PROPOSAL FOR THE DESIGN OF A WASTEWATER TREATMENT SYSTEM FOR DIVISION INTO LOTS BY EMPLOYEES OF 'COOPERATIVA DE LA PEQUEÑA EMPRESA DE PASTAZA LTDA'

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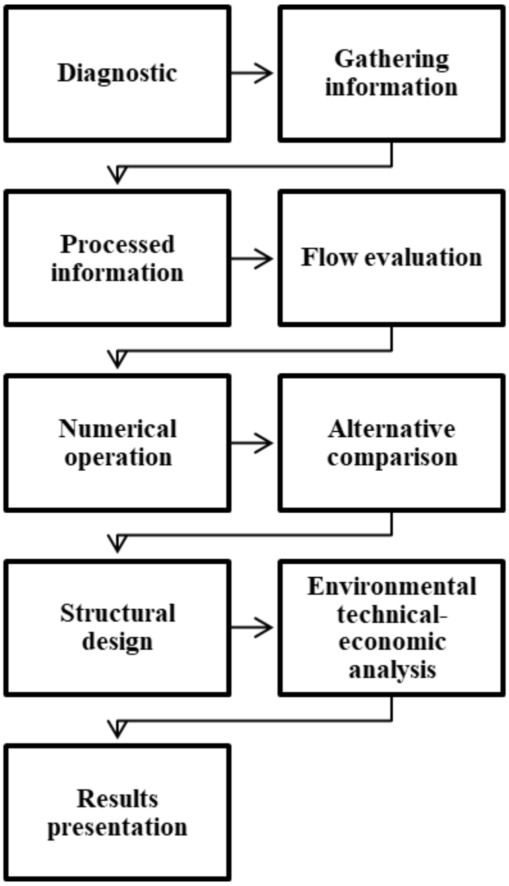
Graphical Abstract



Abstract

This paper presents the sizing of a treatment plant for domestic wastewater generated in the urban planning zone of the Cooperativa de la Pequeña Empresa de Pastaza LTDA, located in Puyo, Ecuador. The population served will be 291 inhabitants and the average flow is 1.48 L/s. The most suitable option for the plant's secondary treatment was selected using the prioritisation matrix methodology. The complete treatment proposal is composed of input, sieving and desanding, two parallel septic tanks, a trickling filter, a secondary decanter and finally a disinfection process of two 12GPM ultraviolet light lamps at the outlet of the secondary decanter. There is also an area for drying the sludge after it has been digested in the septic tank. The calculated cost of the plant was $57,032.88USD and it would occupy an area of 86m^2.

Keywords: wastewater, WTP, trickling filter.

INTRODUCTION

This investigation shows the reality of current problem areas and the need to deal with these environmental problems that, to a certain extent, still go unnoticed by society and government authorities due to disinterest or a lack of environmental awareness or economic resources. A series of treatment processes are proposed based on the typical characteristics of domestic wastewater and on what technology is accessible to the locality. These processes will allow for the fulfilment of the permissible discharge limits to freshwater bodies established within current Ecuadorian environmental regulations. The purpose of constructing the wastewater treatment plant (WTP) is to guarantee the conservation of water resources and the survival of flora and fauna, as well as to avoid the spread of vector diseases and ensure the well-being of the downstream communities who use this water resource on a daily basis to meet their household needs. Nowadays, we must consider new technologies, processes and in general new treatment lines, since the composition of domestic wastewater has changed with a series of new products, such as synthetic detergents, entering the market (Jimenez, Lora, & Ramalho, 2003). Globally, about 2212km^3 of wastewater is generated and released per year as municipal and industrial effluents. This probably makes up more than 80% of the wastewater (UNESCO, 2017).

MATERIALS AND METHODS

Determination of design flows

The necessary design flows of the WTP were calculated based on the water supply, as established by Zaldumbide (2018), where the annual temperature is related to the climate type. The city of Puyo is located within a range of 18-22°C, rendering it a semi-warm climate where the water consumption per inhabitant corresponds to 300L/day. The number of inhabitants for whom the plant is designed was calculated based on the average number of people per household according to the INEC (2010).

Selection of secondary treatment

For the selection of the most appropriate secondary treatment, certain technical and economic parameters of several treatment options were analysed in the literature by modifying the multi-criteria method of prioritisation matrices, as established by Berumen & Llamazares (2007). The treatment options that were compared were the trickling filter (A1), the upward-flowing anaerobic filter (A2) and activated sludge (A3). In step one, the selection criteria were established: efficiency of organic load removal (C1), investment costs (C2), maintenance costs (C3), space requirements (C4), complexity of operation (C5) and energy consumption (C6). In step number two, a rating value scale was proposed for each criterion, in which 0.1 was assigned to the option presenting the lowest or worst condition, 0.5 to that which presented a medium condition, and a value of 1 for the option that generated the best possible condition. As a third step, the sum of each of the scores was calculated and we chose the option with the highest value each time.

Dimensioning the WTP treatment stages

The development of the hydraulic design of the selected treatment stages was carried out through a technical-economic analysis, based on: the national regulations ‘DESIGN STANDARD FOR DRINKING-WATER SUPPLY SYSTEMS, DISPOSITION OF HUMAN EXCRETA AND LIQUID WASTE IN RURAL AREAS’ (IEOS, 1993); the document ‘GUIDE FOR THE DESIGN OF SECONDARY TANKS, IMHOFF TANKS AND STABILISATION TANKS’ (PAHO, 2005); and the procedure proposed by the National Research Council (NRC) of the United States of America for trickling filters. In addition, experts in the area were consulted and contributed technical details to the calculation process. For the financial determination, quotations were made at several hardware stores and water treatment equipment distributors, as was the approximation of labour prices by consulting construction companies.

RESULTS AND DISCUSSION

Determination of design flows

The number of inhabitants for which the WTP is designed was determined based on the average number of inhabitants per household. For the Puyo Parish, this corresponds to 4.47 according to the 2010 INEC census. It was also based on the number of lots in the development, which is 65, occupying an area of 1,3472ha.

$$p = 4.47*65=291hab$$

The flows obtained for the treatment plant are presented below.

Table 1. Determined flows

Parameter	VALUE
AvF (average flow)	1.48 L/s
DomF (domestic flow)	0.81 L/s
InF (infiltration flow)	0.40 L/s
WrF (flow of wrong connections)	0.27 L/s
MinF (minimum flow)	0.44 L/s
PeF (peak flow)	7.40 L/s

Source: Authors' own.

Secondary Treatment Selection

Table 2. Choosing the best option according to the selection criteria

	C1	C2	C3	C4	C5	C6	Total Sum
A1	0.5	0.1	1	0.5	1	1	**4.1**
A2	0.1	0.5	0.5	0.1	0.5	1	2.7
A3	1	1	0.1	1	0.1	0.1	3.3

Source: Authors' own.

In the analysis carried out by means of the prioritisation method, it was determined that the trickling filter is the most suitable option with the highest value based on the qualification of each criterion, highlighting its high removal of organic matter, low energy costs and low operational complexity.

Dimensioning the treatment stages of the WTP

Input

The diameter of the sanitary sewer pipe entering the plant was estimated at 160mm. There will be an input chamber where a gate, a spillway and a by-pass will be installed to divert the excess flow that reaches the WTP.

Pretreatment

Sieving

Table 3. Dimensions of the grid.

Bars	25 * 6	mm
Spacing	3	cm
Minimum speed	0.1	m/s

Source: Authors' own.

Desander

Table 4. Desander dimensions.

Desander depth	0.9m
Area	1.35m^2
Width	0.9m
Length	1.50m

Source: Authors' own.

Primary Treatment

Baseline data

The number of equivalent inhabitants is 291, with a per-capita contribution of 300L/inhab*day. The estimated generation of sludge is 1L/inhab*day, the hydraulic retention time is 0.5 days and the digested sludge accumulation rate is 57 days.

Septic Tank

Table 5. Dimensions of the septic tanks

Total volume	36502L
Volume of each tank	18251L
Useful depth	2.2m
Backup depth	0.3m
Width	1.66m
Length of first chamber	3.3m
Length of second chamber	1.66m
Total length	5m
Bottom edge of through-holes	1.46m
Upper edge of through-holes	1.9m
Total height	2.5m

Source: Authors' own.

Secondary treatment

Trickling Filter

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A daily load of 14.55KgDBO_5/day was calculated and we plan to use Biopack type polythene rosettes of 100m^2 x m^3 as filtering media.

Table 6. Dimensions of the trickling filter

Volume	40m^3
Area	17m^2
Height	2.35m
Diameter	4.6m
Filling volume required	31.45m^3

Source: Authors' own.

Secondary Decanter

The installation of a 20m^3 secondary decanter with a hydraulic retention time of 3.5 hours and a design flow of 5.33m^3/h is recommended. The decanter will be circular and built with high-resistance GRP. A recirculation pipe will be installed at the outlet of this equipment towards the inlet of the trickling filter in order to dilute the organic load, as will a pipe that sends the sludge to the septic tanks to be digested.

Tertiary treatment

Disinfection by Ultraviolet Light

We propose installing two UV lamps with a capacity of 12GPM with a potential requirement of 120 volts.

Sludge treatment

We propose building a drying bed as a final treatment of the sludge previously digested in the septic tanks.

Table 7. Inference of values and dimensions of the sludge drying bed.

Solid loads entering the sedimentation tank	12.15KgSS/day
Per-capita contribution	26.2gSS/day
Mass of solids that comprise the sludge	3.94KgSS/day
Daily volume of digested sludge	47.35L/day
Volume of sludge to be removed from the tank	1.42m^3
Length	1.7m
Width	1m
Area	7.1m^2

Source: Authors' own.

CONCLUSIONS

The WTP proposed in this work has been designed to treat an average flow of 1.48L/s through a treatment train that involves different stages, ranging from pre-treatment to the tertiary level. The plant has an approximate cost of 57,032.88 US dollars and would occupy an area of 86m^2. This in turn would contribute towards complying with Ecuadorian environmental regulations and conserving natural resources.

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