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Quantifying the Economic Benefits of Using Human Excreta-derived Plant Nutrient Sources: "LaDePa" Pellets and Struvite

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ABSTRACT The paper advances the argument that indigenous approaches to waste management could be applied to mitigate contemporary challenges facing local municipalities in provision of sanitation services and contribute to improved agricultural productivity. The paper determined the economic feasibility of human excreta – derived plant nutrient sources Latrine Dehydrated and Pasteurization ("LaDePa") as a soil conditioner and nitrogen source; and Struvite as a phosphorus source for maize, wheat and sugarcane production. The results showed that the use of Struvite as a phosphorus source was financially viable. It was found that LaDePa pellets as sources of high energy density materials (HEDMs) and Struvite have environmental benefits, and improved soil texture and water retention capacity. Future studies should assess the impact of HEDMs use on sanitation or effects on waste treatment plants. This will help to determine the best way to use these HEDMs and improve both the livelihoods and some economic factors.

INTRODUCTION

The marginalisation of indigenous knowledge in its contribution to sustainable solutions to environmental challenges and management is reflected in the issue of waste management facing municipal authorities particularly in Sub-Saharan Africa (SSA) including South Africa. These countries are faced with major challenges with regard to the provision of adequate sanitation facilities in urban and peri-urban settlements. A survey on government-subsidized low-cost settlements in Cape Town, South Africa, showed that most of the houses have at least one informal dwelling at the backyard which have no or poor sanitation facilities (Govender et al. 2011). Only forty-two percent of the toilets were working, which may be a health hazard or pose disease outbreaks. Some of the settlements were located in high wetland and often flooding areas (Mels et al. 2009) making human excreta an environmental hazard. In eThekwini municipality, Durban, South Africa, studies on the impact of increasing water and sanitation facilities on the environment showed that with population increase of about 200,000 new customers both urban and peri-urban who require sanitation services, the municipality would have to consider various options such as enhancing the capacity of the existing sanitation facilities, water recycling and construction of new infrastructure (Friedrich et al. 2009).

However, the costs in terms of infrastructure development and maintenance in efforts to enhance the capacity of the existing sanitation technologies (specifically centralized water-borne systems) can be expensive and unsustainable. The topography and long distances from where these informal settlements are located to the existing sewerage networks means that connecting these areas to the main sewer lines is difficult and can be expensive. The use of dry (waterless) sanitation technologies and decentralized systems and the processing of waste into useable fertiliser products could provide viable and practical and sustainable solutions to the problems of sanitation provision in urban settings.

In the context of indigenous knowledge systems, Dring (2015) revealed that prior to the introduction of synthetic fertilizers, African local farmers like in other parts of the world, used human manure as a form of fertilizer. Human manure was mostly applied to small-scale vegetable plots and other rain-fed household crops. This preference for human manure as a fertilizer was based on the belief that it increased productivity and enhanced flavour of the crops. This paper discusses the way this indigenous approach to waste management could be applied to mitigate contemporary challenges facing local municipalities in provision of sanitation services and contribute to improved agricultural productivity.

The objective is to demonstrate that wastes generated from dry sanitation systems and processed into fertilizer products could provide alternatives to chemical commercial fertilizers if they can be shown to be cheap and effective. The use of chemical fertilizers to address the problems of poor soils in SSA is extremely low (8 - 12kg/ha/yr. compared to 303 kg/ha/yr. in East Asia and 107 kg/ha/yr. in North America) (Sommer et al. 2013). Cultivation practices common among smallholder farmers further contribute to soil degradation and loss of fertility by nutrient mining (unreplenished removal by crops of soil nutrients such as nitrogen (N), phosphorus (P) and potassium (K)). Nutrient mining across Africa ranges from 9-88 kg/ha/year for N, P and K. Organic nutrient sources (for example, crop residues and animal excreta) are also not commonly available. Therefore farmers in SSA including South Africa have to work harder to produce less and crop yields continue to decline.

Furthermore, although fertiliser use in South Africa is comparatively higher than the rest of SSA, the current level of fertiliser production in the country is not sufficient to meet all production requirements, hence South Africa imports huge quantities of agricultural fertilisers (Mostert 2013). LaDePa and Struvite may be potentially low cost, effective and safe fertiliser inputs since they are produced from readily available raw material and their use may result into reduced commercial fertilizer imports into the country.

Studies in other cultural societies using human manure in agriculture demonstrates that there is increasing acceptability and practice of the recovery of nutrients from human waste and processing them into useable waste products for crop production (Dring 2015). The World Health Organisation (WHO 2006) and the International Water Management Institute (IWMI) have developed guidelines that inform the use of treated wastewater and wastes in agriculture (IWMI 2014). Ma et al. (2014) conducted an economical-environmental study with animal waste material in China and observed that composting of animal wastes for effective cropland application were cost effective and also environmentally efficient which in addition also produced biogas.

Another study by Mnkeni and Austin (2009) was conducted in Ntselamanzi, Alice, South Africa to determine the efficiency of using human excreta compared to goat manure and NPK fertilisers on cabbages, human excreta produced greater yield compared to goat manure because it had high phosphorus and potassium levels. However, due to its low nitrogen levels, the yield it produced was less than that of NPK which had greater nitrogen hence it had to be applied with another nitrogen source. Human manure was also found to have an effect of raising the soil's pH hence it is recommended for crops grown under acidic soils due to its liming effect.

With respect to urine, studies have shown that for easy collection of mineral elements such as nitrogen and phosphorus, urine can be collected separately independent of the solid wastes by the use of double flashed urine-diverting toilet and solid wastes from the flush water by means of two parallel Aquatron (Vinnerås and Jönsson 2002). This can lead to very high extraction rates of nutrients from the faecal sludge, with up to ninety-one percent, eighty-three percent and fifty-nine percent extraction of nitrogen, phosphorus and potassium respectively. Apart from fertilisers, faecal sludge wastes can also be effectively used for bio-oil production though pyrolysis (Kim and Parker 2008).

The Struvite production process is very cost effective as it can be done onsite manually (Rhoton et al. 2014). The collected urine is placed in a tank into which a magnesium dosage is added to produce a phosphorus precipitate, that is then collected and dried to become Struvite. The drying process of this Struvite precipitate destroys most of the pathogens present in the urine (Udert et al. 2014).

The LaDePa process includes emptying and collection of the pit latrine material depending on the pit conditions and the environment sludge characteristics. The sludge is then transferred firstly for storage which is followed by pre-treatment and then processing of the sludge into LaDePa pellets. However, generally, wastes do have to undergo treatment processes thereby developing them into pathogen free products that can be used as plant nutrient sources (Lang and Smith 2008; Decrey 2015). The costs of emptying, collection, storage, transportation, treatment and factors that may influence them are largely unknown in eThekwini and should be quantified.

Production of agricultural plant nutrient sources from faecal sludge could be cost-effective (Fernández et al. 2007). Kuai et al. (2000) and Kone (2010) noted that the production of plant nutrient sources from faecal sludge can either be economically viable but can also be economically unfavourable if the economic benefits obtained after processing the waste material are lower than the costs incurred during the production processes.

The economic benefits and value of using LaDePa as a plant nutrient source to supply nitrogen and amend soil and those of Struvite in supplying phosphorus had not been properly assessed in South Africa. They have not been quantified in terms of the yield produced, the efficiency of the potential fertilisers compared to commercial fertilisers and also determining the costs involved in the farm production processes (Uggetti et al. 2011).

Management of these HEDMs in agricultural activities is important in preserving the environment in high-input systems to prevent underuse which leads to plant nutrient deficiencies or overuse which may lead to environmental degradation (Dubeux 2005). Though they have low nitrogen levels, organic plant nutrient sources are good for conservation agriculture to improve soil organic matter (Dube et al. 2012; Kassie et al. 2013). To meet the crops' nutritional requirements, additional nutrients from other sources will be needed. Hence, LaDePa has the potential of performing well in conservation agriculture, also with the benefit of it being a soil amendment.

Agriculture has been known to release chemicals that destroy the environment and contaminate groundwater (Legg and Viatte 2001). Various studies have conducted life cycle assessments (LCA) in an effort to determine the effects of certain agricultural practices. However, valuing environmental damage due to agricultural chemicals by placing monetary values remains a challenge. To make the analysis more complete, the environmental benefits of HEDMs and the environmental costs of inorganic fertilizers have to be estimated.

The environmental impact of recycling nutrients in human excreta to agriculture, they discovered that wastewater treatment plants needed a lot of energy and chemicals to remove nitrogen and phosphorus as these nutrients lead to eutrophication and soil acidification. However, using source-separated recycled nutrient rich wastewater for agriculture proved efficient for conserving energy, cost saving and decreasing global warming potential (GWP). They also discovered that recycled wastewater plant nutrient sources were releasing high levels of ammonia, hence they had to be further developed to capture the full benefits of using wastewater as an agricultural plant nutrient source.

Given this background, the purpose of this study was to assess the economic favourability of using the two potentially new fertilisers (Latrine Dehydrated and Pasteurisation ("LaDePa") Pellets and Struvite) for crop production through a cost-benefit analysis. This was achieved by determining the amount of commercial fertiliser that should be applied to supply major nutrients, nitrogen, phosphorus and potassium to a specific crop on a given area and determining their costs and comparing them to the costs using LaDePa and Struvite as fertilisers to achieve the same yield levels. In doing so, the study sought to:

- To determine the quantities LaDePa, Struvite and a range of few selected commercial organic and inorganic plant nutrient sources to be applied on a per hectare basis to meet the nutrient requirements of the crops maize, wheat and sugarcane,
- To determine the total cost per hectare of using LaDePa, Struvite and other selected commercial organic and inorganic plant nutrient sources for the production of maize, wheat and sugarcane, and
- To analyse the change in farm income that occurs after replacing the least cost commercial organic and inorganic plant nutrient sources with LaDePa and Struvite.

RESEARCH METHODOLOGY

The Conceptual Framework

The challenge of waste disposal has presented an opportunity of sustainable development as these wastes can be collected to manufacture plant nutrient sources. This study sheds light on an alternative to the conventional waste disposal routine through a potentially economical way of providing the necessary plant nutrients to the crops from HEDMs. These nutrients will supplement the existing sources in an effort to reduce fertiliser imports and increasing the level of agricultural output ensuring food security. This also relieves pressure on the existing sanitation facilities that cannot serve the continuously increasing urban population through the use of decentralised sanitation systems which also makes waste collection for processing easier.

The market prices of plant nutrient sources and their nutrient composition help to determine their economic costs and hence evaluate their economic benefits. The costs of using these plant nutrient sources were calculated and analysed to determine their economic feasibility. Partial budgets were then used to make total cost comparisons of these HEDMs with the commercial fertilisers to determine if it was financially viable to use them in place of the commercial fertilisers. These were used to determine what effect a suggested change in a part of the farm business would have on the level of farm profitability or returns (Standard Bank of South Africa Limited 2005). Since LaDePa pellets and Struvite have not yet been used under field conditions, their nutritional and economic effectiveness under field conditions is yet to be determined.

Data Sources

The observable market prices for the other commercial fertilisers that were used in this study were obtained from the COMBUD 2011-2012 copy of field crops. All data concerning "LaDePa" pellets and Struvite that was used in this study was acquired from the University of KwaZulu-Natal Pollution Research Group (UKZN PRG) in Durban who own a LaDePa machine and a Struvite plant. The prices of the HEDMs were derived as a function of the production costs encountered, for example, pit emptying and collection, transportation, treatment, processing and manufacturing, capital and operational costs and also the producer's mark-up, marketing costs and any other costs incurred during the process. However, the market prices for the HEDMs were based on theoretical basis as they have not been supplied to the market yet.

Data Collection and Processing

The quantities of different plant nutrient sources required for crop production were estimated without any field trials. The quantity of a specific nutrient source that had to be applied to a specific crop per hectare was estimated based on the nutrient requirements of the respective crops for optimal productivity and the nutrient compositions of the plant nutrient sources. If the plant nutrient source could not provide any of the three basic nutrients adequately, a pure fertiliser would be added to make up for the deficit.

From the nutrient sources unit price and the quantity to be supplied per hectare for optimal productivity, the cost per hectare was calculated, {price per kilogram (R/kg) × amount required (kg) per hectare} giving the cost of using that nutrient source. Assuming that all costs of production and the yield to be produced was the same, total cost comparisons on the organic (LaDePa) and inorganic (Struvite) nutrient sources with the least cost commercial organic fertiliser and the least cost commercial inorganic fertiliser for economic viability was done.

The following assumptions had to be made to do the subsequent cost estimations:

- The nutrient requirements of the crops for N, P and K of per unit area for optimal productivity were fixed based on agronomic recommendations for optimum productivity.
- The plant nutrient sources are applied to supply the exact required amount of nutrients by that specific crop such that any nutrient source applied will produce the same yield.
- The yield and the income generated by a crop obtained from using any given nutrient source is the same.
- Plant nutrient sources applications are done on the soil of the same type and that these soils have the least or no nutrients.
- The nutrient sources applications aim at supplying the optimal amount of nutrients to the soil that will all be taken up by the crop for maximum productivity.
- All other factors for crop growth are available at their maximum required quantities, for example, water (irrigation), and light etc.

Table 1 indicates the structure of the partial budgets that were used for financial feasibility assessment.

$$\text{The Expected Change in Income} = (c-d) - (a-b) = c-d - a+b = c+b - d-a$$

However, we assume that there will not be any forfeited income for not using a commercial fertiliser or additional income when using LaDePa or Struvite since the produced yield will be the same, which makes the difference between

Table 1: A partial budget structure for plant nutrient sources costs in comparison to inorganic fertilizers

Forfeited income		*Additional income*			
Nutrient Source	*Amount (R/ha)*	*Nutrient Source*	*Amount (R/ha)*	Expected Income Change (R/ha)	Comment
Not using the lowest cost Organic or Inorganic	a	Using La DePa or Struvite	C		
Reduced costs	*Additional costs*	*Nutrient Source*	*Cost (R/ha)*		
Nutrient Source	*Cost (R/ha)*				
Not using the lowest cost Organic or inorganic	b	Using La DePa or Struvite	d		
Sacrifice	a – b	Gain	c - d	c + b – d – a	Positive → Acceptable Negative → Unacceptable

‘*a*’ and ‘*c*’ zero, that is, the expected change in income is *b* - *d*. Table 2 provides the reduced structure for the partial budget.

If the change in income is positive, then switching to using the HEDM is financially desirable as the reduced costs will be greater than the additional costs. However, if it is negative, the change would not be financially viable. Ceteris paribus, the purpose of this exercise is to assess the financial feasibility of HEDMs using the partial budget approach presented above.

Nutrient Sources and Plant Requirements

Inorganic Sources

1. **N: P: K_2:3:2 (22) - R 4.78/kg** (COMBUD 2012)

Contains 6.3% N, 9.4% P and 6.3% K.

2. **N: P: K_3:2:1 (25) - R 4.78/kg** (COMBUD 2012)

Contains 12.5% N, 8.33% P and 4.17% K.

3. **Lime Ammonium Nitrate (LAN) - R 4.28/kg** (COMBUD 2012)

Contains 28% N and is a pure nitrogen source.

4 **Potassium Chloride (KCl) - R 5.27/kg** (COMBUD 2012)

Contains 50% K and is a pure potassium source.

5. **Mono Ammonium Phosphate (MAP) - R 6.78/kg** (COMBUD 2012)

Contains 11% of N and 22% P.

6. **Single Superphosphate (SSP) - R 4.28/kg** (COMBUD 2012)

Contains 10.5% P and is a pure phosphorus source.

7. **Struvite - R 4.00/kg**

Contains 5.6% N and 12.6% P.

Organic Sources

8. **Gromor - R 3.75/kg**

Contains 3% N, 1.5% P and 1.5% K.

9. **LaDePa - R 3.00/kg**

Contains 3.37% N, 0.96% P and 0.19% K.

Table 2: The reduced structure for the partial budget

Reduced costs for not using		*Additional costs of using*			
The lowest cost organic or inorganic fertiliser	Cost (R/ha)	The plant nutrient sources LaDePa or Struvite	Cost (R/ha)	Income Change (R/ha)	Comment
x	B	y	d	b - d	Acceptable/Unacceptable

Source: Adapted from Table 1

Crops

Maize

Target Yield – 12 tonnes per hectare
Requires: 200kg N/ha
: 60kg P/ha
: 45kg K/ha

Sugarcane

Target – 20 tonnes per hectare
Requires: 190kg N/ha
: 30kg P/ha
: 200kg K/ha

Wheat

Target – 7 tonnes per hectare
Requires: 180kg N/ha
: 56kg P/ha
: 120kg K/ha

RESULTS AND DISCUSSION

Table 3 showed that LaDePa yielded the highest costs per hectare in all the three crops. LaDePa and the other organic plant nutrient source, Gromor Accelerator, had the highest production costs. This suggests that the organic plant nutrient sources are expensive to use compared to the inorganic plant nutrient sources. The least cost inorganic nutrient source in all the above enterprises was MAP which was followed by Struvite. The least cost organic nutrient source was Gromor Accelerator. MAP and Gromor were then used to assess the financial feasibility of the HEDMs.

The maize partial budgets in Table 4 which replaced Gromor with LaDePa resulted in an increase in costs that the costs saved, shown by the very high negative value of income change. This was also the case when MAP was replaced with LaDePa. This makes the change unacceptable as it increases the costs per hectare. Replacing Gromor with Struvite was favourable as it reduced the costs per hectare by R8 514.33 which makes the switch financially viable. However, replacing MAP with Struvite would slightly increase the total costs (R106.57). Though this move may be unacceptable, it shows that Struvite is almost a competitive plant nutrient source.

The trend shown in sugarcane partial budgets (Table 5) was the same as that shown in maize. Since LaDePa was the most expensive nutrient source to use in a sugarcane enterprise, using it in place of any other nutrient source would not be financially viable as shown by the negative values in Table 5. This shows that using LaDePa in a sugarcane enterprise will in-

Table 3: Costs per hectare of different plant nutrient sources for maize, sugarcane and wheat

	Plant nutrient source	*Cost per unit area (R/ha)*		
		Maize	*Sugarcane*	*Wheat*
7	LaDePa (organic)	18 836.76	12 711.57	18 648.02
6	Gromor Accelerator (organic)	13 542.86	11 278.94	15 713.99
5	Pure Fertilisers (inorganic)	5 977.14	6 2135.12	6 298.90
4	N:P:K_2:3:2 (22) (inorganic)	5 783.59	6 018.49	5 894.63
3	N:P:K_3:2:1 (25) (inorganic)	5 281.47	5 887.28	5 649.78
2	Struvite (inorganic)	5 028.53	5 733.93	5 413.53
1	MAP (inorganic)	4 921.96	5 707.55	5 314.05

Table 4: Partial budgets for the maize enterprise

Forfeited income		*Additional income*			
Nutrient source	*Amount (R/ha)*	*Nutrient source*	*Amount (R/ha)*	*Income change (R/ha)*	*Comment*
Gromor	13 542.86	LaDePa	18 836.76	**(-) 5 293.90**	Unacceptable
Gromor	13 542.86	Struvite	5 028.53	**8 514.33**	Acceptable
MAP	4 921.96	LaDePa	18 836.76	**(-) 13 914.80**	Unacceptable
MAP	4 921.96	Struvite	5 028.53	**(-) 106.57**	Acceptable

Table 5: Partial budgets for the sugarcane enterprise

Forfeited income		*Additional income*			
Nutrient source	*Amount (R/ha)*	*Nutrient source*	*Amount (R/ha)*	*Income change (R/ha)*	*Comment*
Gromor	11 278.94	LaDePa	12 711.57	**(-) 1 432.63**	Unacceptable
Gromor	11 278.94	Struvite	5 733.93	**5 545.01**	Acceptable
MAP	5 707.55	LaDePa	12 711.57	**(-) 7 004.02**	Unacceptable
MAP	5 707.55	Struvite	5 733.93	**(-) 26.38**	Unacceptable

crease production costs. Struvite, on the other hand, would be financially viable if it is replaces Gromor as shown by high positive change in the partial budget. However, when MAP was replaced with Struvite, there was a very small increase in production costs, (R26.38), which makes Struvite as competitive.

The results for wheat partial budgets (Table 6) also followed the same pattern as the maize and sugarcane enterprises. Due to its very high production costs, LaDePa cannot be used in place of either the cheapest organic plant nutrient source (Gromor) or the cheapest inorganic nutrient source (MAP) as it will increase the production costs and result in losses. Therefore, it is financially not viable to use LaDePa in the production of wheat. Using Struvite in place of Gromor acceptable but using it in place of MAP is unacceptable.

The organic plant nutrient sources, Gromor and LaDePa, had the highest production costs though their market prices were low because they often contain very small nutrient concentrations. LaDePa contains all the three basic nutrients required by the crops but has the lowest nutrient concentration hence large quantities have to be applied to meet the nutrient requirements of the respective crops. However, the organic fertilisers' benefits could be social and environmental relating to pollution management.

This would offset its relatively cheaper price and lead to more costs of production per hectare than the cost saving as a result of the replacement. Because Struvite was compared to MAP in the production processes, it became a second alternative after MAP. This made it financially unacceptable in the enterprises assessed since MAP was the lowest cost nutrient source in the production of all the crop enterprises considered.

Struvite, however, has proved to be very competitive, cost effective and more economical compared to all the organic and most inorganic plant nutrient sources considered. It was the cheapest in terms of price among all the inorganic nutrient sources and it contains high concentrations of both nitrogen and phosphorus. A farmer may consider using Struvite instead of MAP as the production costs difference is small especially in the sugarcane enterprise.

The production costs of using LaDePa and Struvite as plant nutrient sources will decline with increasing size of the farm due to economies of scale and economies of size. The farmer should, however, be aware of the diminishing marginal returns to the input as increased application of the input may result in deceasing output per hectare. Increasing scale will be more beneficial in the case of using the Struvite as its overall production costs were lower compared to those for LaDePa and almost the entire plant nutrient sources assessed for the three crops in this study. In sum, LaDePa has proved to be costly while Struvite has proved to be financially viable.

Table 6: Partial budgets for the wheat enterprise

Forfeited income		*Additional income*			
Nutrient source	*Amount (R/ha)*	*Nutrient source*	*Amount (R/ha)*	*Income change (R/ha)*	*Comment*
Gromor	15 713.99	LaDePa	18 648.02	**(-) 2 934.03**	Unacceptable
Gromor	15 713.99	Struvite	5 413.53	**10 300.46**	Acceptable
MAP	5 314.05	LaDePa	18 648.02	**(-) 13 333.97**	Unacceptable
MAP	5 314.05	Struvite	5 413.53	**(-) 99.48**	Unacceptable

CONCLUSION

The paper examined the marginalisation of indigenous knowledge systems in sustainable environmental waste management by quantifying the economic benefits of using human excreta – derived plant nutrient sources: "Ladepa" pellets and struvite. In the context of indigenous knowledge systems it was shown that prior to the introduction of synthetic fertilizers, African local farmers used human manure as a form of fertilizer. Human manure was applied to small-scale vegetable plots and other rain-fed household crops. This implies that such indigenous approaches to waste management could be applied to mitigate contemporary challenges facing local municipalities in provision of sanitation services and contribute to improved agricultural productivity. It was found that human excreta-derived nutrient sources such as Ladepa pellets and struvite as sources of high energy density materials (HEDMs) have environmental benefits, and improved soil texture and water retention capacity through the addition of organic matter and carbon. This has implications on climate change mitigation due to reduced greenhouse emissions and atmospheric temperatures.

RECOMMENDATIONS

The government should subsidize these human excreta-derived plant nutrient sources as agricultural inputs and also reduce fertiliser imports so as to facilitate adoption of HEDMs by farmers. Production of LaDePa should focus on making it more concentrated making it more effective in plant production. LaDePa can also be used together with another HEDM, Concentrated Nitrified Urine, which is highly nitrogen concentrated. The study recommends that contemporary challenges of waste management could be improved through building on indigenous knowledge systems. For instance the use of LaDePa and struvite could build on traditional way of using human manure for agricultural production. These sources of HEDMs should be further analysed to establish their market demand, cost competitiveness, product branding and storage properties. Furthermore, producers of indigenous-based HEDMs should consider the end user acceptance, health and safety issues, alternative market routes and the value they may add to the end users.

The study recommends the development of policy programmes which promote the use and production of indigenous-based HEDMs for increased and better sanitation, reduction of environmental contamination by human wastes, job creation, possibly environmental conservation and soil fertility boost. To maximise revenue, HEDMs should be used as products for niche markets such as the flower growing industry or be used as some kinds of special fertilisers. Future research on HEDMs use should also focus on the creation of other products from waste faecal sludge such as incinerated ash as a plant nutrient source, power cells from urine, purified urine as healthy drinking water or bio-oil for other uses. Concentrated Nitrified Urine, an HEDM, though not evaluated in this study, which is a rich nitrogen source, uses a lot of energy during its production. Alternative ways of reducing the energy requirements should be introduced so as to reduce the production costs and the final product market price.

HEDMs could be the world's future since they have shown their potential viability, meaning that their production should be increased. However scaling up will also require greater participation from the households, improving the collection methods and replicating the treatment and processing plants. If done well, the lower final product price will offset all the collection and treatment, public service and environmental costs. This is also a potentially high profit business in which the private sector may venture into through tenders or private investments. Future studies should assess the impact of HEDMs use on sanitation or effects on waste treatment plants. This will help to determine the best way to use these HEDMs and improve both the livelihoods and some economy factors.

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