Transformation of solid and liquid wastes into fertilizer to minimize urban catchment pollution

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Background

Sub-Saharan Africa (SSA) is experiencing rapid population growth that is outpacing sanitation infrastructure development and service delivery especially in urban catchment areas. In Ghana, improved sanitation coverage is only 14% and about 47% of households dispose their greywater in street gutters, which drains to pollute water bodies. Only 16% of the 74 wastewater and faecal sludge (FS) treatment facilities in Ghana are functional while some 27% are not able to treat the waste to a level that render it safe for public health prior to discharge into the environment. Similarly, solid waste is poorly managed. The release of both solid and liquid waste into the environment is leading to increasing freshwater pollution and other sanitation related health risks and accelerating sedimentation in water bodies reducing their effective carrying capacities to absorb urban run-off and storm water.

There is therefore the need to look at alternative and appropriate solutions to these challenges. One of the solutions include nutrient, organic matter and water recovery from urban wastes to prevent nutrient run-off, catchment pollution and to divert pathogens from contamination pathways thereby enhancing recovery and reuse of useful resources. The International Water Management Institute (IWMI) has converted urban solid (food waste, FW) and liquid wastes (FS) through co-composting into various faecal derived fertilizer materials for use in urban and peri-urban crop production. Some strides have been made in developing the faecal derived fertilizer product and commercializing it, however there are still some research and knowledge gaps that need to be addressed to optimize the processes. Identified research/knowledge gaps include limited information on the nutrient and pathogen flow (including antimicrobial resistance) in the composting system.

The overall aim is to generate new knowledge and understanding on the recovery of nutrients and *E. coli* inactivation during treatment and use of fertiliser produced from faecal sludge and solid waste. The specific objectives are:

1. To determine NPK fluxes, losses and recovery efficiencies in a faecal sludge and solid waste treatment system.
2. To assess the effect of faecal sludge and solid treatment system on *E. coli* inactivation.
3. To determine the effect of storage conditions on inherent *E. coli* loads and nutrient levels of faecal derived fertiliser in storage.
4. To determine the direct and residual effects of one-off application of faecal derived fertiliser on soil nutrient, nutrient uptake, and yield of lettuce.
5. To assess the costs and benefits of the direct and residual effect of faecal derived fertiliser on lettuce growth and yield at farm level.
6. To recommend an approach to the assurance of the quality of product arising from faecal sludge and solid waste treatment processes.

The specific objectives of this project align well with the SWF mandate of furthering research into water and sanitation in Africa especially protecting catchment areas and contributing to the welfare of people. Objectives 1 and 2 are addressing the environmental pollution and inadequate sanitation arising from improper management and treatment of wastes such as faecal sludge and food wastes in local communities of Africa. It is expected that, these objectives will benefit the local community by minimising run-off of nutrients into freshwater bodies in target catchments by recovering nutrients from wastes, improving overall community health and reduction in sanitation related diseases by eliminating pathogens from contamination pathways and providing cleaner environment for the local community to thrive in. Objectives 3, 4, 5 and 6 are addressing consumer food safety and food security issues as well as improving soil fertility and crop yields of local smallholder farmers. The key challenge being addressed by these objectives is how the use of faecal derived fertilisers is safe, can improve soil fertility while meeting food security and food safety concerns of the local community. Smallholder farmers can benefit from more affordable sources of fertilisers such as this, which is expected to lead to increased farm productivity. This could lead to better nutrition and food security for the local community; increased productivity means more profits, improved livelihood, economic growth as well as job creation in local economies.

Methodology

The methodological approach was quantitative and involved different set-ups of experiments to collect primary data under different objectives to address the aim of this study. This followed a wholistic approach of assessing treatment of FS and FW to produce faecal derived fertiliser, the storage of it and the use of the faecal derived fertiliser in crop production.

Results

Objective 1 and 2: Main findings from this research show that for nitrogen as a plant nutrient, between 50-70% of it in the FS is lost at the dewatering stages of treatment. The remaining nitrogen comprising 30-50% in the FS mixes/combines with nitrogen from FW for the co-composting treatment stage. More than 50% of the combined nitrogen is lost during co-composting. Hence the nitrogen recovery efficiency of the treatment system is between 20-47%. Similar findings were obtained for phosphorus and potassium. It is therefore recommended that, there is the need for strategies, approaches and technologies that are low-cost, simple and environmentally friendly to reduce nitrogen losses as well as other nutrient losses during dewatering and composting stages of treatment.

For pathogens removal, the inactivation efficiency of the dewatering process was minimal (0-14%) for *E. coli* removal whiles the inactivation efficiency of the composting stage was 100% for *E. coli* removal. Further polishing of the effluent and leachate in stabilization ponds at the treatment plant recorded *E. coli* inactivation efficiency of 69-95% for the facultative pond and 99-100% for the maturation pond. It is recommended that, the composting stage and the maturation pond treatment stages should never be avoided in a FS and FW treatment system.

Objective 3: Process consistency is a cornerstone for consistent quality product for both producers, consumers, and regulators in the value chain and helps to instill confidence in its quality and acceptability. Main findings show that, *E. coli* levels were not consistent between the successive batches of FS and FW co-compost production. Variations between production batches were observed for electrical conductivity and nutrient parameters only. However, variations were observed for several measured parameters within batches. The measured coefficient of variations (CVs) within batches ranged between 0 – 125% and 3 – 111% for heavy metals and nutrients, respectively. In conclusion, there was less consistency in nutrients between successive batches and CV within batches was wide. Consistency levels for *E. coli* may not be an issue if pathogen inactivation is complete after production.

An oral presentation on these findings was made to the WASH sector stakeholders at the 21st AfWA Congress & FSM7 2023 in Abidjan, Cote D'Ivoire. Click here for the full published paper

Turning FS and FW co-compost batch pile.
Photo: Eric G. Nartey

Bags of FS and FW co-compost in storage.
Photo: Eric G. Nartey

Fertiliser storage is a critical stage in the production value chain as the duration and conditions of storage could alter the characteristics of the stored fertiliser. Main findings from my research show that, storage temperature and duration did not affect or influence indigenous *E. coli* regrowth in stored FS and FW co-compost (faecal derived fertilisers) whether enriched or non-enriched. Longer storage of enriched feacal derived fertiliser under lower temperatures results in losses of NH4-N (available nitrogen) concentrations. The research recommends that enriched faecal derived fertiliser should not be kept for more than four months in storage. Click here for the full published paper.

Objective 4 and 5: Main findings from the lettuce cultivation experiments show that, for the direct effect (first cycle), the highest lettuce yield of 27.9 t/ha was recorded in faecal derived co-compost fertilised plots (Soil + Co) followed by 11.1 t/ha for mineral fertilised plots (Soil + mineral) (Figure 1).

Lettuce cultivation on successive cycles on four different fertiliser treatment. Photo: Eric G. Nartey

The residual effect of faecal derived fertiliser improved lettuce yield by as much as 344% by the second cycle (Figure 1). Nitrogen uptake was highest in Soil + Co during the second cycle. *E. coli* was absent on lettuce leaves after successive cultivations implying the safety of crops grown with faecal derived fertilisers. It is however recommended that, there is the need for faecal derived fertiliser application on a repetitive cycle (after the second cycle) to ensure yield decline does not occur to cause economic loss to farmers.

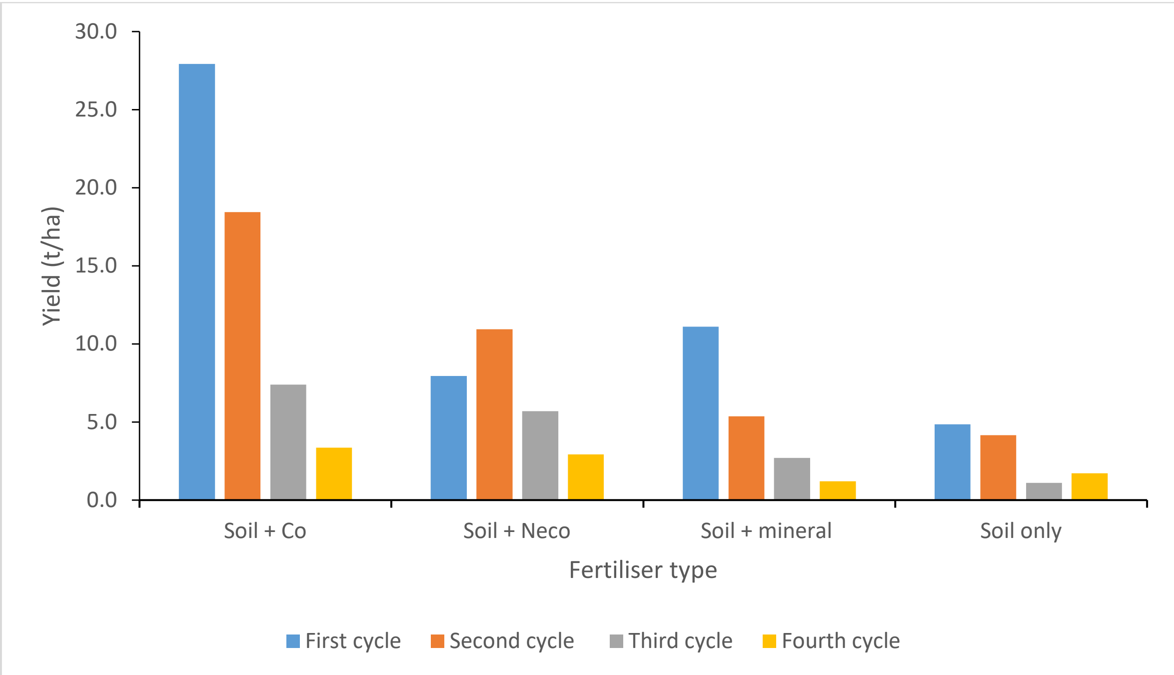

Figure 1. Yield of lettuce after four cultivation cycles in different fertiliser treatment

The faecal derived co-compost fertilised plots (Soil + Co) had higher gross margins/profit per cycle of cultivation (Table 1). Profit levels decreased for all fertiliser treatments for the residual effects except the enriched faecal derived plots cultivation cycle 2. The ROI for Soil + Co is 385.7 for cultivation cycle 1 and 309.2 for cultivation cycle 2.

Table 1. Gross margin and profits of different fertiliser regimes for four cultivation cycles

Parameters	No Fertiliser	Mineral	N-enriched	Co-compost
		Cultivation Cycle 1		
Gross Return (USD/ha)	4,410.00	9,990.00	7,110.00	25,110.00
Total Variable Cost (USD/ha)	1,168.37	1,639.93	1,915.76	2,829.86
TOTAL COST (USD)	1,176.26	1,647.82	1,923.65	2,837.75
Gross Margin (USD/ha)	3,233.73	8,342.17	5,186.34	22,272.24
		Cultivation Cycle 2		
Gross Return (USD/ha)	3,735	4,833.00	9,846.00	16,596.00
Total Variable Cost (USD/ha)	1,168.4	1,168.4	1,168.4	1,168.4
TOTAL COST (USD)	1,175.2	1,175.20	1,175.20	1,175.20
Gross Margin (USD/ha)	2,559.75	3,657.75	8,670.75	15,420.75
		Cultivation Cycle 3		
Gross Return (USD/ha)	973.23	2,447.71	5,157.4	6,668.6
Total Variable Cost (USD/ha)	1,168.4	1,168.4	1,168.4	1,168.4
TOTAL COST (USD)	1,175.2	1,175.2	1,175.2	1,175.2
Gross Margin (USD/ha)	-202.01	1,272.47	3,982.16	5,493.36
		Cultivation Cycle 4		
Gross Return (USD/ha)	153.9	111.6	2,642.86	3,025.05
Total Variable Cost (USD/ha)	1,168.4	1,168.4	1,168.4	1,168.4
TOTAL COST (USD)	1,175.2	1,175.2	1,175.2	1,175.2
Gross Margin (USD/ha)	-1,021.3	-1,063.6	1,467.66	1,849.85

The research recommends that smallholder farmers should be encouraged to use FDF Co to increase yield and farm income.

Impact on community and my career

The findings above show that there is a huge amount of plant nutrients lost during end-to-end treatment of FS and FW for compost in Ghana. These losses in fertilising value translates to huge economic losses that could be recovered from waste treatment. These findings will help faecal sludge treatment plant operators, research institutions and governments to jointly develop and implement strategies, approaches and technologies that are low-cost, simple and environmentally friendly to reduce nutrient losses during treatment of faecal sludge in Ghana and beyond.

My research on consistency of the faecal sludge co-composting process and the storage effect on product characteristics will help local faecal sludge co-compost producers understand and communicate with certainty the quality of their product right from the production process to storage. It would also promote user trust which includes small holder farmers, landscapers, the entire community in the use of the faecal sludge co-compost (faecal derived fertiliser). It would also facilitate replication and easy regulation by relevant authorities. Smallholder farmers would have more information and benefit from the findings of this research especially on the residual effect of faecal derived fertiliser application on crops. The findings show that the residual effect of one-time application of faecal derived fertilisers can support yields of up to 2 or 3 crop cultivation cycles. These will afford the farmers some cost savings on fertiliser purchase (especially mineral fertiliser which must be applied every cropping time), some savings on cost of labour to apply fertilisers etc. These savings directly translate into more income for the farmers and their families which will in turn improve their livelihoods.

This support from the Sue White Fund towards my PhD study was timely and delivered an enormous push in my research career. My long-term career goal is to be a researcher contributing to improved faecal sludge management linked to soil fertility improvement and sanitation in Africa. This has opened opportunities for interactions with other research institutes and industry partners, which are relevant professional network capital for my career. I am currently exploring post-doctoral fellowship opportunities or promotion to researcher level with the International Water Management Institute (IWMI) where I previously worked as a research officer prior my PhD.