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Challenges to the use of fertilisers derived from human excreta: The case of vegetable exports from Kenya to Europe and influence of certification systems

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ABSTRACT

Land degradation and inadequate faecal sludge management are two major issues in Sub-Saharan Africa (SSA). The transformation of human excreta into soil amendments and their wide-scale adoption could improve soil health and contribute to solving the sanitation crisis in SSA. There are however perception challenges around these fertilisers because of the potentially harmful components they contain such as pathogens and heavy metals, which can be removed with appropriate treatment such as composting. A major barrier to the wide scale commercialisation of human excreta derived fertiliser (HEDF) is the unclear regulations surrounding their use. The aim of this study was to identify barriers to the use of HEDF by farmers participating in the horticultural export market with Kenya as focus area since horticultural exports are a major contributor to the country's economy. Global GAP is the most widely adopted standard for quality assurance of horticultural crops and the use of human sewage sludge is currently not allowed on certified farms. Interviews with stakeholders along the food export chain highlighted the complex interactions that exist between them and showed that Global GAP certified farmers were not willing to use HEDF on their farms even if local regulations recognise treated sludge as a valid input to agriculture. Several countries (like the UK, Sweden, Australia and the USA) created specific certification or assurance schemes to improve public perception of biosolids. The creation of a similar assurance or certification scheme specific to fertilisers made from source-separated human excreta would be a step into formalising them as a product, establishing production procedures, limits on contaminants content as well as testing protocols. Such a certification scheme could increase the confidence of regulating bodies in HEDF and lead to their acceptance by global farming standards.

1. Introduction

1.1. Soil fertility and sustainable sanitation in SSA

Land degradation is a global issue that affects millions of people worldwide by compromising food security, inducing loss of livelihoods and even causing migration (Reed et al., 2011). It is estimated that 25% of all agricultural land is affected by soil degradation (DeLong et al., 2015). Soil degradation in Sub-Saharan Africa is a major challenge, which is primarily caused by agricultural intensification and expansion (Tully et al., 2015). Limited application of fertilisers in many parts of Africa is the leading cause of reduced crop productivity and depletion of soil fertility (Chauvin et al., 2012; Tully et al., 2015). Soil health can be restored with appropriate measures such as application of organic amendments to increase soil organic matter, essential for maintaining healthy soils (Bationo et al., 2007). An abundant source of organic matter in cities is organic residues such as vegetable wastes or human excreta.

Another issue prevailing in SSA is the safe treatment and disposal of human excreta, especially in urban areas. It is estimated that between 65% and 100% of sanitation in SSA is provided by on-site sanitation systems (Strauss et al., 2000; Blackett et al., 2014), which require emptying and appropriate treatment and disposal to prevent public health and environmental hazards. In areas where safe, effective and appropriate faecal sludge management practices are not in place, it is essential to create incentives locally for the collection and treatment of faecal sludge.

Human excreta have been shown to have a good fertilising potential, providing essential plant nutrients as well as organic matter contributing towards building soil structure and reducing erosion (Jonsson

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et al., 2004; Guzha et al., 2005; Begum, 2011). With an appropriate heat treatment such as composting, all harmful pathogens in human excreta can be eliminated to produce fertilisers safe to use in agriculture (Berendes et al., 2015; Piceno et al., 2017).

In SSA the use of human excreta derived fertilisers (HEDF) could contribute to solving two problems at once: the issue of low soil fertility as well as the problem of faecal sludge management, especially in densely populated areas. However, fertilisers derived from human excreta suffer from significant stigma and unclear regulations create a barrier to their use in agriculture. In Europe, the application of biosolids to land is regulated by the sewage sludge directive, which has been integrated into the member countries' legislations (European Commission, 1986). In the case of source-separated human excreta however, regulations are generally less clear on the reuse of treatment products, which has implications on farming practices and is an obstacle to commercialising HEDF. This research focused on the horticultural exports industry to investigate a specific case where unclear regulations of HEDF have an impact on their acceptability as an input material on farms.

1.2. Global food trade and its implication on farming practices

In an increasingly globalised world, food production and trade across borders are common practice and customer expectations have evolved accordingly. Changes in dietary habits, especially in high-income countries, have increased the demand for year-round availability and a wider range of fruits and vegetables, which fuel the global trade of fresh fruits and vegetables. Between 2000 and 2012 the volume of global agricultural exports increased by 60% and the value of global food trade tripled in the last decade (WTO, 2014; FAO, 2015).

The international trade of fresh vegetables started through wholesalers. In Europe however, this trend changed when the largest supermarkets gained the majority of shares of the food market in the 1980s and 1990s and hence got more involved in the direct procurement of produce (Dolan and Humphrey, 2000). Supermarkets now dominate the fruit and vegetable market in Europe, between 60 and 90% of produce is sold through supermarkets depending on the country (CBI, 2015). In the UK, the five supermarkets with the largest market share currently capture more than 75% of the grocery market (Kantar, 2017). About 14% of crops imported to the UK originate from Africa (DEFRA, 2007). There is now a tight relationship between large supermarket chains and horticultural exporters, they are dependent on each other and don't want to compromise their relationship (Dolan and Humphrey, 2004).

In many countries of SSA the export of fresh horticultural produce is becoming an increasingly important and lucrative practice. In low-income countries (LIC), it is more profitable for farmers to participate in the global trade of horticultural products than the local market alone (Reardon et al., 2009). In Sub-Saharan Africa (SSA) the three main countries exporting horticultural products are Cote d'Ivoire, South Africa and Kenya, together accounting for 90% of the region's fruit and vegetable exports (Diop and Jaffee, 2004; Asfaw et al., 2009). Kenya is the largest horticultural exporter to the EU in SSA, horticultural exports make up 70% of the horticultural earnings, the value of exports rises on average 10% per annum and is the third source foreign exchange from exports after tourism and tea (Kenya Horticultural Council, 2017). Given the importance of horticultural exports in Kenya and the presence of an SME producing and selling HEDF in Nairobi, Kenya was chosen as the focus for this study.

The development of a large horticultural industry in Kenya resulted in more reliance on larger farms. These large farms supply the majority of fruit and vegetables to exporters; considering the 4 largest exporting firms, in 1992 about 75% of exported produce was sourced from smallholders whereas in 1998 only about 18% of produced was supplied by smallholders for (Dolan & Humphrey, 2000). The UK is the destination for over 70% of Kenya's vegetable trade (Jaffee and Masakure, 2005). According to Otieno (2016) smallholder farmers have difficulties in competing with larger players due resource constraints: (i) their planting areas are considered too small by the contractor exporters, (ii) they have limited knowledge and little access to training on appropriate farming practices, (iii) due to unaffordability of top quality seed, they tend to grow less expensive varieties not preferred by client and get a lower price at farm gate, (iv) some contract relations with exporters were lost due to contract term violations, (v) their farming practices do not meet the minimum standards of Global GAP (Global Good Agricultural Practices).

Producing for export has implications on farming practices and product quality: produce needs to meet specific safety and quality standards. International good agricultural practice standards were created to guarantee the safety of produce traded internationally. A wide range of third-party accredited agricultural production standards now exist worldwide, the 24 major ones are described and summarised in SAI (Sustainable Agriculture Initiative) Platform (2009). The most widely adopted standard for guaranteeing the safety of produce is Global GAP which specify farming practices to minimise the risk of contamination in produce and protect farm workers' health. Global GAP is now present in more than 120 countries and has its headquarters in Germany (Global GAP, 2017).

Kenyan standards recognise treated sewage sludge as a valid farming input to be used as a fertiliser (KS2290:2011). One of the clauses in Global GAP however states that "no human sewage sludge can be used on accredited fields" (Global GAP, 2011), though it is unclear whether this includes compost derived from human sewage sludge. Vegetable exporters therefore usually ban the use of HEDF on fields growing crops for export as a precautionary measure, creating a major barrier to the commercialisation of HEDF and for recycling nutrients to soil in areas with large horticultural export sectors.

1.3. Issues of public perception of HEDF

Perception is one of the main challenges with products derived from human excreta (Beecher et al., 2004; Gale, 2007). Farmers generally do not have an issue with the origin of organic amendments if they have a positive effect on soil (Danso et al., 2002; Cofie et al., 2005; Moya et al., 2017). However, customer and regulator perceptions of products derived from wastewater or human excreta is a common barrier to their commercialisation. Buit and Jansen (2016) discussed the phenomenon of faecophobia in Ghana and acknowledge the influence of cultural aspects (ranging from farmers' region of origin, age, neighbours, ethnic background/religion etc.) when dealing with faecal derived fertiliser. Whilst the focus of study was in Ghana it has relevance to the wider SSA. According to Jewitt (2011), SSA cultures are generally characterised as faeces fearing or faecophobic. Jewitt (2011) also carried out a study focusing on the global South (with emphasis on India). In India handling of human waste is taboo for many Hindus and has been traditionally designated as a job for so-called "untouchable" or "sweeper" communities that have responsibility, under India's caste system, for disposing of human excreta. On contrary in Vietnam and China there is long tradition of using human waste in rice fields and night soil handling in unsewered parts of the country respectively.

According to Mariwah and Drangert (2011), selected households for the study were reluctant to handle fresh excreta whilst they do realise its potential as a fertiliser. However they are reluctant to apply it to soil and consume produce grown on associated land. The study found that communal approach to educate households including open discussions can be a way forward to tackle the challenge.

Danso et al. (2006) report that effective demand for composted faecal sludge is limited by transportation costs. There needs to be subsidies for composted faecal sludge if it were to match with abundant poultry litter which is cheap. Public private partnership play a key role in Ghana in facilitating subsidies for composted faecal sludge through provision of collection facility and composting technology.

Olufunke et al. (2008) report that whilst recycling in not high in the

agenda, a community based approach to tackle this challenge shows promise especially when related to faecal sludge application which is sensitive in certain ethnic groups

As a result of these perception issues, several countries have developed assurance schemes specific to biosolids. The Biosolids Assurance Scheme (BAS) in the UK for instance, ReVAQ in Sweden, the National Biosolids Partnership (NBP) in the USA or the Australasian Biosolids Partnership (ABP) in Australia and New Zealand provide a certification scheme for biosolids to increase customers' confidence in biosolids use in agriculture (Gale, 2007; NBP, 2011; L'Ons et al., 2012; BAS, 2016). It is proposed in this study that a similar scheme specific for HEDF could help reduce the barriers to its use.

1.4. Concerns with the use of products derived from human excreta on agricultural land

The main concerns over fertilisers derived from human excreta are generally pathogens, heavy metals and other chemical contaminants such as pharmaceuticals. This study does not cover aspects related to pharmaceutical products as it was not within the scope. Another emerging concern that has been reported beyond the treatment stage of human excreta is the regrowth of pathogens. Ward et al. (1999) for instance reported the regrowth of *Salmonella* as well as other pathogens after pasteurisation of sewage sludge digestate (Ward et al., 1999). It is believed that if a few pathogens survive in the end-product after treatment, under the right conditions they can start colonising the environment again. Another hypothesis is that pathogens can effectively become inactive or dormant under extreme conditions such as thermal treatment or dewatering but can become reactivated when the conditions become viable for microbial growth and pathogen recolonisation occurs (Higgins et al., 2007). Williams (2014) studied the use of competitive exclusion as a prevention mechanism for the regrowth of *E. coli* on treated sludge from centralised wastewater treatment plants: experiments showed that introducing certain microorganisms that competed with *E. coli* for growth effectively halted the regrowth of *E. coli* colonies and hence stopped recontamination of the treated sludge.

The aim of this study was to identify the barriers along the food chain to the use of HEDF in agriculture and formulate strategies to overcome them. The research activities were carried out in Kenya and several stakeholders along the horticultural export chain were interviewed.

2. Methodology

Stakeholder interviews were carried out as semi-structured interviews covering the topics of crop production and exports, agricultural certifications, fertiliser use and opinions regarding fertilisers derived from human excreta. These interviews were a means to explore the issues related to crop production, export and regulations. Stakeholders along the whole food chain between Kenya and the UK were interviewed: regulatory bodies, certification bodies, supermarket representatives and horticultural crop exporters as summarised in Table 1.

A criteria-based purposive sampling approach was followed to select respondents from exporting companies. The criteria to select respondents were as follows:

- Certified to Global GAP
- Have their own farms and subcontract smallholders as well (these exporters have a more detailed knowledge of farming practices and are familiar with differences between smallholder farmer and large commercial farms practices)
- Export to UK market
- Directly supplying to supermarkets (not via wholesalers) (these exporters are aware of supermarket-specific requirements)
- Supply to large supermarket chains in the UK and Europe.

Six interviews were carried out between December 2016 and March 2017, they were recorded and transcribed when respondents agreed. One of the interviewees did not agree to voice recording so detailed notes were taken throughout the conversation. Interviews were coded manually using the software NVivo (QSR International, 2015), initially using descriptive coding methods which is best suited for identifying the topics emerging from an interview (Saldaña, 2013). Codes describing the topic or principal argument were first applied to conversation sections without considering the connection of codes between different sections. These codes were then analysed and grouped to draw out emerging themes from the interviews and their frequency.

3. Results and discussion

The barriers to the use of HEDF by the largest horticultural producers in Kenya, vegetable exporters and in particular those who export to Europe were evaluated. Interviews with vegetable exporters in Nairobi highlighted the challenges faced to meet the existing regulatory and commercial demands for exporting horticultural crops. The main findings and recurring themes are summarised in the following sub-sections.

3.1. Accessing the horticultural export market requires compliance with a wide range of regulations and certifications

Imports into the EU are regulated by EU laws for product quality and safety, chemical residues and marketing requirements. Compliance with these regulations is the first hurdle for Kenyan farmers and exporters, and non-compliance leads to market loss for exporters.

> "*We have a regulating authority, KEPHIS [Kenya Plant Health Inspectorate]. Because it's the image of the nation, if they don't put regulations strict we will lose on trades with other countries. They are strict on pesticides, on seed materials, seed source, very strict*" Exporting company 1

Access to certain supermarket clients also requires abiding to additional private third-party certified standards. Global GAP dominates as the standard of choice by food retailers in the EU for assuring product

Table 1
Stakeholders interviewed along the food chain, organisation and stakeholder type are indicated.

Stakeholder organisation	Stakeholder group
EU commission DG Grow	International regulator on fertilisers
Biosolids Assurance Scheme	UK-specific biosolids certification
Exporting company 1 Large exporter (provider to 3 major UK supermarkets)	Fertiliser user in Kenya, certified to Global GAP
Exporting company 2 Large exporter (provider to one major UK supermarket)	Fertiliser user in Kenya, certified to Global GAP
Exporting company 3 Medium exporter (provider to continental Europe supermarkets)	Fertiliser user in Kenya, certified to Global GAP
Supplier Relationship Manager for a UK supermarket in Kenya	Large UK food retailer

safety and traceability and is now effectively a precondition for entering the European market (CBI, 2016). The cost of certification falls on the producers and adherence to Global GAP requires the adoption of specific farm practices and infrastructure, which can have significant cost implications.

> "*If you want to enter that market, it's up to you to get the certification*" Exporting company 1

Certification also requires a yearly renewal, which imposes significant recurring costs (Kariuki, 2014). Investment costs related to Global GAP certification can represent up to 30% of the annual crop income for farmers in Kenya (Asfaw et al., 2010). It therefore becomes challenging for smallholders to afford certification as well as apply and comply with all the control points and technical and administrative requirements set out by Global GAP.

Another constraint identified was a trend for increasing the number of certifications required from producers covering farm practices, labour conditions and fairness of trade, increasing certification expenses. One of the exporting companies interviewed reported spending up to 11 million Kenyan Shillings a year on certification costs (about 80000 GBP) and refusing new clients that required additional certifications. Currently worldwide there exist over 132 standards for the agriculture and fresh fruits and vegetables sector (ITC, 2017). The benefits of these standards are questioned by some: Oya et al. (2017) carried out a systematic literature review of studies that had analysed the effect of various agricultural certification schemes on the welfare of farmers and found that certified farmers did improve the income obtained from their produce but the effect on overall household income or children's educational level was not significant. Asfaw et al. (2009) on the other hand claim that certification schemes significantly increase farmers' financial performance although they admitted that certification mechanisms can leave out the poorest farmers from participating in lucrative export chains. Growth of the trade in fresh produce has however been highest in countries where the most standards are adopted. The adoption of certification schemes has also been shown to positively impact farmers' health by controlling the application and handling of chemicals on farms (Asfaw et al., 2010; FAO, 2015).

Certain supermarket chains require additional certifications, but all the exporters identified Global GAP as a benchmark for the other supermarket-specific certifications. Respondents saw these partly as a marketing tool for the supermarkets. The most up-market supermarkets are the ones that have the tightest constraints and tests but also offer the highest premium in crop purchase price, so the producers abide to these strict requirements.

3.2. Horticultural exporters depend on supermarkets and the criteria they set

Exporters have a close relationship with supermarkets. They both agree at the start of the season on the volumes that will be provided but the volumes purchased sometimes are reduced leaving producers with a surplus. All exporters interviewed said that the produce they grow for export is difficult to resell in the local market because crops such as fine beans or tender stem broccoli are not common in the local consumer's diet so most often these crops go to waste or used as animal feed. Exporters are therefore dependent on the supermarkets buying their produce and have to respect the criteria and standards they set.

3.3. Vegetable producers face challenges to increased productivity

Interviewees identified several factors that affected productivity on their farms as well as smallholders. Climate change was seen as a main challenge for smallholders for growing crops and one of the respondents even reported reducing their farm production area from 7 to 9 ha to 2–3 ha due to water shortages. The climate conditions in Kenya are favourable to the breeding of pests and interviewees felt that they were running out of options for fighting infestations due to increasing regulatory restrictions.

> "*…the weather has been very erratic. You can no longer plan well. Normally around this time we have heavy rains. The rains have been delayed, volumes have been distorted, there's a lot of quality issues […] you can't compare the yields now and ten years ago*" Exporting company 3
>
> "*Kenya is on the equator so we have a very conducive climate for most pest and diseases and […] it's very difficult to grow crops without using any spray unless you are doing under a controlled environment. Most farmers cannot afford greenhouse cover*" Exporting company 3

The reduction in crop productivity was also coupled with high volumes of crops being wasted at the farm level because of cosmetic constraints set by the standards. Such cosmetic restrictions lead to large volumes of crops going to waste with one of the respondents reporting that over 40% of the produce was wasted at farm level. A study carried out on food waste in the horticultural export chain in Kenya by Colbert and Stuart (2015) reported that up to 50% of produce was rejected before export.

> "*…it's become a bit ridiculous in Europe like if it's not straight and a certain size then you can't sell in a supermarket*" Exporting company 3
>
> "*There is no difference in between the taste of a straight bean and the taste of a bent bean, it's the same taste. But these guys will all have these specifications, they will say that I want bean that are maybe 9–15 cm, if it is longer than that or shorter than that I can't sell it*" Exporting company 2

3.4. Exporters are pushed to innovate to increase their competitiveness but don't want to risk breaching certification terms

Exporters also expressed concerns with an increasing price of farm inputs, which is not matched by sales price increases, pushing them to innovate. Larger exporters are starting to provide post-harvest processing services or grow new types of crops to keep ahead of competition. One of the exporting companies even had a dedicated innovation team.

The need for improving soil health was expressed by one of the respondents particularly. They expressed the need for additional organic matter and pH regulation on their fields:

> "*Our soils are depleted, they are finished because of continuous use of inorganic fertilisers, they're done, they're tired […] we try to renovate, we try to close some farms and leave it for some time. The soil can't have it, you put an inorganic fertilizer, it doesn't work you go and check the pH is below five you know that's a very acidic and no crop will grow there.*" Exporting company 2

A company in Nairobi produces HEDF and found that up to 30% yield increase was observed with local application of HEDF to grow French beans. During interviews respondents were informed of this and photos of the compost production site were shown, highly mechanised and modern (mechanised mixer and mechanised windrow turning and watering). All respondents were interested in finding out more about the product, they however voiced a concern over Global GAP compliance if they used HEDF. Since the standard currently does not allow the use of treated human sewage sludge on fields, all respondents said they were not willing to use HEDF even if it had a positive effect of soil because of the potential loss of contracts.

> "*It's something that we cannot engage in. Unfortunately, Global GAP takes preference*" Exporting company 3

The supermarket representative interviewed thought that if the HEDF are made up to standards and safety assurance, they use could maybe be allowed, but only if it was approved by Global GAP. One of the respondents also voiced a concern over the perception of HEDF and the willingness of farmers to use them. There is however evidence that

local farmers are willing to use HEDF if they have a positive effect on their soil and are affordable (Danso et al., 2002; Cofie et al., 2005; Moya et al., 2017).

The general impression from respondents was that the modification of Global GAP standard is not impossible; the standards are reviewed regularly and open to consultation by technical groups. There seems to be a possibility of dialogue: each country has technical groups who are consulted prior to changes to the standard. Sustainability is a key issue for Global GAP so the use of HEDF could be seen as beneficial. Exporters suggested that lobbying to Global GAP could be possible with appropriate evidence of the safety of HEDF.

3.5. The need for more sustainable fertilisers is recognised

Despite reservations and lack of clarity towards biosolids, there is a global recognition for the need to produce more sustainable fertilisers. The EU directive on fertilisers is currently being updated (EPRS, 2017). One of the key drivers for the fertiliser regulation update is to promote the circular economy. The aim of the European Commission is to increase the sustainability of European agriculture and reduce dependency on imports from outside the EU for fertilisers (European Commision, 2015). This is especially the case for phosphorus since all the mineral resources are outside the EU and in geopolitically sensitive areas. Another key issue is the accumulation of heavy metals in European soils, especially cadmium, which is a by-product from phosphorus extraction – (Nziguheba and Smolders, 2008). Organic residues are a valuable source of phosphorus and the EU Commission stakeholder interviewed explained that the aim of the EU is to encourage their recycling to land by increasing the value of organic fertilisers through regulations. They recognised a need to "*create a level playing field between the mineral fertilisers and the organic ones*".

Sewage sludge however is not currently included in the EU's 'end-of-waste' criteria, which define materials that cease being considered wastes and are eligible as inputs for other processes. A report in 2014 recommended sludge not to be included in the EU end of waste criteria, creating a barrier to the production and commercialisation of composts derived from sewage sludge (Mininni et al., 2015). The EU interviewee recognised that there is a fear of contamination with persistent organic compounds from sewage sludge, which are not regulated yet so currently sewage sludge is not listed as a potential input for fertilisers. The view for source-separated human excreta however was different, they admitted that HEDF didn't fit into a specific category at the moment and perhaps could be included as an animal by-product. This highlighted the grey area which HEDF fall into with regulations.

The respondent from the EU Commission also recognised that private standards are often more efficient at achieving specific outcomes and more powerful than regulations with stricter implementation checks. Their opinion echoed that of the Kenyan exporting companies: unless private certification schemes such as Global GAP change their stance on the use of HEDF, it is very unlikely that farmers trading with supermarkets will adopt them.

In this work, a small component involved soil analysis of farms that had received HEDF and the results were encouraging in terms of safety (from a pathogen and heavy metal perspective) of its use in horticulture. The results as detailed in Moya (2018) on safety aspects explored in this study is not exhaustive and need to be considered as preliminary, needing further long-term validation.

Other similar studies comparing the effect of soil amendments derived from sewage sludge had longer time frames of 4 years (Odlare et al., 2008), 16 years (Mantovi et al., 2005), 22 years (Zaman et al., 2004) or 25 years (Charlton et al., 2016) for instance. After 4 years of crop trials with different fertiliser applications, Odlare et al. (2008) found few trends or significant differences in soil chemical and biological properties between plots treated with a range of fertilisers: Municipal Solid Waste (MSW) compost, digestate from MSW anaerobic digestion, digestate from sewage sludge digestion, cow and pig manure and chemical fertilisers. They did however see differences in soil microbial processes such as ammonia oxidation rate and nitrogen mineralisation capacity and suggest these as better indicators for short term effects of fertilisers derived from organic wastes on soil. Mantovi et al. (2005) saw significant increases in organic matter, nitrogen ($p \leq 0.01$) and available phosphorus ($p \leq 0.001$) in soil as well as significant increases in nitrogen ($p \leq 0.01$), phosphorus ($p \leq 0.001$), zinc ($p \leq 0.001$) and copper ($p \leq 0.01$) content in the wheat crops grown in plots treated with three different fertilisers derived from sewage sludge compared to plots treated with chemical fertilisers only. They found a significant build-up of zinc and copper in top soils of plots treated with the fertilisers derived from sewage sludge but concentrations remained below regulatory limits. Zaman et al. (2004) found that fields that had received sludge-derived composts had significantly higher concentrations of total nitrogen and carbon as well as soil microbial biomass than fields treated with chemical fertilisers. Charlton et al (2016) in a meta-analysis study on impact of heavy metals from biosolids on soil microbial biomass found a negative impact related to Cu with signs of recovery after 6 years but no effect from treatments related to Cd.

Options to use chemical fertilisers is preferred as it is well characterised and largely classed as safe mainly from a pathogen perspective but is not free of contaminants such as cadmium (and other heavy metals) in phosphorus fertilisers. Other important factors that are also important to consider include better irrigation system if suitable to the crop, seed vigour, more resilient crop variety to pest and disease, reduced inputs such as fertilisers, mechanisation to harvest crop to minimise wastage and better cold storage to minimise post-harvest lost.

3.6. The value of biosolids-specific assurance schemes

In the UK, nearly 80% of biosolids are applied to soils following Safe Sludge Matrix guidelines, 75% of which are applied to agricultural land (UKWIR, 2015). Nevertheless challenges remain in terms of perception and risk to the produce which resulted in development of the Biosolids Assurance Scheme (BAS) to ensure that its recycling into land is transparent and subject to external controls (Water UK, 2013). This initiative came from the Water Utilities to increase customers' confidence by compiling regulations, codes of practices and best practice guidelines to provide evidence and assurance of the quality of biosolids they produce. Several stakeholders along the food chain were actively involved during the creation of the BAS to ensure their concerns were addressed and produce a scheme that met their requirements and provided the assurance they need.

"*It's about direct reassurance to the people who matter*" BAS creator

The creators of the BAS admitted that there are still major barriers for widespread use of biosolids in agriculture. In the UK currently biosolids are only applied to 1.3% of the total agricultural land (though this is mainly limited by sludge availability) and to combinable crops, not to any vegetable crops.

"….. *almost nothing goes anywhere near any vegetable crop by a long mile.*" BAS creator

The use of biosolids directly onto fields growing vegetables is still controversial and not accepted at present. Respondents were of the opinion that food retailers would not allow the use of biosolids on farms that they purchase from.

"*Really is more about a perception issue than a science issue.*" BAS creator

The creation of BAS seems to have had a positive effect on the acceptance of biosolids for agriculture in the UK but their application remains limited to certain crops. It is suggested that a similar scheme could be developed for HEDF to increase confidence in the quality and safety of these products and therefore increase their acceptance from farming standards and regulatory bodies. Certification of HEDF could

also increase the willingness to pay for compost as Danso et al. (2017) found in Ghana.

The focus of this work has been on the export market, hence that is why emphasis is not on small holders. In our opinion, use of HEDF amongst small holders needs a community based approach to educate and inform them of its benefits. There cannot be a compromise to the quality of the composting of HEDF to ensure that its safety in terms of pathogen and contaminants are minimum to instil confidence in the users.

The recommendations for the smallholders is to engage closely with extension officers and fellow farmers to learn from and each other in a community approach to ensure safe use of HEDF is implemented.

4. Conclusion

The production of fertilisers from source-separated human excreta for use in agriculture provides an incentive for collecting and treating faecal sludge as well as an addition of organic matter to soil, both of which are needed in many low and middle-income countries. The production and use of HEDF in Kenya could help solve the issue of sludge management in urban slums and improve the fertility of organic matter depleted soils. Several barriers were however identified in this study for the adoption of HEDF in Kenya. The largest agricultural producers are oriented towards exporting crops and are required to abide by international certifications to be able to trade with most supermarkets, Global GAP being the most widespread standard. Interviews revealed that vegetable exporters face issues of crop productivity and decreasing soil health but can't innovate outside the boundaries set by the standards. It is unclear whether the use of HEDF on certified farms is allowed at present so producers of horticultural exports are not willing to use them on their fields. Local regulations in Kenya recognise sewage sludge as a valid input for organic fertilisers but private standards have more weight in defining farmer practices. Unless the main standard-setting body, Global GAP, explicitly allows the use of HEDF, it is unlikely that these fertilisers will be adopted by farmers producing for export.

Interviews with regulators highlighted their main concerns with the application of biosolids: soil contamination with heavy metals (especially cadmium), pathogens and pharmaceuticals. One of the recurring opinions that was found throughout the interviews was that not enough was known about the HEDF and their effect on soil and additional tests and experiments were needed.

The use of biosolids commonly faces prejudices and negative public perception. Standards specific to biosolids have been developed in several countries to improve the perception of these fertilisers and increase their use. A similar scheme specific for fertilisers derived directly from human excreta from dry toilets could be beneficial for lifting a barrier to their use and provide a safety and quality assurance for this type of soil amendments. This assurance would be achieved through a set of requirements and controls ensuring product safety along the whole production chain and provide evidence to all stakeholders along the food chain of the safety using HEDF. The creation of a certification scheme would give more legitimacy to HEDF as a product and would help in lobbying for the inclusion of HEDF in regulations and standards.

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