Sewage as a source of plant macro-nutrients

Technical Article: TA11

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 system.

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 plant nutrients (fertiliser) that could be recovered from human sewage in Sierra Leone is large enough to be significant. Clearly it will be difficult to achieve 100% "capture, treatment and reuse" of the sewage. The percentage figures show the nutrients that could be obtained with varying levels of population involvement.

In a paper by the Norwegian NGO, GRID-Arendal (ref 4) which is part of the United Nations Environment Programme, they use Mauritania as a example of the financial value of fertiliser in sewage. 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 taken from three different data sources. For further information on these sources see references cited.

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In order to extrapolate these data to a population, it is necessary to assume a single set of figures for waste arisings. The data sources show a wide range of faeces arising; 69 - 520 g/p/day. For the purpose of this article, an mid-range assumption of 300g/p/day has been used. The figure for urine generation is consistent between data sources so a figure of 1.2L/p/day (equivalent to 1.2kg/p/d) has been used.

The figures used in the per capita calculations are therefore summarised in Table 4 below.

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

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

These figures are in close agreement with those published by GRID-Arendal (ref 4) which state that "*Humans produce roughly 500 litres of urine and 50 litres of faeces per person per year. These contain about 4 kg of nitrogen, 0.5 kg of phosphorous and 1 kg of potassium"*.

Treating sewage by anaerobic digestion in a Flexigester

The process of anaerobic digestion (AD) will decompose sewage and render it suitable for reuse as a fertiliser. The following section describes what can be achieved by a modest scale AD system, the Flexigester V10. It also highlights the effects of the AD process upon the levels of plant nutrients captured and the chemical form and plant availability of those nutrients.

The capture of plant nutrients 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. So the total input to the Flexigester will be 1.5kg of excrement and 2.5kg of flush water making a total of 4kg input per person per day.

The breakdown of the sewage in a digester requires time and the amount of time needed is affected by factors such as temperature. A reasonable assumption for a V10 digester would be that it could process waste from 50 people in a subtropical climate without additional heating.

A Flexigester being used by 50 people each day would have an annual input amount of 73,000kg of waste including flush water. As the Flexigester V10 has a nominal capacity of 10m^3 (10,000kg of waste) this means that the waste will stay in the Flexigester for around 50 days (Retention Time).

During the process of anaerobic digestion there is biogas being produced and removed but this has an insignificant effect on the volume of material in the digester. It is therefore assumed that the amount of material being output from the Flexigester is equivalent to that being input. There will therefore be an annual output of 73,000kg of digestate or biofertiliser.

Table 5 illustrates the calculations which show what the nutrient value of such a system output would be. This table uses the nutrient values given in ref 6.

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A Flexigester V10 will therefore output	228 kg of N/year 27 kg of P/year 64 kg of K/year
This gives a % nutrient value in the digestate of	0.31% N 0.04% P_2O_5 0.09% K_2O

Table 5: Macro-nutrients captured by a Flexigester V10 from human waste annually

How the process of AD affects the capture and form of plant nutrients

Sewage left untreated and exposed will loose nitrogen due to the loss of volatile ammonia. The capture of fresh waste by the gas tight Flexigester means that all the potential nitrogen is captured.

The form of nitrogen changes during the AD process. 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 is the form of nitrogen which can be readily used by the plants (ref 8).

The plant available form of phosphate (P_2O_5) is around 50% of the total phosphorous content and it is not adversely affected through losses or conversion by the AD process (ref 8).

Plant available potassium (K_2O) is also unaffected by anaerobic digestion. It is estimated that 75-100% of the total potassium would be available to plants (ref 8).

Discussion and Conclusion

Human waste can be a rich source of macro-nutrients for plant growth. However it should be noted that around 70% of the nutrients are found in urine fraction compared to faeces. For the highest levels of nutrient recovery, this means that as much as possible of urine produced needs to be captured. This requires the use of latrines that can contain both the urine and the faeces.

The figures given in this Technical Article illustrate the significant scope of the potential for sewage derived fertilizer. The figures quoted can only be indicative due to the variability of the source data. Nevertheless, reference to third party assessments show our projections are in line with other similar studies.

Anaerobic digestion does not increase the amount of nutrient beyond that which is in as waste. However the process can improve both the capture and plant-availability (chemical form) of the nutrients. The nutrients in the output are in a dilute form. This can be concentrated up by, for example, solar evaporation should a more concentrated form be required and the water not needed for irrigation purposes.

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