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Impact of wastewater-irrigation on in-household water contamination. A cohort study among urban farmers in Ahmedabad, India

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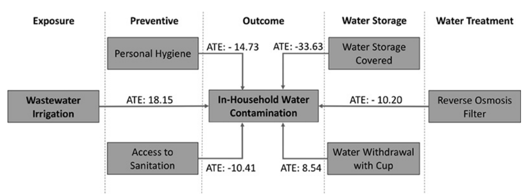
HIGHLIGHTS

- 78% of households drinking water further deteriorated between point-of-source (PoS) and point-of-use (PoU).
- During the monsoon only 6% have access to safe PoU water.
- Wastewater irrigation increases the odds of in-household water contamination 2.5.
- Reverse osmosis filters reduce the odds of in-household water contamination by 94%.
- Access to sanitation and good personal hygiene show preventive effects.

GRAPHICAL ABSTRACT



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ABSTRACT

This cohort study explores the contribution of wastewater irrigation, in the context of WASH (Water, Sanitation, Hygiene), on in-household water contamination among urban farming households in Ahmedabad, India. Drinking water samples of 204 households in four peri-urban farming communities were collected from the point-of-source (PoS) and point-of-use (PoU) of each household four times over the 12-month follow-up period. Next to the quantification of *E. coli*, three household surveys (baseline, hygiene and farm) were conducted. Additionally, an observational spot-check was undertaken in bi-monthly intervals throughout the follow-up period. Significant positive differences in water quality between PoS and PoU samples were identified in 78% of households. During the monsoon, the peak of contamination, only 6% of households had access to safe drinking water at PoU. The Average Treatment Effect (ATE) of wastewater irrigation indicates an adverse effect on in-household water contamination, larger in effect size than the mitigation effect of access to sanitation or personal hygiene. To control transmission of fecal pathogens, effective barriers are required for wastewater irrigation similar to the necessity of ensuring access to sanitation and practicing adequate hygiene behavior.

1. Introduction

Globally, the utilization of wastewater for irrigation is widespread (Molden, 2007; Drechsel & Evans, 2010). Its importance is continuously growing in light of scarce fresh water resources and increasing water demand due to population growth, urbanization and increasing living standards. While the planned reuse of wastewater, as promoted by

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urban agriculture, can induce significant environmental and economic advantages (Bellows et al., 2003; Holt-Giménez & Patel, 2009; Drechsel et al., 2010), the unstructured and often unaware utilization of wastewater for irrigation bears health risks to the farmers and their families, the consumer as well as the wider community (Lee-Smith & Prain, 2006; Hamilton et al., 2007). The release of large volumes of untreated wastewater into surface waterways is common in many emerging economies (UNESCO, 2003), while farmers often rely on these surface waterways for irrigation purposes. Wastewater irrigation therefore forms a pathway of reintroducing fecal pathogens as well as introducing new pathogens into the community and thus forming an integral element of the WASH (Water, Sanitation and Hygiene) nexus (see Fig. 1). Fig. 1 is an expansion of the F-diagram, where wastewater irrigation is conceptualized as an exposure source parallel to lacking sanitation, transferring fecal pathogens via hands, water, farm, environment and food into the community and inducing adverse health impacts.

Water-borne infections remain a key public health challenge on the global level. Diarrheal disease threatens the health and adequate development of young children, with 800,000 premature deaths still attributed to the disease annually (UNICEF, 2012). Diarrheal disease remains the second leading cause of death for young children in developing countries (UNICEF, 2012). In recent years, various global and national efforts to reduce the burden of diarrhea have been initiated, aiming at creating safe and improved drinking water sources through the adequate provision and treatment of drinking water, as well as providing access to improved sanitation (Wolf et al., 2018). Such efforts are often coupled with hygiene interventions, as it has been understood that the disease risk cannot be eliminated in isolation but integrative WASH programs are required to simultaneously educate the community, develop infrastructure and promote behavior change. The key indicators of progress: access to improved water sources and sanitation facilities, often fail to provide the full picture.

In most low- and middle-income countries, even where the government provides piped household drinking water, the supply is intermittent (Brown et al., 2013). Households are thus required to store their drinking water over prolonged periods of time (see Fig. 2). Nonetheless, households with such non-continuous water connections are classified as 'improved water source' under the original JMP definition (Howard & Bartram, 2003; UNICEF & WHO, 2015) and achieve the second highest rung of the JMP service ladder (corresponding with "basic" access) (WHO/UNICEF, 2017). It can therefore be assumed that the water is monitored and treated by the government, ensuring the provision of safe water to the population. Nonetheless, it needs to be noted that while "improved" water sources do exhibit lower odds of contamination compared to "unimproved" sources, it is estimated that a quarter of "improved" sources are fecally contaminated (Bain et al., 2014). Regardless of the source contamination level, higher effectiveness of

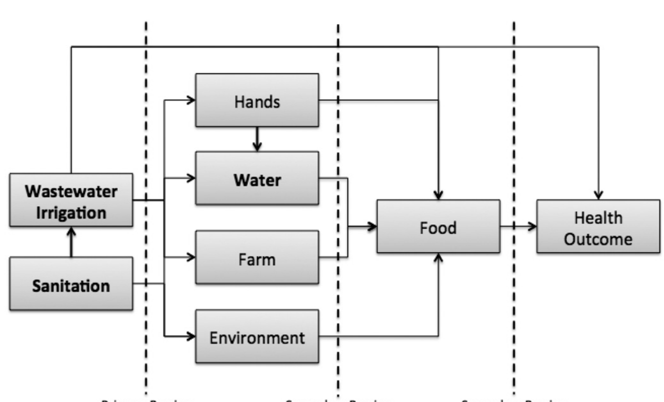

Fig. 1. Fecal-oral transmission pathway. Based on Wagner & Lanoix, 1958. Boxes represent the variable quantified in the study. Arrows represent transmission routes of fecal-oral pathogens. Dashed lines represent primary and secondary barriers.

Fig. 2. Drinking water storage. Drinking water storage in matakas (clay vessels), one wrapped in wet cloth to cool water. Blue plastic drum stores general purpose water. Plastic sieve used for water filtration when filling the matakas. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)
Foto: Timo Falkenberg.

point-of-use (PoU) water treatment compared to treatment at the point-of-source (PoS) has been observed (Clasen et al., 2007; Waddington et al., 2009); as in-household water contamination may render previously safe PoS water unsafe at the PoU. A meta-analysis of Shields et al. (2015) highlights that noncompliance with the water standard is more common in PoU water than PoS water, a finding confirmed by Alarcon Falconi et al. (2017). In this study PoU is defined as water as it is consumed, thus water drawn from the household water storage container. PoS is defined as the point where households collect their drinking water, this may be a household tap or a bore well. The intermittent water supply forces households to collect and store their drinking water, which form key points of in-household water contamination (Eshcol et al., 2009; Rufener et al., 2010, Adane et al. 2017). It is hypothesized that exposure to wastewater irrigation increases the likelihood of contamination of hands, feet and clothing and thus also the risk of transferring these contaminants to the drinking water during storage and withdrawal. It has been demonstrated that safe water storage and transport does not only lead to improvements in water quality, but also induces health benefits (Günther and Schipper, 2013). Therefore, adequate hygiene behavior, including safe water storage and use, are essential for disease prevention. While the association between WASH and diarrheal disease is well established (Esrey & Habicht, 1986; Clasen et al., 2006; Wolf et al., 2014; Wolf et al. 2018), the role of wastewater irrigation in regard to in-household water contamination and PoU water quality is seldom discussed.

In this study wastewater irrigation is treated as an integral component of the WASH nexus, essentially forming a potential failure of the primary barrier (sanitation) on the municipal and farm level, leading to the release of fecal pathogens into the environment (Fig. 1). Regardless of the sanitation coverage of a particular community, wastewater irrigation may reintroduce fecal pathogens (as well as potentially harmful chemicals) into the community. This study assesses the extent to which wastewater irrigation influences the degree of in-household water contamination, underlying the assumption that fecal pathogens are transferred from the farm to the household and ultimately into the water storage vessel.

2. Material and methods

2.1. Study area

The study was conducted in Ahmedabad, the most populous city of the state Gujarat, India (census India, 2011). The infrastructure of the