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Proposal for the treatment of sludge generated at the Tereré WTP in the city of Tena by means of a physical-chemical and microbiological characterisation

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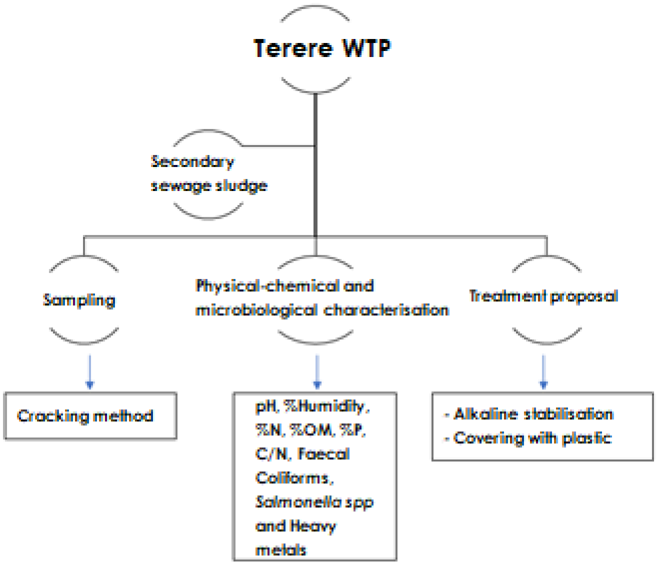
Graphical Abstract



Abstract

The Tereré wastewater treatment plant located in the city of Tena in the Ecuadorian Amazon region treats urban liquid inflows by means of a membrane bioreactor, which has an organic load removal efficiency of 98%. Within the treatment plant, sewage sludge is generated, which goes through a drying process and is disposed of at a landfill site. In this project, the sludge's physical-chemical and microbiological characteristics were determined using three samples where nine parameters were analysed (pH, %Humidity, %N, %OM, %P, C/N, Faecal Coliforms, *Salmonella spp*. and Heavy metals). The results highlight the presence of a large amount of pathogens (faecal coliforms, *Salmonella spp*.), for which two treatment proposals were established, consisting of alkaline stabilisation and composting, where the latter presents greater viability due to its low investment costs and simple operation technique. In addition, the city council will be able to utilise and commercialise the compost bags that will be obtained from the treatment.

Keywords: secondary sludge, characterisation, stabilisation, compost, utilisation.

Introduction

Wastewater treatment plants (WTPs) are the only option for purifying liquid waste generated in a city (Ramon et al., 2015). One of the by-products that they produce is sewage sludge, characterised by high percentages of organic matter and microorganisms of faecal origin, such as bacteria, protozoa and helminths (Guillén & Arévalo, 2006). Unfortunately, only 8% of wastewater is treated in Ecuador (Barreto & Heredia, 2014).

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Within this context, in the year 2015, two WTPs were inaugurated in the city of Tena, which treat the water coming from the whole city, thus minimising contamination of the rivers by a large percentage since they comply with the maximum permissible limits for discharges in freshwater bodies according to Ecuadorian regulations.
Within these plants, the waterline has been characterised; however, as far as the sludge line is concerned, no study has been carried out, therefore there is no adequate use of these products.
In this paper, a proposal for the treatment of secondary sludge generated in the Tereré Urban Wastewater Treatment Plant in the city of Tena was elaborated based on the sludge's physical-chemical and microbiological characteristics.

Materials and Methods

In order to take samples of the sludge from the WTP, we used the quarantine method established in the Mexican regulation no. NOM-004-SEMARNAT-2002 (SEMARNAT, 2002) based on the collection of 8 bags of 0.15m x 0.17m. The laboratory analyses were carried out at the Universidad Estatal Amazónica and the Universidad Nacional de Chimborazo.
The methodologies for the physical-chemical and microbiological analysis of the sludge are presented in Table 1.

Table 1: Methods for the physical-chemical and microbiological characterisation of the sludge

PARAMETER	METHOD
pH	Potentiometric method
Humidity	Gravimetric method
Organic matter	Calcination method
Total nitrogen	Modified KJELDAHL method
Phosphorus	Spectrophotometric method
Faecal coliforms	Dilution method
Salmonella spp.	Plate count method
C/N Ratio	C/N Ratio
Heavy metals	Atomic absorption method

Source: Authors' own.

The sludge treatment proposals were developed through research and data collection obtained from physical and digital texts, scientific articles, websites and scientific journals.

Results and Discussion

The results of the sludge characterisation are presented in Table 2, from which it can be concluded that they present typical characteristics of secondary sludge (Fernandes and de Souza, 2001; Metcalf and Eddy, 2003).

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Table 2: Results of the parameters of the samples

PARAMETER	RESULTS			RANGE OF UTILISATION
	M1	**M2**	**M3**	
pH	5.81	5.93	5.25	5 - 7
Humidity (%)	47	79	67	65 - 70
Nitrogen (%)	0.82	0.501	1.17	0.46 - 4.20
Organic matter (%)	36.81	37.91	41.58	26.6 - 57.4
Phosphorus (mg/L)	16	150	81	40 a 300
Faecal coliforms (MNP/ml)	17000	160000	54000	100-1000
Salmonella spp. (UFC/g)	$20x10^7$	90×10^4	4253×10^3	<1 E (+3)
C/N Ratio	46	76	36	25 - 40
Heavy metals (mg/kg)	Cr (21.70) Cd (1.72) Pb (20.09) Zn (165.78)	Cr (6.25) Cd (1.24) Pb (24.60) Zn (550.95)	Cr (64.98) Cd (0.91) Pb (7.71) Zn (140.55)	1200 – 3000 39 – 85 300 – 840 2800 - 7500

Source: Authors' own.

Likewise, Table 2 shows a comparison of the results with the range of utilisation proposed by the 'MEXICAN OFFICIAL STANDARD, ENVIRONMENTAL PROTECTION - SLUDGE AND BIOSOLIDS - SPECIFICATIONS AND MAXIMUM PERMISSIBLE LIMITS OF CONTAMINANTS FOR THEIR UTILISATION AND FINAL DISPOSAL' (SEMARNAT, 2002). A foreign standard was used since in Ecuador there is no regulation that indicates the adequate parameters for the reuse of this type of product.
This comparison showed that the only parameters not within the range of utilisation are faecal coliforms and *Salmonella spp.*, thus generating the need to apply a treatment to this sludge before its use.
In order to establish the most adequate treatment, we took into account the availability of economic resources and the area needed to implement each treatment. A bibliographic review was performed of the different existing sludge treatments that have been experimented with in similar works. In one of these investigations, Amador et al. (2015) stated that stabilisation decreases the presence of pathogens and unpleasant odours existing in the sludge, therefore two treatment options are proposed: alkaline stabilisation and composting.

Alkaline Stabilisation

Alkaline stabilisation aims at raising the pH above 11, thus eliminating odours and pathogens. In order to establish the amount of lime to be added, the concentration of solids present in the sewage sludge was taken into account and was found to be 1.2%.
According to the Notes on "New Post-Treatment of Dehydrated Sludge with Final Lime" by the German Association of Lime Manufacturing, the dose of lime should be within a range of 210 to 430kg Ca (OH)/ton of dry solids, thus a value of 210kg is proposed.
The capacity of the container where the sludge is stored at the WTP is $3.3m^3$ (3300kg), hence approximately 700kg of lime would need to be added for every 3300kg of sludge generated weekly to achieve a total stabilisation of the sludge. For the implementation of this proposal, a total of sixteen 45kg

bags would be needed with a total value of $76USD ($4.75 each) per week, and a total of $304 over the four-week process.

Composting

Within this alternative, temperature and time are factors that directly influence the stabilisation of the sewage sludge. In a composting process, a temperature of 60°C in the pile can be reached according to Torrencillas et al. (2003), which would achieve a safe elimination of the pathogens present, as shown in Table 3.

Table 3: Temperature limits for the survival of various common pathogens and parasites

ORGANISM	TEMPERATURE	SURVIVAL TIME
Salmonella typhosa	< 46°C	Does not grow
	55 - 60°C	30 minutes
Salmonella spp.	56°C	1 hour
	60°C	15 to 20 minutes
Shiguella spp.	55°C	1 hour
Escherichia coli	55°C	1 hour
	60°C	15 to 20 minutes
Taenia saginata	71°C	5 minutes
Necator americanus	45°C	50 minutes
Brucella abortus or suis	61°C	3 minutes
Micrococcus pyogenes var. *Aureus*	50°C	10 minutes
Streptococcus pyogenes	54°C	10 minutes
Mycobacterium tuberculosis var. *Hominis*	66°C	15 to 20 minutes

Source: Torrecillas et al. (2003).

Analysis of the Proposals

Table 4: Analysis of the proposals using a technical, economic and environmental comparison

	PROPOSAL	
	Alkaline stabilisation	**Composting**
Technical	It is necessary to carry out continuous follow-ups, therefore, more highly-qualified personnel are required.	Fewer personnel members will be needed due to its simple operation, taking into account that temperature measurements and a weekly turnaround must be made.

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Economic	The operating costs of this system are higher due to the amount of lime bags needed.	The investment costs are similar to the alkaline stabilisation process, but in terms of operation, this process has a very important advantage.
Environmental	Lime is a chemical component that can affect the health of workers when inhaled regularly over a long period of time. Lime consumption implies that there is an exploitation of resources.	The only waste produced would be the plastic used to cover the pile and generate more heat within the process.

Source: Authors' own.

Through the comparative analysis shown in Table 4, it can be seen that the most feasible proposal is composting, since it does not require skilled labour, is a simpler treatment and does not require excessive investment or maintenance costs.

Utilisation

Once the proposal is implemented, a biofertiliser will be obtained within a maximum of 2 months, which can be used as a soil improver by the city council institution that administers the WTP.

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