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Design of Sewerage System and Wastewater Treatment in a Rural Sector: A Case Study

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ABSTRACT

The accelerated growth of the population in recent years presents, as a great consequence, a significant increase in wastewater, which, on many occasions, is not discharged properly. This work aims to design a sewerage and wastewater treatment system in Las Mercedes commune in southern Ecuador based on geological, topographic, hydrological, geochemical and demographic parameters. All this focused on reducing pollution and complying with current national and international regulations, meeting the needs of the rural population studied. The methodology used consists of four phases: i) collection, inventory and processing of the base information ii) design of the sewerage system, ii) design of a wastewater treatment system and iv) environmental impact assessment and referential budget. The sewerage system consists of 3.2 km long PVC pipes that transport wastewater to a purification system of water pretreatment and facultative and maturation ponds. The designed system complies with a total purification of 636.27 MPN/100 ml of faecal coliforms (99.994%) and 35.30 mg/l of BOD5 (88%). The proposed design contributes to wastewater management and environmental education research, defining a combined model of a sewerage system with stabilisation ponds replicable in communities with similar conditions.

1. INTRODUCTION

The quality of the environment is part of the priorities of sustainable development and, together with socio-economic development, determine living conditions [1]. Access to safe water and sanitation are vital priorities in the existence, health and well-being of humans. The supply of clean water allows the continuity of various human activities. However, the liquid and solid wastes produced after using clean water pollute most of the world's water sources [2]. The demand for water and wastewater discharge depends on economic development, population growth, water use, technological development and acceleration of climate change. Faced with these variables, transport and treatment systems face unexpected changes that affect their operational efficiency [3, 4]. In urban areas, sewerage systems become essential for collecting and transporting the generated wastewater, moving the contamination away to the place selected for the treatment plant. The treatment plants will be responsible for returning the water safely to the environment. In rural areas, individual excreta disposal systems may be suitable according to the form of the water supply. However, sewage systems could also be used as long as there is sufficient flow to avoid sedimentation in the pipes due to low flow rates and velocities.

Numerous urban areas lack preventive systems against contamination by domestic wastewater [5]. At a global level, inadequate sanitation and wastewater treatment systems and the lack of reusable water mainly affect small cities and rural communities [6]. Eighty-two per cent of the rural population in developing countries lack basic sanitation [7].

According to ref. [8], wastewater management is essential to prevent potential public health risks and environmental contamination. However, low local budgets, lack of experience, and funding constraints are the leading causes of inadequate operation of wastewater treatment systems [9]. There are several studies focused on solving problems with wastewater management (e.g. [10-12]). Although sustainable development in water management includes environmental, technical and sociocultural factors, the economy is an essential criterion in decision-making in most developing countries.

To solve economic problems in wastewater treatment, small settlements with low population density can opt for decentralised systems that are generally simple and cost-effective [9, 13]. However, the effectiveness of decentralised systems depends on good quality management that ensures regular maintenance and inspection. In general, decentralised systems are characterised by the collection, treatment and reuse/disposal of wastewater near or at the point of generation [14, 15]. These systems represent a less resource-intensive and ecologically sustainable sanitation alternative [16, 17].

The most common methods in decentralised wastewater treatment are primary (e.g. septic tank, Imhoff tank) and secondary methods (e.g. Facultative Ponds (FP), Aerated Ponds (AP), Anaerobic Ponds (AnP), Aerobic Ponds (AoP)) [7]. Stabilisation ponds are ideal for small communities' wastewater treatment methods [18]. The structure of this method consists of one or more connected ponds, in which biological processes such as temperature, sunlight, wind and biological interaction of microorganisms degrade organic matter at a natural rate [19]. Stabilisation ponds are projects characterised by their low cost of operation and maintenance [20], environmentally sustainable thanks to their low energy consumption [21], reduced gas emissions, and return of nutrients to the surrounding environment [21].

In Ecuador, 48.5% of the rural population has safe drinking water, and 86.3% have basic sanitation [22]. However, in southern Ecuador, the Las Mercedes commune is a rural area that lacks a sewerage system and wastewater treatment. Sewage disposal in this area is generally done through septic tanks that have exceeded their useful life. Faced with this situation, a large part of the population discharges the residual water from these clogged wells into the rainwater channel, polluting the environment and jeopardising the health of the people and tourists [23]. This study aims to design a wastewater collection, transport and treatment system that complies with national and international regulations. The design was carried out by studying different parameters (e.g. topography, geology, water quality, population analysis) that ensured a viable system focused on reducing environmental pollution and, mainly, prioritising people's health.

This article is divided into five sections: i) a general description of the studied area (Study Area), ii) description of the general methodology used in the design (Methodology), iii) description of the results obtained for the transport and purification system of wastewater (Results), iv) analysis of the results obtained (Analysis of results), and v) conclusions about the efficiency of the system, limitations, and future lines of research (Conclusions).

2. STUDY AREA

Mercedes commune is located in the southwest of Ecuador, in Guayas province (Figure 1a, b). This commune belongs to the Jesús María Parish of the Naranjal canton (Figure 1c). The parish has an approximate area of 12,306.62 ha. The study area's climate is tropical, with temperatures ranging from 18 to 28°C. Agriculture, livestock, forestry, fishing, and trading are the main economic activities [24]. According to the last census carried out, the area has 1802 inhabitants.

About geology, the low permeability of alluvial clay and sand deposits is the characteristic lithology of the area. The topography characterises the terrain with maximum heights of 30 meters above sea level and slopes reaching 2% [24]. From the hydrographic point of view, the Guayas province is characterised by the presence of the Guayas River basin. This basin is one of the essential areas in the country, with an area of 32,218 km^2. It comprises six sub-basins (Daule, Vinces, Macul, Babahoyo, Yaguachi, Jujan) and minor drains [25]. The hydrographic system comprises several rivers and estuaries, widely used for agriculture and human consumption. The Cañar, Norcay and Tixay rivers border the Jesús María parish. Furthermore, the Jesús María and Cañas rivers cross the parish and are the main source of irrigation for agriculture and human consumption [24].

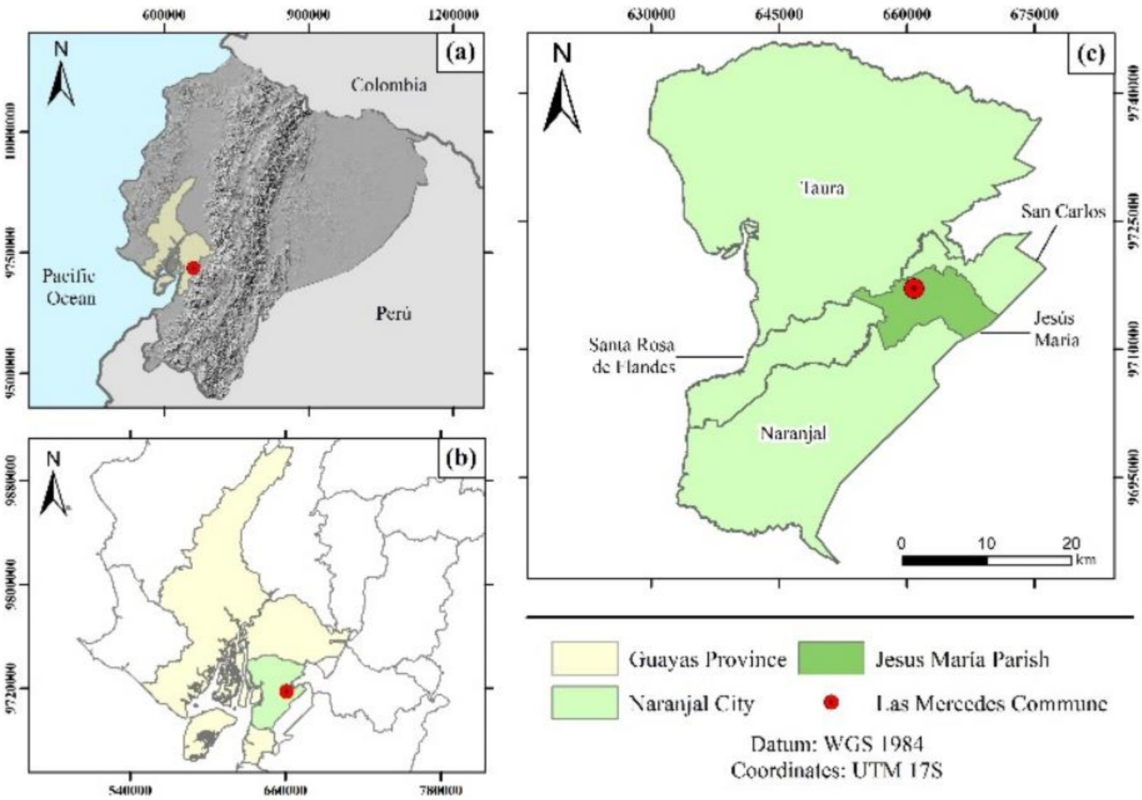

Figure 1. Location of the study area

The climate in the basin depends on the morphology, directly influencing the temperature and precipitation. Temperatures vary from 12 to 26°C, with rainfall reaching 3,000 mm per year [25]. Within the basin, there are several rural communities with limited access to drinking water and sanitation services. Specifically, in the Naranjal canton, where the study area is located, 50.4% of the population is supplied with water through the public network, 47.3 through wells, springs or rivers, and 0.7% through the delivery car. On the other hand, in the canton, only 24.3% of the population has access to a public sewer network, the remaining population uses specific methods such as septic tanks, and in many cases, the effluent is discharged directly into the environment [22].

3. METHODOLOGY

This study includes four work phases: i) compilation and processing of information from the study area, ii) design of the sewerage system, iii) design of a wastewater treatment system, and iv) environmental impact assessment and referential budget for the execution of the works (Figure 2).

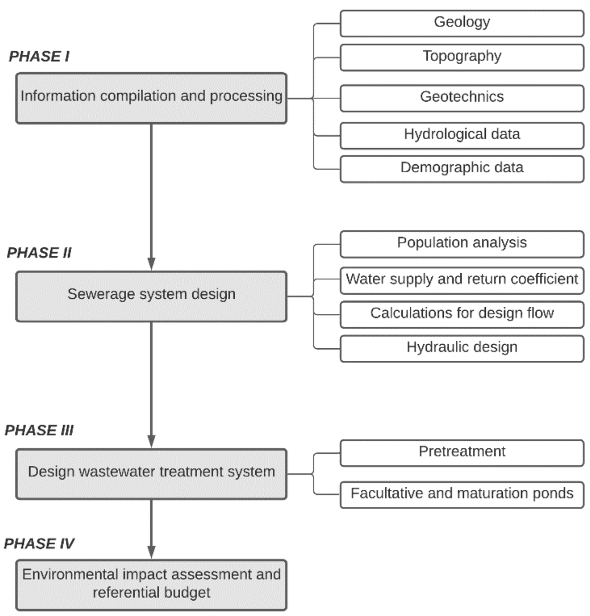

Figure 2. General methodology of the study

3.1 Information compilation and processing

The study begins with the compilation of information from the study area, including topographic, geological, geotechnical, hydrogeological, and demographic data. Data processing involves analysing and comparing existing information, evaluating wastewater quality parameters, and population growth projection.

The population growth projection is carried out through three different methods (arithmetic, geometric and exponential) following the regulations established in the Ecuadorian Code of Practice (ECP) [26], with starting data taken from the censuses carried out from 1990 to 2010 in the country. The results will make it possible to establish comparisons and define the future population, considering economic, geopolitical and social aspects that influence demographic movements.

The data compiled in this phase are the basis for designing the wastewater collection, transport and purification system, according to the studied area with optimal operability.

3.2 Sewerage system design

The sewerage system design was based on three fundamental criteria: i) consideration of the natural slope of the land prioritising transport by gravity, ii) selection of the implantation site of the wastewater treatment plant (WTP), and iii) adjustment of the sewerage system according to the layout of the main roads.

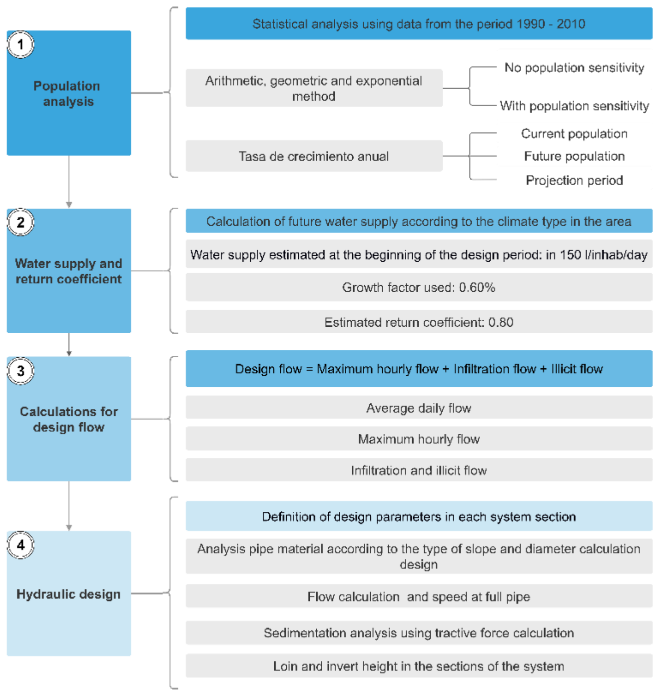

Figure 3. Factors for sewerage system design

The design considers the current regulations of the country [27] and the conditions of the study area. It explicitly assumed population analysis, calculation of parameters for configuration, system implementation area and location (Figure 3). The design period was projected for 20 years so that the selected alternative effectively fulfils the transport of wastewater and minimises the costs of its implementation.

3.3 Design of wastewater treatment system

In this phase, a pretreatment system was designed that eliminates solid material, garbage, avoids the deposition and accumulation of sand, compromising the subsequent treatment. Additionally, installing a secondary purification system based on stabilisation ponds of the facultative and maturation type is proposed, whose main objective is to disinfection of wastewater, notably eliminating the organic load and bacterial and viral pathogens.

The design of the treatment system is based on the analysis of different criteria (e.g. dimensions of the inlet channel and gratings, dimensions of the sand trap, dimensions of stabilisation ponds based on the daily organic load and total BOD_5) that, according to the regulations Ecuadorian [26] ensure the operational efficiency of the system. Therefore, this phase began with the analysis of the wastewater pretreatment to subsequently analyse the design and capacity of the stabilisation ponds (Figure 4).

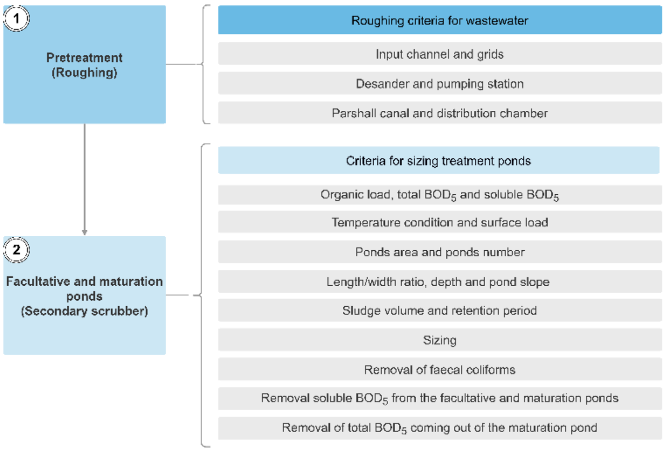

Figure 4. Factors for the design of the treatment system

3.4 Environmental impact assessment and referential budget

In this phase, the authors conducted the environmental impact assessment of the study area's sewerage and wastewater treatment project. This evaluation was carried out through the Unique Environmental Information System (UEIS) [28], a web application developed to manage projects aimed at controlling, registering, maintaining and preserving the environment in the country. The system considers the analysis of three environmental factors: physical environment, biotic environment and social environment. The project's viability was determined from this phase, and alternatives for mitigating the environmental impact were proposed.

4. RESULTS

4.1 Sewerage system

According to the analysis of the population growth curves obtained by the three methods, the equation of the trend line of the geometric method presents a higher correlation coefficient, ensuring a better population projection in the Las Mercedes commune. Therefore, according to the estimate made, the design population is 3,843 inhabitants (Figure 5).

Based on the parameters for the calculation of the design flow and hydraulic design (Table 1), the sewerage system for the Mercedes commune has been designed considering a simplified type with gravity flow conduction. The system will use PVC pipes; this material is characterised by low weight, resistance to residual water leakage due to breaks, ease of installation and transportation. The internal diameters of the pipes vary from the initial sections with ø150 mm to the final sections with a diameter of ø700 mm (Figure 6). The entire route of the designed route is 3.2 km, distributed in 51 sections (Table 2).

The system has 52 concrete inspection chambers built in a cylindrical shape. The upper part has a truncated cone in which the height varies depending on the depth of the sewerage system (0.5 m minimum depth and 4.40 m maximum depth). In Figure 7, a sectional view of an inspection chamber is shown with its dimensions.

Table 1. Parameters for design flow calculation

Parameter	Value
Current population	2,245
Future population	3,483
Design period	20 years
Annual growth rate	2.23%
Water supply	170 l/inhab/day
Return coefficient	80%
Total area	32.3 ha
Population density	108 Inhab/ha
Roughness coefficient	0.009
Average daily flow	5.48 l/s-ha
Maximum hourly flow	600.03 l/s
Infiltration flow	4.85 l/s
Design flow	0.61 m^3/s
Slope	3/1000
Design diameter	760 mm
Flow to full pipe	0.73 m^3/s
Full pipe speed	1.91 m/s
Tractive force	0.64 Kg/m^2
Loin height	22.39 m
Invert height	22.22 m
Water sheet height	22.25 m
Energy height	22.26 m

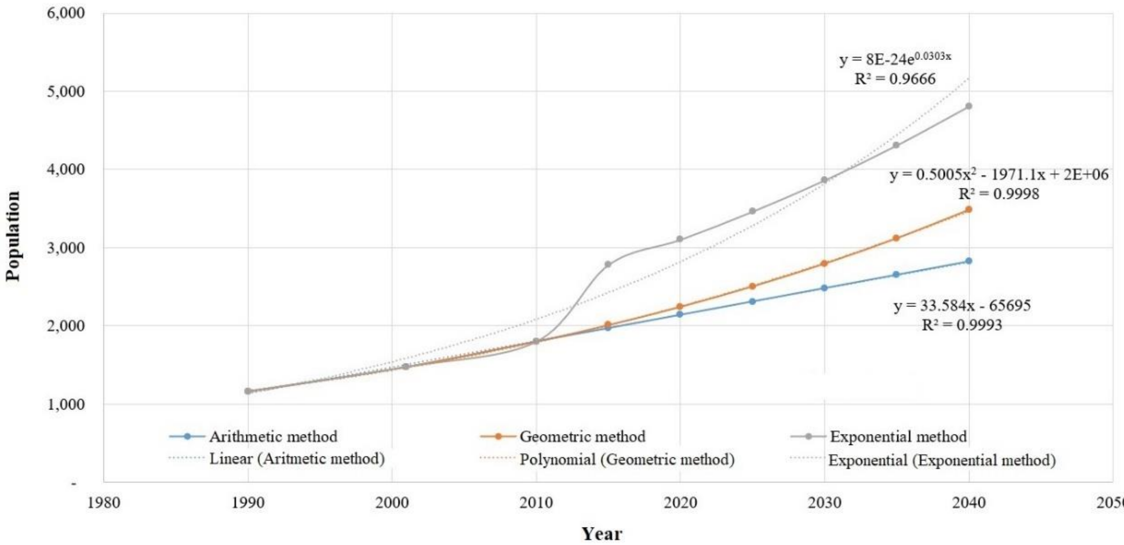

Figure 5. Population projection curve

Figure 6. Sewerage system: a) general implementation, b) detail of strands, straps and collector, and c) detail home corner box

Table 2. Sections and total lengths

Sections – pipes Ø-internal	Sections	Length(m)
Section – pipes Ø150 mm	3	132.35
Section – pipes Ø200 mm	25	1,556.81
Section – pipes Ø250 mm	5	331.33
Section – pipes Ø300 mm	3	144.42
Section – pipes Ø364 mm	2	221.01
Section – pipes Ø500 mm	1	71.21
Section – pipes Ø600 mm	3	169.85
Section – pipes Ø700 mm	10	574.08
Total	**51**	**3,201.06**

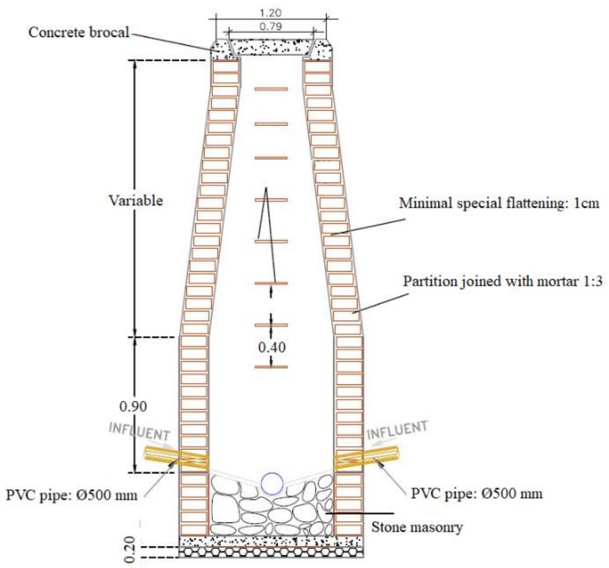

Figure 7. Inspection Camera: sectional view

4.2 Wastewater treatment system

The wastewater treatment system designed has a pretreatment and a stabilisation ponds system (facultative and maturation). A roughing system (inlet channel and grids, desander) and a pumping station were designed to transfer the water to the facultative ponds for the pretreatment. The design included calculating different parameters that allowed the sizing to ensure its operability (Table 3).

Table 3. Parameters for the design of the treatment system

	Parameters	Value
Inlet channel and grids	Channel area	1,875 m^2
	Length grids	1.1 m
	Speed before grids	0.33 m/s
	Speed through the grids	0.40 m/s
	Runoff speed	0.44 m/s
Desander	Sedimentation chamber height	1.2 m
	Chamber length	38 m
	Sedimentation rate	2.52 cm/s
	Retention time	46 s
Pumping station	Rate	0.80 m/s
	Piezometric height	3.77 m
	Power	19 HP

The pumping station has an area of 33.75 m^2, defined based on the size and number of pumps and the necessary access for maintenance. Three pumps with 19HP of power will be implemented in the station and an 8 h/day operating time. The pump characteristics have been obtained through total flow, discharge pipe diameters, density, and gravity criteria.

This installation will allow water conduction from the desander to the Parshall canal for flow determination (Figure 8).

The treatment plant will be located 500 m from the inhabited area with an area of 4.14 ha. The system will have two optional ponds 64 m long, 35 m wide and 2.5 m deep, in which a maximum flow of 0.61 m^3/s will be discharged with a retention time of 25 days—followed by two maturation ponds 61 m long, 32 m wide and 1.5 m deep with a retention time of 20 days. Finally, the treated water will be discharged towards the Cañar River (Figure 9).

The facultative and maturation type ponds' purification function reaches a good removal percentage, complying with the limits established for their subsequent discharge into the river. Tables 4 and 5 show the removal percentages of faecal coliforms and BOD_5 for each type of pond designed.

Table 4. Faecal coliforms removal results

Ponds	Initial FC (NMP/100mL)	Outgoing FC (NMP/100mL)	Removal (%)
Facultative	1.00E+07	47,591.18	99.99
Maturation	47,591.18	636.27	99.00
Total	1.00E+07	636.27	99.994

Table 5. BOD_5 removal results

Ponds	Initial BOD_5 (mg/l)	Outgoing BOD_5 (mg/l)	Removal (%)
Facultative	294.12	95.43	68.00
Maturation	95.43	35.30	63.00
Total	294.12	35.30	88.00

4.3 Environmental impact and referential budget

The environmental impact analysed for this project includes the different activities developed and their possible effects on various factors (e.g. air, water, soil). Specifically, the activities to be carried out mainly reflect impacts on air and water due to the emission of particulate matter and solid waste (Table 6).

A series of activities is necessary to mitigate the impact, including irrigation in areas where particulate matter is generated, solid waste management, and road rehabilitation. Table 7 details the proposed mitigation activities.

The wastewater transport and treatment system budget include two construction stages that can be carried out in parallel, optimising time and resources. The first construction phase corresponds to the sanitary sewerage system, and the second phase is the wastewater treatment plant. Finally, a budget is proposed for the environmental management plan, as detailed in Table 8. The total budget for the work is USD 969,814.66.

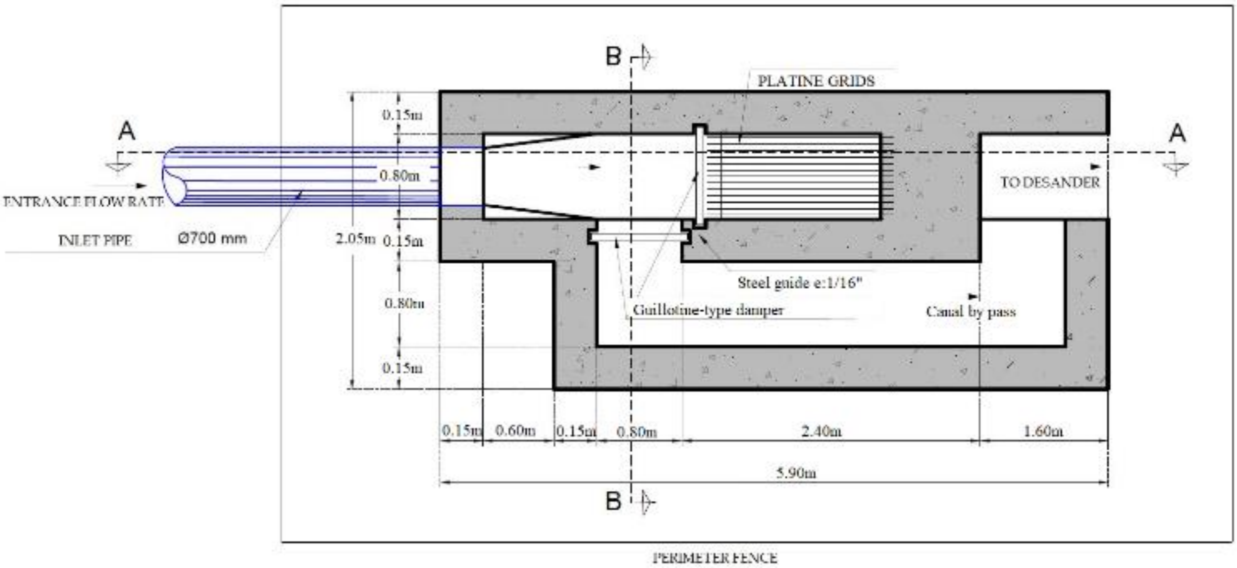

Figure 8. Inlet channel and grids. Plan view

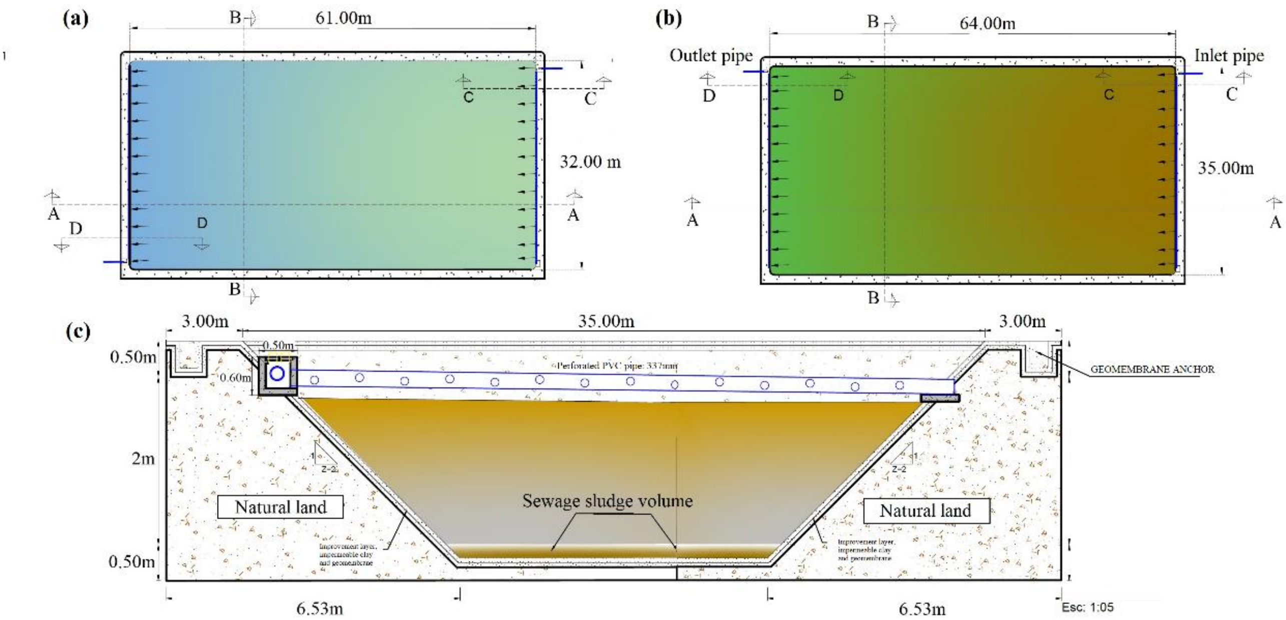

Figure 9. Treatment system: a) Maturation Pond, b) facultative pond, and c) Section B-B of the facultative pond

Table 6. Main environmental impacts

Activity	Factor	Impact
Civil engineering construction (offices, workshops, warehouses)	Air	Particulate matter emission
	Acoustics	Noise generation
	Soil	Hazardous waste generation
	Water	Solid waste generation
	Socioeconomic	Human and occupational health risk
Cleaning and removal of debris or remains of construction materials	Acoustics	Noise generation
	Soil	Erosion
	Soil	Loss of topsoil
	Landscape	Landscape alteration
	Socioeconomic	Human and occupational health risk
Excavation and adaptation of the land	Air	Solid waste generation
	Acoustics	Noise generation
	Socioeconomic	Human and occupational health risk
Debris removal	Air	Particulate matter emission
	Acoustics	Noise generation
	Socioeconomic	Human and occupational health risk
Setting out and levelling	Air	Particulate matter emission
	Socioeconomic	Human and occupational health risk
Lowering the phreatic level	Air	Particulate matter emission
	Acoustics	Noise generation
	Socioeconomic	Human and occupational health risk
Pipes and fittings installation	Acoustics	Noise generation
	Air	Particulate matter emission
Materials collection	Air	Generation of combustion gases
	Soil	Soil pollution
	Socioeconomic	Alteration of vehicular traffic
Signage replacement	Landscape	Landscape alteration
Inspection wells construction	Air	Particulate matter emission
	Acoustics	Noise generation
	Socioeconomic	Human and occupational health risk
	Air	Particulate matter emission
	Air	Generation of combustion gases
	Landscape	Landscape alteration
	Socioeconomic	Human and occupational health risk
Trench filling and compaction	Acoustics	Noise generation
	Air	Generation of combustion gases
	Air	Particulate matter emission
	Soil	Solid waste generation
	Landscape	Landscape alteration
	Socioeconomic	Alteration of vehicular traffic
Shoring	Acoustics	Noise generation
	Landscape	Landscape alteration
	Air	Particulate matter emission
	Soil	Solid waste generation
	Socioeconomic	Human and occupational health risk
Asphalt breakage and replacement	Socioeconomic	Landscape alteration
	Soil	Noise generation
	Air	Generation of combustion gases
	Acoustics	Human and occupational health risk
		Human and occupational health risk

Table 7. Environmental management plan

Plan	Activity
Impact Prevention and Mitigation Plan (IPMP)	Irrigation of particulate material generation areas (2 times a day)
Waste Management Plan (WMP)	Latrine implementation
	Waste storage in airtight containers. Have an oil and fuel change kit
Community Relations Plan (CRP)	Project socialisation with the community
Contingency Plan (CP)	Trench shoring
	Preparation of contingencies
	Training plan
	Provision of materials and equipment for action in case of incidents
Communication and Training Plan (CTP)	Environmental education for work personnel
Occupational Health and Safety Plan (OHSP)	Information signs implementation
	Implementation of vertical and preventive signage

	Provision of Personal Protective Equipment (PPE) to workers
Monitoring and Tracking Plan (MTP)	Resident-Environmental Engineer
Rehabilitation Plan (RP)	Road rehabilitation
Area Closure, Abandonment and Delivery Plan (ACADP)	Final cleaning of the work includes eviction

Table 8. Referential budget of the proposed project

Sewerage system	
Preliminary works	USD 3,002.90
Sewerage system	USD 206,508.09
Inspection well construction	USD 56,895.51
Record boxes construction	USD 160,946.35
Quality control testing	USD 5,832.08
Wastewater treatment plant	
Preliminary works	USD 9,452.43
Inlet channel and grids	USD 1,010.09
Desander	USD 1,572.86
Parshall channel	USD 451.95
Pump station	USD 23,854.41
Flow distribution chamber	USD 3,314.90
Facultative and maturation ponds construction	USD 487,591.97
Environmental management plan	
Impact prevention and mitigation plan	USD 9,381.12
Total	USD 969,814.66

5. ANALYSIS OF RESULTS

The methodology used in this study made it possible to establish a wastewater transport and treatment system adapted to houses located relatively close to each other and ordered in their distribution (compact community structure), economic level and terrain conditions (Figure 10).

The designed sewerage system consists of 3.2 km PVC pipes that support a maximum flow of 0.734 m^3/s as the primary means of transporting wastewater [29]. However, failures in sewage pipes can cause accidents involving groundwater and surface water contamination, compromising human health [30-32]. Several studies have shown that groundwater contamination is related to leakage problems in sewerage systems. They can reach great depths and lateral distances (e.g. [33]). Faced with this problem, proper management of sewerage systems is essential. In the design proposed in this study, the authors have considered a system that adapts to the volume of wastewater generated in the study area, with adequate dimensions that avoid leakage problems in pipes that compromise the environment and the safety of the inhabitants.

In general, the municipalities' lack of budget creates a need for cost-effective methods to maintain and rehabilitate the sewerage system [34]. Due to the economic problems, the designed system is a cost-effective method of solving wastewater transport. However, its operability is a function of adequate maintenance and control of pipelines. Therefore, a risk assessment study that identifies damage to the collection system is recommended [35].

On the other hand, the transported water is stored in a treatment system that consists of facultative and maturation ponds. This type of configuration is applied worldwide because it offers a good level of water purification, is cost-effective and straightforward [36]. For example, half of the treatment plants are stabilisation ponds in the USA, as in rural communities in northern Canada [37], New Zealand with more than 1000 stabilisation ponds [38] and Ecuador [11]. In the study area, wastewater enters two facultative ponds, with a maximum retention time of 20 days for a flow of 0.61 m^3/s. In this type of pond, the water reaches a removal of 99.99% of faecal coliforms and 69.00% of BOD_5 (Table 4). Subsequently, the water is directed to the maturation ponds, with a maximum retention time of 20 days, reaching a removal of 99.00% of faecal coliforms and 63.00% of BOD_5 (Table 5). Based on the total removal percentages achieved (636.27 NMP/100 mL of faecal coliforms and 35.30 mg/l of BOD_5), the treated water complies with national regulations, allowing discharge into the river near the studied area.

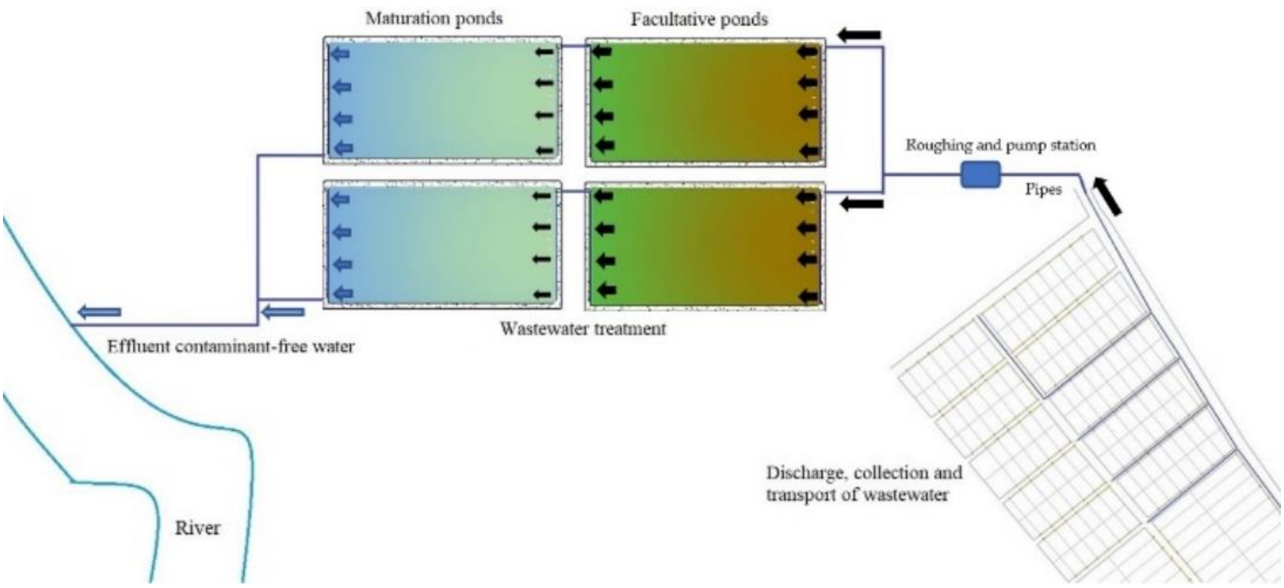

Figure 10. General scheme of wastewater collection and treatment

It is essential to consider the design of a maintenance plan for the stabilisation ponds to ensure the treatment system's operation and the quality of the effluents generated. Specifically, it is advisable to monitor water quality, greenhouse gas emissions, sludge accumulation, excessive algae growth, and finally, nutrient and organic overload [39-43]. The constant and growing supply of organic matter and nutrients in treatment plants contributes significantly to the emission of greenhouse gases [44]. Furthermore, these compromise the performance of the system as they are potential sources of contamination for the soil and crops [45].

The gas emissions level in the pons has had a limited investigation. However, according to ref. [46, 47], these depend mainly on the pond's configuration, size, and climatic conditions. The proposed treatment system in the Las Mercedes commune corresponds to a small-scale design, considering its population projection. Although its size is small, biannual monitoring is recommended to prevent the effluent from contaminating the river waters if the required removal percentages are not met, according to the system's calibration. In addition to ponds monitoring, another option is to adapt the design with enhancements that integrate innovative technologies (e.g. rock filters [48], artificial wetlands [49], and green filters [50]).

The design study included an environmental impact assessment for the civil works designed. The evaluation considered the significant impacts during all stages of the project. The removal of material, adaptation of the terrain, installation of pipes, and repair of roads are the main activities that would impact air and water due to the emission of particulate material and solid waste. Therefore, the authors considered including an environmental management plan to solve the different impacts (Table 7). In the plan, in addition to everyday activities for the construction of civil works, the importance of socialising the project with the community, environmental education for workers and the importance of using personal protective equipment-PPE is highlighted. These three aspects ensure the viability of the execution of the work, avoiding large-scale environmental impacts.

The work designed in this study includes a total budget of USD 969,814.66 that provides for all the construction stages of the sewerage system, treatment system and environmental management plan. Considering that the economic level of the population is low, the project budget is affordable, with a value of USD 278.33/inhabitant in 32.3 ha. Thus, this project solves water and air pollution that affects the inhabitants' health, well-being, and quality of life.

6. CONCLUSIONS

Las Mercedes in southern Ecuador is a typical example of a compact rural commune that needs a sanitary sewerage system and a wastewater treatment system. The proposed design considers the transport and treatment of wastewater according to the current regulations of the country. The system ensures the health and well-being of the inhabitants and avoids water and air pollution cost-effectively and affordably. The total removal levels achieved are 99.99% of faecal coliforms and 88.00% of BOD_5.

The proposed environmental management plan considers different activities to mitigate the environmental impact in the project's construction stage: noise control, particulate material, and solid waste, which is complemented by the socialisation of the project. For the operational phase, the authors recommend designing a water quality monitoring plan, sludge removal, control of algae growth, and gas emissions that ensure the operational efficiency of the treatment system and avoid environmental contamination problems. It should be borne in mind that this type of operation and maintenance are critical to the efficiency of the process; they are routine tasks that are easy to carry out by trained operators.

Despite the limitations for fieldwork due to the health crisis caused by COVID-19, this study lays the foundations for replicable wastewater transport and treatment system in rural communities with nearby housing distribution that lacks a wastewater management plan and limited financing. A future line of work is the tertiary treatment of the effluent from the maturation ponds by implementing green filters, allowing reforestation strategies for protection and sustainable development in this type of community.

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NOMENCLATURE

°C	Degree Celsius
Ǿ	Steel diameters
cm	Centimetre
m	Meters
kg	Kilogram
mm	Millimetres
l	Litres
ha	Hectares
cm^2	Square centimetre
m^3	Cubic meters
USD	United States Dollar
NMP	Most Probable Number
mL	Millilitres
mg	Milligrams
HP	Horse Power
m^2	Square meters
s	Seconds
FC	Faecal Coliforms
BOD	Biochemical Oxygen Demand
PVC	Polyvinyl chloride