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Microbial contamination along the main open wastewater and storm water channel of Hanoi, Vietnam, and potential health risks for urban farmers

Samuel Fuhrimann [a,b,*], Phuc Pham-Duc [c], Guéladio Cissé [a,b], Nguyen Thuy Tram [d], Hoang Thu Ha [d], Do Trung Dung [e], Pham Ngoc [f], Hung Nguyen-Viet [c,g], Tuan Anh Vuong [d], Jürg Utzinger [a,b], Christian Schindler [a,b], Mirko S. Winkler [a,b]

[a] Department of Epidemiology and Public Health, Swiss Tropical and Public Health Institute, Basel, Switzerland
[b] University of Basel, Basel, Switzerland
[c] Center for Public Health and Ecosystem Research, Hanoi School of Public Health, Hanoi, Vietnam
[d] Department of Microbiology, National Institute of Hygiene and Epidemiology, Hanoi, Vietnam
[e] Department of Parasitology, National Institute of Malaria, Parasitology, and Entomology, Hanoi, Vietnam
[f] Department of Animal Hygiene, National Institute for Veterinary Research, Hanoi, Vietnam
[g] International Livestock Research Institute, Hanoi, Vietnam

HIGHLIGHTS

- We assessed the wastewater systems in reducing microbial contamination in Hanoi, Vietnam.
- We found that bacterial contamination in water used in agricultural field exceeds safety limits.
- We propose a series of control measures that would allow reducing microbial contamination.
- This paper can guide cities in Asia on how to work towards the Sustainable Development Goal 6.3 linked to safe use of wastewater.

GRAPHICAL ABSTRACT

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ABSTRACT

The use of wastewater in agriculture and aquaculture has a long tradition throughout Asia. For example, in Hanoi, it creates important livelihood opportunities for >500,000 farmers in peri-urban communities. Discharge of domestic effluents pollute the water streams with potential pathogenic organisms posing a public health threat to farmers and consumers of wastewater-fed foodstuff. We determined the effectiveness of Hanoi's wastewater conveyance system, placing particular emphasis on the quality of wastewater used in agriculture and

Abbreviations: CFU, colony forming unit; HSDC, Hanoi Sewerage and Drainage Company; MPN, most probable number; NIHE, National Institute for Hygiene and Epidemiology; QMRA, quantitative microbial risk assessment; SDG, Sustainable Development Goal; SSP, sanitation safety planning; Swiss TPH, Swiss Tropical and Public Health Institute; TC, total coliforms; WHO, World Health Organization.

* Corresponding author at: Department of Epidemiology and Public Health, Swiss Tropical and Public Health Institute, Basel, Switzerland.
E-mail address: samuel.fuhrimann@unibas.ch (S. Fuhrimann).

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aquaculture. Between April and June 2014, a total of 216 water samples were obtained from 24 sampling points and the concentrations of total coliforms (TC), *Escherichia coli*, *Salmonella* spp. and helminth eggs determined. Despite applied wastewater treatment, agricultural field irrigation water was heavily contaminated with TC (1.3×10^7 colony forming unit (CFU)/100 mL), *E. coli* (1.1×10^6 CFU/100 mL) and *Salmonella* spp. (108 most probable number (MPN)/100 mL). These values are 110-fold above Vietnamese discharge limits for restricted agriculture and 260-fold above the World Health Organization (WHO)'s tolerable safety limits for unrestricted agriculture. Mean helminth egg concentrations were below WHO tolerable levels in all study systems (<1 egg/L). Hence, elevated levels of bacterial contamination, but not helminth infections, pose a major health risk for farmers and consumers of wastewater fed-products. We propose a set of control measures that might protect the health of exposed population groups without compromising current urban farming activities. This study presents an important example for sanitation safety planning in a rapidly expanding Asian city and can guide public and private entities working towards Sustainable Development Goal target 6.3, that is to improve water quality by reducing pollution, halving the proportion of untreated wastewater and increasing recycling and safe reuse globally.

1. Introduction

Asia has a long tradition in the use of wastewater in agriculture and aquaculture (Qadir et al., 2010). Particularly, in peri-urban areas of large urban centres, farmers benefit from the all-year-round availability of wastewater and its high nutrient content (Drechsel et al., 2015). However, as Asian cities have grown rapidly, and continue to do so, appropriate infrastructures to collect and treat wastewater are often lacking, and hence, there are high levels of environmental pollution (Evans et al., 2012). Moreover, sewerage usually receive combined effluents from households, hospitals and industries, which in turn can contaminate the environment with a diffuse mix of pathogenic organisms and toxic chemicals (Phung et al., 2015). Consequently, safe wastewater management is of considerable public health relevance for people living along wastewater channels, farmers using wastewater, as well as consumers of wastewater irrigated crops and wastewater-fed fish (Hanjra et al., 2011; Utzinger et al., 2015). Safe wastewater management and use is also prominently featured in the Sustainable Development Goal (SDG) target 6.3, which was put forth by the United Nations and aims at improving water quality by reducing pollution, eliminating dumping and minimising release of hazardous chemicals and materials, halving the proportion of untreated wastewater and increasing recycling and safe reuse globally (UN, 2015).

A prominent example is Hanoi, the capital city of Vietnam. Over the past 20 years, the urban area has expanded, the population grew at an annual rate of 3.5%, resulting in 6.7 million people living on an area of 3329 km^2 in 2011 (GSO, 2011). More than 90% of the households in Hanoi rely on flush toilets that are connected to septic tanks, from where effluents are informally discarded into a wide network of drainage channels. In addition, these channels receive industrial effluents. In response to these challenges, the system was expanded in recent years to control the water flow out of the city and treat the wastewater with conventional treatment plants and decentralised water management systems (Kuroda et al., 2015). The latter should prevent flooding events, while regulating the water flow with water gates and a series of artificial ponds. In these artificial ponds, the wastewater is partially treated through sedimentation in combination with oxygenation. As a common practice, this partially treated wastewater is used in aquaculture and agriculture (Lan et al., 2012). Indeed, an estimated 658,000 farmers use wastewater on an area of approximately 43,778 ha in Hanoi (Raschid-sally and Jayakody, 2008). It must be noted that the use of wastewater creates important livelihood opportunities, as its high nutrient load is valuable for growing fresh vegetables and farm livestock and fish (Lan et al., 2012).

Several studies have reported high levels of microbial and chemical pollution in river sediments, irrigation water, splashing water used on markets and wastewater-fed foodstuff in Hanoi (Ingvertsen et al., 2013; Nguyen and Dalsgaard, 2014; Kuroda et al., 2015). Adverse health outcomes, such as diarrhoeal diseases, helminth infections and dermatitis, due to exposure to wastewater are well documented (Anh et al., 2007; Do et al., 2007a; Hien et al., 2007; Pham-Duc et al., 2013). Of note, as far as 60 km downstream of Hanoi, in Hanam province, adverse health conditions were associated to the city's wastewater (Pham-Duc et al., 2013, 2014). Additionally, flooding events exacerbated negative health impacts with considerable burden for public health such as drowning of people and cholera epidemics (Bich et al., 2011). While the current evidence suggests multiple environmental and health issues, a systematic assessment of the effectiveness of the different components of Hanoi's wastewater conveyance and treatment system that might reduce microbial contamination is currently lacking. This includes the identification of targeted mitigation strategies for improving the quality of products from urban farming in Hanoi (Fuhrimann et al., 2014; WHO, 2015).

The objectives of the present study were: (i) to assess whether the existing treatment scheme is effective in reducing microbial (bacteria and helminth) contamination along the main wastewater channels and retention drainages prior to the use of water in aquaculture ponds and agricultural fields; and (ii) suggest control measures that might provide a safe management and use of wastewater in agriculture and aquaculture in Hanoi. This environmental assessment was part of a larger study, comprising of a cross-sectional parasitological survey in selected population groups exposed to wastewater and a quantitative microbial risk assessment (QMRA) to determine disease burden related to microbial contamination (Fuhrimann et al., in press). Moreover, the data contributed to the development of the sanitation safety planning (SSP) manual that has recently been published by the World Health Organization (WHO) (WHO, 2015).

2. Materials and methods

2.1. Study area

Hanoi is located in the north of Vietnam, situated in the Red River delta (geographical coordinates: 21° 01′ 42.5″ N latitude and 105° 51′ 15.0″ E longitude). Hanoi's climate is sub-tropical. The main rainy season occurs from April to September. There is year-round high humidity ranging from 80% to 90% (Climate-Data.org, 2015). The wastewater flows from north to south, along a topographic gradient from 20 m to 5 m above mean sea level in four main rivers, namely To Lich River, Nhue River, Kim Nguu River and Red River (Nguyen and Parkinson, 2005; Kuroda et al., 2015).

2.2. Sampling sites and procedure

A cross-sectional survey was conducted between April and June 2014. The present study focused on three parts of Hanoi's wastewater system, namely (i) the urban wastewater conveyance and treatment system (operated by the Hanoi Sewerage and Drainage Company