Land Treatment and Wastewater's Final Destination – Case Study in Aveiro, Portugal and in Calheta, Ilha do Maio, Cap-Vert

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Abstract

Land treatment and wastewater's final destination is a topic that is becoming more relevant each day due to the need for protection of the receiving water bodies, increasing water scarcity and due to the fact that the land treatment contributes for the artificial recharge of aquifers.

In this field, it was mentioned three types of land treatments: rapid infiltration, slow infiltration and overland-flow.

Throughout the thesis, there were described the principles, limitations, applicability, and sizing criteria of each of these treatments processes. It was described also the soil characteristics that have an influence on wastewater treatment, especially the permeability of the soil on the site and the water table's existence. The influence of the plants and soil on wastewater treatments was also described.

Based on this information, it was developed a method, in a form of a flow chart, for the selection of the land treatment to be applied in each case.

The proposed methodology is applied for illustrative and merely academic purposes (hypothetical cases based on real cases) to two cases studies, in the Aveiro area and in Calheta, Cap-Vert, where the land treatment solutions are used, and it's also presented the sizing and cost estimates.

In the first case, the adopted solution mitigated the problems associated with a possible failure of the pumping station, by diverting the flow basin to a rapid infiltration basin and subjecting it to a screening as pre-treatment.

In the second case, the effluent from a WWTP was subjected to the pre-treatment by screening and grit removal, a primary treatment in a septic tank and subsequently treatment and a final disposal through the implementation of a rapid infiltration system.

The work carried out highlights the importance and benefits of the wastewater treatment through a land treatment system solution, a natural and sustainable approach that contributes to the process of aquifer recharge.

Keywords: Soil treatment systems; Wastewater; Infiltration Basins; Rapid Infiltration; Slow Infiltration or Overland-Flow.

1. Introduction

Land treatment systems are mainly used due to the need to protect the water bodies that receive effluents and in situations where it is important to recharge aquifers because of the growing scarcity of water, aggravated by climate change.

The need for sustainability management of water resources, which includes the reuse of treated wastewater, means that treatments that don't require mechanized processes and use nature as an alternative, are considered a strategic solution to be implemented nowadays (Silva et al., 2017).

Land treatment systems are defined as the application of wastewater partially treated (that undergone a pretreatment and usually also a primary treatment) at a controlled rate to a previously defined location. The goal of this kind of treatment is to obtain an effluent with great quality and eliminate its pollutant load in a simple and effective manner, contributing to the environmental sustainability. These treatments are characterized as lower cost option compared to conventional systems (Crites, 2000). Additionally, it is easy to implement land treatments systems and require low maintenance (Sachin, 2019).

Land treatments work through the soil that acts as a filter, removing organic pollutants, nitrogen, heavy metals and pathogenic microorganisms (Silva et al., 2017).

The systems mentioned are: Rapid infiltration, Slow infiltration and Overland-flow.

In comparison to the conventional systems, land treatment systems, when coupled to a proper pretreatment, obtain similar nutrient removal rates to those obtained by the prior ones. One of the main benefits is the possibility of recovering and reusing the wastewater. This is a relevant source for the urban, industrial and agriculture field, especially, in arid and semi-arid areas, which present water deficit in the summer months and in the dry years. Also, when opting by these kinds of procedures it avoids the over-exploitation of aquifers (Silva et al., 2017).

Additionally, land treatments are a viable choice when it comes to small agglomerations as well as those moderately large, for industries and commercial activities and for portions of large metropolitan areas (Crites, 2000).

2. Methodology and Procedures

Two case studies were analyzed: the first in national territory and second in Cap-Vert. In both cases it is intended to implement a land treatment, an alternative to more conventional solutions, given the local constraints.

Taking into consideration the Table 1 and through the flowchart developed, it was possible to determine the most appropriate land treatment to be applied.

Table 1 - Characteristics of land treatment systems (adapted from The Water Environment Federation, 2018)

Parameters	Slow infiltration	Rapid infiltration	Overland-flow
Slope	<20% on vegetated land; 40% without vegetation	Not important; excessive slope requires earthmoving work	Slope between 2 and 8%
Soil permeability	Moderately low to moderately high	High (sandy soils)	Low (clays and impermeable barrier soils)
Distance to the water table	> 0.6 to 1 m	1 during wet weather; 1.5-3 during dry weather	Not critical
Climate restritions	Moderate climate / Storage required in cold seasons	Not important	Moderate climate / Storage required in cold seasons
Pre-treatment	Primary sedimentation	Pretreatment and primary sedimentation	Pre-treatment and screening
Vegetation	Yes	No	Yes
Area (Ha)	23-280	<23	7-46
Annual application rate (m)	0.5 - 6	6 -100	3 - 20

For each case, the average daily flow was determined taking into consideration the number of inhabitants and its capitation. Then, the next step was designing both systems and doing an estimated initial investment cost of each one of the systems.

In the first case study, it was needed a solution that would allow an adequate treatment of the discharges when there is a power/eletromechanical failure of the lifting station. In the Figure 1 it is possible to observe the location of the pumping station.

Figure 1- Location of the pumping station in Calheta, Cap-Vert

Regarding the case study 1, the Table 2 shows the parameters needed to design the system.

Table 2 – Values required for the design of the basin

Grandeza	Unidade	Valor
Design peak flow rate (Q_{dim})	m^3/day	1728
Soil permeability (k)	[cm/h]	52.08
Hydraulic load (Lw)	[m/year]	156
Area needed (A)	[m^2]	3024

As a pre-treatment process for the effluent, it was implemented a screening operation. it was implemented to obtain the value of the soil permeability it was needed to do three permeability tests. The results obtained are shown in the Table 3.

Table 3 – Water table levels

Piezometer	Elevation [m]	Groundwater Level Depth [m]	Groundwater Level Elevation [m]
PZ01 (S01)	9.45	2.00	11.45
PZ02 (S02)	9.61	3.45	13.06
PZ03 (S03)	9.28	2.20	11.48

In the second case study, Calheta is served by a wastewater drainage system, executed between 2014 and 2016, which did not go into operation because the household connections of the branches were not made. From an academic point of view, for the purposes of this case study, it was assumed that the drainage system would finally be put into service and that the effluent would be treated in a WWTP with ground treatment, by recharging aquifers.

The WWTP is located about 2 km from the village center. For the population design horizon, an average design flow of approximately 3.95 m^3/h was considered. The effluent is pumped to the WWTP, along the road outlined in blue in Figure 2.

Figure 2 – Distance between the pumping tower, located in Calheta, and the wastewater treatment plant

Regarding the case study 2, the Table 4 shows the parameters needed to design the system.

Table 4 - Values required for the design of the basin

	Unit	Value
Design peak flow rate (Q_{dim})	[m^3/h]	3.95
Soil permeability (k)	[cm/h]	20
Hydraulic load (Lw)	[cm/week]	140
Area needed (A)	[m^2]	474*2 = 948

As a pre-treatment process for the effluent, it was implemented a screening and grit removal operation. Calheta is in an area of alluvium, sands, dunes and gravel (Garcia, 2010). To obtain average permeability values in the area in question, the permeability coefficients of medium sands and fine sands were considered. In Figure 3, signaled by the circle in red, one can observe the site in question on the local geological chart, so that permeability values between 3.6 and 36 cm/h were admitted.

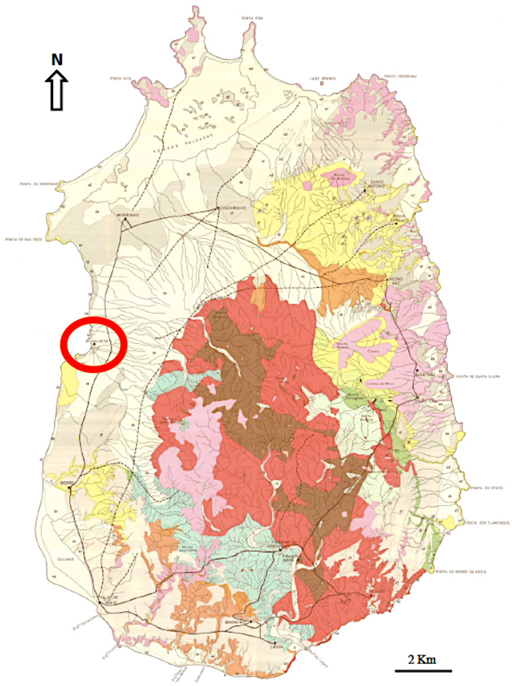

Figure 3- Geologic map of Ilha do Maio (Garcia, 2010)

3. Results and Discussion

For the case study 1, after pre-dimensioning, it was proceeded to the full description of the sizing of the treatment by rapid infiltration. The Table 5 indicates all the infiltration basin characteristics. The defined solution aims to enhance the infiltration capacity and natural purification of the soil, culminating in greater protection of the receiving medium and increasing the level of effluent treatment. In addition, it foresees a controlled discharge, through perforated piping dispersed in the bottom of the basin, properly protected by rockfill.

The Table 6 shows the quantities, unit prices and totals for each of the activities required to realize the system in question, used to estimate the initial investment for in-ground treatment systems. This budget does not include operation and maintenance costs. The Figure 4 shows the design of the system for case study 1.

Table 5 – Case study 1 ‘s infiltration basin characteristics

	Unit	Value
No. of Basins	-	1
Length	m	61.51
Width	m	48.09
Surface area	m^2	3025.81
Depth	m	0.70
Slopes	-	2/1

Table 6- Estimated budget for the system developed for Case study 1

	Unit	Quantity	Budget	
			Price per unit (€)	Total price (€)
1. Exterior				
1.1. Fencing	m^3	220,08	7,5	1650,6
2. Piping and accessories				
2.1. Supply and installation of ductile iron piping	m	200	250	50000
3. Discharge site				
3.1. Workloads	m^3	2123,8	7,5	15928,5
3.2. Supply and application of non-woven polypropylene geotextile	m^2	3021	20,97	63344,7
4. Manholes	Un	2	300	600
			TOTAL	130923,8

Figure 4- Design of the new land treatment system in the case study 1, in the Aveiro area

The Figure 5 shows the design of the system for case study 2. Thus, the wastewater will be conducted through a collector with a small slope (less than 1%) that, after the screening chamber, is divided into two (two outlets with a valve), so that the flow can have access to one of the desired basins. There will be alternation between the 2 basins, which will occur every 1 week, so there is no saturation and to allow the corresponding maintenance. The Table 7 indicates all the infiltration basin characteristics.

Along the basins, a gravel protection was placed, and the flow distribution is done by a perforated pipe wrapped in gravel, in order to distribute the effluent homogeneously by the respective basin.

To limit the area of each basin, an embankment was designed with a slope of 2/1. A fence (outlined in blue in Figure 4) was placed around the entire work area.

To allow a good maintenance of the system, an operator will access the support building daily, cleaning the grid and changing the effluent discharge from one basin to the other, when necessary

The Table 8 shows the costs associated with the activities necessary to realize the system corresponding to the case study in question. This budget does not include operation and maintenance costs.

Table 7 - Case study 2 ‘s infiltration basin characteristics

	Unit	**Value**
No. of Basins	-	2
Length	m	39.7
Width	m	11.87
Surface area	m^2	474.31
Depth	m	0.70
Slopes	-	2/1

Table 8 - Estimated budget for the system developed for Case study 2

	Unit	**Quantity**	**Budget**	
			Price per unit (€)	**Preço total (€)**
Screening chamber	Un	1	-	2000
Support building	Un	1	-	8000
1. Exterior				
1.1. Fencing	m^3	410,18	7,5	3076,35
2. Piping and accessories				
2.1. Supply and installation of ductile iron piping	m	200	250	50000
3. Discharge site				
3.1. Workloads	m^3	724,43	7,5	5433,23
3.2. Supply and application of non-woven polypropylene geotextile	m^2	949	20,97	19893,31
4. Manholes	Un	2	300	600
			TOTAL	89002,9

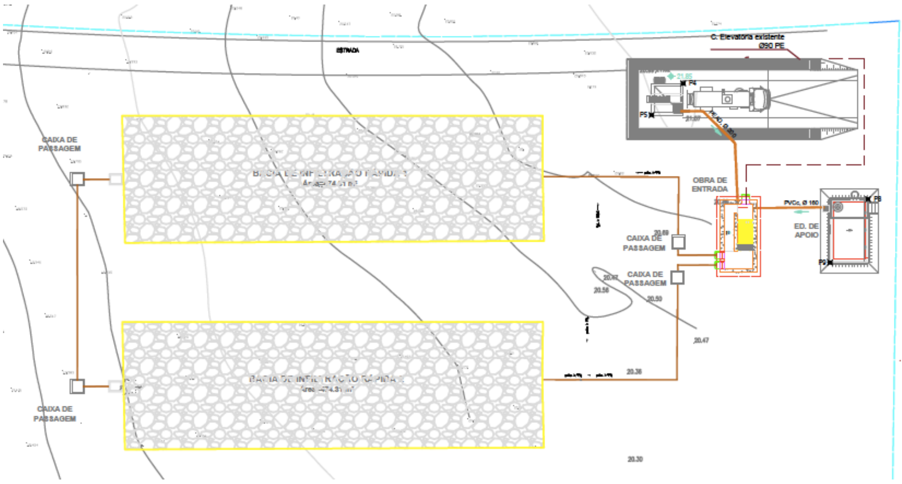

Figure 5- Design of the new land treatment system in the case study 2, in Calheta, Cap-Vert

4. Conclusion and recommendations

As it was said before, land treatment systems are becoming more and more relevant due to the need of protection of the receiving water bodies, due to the increasing scarcity of water and since they contribute for the artificial recharge of aquifers. It was mentioned three types of treatments: Rapid infiltration, Slow infiltration and Overland-flow.

Given the importance of the pre-treatment of the effluent, it was mentioned in each case examples of processes to be applied.

It was also described the principles, limitations, applicability, and sizing criteria of each of the land treatment processes mentioned before, including the main soil characteristics that influence the wastewater treatment: the physical soil characteristics; its permeability and the site's hydrogeology. Also, it was described the action of the plants and soil when it comes to the wastewater treatment.

Based on this information, it was developed a flow chart to guide and proceed to the selection of the most adequate system. The proposed methodology is applied for illustrative and merely academic purposes (hypothetical cases based on real cases) to two case studies in the Aveiro area and Calheta, Cap-Vert, where were applied land treatments and after that it was presented design of the system and cost estimates.

In the first case, it was intended to be implemented a land treatment system that procedures to the wastewater treatment and mitigates unwanted environmental impacts caused by an emergency discharge of effluents, following the failure of the pumping system.

In the second case, the goal was to treat wastewater from a wastewater treatment plant located in Calheta, Cap-Vert, through a land treatment to procedure after to an aquifer recharge.

In both cases, the design is similar, and it was applied the same type of procedure. The initial investment costs were also estimated through a simplified measurement of the main quantities of workload requires for the execution of the land treatment solution.

Regarding the reference values presented, there are cost differences that maybe be due to the way how it was obtained these results (being that the reference values are taken from an American book and are not current).

When it comes to future developments, it is important to increase the knowledge regarding the field of land treatment and it would be suggested a cost update and a

more standardized way of estimating them. This could be done through a calculation tool for the dimension and budgetary comparison of different land treatment systems, including rapid infiltration, slow infiltration and overland-flow.
In summary, the work done highlights the importance and benefits of land treatments systems as a wastewater treatment solution, a natural based and sustainable approach, which contributes to aquifer recharge.

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