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Experience of Application of Natural Treatment Systems for Wastewater (NTSW) in Livestock Farms in Canary Islands

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Abstract: A real-scale application experience Natural Treatment Systems for Wastewater $(NTSW)$ operating in continues with livestock farms for one year. These systems are based on digesters, subsurface vertical flow constructed wetlands $(SVFCW)$ and facultative ponds. Chemical Oxygen Demand removal efficiency (COD_{RE}) has obtained between 70 and 90%. Likewise, it have been possible to compare the operation of cascade flow digesters (CFD) (<76% COD_{RE}) versus complete mixing digesters (CMD) (<50% COD_{RE}). Facultative ponds (FP) when combined with $(SSFCW)$, removed a higher percentage of COD_{RE} compared with ponds (92%). Correlations of interest have been found between the variables evaluated in each plant. Finally, different elements are alternated in the same system, this system is capable of supporting variations in changes in flow rate and organic load coming from the farm, maintaining an adequate elimination of COD and other parameters of interest.

Keywords: natural systems; anaerobic digester; wastewater treatment; constructed wetlands; ponds; COD removal

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1. Introduction

Natural treatment systems for Wastewater $(NTSW)$ or low-cost wastewater treatment systems have proven to be applicable in small communities (with a population equivalent of <2000 inhabitants) with low energy and operating costs in isolated territories [1–9]. These systems stand out, compared to conventional treatment systems, with several features such as long residence times, low or null energy cost, reduced maintenance costs and good applicability of effluents in their reuse [10–12]. The key is to know if these systems are equally valid for existing livestock farms in isolated island environments, as they have similar sizes in terms of equivalent population. These systems must have a mechanical separation pre-treatment to remove coarse solids and prevent obstructions in the rest of the equipment [13].

The target of this paper is to show the study, at steady state operation, of three types of experimental pilot $NTSW$ plants to manage pig livestock waste, in Gran Canaria Island, which is localized in the Atlantic Ocean Figure 1.

Gran Canaria Island (Spain), with an area of 1560 km^2, and large areas of environmental protection (Figure 2), has become a territory with problems of elimination and waste management general and particularly from farms, which generate undesirable infiltrations in underground aquifers [14].

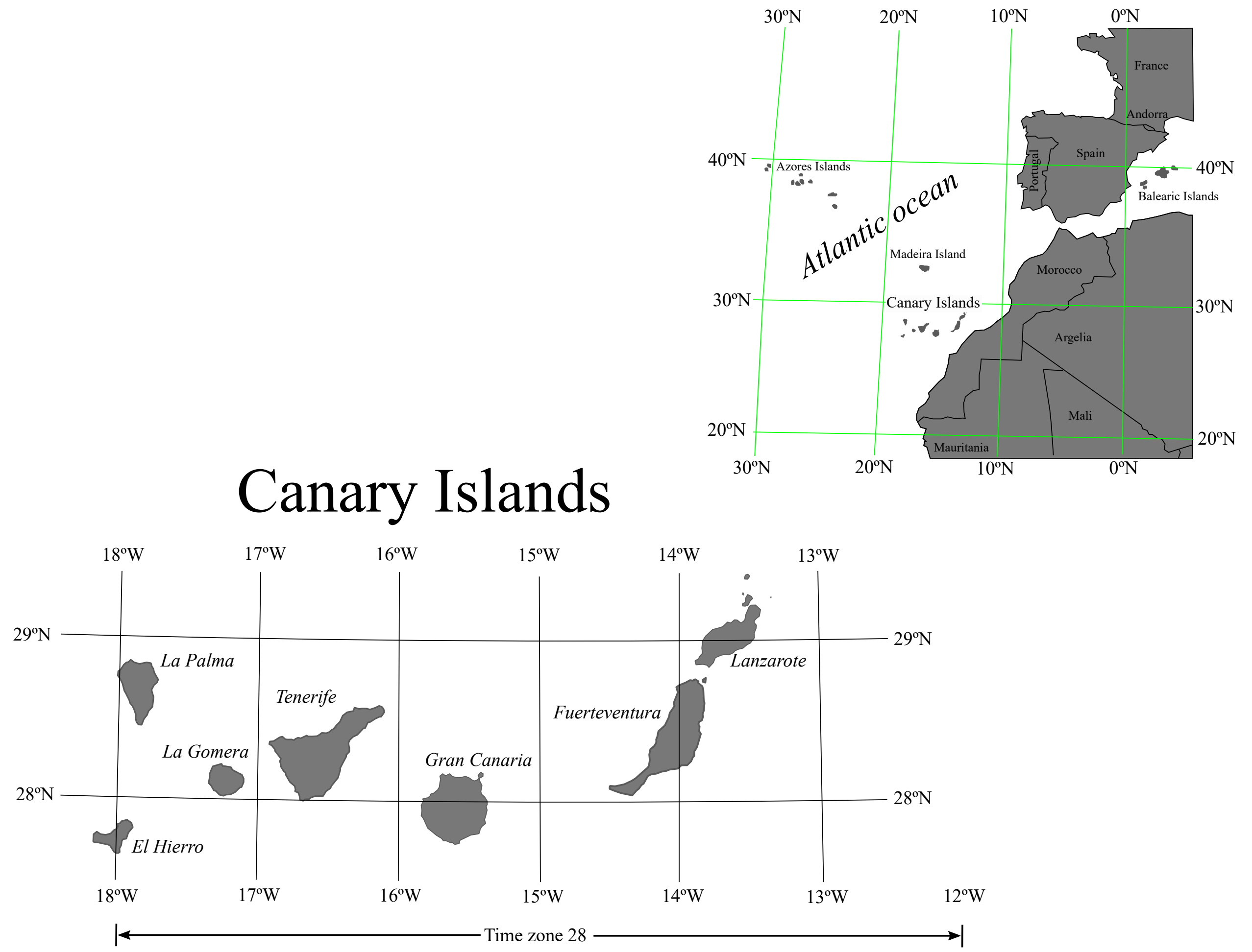

Figure 1. Location of Gran Canaria island in the Atlantic ocean.

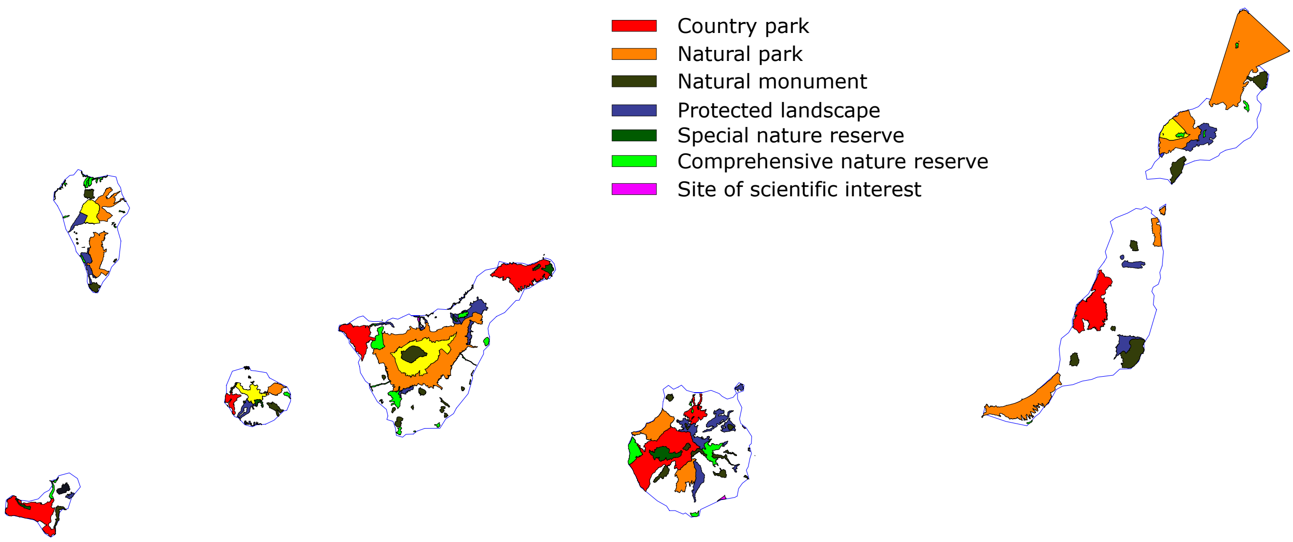

Figure 2. Areas of environmental protection.

In Spain, the legislation on protection against agricultural nitrate and phosphate pollution is Royal Decree 47/18 January 2022 on the protection of water against diffuse pollution caused by nitrates from agricultural sources. This regulation is based on Regulation (EC) 2003/2003 of 13 October 2003 of the European Parliament and of the Council on fertilizers and other implementing legislation. Specifically, the protection of water against pollution by nitrates and phosphates has its main legal instrument in Directive 91/676/EEC, known as the Nitrates Directive, and incorporated into national legislation through Royal Decree 261/16 February 1996, on the protection of water against pollution caused by nitrates and phosphates from agricultural sources, and replaced by RD 47/2022. It considers the following to be waters affected by nitrates: Inland surface waters with a nitrate concentration of more than 25 mg/L, Groundwaters with a nitrate concentration of more than 37.5 mg/L.

This regulation establishes Nitrate Vulnerable Zones (NVZ), which are areas of land whose runoff flows into waters affected by nitrates and which contribute to such pollution. Decree 54/4 June 2020, of the Government of the Canary Islands determines the zones of water affected by nitrate pollution of agricultural origin and designates the zones vulnerable to such pollution at altitudes of less than 300 meters on the island of Gran Canaria. In addition, a limit of 170 kg of N/ha per year is established invulnerable zones and a limit for wastewater discharges of 5 mg/L for total phosphorus, 20 mg/L for total nitrogen and 2500 µS/cm for conductivity.

At the moment, In Gran Canaria there are 136 livestock farms of pigs, Figure 3, 90%, is little family farms. The rest are industrial-sized farms that make up the majority of the island's census. These farms are around 1400 animals in size and represent a strong impact. This fact is equivalent to an organic load to a population of about 2000 equivalent inhabitants, a considerable amount and comparable to the total population of a town or small city on the island of Gran Canaria. Figure 4 displays, on the left, all the livestock farms (red dots) of Gran Canaria Island, and on the right the detail of the three livestock farms for which proposed the plants established in the objective of this paper.

This work presents the novelty of applying these $NTSW$ in similar pig farms (in terms of equivalent inhabitants) with real scale and under normal production conditions. It presents an approximation of the treatment of the waste on the farm itself, favoring integrated production. This management improves the integration of the livestock farm into its environment and promotes the circular economy by converting the waste-resource.

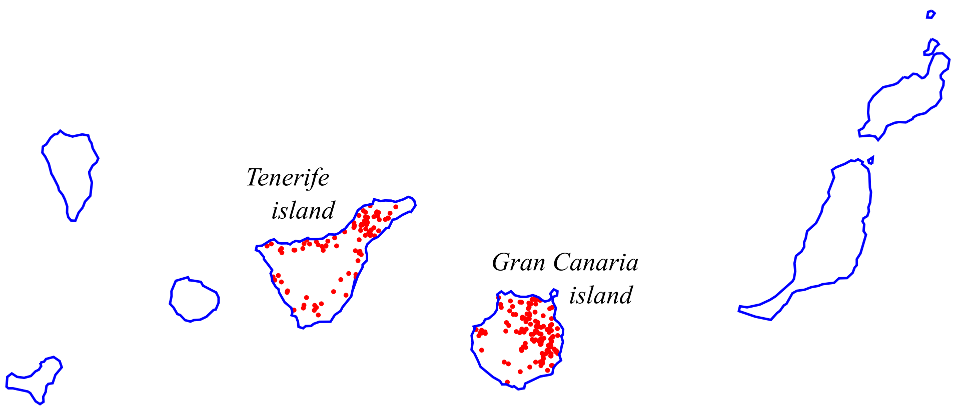

Figure 3. Location of the livestock farms of pigs of Tenerife and Gran Canaria Islands.

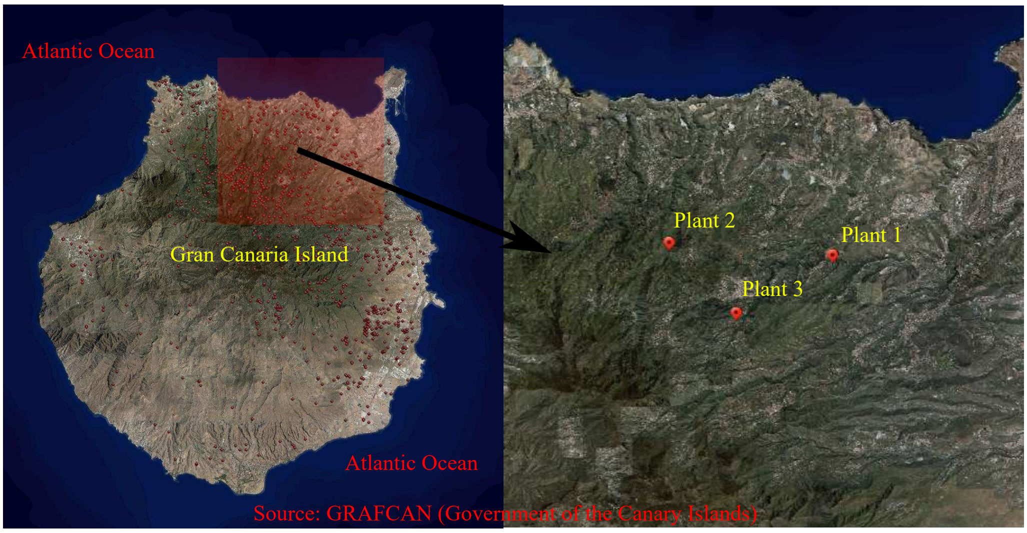

Figure 4. Location of the plants in Gran Canaria Island.

2. Materials and Methods

2.1. Pilot Plants Features

Pilot plants are in the midland of Gran Canaria Island, Figure 4, their photographs are showed in Figures 5–8, and their characteristics in Table 1 and in Figure 9 is shown the schematics of the plants and sampling points. Rotary screens are different in each of the plants and work in batches. It has carried out specific analyzes of the solid whose results and the treatment alternatives that have been studied will be published in another article. Figure 9 are schematic, each of the screens has an input tank that feeds the farm effluent by batch, once screened, the liquid fraction is discharged directly into the lagoon (plant 1), in the second chamber (digester with 6 chambers—plant 2) and in the second camber (digester with 4—plant 3).

- **Plant 1.** Farm located at 450 m of altitude (UTM coordinates x: 450,052.41 m, y: 3,105,359.68 m), with 1600 animals. The effluent from the farm (13.60 m^3/day) is discharged to a holding tank, which has been fitted with a 10 micron rotary screen and it is deposited in a pond of $length/wide$, 2/1 and 1100 m^3 of effective capacity. The depth is 1.5 m. Figure 5 displays a photograph of Plant 1, with a detail of the pond. The total hydraulic retention time (HRT) is 80 days.
- **Plant 2.** Farm located at 540 m above sea level (UTM coordinates x: 443,504.65 m, y: 3,105,955 m), with 1100 animals. The effluent (6.40 m^3/day) is conveyed in the retention tank. In the holding tank (capacity 40 m^3, and retention time 4–6 days), it will be stored the manure until it is sieved. At the top of the half-closed closed digester is a 100-micron mesh rotary screen. The dimensions of the rectangular half-buried digester are 17.50 m $\times$ 6.50 m $\times$ 3.50 m and an effective height of 1.70 m. It is constituted by six rectangular chambers of dimensions 3.00 m $\times$ 3.00 m, being of all them equal and intercommunicated by siphon, with an effective capacity unit of 22.90 m^3 each, and 132.60 m^3 of total volume. By the type of flow, it is possible to assimilate it to the operation of a cascade digester. Figure 6 displays a photograph of Plant 2, with a detail of the rotary screen, and the anaerobic digesters. The HRT is 25 days.
- **Plant 3.** Farm located at 700 m of altitude (UTM coordinates x: 446,164 m, y: 3,102,557.64 m 28°2.83′ N, 15°32.87′ W), with 1400 animals. Effluent (8.70 m^3/day) is collected in a reception tank with a capacity of 10 m^3, then it is taken to the chamber 1 of an anaerobic digester. In the **chamber** 1, the slurry is stored until it is pumped to the 100 micron rotary screen on top of the anaerobic digester. The rectangular anaerobic digester consists of four equal and interconnected rectangular chambers with an effective capacity of 103.00 m^3 in total and HRT of 10 days. At the exit of the digester, the waste past to the first of the constructed wetlands with subsurface vertical flow $(SVSFCW)$

constituted by a cubicle with rectangular form, this volume is filled by stones of varied granulometry, being the free volume 22.95 m^3 and a HRT about of 4 days. In the subsurface constructed wetland $SSFCW$ several types of plants are developed that degrade the organic matter. It has two vertical ventilation tubes. The passage of the water to be treated is performed below the surface throughout the lateral contact area with the pond. Slurry from $SSFCW$ 1 flows into a pond of $length/width$ ratio, 2/1 and 90 m^3 of effective capacity. The depth will be 1.5 m. The residence time is 10 days. The pond is surrounded by constructed wetlands, this has allowed us to experiment with a pond of inferior capacity and on the plant 1. The $SVFCW$ 2, at the outlet of the effluent, has an identical design to the previous one. The installation has a recirculation circuit that allows recirculating of all or part of the liquid that exists in the lagoon to a control pool that is connected to the homogenization tank. At the end of $SVFCW$ 2, it is the final tank of dimensions of 10.50 m^3 of capacity. The stabilized effluent percolates from the wetland to the final tank. Figure 6 displays a photograph of Plant 3, with a detail of the pond, and the constructed wetlands. The HRT is 28 days.

For the loading of digesters and ponds, it has been followed the following steps:

1. Each chamber of the digesters and ponds were initially filled with clean water.
2. No external resources have been added, such as bacteria cultures, sewage sludge, etc., leaving only the slurry to rest so that the native bacterial flora develops its performance.

Figure 5. Photograph of Plant 1, with a detail of the pond.

Figure 6. Photograph of Plant 2, with a detail of the rotary screen, and the anaerobic digesters.

Figure 7. Photograph of Plant 3, with a detail of the rotary screen, and the anaerobic digesters.

Figure 8. Photograph of Plant 3, with a detail of the pond, and the constructed wetlands.

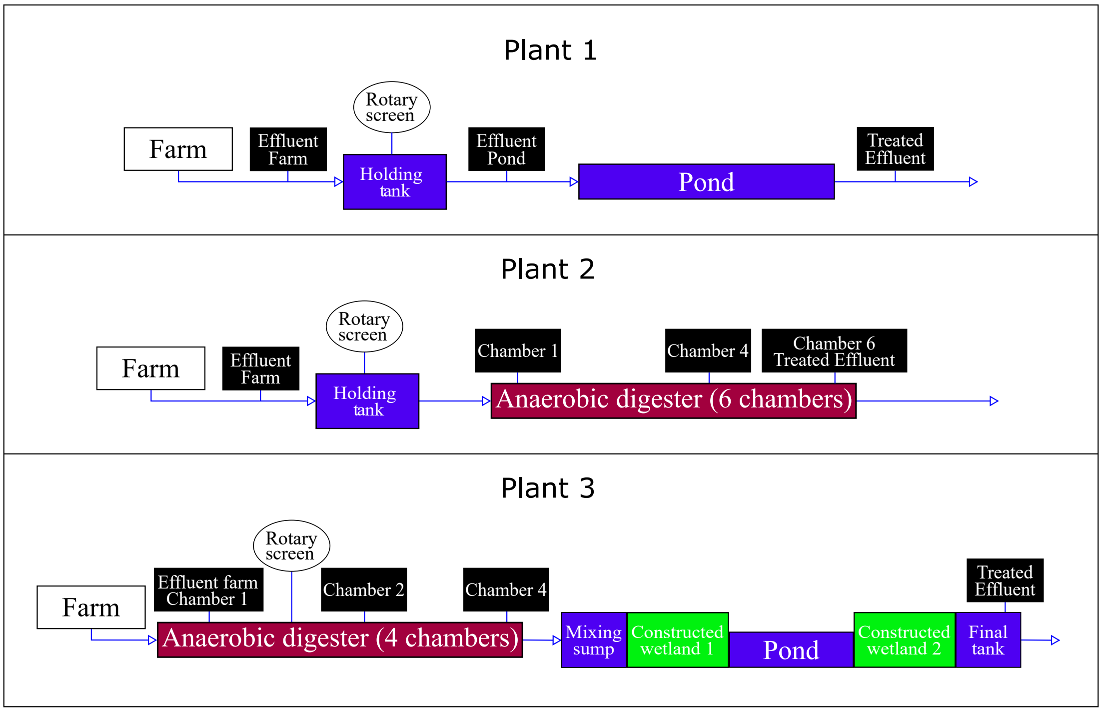

Figure 9. Schematics of the plants and Sampling Points.

Table 1. Data pilot Plants.

Plant	COD_{EF}mg/L	Q_{eff} (m^3/day)	$N_{Br} - N_T$	V_{RT} − HRT (m^3) − (day)	V_{AD} − HRT (m^3) − (day)	V_{SSFCW} − HRT (m^3) − (day)	V_P − HRT (m^3) − (day)
1	45,600	13.60	(180) − (1890)	(10) − (1)	–	–	(1100) − (80)
2	29,000	6.40	(115) − (1068)	(40) − (4)	(132) − (21)	–	–
3	50,000	8.70	(160) − (1432)	(10) − (1)	(104) − (11)	(46) − (5)	(90) − (10)

Plant	Total Capacity (m^3)	Occupied Surface (m^2)	HRT Global (day)
1	1115	750	81
2	172	180	25
3	250	140	27

The SSFVCW-type wetlands are considered a submerged biofilm biological reactor. The effluent meets macrophytes, which are plants capable of attaching themselves to such soils (waterlogged or waterlogged), with one part submerged and one part emergent [15,16]. Authors such as [17–19] have indicated that a large part of the depuration process was due to the presence of plants. However, other studies [20,21] have indicated that the oxygen supply and the depuration capacity is provided by the biofilm that forms in the rhizome areas, with aerobic processes complementing the anaerobic processes in remote areas and therefore a depuration mechanism that is more independent of the type of vegetation selected.

The plants most used and evaluated by other authors are Aneas (Typha), reeds (Phragmites), rushes (Juncus), Scirpus, Carex, etc. [17,20]. macrophytes can transport oxygen to their roots and rhizomes, but in SSFVCW, the amount of oxygen is small compared to the demand and anaerobic processes predominate. However, in our first study, nature was left free to colonize the wetlands of plant 3, focusing on the overall management of the treatment systems and their integration into the management of the livestock farm.

2.2. Parameters and Samples

From plants 1 and 3, 46 samples have been taken; meanwhile, in Plant 2, 39 samples have been taken, totaling 545 days, as an initial follow-up of the implementation of an anaerobic biological treatment facility. The parameters measured were: pH, T, EC, and COD, and the periodicity of the samples was delivered in the following way:

1. During the first half of the year, the samples were taken four times a month, equally spaced in time.
2. In the second half of the year, the samples were taken twice a month, equally spaced in time.
3. After the first year, samples were taken on a monthly basis.

For measuring the parameters were used the **Standard and Methods (APHA 2005)**. Each plant has a meteorological station with measurement of; ambient temperature T_A, humidity ϕ, and rainfall R_{acc}. For the statistical analysis of the data, the COD has been set as the central variable so that this variable can be compared with the rest to be able to observe possible correlations. On the data set, under the approach of finding relationships between the parameters of the waste in the sampling point in each one of the digesters chamber and ponds, it was attempted to demonstrate that the variations of COD during the weeks, it was related to the variation of pH or EC at that same sampling point. When the homoscedasticity tests were carried out, which are a fundamental requirement for good factor analysis, it was not found any relationships between parameters at the point of sampling in each of the chambers and lagoons, and in consequence no significant correlation was going to be obtained from this hypothesis. Therefore, another approach to the data was sought, and it was decided to analyze the behavior of the installation during the complete cycle, in which the slurry passes through the plant, defined by the Global Hydraulic Retention Time for the plant (HRT_G) of 82, 27 and 27 days (plant 1, 2 and 3, respectively). The initial hypothesis is established, that it is possible to relate punctual data of parameters with their respective evolution at the outlet, after the days of the treatment cycle. From the 131 samples available, for the three plants, we selected 30, 21 and 21 sampling data from the 131 available samples, making the grouping of the corresponding values of the study parameters possible.

3. Results and Discussions

3.1. Atmospheric Conditions

There was no temperature control in the digesters and ponds and wetlands, which were subject to rainfall. It is possible to observe, in Figure 10, for all the plants, throughout the time period, during the months of July and August (Table A1), that the highest ambient temperatures are reached (28 to 32 °C), with minimums of 10–14 °C in January and February. In addition, the values of the dew point and sky temperatures, estimated according to [22,23], can be observed in the same Figures, which affect the thermal conditions of the systems.

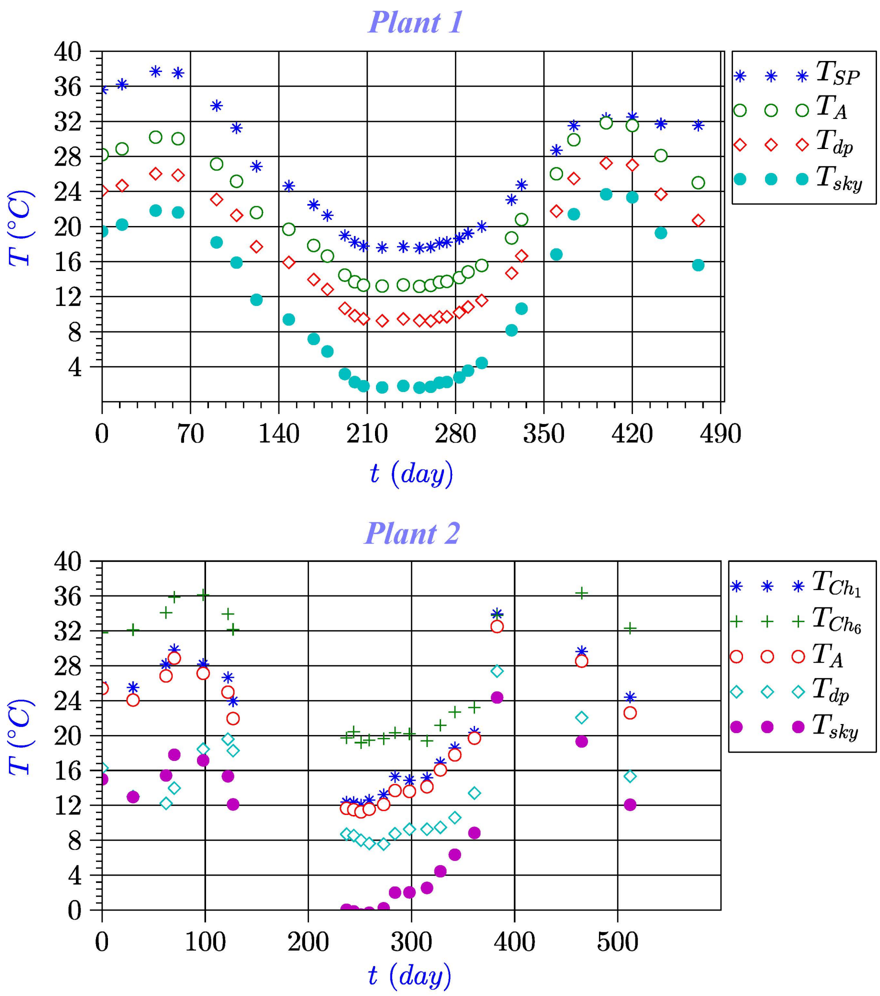

Figure 10. *Cont.*

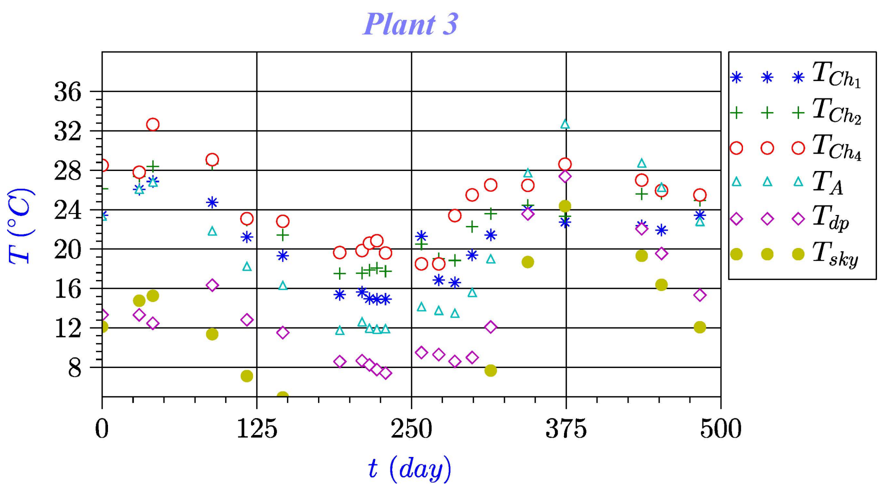

Figure 10. Temperature results for plant 1, 2, and 3.

Regarding rainfall, from May to August they are negligible while the months of November to February are the wettest. Figure A1. Because the systems are open, and subject to environmental conditions, rainfall contributions and evaporation losses (associated, among other causes, with the variability of relative humidity, Figure A2), the plants processes were influenced by modification of the liquid fraction, it has been quantified that the difference, in evaporation losses, was between 5 and 20%, depending on the time of year.

3.2. Temporal Evolution of the Analyzed Variables

The temporal evolution of the variables, can be analyzed in the graphs represented in the following Figures: the behavior of the temperatures in Figure 10, the values of COD in Figure 11, the values of EC in Figure 12, and the response of pH in Figure A3. The cyclical behavior shown in the graphs and samples indicates that the three plants operate at a steady state, damping and adapting according to the type of natural purification system the transient variability of the effluent input to the installation resulting from the operation of the operation Livestock. If, it is considered the operating charts of the three plants,

- The curves of variables, which are labeled EF, for plants 1 and 2, and subindex Ch_1, for plant 3, represent the discharge in the pilot plants of the pools and intermediate tanks that each of the livestock farms have in their pens.
- The curves of variables, which its label has the subindex EP, for plant 1, and subindex Ch_1, for plant 2, and subindex Ch_2, for plant 3, represent the initial point of the system.
- An finally, the curves of variables, which its label has the subindex TE, for plants 1 and 3, and subindex Ch_6, for plant 2, represent the effluent treated of the plants.

Although the pond of plant 1 multiplies by 10 the capacity of the pond in plant 3, its performance is similar, but when comparing the performance per cubic meter, the pond on plant 3 shows a better performance. In the digester of the plant 2, only the variability dampens from the sixth chamber. In plant 3, the most complete one, we could observe how the system is able to better cushion the variations due to alterations from external factors (climatology and plant growth) than those motivated by the operating regime itself.

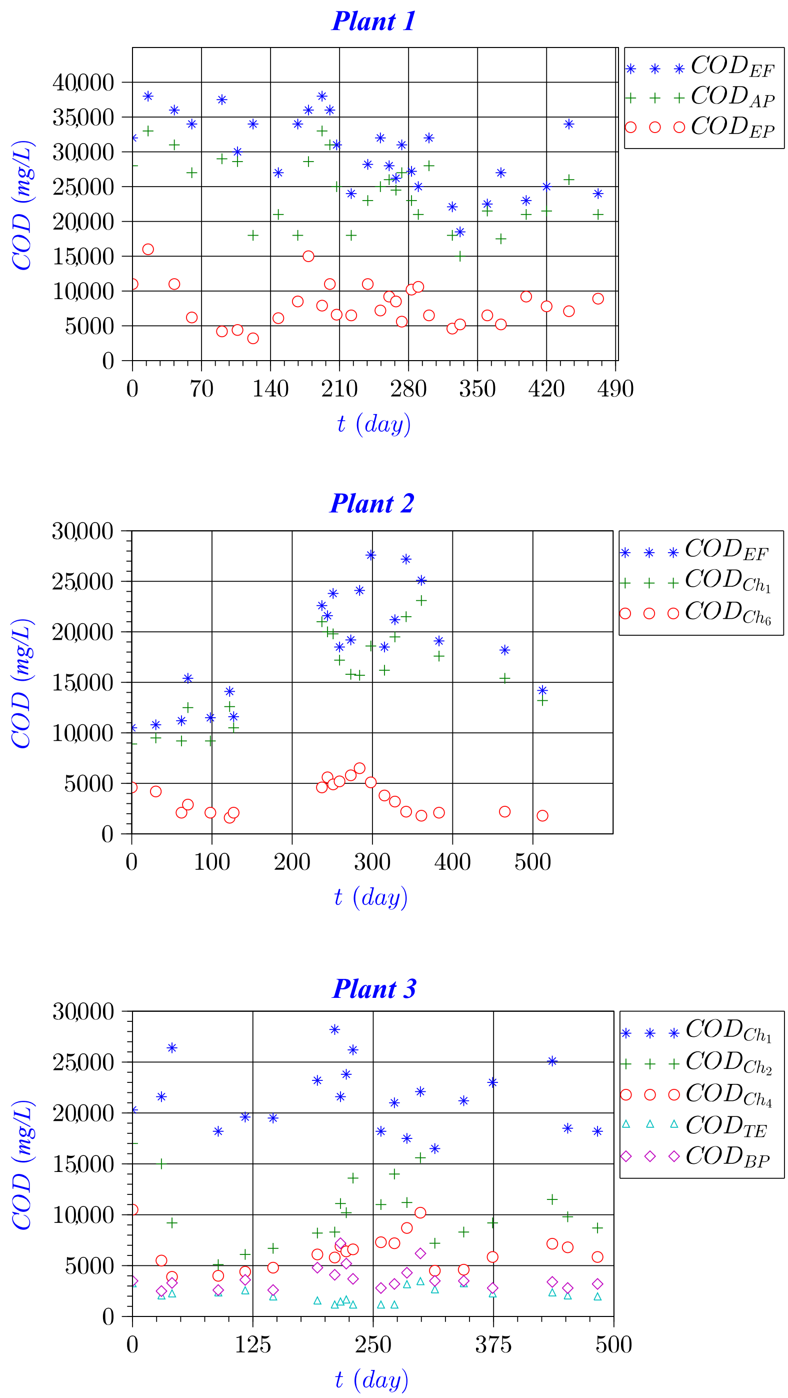

Figure 11. *COD* results for plants 1, 2, and 3.

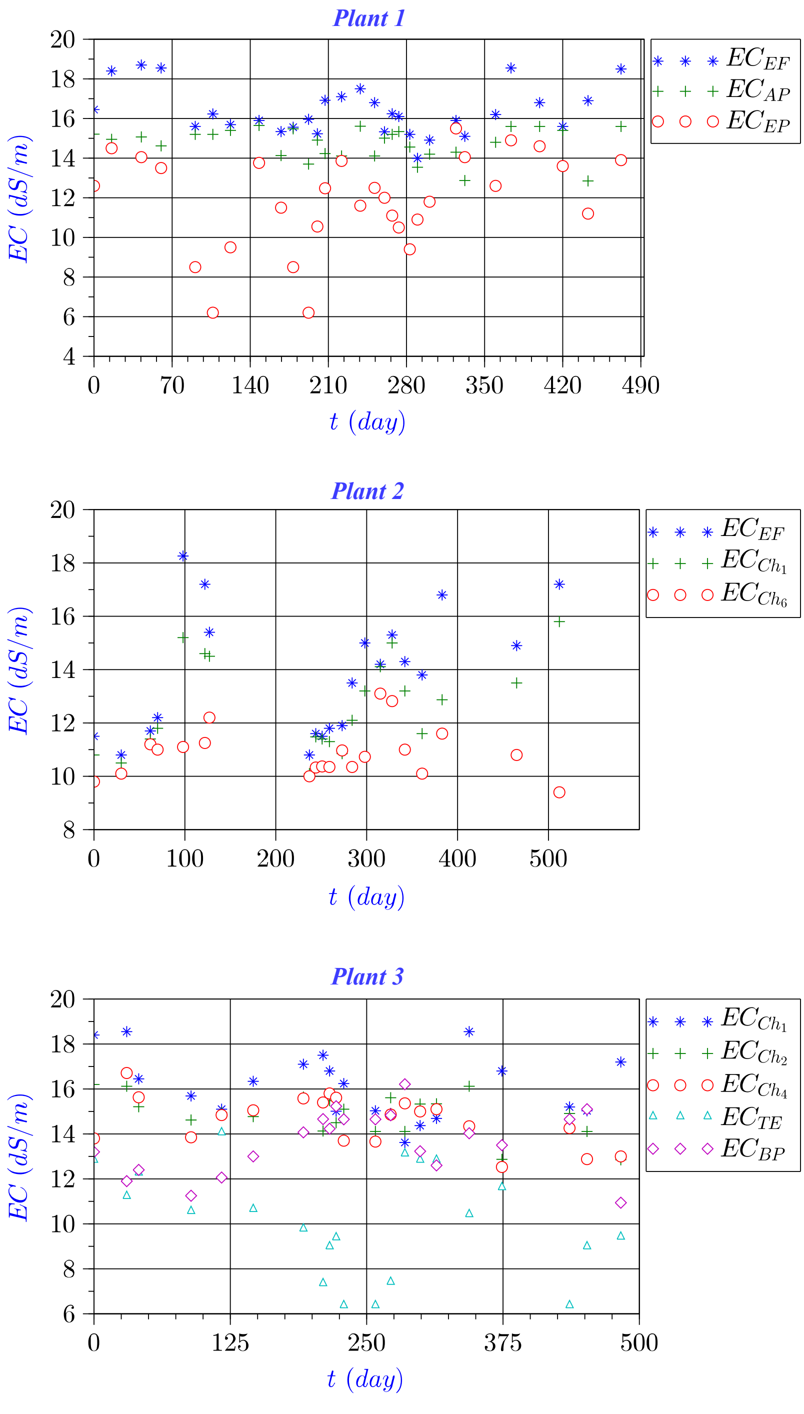

Figure 12. *EC* results for plant 1, 2, and 3.

3.3. Correlations

For the three plants, it has been possible to propose significant correlations for the studied variables, among them. In Table 2, it is showed several relationships, established in form of correlation, between several variables of the plants. For example, for plants 2 and 3, it is possible to relate the removal of COD_{REG} throughout the entire cycle and the removal in EC_{RE} in the same period. It was demonstrated that there is a direct relationship between these two variables, which is reasonable because of the direct relationship between the amount of salts in a slurry (represented by *EC*) versus methanogenic activity in a biological reactor, if the quantity of salts is low, more methane will be produced and therefore more organic matter (*COD*) will be removed. In this way, it is possible to confirm that periodicity sampling, based on global *HRT*, allows to evaluate the best installation and to obtain meaningful relationships between different parameters of study in the complete treatment cycle.

Table 2. Relations between variables of Plants.

	Plant 1
R^2	Correlation
0.866	$COD_{REG} = 43.2947 + 70.5771 \cdot COD^2_{REEP} - 8.781 \cdot COD^3_{REEP}$
0.500	$EC_{REG} = 19.202 - 0.097 \cdot R_{acc} + 0.002 \cdot R^2_{acc} - 1.488 \times 10^{-5} \cdot R^3_{acc}$
0.798	$EC_{REG} = 18.250 - 0.60 \cdot EC_{REP} + 0.020 \cdot EC^2_{REP} + 38.87 \times 10^{-5} \cdot COD^3_{REP}$
	Plant 2
R^2	Correlation
0.942	$COD_{REG} = 5.923 + 0.437 \cdot EC_{RED} + 0.0161 \cdot EC^2_{RED} - 0.001 \cdot EC^3_{RED}$
0.602	$EC_{REG} = 7.213 + 1.023 \cdot EC_{RES} + 0.135 \cdot EC^2_{RES} - 0.006 \cdot EC^3_{RES}$
0.847	$EC_{REG} = 5.923 + 0.437 \cdot EC_{RED} + 0.061 \cdot EC^2_{RED} - 0.001 \cdot COD^3_{RED}$
	Plant 3
R^2	Correlation
0.748	$COD_{REG} = 92.559 - 1.087 \cdot EC_{REP} + 0.0501 \cdot EC^2_{REP} - 0.001 \cdot EC^3_{REP}$
0.769	$EC_{REG} = 19.854 - 0.759 \cdot EC_{REP} + 0.063 \cdot EC^2_{REP} - 0.001 \cdot EC^3_{REP}$
0.426	$EC_{REG} = 18.824 - 20.123 \cdot R_{acc} - 6.424 \cdot R^2_{acc} - 0.824 \cdot R^3_{acc}$

Studies have been published with relationships between the variables studied COD and Conductivity (EC) [24,25]. As reported by [26], as indicated, Refs. [26–29] chemical analyses with standard laboratory methods are accurate, but involve a certain cost for the farmer and it is interesting to have COD values related to conductivity that can be taken on the farm. In this study, significant correlations with conductivity (EC), better than the $r = 0.511$ and $r = 0.571$ [24,25], were found.

3.4. Performance

Overall, the best COD and conductivity removal efficiency is found in plant 3 (90.42% and 36.26%, respectively, Table 3). With respect to the equipment, the sieves have a similar average COD performance, the digester of plant 2 (with 6 chambers) has a better performance both at a global and specific level with respect to the digester of plant 3 (with 4 chambers), while it is observed that the performance per day of residence is higher in plant 3. However, in conductivity removal, plant 2 is superior both globally and specifically. The ponds show differences in volume in the order of 10:1, with a higher volume in plant 1. However, although globally the two ponds (plant 1 and 3) have similar COD removal rates (66.67% and 66.27%, Table 3). The pond of plant 1, despite having a 10:1 volume ratio with respect to plant 3, has a lower specific performance both per volume and per day of residence. This advantage is confirmed by the ability of the plant 3 (which has two associated subsurface vertical flow wetlands) to reduce the overall and specific conductivity. These results can be explained, mainly, because the constructed wetlands are self-sustaining in relation to the removal of contaminants, since different mechanisms are produced in them, which can be classified as: biological (bioremediation and phytoremediation), chemical and physical [30,31]. Constructed wetlands are, as far as possible, controlled environments in which they can act on macrophytes, some plants, fill or gravel, and microbial populations, which act anaerobically to a considerable extent. Macrophytes and microbes take contaminants that reach wetlands as a source of energy, with which a removal of contaminants is achieved [30,32].

Although precipitation has an influence, for an open system it can be found in all three plants, and (to a greater extent in plants 1 and 3, with ponds), it can be affirmed that, although plant 1 has the highest level of average accumulated precipitation, the conductivity reduction capacity of plant 3 is clearly better than that of plant 1, although its capacity and surface area are notably lower. In this case it is clear the contribution of salt elimination caused by the presence of *SFS* artificial wetlands in plant 3. The role of salts in anaerobic digestion plays an important role in the methanogenic stage, since it has a condition in the form of possible inhibitions [33–35], which can reduce methanogenic activity. This could be observed, directly, in the measurement of the pH of the system, since it would cause changes in suitable ranges for the pH in anaerobic digestion, Table 4, to favor the production of biogas, and therefore for the degradation of contaminants.

Plant 2 has a 6 chamber cascade digester in which the layout resembles a channel (or piston flow) digester with better performance than plant 2 (or complete mix) and with a good load buffering capacity. Plant 3 has neither the best digester nor the best pond, but has the best performance, because the integration of different systems results in better treatment and observed performance in terms of *COD* and conductivity removal. Regarding the *HRT*, total capacity, and occupied surface, it can be observed that the COD removal capacity and conductivity are clearly better in plants 2 and 3, being smaller than plant 1 (in capacity and occupied surface), with specific removals 0.464 and 0.377 %/m^3, respectively, and 3.190 and 3.229 %/day. It is further influenced by the fact that the system is composed of complementary elements that allow the microbial fauna to better adapt to these changes.

Table 3. Removal rate values (COD, EC. . .).

Plant	**COD_{RES} (%)**	**COD_{RED} (%)**	**COD_{REP} (%)**	**COD_{REG} (%)**	**EC_{RES} (%)**	**EC_{REP} (%)**	**EC_{RED} (%)**	**EC_{REG} (%)**
1	18.08	–	66.67	72.64	9.56	19.37	–	27.63
2	14.63	75.92	–	79.75	7.78	–	12.94	19.41
3	15.41	46.86	66.27	90.42	8.31	30.79	5.41	36.26
Plant	**COD_{RES} (%/m^3)**	**COD_{RED} (%/m^3)**	**COD_{REP} (%/m^3)**	**COD_{REG} (%/m^3)**	**EC_{RES} (%/m^3)**	**EC_{REP} (%/m^3)**	**EC_{RED} (%/m^3)**	**EC_{REG} (%/m^3)**
1	1.291	–	0.061	0.065	0.683	0.018	–	0.025
2	0.366	0.575	–	0.464	0.195	–	0.091	0.107
3	4.541	0.455	0.488	0.377	0.831	0.342	0.053	0.146
Plant	**COD_{RES} (%/day)**	**COD_{RED} (%/day)**	**COD_{REP} (%/day)**	**COD_{REG} (%/day)**	**EC_{RES} (%/day)**	**EC_{REP} (%/day)**	**EC_{RED} (%/day)**	**EC_{REG} (%/day)**
1	–	–	0.833	0.897	–	0.922	–	0.776
2	–	3.615	–	3.190	–	–	0.345	0.341
3	–	4.686	3.898	3.229	–	0.907	2.226	1.295

Table 4. Average values ($\overline{pH}$, $\overline{R}_{acc}$, $\overline{\phi}$, $\overline{T}$).

Plant	**$\overline{pH}_{EP}$**	**$\overline{pH}_{SP}$**	**$\overline{pH}_{D}$**	**$\overline{pH}_{G}$**	**$\overline{R}_{acc}$ (L/m^2)**	**$\overline{T}_{A}$ (°C)**	**$\overline{\phi}$ (%)**	**$\overline{T}_{SP}$ (°C)**	**$\overline{T}_{D}$ (°C)**
1	7.58	7.55	–	7.55	68.11	20.79	77.56	25.44	–
2	6.07	–	8.48	7.44	52.95	19.80	67.30	–	26.86
3	9.40	7.95	5.80	7.95	41.46	22.60	63.50	21.74	22.38

NTSWs evaluated are compared in Table 5 with other similar ones both on farms and domestic waters (with equal number of equivalent inhabitants) [5–7,36], it can be observed that similar COD removal values both in % and %/*HWR* are obtained with livestock effluent treatment plants [37] and the more complete the installation ($NTSW$ Plant 3). Likewise, if the results given are compared against conventional systems, it is observed that they have comparable overall COD removal rates, and again the best installation is Plant 3 [38–41]. However, as the conventional systems are intensive in energy consumption and with shorter retention times (HRT), in all cases except for those found by [39–41] it can be observed that by $\%/HRT$ the conventional systems are superior to the natural systems studied, this being the weak point of these systems in terms of retention times [42–46].

Table 5. Comparison between natural treatment systems.

Treatment	HRT (days)	Total Removed (%COD)	Total Removed (%COD/HRT (day))	References
Anoxic-aerobic	54	95.90	1.78	[39]
Anerobic-anoxic-aerobic	48	95.00	1.98	[39]
Anaerobic	14	94.00	6.71	[40]
Codigestion anaerobic	15.5	69.20	4.46	[41]
Anoxic-aerobic	13	86.90	6.68	[38]
Anoxic-aerobic	13	93.60	7.20	[38]
Activated Slugge	10	95.00	9.50	[38]
NTSW Domestic	20	96.00	4.80	[6]
NTSW Domestic	28	90.00	3.21	[4]
NTSW Domestic	30	90.00	3.00	[7]
NTSW Livestock	25	65.00	2.60	[37]
SBR and MBR technology	6.5	96.00	14.77	[47]
Anaerobic-Biofilters	6	98.00	16.33	[45]
Aerobic termofilic	3	62.00	20.67	[46]
Anaerobic-SBR	4.5	96.70	21.49	[42]
MBR technology	1	51.20	51.20	[43]
Aerobic termofilic	3	60.00	20.00	[44]
NTSW Plant 1	81	72.64	0.90	This work
NTSW Plant 2	25	79.75	3.19	This work
NTSW Plant 3	28	91.70	3.28	This work
SBR	6	70.40	11.73	[39]
SBR and MBR technology	8	98.00	12.25	[47]

4. Conclussions

The $NTSW$ has the capacity to cushion the fluctuations of the organic load due to livestock exploitation, having stable effluents. Systems that combine different alternatives are superior in performance and load capacity. These systems can be an alternative to conventional systems in farms of a similar size in insular and/or isolated territories and provide a low management cost alternative by offering a stabilized effluent. This effluent can be reused and promote the principle of integrated production.

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Abbreviations

The following abbreviations are used in this manuscript:

COD	Chemical oxigen demand
COD_{EF}	Effluent farm COD
COD_{EP}	COD of Effluent pond
COD_{TE}	COD of Treated Effluent
COD_{Ch_i}	COD of chamber number i
COD_{BP}	COD at bottom of pond
COD_{RE}	Percentage ratio of the removal efficiency of Chemical oxigen demand
COD_{REG}	COD_{RE} of the global plant
COD_{RES}	COD_{RE} at the screen
COD_{RED}	COD_{RE} at the digester
COD_{REEP}	COD_{RE} at the effluent pond
EC	Electrical conductivity
EC_{EF}	Effluent farm EC
EC_{EP}	EC at Effluent pond
EC_{EF}	EC of the treated effluent
EC_{Ch_i}	EC at chamber number i
EC_{BP}	EC at bottom of pond
EC_{RE}	Percentage ratio of the removal efficiency of electrical conductivity
EC_{REG}	EC_{RE} of the global plant
EC_{REP}	EC_{RE} of the pond
EC_{RES}	EC_{RE} of the screen
EC_{RED}	EC_{RE} of the digesters
HRT	Hydraulic retention time
HRT_G	Global Hydraulic retention time for the plant
$NTSW$	Natural treatment system for wastewater
N_{Br}	Number of bristles
N_T	Total number of animals
pH	Measure of the concentration of protons $[\boldsymbol{H}^+]$ in a solution
pH_{EF}	pH at effluent farm
pH_{SP}	pH at the surface pond
pH_D	pH at the digester
pH_{Ch_i}	pH at chamber number i
pH_G	pH of the global plant
$\overline{pH}_G$	Average pH of the global plant
$\overline{pH}_D$	Average pH of the digester
$\overline{pH}_{SP}$	Average pH at the surface pond
$\overline{pH}_{EF}$	Average pH at effluent farm
Q_{eff}	Effluent flow rate
R_{acc}	Accumulated rainfall

$\overline{R}_{acc}$	Average accumulated rainfall
$SSFCW$	Subsurface flow constructed wetland
T_{SP}	Temperature surface pond
T_A	Ambient temperature
T_{Ch_i}	Indoor temperature chamber number i
$\overline{T}_{SP}$	Average temperature surface pond
$\overline{T}_A$	Average ambient temperature
$\overline{T}_D$	Average digester temperature
V_{RT}	Reception tank volume
V_{AD}	Anaerobic digester volume
V_{SSFCW}	SSFCW volume
V_P	Pond volume
ϕ	Relative humidity
$\overline{\phi}$	Average relative humidity

Appendix A. Samples for the Plants

Table A1. Samples for the plants.

Plant 1			Plant 2			Plant 3		
Monthly day	Time (day)	Sample	Monthly day	Time (day)	Sample	Monthly day	Time (day)	Sample
June 27	0	1	June 4	0	1	July 4	0	1
July 13	16	2	July 4	30	2	August 3	30	2
July 30	43	3	August 6	62	3	August 14	41	3
August 18	61	4	August 14	70	4	October 2	89	4
September 18	92	5	September 12	98	5	October 30	117	5
October 4	108	6	October 6	122	6	Nobember 29	146	6
October 10	124	7	October 11	127	7	January 14	192	7
November 16	150	8	January 31	237	8	February 2	210	8
December 7	170	9	February 7	244	9	February 8	216	9
December 18	181	10	February 14	251	10	February 13	222	10
January 2	195	11	February 22	259	11	February 20	229	11
January 10	203	12	March 6	273	12	March 19	258	12
January 17	210	13	March 17	284	13	April 3	272	13
February 3	225	14	March 31	298	14	April 16	285	14
February 20	242	15	April 17	315	15	April 30	299	15
March 3	255	16	April 30	328	16	May 15	314	16
March 12	264	17	May 14	342	17	June 15	344	17
March 19	271	18	June 3	361	18	July 15	374	18
March 25	277	19	June 25	383	19	September 17	436	19
April 5	287	20	September 17	465	20	October 3	452	20
April 12	294	21	November 4	512	21	Nobember 4	483	21
April 23	305	22						
May 17	329	23						
May 25	337	24						
June 23	365	25						
July 7	379	26						
August 03	405	27						
August 24	426	28						
September 17	449	29						
October 18	479	30						

Appendix B. Rainfall, Relative Humidity and pH Results

In this appendix is displayed the results above rainfall, relative humidity and pH.

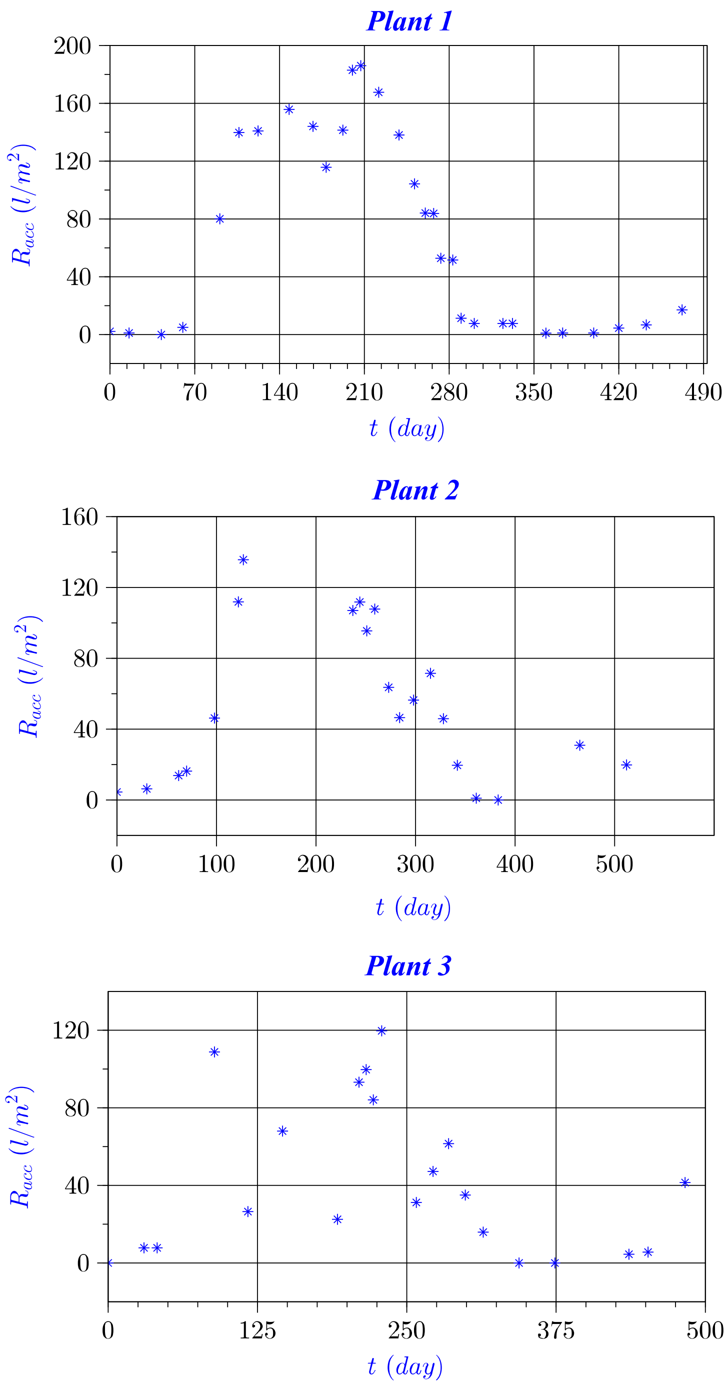

Figure A1. Rainfall results for plants 1, 2, and 3.

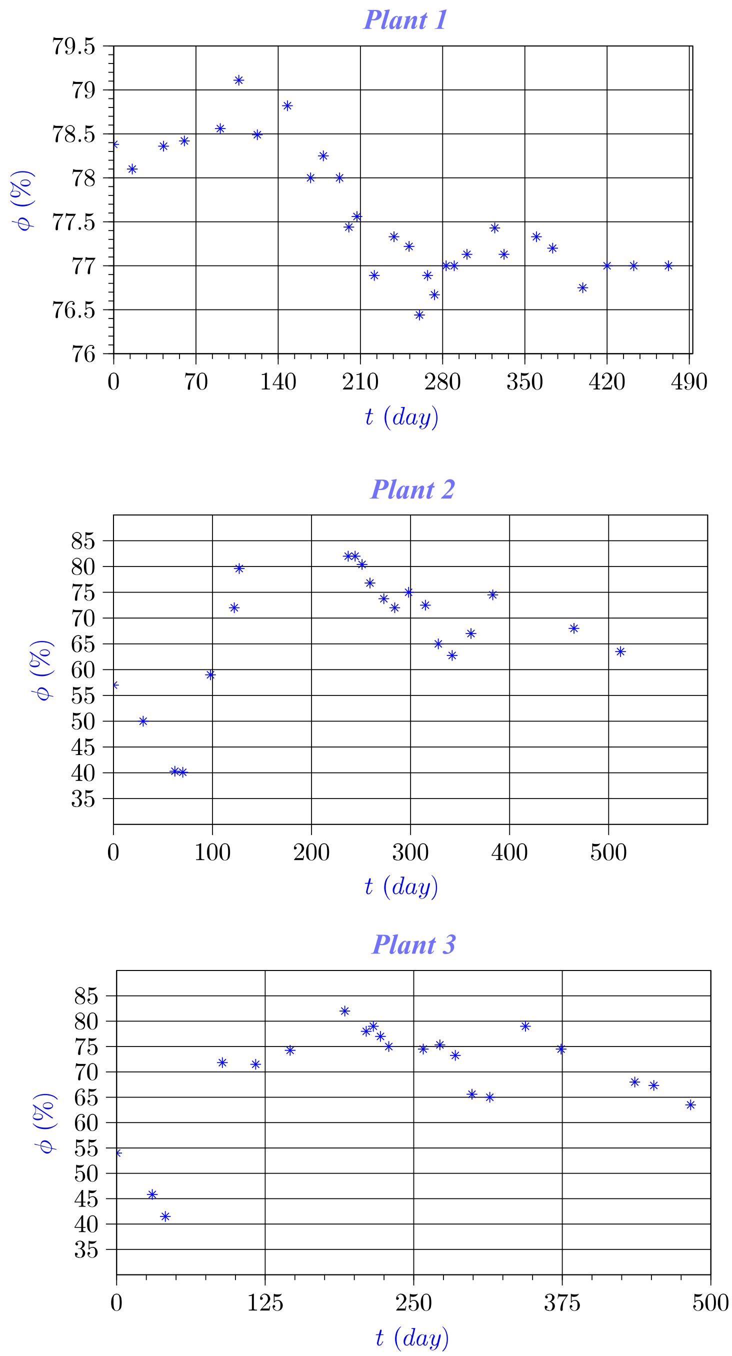

Figure A2. Relative humidity results for plants 1, 2, and 3.

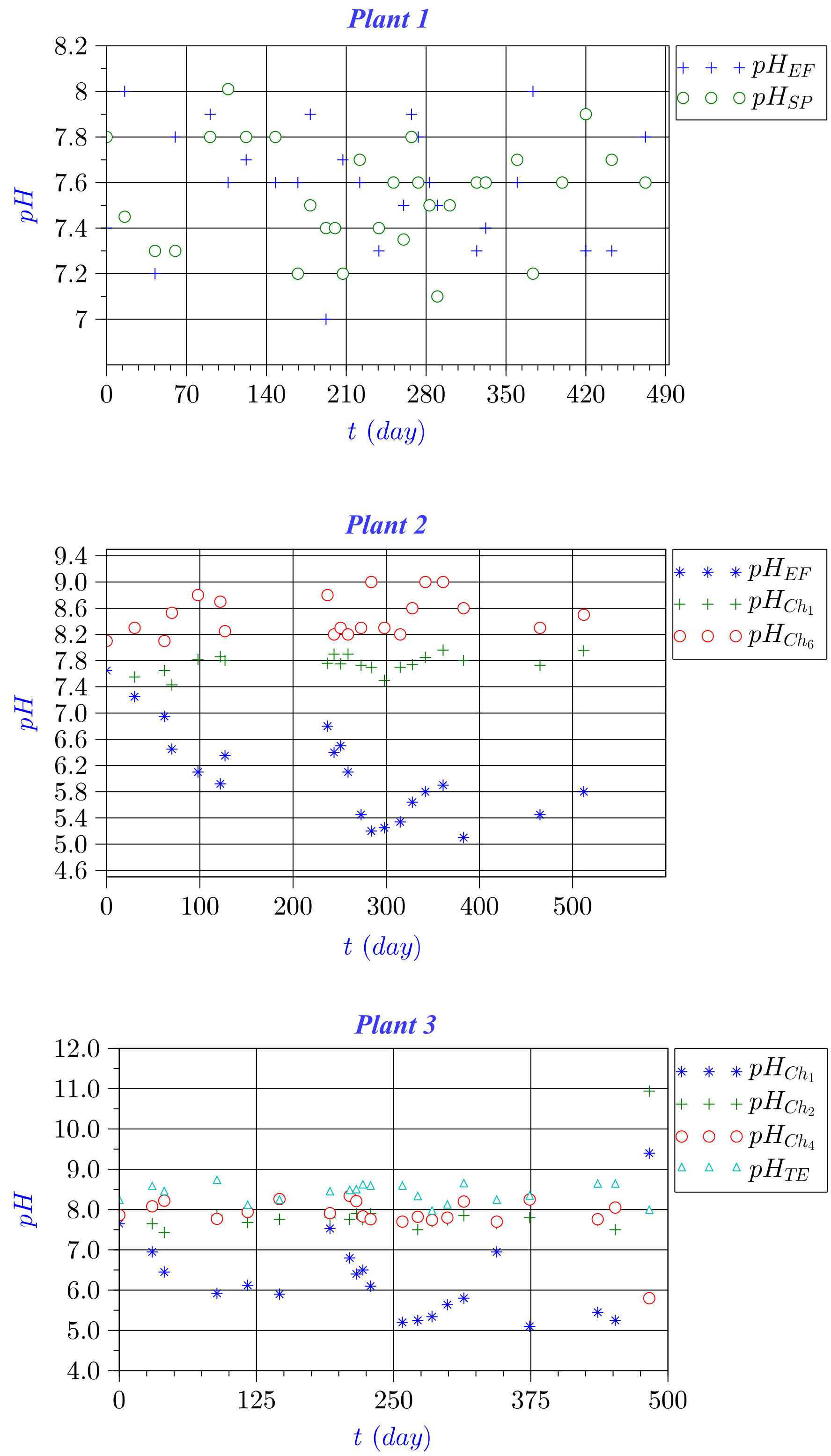

Figure A3. pH results for plant 1, 2, and 3.

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