LIFE DeNTreat

Decentralized innovative treatment of ammonium-rich urban wastewater

The demonstration reactor performance and management

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LIFE DeNTreat FINAL EVENT – web meeting

February 24th, 2021

The project has received funding from European Union´s LIFE Programme under Grant Agreement LIFE16 ENV/IT/000345

Steps

1. Verification of the feasibility of wastewater treatment through laboratory tests: tests done on printing companies that are not SCR (Stamperia of Cassina Rizzardi), the chosen company, but they have similar wastewater composition
2. Characterization of the chosen company (SCR) and definition of possible future scenarios
3. Design and construction of demonstration plant
4. Conduction, problems encoutered and future perspectives

Company characterization

The characterization was carried out on two fronts:

1. Collection of data referring to the year 2017, concerning:

   - The production → process scheme
     → machines hours and cycles
     → meters and weight of fabric worked for each machine
   - The use of production reagents purchased or formulated on site
   - The water and urea flows within the company

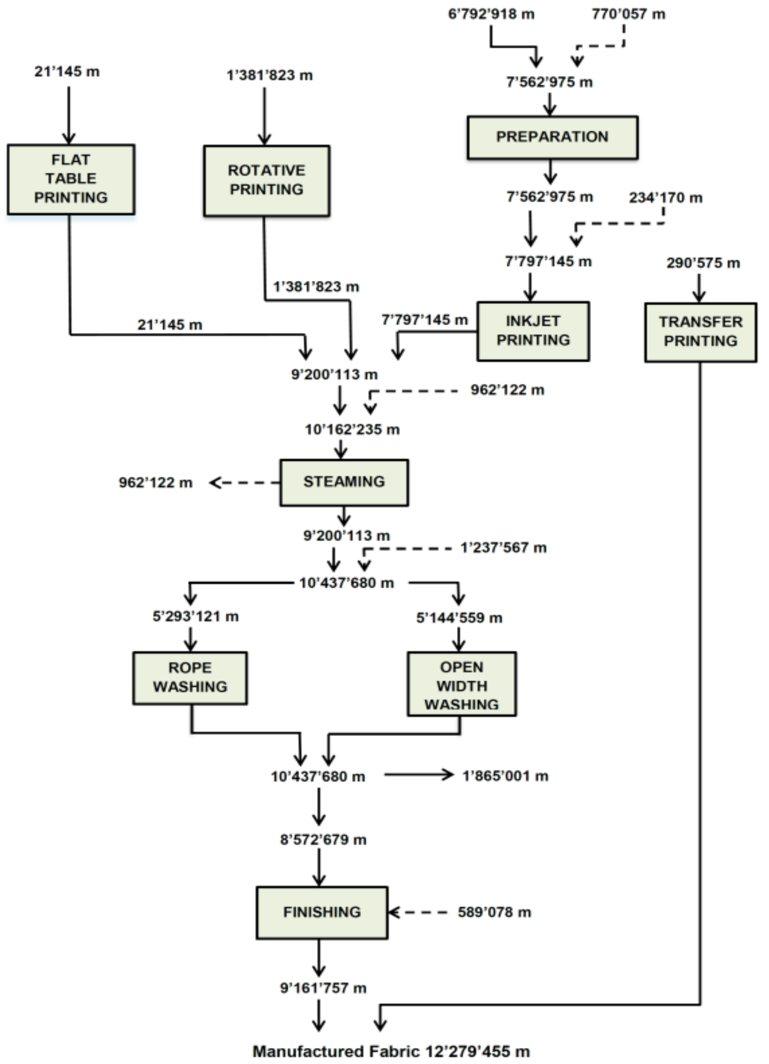
2. Sampling and analysis of the incoming and outgoing water to all the machines (production steps) in order to perform a mass balance on the most important chemical-physical parameters (September 2017 – June 2018):

   - Consumption rates of water
   - COD, TKN, NNH4, pH, T, SST, P, conductivity and color

LIFE DeNTreat

Company characterization – Collected data

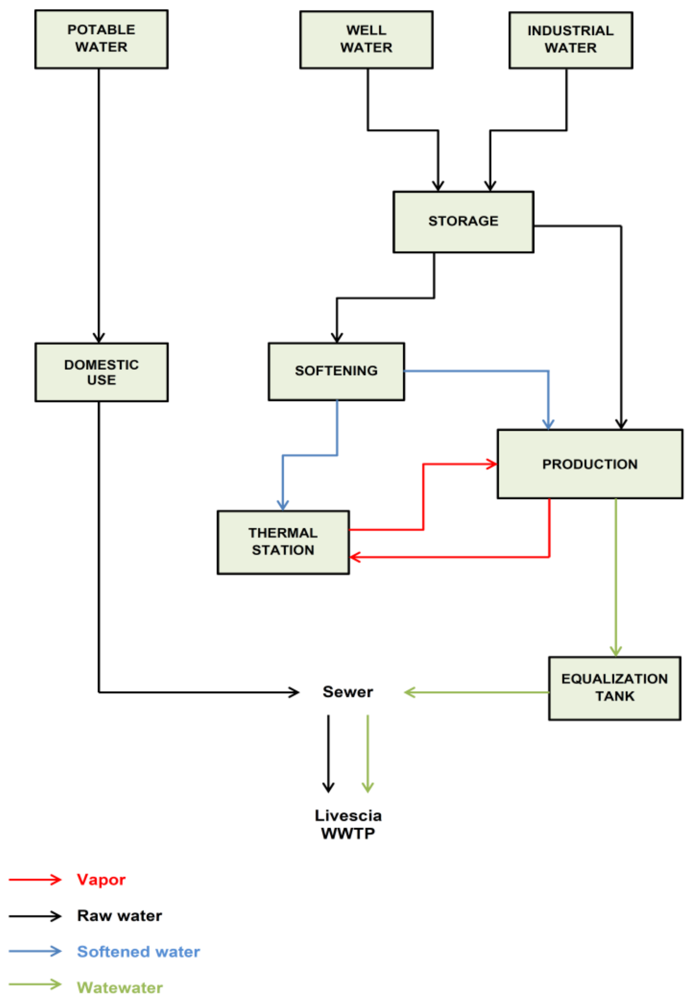
The production process is schematized in this graph in which all the production departments and the fabric meters manufactured for each type of process are highlightened



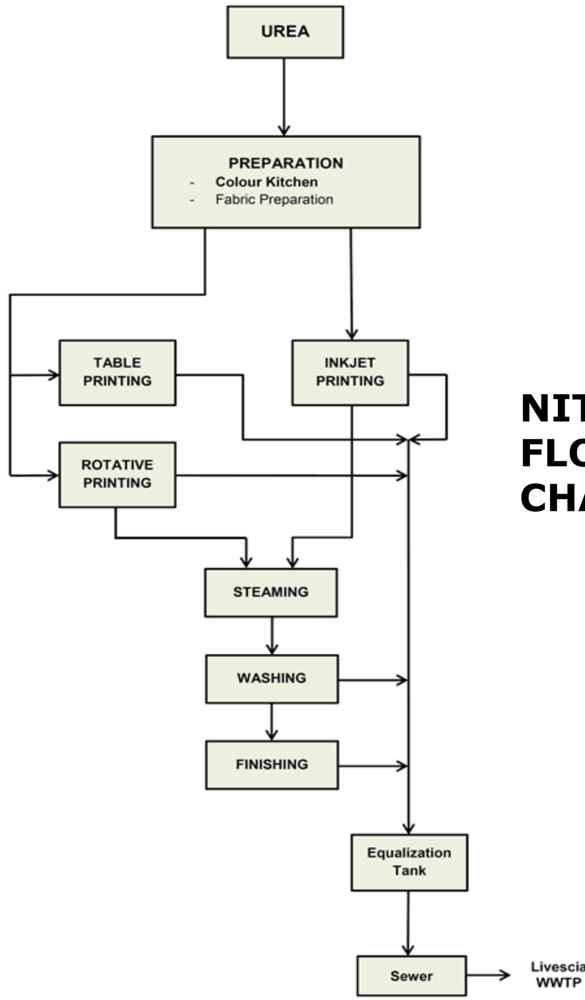
Fibre	*Type*	*(%) on total weight manufactured*
Cotton (CF)	Fabric	53.62
Viscose (VF)	Fabric	1.96
Polyester (PEF)	Fabric	27.39
Silk (SF)	Fabric	2.72
Lycra (LF)	Fabric	14.30
TOTAL		***100***

Company characterization – Collected data

WATER FLOW CHART



NITROGEN FLOW CHART



Company characterization – Collected data

WATER CONSUMPTIONS

	Water type W1	*Water type W2*	*Total water consumption*			
	m3 tot/y	*m3 tot/y*	*m3 tot/y*	*% m3/y*	*l/mt*	*l/kg*
General facilities	3'245	24'536	27'781	7.7	2.3	13.3
Preparation	1'048	2'910	3'958	1.1	0.5	3.1
Printing	100’700	0	100’700	28	11	64.3
Steaming	0	0	0	0	0	0
Fabric washing	137’289	87’319	224’608	62.5	21.5	126.5
Finishing	1'539	550	2'089	0.6	0.2	1.3
Total	***243’821***	***115’315***	***366'238***	***100.0***	***29.3***	***171.9***

Company characterization – Analysis performed

The company doesn't have its own wastewater treatment plant but has an **equalization tank** of about 1400 m^3 which collects all the process wastewaters before discharging it to the Livescia municipal wastewater treatment plant

The analysis carried out from September 2017 to June 2018 on the mixed and homogenized wastewater of the tank give the ratio of N-NH4/TKN = 0.66 with a concentration of TKN ranging from 150 mgN/l to 250 mgN/l.

→ This concentration is higher than the authorized discharge limit in the sewer (100 mgN/l), indeed today SCR discharge with derogation

The analysis on individual wastewater gave the ratio N-NH4/TKN = 0.029 probably due to a hydrolysis reaction that takes place inside the equalization tank where more than 60% of organic nitrogen is ammonified (ureolysis).

The results of the analysis show that 80-90% of the company's load is due to the washing phase, followed by the printing phase

Company characterization – Scenarios

TARGET: Define the demonstration scenario starting from data collected

SCENARIOS

- Scenario 0 → actual scenario
- Scenario 1 → treat the final discharge after the buffer tank
- Scenario 2 → treat only fabric washing discharge
- Scenario 3 → treat only those discharges from the fabric washing process with the nitrogen concentration above 350 mg/l
- Scenario 4 → treat only those discharges from the fabric washing process with the nitrogen concentration above 1’000 mg/l

	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Direct SCR discharge into the sewer					
Volume m^3/y	324'888	0	103'702	291'844	314'858
COD kg/y	335'327	0	73'010	271'239	301'679
COD mg/l	1'032	0	704	929	958
N kg/y	**52'488**	**0**	**2'631**	**11'684**	**23'808**
N mg/l	**162**	**0**	**25**	**40**	**76**
N-NH4 kg/y	1'506	0	237	1'045	1'335
N-NH4 mg/l	5	0	2	4	4
SCR discharge to the on-site treatment					
Volume m^3/y	0	324'888	221'185	33'043	10'030
Volume m^3/d	0	985	670	100	30
% on total SCR discharge volume	**0**	**100.00**	**68.08**	**10.17**	**3.09**
COD kg/y	0	335'327	262'317	64'087	33'647
COD kg/d	0	1'016	795	194	102
COD mg/l	0	1'032	1'186	1'940	3'355
% on total SCR discharge COD load	0	100.00	78.23	19.11	10.03
N kg/y	**0**	**52'488**	**49'856**	**40'804**	**28'680**
N kg/d	0	159	151	124	87
N mg/l	0	157	190	637	852
% on total SCR discharge N load	**0**	**100.00**	**94.99**	**77.74**	**54.64**
N-NH4 kg/y	0	1'506	1'270	461	171
N-NH4 kg/d	0	5	4	1	1
N-NH4 mg/l	0	29	25	11	6
% on total SCR discharge N-NH4 load	0	100.00	84.29	30.62	11.37
Final SCR discharge into the sewer					
Volume m^3/y	324'888	324'888	324'888	324'888	324'888
COD kg/y	335'327	184'430	217'284	306'487	320'185
COD mg/l	1'032	568	669	943	986
N kg/y	**52'488**	**21'070**	**22'637**	**28'029**	**35'288**
N mg/l	**162**	**65**	**70**	**86**	**109**
N-NH4 kg/y	1'506	7'948	7'779	7'189	5'646
N-NH4 mg/l	5	24	24	232	17

RESULTS

- In all Scenarios (except the 4th) SCR respects the Total Nitrogen discharge limit
- In Scenario 1 is feasible without changes in the company sewage system.
  In Scenarios 2, 3 and 4 it is necessary to create a separate sewer system

RESULTS

The comparison of the data collected during the 2017-2018 sampling campaign and those acquired during the experimentation showed a change in the relationship between COD and TKN

↓

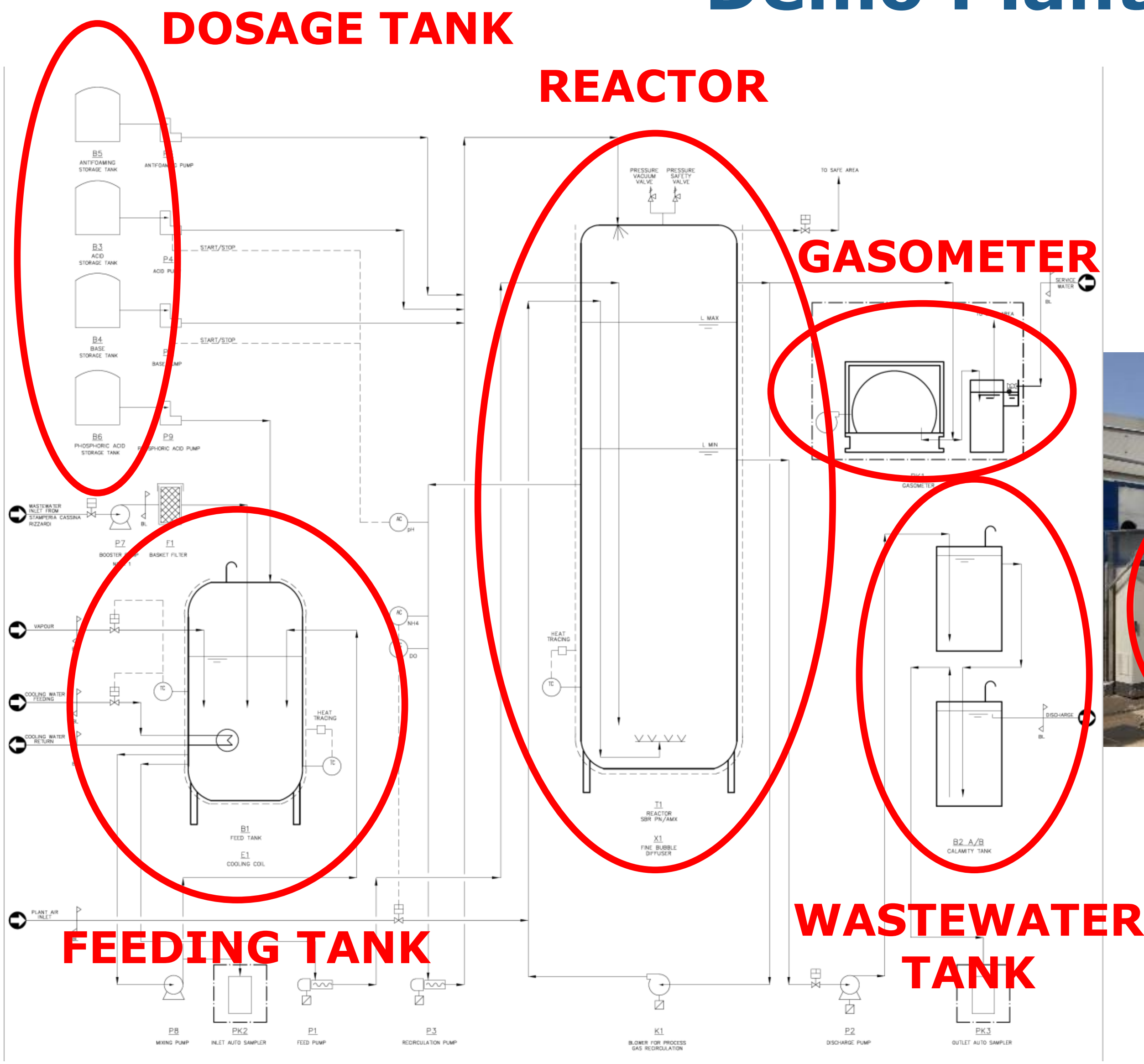
2018 COD/TKN = 6.37 gCOD/gTKN of which 3.78 gbCOD/gN

2020 COD/TKN = 4.72 gCOD/gTKN of which 2.22 gbCOD/gN

Difference due to the fact that the company has increased the use of digital printing.

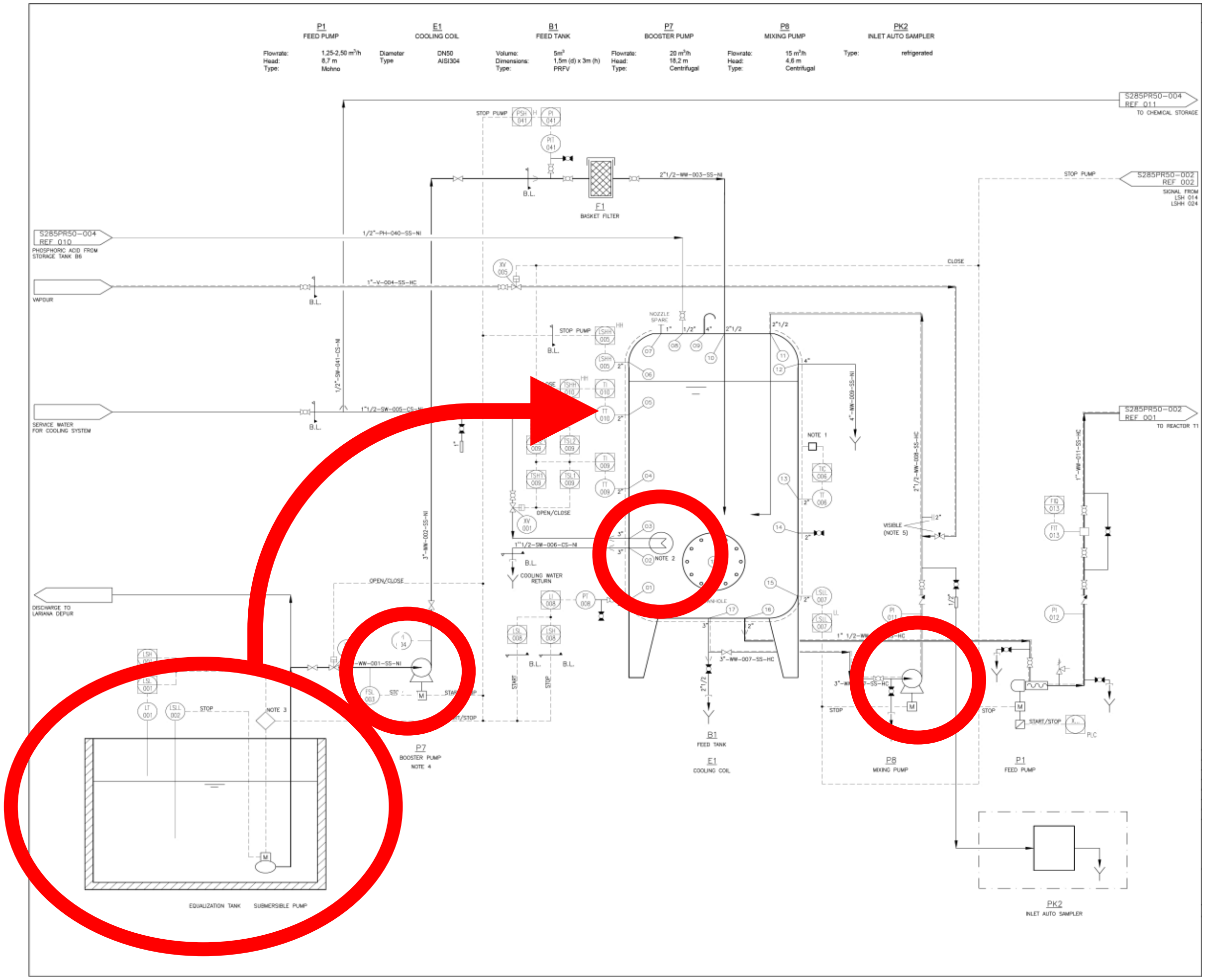
The data indicate the presence of 53% of recalcitrant COD which makes the wastewater difficult for a traditional nitro-denitro application but makes it good for treatment with Anammox

Demo Plant



DOSAGE TANK
REACTOR
GASOMETER
FEEDING TANK
WASTEWATER TANK

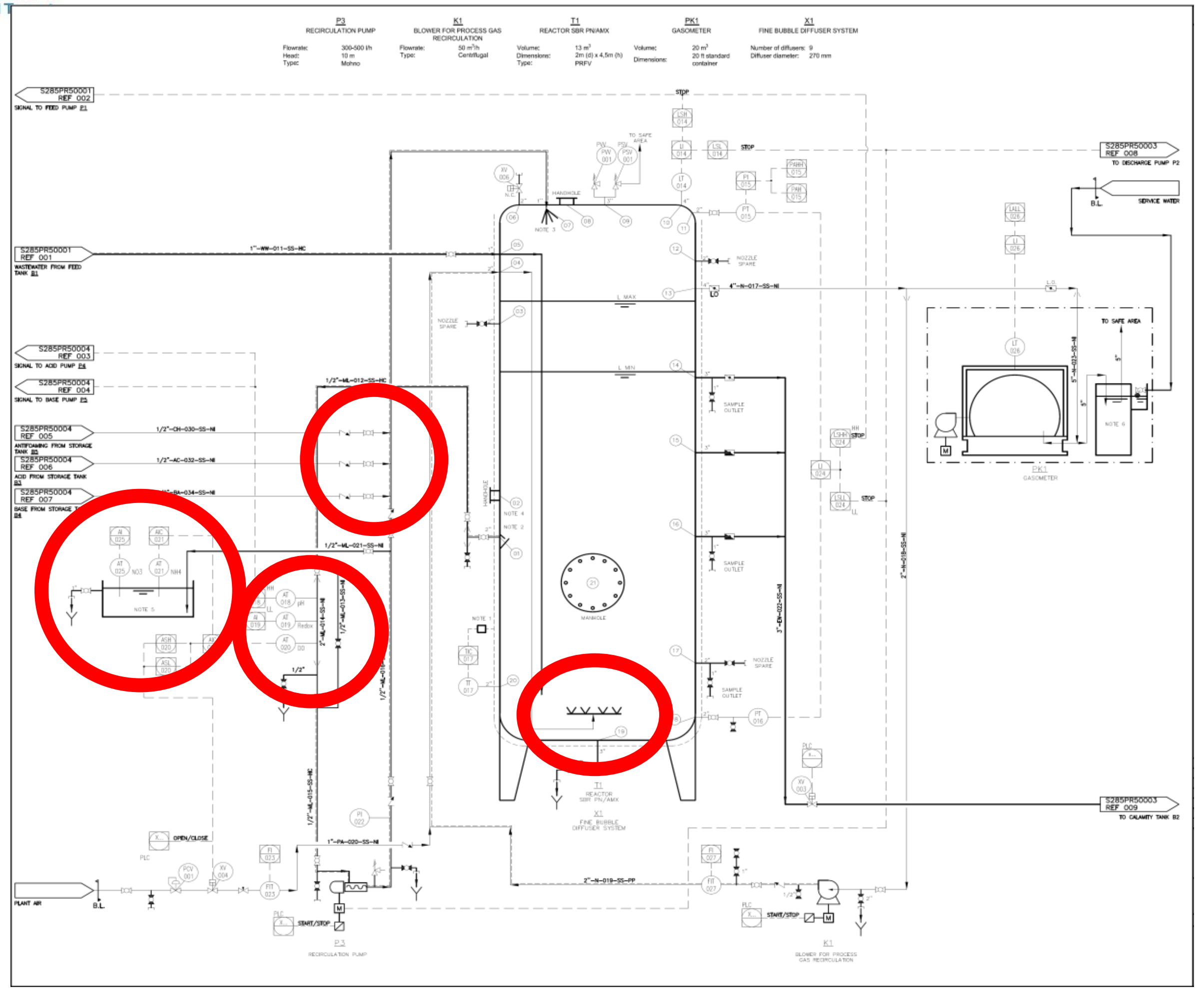
Feeding tank



The feeding tank is insulated and equipped with a coil cooling system and a steam heating system.

- The factory wastewater is pumped from the equalization tank to feed tank; the filling is regulated by limits defined by automation thanks to the presence of an analogic pressure gauge
- In the feed tank a centrifugal pump keeps mixed the wastewater
- A micronutrient solution is also dosed into the tank

Reactor tank



Nitrogen recirculation takes place thanks to K1 blower and 9 microbubble plates placed at the base of the reactor, capable of distributing the nitrogen uniformly and keeping the granules under stirring

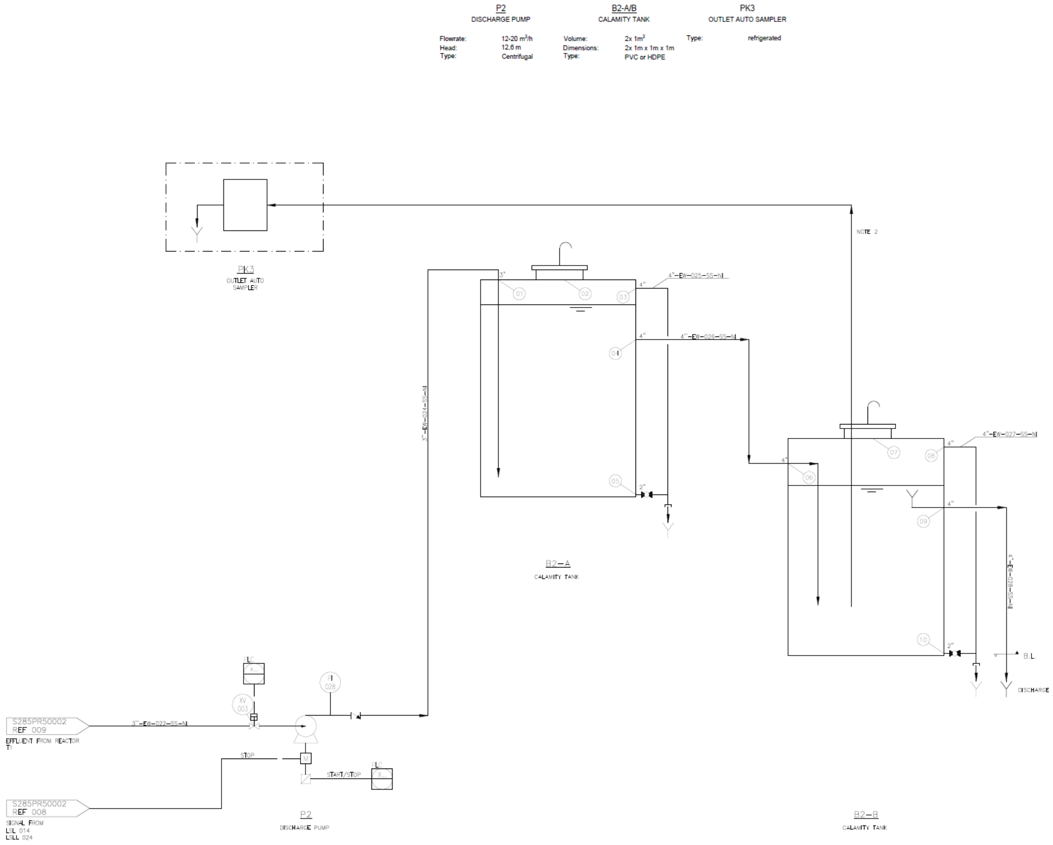
The reactor has a recirculation line that was equipped with:

1. pH, redox, dissolved oxygen, ammonia and nitrate probes to monitor the parameters necessary for good bacterial activity

2. Dosage points of reagents such as antifoam and acid (hydrochloric acid) and base (caustic soda) to adjust the pH

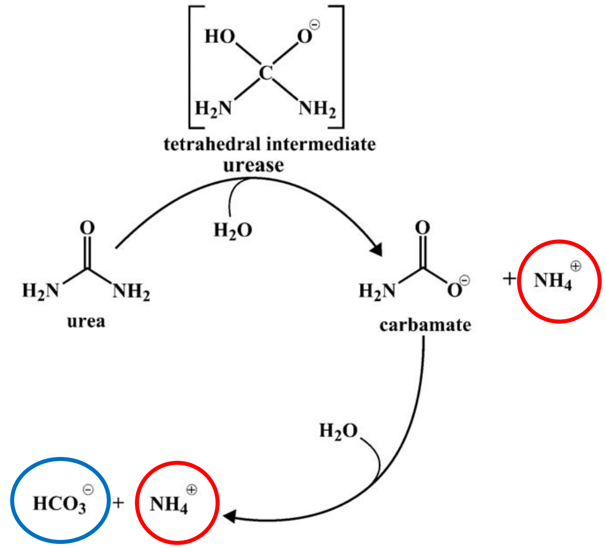
The nitrogen recirculation and the maintenance of the pressure inside the reactor are ensured by the presence of a **gasometer**

The **wastewater discharge** following the treatment is carried out through two small tanks placed in series that allow the drainage and, in case of necessity, to return the washout biomass to the process reactor.



Wastewater characteristics

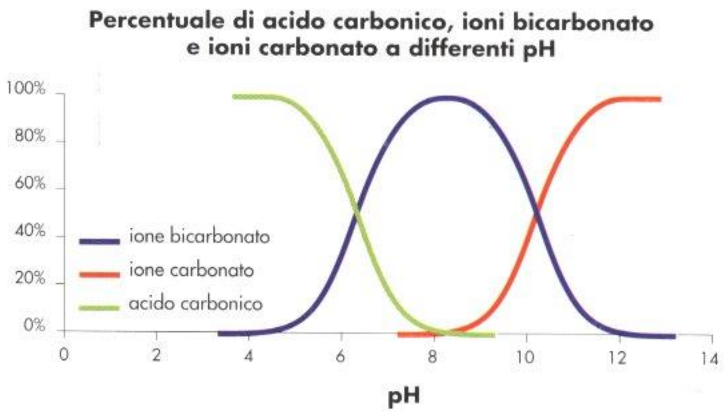
Printing waste is a wastewater whose ammonium derives from ureolysis, which means that unlike an ideal wastewater such as digestate, the ratio of bicarbonate to ammonium is unbalanced on ammonium with a molar ratio of 1: 2 (digestate 1:1)



Normally → 66% of the ureolytic phase → in equalization tank
→ 22% of the ureolytic phase → in the process reactor
→ 12% remains like a recalcitrant organic nitrogen

Sometimes → most of the ureolytic phase takes place in the process reactor, when hydrolysis occurs in a reduced way in the tank
→ 12% remains like a recalcitrant organic nitrogen

Wastewater characteristics



The amount of INORGANIC CARBON should be sufficient but being a wastewater tending to basic (8.5 - 9.3) the balance of carbonates is unbalanced towards their precipitation, decreasing the ratio and POTENTIALLY becoming a limiting factor.

This is confirmed by the low alkalinity of the wastewater (~ 600 mgCaCO3/l).

Request for soda to balance the pH

Analysis are being carried out to verify the carbonate

The IC / TKN imbalance, if confirmed, could force a dosage not only of soda but also of inorganic carbon, for example as carbonates.

Wastewater characteristics

In the industrial printing process, detergents containing amines and quaternary amines are used. In the literature there are no specific studies on the consequences of these substances on the Anammox component but being recognized biocides their influence on performance is not excluded.

↓

Further investigations are being carried out with specialized laboratories

Why an SBR?

- The laboratory tests in SBR started before the project and gave good results on other printing presses whose effluents are not equal to SCR but similar

- The design of an SBR is simpler and more flexible for biomass retention by lengthening or shortening sedimentation and discharge times.

  → A continuous system should have a three-phase separator too large to have the same variability and for the scale of the demonstration

- An SBR allows a high VER (Volume Exchange Rate) and therefore a greater accumulation of substrate which allows

  - Higher biomass kinetics and higher removal rates, accelerating ureolysis, Anammox reactions and nitrification
  - Greater control of NOBs thanks to the possibility of accumulating NH3 at inhibitory levels for this biomass

Criticalities and Resolutions

The criticalities that have been found in the reactor are due to both plant problems and specific wastewater problems:

<u>JANUARY 2019</u> Being a system based on alternating start and stop cycles, the first problem was the breakdown of the loading and unloading pumps due to freezing	→ Problem solved with the installation of electric heaters around the machines and pipes that are most at risk
Accumulation of flakes biomass: → causes the preferential growth of biomass external to the grain on the flakes, thus not allowing the formation of the anoxic layer → reversible inhibition from OD to Anammox	→ To control this quantity, the sedimentation times are changed, lengthening or shortening them as needed (management allowed by the SBR system)

Criticalities and Resolutions

Another cause of oxygen limitation is due to the SBR system:

→ variable volume inside the reactor, which in turn leads to a non-constant head

→ different dissolution of oxygen during the wastewater loading cycle so that the availability of oxygen is not always the same during the loading and reaction phase

Criticalities and Resolutions

MARCH-MAY 2019

The online installation of the nitrate and ammonia probes immediately gave management problems:

- The NITRATE PROBE was installed in a special measuring cell connected directly to the recirculation line. The accumulation of biomass in the loading tubes of the cell does not allow the flow of wastewater to the probe and therefore the analysis of the parameter
- The AMMONIA PROBE was installed in a container with disposable flow, the biomass that accumulated in significant quantities was lost

→ To solve the problem, these two probes were installed in the two discharge tanks

↓

it allows to have a measurement at the end of each cycle, even if not continuously

↓

Lost the possibility of having an automated control of the process which is therefore regulated manually

Criticalities and Resolutions

FEBRUARY 2020

From the biomass investigations, a gradual degranulation of the granules was noted, which lost their typical circular shape. After several hypotheses, it was verified that the degranulation was due to the conformation of the recirculation line (presence of divergent and convergent ones) and to the dedicated pump which with important cutting effects led to the disintegration of the granules cycle after cycle

To solve the problem:

- the recirculation line was dismissed
- the probes installed on the line (ph, redox and OD) were moved and installed on a reactor manhole
- the dosages were moved above the reactor

Criticalities and Resolutions

Company stops for holidays and COVID emergency

→ Progress decrease in loads due to dilution o reactionsthat takes place equalization tank

→ Possible use of biocidal cleaning products

➡ These stops were addressed by installing timers to the wastewater loading pumps from the equalization tank to the feeding tank, in order to give a continuous supply of wastewater to the system

OCTOBER 2020

The characteristics of the wastewater may vary within the week depending on the production and it may happen that the ammonia concentration remains low for many consecutive days

➡ Special dosage of an ammonium salt

↓

Plant engineering did not allow to obtain a well dissolved salt in solution and therefore it was impossible to dose a sufficient known quantity

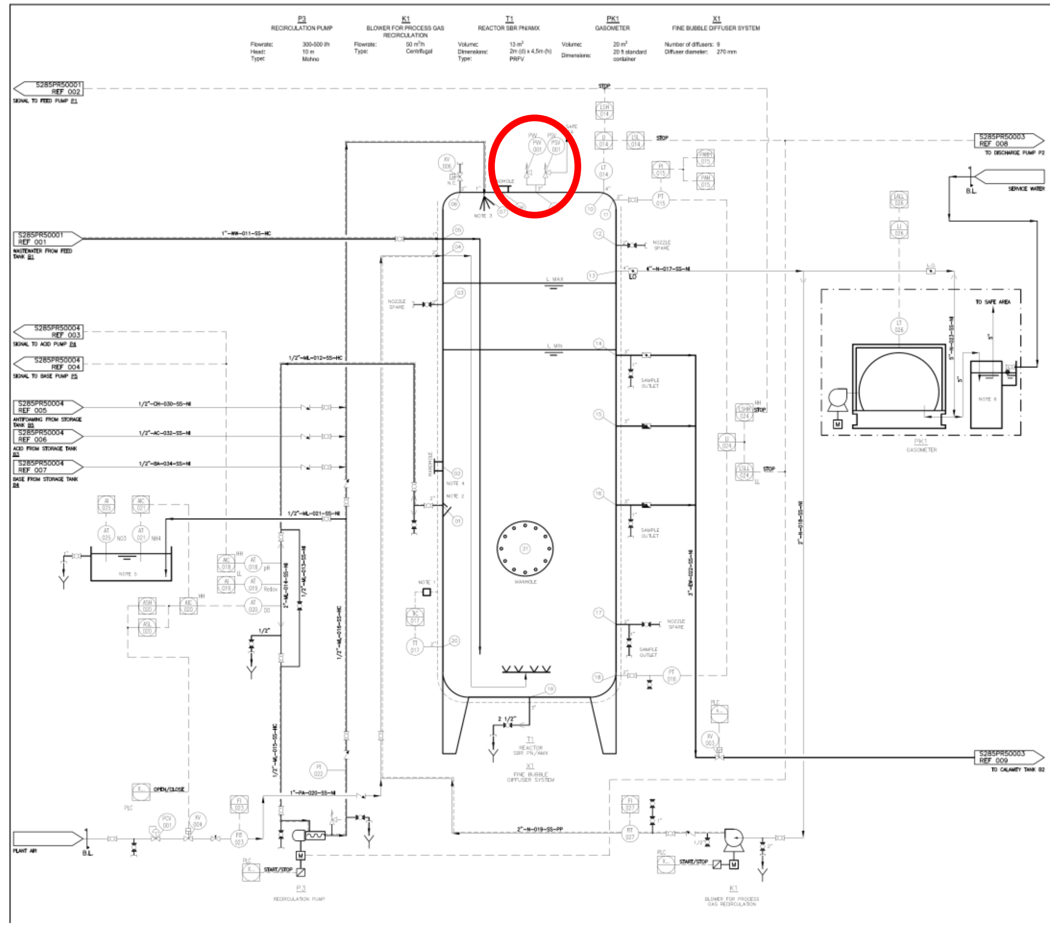
Criticalities and Resolutions

<u>NOVEMBER 2020</u>

Another limiting parameter is the oxygen transfer capacity of the system

- → supply of oxygen given by compressed air
- → Not enough for nitritation and COD oxidation

The system was separated from the gasometer and placed in the air by keeping the valve at the top of the reactor open in order to increase the amount of oxygen during the operation of the blower



Successful outcomes

+ Excellent suppression of NOBs and the possibility of implementing partial nitritation
  - → The experiment showed that in addition to allowing the PN/Anammox process, it can allow a nitro-denitro via nitrite
    - → energy saving of about 25%
    - → biodegradable COD saving of about 33%
      - → proportional sludge production

+ The obtainable removal rates are of the order of 300 gTKN/m3/d and complete removal of the bCOD.
  - → not comparable to digestate which is from 5 to 10 times higher (Demon 600 gTKN/m3/d and Paques 1500-2000 gTKN/m3/d) but given the previously mentioned criticalities these removal rates are still good

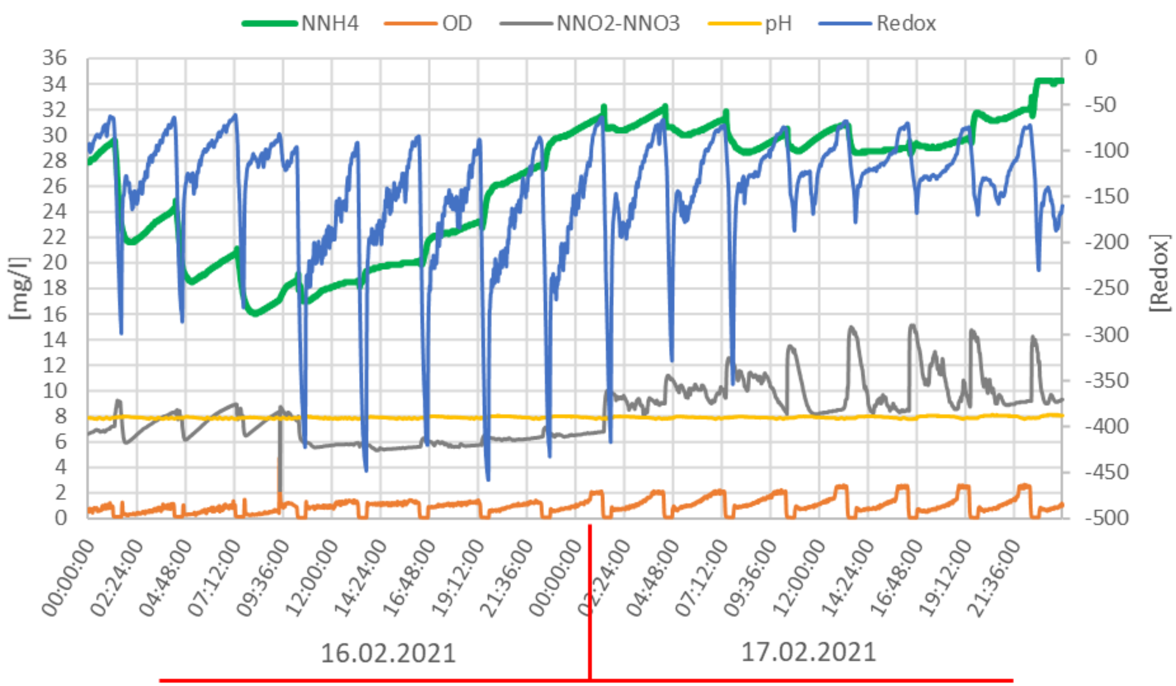
+ The ureolysis occurs completely

Successful outcomes

+ Due to the critical issues found, the process has never been stable for long periods, but only for alternating periods and on the order of weeks

In stable periods the trend is good and the typical trend is like the one shown in the figure with:

- nitrates close to zero
- nitrites accumulated in correct concentrations
- variable PH from 7.8 to 8.1
- variable REDOX from -210 to -61
- variable OXYGEN from 0.3 to 2.7



Demonstration of good <u>RESILIENCE</u>

Future perspectives

Some problems encountered with the SBR system can be solved with a system operating continuously:

- A CSTR has a volume that remains fixed and at its maximum value

  → the oxygen transfer efficiency is always constant and at its maximum possible value allowed by the head

  → The problem of oxygen transfer would be partially solved

- The probes would be installed directly in the process volume and this would allow a continuous and precise control

- The problem of the variability of the wastewater, both for toxic elements and for ammonia and pH, would be solved in part with a CSTR

  ← damping the concentrations variations

  → not keep the biomass in contact with more or less high concentrations of substances until the next discharge.

Future perspectives

- In a CSTR with a three-phase separator biomass retention system it allows a continuous control of the flocked part as opposed to an SBR which makes a selective pressure only in cycles

- To overcome the possible carbon problem, a sodium carbonate dosage will be prepared, in parallel with caustic soda: the first to increase the inorganic carbon and the second to buffer the pH

Thank you

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The project has received funding from European Union´s LIFE Programme under Grant Agreement LIFE16 ENV/IT/000345