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infusion

Intensive treatment of waste effluents and conversion into useful sustainable outputs: biogas, nutrients and water.

Project:

Intensive treatment of waste effluents and conversion into useful sustainable outputs: biogas, nutrients and water (Life INFUSION)

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4.0				

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1. Objective and scope action A1.1

The main objective of this report is to characterise the composition and the variability of the effluents from the waste treatment plant in Barcelona, Ecoparc of Montcada i Reixac, and the landfill in Gijon from the last 3 years. The results of this action will define the baseline of the project in the two demo-sites so to be able to compare the benefits of INFUSION solutions.

The organic fraction of the MSW in the Waste treatment plant (WTP) in Barcelona is currently treated by an anaerobic digestion deriving into three products: solid fraction of sludge, liquid fraction of the digestate and biogas. The same process occurs in Gijon for their OFMSW. The sludge is further composted, the liquid fraction of the digestate is further treated in their wastewater treatment plant (WWTP) and the biogas is burnt to recover energy.

Hence, in order to set a baseline for INFUSION, the physicochemical characteristics of the liquid digestate are going to be gathered as well as the biogas purity and the heat and electricity generated during the co-generation process of the biogas. INFUSION project aims to provide a circular economy approach to the liquid effluents of waste treatment plants and landfills by recovering bio-fertilizers. Thus, current physicochemical characteristics of the current waste products (leachate and liquid fraction of digestate) will be compared to the Spanish and EU legislation stating the required water quality to be used in irrigation purposes (RD1620/2007) as well as to the requirements to be applied in fertigation and, in the case of the biogas, in biomethane (UNE EN 16723).

Additionally, operation parameters of the current treatment in both demo-sites such as flowrates, energy and reagent consumptions, etc. will be collected to also compare with actions B3 and B4 in regard of the site.

2. Description of WWTP in both demo-sites Barcelona and Gijon

2.1. Description of WWTP in Ecoparc of Montcada i Reixac (Barcelona, Spain)

Ecoparc of Montcada I Reixac, Ecoparc2, processes 80,000 t/y of organic fraction of municipal solid waste (OFMSW) using dry anaerobic digestion in two reactors of 4,500 m^3 each. Collected OFMSW from households is pretreated for the separation of inorganic matter, plastics and other valuable waste. After anaerobic digestion, digestate follows three serial solid/liquid separation processes, screw press and two centrifugations. The obtained liquid fraction (anaerobic supernatant) is collected in a stirred tank, from where is fed into Membrane Bioreactor, MBR, Biomembrat® wastewater treatment plant to treat the leachate generated before being discharged into the polygon collector (destined for the Montcada i Reixac WWTP), so that the organic load is reduced (COD) and nitrogen (ammonium, nitrates and nitrites) in accordance with the discharge parameters established in Decree 130/2003.

To do this, it has:

- 3 leachate storage tanks of 406 m^3 each
- 1 rotary filter
- 2 vibrant filters
- 1 denitrification tank of 203 m^3

- 2 nitrification tanks of 683 and 1,216 m^3

- 1 combined tank (nitrifier / denitrifier) of 141 m^3

- 2 ultrafiltration lanes in parallel with 6 modules per lane

- 1 homogenization tank of 225 m^3

Initially, the plant was designed to treat 142 m^3/d with a load of 10,000 mg/L of COD. However, it was observed that the COD in the leachate was much higher than the design, therefore, in January 2009, an expansion was carried out adding one more nitrification unit, expanding the capacity of the plant to treat 40,000 mg/L of COD with the same flow of 142 m^3/d.

2.1.1. Description of the primary treatment

The leachates produced in the anaerobic digestion are collected in a holding tank, where they are mixed with the leachates produced in the rest of the Ecoparc 2 processes. By overflow, they go to the second tank which, in turn, by overflow goes to the third tank with an agitator to homogenize the entrance to the treatment plant, avoiding high variations in the composition of the leachate to be treated and minimizing exposing the plant to stressful situations in which you must constantly be looking for a new steady state.

The homogenized leachate goes through a filtration process consisting of a rotary filter and 2 vibrating sieves with a mesh of 800 µm.

Figure 1. Image of vibrating sieve of Ecoparc 2 WWTP

2.1.2. Description of secondary treatment

Next, it undergoes a biological nitrification / denitrification process in order to convert biodegradable organic compounds and the different forms of nitrogen (organic nitrogen, ammonia, nitrites and nitrates) into carbon dioxide (CO2), nitrogen gas (N2) and water (H2O), through the action of different microorganisms. For this, there are 4 reactors:

1) Firstly, an anoxic biological reactor, where denitrification is carried out, reducing nitrates to nitrogen gas through a carbon source (in this case, COD) and H^+ ions, creating a more basic medium.

$$4\,NO_3^- + 4\,H^+ + 5\,[C] \xrightarrow[\text{facultativas}]{\text{bacterias heterotrofas}} 2\,N_2 + 5\,CO_2 + 2\,H_2O$$

2) Then, it goes through 2 aerobic biological reactors in series, where nitrification is carried out by first oxidizing the ammonium to nitrites and these to nitrates. In this part of the process, H+ are produced, which causes an acidification of the medium. Since the reactions that take place are exothermic, it is necessary to

have heat exchangers that prevent overheating of the reactors and their inhibition.

$$NH_4^+ + 1{,}5\ O_2 \xrightarrow{\text{nitrosomonas}} NO_2^- + H_2O + 2\ H^+ \qquad \Delta E = -352\ kJ/mol$$

$$NO_2^- + 0{,}5\ O_2 \xrightarrow{\text{nitrobacter}} NO_3^- \qquad \Delta E = -352\ kJ/mol$$

$$NH_4^+ + 2\ O_2 \longrightarrow NO_3^- + H_2O + 2\ H^+ \qquad \Delta E = -425\ kJ/mol$$

3) Finally, it goes through a combined reactor, which can act as a denitrifier or nitrifier depending on the established operating parameters in which the carbon source dosing time (methanol, if there is not enough COD) for denitrification is indicated, the aeration time for nitrification and the pause time between processes for the total consumption of dissolved oxygen creating anoxic conditions.

2.1.3. Description of tertiary treatment

Finally, it goes through a filtration process consisting of 2 parallel ultrafiltration lanes of 6 modules each, resulting in obtaining the permeate on the one hand and the concentrate on the other. Both effluents obtained can recirculate or end the process:

The concentrate can be recirculated to meet the age of the sludge or purged to avoid concentration of solids in the biological process. In the event of purging, the concentrate is centrifuged, recirculating the liquid phase either in the initial holding tanks to dilute the input leachate or in the denitrifier, taking advantage of it to break the foams created in the process.

o The permeate can be recirculated to the denitrifier by diluting the leachate to be treated or it is sent to the homogenization tank, where it is mixed with the gray water that does not need to be treated in the treatment plant.

The homogenization tank has aeration that helps to release the residual nitrogen gas and homogenize the mixture before being poured into the collector, thus avoiding large variations in both quantity and quality of the discharge.

The following **figure 2** shows a diagram of the current leachate treatment process at Ecoparc 2 from the collection of the leachate to its discharge to the collector.

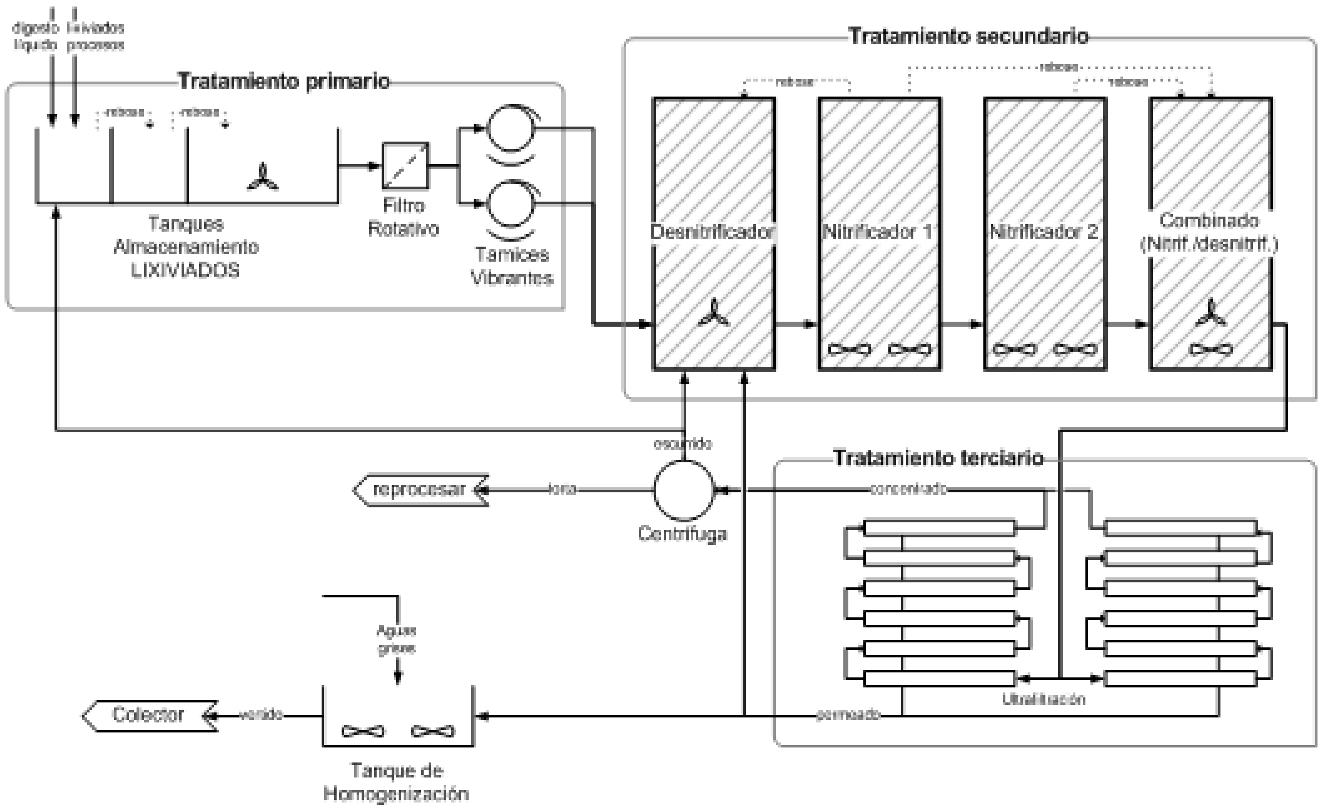


Figure 2. Diagram of the current leachate treatment process at Ecoparc 2 from the collection of the leachate to its discharge to the collector

Figure 3. MBR wastewater treatment plant in Ecoparc 2

2.1.4. Water and energy consumption

Next, the table below shows the water and energy consumption in the Ecoparc 2 treatment plant in the last 3 years

Table 1. Water and energy consumption of Ecoparc 2 in the last 3 years, related to WWTP.

Resource	Units	2019	2018	2017
water	m^3	9,141	10,223	12,580
energy	kWh	2,077,090	2,093,163	2,230,437

2.1.5. Reagent consumption

We can see the reagent consumptions in this table, where all “Membrane Clean” are membrane net products.

Table 2. Reagent consumption of WWTP in Ecoparc 2

Reagent	Unit	2019
Membrane Clean HC	kg	144
Membrane Clear AL10	Kg	150
Membrane Clean NE10	kg	90
Membrane Clean set	L	40
Defoamer	kg	28,580

In relation to methanol, it is going to stop dosing by February 2018 per million of the process in which it is not possible to provide an external carbon source, since there is enough COD to the combination for the denitrification reactions. For which thing, the last thing that is going to buy methanol will be in 2017 with a consumption of 77 m^3.

2.2. Description of WWTP at the Gijon Landfill (Asturias, Spain)

The leachate depuration plant of landfill is based on the same technology as in Ecoparc 2, MBR treatment. It started operation in 1996 (first Biomembrat® in Spain) with a capacity of 400 m^3/d. The facility was enlarged in 2000, 2004, and 2013, so the current capacity is 705 m^3/d considering a daily load of 1,800 kg/d of nitrogen expressed as N-$NH4^+$ and 4,700 kg/d of COD.

The plant is constituted of the following main elements:

- 6 pressurised reactors (2,5 bar at head space) including 1 anaerobic reactor for denitrification process, 4 aerobic reactors for nitrification process, and 1 combined reactor for both denitrification (inner part) and nitrification (extemal part).
- Storage and dosage of additives: 2 buried tanks (30 and 50 m^3) for methanol as BOD supplement, 1 large bulk container (1 m^3) for H3PO4 as P supplement if necessary, and 1 large bulk container (1 m^3) for antifoam.

- 4 air compressors for aeration of nitrification process, and pneumatic devices (valves, pumps, etc.)
- 5 independent ultrafiltration lines (0,020 µm) to separate the activated sludge from the treated water (permeate)
- On-line analysers: dissolved oxygen, temperature and head-space pressure of biological reactors; ammonium concentration of permeate; pH, temperature and conductivity of both leachate and permeate.
- Supervisory Control and Data Acquisition system (SCADA).
- Physicochemical treatment of excess of sludge, including Ca(OH)2 and polyelectrolyte addition and subsequent centrifugation.
- 2 heat exchangers
- 6 reactors with activated carbon for COD reduction in permeate, including NaClO dosage.

Figure 4. MBR wastewater treatment plant at the Gijon Landfill

2.1.6. Water and energy consumption

The water consumption since second quarter of 2019 has been ranging between 27 and 54 L/m^3 treated leachate. The need of water is strongly affected by UF cleaning, $Ca(OH)_2$ slurry preparation for sludge centrifugation, etc.

Table 3. Water consumption in WWTP process of Gijon Landfill

Quarter	Treated leachate (m^3)	Water (m^3)	Water (L/m^3 leachate)
2019-2	63,860	3,417	54
2019-3	62,660	2,621	42
2020-1	86,453	2,336	27
2020-2	86,901	4,401	51

The energy consumption since 2017 has been ranging between 25.6 and 13.3 kWh/m^3 of treated leachate, showing the lowest during the last year as the treated leachate increased. The electric consumption involves a physicochemical pre-treatment to reduce suspended solids of leachate, the Biomembrat® process, and the dehydration of the excess of biological sludge. The main consumer is the Biomembrat® process (above 93%).

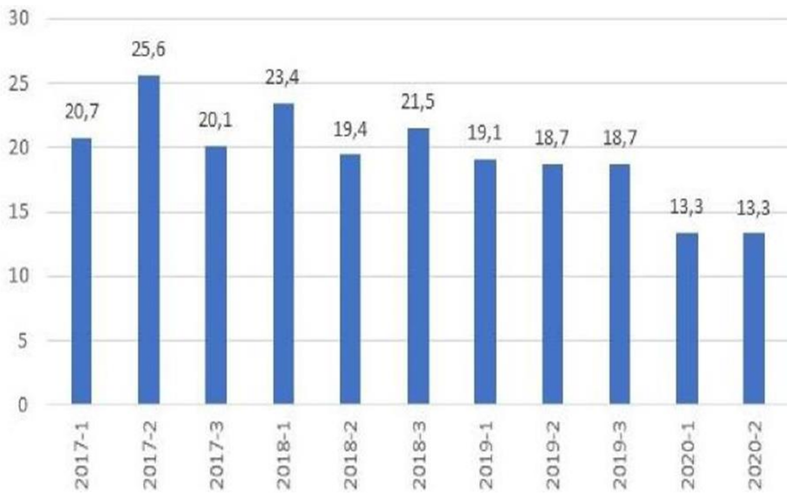


Figure 5. Energy consumption of the depuration process at Gijon Landfill (kWh/m3 leachate)

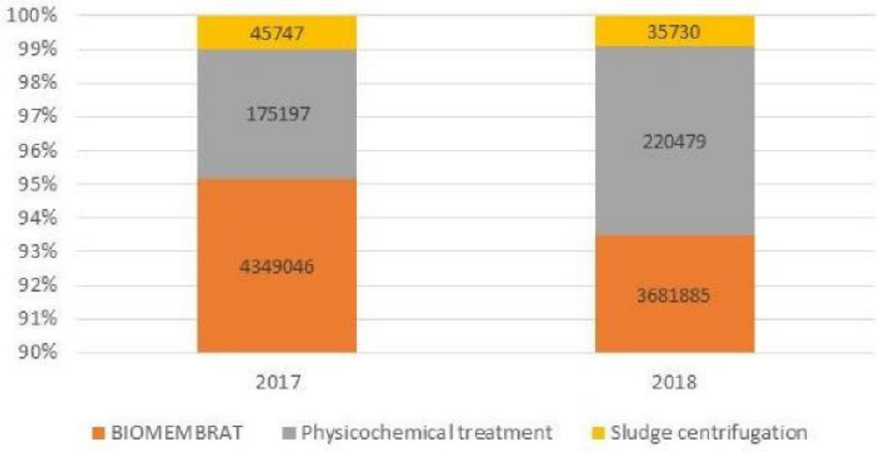


Figure 6. Distribution of energy consumption by sub-process (%)

2.1.7. Reagent consumption

The main consumptions of the depuration process are methanol, calcium hydroxide, anti-foam and phosphoric acid.

The methanol consumption since 2017 has been ranging between 2.4 and 3.2 kg per cubic meter of treated leachate. The methanol dose has stabilized at 3 kg/m^3 of leachate for the last year.

Although calcium hydroxide consumption has been referred to the treated leachate, its consumption depends on both the excess of sludge of the process and dehydration demand. Some fresh sludge is recovered as inoculum for external N-DN facilities; therefore, the need of dehydration is affected by external demand of Cogersa's sludge.

Table 4. Consumption of calcium hydroxide at wastewater treatment plant in Gijon Landfill

Quarter	Treated leachate (m^3)	Ca(OH)2 (kg)	Ca(OH)2 (kg/m^3 leachate)
2018-3	65,534	81,000	0.40
2019-1	58,162	32,000	0.16
2019-2	63,860	29,240	0.16
2019-3	62,660	75,460	0.41
2020-1	86,453	188,000	0.88
2020-2	86,901	295,300	1.25

The average consumption of anti-foaming is 33 L/d, approximately one large bulk container of 1 m^3 capacity per month.

The phosphorous concentration of crude leachate is considered adequate for the biological process, therefore there is no need to add commercial H_3PO_4 into the system. In fact, the remaining P in the permeate is over 7.5 mg/L.

3. Mechanical and biological treatment plant leachate in Ecoparc 2

Currently, 80% of the water being treated in the MBR wastewater treatment process comes from centrifuge runoff from the OFMSW biomethanization process in Ecoparc 2. Usual parameters in leachate entering the WWTP were measured according to Standard Methods:

Table 5. Analytical methods used to measure the characteristic parameters of the leachate in Ecoparc 2.

Parameter	Method
Alkalinity	2320 B del Standard Methods for the Examination of Water and Wastewater
CE	2510 B del Standard Methods for the Examination of Water and Wastewater
Tª	2550 B del Standard Methods for the Examination of Water and Wastewater
pH	4500-H+ A del Standard Methods for the Examination of Water and Wastewater
DM-Dry material	2.3.1 del Manual de Formación Biológica de Valorga
DQO	Kits Hach Lange standards-based ISO 6060-1989, DIN 38409-H41-H44
N TOTAL	Kits Hach Lange standards-based EN ISO 11905-1
NH_4^+	Kits Hach Lange standards-based ISO 7150-1, DIN 38406 E5-1, UNI 11669:2017
NO_3^-	Kits Hach Lange standards-based ISO 7890-1-2-1986, DIN 38405 D9-2
P total	Kits Hach Lange standards-based vanadate-molibdate
TOC	Kits Hach Lange standards-based EN 1484, DIN 38409-H3
TSS - Total suspended solids	2540 B and 2540 E del Standard Methods for the Examination of Water and Wastewater
Inert dissolved solids	
Total dissolved solids	
Volatile dissolved solids	
Total inert solids	
Inert suspended solids	
Volatile suspended solids (bacteria)	
Total solids	
Total volatile solids	

Below is the characterization of these waters from January 2017 to week 42 of 2020:

Table 6. Characterization of leachate from mechanical and biological treatment plant of organic waste in Ecoparc 2.

	Treated flow	pH	CE	Tª	DM	DQO	N-NH4	N TOTAL	TOC	Alkalinity
	m^3/d		mS/cm	ºC	g/L	mg/L	mg/L	mg/L	mg/L	
ẋ	125	8	33	28	26	26,723	3,806	4,999	11,975	316
σ	18.10	0.09	4.322	3.85	3.01	3,332	557	942	2,783	46.04
Max	172.26	8.21	41.26	34.66	36.48	37,023	4,919	8,750	19,100	400
Min	59.71	7.77	18.96	19.47	20.22	19,344	1,848	2,350	4,310	32

4. Landfill leachate in Gijon

Landfill leachate is the liquid that drains or 'leaches' from a landfill. It varies widely in composition regarding the age of the landfill and the type of waste that it contains. The waste treatment centre of Cogersa includes 3 different landfills for non-hazardous, hazardous and inert waste, respectively. Regarding Life Infusion project, the leachate to be considered drains from the landfill for non-hazardous waste.

4.1. Landfill for non-hazardous waste (LfNHW)

The construction of the LfNHW started in 1983 and the facility begun operating by the end of 1985. Its initial capacity was 10.5 Mm^3, being enlarged in 2005 (+2.1 Mm^3) and 2010 (+3.5 Mm^3).

The landfill is located across 3 municipalities (Gijon, Llanera and Corvera). Currently, the landfill is almost full, thus a new enlargement is in progress to provide an additional capacity of 2.1 Mm^3. The annexes 8.1 and 8.2 show the topography in 2011 and 2019, respectively.

Figure 7. Bird's eye view of Cogersa's landfill for non-hazardous waste (2020)

The LfNHW receives mainly municipal mixed waste (MMW) from the 78 municipalities of Asturias, but also non-hazardous waste from the regional industry and commercial activity, as well as non-hazardous refuse produced by the rest of waste treatment plants of Cogersa if its recycling or recovery are not feasible.

As can be seen in figure 8, since 2011, the LfNHW has been receiving yearly between 500-600 kt of waste, mainly unsorted municipal mixed waste (some 380 kt/y).

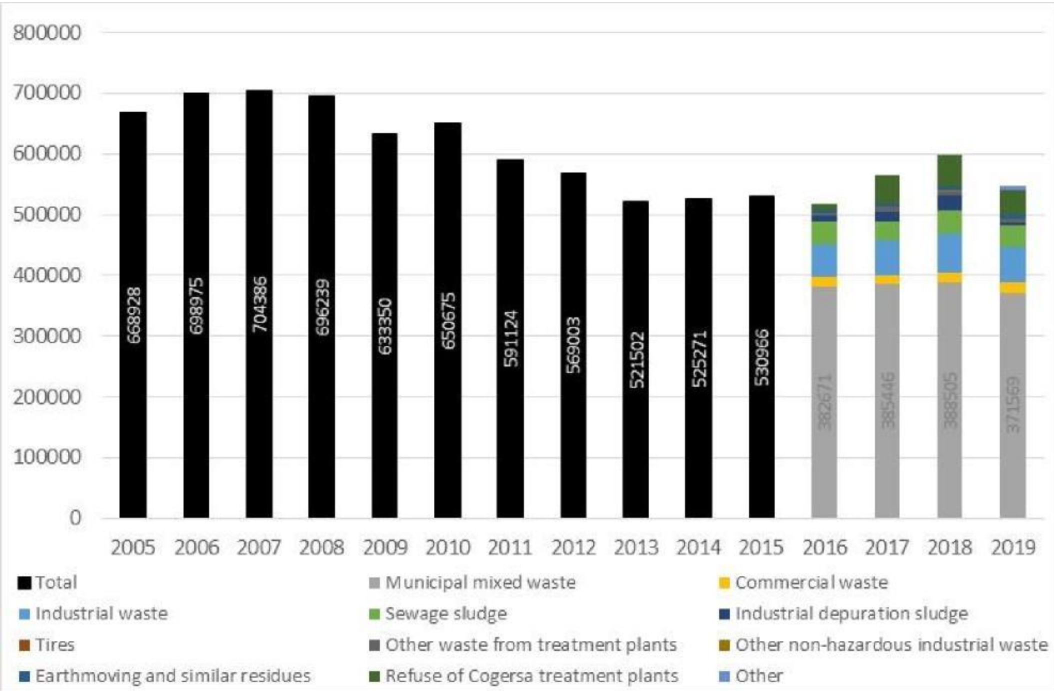


Figure 8. Evolution landfilling in the LfNHW of Cogersa since 2005

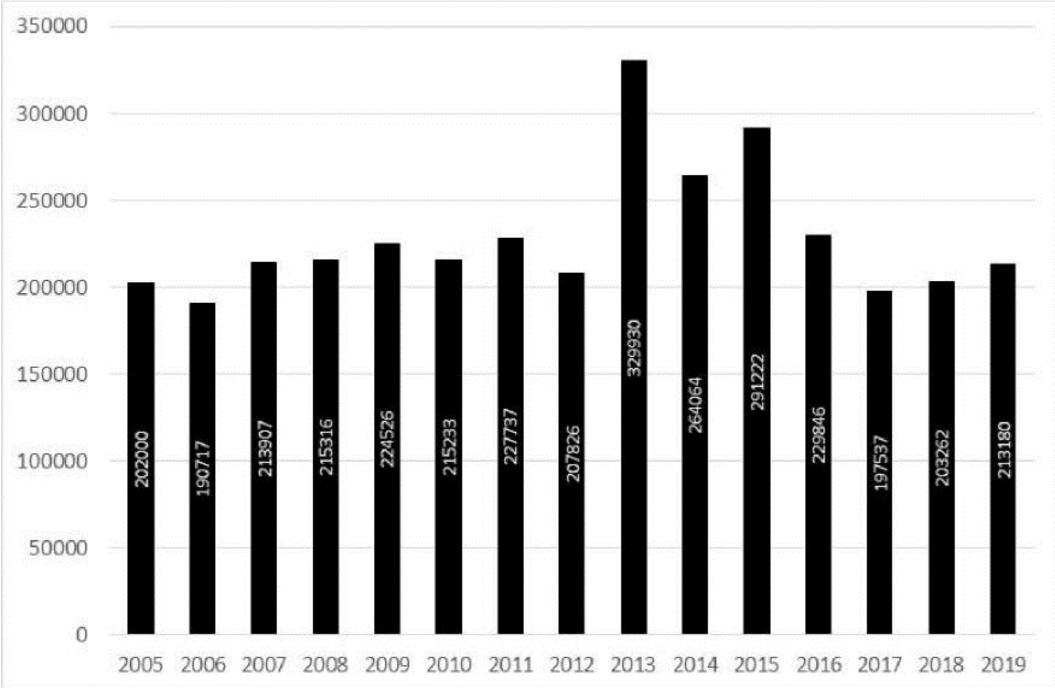


Figure 9. Treated leachate from the LfNHW in Gijon Landfill (m^3/y)

4.2. Generation of landfill leachate

The production of leachate in Cogersa is mainly affected by the large amount of landfilled municipal mixed waste, as well as the high rainfall in Asturias (some 850 L/m^2 per year). Since 2017, the treated landfill leachate is over 200,000 m^3/y (figure 9)

4.3. Characteristics of landfill leachate

Cogersa's landfill for non-hazardous waste produces several types of leachate depending on the area and age, which are collected in a number of waterproof/concrete ponds. Mature and fresh leachates are mixed in the pond nº 4, prior to a physico-chemical process that produce a crude leachate which is finally treated by a nitrification-denitrification process under pressure (Biomembrat®). During action A1 of project Life Infusion, an inventory of historical data of fresh, mature and crude leachates has been produced to provide the characteristics and trends of Cogersa's leachates.

Figure 10. Location of leachate ponds

4.3.1. Fresh leachate

Fresh leachate still contains a relevant fraction of drained liquid from waste, as degradation has not been completed. The characteristics of the fresh leachate produced by the LoNHW of Cogersa between January 2017 and September 2020 are summarised below. Suspended solids (SS) is a critical parameter considering its low degradation and the need to protect ultrafiltration. In case of high levels of SS, the fresh leachate must be diluted with more mature leachate, and the pre-treatment of crude leachate must be optimised to prevent Biomembrat® disturbances. The average of ammonium is 2.9 g N/L, ranging between 1.8 and 3.6 g N/L. The average of BOD5 is 865 mg/L, quite lower than the average of COD (4,603 mg/L). The average of suspended solids is 39 mg/L, reaching a maximum of 340 mg/L. Total solids range between 8.6 and 14.6 g/L (11 g/L in average), out of which 3,5 g/L are volatile solids. The average of conductivity is 26.2 mS/cm, ranging between 20.9 and 31.7 mS/cm.

Table 7. Characteristics of fresh leachate in Cogersa (Jan'2017-Sep'2020)

	2017	2018	2019	2020	Average	Min	Max	Number of analyses
Ammonium (mg N/L)	3,069	2,693	2,654	3,055	2,868	1,760	3,561	389
BOD_5 (mg/L)	1,235	775	638	811	865	500	2,300	46
COD (mg/L)	5,346	4,308	4,096	4,663	4,603	2,450	8,170	389
pH	8.9	8.4	8.6	8.4	8.6	8.1	9.2	46
Conductivity (µS/cm)	26,708	26,067	25,262	26,669	26,176	20,900	31,700	46
Total solids (mg/L)	11,486	10,510	10,311	11,947	11,063	8,576	14,624	45
Total volatile solids (mg/L)	3,864	3,687	3,244	3,578	3,593	2,413	7,546	45
Suspended solids (mg/L)	51,0	36,8	37,4	32,1	39	15	340	387
Alkalinity (mmol/L)	276	250	251	283	265	202	308	45

4.3.2. Mature leachate

Retention time of mature leachate in the landfill is grater than fresh leachate, thus anaerobic degradation can be considered completed under landfill conditions, decreasing BOD, COD and volatile solids compared to fresh leachate. The characteristics of the mature leachate produced by the LoNHW of Cogersa between January 2017 and September 2020 are summarised below. The average of ammonium is 2 g N/L, ranging between 1.5 and 2.9 g N/L. The average of BOD_5 is 515 mg/L, quite lower than the average of COD (2,886 mg/L). The average of suspended solids is 29 mg/L, reaching a maximum of 320 mg/L. Total solids range between 7.2 and 11.4 g/L (8.8 g/L in average), out of which 2,7 g/L are volatile solids. The average of conductivity is 21.5 mS/cm, ranging between 18.7 and 26.1 mS/cm.

Table 8. Characteristics of mature leachate in Cogersa (Jan'2017-Sep'2020)

	2017	2018	2019	2020	Average	Min	Max	Number of analyses
Ammonium (mg N/L)	2,243	1,855	1,940	1,966	2,001	1,480	2,898	388
BOD_5 (mg/L)	556	602	438	464	515	250	1,050	45
COD (mg/L)	3,430	2,651	2,822	2,643	2,886	1,115	4,740	388
pH	8.4	8.2	8.3	8.3	8.3	8.2	8.5	45
Conductivity (µS/cm)	23,717	20,028	21,271	21,113	21,532	18,710	26,100	45
Total solids (mg/L)	9,772	8,125	8,832	8,598	8,832	7,217	11,427	45
Total volatile solids (mg/L)	2,658	2,586	2,550	2,998	2,698	1,861	6,180	45
Suspended solids (mg/L)	24.3	22.5	29.1	39.1	28.7	12	320	388
Alkalinity (mmol/L)	214	184	196	195	197	164	244	45

4.3.3. Crude leachate

The crude leachate is a mixture of fresh and mature leachates, which has been pre-treated to reduce solids before Bioembrat® process. The characteristics of the crude leachate of Cogersa between January 2017 and September 2020 are summarised below. The average of ammonium is 2.2 g N/L, reaching a maximum of 2.8 g N/L. The average of BOD_5 is 647 mg/L, quite lower than the average of COD (3,649 mg/L). The average of suspended solids is 20 mg/L, reaching a maximum of 109 mg/L. The average of conductivity is 23.4 mS/cm, ranging between 19.6 and 27.1 mS/cm. The average of alkalinity is 231 mmol/L.

Table 9. Characteristics of crude leachate in Cogersa (Jan'2017-Sep'2020)

	2017	2018	2019	2020	Average	Min	Max	Number of analyses
Alkalinity (mmol/L)	227	204	212	283	231	178	2,320	195
Ammonium (mg N/L)	2,365	2,074	2,123	2,305	2,217		2,756	932
Conductivity (µS/cm)	24,545	21,924	22,635	24,320	23,356	19,570	27,100	375
BOD_5 (mg/L)	806	652	540	589	647	350	1,350	45
COD (mg/L)	4,089	3,389	3,373	3,747	3,649	600	33,510	933
pH	8.6	8.4	8.4	8.5	8.5	8.2	8.9	375
Suspended solids (mg/L)	25.8	14.3	15.2	24.5	20.0	12	109	930

4.3.4. Comparison of leachates

The following table summarises the average data for fresh leachate, mature leachate, and their mixture before depuration: crude leachate. Accordingly, it can be estimated that crude leachate is constituted of approximately 60% mature and 40% fresh leachates.

It must be highlighted that crude leachate is not just a simple mixture of mature and fresh leachate, as a previous physicochemical pre-treatment, a settling process and a 100 µm filter reduce the suspended solids of the mixture of leachates, resulting in the crude leachate pumped into de Biomembrat® process. This justify the lower concentration of suspended solids of crude leachate compared to the fresh and mature ones.

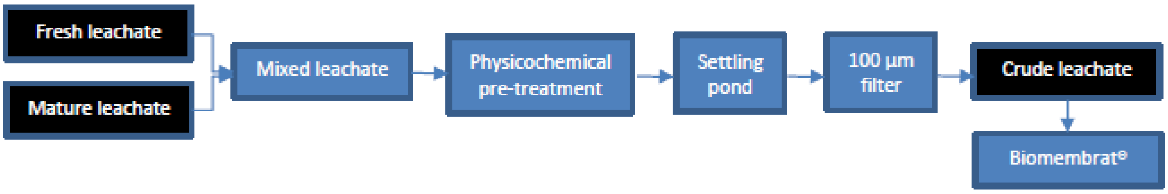


Figure 11. Production of crude leachate prior to Biomembrat® depuration

Table 10. Comparison of the leachates of Gijon landfill. Average of the parameters for the period Jan'2017-Sep'2020

	Fresh	Mature	Crude
Ammonium (mg N/L)	2,868	2,001	2,217
BOD5 (mg/L)	865	515	647
COD (mg/L)	4,603	2,886	3,649
pH	8.6	8.3	8.5
Conductivity (µS/cm)	26,176	21,532	23,356
Total solids (mg/L)	11,063	8,832	
Total volatile solids (mg/L)	3,593	2,698	
Suspended solids (mg/L)	39	28.7	20.0
Alkalinity (mmol/L)	265	197	231

5. Characteristics of discharged effluent (permeate) in both demo-sites

The aerobic process MBR is an effective treatment for both the water from the treatment of organic matter from municipal waste and from the leachate from a landfill, since the discharge quality parameters are achieved. However, aeMBR is not very efficient since it requires a lot of energy to achieve the oxidation process of the organic and ammonia load and the contribution of extra chemicals, such as methanol, to carry out the denitrification stage.

Below we will present the characterization of both the permeate in Ecoparc 2 and in the Gijon landfill.

5.1. Permeate obtained in the MBR of Ecoparc 2

Below is the characterization of these permeate from January 2017 to week 42 of 2020:

Table 11. Characterization of permeate in the MBR of Ecoparc 2.

	pH	CE mS/cm	DQO mg/L	P total mg/L	NH_4^+ mg/L	NO_3^- mg/L
ẋ	7.49	16.90	1,286	38.61	33.29	33.03
σ	0.26	2.11	141	10.12	18.79	24.89
Max	8.11	21.02	1,533	75.00	59.78	96.36
Min	6.07	11.25	904	12.12	2.45	10.68

5.2. Permeate obtained in the MBR of Gijon Landfill

Table 12. Characterization of permeate in the MBR of Gijon Landfill

Parameter	Average				Jan 2017 - Sep 2020				Limit for discharge
	2017	2018	2019	2020	Average	Min	Max	Analyses (nº)	
pH	6.7	6.7	6.8	6.8	6.7	6.1	7.3	944	6-9
Conductivity ('iS/cm)	12,793	11,223	12,103	12,710	12,207	9,300	14,750	931	16,000
Suspended solids	12.3	12.3	12.3	12.3	12.3	12.0	16.0	45	1,000 mg/L
Total dissolved solids	10,591	8,029			9,310	8,029	10,591	2	
BOD_5 (mg/L)	16.8	15.5	18.8	18.7	17.5	10.0	26.0	45	1,000 mg/L
COD (mg/L)	1,284	1,097	1,131	1,252	1,191	800	1,764	933	1,600 mg/L
Ammonium (mg N/L)	10.6	7.9	8.1	13.1	9.9	5.0	157	938	60 mg N/L
Nitrate (mg N/L)	513	471	458	524	491	180	862	574	
Nitrite (mg N/L)	3.8	1.4	5.0	13.1	5.8	1.0	157.0	397	
Phosphate (mg P/L)	7.5	7.5	7.6	8.5	7.8	0.5	19.5	391	
Fluorides	3.0	2.0	1.8	1.7	2.1	1.4	4.3	45	12 mg/L
Iron (Fe)	1.1	0.7	0.9	0.7	0.8	0.5	2.2	45	10 mg/L
Manganese (Mn)	0.08	0.13	0.07	0.06	0.1	0.1	0.2	45	2 mg/L
Nickel (Ni)	0.18	0.16	0.17	0.17	0.2	0.1	0.2	45	5 mg/L
Lead (Pb)	0.20	0.20	0.20	0.21	0.2	0.2	0.3	45	1 mg/L
Zinc (Zn)	0.22	0.14	0.14	0.13	0.2	0.1	0.7	45	10 mg/L
Alkalinity (mmol/L)	22.4	19.8	26.0	21.1	22.3	10.6	224	386	

6. Production and characteristics of biological slugde in both demo-sites

In this section we will know the amount of sludge generated in the MBR treatment from the treatment of organic matter from municipal waste and leachate from a landfill. As well as the characteristics of the active biomass.

6.1. Production and characteristics of biological slugde in Ecoparc 2

In 2019, were produced at Ecoparc 2 27,655 t/y of concentrates, 5,531 t/y of WWTP sludge and 22,124 t/y of recirculated drain.

This table shows the main characteristics of the active biomass from January 2017 to week 43 of 2020, analyzed according to the standards indicated in the section 3.

Table 13. Characterization of active biomass in Ecoparc 2

	Total solids	Total suspended solids	Total dissolved solids	Total inert solids	Total volatile solids	Volatile suspended solids (bacteria)	Inert suspended solids	Volatile dissolved solids	Inert dissolved solids
	%	%	%	%	%	%	%	%	%
ẋ	2.55%	1.43%	1.12%	1.19%	1.36%	1.19%	0.25%	0.17%	0.94%
σ	0.36%	0.38%	0.08%	0.15%	0.29%	0.29%	0.14%	0.09%	0.10%
Max	3.70%	2.59%	1.43%	1.50%	2.37%	2.22%	0.69%	1.12%	1.16%
Min	1.68%	0.67%	0.94%	0.00%	0.75%	0.54%	0.00%	0.03%	0.00%

6.2. Production and characteristics of biological slugde in Gijon Landfill

Since 2017, the production of excess of biological sludge has been ranging between 60-79 kg per cubic meter of treated leachate, but the last months the ratio seems to have stabilized at 60 kg/m^3. The total solids of the activated sludge show an average of 2 g/L, ranging between 19.7 and 40.2 g/L; out of which 22 g/L in average are total volatile solids. The excess of sludge is recovered directly for anaerobic digestion or as inoculum for other depuration plants. The remaining wet sludge is dehydrated, and finally, the dried sludge (71% humidity in average, ranging between 58-77%) is preferably recovered for composting process. The excess of sludge (wet or dried) is rarely devoted to elimination in landfill.

Table 14. Concentration of solids in the biological sludge (Jan’2017-Nov’2020) in Gijon Landfill

	2017	2018	2019	2020	Average	Min	Max	Number of analyses
Total solids (mg/L)	28499	28271	27179	30852	28000	19698	40253	595
Total volatile solids (mg/L)	19263	20207	18646	21442	22027	13284	82189	591

Table 15. Sludge production by Cogera’s MBR since 2017 and sludge management choices

	2017	2018	2019	2020	
				1st quarter	2nd quarter
Excess of biological wet sludge of Biomembrat® (t)	**1,558**	**12,427**	**12,168**	**5,167**	**5,206**
Treated leachate (m^3)	1	20,326	18,468	86,453	86,901
Ratio of excess of wet sludge (kg/m^3 leachate)	**79**	**61**	**66**	**60**	**60**
Excess of wet sludge to anaerobic digestion process (t)	1,859	154	148	42	128
Excess of wet sludge to other companies as inoculum (t)	8,637	8,724	7,847	946	0
Excess of wet sludge to elimination (t)	0	0	0	586	0
Excess of wet sludge to dehydration process (m^3)	5,092	3,549	4,173	3,593	5,078
Production of dehydrated sludge to landfill (t)	1,017	561	688	113	19
Production of dehydrated sludge to composting process (t)	0	0	0	888	1326
Total production of dehydrated sludge (t)	**1,017**	**561**	**688**	**1,001**	**1,345**

7. Production and characteristics of biogas from Gijon Landfill

In 1989, the landfill of Cogersa was the first in Spain to start collection and use of biogas for energy production.

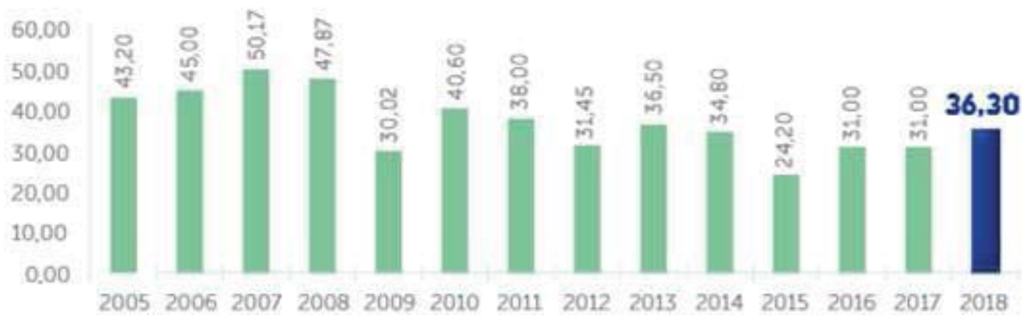


Figure 12. Biogas collection between 2005 and 2018 (Mm^3)

The biogas collected by the system in 2019 was 34.7 Mm3. It was recovered for electricity production (85.3%), clinical waste incineration (4.9%), and animal byproducts treatment (2.4%). The rest, 7.4%, was burned in a biogas flare stack to prevent CH4 emissions.

In 2020, Cogersa collaborated with the Institute of Technology and Renewable Energies (ITER) within VERTEGAS project1, which is aimed to estimate the uncontrolled diffuse emission of methane into the atmosphere from landfills in Spain. The results showed the landfill of Cogersa as one of the Spanish landfill with lower methane diffuse emissions (13%), while the degasification system collects most of the methane (87%).

7.1. Landfill degasification system

Currently, the biogas collection system consists of some 367 vertical wells distributed each 20 meters across the landfill. The 315 mm diameter PVC wells are connected to a suspended 90 mm PEAD pipe. Some 61 km of PEAD pipes carry the biogas to the 17 regulation and measurement stations, which are connected to the 4 extraction stations where the vacuum extracts the biogas which is pumped to the consumers: the biogas motors for electricity production, the incineration plant for clinical waste, and the plant for the treatment of

[1] VERTEGAS project https://www.iter.es/portfolio-items/vertegas/?lang=en

animal by-products not intended for human consumption. Any eventual excess of biogas is burned in a biogas flare stack.

The biogas produced by the anaerobic digestion plant is also injected in the general system through the impulsion side.

Figure 13. General view of the landfill degasification system in Cogersa

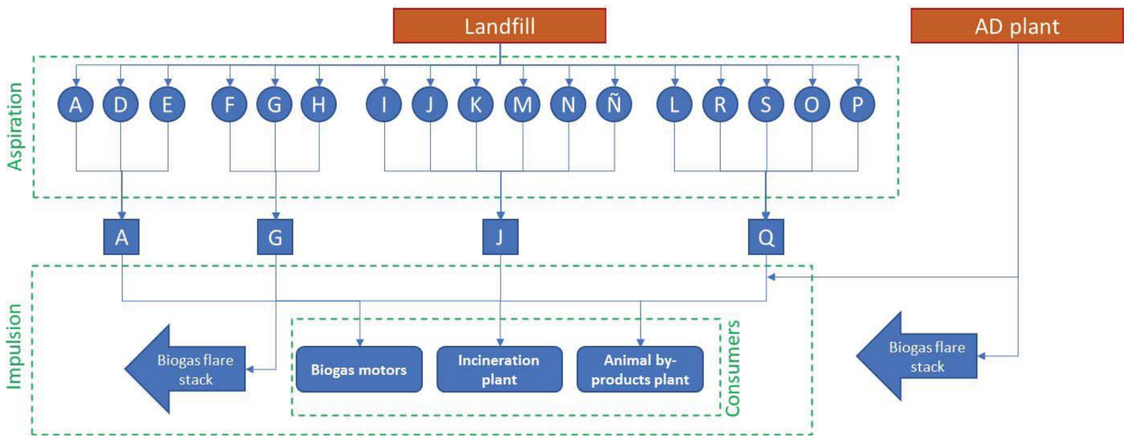


Figure 14. Biogas system including de producers (landfill and AD plant), 17 regulation stations for landfill biogas (○), 4 extraction stations (□), 2 biogas flare stacks, and the consumers.

Each extraction station is connected to 3-6 regulation stations which, in turn, provide vacuum to 12-16 PEAD pipes. Each PEAD pipe in the landfill is connected to 1 (or maximum 2) well/s to ensure the proper vacuum. The pressure set point established in the general manifold of the station is -30 mbar.

The biogas system analyses sequentially each PEAD line to control CH_4 and O_2 and open or close the corresponding valves to produce a ≈50% methane biogas pull. The pipes with higher content of methane are progressively open to increase their collection. On the contrary, the pipes with lower methane content are progressively closed to decrease their flow. In case of dangerous levels of oxygen in the line (≥7%) the SCADA system closes the automatic valve of the dangerous pipe. To evacuate condensates, a siphon-shaped self-purge is installed in the lower positions of the catenary.

All the parameters, including the GPS coordinates of the wells and the information relative to their connection to the pipes/stations, are recorded by BioGaps software, developed by Cogersa.

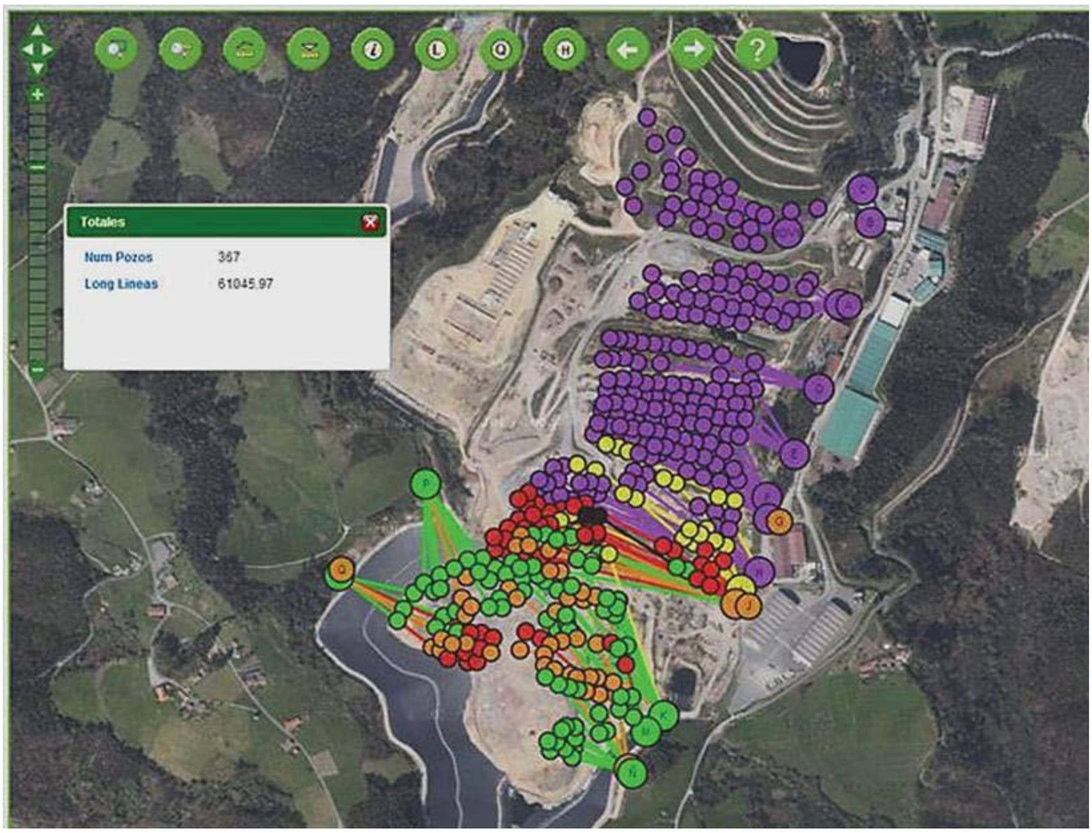


Figure 15. Screen shot of BioGaps software developed by Cogersa

7.2. Biogas composition

Most of the biogas of Cogersa's grid comes from the landfill (≈34 Mm3/y), while the contribution of the AD plant is some 0.5 Mm3/y. Whenever the AD plant is in ordinary situation, the exportation of the AD biogas to the general biogas grid is permanent.

Accordingly, to external analyses carried out in 2013 and 2017, the composition of the biogas of Cogersa's grid is summarized in the following table. During 2021, a new set of analyses of biogas will be carried out.

Table 16. Characteristics of biogas of Cogersa's grid (mixture of Landfill biogas and AD biogas)

	Sample 1	Sample 2	Sample 3	Sample 4
Methane (CH_4) %	47.77	49.09	44.48	
Carbon dioxide (CO_2) %	29.13	28.80	28.55	
Nitrogene (N_2) %	19.32	19.34	21.28	
Oxygen (O_2) %	5.00	4.97	5.69	
Hydrogene %	<0.3	<0.3	<0.01	
Carbon monoxide %	<0.02	<0.02	<0.01	
Propane %	<0.02	<0.02	<0.01	
Isobutane %	<0.02	<0.02	<0.01	
n-butane %	<0.02	<0.02	<0.01	
Ethane %	ND	ND	<0.01	
Ethilene %	ND	ND		
Propilene %	ND	ND		
1-butene %	ND	ND		
N-pentane %			<0.01	
Humidity (mg/L)			4	
H_2S (ppm)				50

Figure 16. Methane concentration (%) of biogas grid at Cogersa between 01/12/2019

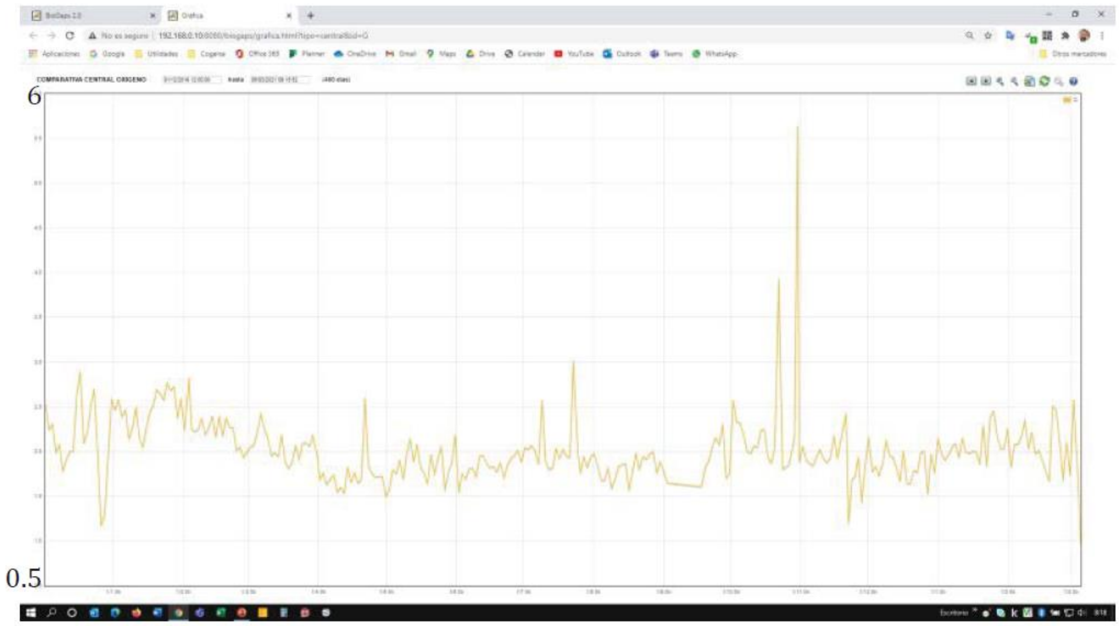


Figure 17. Oxygen concentration (%) of biogas grid at Cogersa between 01/12/2019

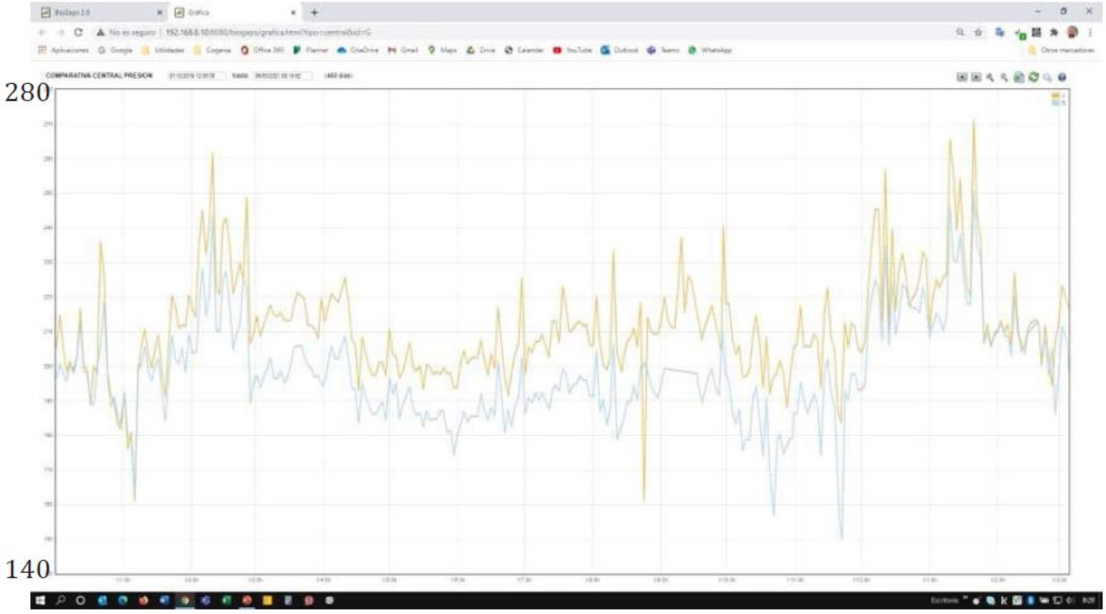


Figure 18. Pressure (mBar) of biogas grid at Cogersa between 01/12/2019 and 05/03/2021

Cogersa is progresively decreasing the dircharge of organic matter in landfill. A recent sewage sludge composting plant was commissioned by the end of 2019, increasing the capacity from 20,000 to 49,000 t/y of sewage sludge, thus diverting some additional 29,000 t/y from landfill. The promotion of separate collection of biowaste (brown bin) is reducing the discharge of biodegradable waste in landfill, while the production of the anaerobic digestion process increases. The most important measure to prevent discharge of biodegradable waste in Cogersa is the expected 58 M€ mechanical and biological treatment (MBT) plant to be commissioned by 2023. Therefore, Cogersa expects to reduce rapidly the landfill biogas production and increase the generation of AD biogas. Accordingly, the characteristics of the future biogas mixture (biogas grid) will be more similar to the AD biogas, decreasing N_2 and O_2 concentrations and increasing CH_4 and H_2S levels.

Therefore, any future project for biogas ugrading in Cogersa must be flexible in order to adapt its performances considering the current biogas characteristics (mainly landfill biogas) and the future ones (mainly AD biogas).

8. Results of the Life Methamorphosis project to be considered in this project

The treatment of leachates and supernatants obtained in solid waste treatment, either in landfills or in source separated OFMSW management plants is challenging from a technical and economical point of view due to high concentrations of contaminants, recalcitrant and inhibitory compounds. The anaerobic supernatant is a liquid stream with specific characteristics that guide the subsequent treatment options, it is characterized by very high N-NH_4^+·content and high COD / biochemical oxygen demand (BOD5) ratio.

The integration of anaerobic and aerobic processes is gaining increasing interest for the treatment of source sorted OFMSW. The combined treatment ensures the recovery of energy from the biogas along with the production of compost which can be used as soil conditioner.

Nowadays, for the treatment of landfill leachate and OFMSW supernatant one of the most applied technology is the membrane bioreactor (MBR). The application of aerobic MBR (AeMBR) technology for the treatment of landfill leachate started already in the nineties.

This high energetic need of AeMBR is due to a combination of two factors: firstly, the high content on COD and N content of OFMSW supernatants that need oxygen to be oxidized, e.g., in Ecoparc 2, COD content ranged from 22 to 46 kg/m^3 and TKN from 5.3 to 6.8 kg/m^3 Secondly, the high suspended solid content on the mixed liquor of the AeMBR decreases dramatically the oxygen transferability; in order to compensate this low oxygen transferability, higher air flow are needed.

With such influent characteristics, cross flow membranes are generally used due to the fact that higher shear stress (cross flow velocities of 1-4 m·s^{-1}) can be achieved compared to submerged modules (generally lower than 0.25 m·s-1).

In anaerobic supernatants with high solids content, besides the needs of fouling control in cross flow membranes and aeration needs, extra energy inputs could be required in AeMBR in terms of cooling energy, since heterotrophic growth is exothermic and the temperature of operation has to be kept under 40ºC for stability.

8.1. Life Methamorphosis' objectives and scope

The LIFE Methamorphosis project was cofounded by the European Commission within the LIFE programme. This project was coordinated by Aqualia and had the participation of companies such as Fomento de Construcciones y Contratas (FCC), Naturgy, SEAT, the Barcelona Metropolitan Area (AMB) and the Catalan Institute for Energy (ICAEN).

This was a technology demonstration project with the same goals as the LIFE Programme, in particular climate change mitigation through the use of renewable energy, and more specifically the production of biomethane from waste treatment plants. Furthermore, this initiative is in line with the guidelines about circular economy promoted by the European Community.

The project wanted to demonstrate the feasibility at an industrial scale of two innovative waste treatment systems; UMBRELLA prototype and METHAGRO prototype. For the Life INFUSION project, the prototype of interest is the UMBRELLA, specifically its wastewater treatment process.

The UMBRELLA prototype was installed at the municipal waste treatment plant located in Montcada i Reixac, (Barcelona, Spain). The energy uses to treat water from the organic fraction treatment was been optimized by using innovative anaerobic and atotrophic processes applied in series: the anaerobic membrane reactor (AnMBR) and the autotrophic nitrogen elimination system Anammox ELAN®.

eurecat AMB aqualia IRTA amiu GENOVA COGERSA DETRICON ECOPARC DEL BESOS, S.A.

8.2. Results to be considered

In order to overcome all the above mentioned limitations of AeMBR, in the Life Methamorphosis project anaerobic membrane bioreactor (AnMBR) of 42 m^3 was tested for the treatment of anaerobic supernatant.

An AnMBR can be simply defined as a biological treatment process operated without oxygen and using a membrane to provide solid–liquid separation. Membrane fouling is also the major obstacle to the application of the AnMBR. The macromolecules (e.g. proteins, colloids, and bio-refractory pollutants) contained in OFMSW AD supernatant are deposited onto the membrane surface; this phenomenon is exacerbated with increasing strength of the supernatant, which aggravates membrane fouling. Membrane fouling is also correlated with the operational control of an AnMBR. This technology tends to have a good performance only at feeding COD <20 kg/m^3 or OLR <10 kg COD·m^3/d.

Application of AnMBR for OFMSW AD supernatant is challenging, since in submerged membranes with 4 LMH (Trcinski and Stuckey, 2010) and in cross flow configurations very poor fluxes were achieved, between 8.3 and 2.5 LMH according with Zayen et al. (2012). However, compared with traditional, granular sludge based, anaerobic treatment technology, AnMBR can overcome usual features of the anaerobic supernatant, like high suspended solids (SS), toxicity, high salinity or drastic changes in organic loading rate (OLR) (Dereli et al., 2012).

Besides filtration performance, biomethane production with AD supernatants from OFMSW is also challenging due to the high ammonium concentration. Westerholm et al. (2013) observed at lab scale a 50% reduction in methane production when TAN went up to 5.5 kg·m^{-3} caused by ammonia inhibition when treating OFMSW. In aerobic systems, ammonia stripping was reported as a major ammonia removal mechanism at elevated temperatures with high rate aeration in an open reactor (Visvanathan and Abeynayaka, 2012).

The objective of the Life Methamorphosis study was to assess the operation of an anaerobic membrane bioreactor (AnMBR) treating the liquid fraction of the anaerobic digestate from the organic fraction of municipal solid waste (OFMSW), in a pilot plant coupled to these facilities and under real field conditions. The final aim is to characterize operational problems and limiting factors to take into account for scaling-up the system.

To the authors' knowledge, AnMBR technology applied to waste treatment streams has only been tested at lab scale. In terms of technology readiness level (TRL), this corresponds to a TRL = 4. Through this work, we aim to validate the AnMBR technology in relevant environment, thus increasing the TRL up to 6.

To carry out a correct control of the AnMBR process, the following points must be taken into account:

- ✓ The characterization of the anaerobic supernatant there was a first period from 28/05/2018 to 02/08/2018 debugging tests were performed with a CSTR and then with AnMBR the following detailed data is shown in the following table 2.
- ✓ Correct elimination of COD and suspended solids from the supernatant from the anaerobic digestion of OFMSW.
- ✓ Evaluate the performance of ultrafiltration.

In this section, we will focus on control points for water effluents. The following figure shows the prototype with all the water and gas sampling points:

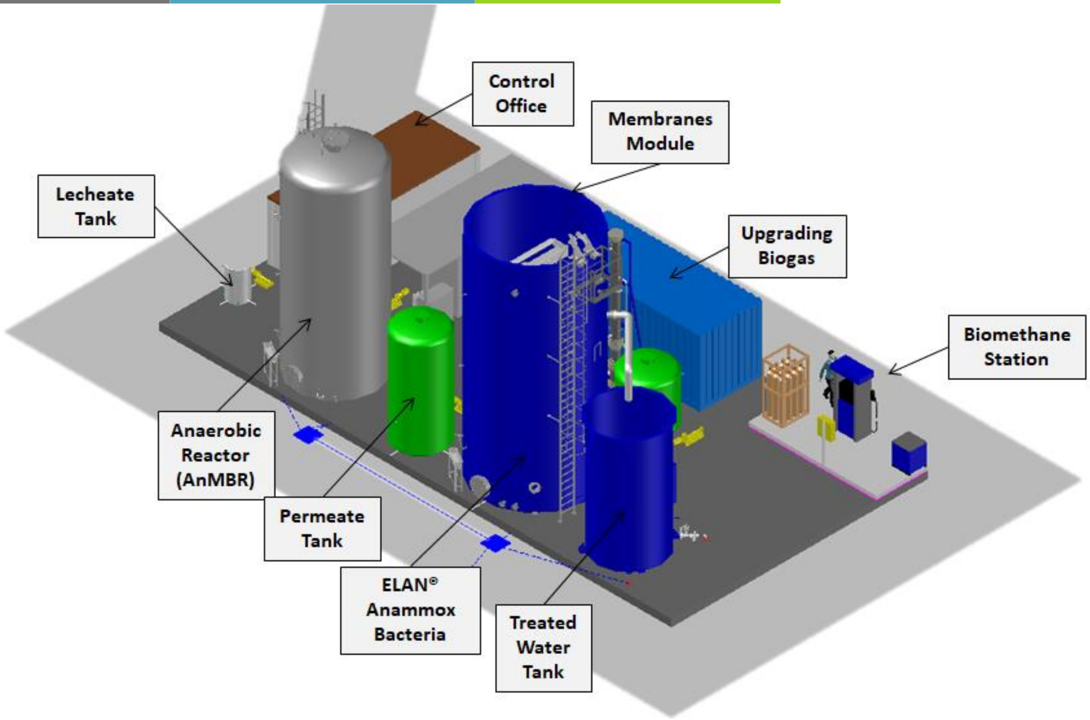


Figure 19. Plant Life Methamorphosis project Ecoparc of Montcada i Reixac

Next in this flow diagram we can see which are the sampling points in the AnMBR process:

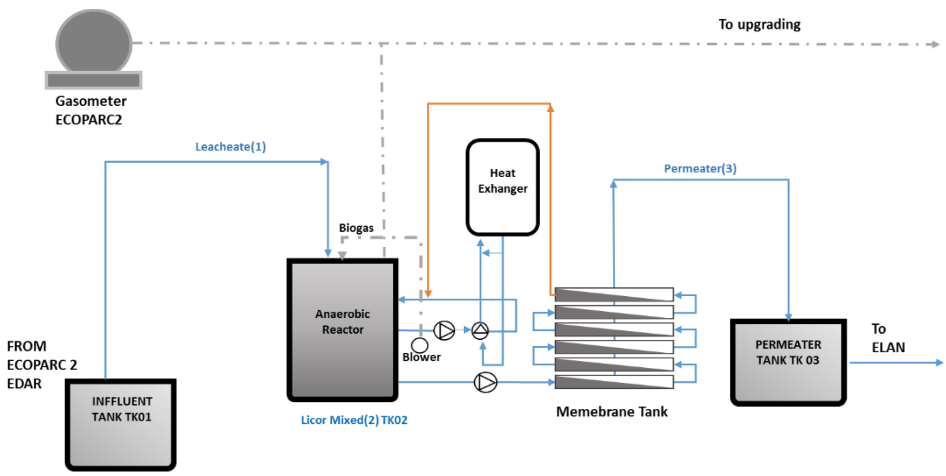


Figure 20. Flow diagram of wastewater treatment in the Ecoparc, where we can see the sampling points

Three sampling points are made, inlet, sludge and outlet of the AnMBR reactor to perform a process control to obtain:

- ✓ Reduction of the chemical oxygen demand (COD):> 75%
- ✓ Reduction of suspended solids (SS) in the effluent: 95%

There was a first period from 28.05.2018 to 02.08.2018 debugging tests were performed with a CSTR and later with AnMBR. The results obtained are detailed below:

Table 17. Characterization of the leachate in tests in CSTR configuration and in AnMBR configuration.

Parameter	Units	CSTR From 28.05.2018 to 02.08.2018		AnMBR From 03.08.2018 to the end	
		Number of samples	Average±SD	Number of samples	Average±SD
TCOD	mg O2·L-1	23	22,783±1,516	371	28,485±3,124
sCOD	mg O2·L-1	-	13,765±916	-	17,964±1,385
BOD5	mg O2·L-1	22	5,652±1,267	84	5,669±1,053
Ammoniacal Nitrogen	mg N-NH4·L-1	27	3,407±459	90	3,313±1,002
Ammonium	mg/l	27	4,423±584	250	4212±786.87
Alkalinity	mg CaCO3·L-1	17	325±15.93	83	340±22.38
TS	mg TS·L-1	23	25,313±743	85	26,923±1,745
VS	mg VS·L-1	23	13,741±688	85	15,006±1,992
IS	mg IS·L-1	23	11,572±609	85	12,095±941
sulfides	mg S2-·L-1	7	48.17±16.03	-	-

The leachate has a large fluctuation in both the total COD, Ammonium and the BOD5 as shown in before table.

The characterization of the mixed liquor was as shown in Table 17:

Table 18. Characterization of mixed liquor

Parameter	Units	CSTR test		AnMBR test	
		Number of samples	Average±SD	Number of samples	Average±SD
TCOD	mg O2·L-1	24	19,453±1,350	80	31,343±3,674
BOD5	mg O2·L-1	20	4,173±577	--	--
TS	mg TS·L-1	23	22,459±1,092	116	33,688±5,552
VS	mg VS·L-1	23	11,232±715	116	20,075±4,620
IS	mg IS·L-1	23	11,228±757	116	13,621±1,989

There are a high concentration of chemical oxygen demand and total solids, this parameter affects the fouling of membranes.

Table 19. Characterization of the permeated

Parameter	Units	CSTR test		AnMBR test	
		Number of samples	Average±SD	Number of samples	Average±SD
pH	upH	24	8.15±0.06	123	8.14±0.11
Conductivity (20ºC)	µS/cm	23	27,639±3.992	123	31,293±5.358
Conductivity (25ºC)	µS/cm	23	30,801±4,455	123	35,217±5,299
TCOD	mg O2·L-1	24	4,533±1,118	77	5,784±816
BOD5	mg O2·L-1	23	2,998±647	79	2,608±595
Alcalinity	mg CaCO3·L-1	14	14,693±2,249	121	15,892±3,649
Bicarbonates	mg L-1	4	16,183±319	36	20,359±2,291
VFA	mg Ac L-1	21	4,781±1,420	86	3,998±1.747
Ammoniacal Nitrogen	mg N-NH4/l	22	2,983±560	122	3,258±856
Ammonium	mg L-1	22	3,835±721	122	4,189±1,090
TSS	mg TSS·L-1	--	--	50	55.64±44.83
TS	mg TS·L-1	21	10,285±2,251	117	11,826±1,661
VS	mg SV·L-1	20	2,918±474	117	2,521±879
IS	mg IS·L-1	20	7,374±2,066	117	9,304±1,327
Sulfide	mg S2-·L-1	--	--	31	13.32±9.84

In the permeated, the low concentration of total suspended solids is observed, corresponding to the high efficiency of the membrane.

The AnMBR has managed to reach elimination targets in both COD an BOD_5.

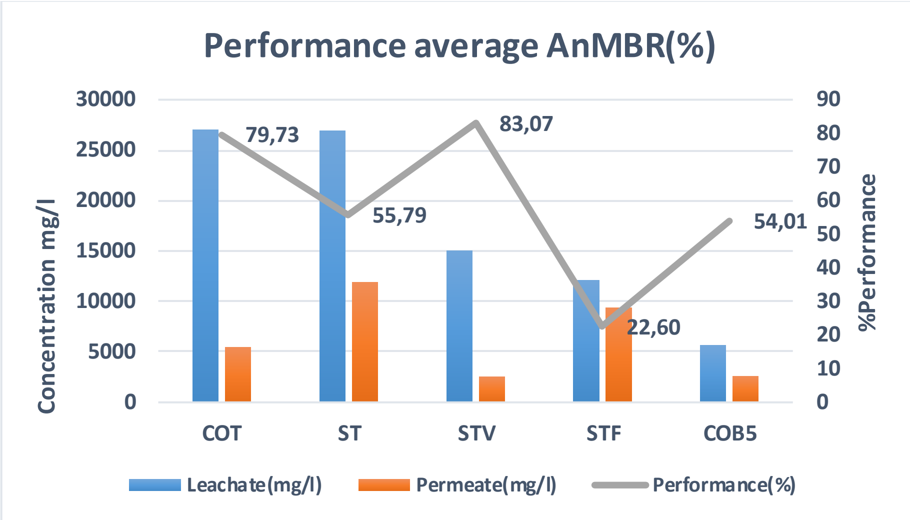
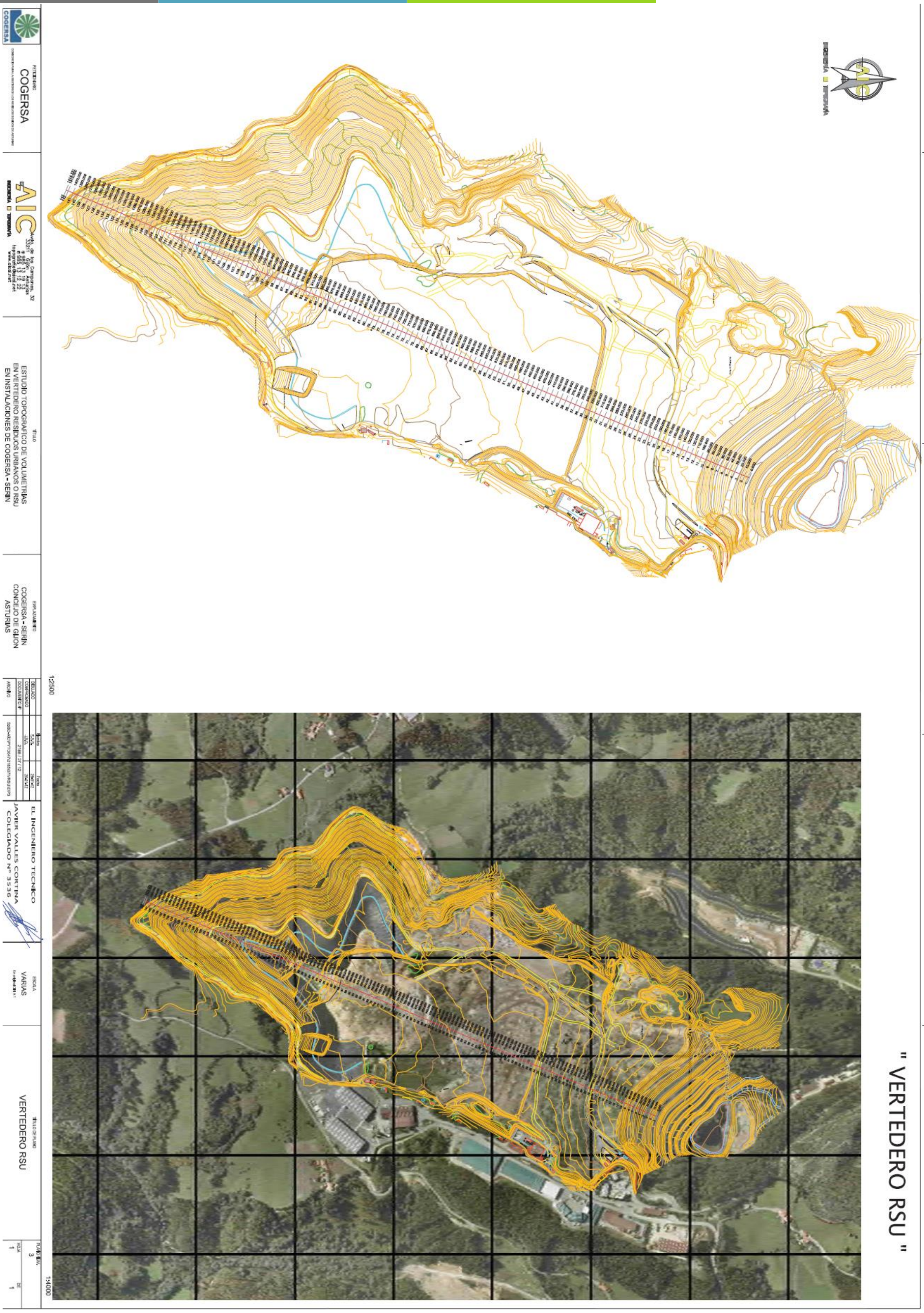


Figure 21. % Performance Average AnMBR

9. Annexes

9.1. Topographic map of the LfNHW in 2011


COGERSA
ESTUDIO TOPOGRÁFICO DE VOLUMETRÍAS
EN VERTEDERO RESIDUOS URBANOS O RSU
EN INSTALACIONES DE COGERSA - SERÍN
COGERSA - SERÍN
CONCEJO DE GIJÓN
ASTURIAS
1:2500
EL INGENIERO TÉCNICO
JAVIER VALLES CORTINA
VARIAS
VERTEDERO RSU
1:4000
" VERTEDERO RSU "

9.2. Topographic map of the LfNHW in 2019