Sewage as a source of plant macro-nutrients

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Human sewage can be a source of macro-nutrients for plants. In the UK over 100,000 hectares of agricultural land are beneficially treated with sewage sludge per year. However in many countries in the Global South this waste is not captured and used, depriving the land of a sustainable source of fertiliser.

Using Sierra Leone in West Africa as an exemplar country this Technical Article details the calculations and assumptions made by SOWTech to calculate the main plant nutrients which can be potentially found in the biofertiliser produced by treating human waste in a Flexigester V10.

Introduction

Biofertiliser is made from the anaerobic digestion (AD) of organic material. This Technical Article deals specifically with human waste collected from pour-flush toilets.

The use of human waste to fertiliser fields is not a new idea. The sludge for sewage treatment works has been used to fertilise agricultural land in the UK for decades. In 2007 in the UK over 100,000 hectares of agricultural land was treated with sewage sludge (ref. 1). In the Global South human sewage is seldom collected and rarely used as fertiliser.

The calculations presented here are for the three primary nutrients required by plants. It is acknowledged that these nutrients alone are not sufficient for healthy plant growth and that there are many other factors which affect plant growth and the health of the crop including water availability, seed variety, pests and disease. Plants also require other secondary nutrients (sulphur, magnesium and calcium) and a number of other micro-nutrients as well as carbon, hydrogen and oxygen for growth. Human waste does contain micro-nutrients but they are not considered here as there is limited published quantifiable data of their presence in sewage.

SOWTech are involved with projects for the collection and treatment of sewage in Sierra Leone and therefore that country has been chosen to illustrate the potential of sewage as a form of biofertiliser.

The Scale of the Potential in Sierra Leone

Part of the human system is that we need to get rid of waste products in the form of urine and faeces. In an ideal world all of this waste would be collected and treated. The population of Sierra Leone, as estimated by the World Bank (ref 2), is over 6 million people. This equates to around 3.3 million tonnes of sewage per year. Obviously at the present time it is unrealistic to use these figures due to the problems of collecting such waste. In this Technical Article we will focus on some of the areas that are more closely related to the Flexigester projects in Sierra Leone, namely Freetown, the country's capital; Bombali District, which is a rice growing area; and Makeni, the capital town of Bombali and close to a rice mill.

The populations of these areas are given in Table 1 below. Assumptions have been made as to the amount of waste produced per person per day and the amount of macro-nutrients in such waste. Details of these assumptions are given later in this article. The amount of macro-nutrients that could be recovered if the sewage was collected from various percentages of the population are given in Table 2.

Population of Sierra Leone	6,000,000
Population on Makeni	112,000
Population of Bombali District	440,000
Population of Freetown	773,000

Table 1: Population statistics for areas of Sierra Leone

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Percentage of population		tonnes N per year	tonnes P per year	tonnes K per year
From Makeni				
	25%	128	15	36
	50%	256	31	72
	75%	383	46	107
	100%	511	61	143
From Bombali district				
	25%	502	60	141
	50%	1,004	120	281
	75%	1,506	181	422
	100%	2,008	241	562
From Freetown				
	25%	882	106	247
	50%	1,763	212	494
	75%	2,645	317	741
	100%	3,527	423	988

Table 2: Potential nutrients available in t/yr from exemplar areas of Sierra Leone from the sewage output from different percentages of the populations in those areas

As can be seen from Table 2, the available nutrients that could potentially be recovered from human sewage in Sierra Leone to be used as fertiliser was it collected in usable form is large.

In a paper for GRID-Arendal (ref 4) they use Mauritania as a example of the savings that could be made. The paper states *"In Mauritania, which has a population of about 3 million, the excreta from the entire population is worth annually about EUR 25 million for the equivalent amount of chemical fertilizer"*. This illustrates the potential value of human waste as fertiliser.

Basis of assumptions made in calculating the nutrients available in sewage in Sierra Leone

Nutrients in Human Waste

The volume of sewage produced per person per day various according to diet but figures quoted in literature for Africa range from 69 to over 500g faeces and around 1.2L urine per person per day (ref. 3-5).

Equally the amounts of nutrients in that sewage vary according to diet but an illustration of the amounts that could be expected are given below (ref 4,6-7). The values from ref 6 were used in the calculations in this Technical Article.

	N (g/p/d)			P2O5 (g/p/d)			K2O (g/p/d)		
	(ref 4)	(ref 6)	(ref 7)	(ref 4)	(ref 6)	(ref 7)	(ref 4)	(ref 6)	(ref 7)
Urine		11	15-19		1	2.5-5		2.5	3-4.5
Faeces		1.5	5-7		0.5	3-5.4		1	1-2.5
Urine + Faeces	10.9	12.5		1.4	1.5		2.7	3.5	

Table 3: Macro-nutrients in human sewage in g per person per day

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Using the nutrient figures above with excreta values of 300g faeces and 1.2L of urine per person per day the potential nutrients excreted per person per year are given below.

Amount of waste production	
Faeces	0.3 kg/p/d
Urine	1.2 l/p/d
Faeces + Urine	1.5 l/p/d
Therefore in one year each person will produce	
Faeces + Urine	548 L
containing	4.6 kg N
	0.5 kg P
	1.3 kg K

Table 4: Quantity of Marco-nutrients per person per year

Nutrient availability

Of the nutrients present in urine and faeces the phosphate in the plant available form of P_2O_5 is not affected by digestion. Some 50 % of the total phosphorous content in digestate is available for plants in the form of phosphate.

Plant available potassium is also not altered by anaerobic digestion. It is estimated that 75-100% of the total potassium would be available to plants. Nitrogen is however altered. In fresh excreta 75% of the nitrogen is in the form of organic macromolecules and only 25% as available ammonium compounds. During digestion the organic macromolecules are broken down to give more ammoniacal nitrogen which can be readily used by the plants (ref 6).

It should be noted that around 70% of the nutrients are found in urine compared to faeces and this is often the most difficult portion to collect.

Potential Nutrient capture from human sewage by the Flexigester V10

The Flexigester V10 is designed to be connected to pour-flush toilets enabling it to capture all the waste from those toilets. To collect the waste there will need to be the addition of water to flush the waste away from the toilet. This has been calculated at approximately 2.5L of water per day. This can be water used for cooking etc which would contain additional nutrients but for the purposes of these calculations it has been assumed that clean water has been used. This means that, using the above assumptions, every litre of digestate produced will contain the following:

Assuming that each person uses	2.5 l/p/d	flush water
Then every	1 L of digestate will contain	
	8.3 g N	
	1.0 g P	
	2.3 g K	

Table 5: Marco-nutrients per litre of digestate from pour-flush toilets

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The Flexigester V10 has a capacity of $10m^3$ assuming that the waste remains in the digester for 30 days this gives and annual capacity of $122m^3$. Using the previous assumptions for volume input this equates to 83 people using the toilets every day.

Using the nutrient values given in ref 6 the potential nutrients recovered annually by a Flexigester V10 from the human sewage are given in the table below.

A Flexigester V10 with a	30 day retention time
will process	122 m3 of waste per year
This equates to	83 people using the toilets daily
A Flexigester V10 will therefore produce	0.4 tonne of N
	0.05 tonne of P
	0.1 tonne of K

Table 6: Marco-nutrients captured by a Flexigester V10 from human waste annually

Conclusion

Human waste can be a rich source of macro-nutrients for plant growth. If the waste can be captured and treated to release the nutrients it can prove to be a valuable fertiliser. This requires the use of latrines that can contain both the urine and the faeces.

The figures given in this Technical Article are for illustrative purposes only. The nutrients available for use as fertiliser is dependent on the amount of waste being produced and captured as well as the amount of nutrients in the incoming waste. Anaerobic digestion can not make nutrients but it can make those present in the waste available for reuse as fertiliser.

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