

Health risk assessment along the wastewater and faecal sludge management and reuse chain of Kampala, Uganda: a visualization

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Abstract. Reuse of wastewater in agriculture is a common feature in the developing world. While this strategy might contribute to the livelihood of farming communities, there are health risks associated with the management and reuse of wastewater and faecal sludge. We visualise here an assessment of health risks along the major wastewater channel in Kampala, Uganda. The visualization brings to bear the context of wastewater reuse activities in the Nakivubo wetlands and emphasises interconnections to disease transmission pathways. The contextual features are complemented with findings from environmental sampling and a cross-sectional epidemiological survey in selected exposure groups. Our documentation can serve as a case study for a step-by-step implementation of risk assessment and management as described in the World Health Organization's 2006 guidelines for the safe use of wastewater, greywater and excreta in light of the forthcoming sanitation safety planning approach.

Keywords: wastewater reuse, faecal sludge, sanitation safety planning, health risk assessment, visualization, Uganda.

Link: https://www.youtube.com/watch?v=CQEC3d4iE_A&spfreload=10

Background

Reuse of wastewater and faecal sludge is commonly practised in many parts of the world, as it generates livelihood opportunities, especially in urban settings of low- and middle-income countries (Drechsel et al., 2010). However, direct or indirect contact to wastewater and faecal sludge is associated with microbial and chemical hazards, which frequently result in adverse health outcomes as mentioned in specific guidelines issued by the World Health Organization (WHO) (WHO, 2006). Indeed, various pathogenic

bacterial and viral strains can cause ill-health, such as diarrhoea, respiratory tract infection and skin disease (WHO, 2006). Environmental contamination with helminth eggs and larvae (e.g. *Ascaris lumbricoides*, hookworm and *Trichuris trichiura*) and intestinal protozoa cysts and oocysts (e.g. *Entamoeba histolytica* and *Giardia intestinalis*) can lead to intestinal parasitic infections in animals and humans (Becker et al., 2013; Strunz et al., 2014). Toxic chemical compounds, such as heavy metals discharged in industrial effluents, can lead to chronic disease and cancer (Ackah et al., 2013).

Urbanisation continues at a rapid pace, particularly in low- and middle-income countries posing challenges for the sanitation infrastructure with regard to operation and maintenance of wastewater and faecal sludge treatment plants (Rydin et al., 2012). Rapidly growing cities, such as Kampala in Uganda, are characterised by aging, overloaded wastewater treatment facilities serving a small proportion of the population, which is coupled with limited faecal sludge collection and treat-

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ment from on-site facilities. This is a scenario the majority of the population commonly has to face in densely populated, unplanned, low-lying parts of such cities. As a result, water used for irrigation generally carries faecal and chemical contamination from a number of sources, including treatment plant effluent, leakage or illegal discharge of faecal sludge, industrial sewage and open defecation within catchments. Limiting this exposure requires a better understanding of the sources of contamination and barriers that can be applied at various stages (WHO and UNICEF, 2014). Achieving targeted levels of service for wastewater and faecal sludge collection and treatment is extremely challenging in the context of rapid growth and limited funding for capital investment, operation and maintenance. There is thus a need for risk assessment and management approaches to identify and mitigate health risks especially for the most vulnerable populations. This can be done by a combination of treatment and cost-effective non-treatment measures and by mobilising a wide group of stakeholders to implement and monitor such risk assessment approaches (WHO, 2006).

Recognising the growing use of wastewater and faecal sludge, WHO has published guidelines for the safe use of wastewater, excreta and greywater (i.e. water generated from washing food, clothes and dishware, as well as from bathing, but not from toilets) (WHO, 2006). These guidelines provide a detailed methodology on how to assess and mitigate health risks in connection with the reuse of wastewater, excreta and greywater in agriculture and aquaculture. An important feature of the guidelines is that health-based targets are set out (e.g. maximum contamination of *Escherichia coli* and helminth eggs in treated wastewater in relation to the reuse scheme) by employing a multiple barrier approach. For this purpose, a broad set of technical and non-technical control options are proposed that are tailored for the different stages of a reuse system. Health-based targets should be set at the national level and might be based on well-defined health metrics, e.g. 10^{-6} disability-adjusted life years (DALYs) per person per year. While the WHO guidelines are valuable, their practicability and uptake in low- and middle-income countries proved difficult (Mara et al., 2010).

Against this background, WHO initiated the development of a sanitation safety planning (SSP) manual with the aim of providing a simple, step-by-step guidance on how to use and apply these guidelines. The approach takes users through the process of risk assessment, management and monitoring that com-

prises six distinct steps that include definition of the sanitation system, hazard identification and development of monitoring plans and supporting programmes. Importantly, the development of the SSP manual includes an extensive pre-testing phase in various settings across the world.

The motivation of the current visualization is to explain and feature the risk assessment and management concept covered by the SSP using the experience from Kampala as an example. The following questions guided the script:

- (i) How can the rich evidence-base of the WHO guidelines be encapsulated in a simple and accessible format to trigger a step-by-step implementation of the SSP approach?
- (ii) What are the lessons learned from validating the SSP approach in Kampala?
- (iii) How can we visualise an in-depth assessment and mapping of health risks related to different exposure groups along the wastewater and faecal sludge reuse chain in the Nakivubo wetlands?

Our visualization is structured as follows. First, we provide a general introduction to the concepts and challenges of wastewater and faecal sludge management and reuse in low- and middle-income countries. Second, we demonstrate the application of risk assessment, management and monitoring as described in the WHO guidelines. Third, we show how our work and experience in Kampala can contribute to a step-by-step implementation of the six SSP steps.

The SSP validation in Kampala was focused on the major wastewater system in this city of 1.8 million people, the capital of Uganda, which is located on the northern shores of Lake Victoria at an altitude of 1,140 m above the mean sea level at latitude $0^{\circ} 18' 49.18''$ N and longitude $32^{\circ} 36' 43.86''$ E. Like the case in many African cities, Kampala's sewage system is constrained with less than 10% of the population currently covered. Hence, the large majority of the population relies on local sanitation facilities such as pit latrines and septic tanks. Open defecation is still commonly practiced (Uganda Bureau of Statistics, 2013). For the SSP manual validation, the wastewater chain was divided into four study areas: (i) the Nakivubo channel with its wastewater treatment plant "Bugolobi Sewage Treatment Works" (BSTW); (ii) the Nakivubo wetlands; (iii) community areas bordering the wetlands, which are often affected by flooding events; and (iv) the Inner Murchison Bay within Lake Victoria (Fig. 1). The Nakivubo channel is 12.3 km long and transports wastewater from the communities, markets, industries and the treated

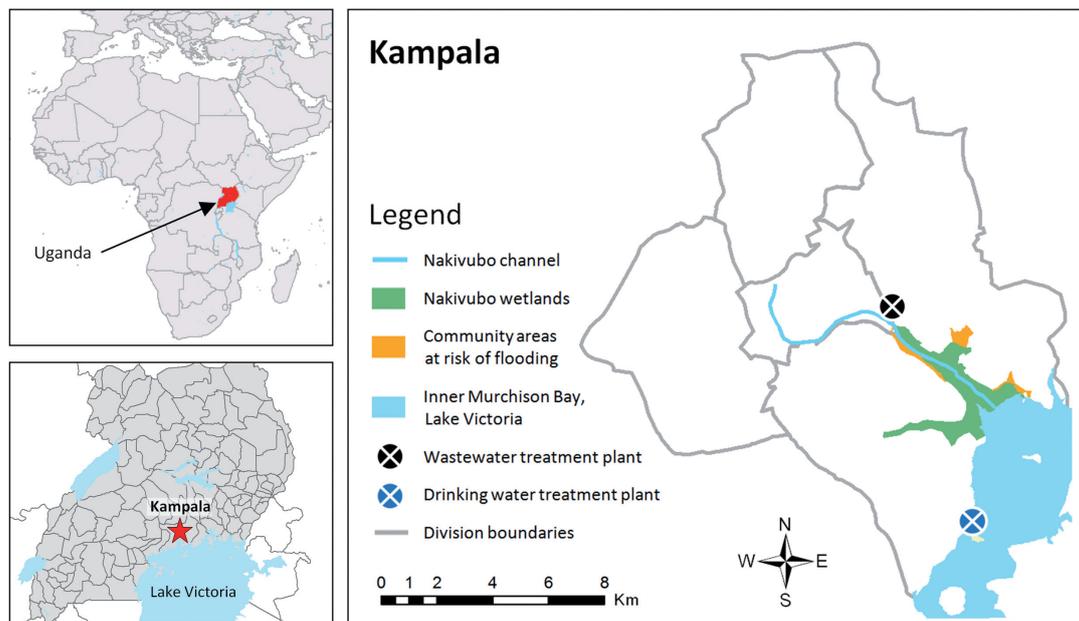


Fig. 1. Map of Kampala, the capital of Uganda, showing the study areas from the wastewater treatment to the drinking water treatment plant, highlighting the four specific study sites (Nakivubo channel, Nakivubo wetlands, community areas and the Inner Murchison Bay in Lake Victoria).

effluent of the BSTW. The final stretch of the channel comprises 4.5 km through the Nakivubo wetlands before reaching the Inner Murchison Bay within Lake Victoria. The Nakivubo wetlands cover approximately 5.3 km² and have a total catchment area of approximately 40 km². The whole wetland area is divided into a northern and a southern part separated by a railway. North of the railway is mainly drained farmland, while the South consists mainly of wetlands with floating “vegetational islands”. Both areas are extensively cultivated with yams and sugar cane. Informal communities that are at highest risk of flooding events are situated along both sides of the wetlands (approximate population: 12,000 people). The Inner Murchison Bay also supplies Kampala with drinking water which is pumped and treated only 4 km away from the outlet of the Nakivubo channel. Moreover, the lake is economically important for fishery (Mbabazi et al., 2010).

The case study involved an in-depth characterisation of the wastewater and faecal sludge reuse system and specific risk assessments in different exposure groups. Since major data gaps on water- and soil-related diseases and chemical pollutants were identified, a cross-sectional survey and an environmental sampling were carried out in late 2013. In short, a total of 915 participants were enrolled and stratified into five groups according to their exposure risk to wastewater: (i) wastewater treatment plant workers; (ii) faecal sludge collectors; (iii) farmers; (iv) exposed community mem-

bers who are at risk of flooding; and (v) non-exposed community members who are not directly exposed to wastewater within the Nakivubo area. Particular emphasis was placed on intestinal parasitic infections, skin disease, eye disease and diarrhoea. The survey comprised two components: (i) a questionnaire study to obtain health risk and health outcomes related to the exposure to wastewater; and (ii) collection of stool samples to determine the prevalence and intensity of helminths using the Kato-Katz method (Katz et al., 1972) and intestinal protozoa infections using the formalin-ether concentration technique (Utzinger et al., 2010). For the environmental sampling, water, sediment, soil and plants were collected for 8 weeks in the rainy season from October to December 2013. A broad range of microbial and chemical pollutants were investigated, such as thermo-tolerant coliforms, *E. coli*, *Salmonella* spp., helminth eggs and heavy metals (cadmium, copper, iron, lead, chromium and zinc) to deepen the understanding of the contamination of different environments and hence, better characterise risk profiles of the different exposure groups.

Results from the cross-sectional survey revealed that, in terms of intestinal parasitic infections, farmers were at highest risk (prevalence of infection: 75.9%), followed by exposed community members (53.2%), non-exposed community members (44.7%), wastewater treatment plant workers (41.9%) and faecal sludge collectors (35.8%). Our results from the environmental sampling showed that in water of the

Nakivubo channel and the Nakivubo wetlands, mean concentrations of thermo-tolerant coliforms (4.3×10^6 and 10^5 CUF/100 ml, respectively) exceeded the national standards. Moreover, mean *E. coli* concentrations (3.8×10^5 and 9.9×10^4 CUF/100 ml, respectively) were in excess of thresholds put forth in the WHO guidelines for the safe use of wastewater in agriculture. A fifth of the water samples were found positive for hookworm eggs. Copper, iron and cadmium with 3.3, 21.5 and 0.14 ppm in water, lead with 132.7 ppm in soil and lead, cadmium and chromium in plant samples (yams 0.2, 4.0 and 4.4 ppm; sugar cane 0.2, 4.3, 8.4 ppm) were above international safety standards.

Outlook

We visualise a health risk assessment along a wastewater and faecal sludge management and reuse system in the context of a major East African city, reporting applications of risk assessment, management and monitoring along the sanitation chain as described in the 2006 WHO guidelines and the SSP manual. We believe that our contribution further underscores the value and potential of visualizing complex health issues in the form of a short video that is readily accessible by multiple stakeholders and local communities (Krieger et al., 2012; Winkler et al., 2012). Hence, our visualization can serve as a case study to be used as a part of the training material to facilitate SSP and support a step-by-step implementation of the WHO guidelines for the safe use of wastewater, excreta and greywater in agriculture and aquaculture in other cities across the developing world.

Box 1. Overall aim.

- A visual tool to characterise a major wastewater and faecal sludge management and reuse system in a major East African city context that could reach a broad range of stakeholders.
- An educational tool to facilitate sanitation safety planning and the step-wise implementation of the WHO guidelines on the safe use of wastewater, greywater and excreta reuse in agriculture and aquaculture.

Box 2. Applied software.

- Content visualization, including geospatial components: Microsoft Power Point 2013 (Microsoft Corporation; Edmond; WA, USA)
- Production of video for Internet streaming: Camtasia Studio 8 (TechSmith Corporation, Okemos, MI, USA)
- Three-dimensional fly-through visuals: Google Earth Pro (Google Earth Pro version 7.1.2.2041; Google, Inc., Mountain View, CA, USA)

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Disclaimer

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