Towards a Sustainable use of Metal Resources in the Galvanic Industry

Hacia un uso sostenible de los recursos metálicos en la industria del galvanizado

LIFE2acid

LIFE16 ENV/ES/000242

Final event

15th December 2021

www.life2acid.eu

APRIA systems · UNIVERSIDAD DE CANTABRIA · UNIVERSITAT POLITÈCNICA DE VALÈNCIA · AIDIMME INSTITUTO TECNOLÓGICO METALMECÁNICO, MUEBLE, MADERA, EMBALAJE Y AFINES · AIAS ASOCIACIÓN DE INDUSTRIAS DE ACABADOS DE SUPERFICIES · mare · GALESA GALVANIZADORA VALENCIANA, S.L.U.

Agenda

11.00 – 11.10 h Reception of participants.

11.10 – 12.10 h The project and main results achieved

1. System prototype & Construction (APRIA)
2. Membrane prototype validation & iron chloride valorisation (UC-APRIA)
3. EW prototype validation & zinc valorisation (UPV-AIDIMME)
4. Environmental sustainability (UC)

12.10 – 12.50 h Round table on results application (GALESA, MARE, AIAS)

1. Zinc market, current behaviour, and future perspectives
2. Opportunities in the technology application for zinc recovery
3. Iron chloride use and perspectives from a WWTP perspective

12.50 – 13.00 h Final remarks & Conclusions

13.00 – 14.00 h Brunch & Networking

Project overview

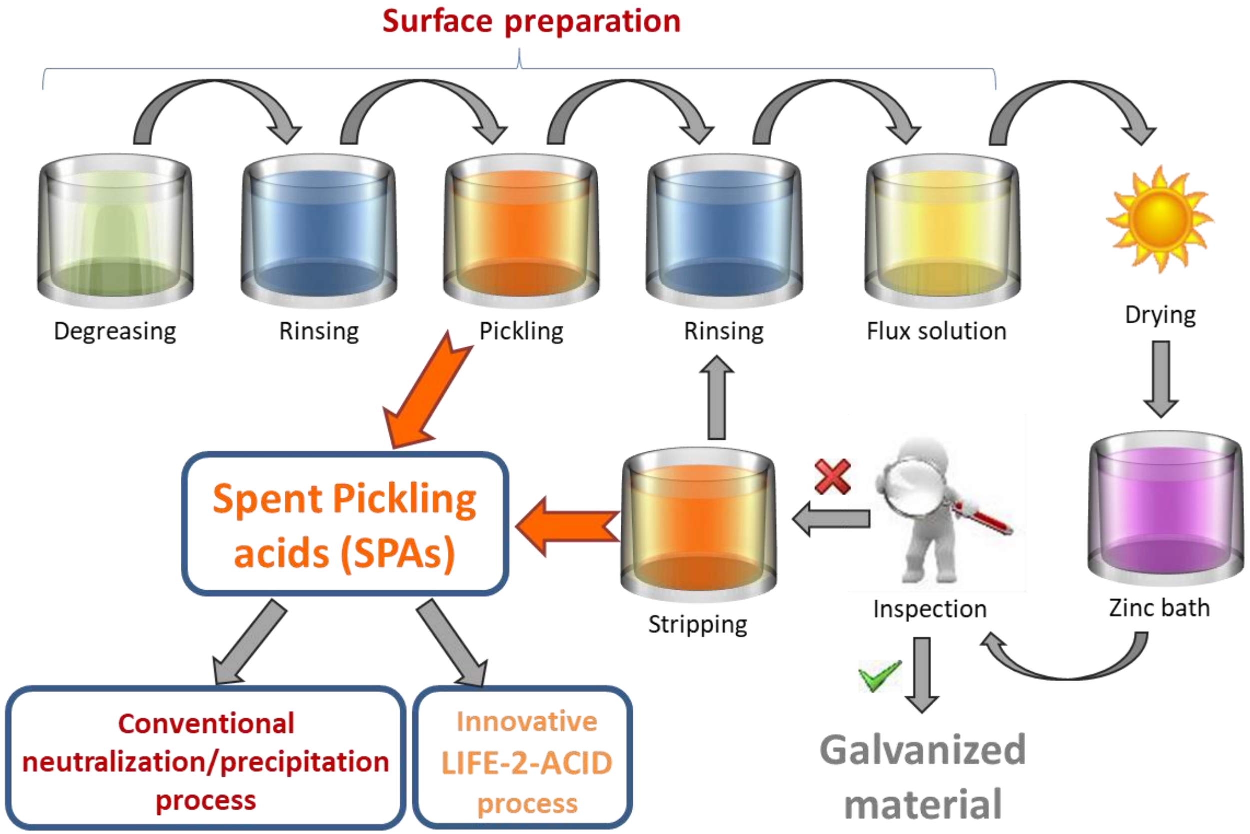
Project overview

LIFE-2-ACID video

The galvanizing process

Background

- Zinc surface treatment → > 50% of worldwide metal zinc production (> 6 Mt/year).
- 1 t of galvanized pieces → 40 – 70 kg of SPAs.
- Galvanizing companies → > 300,000 m^3/year of SPAs.
- Conventional treatment of SPAs → > 400,000 t/year of waste sludge to landfill.
- SPAs → Environmental impact (LER code 11 01 05).
- SPAs have certain valuable materials:
    - Zn (90 – 140 g/L)
    - Fe (80 – 120 g/L)
    - Acids
    - Chlorides



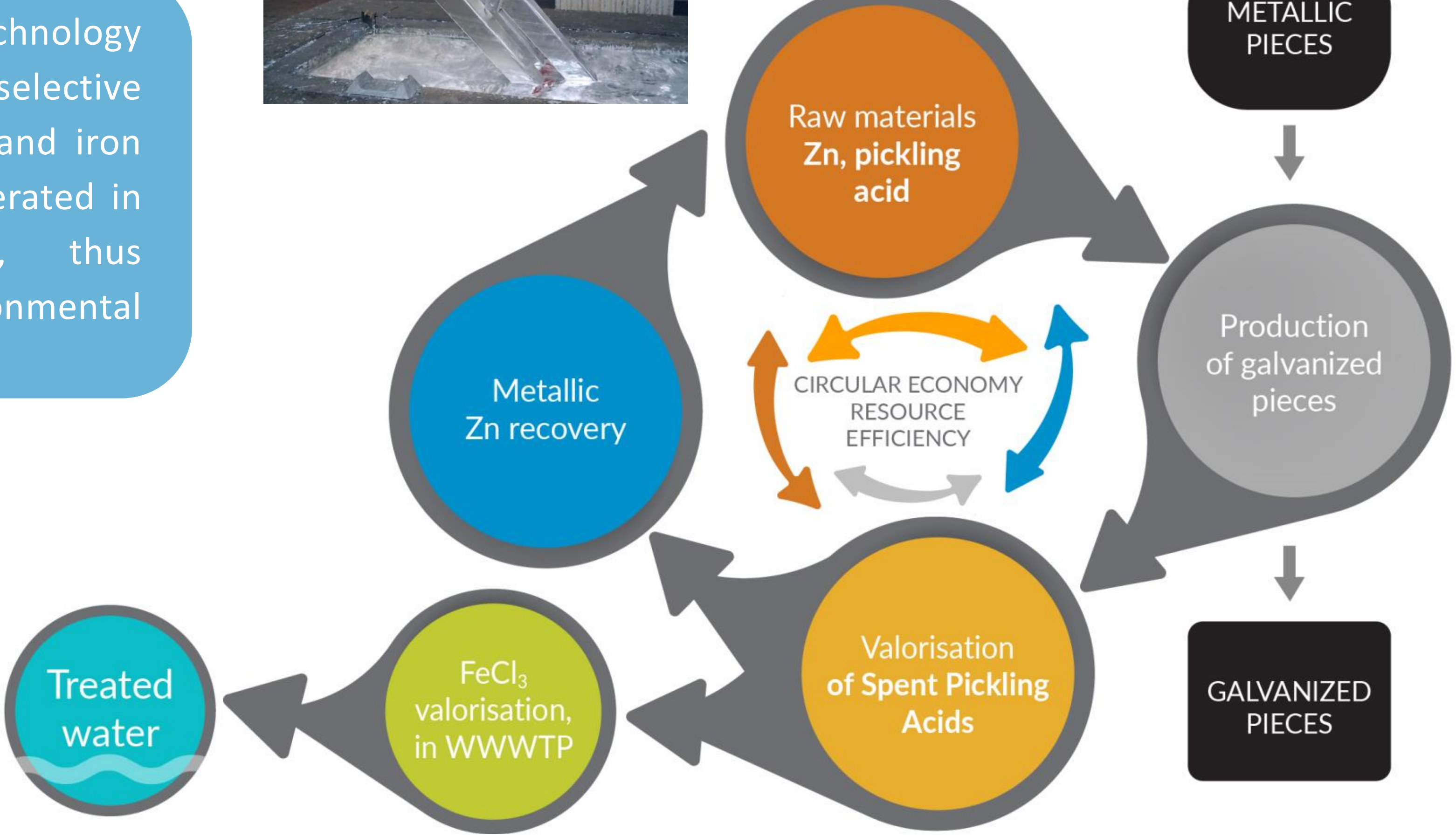
Project overview

Circular economy approach

Demonstrate a new technology that allows the selective recovery of metal zinc and iron chloride from SPAs generated in galvanizing processes, thus minimizing their environmental impact.

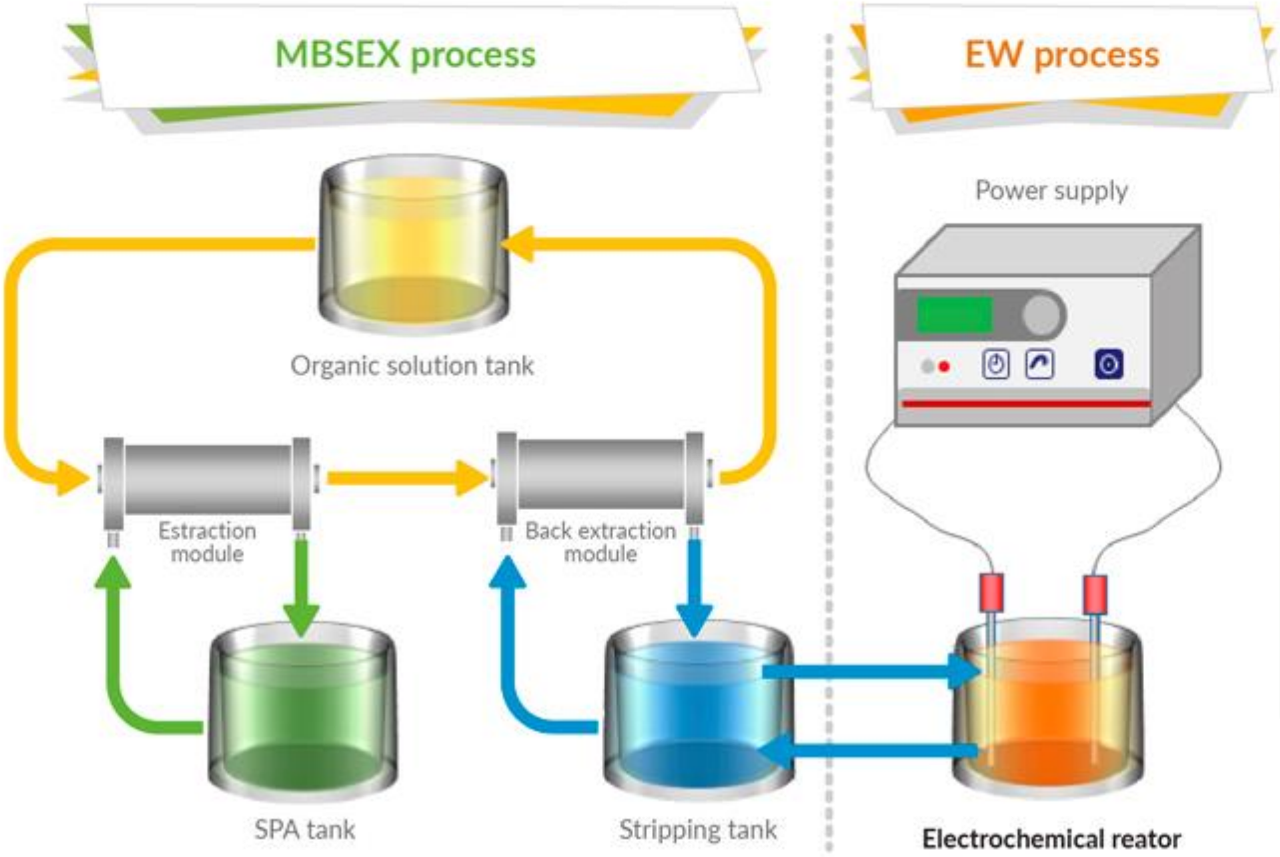
Zn reuse

$FeCl_3$ valorisation



Project overview

Proposed solution



The innovative technological solution developed by LIFE-2-ACID integrates membrane based selective extraction (MBSEX) and electrowinning (EW):

1. **Separation unit based on reactive membranes**
   Allows the selective separation of the SPAs in two independent streams enriched with iron in the retentate and zinc in the permeate

2. **Electrowinning unit**
   The metallic zinc is obtained from the permeate stream.

Consortium

R&D

- Universidad de Cantabria (UC)
- Universitat Politècnica de València

Associations

- AIAS – Asociación de Industrias de Acabados de Superficies

End-users

- GALESA – Galvanizadora Valenciana, S.L.U.
- mare

Technology integrators

- AIDIMME – Instituto Tecnológico Metalmecánico, Mueble, Madera, Embalaje y Afines
- APRIA systems

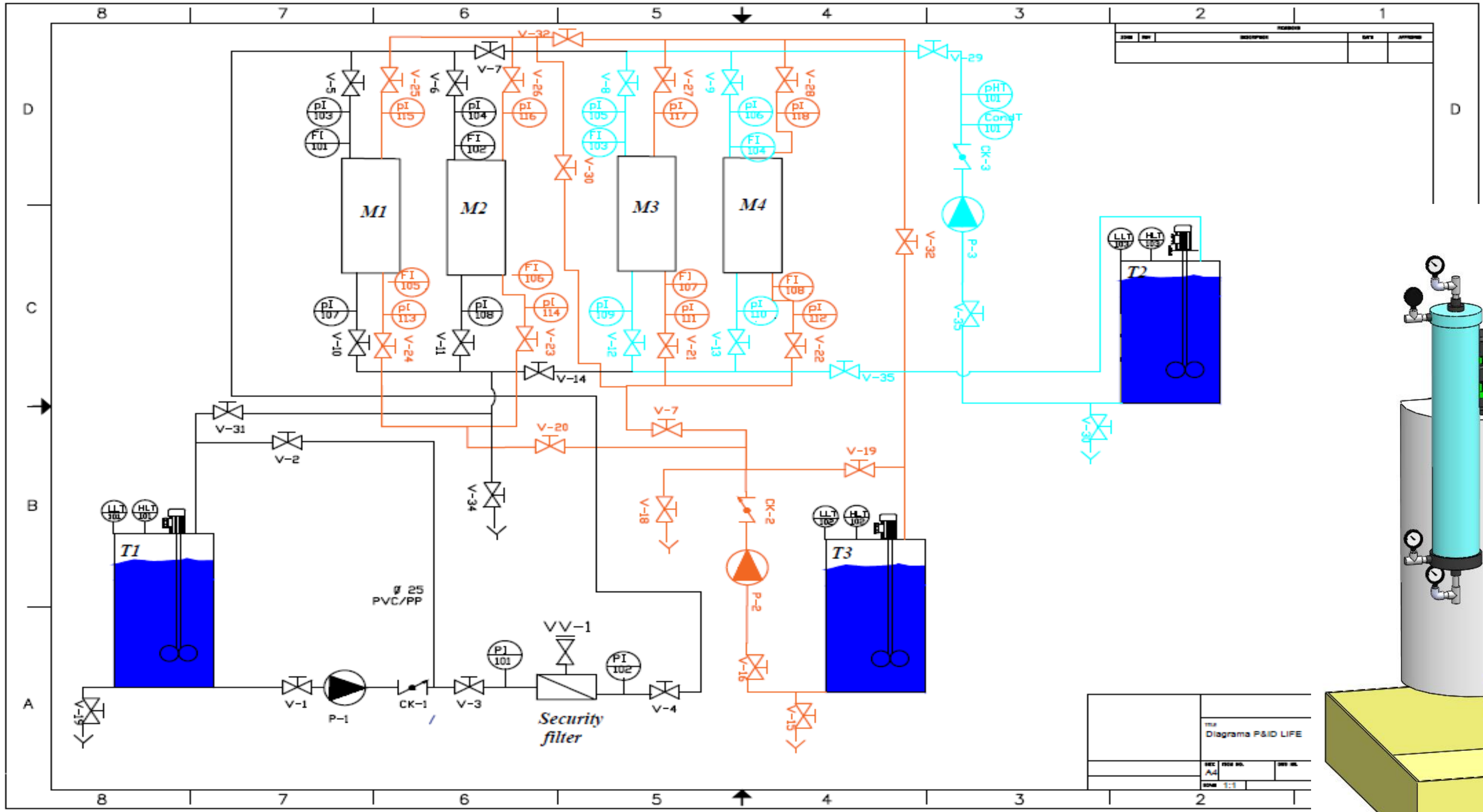
Associated entities

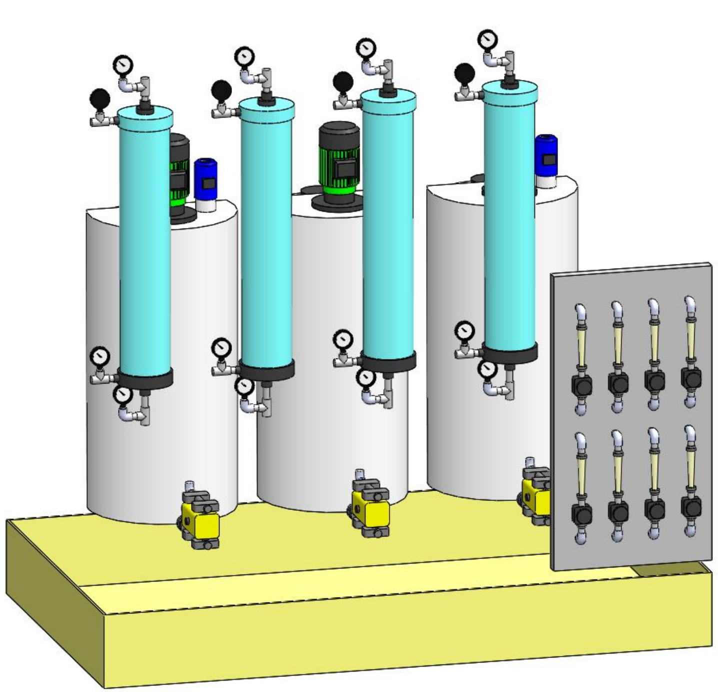
- Gobierno de Cantabria – Consejería de Universidades e Investigación, Medio Ambiente y Política Social
- EGGA – European General Galvanizers Association

System prototype & construction

System prototype & construction

MBSX
Prototype
design

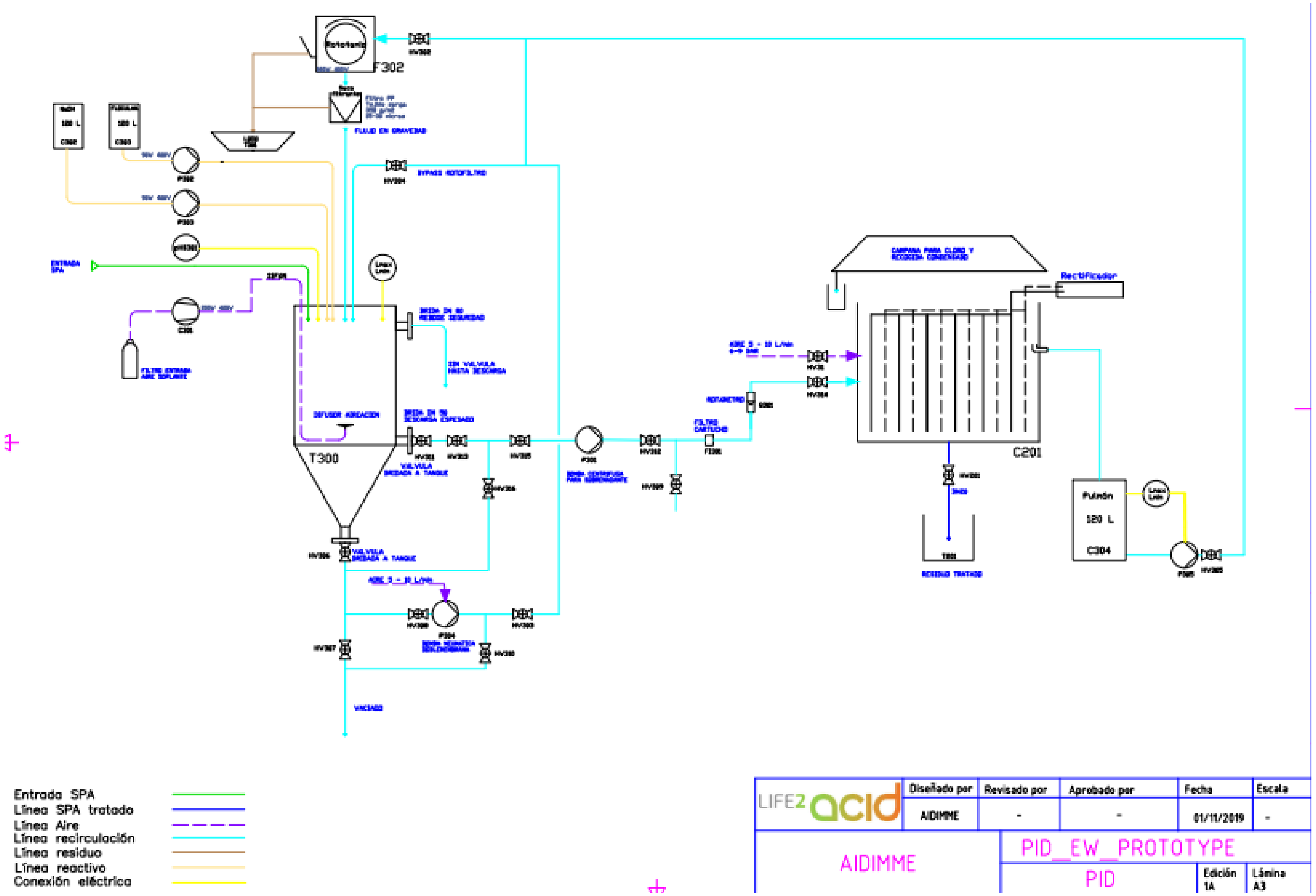




- Original P&I
- Updated with prototype modifications

A2.2. Prototype for Zn recovery by EW

EW
Prototype
P&I



B1.1. Construction of prototypes for MBSX and EW

Initial MBSX construction

B1.1. Construction of prototypes for MBSX and EW

MBSX
Challenges & Improvements

During

👎 Plastic materials obstructing the modules

After

B1.1. Construction of prototypes for MBSX and EW

MBSX
Challenges &
Improvements

PVC

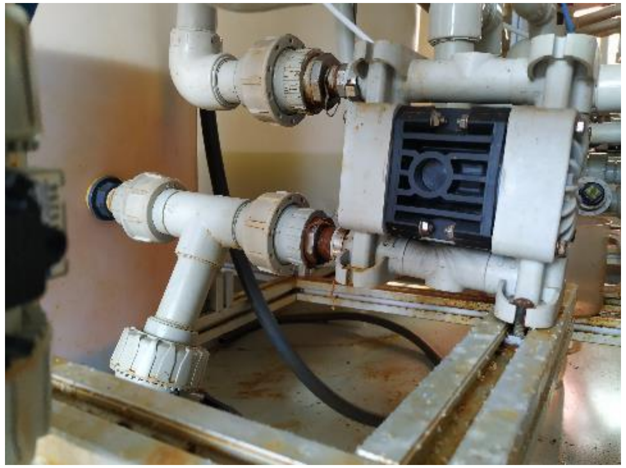
Polypropylene

But there were still some leaks in the joints with the valves and measuring devices

B1.1. Construction of prototypes for MBSX and EW

MBSX Challenges & Improvements

Redesigned pumping system

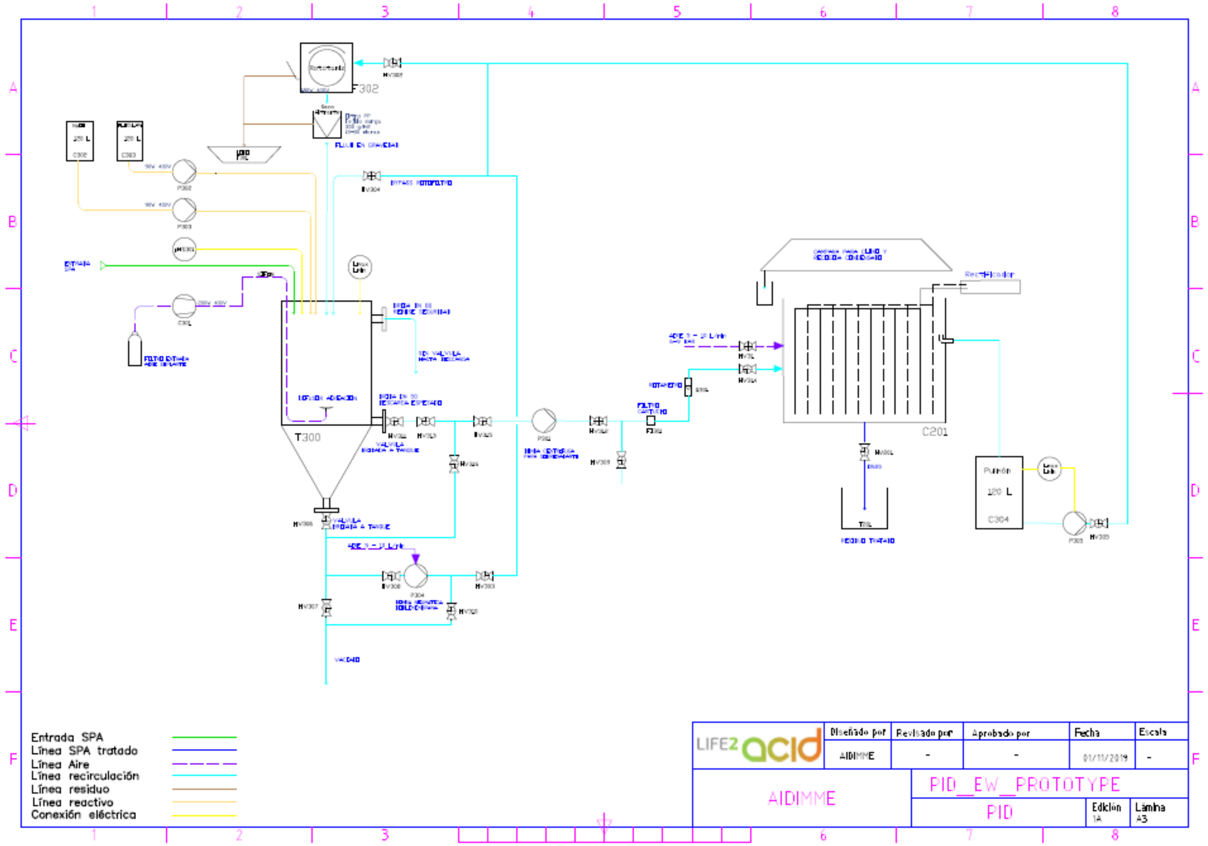


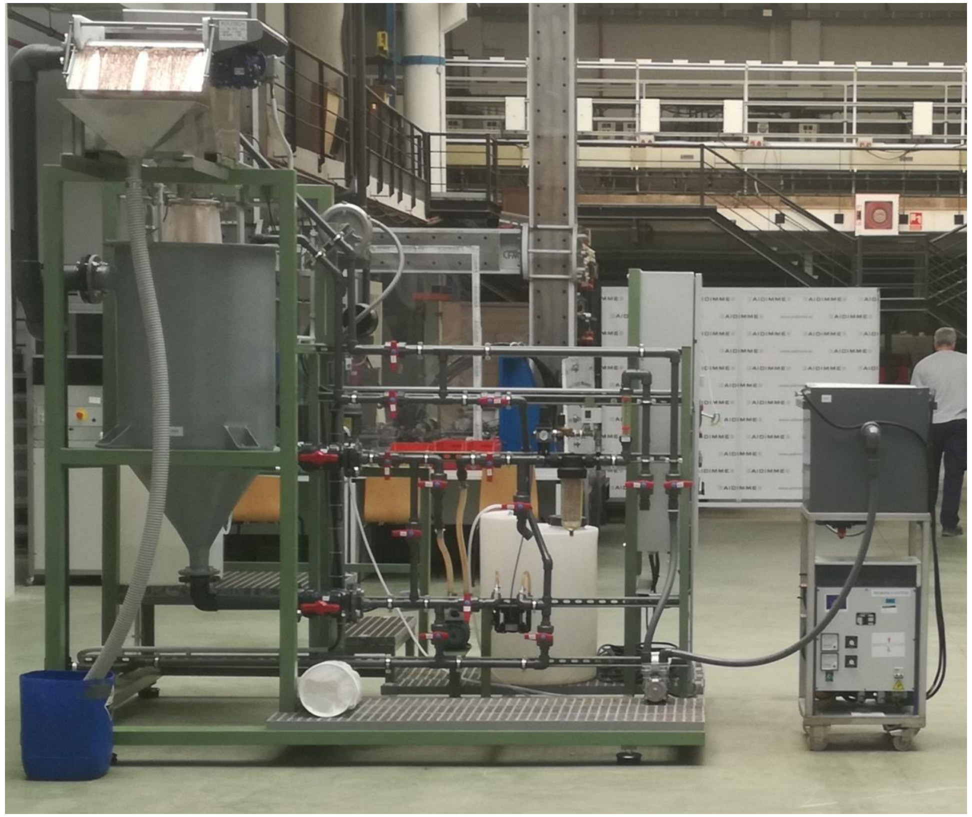
Dryer for the pressure line

Offline filtration system

B1.1. Construction of prototypes for MBSX and EW

Initial EW construction

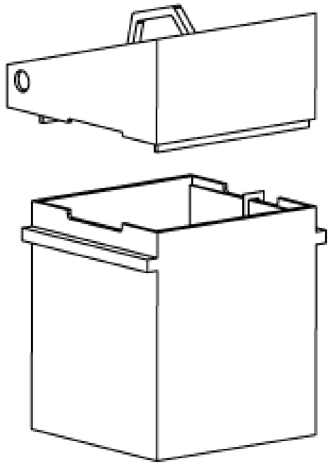




B1.1. Construction of prototypes for MBSX and EW

EW Challenges & Improvements

REACTOR HOOD



Chlorine extraction

AERATION

Improves homogeneity

Avoids holes and empty deposits

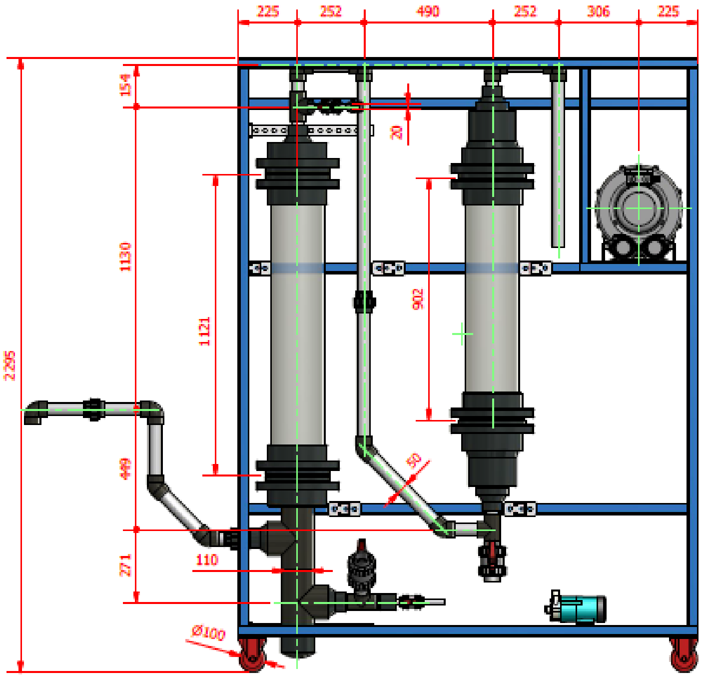
NEW DESIGN

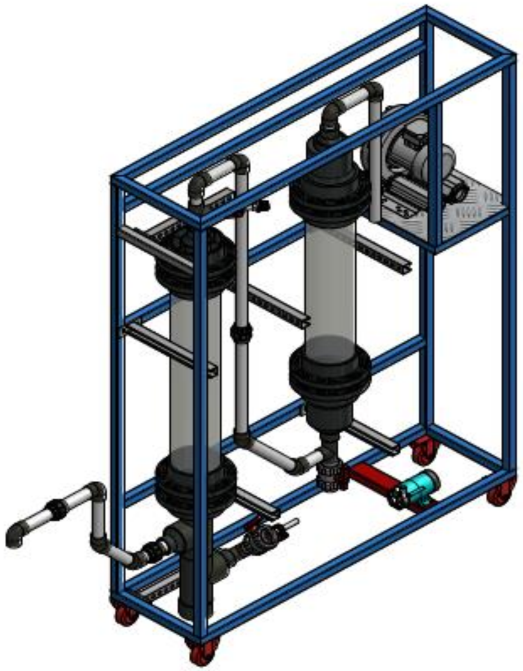
3D PRINTED

B1.1. Construction of prototypes for MBSX and EW

EW Challenges
&
Improvements

Scrubber system



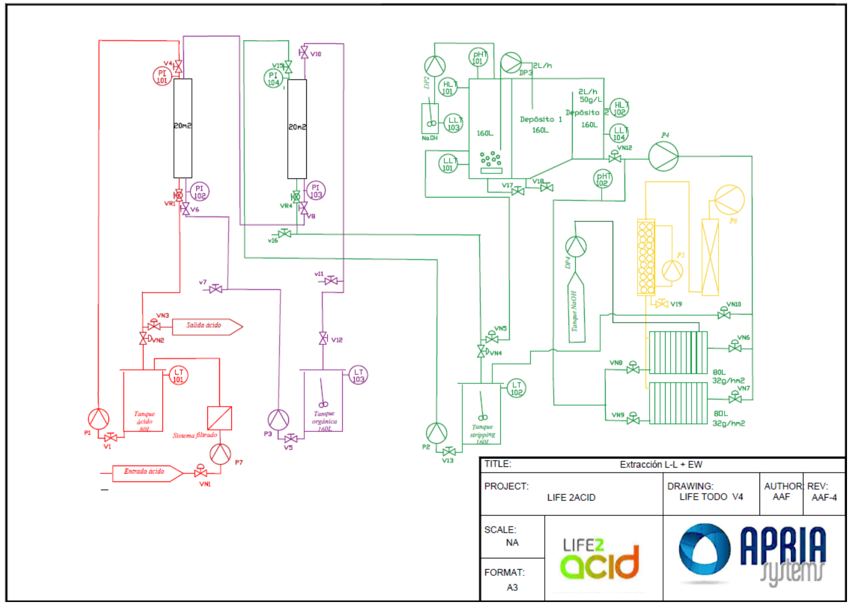


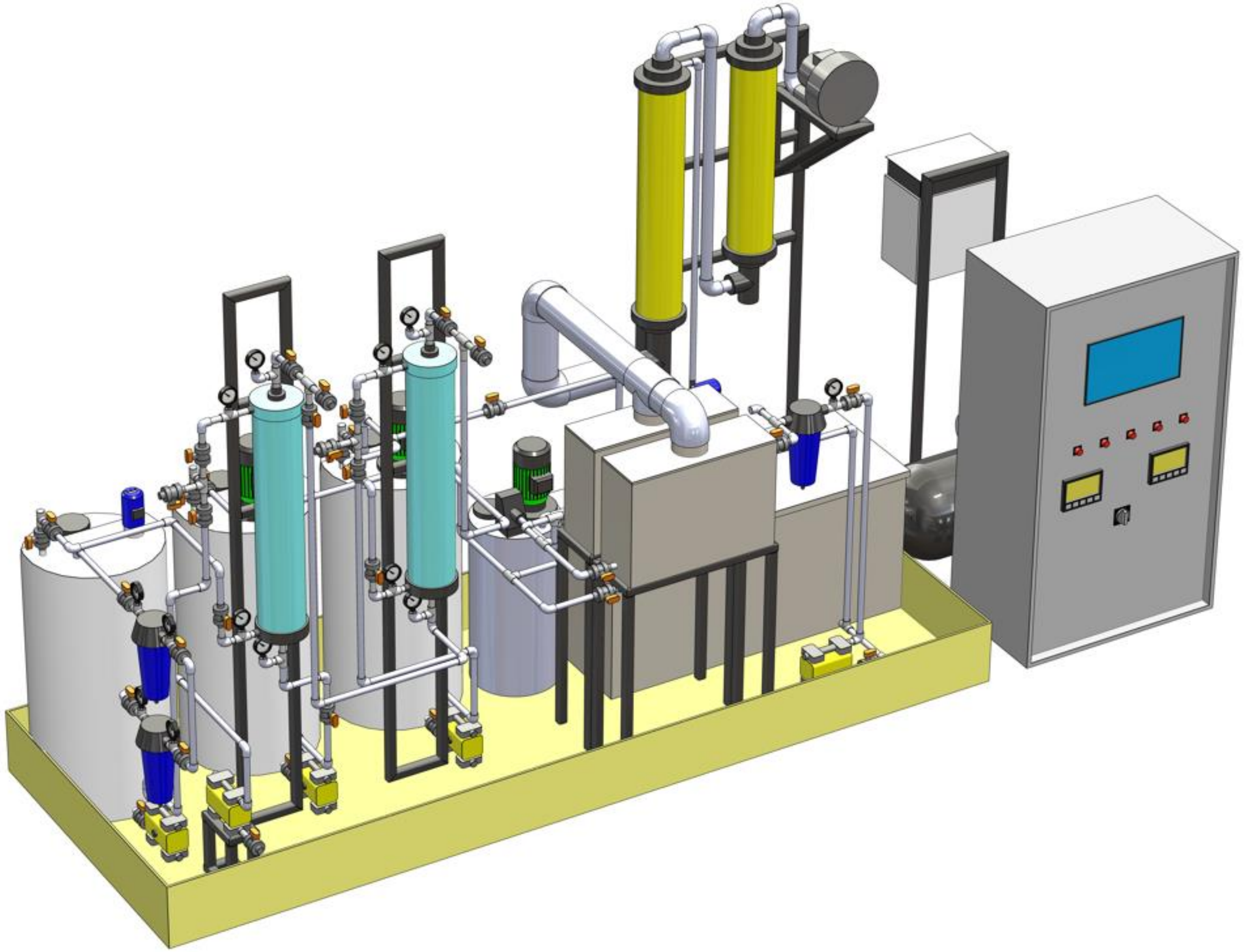
Wet scrubber: Packed bed absorber with pall rings + soda countercurrent

Dry adsorption scrubber: Packed bed high surface area

B1.2. Pilot plant integration

Redefined P&I





B1.2. Pilot plant integration

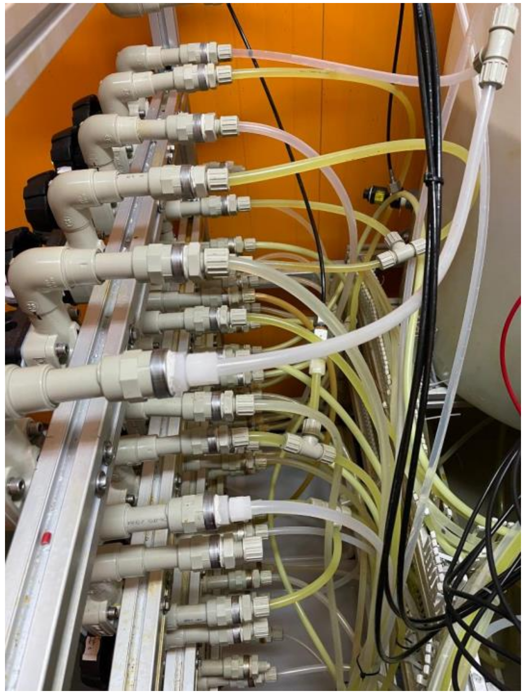
Pilot overview

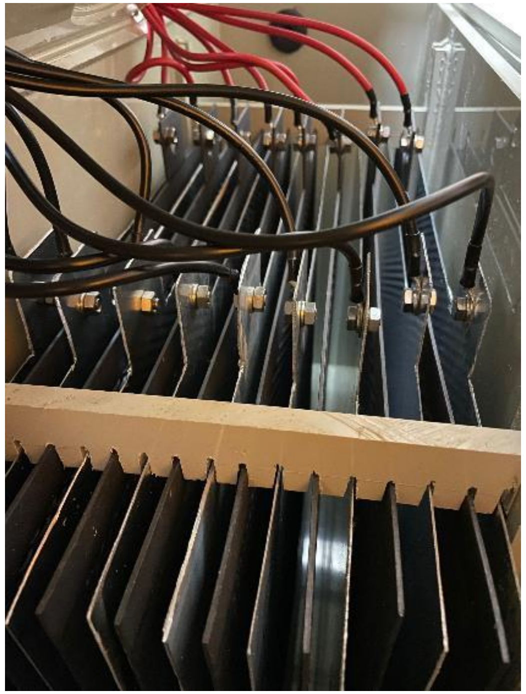
Same elements…but integrating the lessons learned

B1.2. Pilot plant integration

Pilot overview

Same elements…but integrating the lessons learned

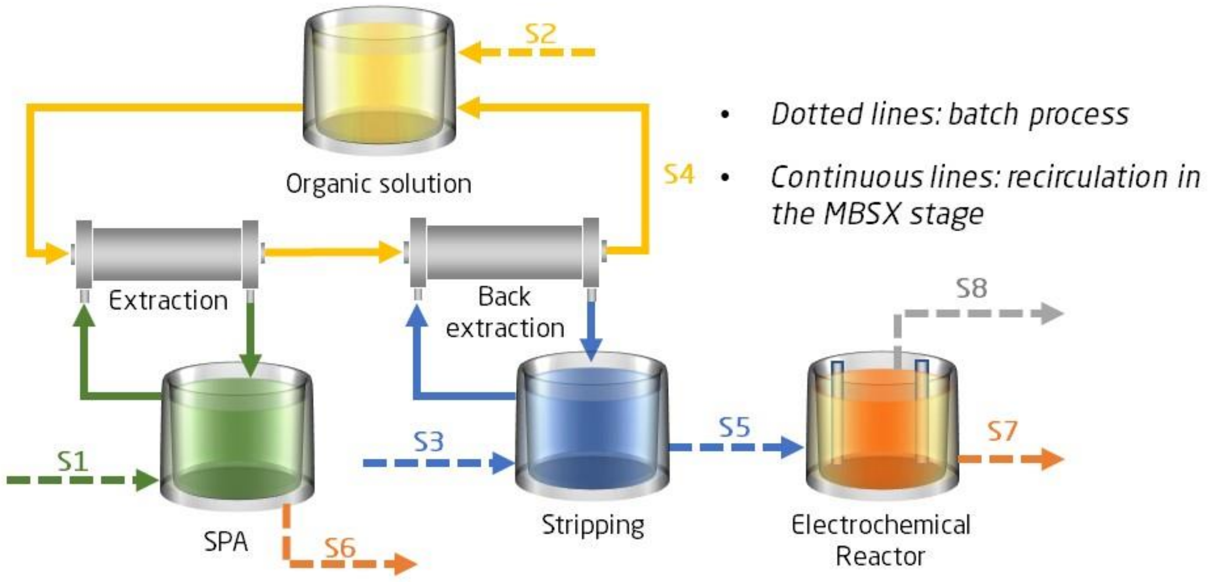




Membrane prototype validation & iron chloride valorisation

Membrane prototype validation & iron chloride valorisation

MBSX start-up & initial trials



- ✓ **4 hollow fiber membrane contactors** (20 m^2 each contactor)
- ✓ **Adjustable flowrates and volumes**
- ✓ **0.15 bar overpressure of the aqueous phase on the organic phase**
- ✓ **Working at continuous mode as soon as possible**
- ✓ **Tap water as stripping**

- ➢ 60% zinc extracted
- ➢ 10/1 Zn/Fe selectivity

Membrane prototype validation & iron chloride valorisation

MBSX validation & demonstration

GALESA
GALVANIZADORA VALENCIANA, S.L.U.

Objective: zinc recovery (maximum zinc concentration in the stripping phase)

$$\frac{V_{stripping}\ (L)}{V_{spent\ acid}\ (L)} = 1.3$$

Stripping
41 – 56 g Zn^{2+}/L
2 – 3 g Fe^{2+}/L
56 – 77 g Cl^{-}/L
pH=0.62 – 0.80

Spent acid
23 – 32 g Zn^{2+}/L
81 – 91 g Fe^{2+}/L
140 – 162 g Cl^{-}/L
pH=0.68 – 0.99

mare

Objective: iron chloride obtention (minimum zinc concentration in the spent acid)

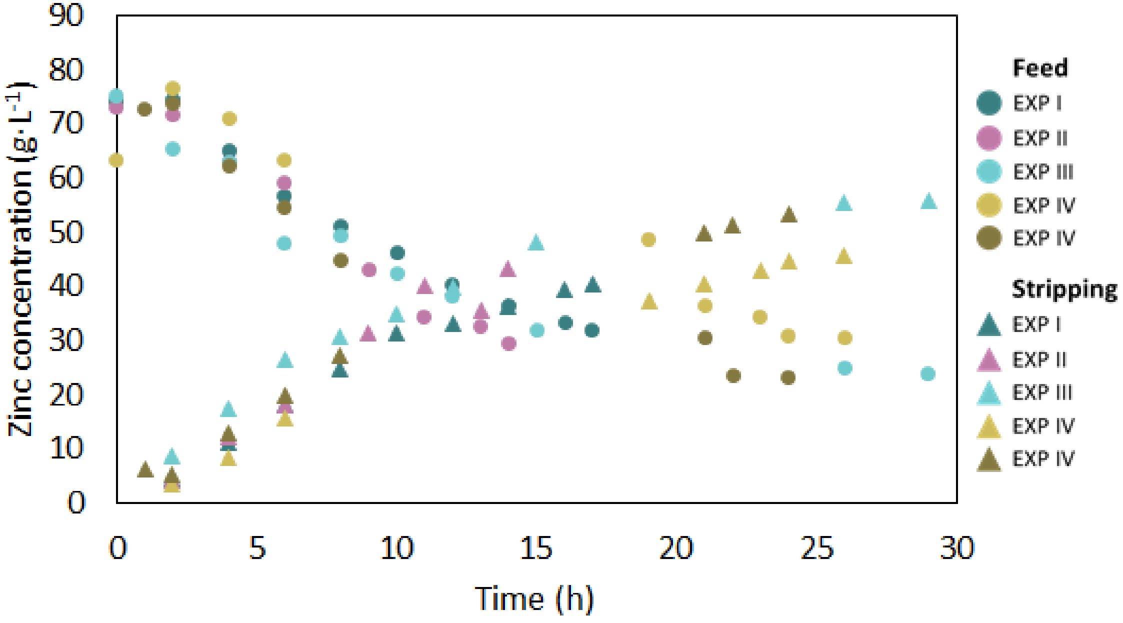
$$\frac{V_{stripping}\ (L)}{V_{spent\ acid}\ (L)} = 2.9$$

Spent acid
3 g Zn^{2+}/L
72 g Fe^{2+}/L
46 g Cl^{-}/L
pH=1.9

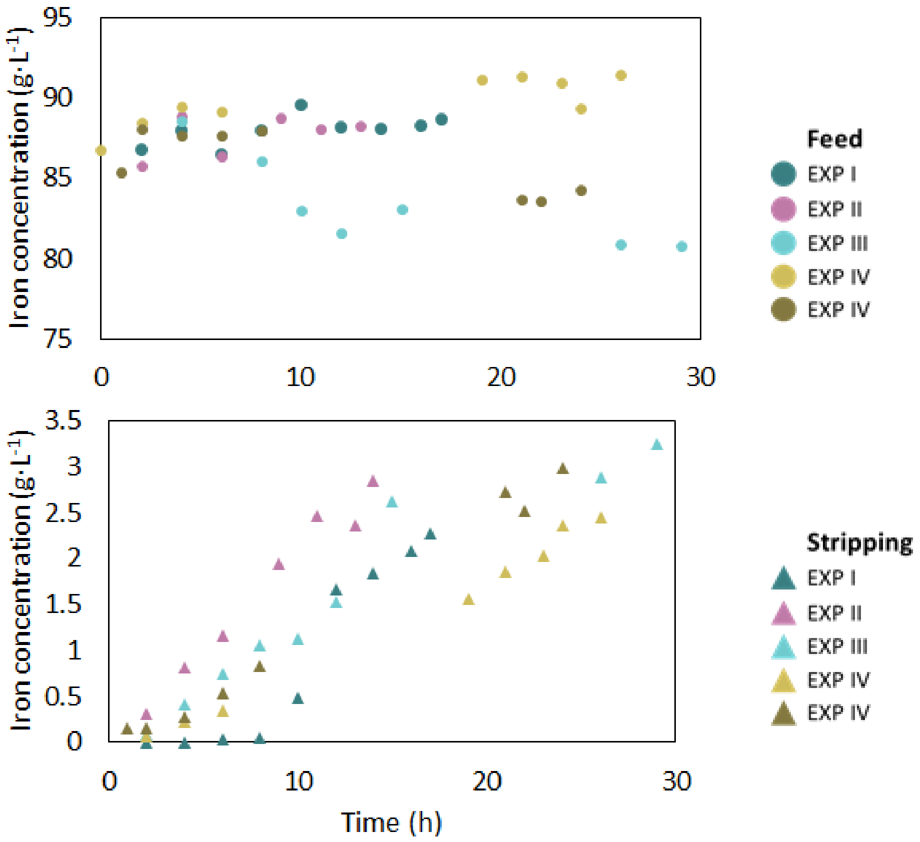
Stripping
24 – 36 g Zn^{2+}/L
3 g Fe^{2+}/L
31 – 52 g Cl^{-}/L
pH=0.75-2.4

MBSX validation & demonstration

Objective: zinc recovery



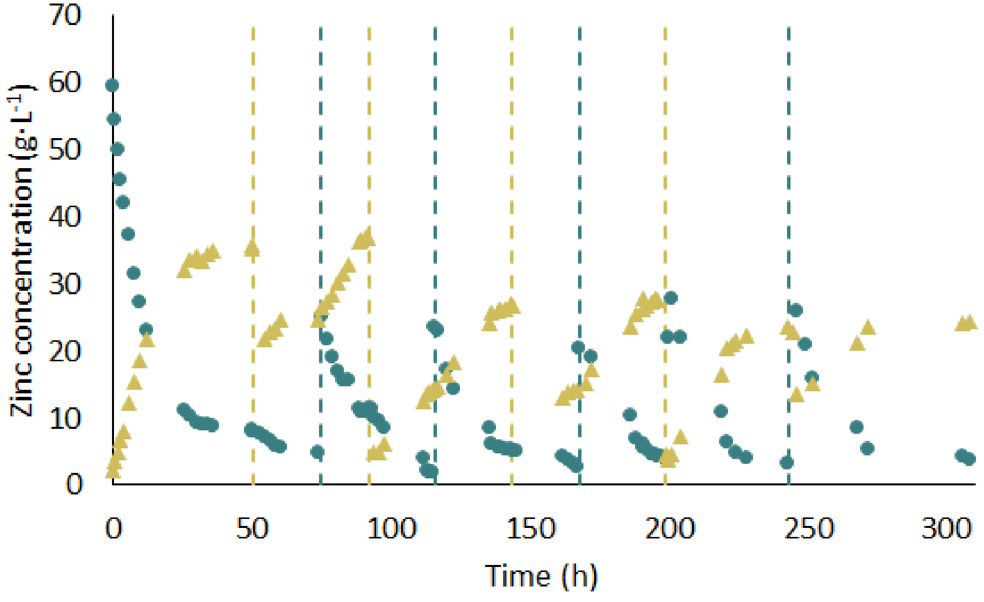
Zinc concentration in the feed (●) and stripping (▲) phases



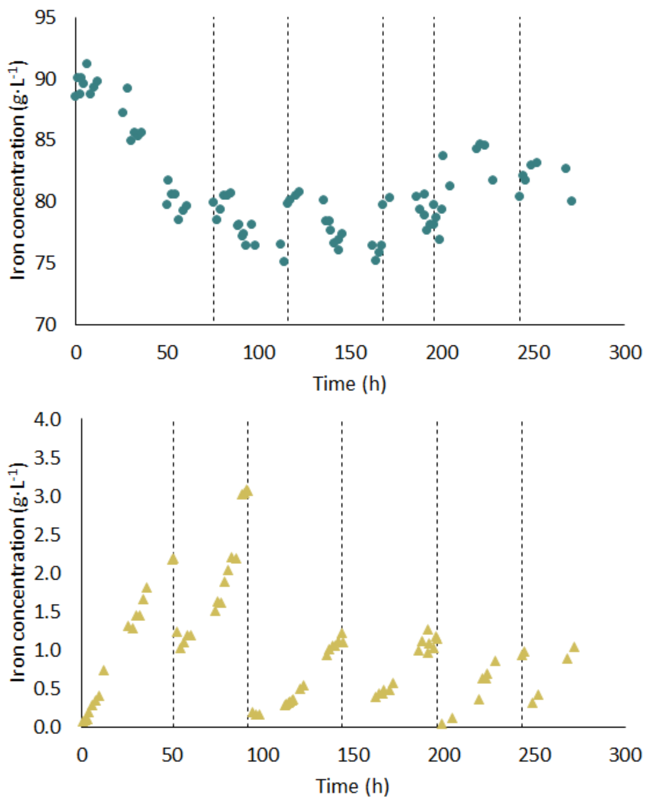
Iron concentration in the feed (●) and stripping (▲) phases

MBSX validation & demonstration

Objective: iron chloride obtention



Zinc concentration in the feed (●) and stripping (▲) phases

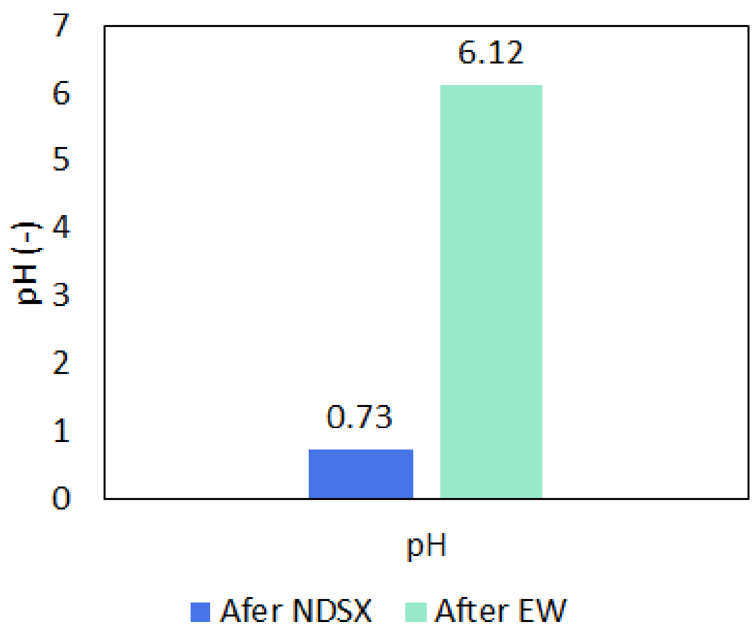


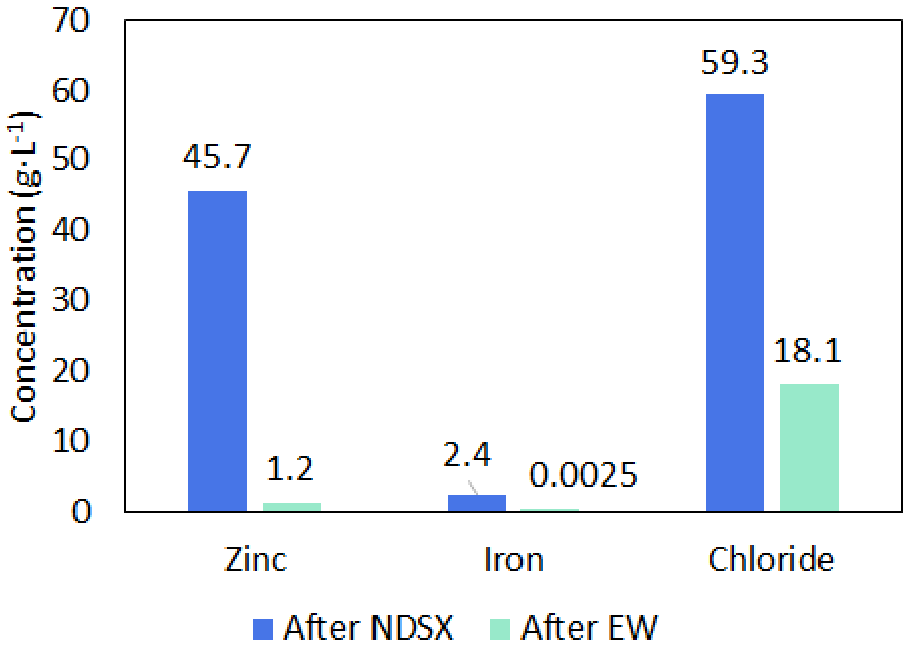
Iron concentration in the feed (●) and stripping (▲) phases

MBSX validation & demonstration

Stripping phase after EW: clarified – can it be reused in our own process?

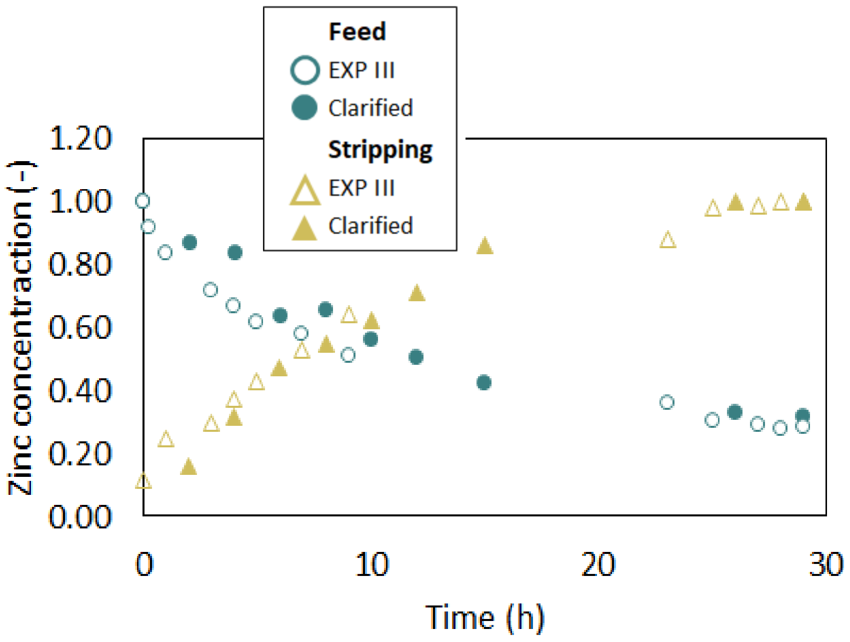
Composition assessment





MBSX validation & demonstration

Clarified as stripping phase of NDSX: Similar operating conditions (volumes, flowrates and time) to EXP III



The clarified effluent after EW can be reused as stripping (closing the loop and avoiding waste stream generation)

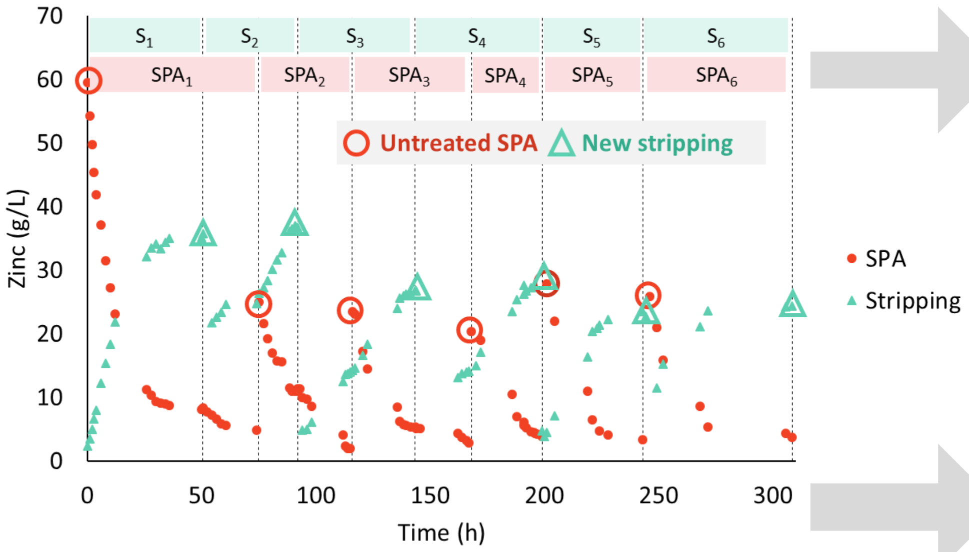
Membrane prototype validation & iron chloride valorisation

MBSX operating conditions

SPA is treated by 6 **cycles** in which untreated SPA or new stripping is added

SPA before valorisation

pH	<0
Chloride	174.3 g/L
Zn	59.5 g/L
Fe	88.5 g/L



Zinc concentration in the SPA (●) and in the stripping (▲) phases with experimental time including operating conditions (time and volume of SPA and stripping in each cycle)

Purified SPA ($FeCl_2$)

pH	1.89
Chloride	83.9 g/L
Zn	2.3 g/L
Fe	71.7 g/L

Substitute of $FeCl_3$ 40% wt.

Stripping ($ZnCl_2$)

pH	1.08
Chloride	43.5 g/L
Zn	29.8 g/L
Fe	1.5 g/L

Substitute of primary zinc

Membrane prototype validation & iron chloride valorisation

Working procedure

1. Experimental study at laboratory scale: search of **inexpensive transformation** of $FeCl_2$ to $FeCl_3$

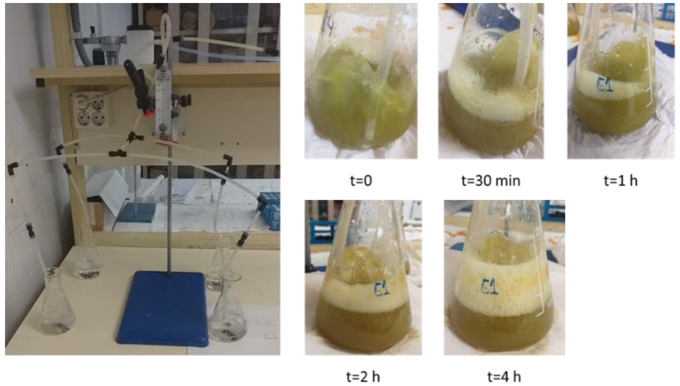
2. **Direct use** of $FeCl_2$ as substitute of $FeCl_3$

3. **Valorisation** of recovered iron chloride at the WWTP facility

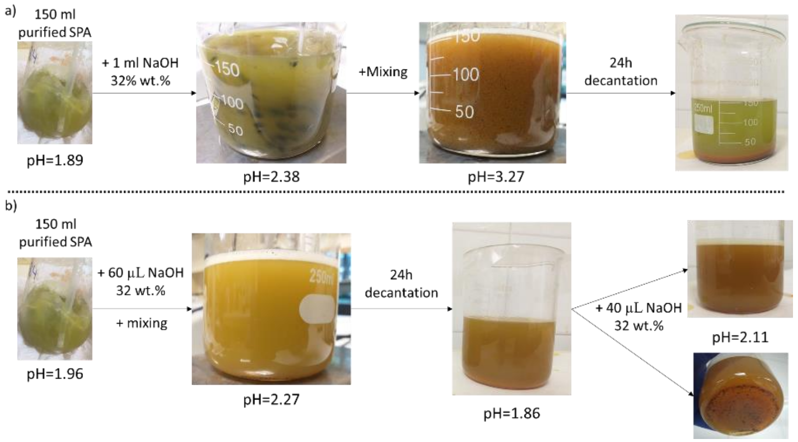
Experimental study

1 Experimental study at laboratory scale: transformation of $FeCl_2$ to $FeCl_3$

Aeration



pH adjustment



NaClO addition

none of the inexpensive methods tested were able to provide **full oxidation** of Fe(II) to Fe(III)

$FeCl_2$ vs $FeCl_3$

2 Direct use of $FeCl_2$ as substitute of $FeCl_3$

Na_2S (1 g/L)

Treated SPA

$$Na_2S + FeCl_2 \rightarrow 2\ NaCl + FeS$$

Literature review

Iron (II) chloride is adequate for hydrogen sulphide suppressor in the biogas produced in the anaerobic digester of WWTP facilities

The use of $FeCl_2$ as a partial replacement for commercial $FeCl_3$ will be tested

Ease of implementation

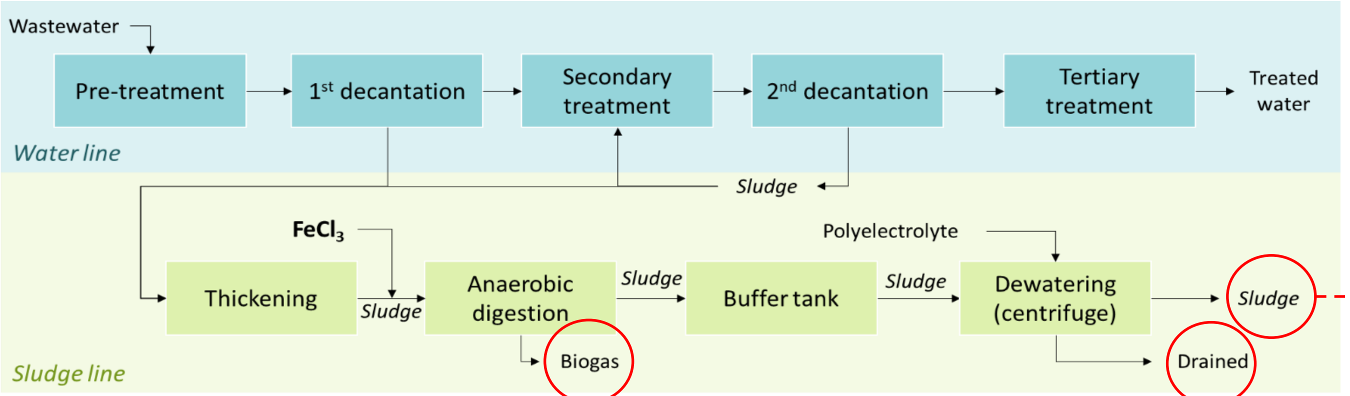
Implementation in WWTP facility

3 Valorisation of recovered iron chloride at the WWTP facility

WWTP of San Pantaleón

Stripping

Humidity and metals concentration



TSS, TOC, chloride and metals concentration

CH_4, CO_2, CO and H_2S

In situ hydrogen sulphide meter

MP-AES

Implementation in WWTP facility

3 Valorisation of recovered iron chloride at the WWTP facility

Deposit with the treated SPA at MARE.
Implementation of treated SPA at MARE as partial substitute of commercial $FeCl_3$

Considering

195.6 g Fe^{3+}/L **commercial $FeCl_3$** 40% wt.
71.7 g Fe^{2+}/L **purified SPA**

151.2 L $FeCl_3$ 40% wt./day (**29.6** kg iron/day)

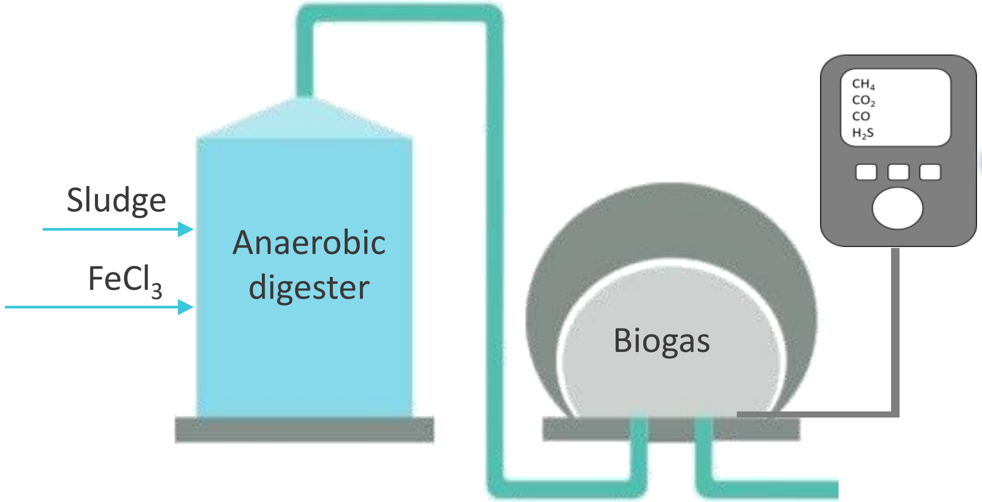
≃300 L purified SPA ($FeCl_2$)

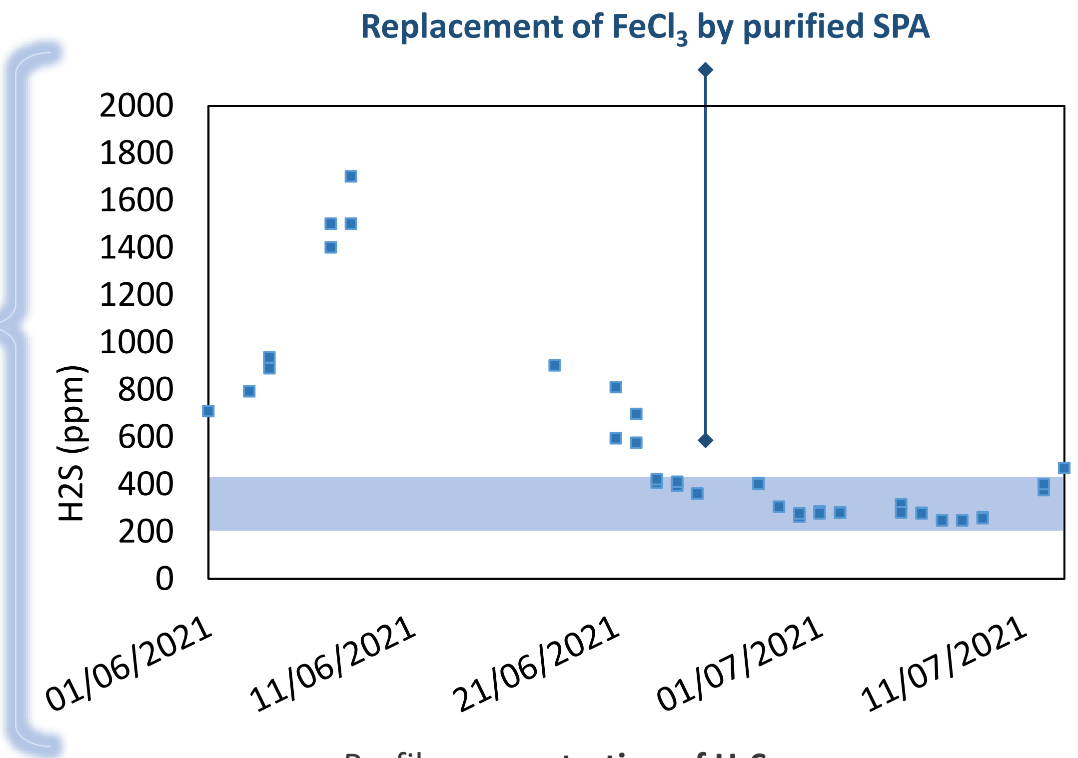
Test
24 -25th June

57.6 L commercial $FeCl_3$ 40% wt. /day
136.8 L purified SPA/day
(**33.7** kg iron/day)

Biogas monitoring

3 Valorisation of recovered iron chloride at the WWTP facility

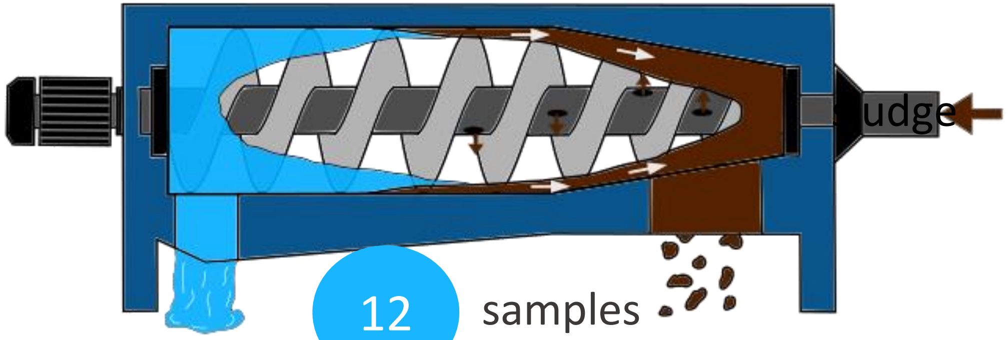




Profile **concentration of H_2S**

MBSX operating conditions

3 Valorisation of recovered iron chloride at the WWTP facility



12 samples

4 — 4 motnhs monitoring

414 — Analytical determinations

Drained

TSS: 702.7 mg/L
TOC: 464.0 mg/L
2.4 g **Cl^-**/L
0.4 – 7.4 mg **Fe**/L

Dewatered sludge

79.2 %H

21,177 mg **Fe**/kg dried sludge
20,374 mg **Al**/kg dried sludge
836.2 mg **Zn**/kg dried sludge

Without limits

<2,500 mg/kg dried sludge

Limits of heavy metals concentration in sludge for agricultural use (**Spanish RD 1310/1990**)

Membrane prototype validation & iron chloride valorisation

MBSX operating conditions

Limits of heavy metals in sludge for agricultural use as soil amendment (Spanish RD 1310/1990)

	Concentration (mg/kg dried sludge)													
Date	**Fe**	**Zn**	**Cd**	**Cu**	**Ni**	**Hg**	**Bi**	**Pb**	**W**	**Sn**	**Mn**	**Cr**	**Al**
09/06/21	20,700	725.0		260.0	5.0				45.0	75.0	270.0	45.0	19,375
22/06/21	20,160	743.5		264.5	10.0				54.9	64.9	249.5	44.9	19,296
30/06/21	25,076	812.3		297.7	10.1				55.5	55.5	262.4	50.5	21,059
09/07/21	23,169	867.6		331.0	10.0				60.2	55.2	245.7	45.1	20,767
21/07/21	23,988	1079.0		409.4	19.3				48.2	53.0	274.6	57.8	20,722
27/07/21	23,374	838.8	<LQO	311.0	9.4	<LQO	<LQO	<LQO	56.6	47.1	230.9	51.8	21,909
04/08/21	21,589	813.1		275.7	9.3				56.1	46.7	210.3	46.7	21,304
13/08/21	21,665	876.3		297.0	9.7				68.2	48.7	204.5	53.6	21,417
26/08/21	20,926	848.6		313.4	9.6				48.2	43.4	183.2	48.2	20,521
06/09/21	17,733	828.5		334.3	9.7				58.1	43.6	164.7	43.6	19,452
16/09/21	18,593	809.0		301.5	10.1				60.3	45.2	165.8	45.2	20,161
29/09/21	17,153	792.0		277.0	9.7				58.3	43.7	150.6	43.7	18,499
Average	21,177	**836.2**		**306.0**	**10.2**	<LOQ	<LQO	<LOQ	55.8	51.8	217.7	**48.0**	20,373
RD 1310/1990	-	2500	20	1000	300	16	-	750	-	-	-	1000	-

EW prototype validation & zinc valorisation

EW prototype validation & zinc valorisation

EW start-up & initial trials

- The **start-up** of the EW pilot was done with **synthetic solution** formulated with Cl_2Zn and $FeSO_4$.[Zn] = 100 g/l. [Fe] = 2 g/l
- **Operating Protocol**

1- Filling up SPA tank and pH adjustment to 4-5

2- Oxidation by aeration $T_{reaction}$: 30 min

3- Flocculation. $T_{reaction}$: 5 min

4- Settling. T : 4 hours. > 99 **% Fe removal**

5- Sludge filtration using rotary sieve and filter bag

6- Electro winning of SPA with recirculation from the EW to the SPA tank. Current density: **10 mA/cm²**

X_{Znf} : 30 % ϕ_{Znf} : 70 %

EW prototype validation & zinc valorisation

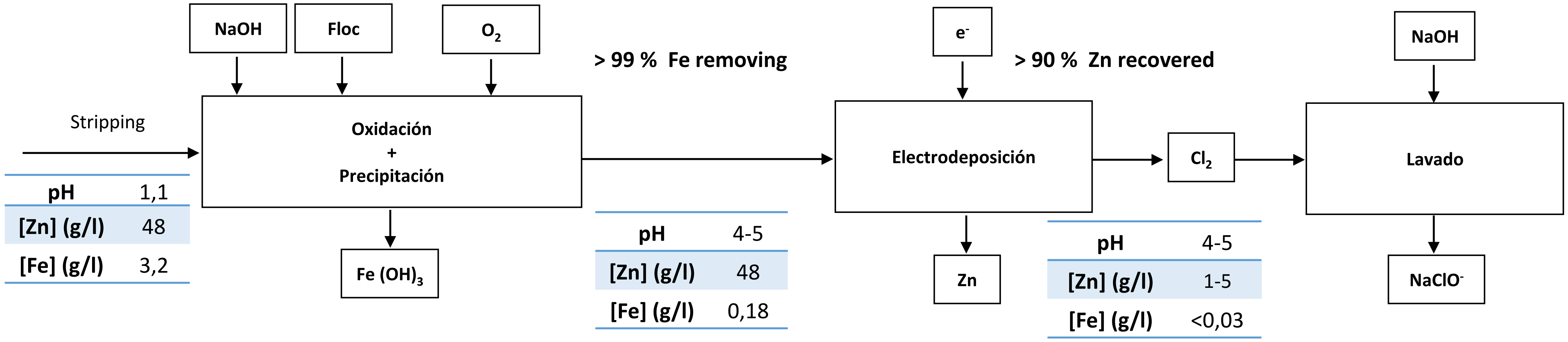
EW start-up & initial trials

EW. Start-up main considerations

- The electric and hydraulic elements of the prototype works properly.
- The times selected for the whole treatment (oxidation, settling..) using synthetic solution are suitable.
- The additional elements added to the system regarding the initial design improve the global system:
  - Recirculation tank manage with level sensors to provide a steady recirculation flow from EW cell to the settling tank
  - Bag filter after the rotary sieve inside the tank to improve removing of $Fe(OH)_3$
- **Despite the double filtering some of solids always get to the EW together with the Fe^{+2} no oxidized**
- **The current density selected 10 mA/cm^2 produce a dentritic growth of Zn which is valid for later recovery by scratching**

EW prototype validation & zinc valorisation

EW validation & demonstration



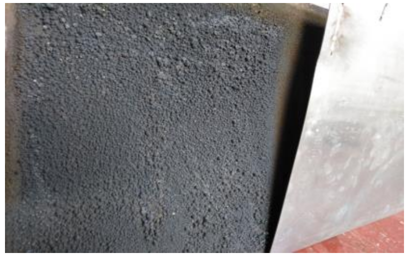
pH	1,1
[Zn] (g/l)	48
[Fe] (g/l)	3,2

pH	4-5
[Zn] (g/l)	48
[Fe] (g/l)	0,18

pH	4-5
[Zn] (g/l)	1-5
[Fe] (g/l)	<0,03

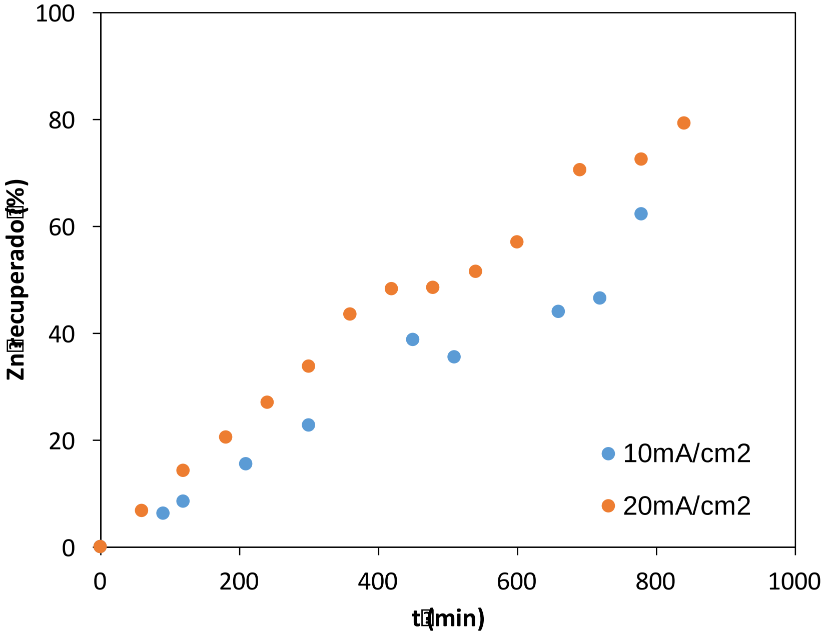


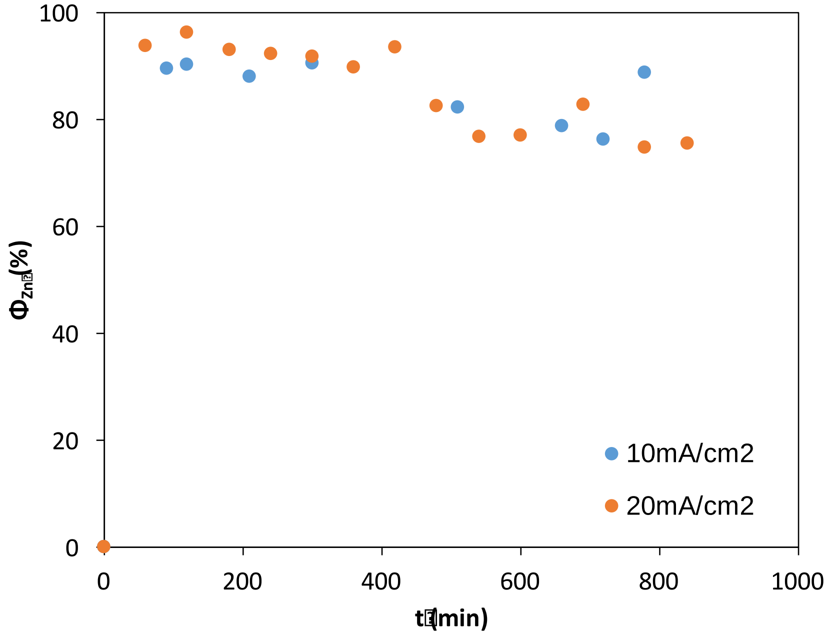


EW validation & demonstration

Zn recovery in different days while maintaining the electrodes polarized





EW prototype validation & zinc valorisation

EW validation & demonstration

DENDRITIC GROWTH

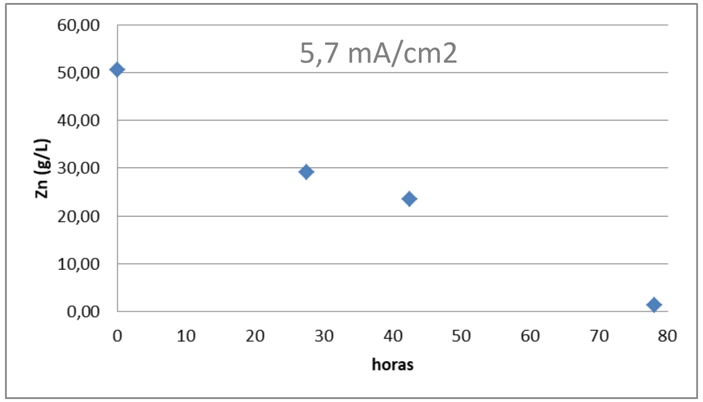
Irregular dendritic growth
Short circuit risk
Difficult valorisation

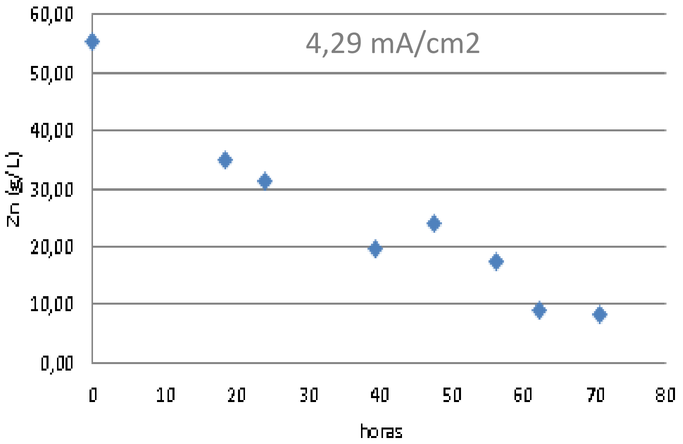
SOLUTION

Reduce current density
Improve homogeneity: aeration o recirculation

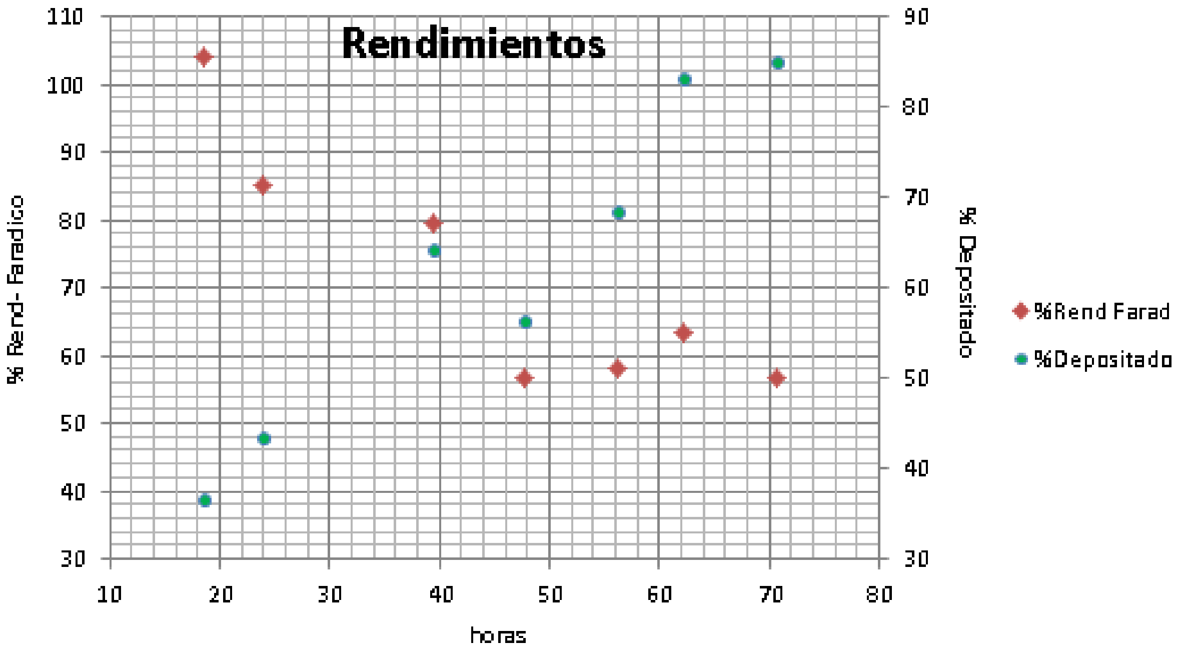
EW prototype validation & zinc valorisation

EW validation & demonstration





> 80% Zn Deposition after 70h



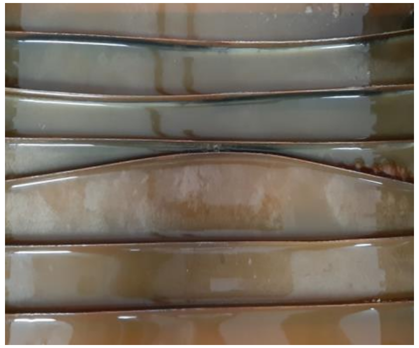
Faradic yield decreasing with time
Due to secondary reactions

EW prototype validation & zinc valorisation

EW validation & demonstration

EW validation & demonstration

CATHODE BENDING




Short circuit risk
Complicates handling
Bad deposition

SOLUTION

Electrode separator
Increase electrode thickness
Daily visual control of the electrodes
Reduce current density

CATHODE PERFORATION


Partial dissolution of the cathodes
Bad homogeneity
Zinc analysis senseless

SOLUTION

Increase cathode thickness
Reduce current density
Improve reactor homogeneity

EW prototype validation & zinc valorisation

Electrode drying

No drying

24h

Oxidation

Two Formats: Electrode-powder

Rinsed electrode

Drying

First trials: hair dryer

Final choice: Oven 70ºC 2h

POWDER

Zn powder analysis

- Zinc: 95%
- ZnO: ∽ 4%
- Fe: 0.04%
- C: 0.11%

- **Metallic Zinc** – recovered via EW
- **Fe** as the most important pollutant of the stripping solution
- **C** as potential pollutant coming from the organic components of previous MBSX steps

EW prototype validation & zinc valorisation

VALORIZATION: HOT-DIP GALVANIZING

DIRECT MELTING ELECTRODE → POST-TREATMENT MELTING ELECTRODE → DIRECT MELTING POWDER → POST-TREATMENT MELTING POWDER → PROCESS MODIFICATIONS

Immersion – NH_4Cl (See table)

(II) (III) (IV)

Sintering - Inert atmosphere - 400ºC 2h

	Rinse + dry	[NH_4CL] %	time	dry	Result
I	Yes	No	No	No	flame
II	Yes	25	1’	Yes	No flame
III	Yes	25	3’	Yes	No flame
IV	Yes	10	1’	Yes	-

Video

RESULTS

no treatment (I)

with treatment (II)

Slag – with treatment (II) and (III)

EW prototype validation & zinc valorisation

VALORIZATION: HOT-DIP GALVANIZING

~~DIRECT MELTING ELECTRODE~~ → ~~POST-TREATMENT MELTING ELECTRODE~~ → DIRECT MELTING POWDER → POST-TREATMENT MELTING POWDER → PROCESS MODIFICATIONS

> 1 mm

< 1 mm

NH4Cl

Immersion

no treatment (I)

with treatment (II)

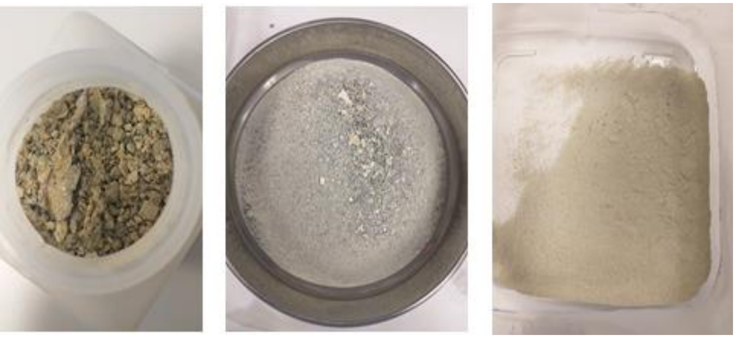
Slag – with treatment (II) and (III)

No flame

High generation of slag

Discarded for HDG

Slag analysis



Molten zinc bath residue

1. 5 replicates of the final sample were crushed and sieved (mesh size 0.25 mm)
2. Acid digestion with HNO_3 using 0.3 g residue
3. Analysis of metals concentration

779.1 ± 157.9 mg Zn/g residue

Fe	**0.756 ± 0.017**	mg/g residue
Ni	0.021 ± 0.001	
Pb	**0.126 ± 0.007**	
Sn	0.006 ± 0.001	
Mo	0.007 ± 0.003	
Mn	**0.623 ± 0.012**	
Cr	0.005 ± 0.001	
Al	**0.505 ± 0.006**	

60-91% corresponds to analyzed metals

- Zinc oxide (ZnO) has 80.34% Zn content
- Similar value to the average result recovered in the acid digestion (77.91%)

- T fusión Zn: 420 ºC
- T fusión ZnO: 1975 ºC

Electrode treatment process modification

DIRECT MELTING ELECTRODE → POST-TREATMENT MELTING ELECTRODE → DIRECT MELTING POWDER → POST-TREATMENT MELTING POWDER → PROCESS MODIFICATIONS

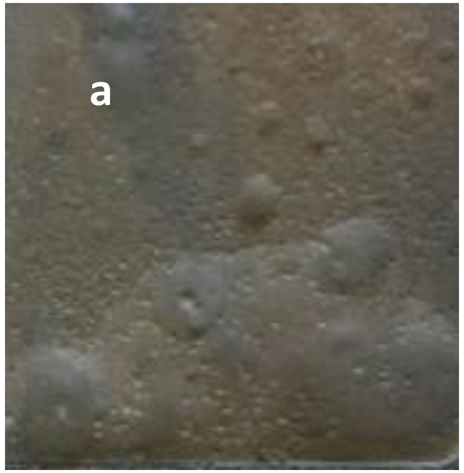
Boric acid addition

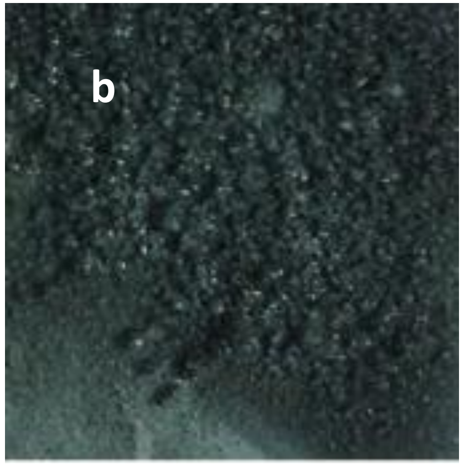
a. Boric acid
No pH control
50 mA/cm^2

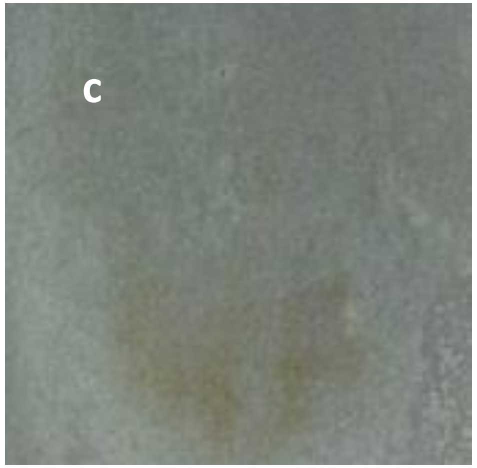
b. Boric acid
pH control
100 mA/cm^2

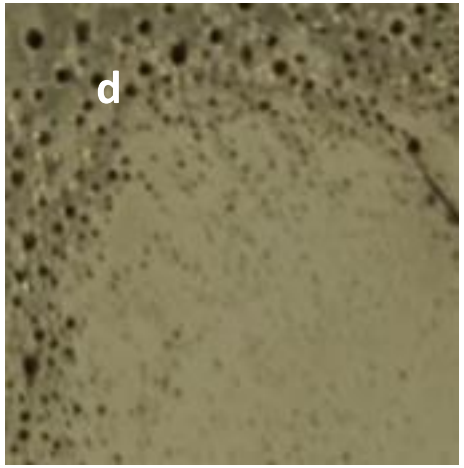
c. Boric acid
No pH control
20 mA/cm^2

d. Boric acid
pH control
50 mA/cm^2









EW prototype validation & zinc valorisation

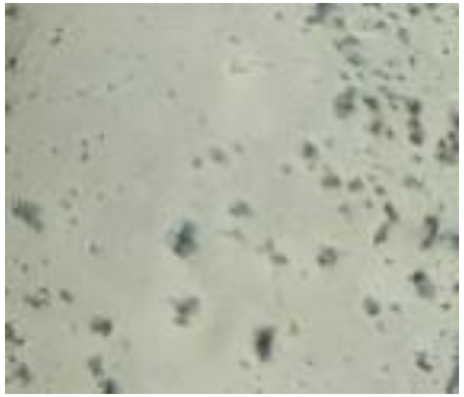
Electrode treatment process modification

~~DIRECT MELTING ELECTRODE~~ → ~~POST-TREATMENT MELTING ELECTRODE~~ → ~~DIRECT MELTING POWDER~~ → ~~POST-TREATMENT MELTING POWDER~~ → PROCESS MODIFICATIONS

Electrorefining in H_2SO_4

H_2SO_4 pH ~ 3

H_2SO_4 pH ~ 2



H_2SO_4 pH ~ 1

H_2SO_4 pH ~ 0

valid for hot-dip galvanizing

Electrode treatment process modification

Addition of additives.

- Compact deposit
- Allows greater current densities

- New reagent. Increases costs and hinders operation
- Additives may complicate the reuse of bath at the stripping stage, damaging membranes
- In that case: generation of a new waste stream

Membrane Reactor.

- Re-dissolution of Zinc is avoided
- Allows greater current densities
- Avoids additives

- More complex operation
- Electrode assembly
- Membranes are expensive. Shelf-life to be determined
- Dendritic deposit

Electrorefining.

- Re-dissolution of Zinc is avoided
- Allows greater current densities
- Compact deposit. Suitable for galvanizing

- Generation of a new waste stream
- Additional operation. Higher costs

Electrode treatment process modification

~~DIRECT MELTING ELECTRODE~~ → ~~POST-TREATMENT MELTING ELECTRODE~~ → ~~DIRECT MELTING POWDER~~ → ~~POST-TREATMENT MELTING POWDER~~ → ~~PROCESS MODIFICATIONS~~

EXTERNAL VALORIZATION

METAL RECYCLERS

OPTION 1.

- Full electrode
- Powder format
- Recovery: Induction furnace
- Separate recovery of ZnO

- Particle size >4mm
- <80% ZnO
- PRICE: ∽ 50% LME

OPTION 2.

- Powder format
- Recovery: Dissolution
- ZnCl2 baths to reduce other metallic pollutants

- Particle size <4mm
- %ZnO TBD
- PRICE: 65% LME

OPTION 3.

- Powder format
- Recovery: Waelz + leaching
- Purified Waelz oxide used for future recovery in electrolytic Zn

- Apparent dens: 2 g/m3 as reference
- >95% Zn. Fe not relevant
- PRICE: 40-60% LME

EW prototype validation & zinc valorisation

Electrode treatment process modification

USER	FORMAT	PROCESS	STEPS - TYPE	METHODOLOGY	RESULT	CONCLUSION
HOT DIP GALVANIZING	ELECTRODE	DIRECT	None	Rinsed after the EW. No further steps.	Zinc oxidation. Not suitable for HDG.	Discarded
		POST-TREATMENT	Drying	Rinsed, dried and immersed in crucible.	Great surface area leads to ignition in the crucible. Not suitable for HDG	Discarded
		POST-TREATMENT	Drying + sintering	Rinsed, dried and sintered at 400ºC in inert atmosphere (Nitrogen) and melt	Great generation of Slag.	Discarded
		POST-TREATMENT	Drying + NH4Cl	Rinsed, dried, immersed in NH4Cl at different times and concentrations, dry again and melt.	It does not burn, however the slag generation is not negligible	Discarded
		PROCESS MOD.	ADDITIVES	Addition of Surfactant (boric acid) during EW.	Compact deposit. Not tested in pilot. Possible incompatibilities with MBSX thus extra waste	Discarded
		PROCESS MOD.	MEMBRANE	Include membranes in EW process	Compact deposit. Expensive process, complicate to scale up.	Discarded
		ADDIT. STEPS	ELECTRO-REFINING	Dissolve electrodes in H2SO4 and repeat EW.	Higher purity of deposited Zinc. Could be feasible but expensive	Discarded
	POWDER	ADDIT. STEPS	Drying + Scraping	Rinse, dry, scrape and melt	> 99% of slag when immersed in crucible	Discarded
		ADDIT. STEPS	Drying + Scraping + NH4Cl	Rinse, dry, scrape and immerse in NH4Cl, dry again and melt.	> 99% of slag when immersed in crucible	Discarded
ALTERNATIVE RECOVERIES EXTERNAL	ELECTRODE	DIRECT	None	Direct recovery with an induction furnace	Technically feasible but not economical	Discarded
	POWDER	ADDIT. STEPS	Drying + Scraping	Direct recovery with an induction furnace	Allows electrode recovery and reuse Recovery of Zinc for galvanizing purposes By-product: PAID UP TO 65% LME	FEASIBLE
		ADDIT. STEPS	Drying + Scraping	Indirect recovery (e.g. dissolution)	Allows electrode recovery and reuse Recovery of Zinc for other purposes. By-product: PAID UP TO 65% LME	FEASIBLE

Environmental sustainability

Life cycle assessment (LCA)

System description, boundaries, functional unit

Data collection

LCI results are translated into an impact indicator

Definition of goal and scope ⇄ Interpretation

⬇⬆

Life cycle inventory ⇄ Interpretation

⬇⬆

Life cycle impact assessment ⇄ Interpretation

Interpretation

Life cycle assessment (LCA)

System description, boundaries, functional unit

Definition of goal and scope

Data collection

Life cycle inventory

LCI results are translated into an impact indicator

Life cycle impact assessment

Interpretation

To analyse the environmental impacts of the **HDG process**

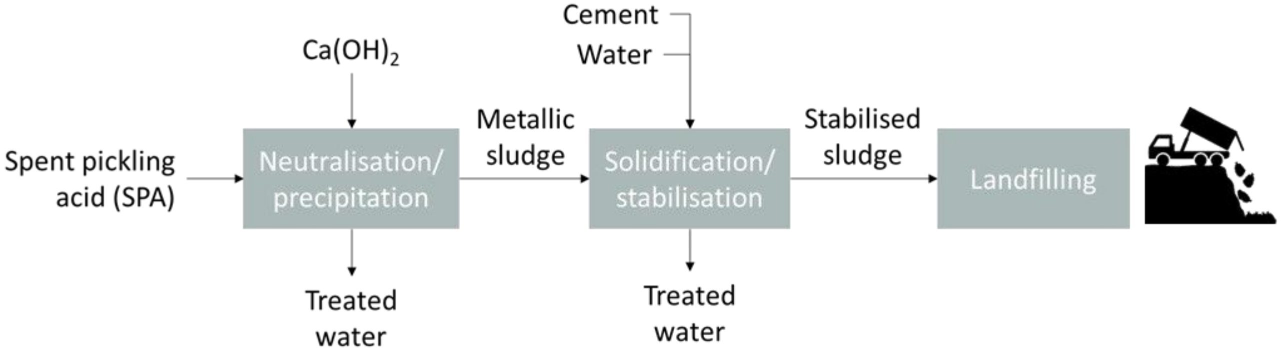
To compare the environmental impacts of SPA **conventional treatment** with the alternative **LIFE2ACID innovative technology**

To analyse the environmental impacts of the **integration** of LIFE2ACID technology in the HDG process

Spent pickling acid

Hazardous waste
(hazardous waste code 11 01 05*)

Conventional treatment



Leaching of heavy metals

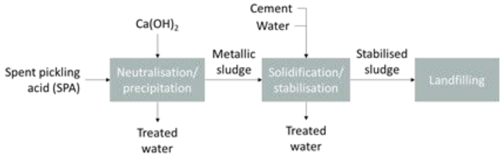
Waste of resources

Background

Spent pickling acid

Hazardous waste
(hazardous waste code 11 01 05)

Conventional treatment

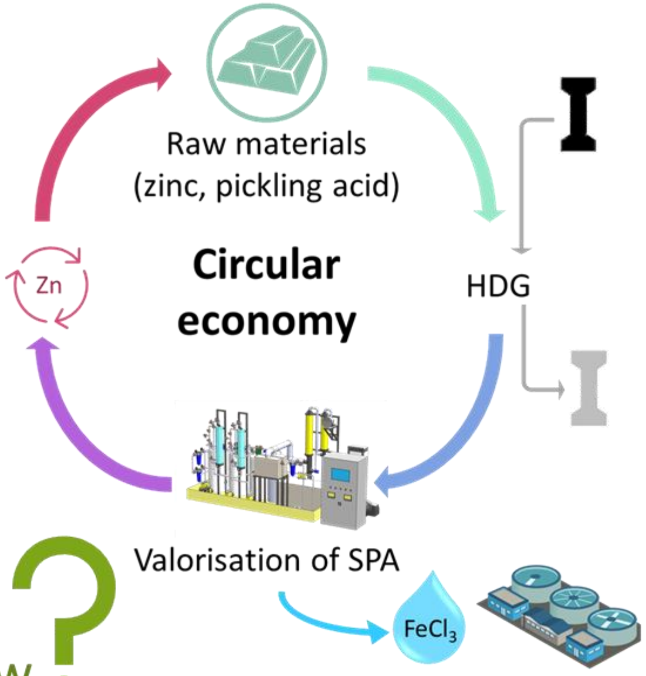


Linear economy

LIFE2ACID technology

Circular economy

Recovery of metallic zinc



Technical feasibility

Which alternative is better from an environmental point of view?

Environmental sustainability

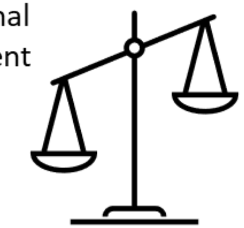
LCA methodology

Goal and scope definition

To compare the environmental impacts of the **conventional treatment** of spent pickling acid and the **LIFE2ACID technology**.

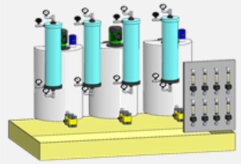
Conventional treatment

LIFE2ACID technology



- **Grave to cradle** approach
- **One m^3 of spent pickling acid (SPA)** as functional unit

Spent pickling acid



Secondary zinc*

Iron chloride*

***Material credits**

=

avoided burdens

Grave (tumba)

Waste

Cradle (cuna)

Secondary materials

LCA methodology

Goal and scope definition

To compare the environmental impacts **of the conventional treatment of spent pickling acid and the LIFE2ACID technology**

- **Grave to cradle** approach
- **One m^3 of spent pickling acid (SPA)** as functional unit

Life cycle inventory (LCI)

Pilot plant results and mass balances
Sphera professional database for secondary data

Life cycle impact assessment (LCIA)

CML 2001 as impact assessment method

LCA methodology

CML 2001 as impact assessment method

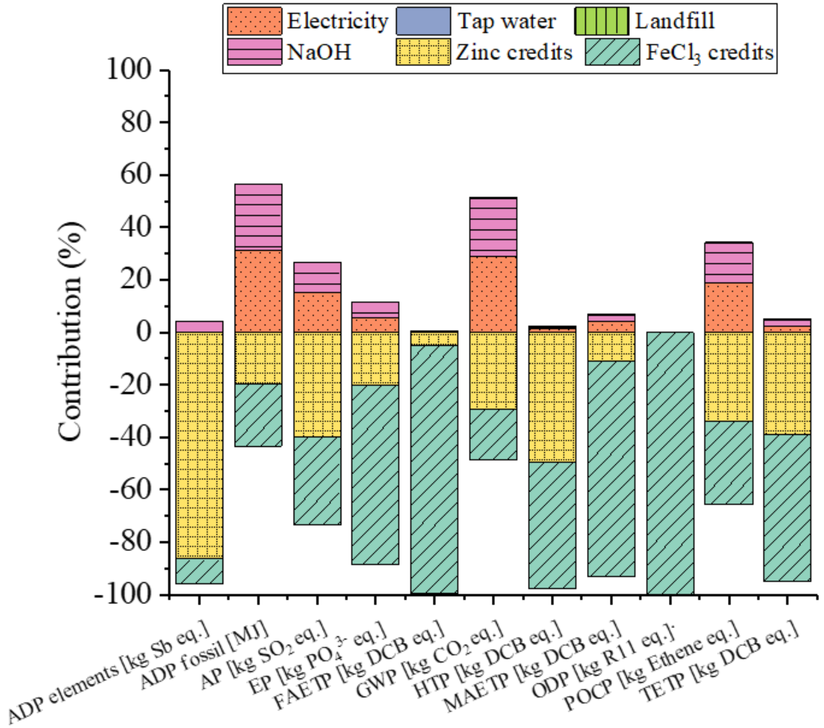
Abiotic Depletion (ADP-elements) [kg Sb-eq.]	Acidification Potential (AP) [kg SO_2-eq.]	Photochemical Ozone Creation Pot. (POCP) [kg ethene-eq.]	Marine Aquatic Ecotoxicity Pot. (MAETP) [kg DCB-eq.]	Terrestric Ecotoxicity Pot. (TETP) [kg DCB-eq.]
Abiotic Depletion (ADP-fossil) [MJ]	Global Warming Potential (GWP) [kg CO_2-eq.]	Eutrophication Potential (EP) [kg Phosphate-eq.]	Freshwater Aquatic Ecotoxicity Pot. (FAETP) [kg DCB-eq.]	Human Toxicity Pot. (HTP) [kg DCB-eq.]

Resources | Air pollution | Water pollution | Soil pollution & waste | Damages, health & biodiversity

LCA methodology

- Goal and scope definition
- Life cycle inventory (LCI)
- Life cycle impact assessment (LCIA)

Results: environmental impacts of the LIFE2ACID technology



Environmental impacts of NDSX/EW with zinc and iron chloride credits.

Material credits

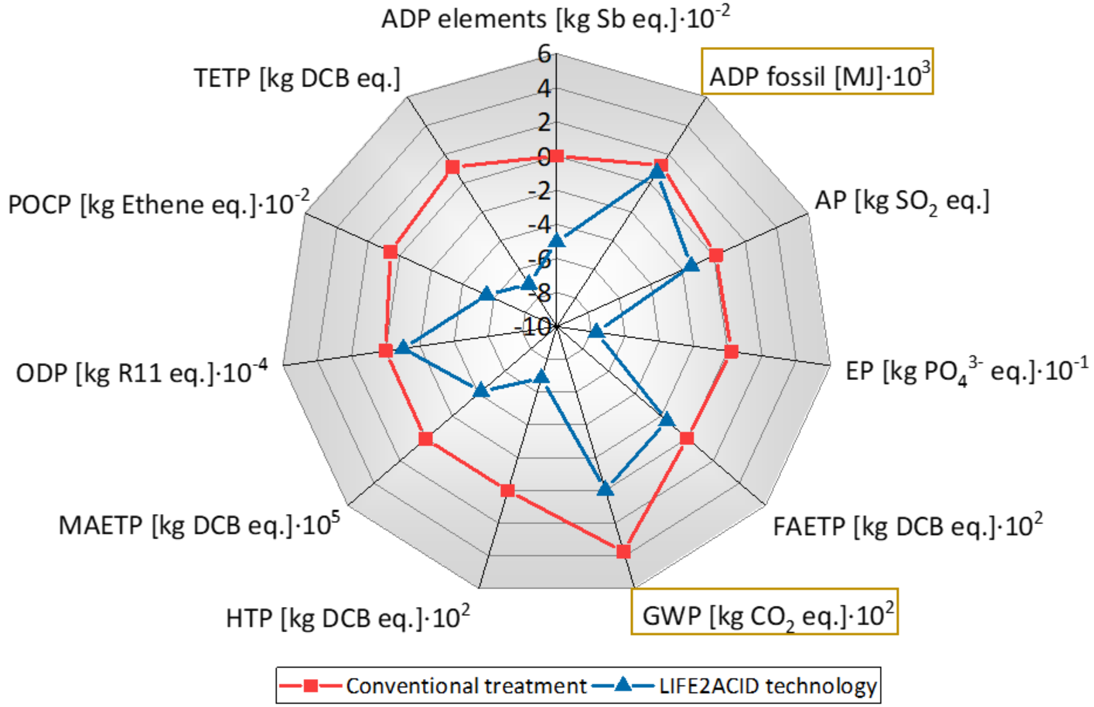
251.9 kg $FeCl_2/m^3$ SPA

Material credits

78.9 kg Zn/m^3 SPA

Energy consumption → ADP-fossil and GWP

Results: conventional treatment vs. LIFE2ACID technology



Comparison between the conventional treatment and the LIFE2ACID technology per m³ of spent pickling acid.

ADP-fossil

Conventional treatment > LIFE2ACID technology

1278.5 MJ/m³ SPA   728.7 MJ/m³ SPA

GWP

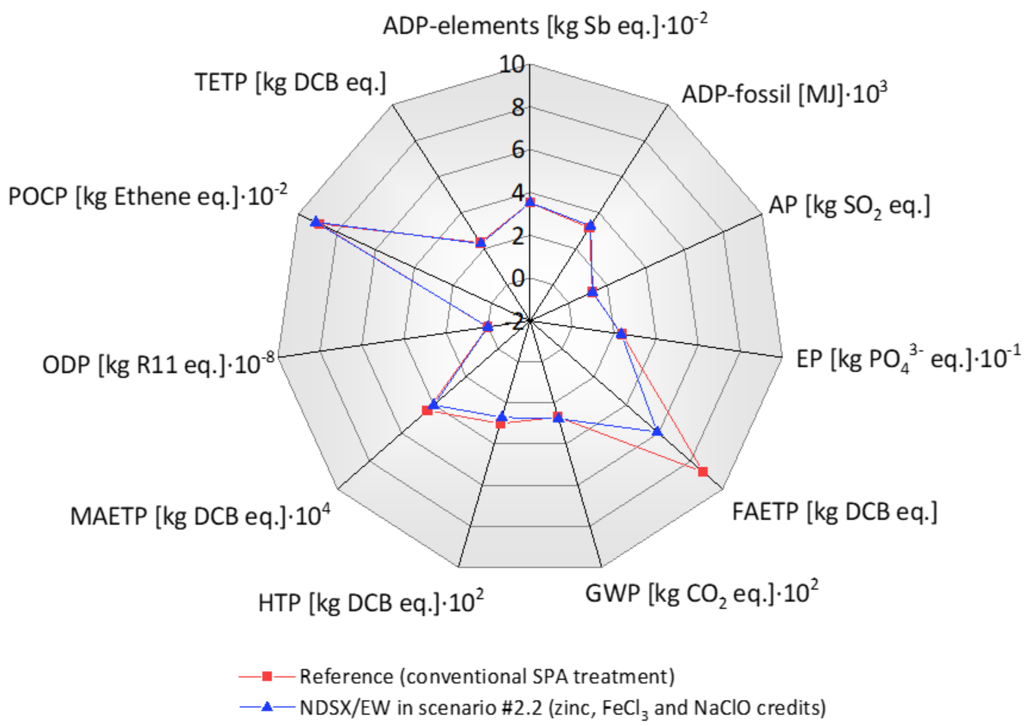
Conventional treatment > LIFE2ACID technology

392 kg CO_2 eq./m³ SPA   -2.5 kg CO_2 eq./m³ SPA

High reduction in the toxicity indicators

Other results: Integration of the LIFE2ACID technology in the HDG process

FU: one tonne of galvanised steel



Environmental impacts of the HDG process in GALESA in 2017 without steel production in the reference case (conventional SPA treatment), and NDSX/EW technology in scenario #2.2.

Energy consumption

ADP-fossil and GWP

Reduction of 6% about the reference case

Toxicity

FAETP, MAETP, HTP, TETP

Reduction of 16 – 80% about the reference case

Depletion of abiotic resources

ADP-elements

Reduction of 4.4% about the reference case

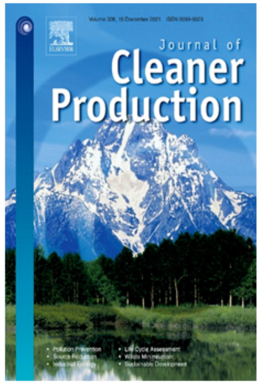
5% of the zinc consumed in the molten zinc bath is lost in the spent pickling acid

Scientific publications

membranes

4.106 (Q1)

A. Arguillarena, M. Margallo, A. Arruti-Fernández, J. Pinedo, P. Gómez, and A. Urtiaga. (2020). **Scale-Up of Membrane-Based Zinc Recovery from Spent Pickling Acids of Hot-Dip Galvanizing**, Membranes. 10 (12), 444.



7.246 (Q1)

A. Arguillarena, M. Margallo, A. Urtiaga, and A. Irabien. (2020). **Life-cycle assessment as a tool to evaluate the environmental impact of hot-dip galvanisation**, J. Clean. Prod., 290, 125676.

Arguillarena, A., Margallo, M. Urtiaga, A. (2021). **Carbon footprint of the hot-dip galvanization process using a life cycle assessment approach**, Clean. Eng. Technol., 2, 100041.

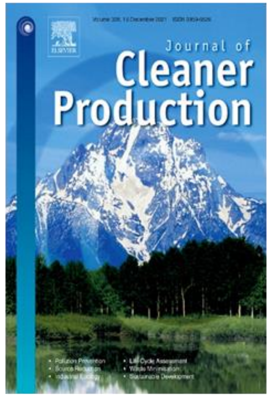
Scientific publications

Article to be sent before

17th December

6.789 (Q1)

Life cycle assessment of zinc and iron recovery from spent pickling acids by membrane-based solvent extraction and electrowinning

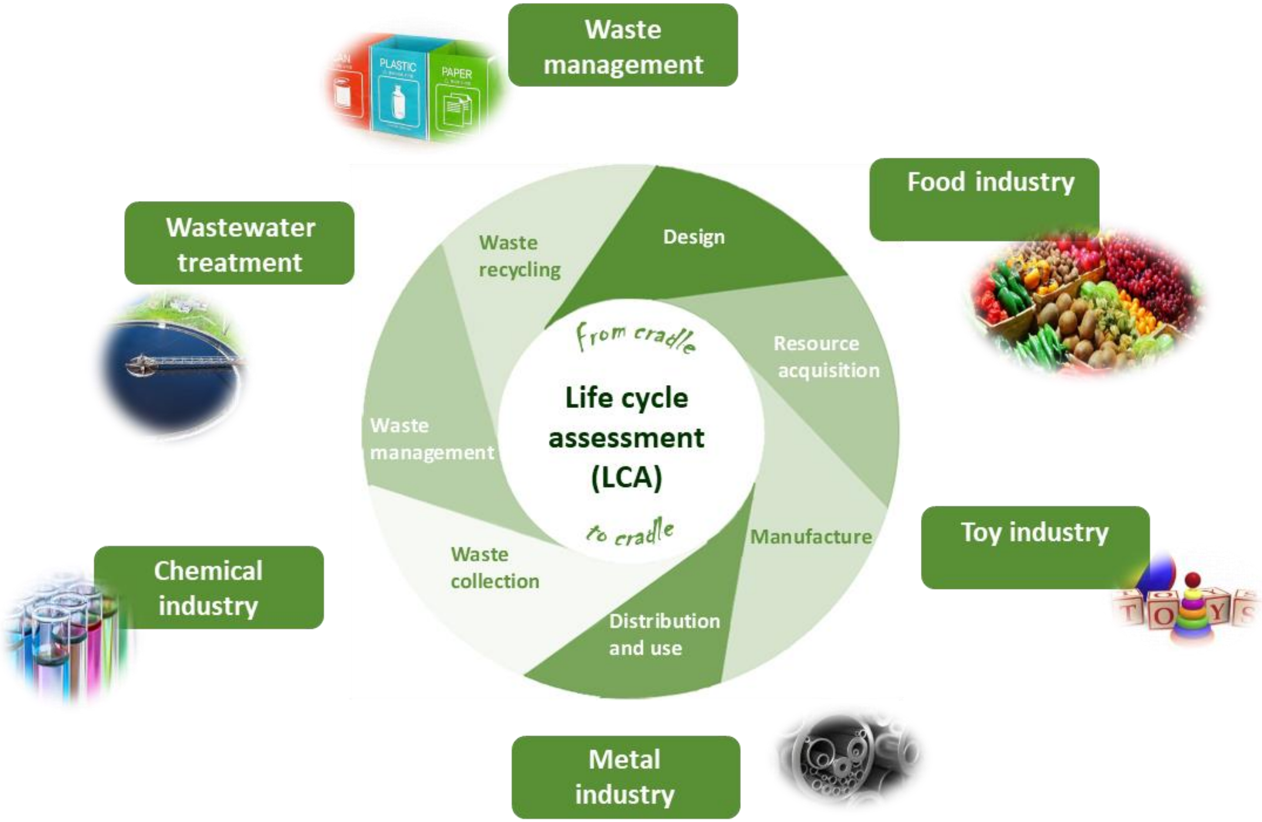


7.246 (Q1)

Towards a cleaner galvanisation: Zinc and iron chloride recovery from spent pickling acids

Article under preparation

Life Cycle Assessment Tools for Decision Support in Processes and Products



KAIROS-BIOCIR

NEPTUNUS PROJECT

Interreg Sudoe greentour

HYLANTIC

LIFE2 acid

COFINANCED BY

LIFE16 ENV/ES/000242

Questions?

www.life2acid.eu

More information, please contact:

Project coordinator: ***pedro.gomez@apriasystems.es***

Project manager: ***javier.pinedo@apriasystems.es***

Are you interested? You can follow us on:

Life-2-Acid

www.linkedin.com/in/life-2-acid-project-95848114b/