research evidence for policy

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FAECAL SLUDGE USE AS A FERTILISER

Are there Risks for Disease Transmission?

Study highlights

* Sludge use can contribute to reaching fertilising targets set by the Fertilizer Policy for Uganda.
* Disease causing *E. coli* and other Gram negative bacterial pathogens (as e.g. salmonella and campylobacter) from sludge are unlikely to be present on harvested crop.
* Helminth infection risk for consumers exists but is only partially caused by sludge application.
* A multi-barrier approach is proposed, according to WHO, to protect consumers of crops fertilized with faecal sludge.
* Implementing the intended drying time (24 weeks) could make the sludge of Lubigi comply with the limits for unrestricted use.
* Mitigation measures can reduce risk for farmers and workers to below 1 in 100 getting ill per year.

How to meet the fertiliser needs in Uganda?

The Ugandan fertiliser policy had the target that by 2020, nutrients applied to agricultural land should be at least 50 kg per ha and year[1], a target that was not met. The low input of fertilisers in Uganda is not balancing the nutrients removed with harvest and by erosion. Recirculating the nutrients in excreta, which originate from food, to agricultural land, coupled with other practices, could help overcome crop nutrient deficiency while decreasing the need for mineral fertilisers. Based on FAO statistics on protein intake, the nitrogen and phosphorus in excreta in Uganda comprise 98,200 tons and 14,800 tons, respectively, annually. This is almost 16-fold and 9-fold the current use of mineral fertiliser[2], and could provide 28% of the input nitrogen to arable land required to reach 50 kg N applied per hectare. In practice, efficiently capturing this resource depends on sanitation coverage and type of sanitation system.

Estimates from Kampala in 2016 suggest that 78% of human excreta ends up as faecal sludge (FS) as only a small proportion of the population is served by a centralised sanitation system. However, the faecal sludge that is contained and treated constitutes only 22% of the total excreta. Improving faecal sludge management through better containment and treatment can provide benefits, from decreased disease transmission and pro-

1 Ministry of Agriculture Animal Industries and Fisheries, 2016. National Fertilizer Policy.
2 FAO, Food and Agriculture Organization of the United Nations, https://www.fao.org/faostat/en/#home

tection of the natural environment to utilization of resources in excreta as e.g. fertiliser. Despite difficulties in optimising faecal sludge use, studies show rather high acceptance for faecal sludge as fertiliser and willingness to pay for it among Ugandan farmers[3]. This is evident at the Lubigi wastewater and faecal sludge treatment plant (WWFSTP) in Kampala, where all the treated sludge produced is bought by small- and medium-scale farmers for use in agriculture. However, when using the sludge as fertiliser there is a potential risk for disease transmission. This policy brief reports the findings and implications of a study assessing the microbial risks related to the use of faecal sludge as fertiliser.

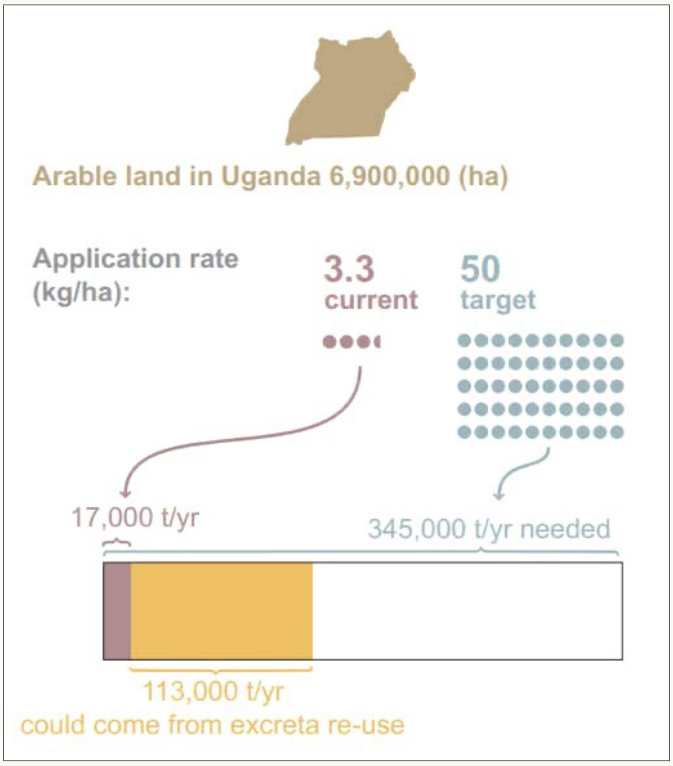

Figure 1: Nutrient requirement to achieve the target of nutrient application of 50 kg/ha and year. Theoretically, the nitrogen and phosphorus in excreta (for which this estimation could be done) could cover 34% of the nutrient gap. In practice when fertilising with faecal sludge other macro- and micronutrients will also be applied to the soil

Study aim

This study aimed at understanding the health risks for consumers of agricultural products fertilised with faecal sludge. The study used Quantitative Microbial Risk Assessment (QMRA), a well-established methodology recognized by the World Health Organisation (WHO), to quantify the risks of infection and disease among different groups: workers at the sludge treatment plant, farmers, and consumers. The part of the study that focused on the treatment at the Lubigi combined wastewater and Faecal Sludge Treatment Plant (WWF-STP) used 36 samples to estimate concentrations of microorganisms and their decay during the treatment process. Crops and soils from fields fertilised with faecal sludge as well as from fields fertilised with other fertilisers (mineral fertilisers and animal manure) were analysed for presence of microorganisms. *E. coli* and *Ascaris* eggs were used to assess the risks related to the treatment of faecal sludge and its use as fertiliser (Box 1).

Box 1: Disease transmission risk

Risk is the product of the severity of a hazard and the likelihood of exposure to the hazard. Using human excreta as fertilizer is associated with different microbiological hazards. Bacterial and viral pathogens in general give more severe disease than helminths, but bacterial and viral pathogens may be more sporadically present in the sludge and are likely to be inactivated by sludge treatment to a higher extent than helminths eggs. *E. coli* is part of normal human intestinal flora and will be present in excreta. Most *E. coli* do not cause disease but some toxin producing strains (that are prevalent in Uganda) may however give severe disease as hemorrhagic fever. In this study, *E. coli* was used as a model for its pathogenic strains and for other similar gram-negative bacterial pathogens. *Ascaris lumbriocoides* is globally the most prevalent helminth. When *Ascaris* infection is endemic, its eggs will be detected in faecal sludge and due to its persistence during treatment, it can serve as a model for persistent pathogens. The health burden from *Ascaris* infection is related to how many eggs you ingest and gives mostly mild, not life threatening disease even if long term development may be hampered.

Short treatment time gave a sludge that isn't fit for unrestricted use

Concentrations of *Escherichia coli (E. coli)* and viable eggs of *Ascaris lumbricoides* in raw sludge at Lubigi WWFSTP were 10^5-10^6 and 29-38 per gram dried sludge, respectively. Sludge storage is intended to be at least six months, but due to high demand, customers often collect it earlier. In this study, sludge was analysed after drying periods of 4-8 weeks representing ac-

3 Danso, G., Otoo, M., et al., 2017. Market Feasibility of Faecal Sludge and Mu- nicipal Solid Waste-Based Compost as Measured by Farmers' Willingness-to-Pay for Product Attributes: Evidence from Kampala. Uganda. Resources 6, 31.

tual drying periods before use as fertiliser. After drying of sludge, *E. coli* could not be detected in 14 of the 33 samples, but for some samples, concentrations were still high (Figure 2). Concentration of viable *Ascaris* eggs after drying was reduced to 11±10 eggs per gram total solids. Based on decay followed in a drying bed, pathogen concentrations could be estimated for an extended period of drying (Figure 2).

The microbial quality of sludge to be used as fertiliser is not regulated in Uganda and no national guidelines exists. Comparing the microbial quality in this study with the WHO *Guidelines for the safe use of wastewater, excreta and greywater*[4], the Lubigi sludge would after the currently practiced drying times (4-8 weeks) not meet the requirements for unrestricted use of faecal sludge (<1000 *E. coli* and <1 viable ova per g TS) (Box 1). However, implementing the intended drying time (24 weeks) could make the sludge of Lubigi comply with the limits for unrestricted use. If concentrations for unrestricted use are not met due to the shorter drying period, additional barriers should be considered (Box 2). Benefits of reaching the concentrations considered safe for unrestricted use during the treatment would be better control of the microbial risks and reduced risk of disease transmission for farmers.

High risk of illness for treatment plant workers

Our study estimated that sanitation workers are at high risk of infection due to their continuous exposure, in particular to raw sludge. Mitigation measures should be adopted such as the use of protective equipment, in particular masks or face shield to avoid involuntary ingestion. Eating and drinking away from the sludge beds and after appropriate handwashing could also decrease infection risks for workers. Current deworming frequency of workers, every third month, should continue.

Does the application of sludge pose a risk to farmers?

The use of sludge with the current drying times poses a risk for farmers with an estimated risk of illness from infection with disease causing *E. coli* and *Ascaris* of 2 and 1.4 in 100 farmers yearly, respectively. This and other studies estimate a higher risk of infection for farmers that are using sludge as fertiliser compared to not using it. However, the field sampling in this study showed the presence of *E. coli* and helminth ova also in fields fertilised with mineral fertiliser or animal manure, which indicates that there are sources of pathogens in farmland and crops other than faecal sludge that have to be considered. Measures to reduce the risks for farmers using the sludge can be to extend the drying time of the sludge at the treatment plant or at the farm and using protective equipment (mask, gloves, shoes) when fertilising so that sludge contact is minimised.

Can consumption of fertilised crops cause disease?

This study assessed the risk from consumption of raw vegetables (leafy greens and cabbage) as a worst-case scenario. Sludge fertilisation (with current treatment times) would theoretically result in 64 and 15 out of 100 consumers yearly being ill from *Ascaris* infection by the consumption of leafy greens and cabbage, respectively.

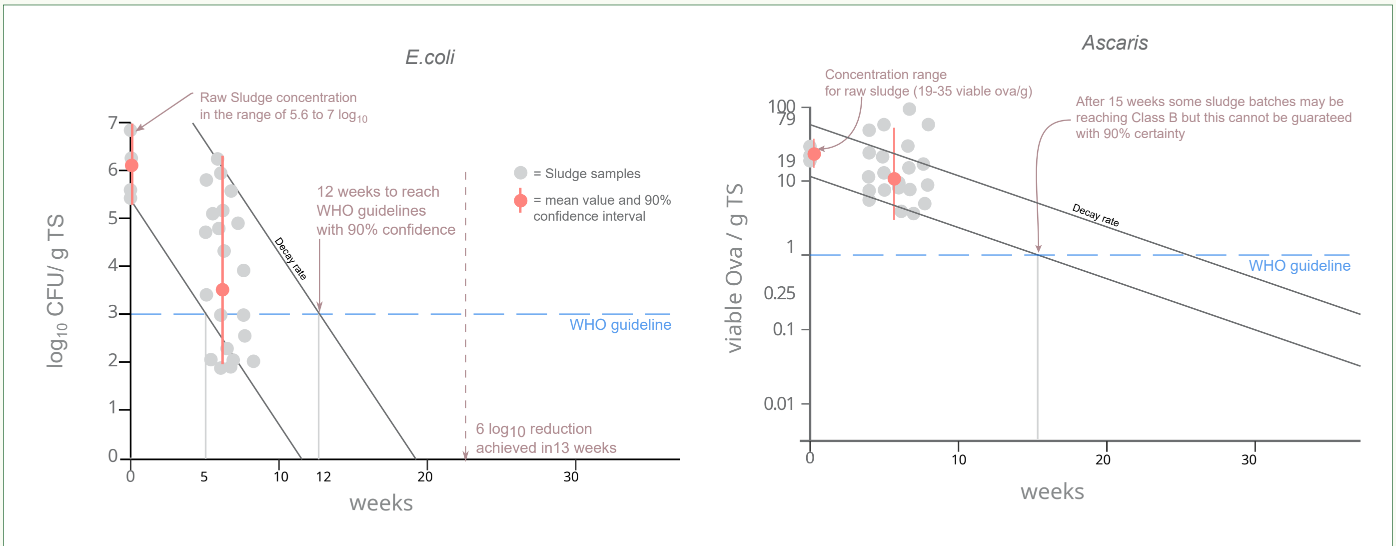

Figure 2: Decrease of *E. coli* (a) and viable Ascaris ova (b) concentrations during sludge drying with the drying time required to meet the WHO Guidelines suggestion for treatment reduction and product quality for unrestricted use of faecal material as fertiliser.

4 WHO, World Health Organisation, 2006. WHO guideline for the safe use of wastewater, excreta and greywater Volume 4

For disease-causing *E. coli* the risk was almost zero for both crops. However, environmental sampling indicated also other sources of pathogens than faecal sludge since microorganisms were detected in fields that had used other fertilisers and microorganisms were present on crops that were not found in the soil. Based on actual concentrations found on plants (disregarding if it was fertilised with faecal sludge or not), risk assessments showed that 100 out of 100 consumers of raw leafy greens yearly would be ill from infection with disease casing *E. coli* and *Ascaris.* Consumer practices of washing and cooking vegetables in general can serve as an important barrier for disease transmission (Box 2).

BOX 2: Safe use of faecal sludge

The WHO *Guidelines for the safe use of wastewater, excreta and greywater in agriculture* (2006) was published with the aim to promote safe use of excreta. The guidelines give general treatment and management recommendations based on risk assessment with the goal to give the same level of protection already set for drinking water (acceptable with 1 in 10 000 persons infected per year). However, the guidelines encourage countries to adjust to local circumstances as local prevalence of disease and other routes of disease transmission when defining tolerable risk levels. To achieve the health-based target of utmost 1 in 10 000 persons infected per year, the guidelines stipulate a collective aim of reducing the potential pathogen load by 8 $\log_{10}$ units compared with fresh faeces. This pathogen reduction does not have to be achieved by treatment only, but can be the result of several health protection measures together in a multi-barrier approach. Since waiting one month between fertiliser application and harvest is estimated to reduce pathogens by a 2 $\log_{10}$, a reduction by treatment of 6 $\log_{10}$ is considered safe for unrestricted use as fertiliser. With insufficiently treated excreta post-harvest processing is an important barrier to disease transmission.

Barriers reducing pathogen concentrations

* Following treatment guidelines for unrestricted use = 6 $\log_{10}$ reduction.
* One month between fertiliser application and harvest = 2 $\log_{10}$ reduction.
* Incorporation into soil = 1 $\log_{10}$ reduction.
* Postharvest processing as washing, disinfection, peeling & cooking = 1-7 $\log_{10}$ reduction

Conclusion and policy implication

Using faecal sludge in agriculture can provide a valuable source of nutrients as nitrogen, phosphorus and potassium, as well as micronutrients and carbon. Safe use of faecal sludge as fertiliser could be achieved by adopting mitigation measures at the different stages of the treatment and food production chain. At the Lubigi WWFSTP enforcing appropriate drying time will produce safer sludge and potentially reach the class for unrestricted use. Workers engaged in the treatment-food production chain should adopt protective equipment and adjust behaviours in order to limit exposure to possible pathogens.

Research partners

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