result in different environmental impacts (Homäki et al., 2003; Prouty, 2013). However, there is no study incorporating people's perception into the evaluation of environmental impacts associated with water provisions and household treatment.

Filling this knowledge gap, the purpose of this work is to reveal the effects of people's perceptions of water quality on household treatment methods and to determine the associated environmental impacts. Integrating a social perspective into a technical life cycle analysis reveals the environmental effects of household behaviors that are particularly important for water provision in developing countries since household treatment is a common practice (Homäki et al., 2003; Held et al., 2013; Prouty, 2013).

2. Study site

This study was conducted in two rural, neighboring villages—Nalugala and Kitala, Uganda. These villages were chosen because the collaboration has been established with the community organization Bega Kwa Bega (BKB) that implements water and sanitation projects in the area. These villages are in Wakiso District, Katabi Sub-county which is located in the central portion of Uganda as seen in Fig. 1. The study site is situated along the highway corridor from Entebbe to Kampala. Entebbe is the major travel hub for the country as it houses the only international airport; Kampala is the central business district where the majority of foreign embassies, government buildings, and corporate offices are located. The area is characterized by significant urbanization along this highway corridor, immediately followed by lush vegetation, rolling hills, family farms, and red clay roads or footpaths.

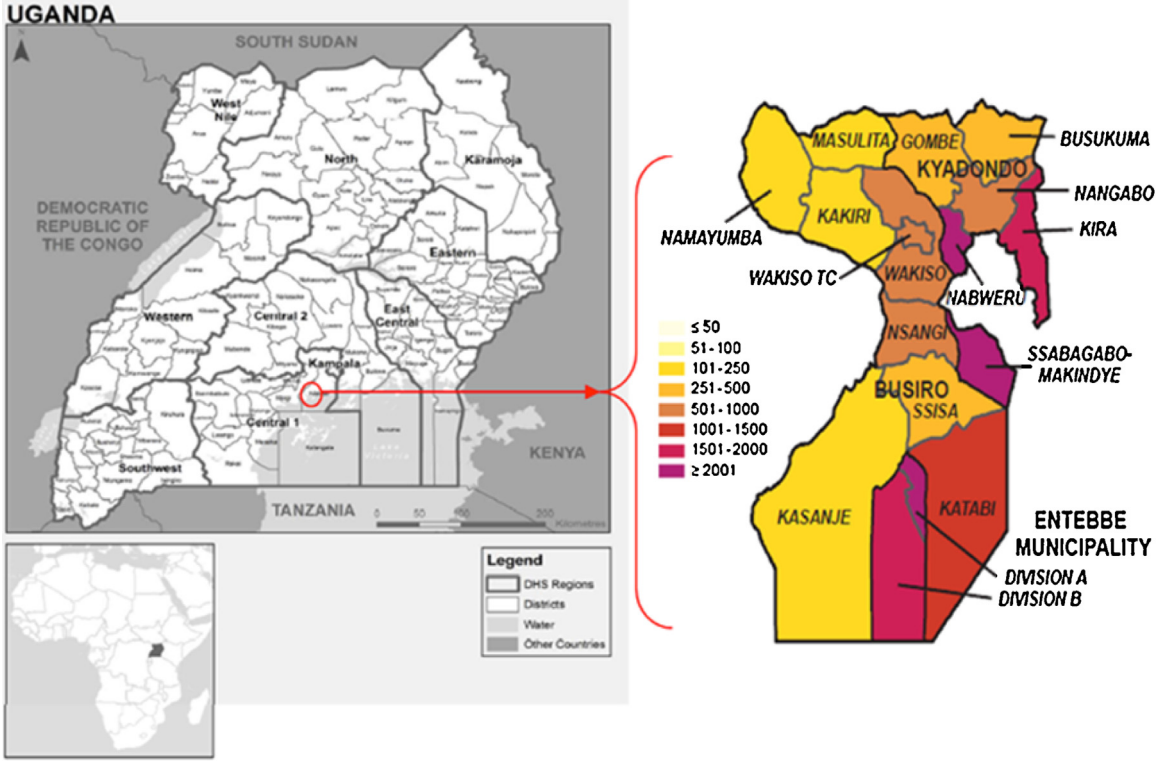

Fig. 1. Geographic context of the study and population density of Wakiso District with units of people/km^2 (Ministry of Water and Environment, 2010).