LIFE Project Number

LIFE17 ENV/ES/000260

Final Report

Covering the project activities from 01/01/2019 to 31/12/2023

Reporting Date

31/03/2024

LIFE PROJECT NAME or Acronym

LIFE SURFING

Data Project

Project location:	Aragon, Spain
Project start date:	01/01/2019
Project end date:	30/06/2022 **Extension date:** 31/12/2023
Total budget:	2,081,507 €
EU contribution:	1,182,452 €
(%) of eligible costs:	60

Data Beneficiary

Name Beneficiary:	Gobierno de Aragón
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Project Website:	lifesurfing.eu

1. Table of contents

2. List of key-words and abbreviations

CHE	Ebro River Authority
DNAPL	Dense Non-Aqueous Phase Liquid
GW	Groundwater
HCH	Hexachlorocyclohexane
ISCO	In-situ Chemical Oxidation
JRC	Journal Citation Reports
MERC	Methanol Extraction
POP	Persistent Organic Pollutant
SEAR	Surfactant Enhanced Aquifer Remediation
S-ISCO	Surfactant Enhanced In-situ Chemical Oxidation
VOC	Volatile Organic Compounds

3. Executive Summary

Project objectives:

The LIFE SURFING project aims to demonstrate the field feasibility of a soil decontamination technique in soils containing residual Dense Non-Aqueous Phase Liquid (DNAPL) of a high pollutant mixture of multicomponent organic contaminants and POPs.
Specifically, this technique will be developed in a demonstration project where well-known chemical oxidation techniques will be combined with the action of surfactants (the so-called SURFING test).
The main objectives of the project are:

- To DEMONSTRATE the applicability of the SURFING test for the removal and decontamination of DNAPL and the transferability of the already performed laboratory test to field.
- To reduce the risk for the health and the environment, generated by the persistent organic pollutants (POPs) existing at the site, by means of the removal of the residual DNAPL at the demonstration project area.
- To guarantee the reduction of the environmental risks and to analyse the full scale applicability of the technique from a technical, economic and environmental point of view, as well as to evaluate the reduction of the pollution for the health and the environment in case of a future full-scale implementation, considering the information gathered during the monitoring of the demonstration test.
- To disseminate the results of the project to stakeholders, as well as the raising of a general public awareness of to the problem
- To innovate the application of the surfactant-enhanced chemical oxidation technology in DNAPL contaminants.
- To analyse the replicability and transferability of the technique to other locations, by the definition of a strategy that allows to multiply the impact of the results obtained for their use in other locations.
- To create a network to share, interchange and transfer knowledge and experiences for projects related to sites affected by organochlorines, POPs, POP pesticides or POPs pesticides and other pesticides soil contamination.

Key deliverables:
The most relevant deliverables of the project are the following:

Name of deliverable	**Action**	**Deadline***
SURFING Test experimental design	A1	15/05/2019
Monitoring protocol, which includes a checklist	E2	30/06/2019
SURFING Test engineering design	A1	30/06/2019
Communication Plan	D1	31/07/2019
Starting LIFE Performance Indicators	C4	30/09/2019
Coordinating Protocol	E1	30/10/2019
Environmental impact monitoring report	C2	31/03/2022
Baseline conditions final report	C1	30/09/2022
On -site SEAR-oxidation results report	B2	31/12/2022
S-ISCO results report	B2	30/06/2023
SURFING Test monitoring report	C2	30/09/2023
Video/App	D1	31/10/2023
After Life Communication Plan	E4	31/12/2023

Assessment on socio-economic impact report	C3	31/12/2023
Finish LIFE Performance Indicators	C4	31/12/2023
FORUM BOOK	D3	31/12/2023
Layman Report	D1	31/12/2023
Replicability and transferability Plan	B4	31/12/2023
SURFING Full Scale applicability preliminary design	B3	31/12/2023
SURFING Test Final Report	B2	31/12/2023

Key outputs:

The most relevant milestones of the project are the following:

Name of deliverable	**Action**	**Deadline***
SURFING Test engineering design	A1	30/06/2019
Dynamic indicators database	C4	30/09/2019
Website of the project fully available	D1	31/10/2019
Construction Preliminary Works	B1	30/06/2020
Midterm Report	E2	31/03/2021
Previous test monitoring	C1	30/03/2022
Replicability and Transferability Test	B4	30/06/2022
2nd Progress Report	E2	30/09/2022
Celebration of the 15th HCH and Pesticides Forum in Zaragoza	D3	30/06/2023
Surfing Test implementation	B2	30/09/2023
Surfing Test implementation results	B2	31/12/2023
Final Report	E2	31/03/2024

**Deadlines after the approval of the project extension*

Section 6 includes the complete list of all the submitted deliverables.

Activities planned vs. progress made:

During the project development, some actions suffered delays due to:

- the complexity of the laboratory tests developed and the absence of DNAPL in the initially selected location of the test cell (action A1)
- suspension of contracts during the covid-19 state of alarm in Spain (actions B1 and B2).

These facts produced an accumulated delay in the implementation actions. Therefore, an extension of the project was needed, which was approved by amendment no.1 dated on 8th June 2022.

All project activities have been successfully completed before project extension date. Field tests were finished on October 2022, and their results were presented on the 14th International HCH and Pesticides Forum, which took place days 21 to 24th February 2023 in Zaragoza (Spain).

4. Introduction

Environmental problem/issue addressed:

Lindane, gamma isomer of the hexachlorocyclohexane (HCH), is an organochlorine pesticide that was used worldwide owing to its insecticidal characteristics. Due to its high persistence, high toxicity, carcinogenic, bioaccumulative and endocrine disrupting properties, lindane has been restricted or prohibited in most of the countries. α, β and γ-HCH are included in Stockholm list of POPs. Directive 79/117/CEE prohibits since 1979 the use of pesticides containing HCH with less of 99% of the gamma isomer. Regulation (EC) no. 850/2004 prohibited all uses of lindane with some exceptions that expired in 2007. This regulation constitutes the legal framework to enforce the main provisions of the Aarhus Protocol and the Stockholm Convention on POPs.

The production of lindane was very inefficient; for each ton produced, 6 to 10 tons of other HCH isomers without commercial value were produced. Methods to destroy or reuse the HCH waste were unsuccessful. Thus, most of the residues were dumped in landfills. This generated a severe environmental problem.

There are 3 HCH contaminated sites in Aragon Region (Spain), one of them located at Bailin ravine, close to the river Gallego. Bailin ravine hosted an old HCH landfill used without the proper isolation measures from 1985 to 1989. 65,000 t of solid HCH, 25 t of liquid HCH and 342,000 t of contaminated soil were dumped there. After several attempts of landfill isolation, the residues were moved in 2014 from the old landfill to a new safety cell.

Nowadays, the old landfill is a naked slope composed of vertical layers of sandstones and siltstones. Groundwater circulates preferably through the sandstone fractures, which constitutes a fractured aquifer. The liquid residues formed a Dense Non-Aqueous Phase Liquid (DNAPL), with a density higher than 1.5 g/cm^3, less than 10% water and up to 400g/l of HCH isomers. Due to its density and strong hydrophobic character, the DNAPL moved till the aquifer deepest fractures.

Since the time it was detected, the free DNAPL is being pumped from wells. Currently, free DNAPL is almost exhausted, but residual DNAPL still adheres to fractures. Although residual DNAPL can be considered immobile, the multicomponent character of the DNAPL favours the incorporation of a large amount of contaminants to the dissolved phase, reaching conditions of HCH saturation in the aqueous phase.

Outline the hypothesis to be demonstrated / verified by the project:

From 2014 to 2017, a demonstrative project showed the effectiveness of ISCO technique on the dissolved phase. Nevertheless, the high concentrations of contaminants in the contamination plume will persist as long as the DNAPL source exists.

LIFE SURFING project aims to demonstrate the effectiveness of the combination of SEAR and S-ISCO techniques to attack the residual DNAPL with the challenge of completely removing the DNAPL in the aquifer.

Description of the technical/methodological solution:

The LIFE SURFING project is divided into three treatment phases that will be developed in a representative area of 100 m^2 with the presence of residual DNAPL:

- Phase 1: SEAR and on site treatment of the extracted fluids. It consists of the extraction of residual DNAPL that is susceptible to being mobilized or solubilized with surfactants and subsequent treatment on-site either with alkaline hydrolysis and aeration, Fenton oxidation and retention on activated carbon and oxidation with temperature-activated persulfate.
- Phase 2: S-ISCO. The objective is to exhaust the residual DNAP that cannot be pumped using surfactants in phase 1 by applying a surfactant-enhanced in situ oxidation.

- Phase 3: rebound effect S-ISCO or ISCO. In case an increase of contamination happens due to diffusion from the matrix, a new injection of S-ISCO or ISCO will be done. Pollutants concentration remained low after Phase 2, thus, this phase was not needed.

Main expected environmental results and benefits:
- At the proposal stage, it was expected to remove 1,800 kg of DNAPL (a mass that may pollute 10,000 hm^3). This amount involves a reduction in the timeframe of water remediation and water treatment costs.
- Reduction of the risks for humans and for the environment.
- Environmental awareness of the affected population due to dissemination activities, together with a positive response in the territory related to the project development.
- Important dissemination at expert level in the 14th International HCH&Pesticides Forum.

Expected longer-term results (as anticipated at the start of the project):
- Full-scale implementation in Bailin site with the removal of all the residual DNAPL
- Transferability to other sites (e.g. Sardas HCH polluted site in Aragon region).

Future contribution to the European Union environmental policy and legislation:
Lindane production and use has been prohibited in EU regulation from 2007, nevertheless, the lindane waste pollution (HCH) still represents a very important risk for human health and the European environment, remaining a quite unknown problem by the population and the political representatives. The LIFE SURFING project makes it possible to progress in the direction of improving the knowledge and the solution of this problem.
Specifically, the Government of Aragon has highlighted the relevance of the problem by carrying out other project initiatives such as the LINDANET project, which gave visibility to the HCH contamination and shows it as a problem extended all over Europe.
LIFE SURFING, LINDANET, HCH in EU, and also LIFE POPWAT projects represent the interest of many different European organisations to find solutions that make it possible to remove the HCH from the European environment.
It is expected that all these efforts have influenced the new Directive for Soil Monitoring and Resilience, as well the Zero Pollution Action Plan for Air, Water and Soil of the Commission.

Replicability and transferability of demonstrated technology; market strategy and economic feasibility:
The report "lindane (persistent organic pollutant) in the UE", written in 2016 for the PETI committee of the European Parliament, gathers a list of the lindane production plants and the HCH landfills in the EU across 14 Member States. Moreover, the European project “HCH in EU” elaborates a comprehensive inventory of sites in all the EU member states where HCH was produced, stored, landfilled, treated and may or may not have polluted the soil and groundwater.
The existence of DNAPL in several of these European megasites has been confirmed. In some other, it might not be found yet. On the other hand, the Government of Aragon manages the remediation of other two HCH polluted sites with DNAPL (Inquinosa and Sardas).
In addition to the HCH DNAPLs, other different DNAPLs of multicomponent organic contaminants are widespread along Europe. However, finding locations with the same ground characteristics and at the same point of decontamination progress is many times complicated.
That is why the LIFE SURFING project has defined a strategy for ensuring the transferability of the SURFING test to sites with different characteristics (action B4.1).

5. Technical part

5.1. Technical progress, per Action

A description of most relevant information and outputs per action is given in this section, including: foreseen and actual dates, activities undertaken and outputs achieved, comparison with planned schedule, modifications, major problems encountered, complementary actions outside LIFE and perspectives after the project.
Foreseen dates consider the extension of Amendment Nr. 1, approved by letter of 08/06/2022.
A mention to deliverables and milestones is also included in the description of the technical progress per action, to facilitate the finding of more detailed information on the relevant action.

ACTION A1: SURFING TEST DESIGN

Foreseen start date: 01/2019	Actual start date: 01/2019
Foreseen end date: 06/2019	Actual (or anticipated) end date: 12/2019

Activities undertaken and outputs achieved:

A1.1 SURFING Test Experimental design:

- A1.1.1 Literature review: A specific section on this is included in the SURFING Test Experimental design deliverable.
- A1.1.2 Cell location: an external company (AECOM) was hired in June 2019 to study the optimal location for the pilot cell. The location was defined in July 2019.
- A1.1.3 SURFING Test experimental design: the DGA and the UCM were working on it from the start of the project. Variables for defining the implementation of the hydrogeological and tracer tests, SEAR, and S-ISCO techniques have been specified. The experimental design was completed in November 2019.

A1.2 SURFING Test Engineering design:

Action 1.2 is strongly dependent on tasks A.1.1.2 and A.1.1.3, specifically:

- A topographic survey is needed after selecting the cell location for completing the SURFING Test engineering design.
- The design of the test equipment could not be fully defined until the A1.1.3 completion.

SARGA completed the SURFING Test engineering design in December 2019.

Compare with planned output and time schedule:
Outputs have been accomplished as planned.
Regarding time schedule, all A1 actions were conditioned to the cell location (July 2019), which was done three months behind schedule. Additionally, the data interpretation at the Experimental design was more complex than expected. Due to all this, a delay of 5 months behind schedule took place in sub-action A1.1 (completed in November 2019) and 6 months behind schedule in sub-action A1.2 (completed in December 2019).

Modifications:
The cell defined during the proposal had to be shifted around 50m, due to the non-existence of DNAPL in the initial location. Therefore, some additional verifications were needed for choosing the precise location of the cell.

Major problems / drawbacks encountered, delays, including consequences for other actions
Delays occurred in sub-actions A1.1 and A1.2 caused a delay in contracts related to action B1.

Complementary actions outside LIFE:
Some additional research works needed for the A1.1.3 were done by the UCM with its own funds, before the LIFE proposal approval and at the beginning of the project.

Deliverables:
Detailed information can be consulted in the following deliverables:

- Deliverable D1_A1 "SURFING Test Experimental Design" (Action A1.1)
- Deliverable D2_A1 "SURFING Test Engineering Design" (Action A1.2)

ACTION A.2: PERMIT APPLICATION AND ADMINISTRATIVE PROCEDURES:

Foreseen start date:
A2.1: 06/2019 | A2.2: 03/2019
A2.3: 06/2019

Actual start date:
A2.1: 03/2019 |A2.2: 03/2019
A2.3: 03/2019

Foreseen end date:
A2.1: 06/2020 | A2.2: 03/2020
A2.3: 03/2020

Actual (or anticipated) end date:
A2.1: 05/2021 |A2.2: 03/2020
A2.3: 03/2020

Activities undertaken and outputs achieved:

A2.1. Information to the Ebro River Basin Authority (CHE) about the Project Execution.
The Ebro River Basin Authority (CHE) was informed about the project by letter of 26th March 2019. Permanent communication has been maintained during the whole project.

A2.2. Information to other organisations.
Organizations included in sub-action A2.2 (other Departments of the Government of Aragon, local administration) were informed about the project by letter of 26th March 2019.

A2.3 Awarding of service contracts needed for the execution of some of the works included in project "SURFING"
All procurements needed for the project development have been completed, being:

- Action A.1: Cell location and topography service
- Action B1: construction of accesses and boreholes
- Actions B1, B2, C1, C2 (previous field tests, test development and test monitoring): purchase of consumables (chemicals, reagents, spare parts); purchase of equipment (FID); rental of the test equipment; technical assistance
- Action D1: Project website, logo and noticeboard designs, Project video
- Action D3: services for the organization of the 14th International HCH & Pesticides Forum (meeting rooms, interpretation, catering, sound, streaming)

Link to the public tenders platform: https://contrataciondelestado.es/wps/portal/plataforma

Compare with planned output and time schedule:
Some delays happened initially in the awarding of contracts, due to 1) A1 delay and 2) the covid state of alarm at the first half of 2020. After the extension of the project final date, all delays have been overcome and new deadlines have been accomplished.

Major problems/drawbacks encountered, delays, including consequences for other actions
Delays in A1.1 and A1.2 did not affect the procurement procedures for the B1 and B2 actions, nor the overall project schedule. However, the following events affected the A2.3 schedule:

- A state of alarm was declared in Spain on 03/14/2020 due to COVID-19, by which all contracts have been suspended. This caused a temporary stoppage and slowing down of the tenders under the procurement process.
- The first public tender for equipment rental was declared annulled and had to be launched again, being finally awarded on 30/07/2020.

Deliverables: Detailed information can be consulted in deliverable D3_A2 "Copy of the letters to the Ebro River Basin Authority and other organisations".

A3 STAKEHOLDERS INFORMATION AND CONSULTATION

Foreseen start date: 04/01/2019 Actual start date: 04/01/2019
Foreseen end date: 31/12/2023 Actual (or anticipated) end date: 31/12/2023

Activities undertaken and outputs achieved:

A3.1. The project was announced in the Official Bulletin of Aragon (BOA) on 05/04/2019 and on the Government of Aragon website (former www.stoplindano.es and current www.descontaminacionlindano.aragon.es).

A3.2. Stakeholders and Committees Information:
The project scope and progress has been shared with the stakeholders in several sessions:

- 11 Sessions for the general public
- 25 Sessions for groups of experts
- 20 Project partner meetings
- The Committees of HCH, were informed about the project start by email.
- An update explanation about LIFE SURFING progress was given to the Committees of HCH on 18/11/2019 (Institutional Committee), 17/12/2019 (Social Committee), 17/11/2020 (Social and Institutional Committee), 03/03/2022 (Social and Institutional Committees) and 01/04/2022 (site visit of Social and Institutional Committees). All members of the Social and Institutional Committees were invited to the LIFE SURFING final event on 30/11/2023.

Questionnaires have been distributed in 4 events to the attendees, which have voluntarily filled them in. Evaluations from 114 people have been obtained.

Compare with planned output and time schedule: activities have been accomplished as planned.

Deliverables:
More detailed information can be consulted in the following deliverables:

- D4_A3 "Copy of the BOA (Official Bulletin of Aragon) publication"
- D5_A3 "Report on outputs of stakeholder´s involvement activities".

B1 SURFING TEST PREVIOUS WORKS

Foreseen start date:
B1.1: 06/2019 | B1.2: 06/2019
B1.3: 06/2019
Actual start date:
B1.1: 01/2020 | B1.2: 12/2019
B1.3: 03/2019
Foreseen end date:
B1.1: 06/2020 | B1.2: linked with B2 1| B1.3: 05/2021
Actual (or anticipated) end date:
B1.1: 09/2020 |B1.2: 07/2021
B1.3: 05/2021

Activities undertaken and outputs achieved:

B1.1 Construction Preliminary Works: accesses, security enclosure, basements and well's construction.

- Subtask 1: access roads were completed in March 2020. Platforms for the equipment were finished in September 2020.
- Subtask 2: borehole drilling was completed in May 2020. A total of 8 boreholes were drilled in the test cell. No boreholes were drilled in the "security barrier", as there were 9 existing boreholes in the area suitable for developing the "security barrier".

- Subtask 3: aeration and chemical oxidation tests have been performed in boreholes of the "security barrier", on existing boreholes. The connection of these boreholes with the ones of the test cell was determined in the hydrogeological and tracer tests (B1.3)

B1.2 Field implementation of equipment, material means, technical supplies.
The installation of equipment and provision of reagents for the baseline tests (B1 action) were completed in September of 2020. The installation of the remaining equipment for the field test (B2 action) was completed in July 2021.

B1.3 Baseline conditions.
This action includes pumping and injection (or hydrogeological) tests, tracer tests, as well as the baseline of the aquifer, essential to design the definitive field test.
Hydrogeological tests provide data about permeability, connection of fracturing and flow speed, to establish the basic conditions for the tracer tests implementation. Tracer tests provide data to determine the injection and pumping strategies, recovery rates, available times for chemical reactions and needed reagent doses.
2 to 3 pumping tests and 1 to 2 tracer tests were planned in the proposal. As the environment was much more complex than expected, finally, the following previous tests were done:

- 2 previous pumping tests in January and February 2020 to know the groundwater behaviour at the cell area before the drilling of the boreholes at the test cell.
- Drop of groundwater level after the drilling of borehole P198
- 7 hydrogeological tests from August 2020 to September 2020 (injection P192, pumping in P171, injection y P192-P195, pumping in P171-P198, injection in P198 with packer in P192-P195, injection in P192-P195 with packer in P198, injection in P198 and pumping in P192-P198)
- 5 tracer tests from November 2020 to March 2021.Tracers used have been sodium chloride (common salt) and sodium bromide. Several tests have been developed using different boreholes as injection points (injection in P192, injection in P198, injection in P198bis, injection in P171 and 172, injection in P196 under packer at inactive area)
- 1 trial test in the barrier area to evaluate the degradation of the surfactant with the oxidant, in September 2021. A total 120kg of residual DNAPL were removed during this trial, thanks to the soil flushing.
- Two new control boreholes (P222, P223) were drilled in January to February 2022 to improve the monitoring at the barrier area. An additional tracer test was needed to know behaviour and representativeness of the new boreholes. This tracer test with injection in the barrier area was developed from February to March 2022.

Additionally, fractures were sampled in the cores obtained during the drilling to determine the surface retention of contaminants and if these correspond to the existence of residual DNAPL.

<u>Compare with planned output and time schedule:</u>
B1.1: The modification in the cell location involved shifting the boreholes to a location with a very steep topography, which made the access construction much more difficult than expected and more expensive. As an example, a cantilever had to be constructed for the drilling of borehole P193. 8 boreholes were finally drilled at the test cell instead of the 15 foreseen in the proposal.
During the drilling of P198, once arrived at 35 m, the groundwater level drop in all the boreholes of the test cell, changing the initial hydrogeological conditions.
On the other hand, once developed the barrier trial test on November 2021, two new boreholes (P222, P223) were decided necessaries.
All these modifications caused delays that were overcome with the project extension.

B1.2: Outputs have been being accomplished as planned. Nevertheless, some delays have occurred due to A1 delays and covid state of alarm.
B1.3: Field conditions regarding the aquifer connectivity were found to be different from the initial assumptions: as pumping and tracer tests were progressing, new discoveries on the aquifer behaviour were obtained. This made it necessary to develop a higher number of hydrogeological and tracer tests than foreseen. In consequence, the data to be analysed increased considerably.
Some previous works were also needed for the preparation of the on-site treatments of SEAR phase (Phase 1 of B2 Action), that required more research efforts than planned by UCM at lab scale, consisting in experiments to treat the emulsions of surfactant and oxidants and to study the kinetic of activated carbon regeneration to select dosages, temperatures and contact times.

Modifications:
The type of treatments in the barrier zone has been modified. The application of zero-valent iron microparticles has been eliminated due to the difficulty of handling, few guarantees in intercepting the contaminated plume and excessively slow kinetics for the flow rate. The injection of soda has replaced it to favour the alkaline hydrolysis of HCHs and Heptachlorocyclohexanes, which improves the volatility of the daughter compounds. The volatile compounds generated are extracted by in situ aeration with gas capture system in 4 boreholes, an approach that has been tested showing high effectiveness. The alkaline treatment also facilitates the application of activated persulfate.

Major problems / drawbacks encountered, delays, including consequences for other actions:
B1.1: The delay in action A1.2 caused a correlative delay in action B1.1.
Access roads construction and borehole drilling had to be stopped for two weeks due to the state of alarm decree by the Spanish Government related to COVID-19. This caused a delay of action B1.1 all the subsequent actions (B1.2, B1.3, B2).
B1.2: The public procurement for the rental of the test equipment was initially launched in January 2020 but was declared annulled. This caused a delay in the performance of the tracer test (action B1.3) and all the subsequent actions (B2.1 and related actions).
B1.3: The accumulated delays in actions B1.1 and B1.2 caused a correlative delay in B1.3 action. The number of hydrogeological and tracer tests needed to get a deep knowledge of the fractured aquifer were much higher than initially planned. Additional time was needed for the execution and interpretation. This was the main reason of the request of extension of the project.

Complementary actions outside LIFE:
Several pilot tests have been carried out to test the application of different aeration techniques in the boreholes of the barrier zone. The aeration and vapour extraction have been selected, the necessary equipment has been designed, and its installation has been carried out within the hydrogeological monitoring contract of Bailín site.

Perspectives for continuing the action after the end of the project:
Aeration techniques and equipment in the barrier zone will be maintained at least until the presence of the dense phase is considered exhausted. The aeration techniques will be applied in aquifer areas with low pollutant load where it can be combined with biological treatments.

Deliverables:
More detailed information can be consulted in the following deliverables:
- D6_B1 “Borehole core-logging geological report”
- D13_C1 “Baseline conditions final report”

Photographs:

B1.1 Accesses construction

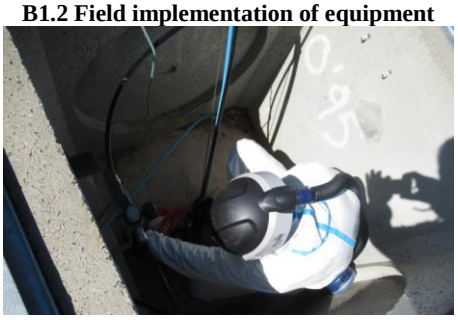
B1.1 Construction of borehole platforms

B1.1 Borehole drilling

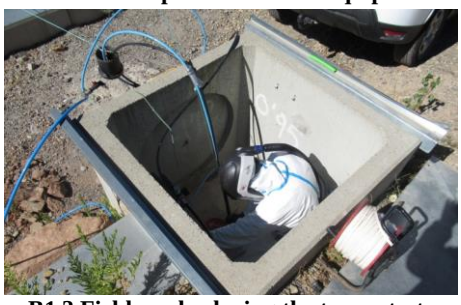
B1.1 Borehole drilling (P193 - cantilever)

B1.2 Field implementation of equipment

B1.2 Field implementation of equipment



B1.3 Field works during the tracer tests



B1.3 Field works during the tracer tests

B2 SURFING TEST IMPLEMENTATION

Foreseen start date:
B2.1: 06/2022 | B2.2: 12/2021
B2.3: 06/2022

Actual start date:
B2.1: 05/2022 | B2.2: 09/2022
B2.3: 05/2022

Foreseen end date:
B2.1: 12/2022 | B2.2: 12/2022
B2.3: 12/2023

Actual (or anticipated) end date:
B2.1: 10/2022 | B2.2: 11/2022
B2.3: 12/2023

Activities undertaken and outputs achieved:

B2.1 SURFING test execution.

According to the proposal, the SUFING test execution consisted in three phases:

- PHASE 1: SEAR-On Site oxidation -Vapour extraction
- PHASE 2: Surfactant Enhanced - In Situ Chemical Oxidation (S-ISCO)

- PHASE 3: Rebound effect evaluation

Phase 1: Two SEAR trials were carried out. The first was in May 2022, and the second in June 2022. The objectives of the SEAR (Surfactant Enhanced Aquifer Remediation) trials were to remove a significant portion of residual DNAPL located in the most contaminated areas of the test cell (wells 195-198 in SEAR-1 and wells 171-172 in SEAR-2). In both trials, strategies for injecting the surfactant solution with simultaneous extraction at wells downstream from the injection wells and recirculation at the injection wells were tested to ensure sufficient contact time for the solubilisation of the contaminant trapped in the fractures while preventing the contaminated emulsion from escaping downstream to the river. After the injection-recirculation stage, there is a process for extracting the injected fluids and on-site treatment of the extracted contaminated emulsions. Two weeks after the last SEAR trial, vacuum extraction is performed to purge the wells where the surfactant was injected to mobilize the residual DNAPL, whose interfacial tension has been reduced by surfactant absorption, making it more easily extractable. A total 100kg of DNAPL were extracted.

Phase 2: The S-ISCO test was carried out in October 2022. The objective of the S-ISCO trial is to eliminate the residual contamination remaining in the test cell after the application of SEAR, through the simultaneous addition of oxidants and surfactants, without extraction. Twenty-two cubic meters (22 m3) of the surfactant-oxidant solution were injected into wells P195 and P198 in 16 pulses over 30 hours in October 2022. A total 20kg of residual DNAPL were removed.

Phase 3: The analytics performed after Phase 2 shown that no rebound effect had taken place.

B2.2 Dismantling of equipment

The equipment was removed in November 2022, after the field implementation of the test.

B2.3: SURFING pilot test final assessment

A very intense labour of processing and interpreting all the huge number of data collected during LIFE SURFING test has been done since the end of every injection in phases 1 and 2, up to the very end of the project. Indeed, an extension of one month for the submission of this information was required due to this.

Compare with planned output and time schedule:

The SURFING test execution was longer than expected due to the longer times required for each one of the injections, which duration was justified by the reaction time needed for the reagents to act. This times were established after the interpretation of the tracer tests. Additionally, two SEAR injections were needed to get the maximum DNAPL recovery rate, instead of one (assumed in the proposal). And more time than planned was needed for the preparation of the field test previous protocols and for the organisation of the site personnel and the site equipment, activities considered essential for the development of the test in safety conditions.

Modifications: One additional injection than foreseen in the proposal was performed in Phase 1 (SEAR). Additionally, the phase 3 shown that there was no rebound effect (concentrations of pollutants in the test cell remained low after the phase 2) and, in consequence, an application of in situ chemical oxidation (ISCO) was not needed.

Major problems/drawbacks encountered, delays, including consequences for other actions

Minor problems have occurred during the field implementation of the test (e.g. some pumps failed and had to be substituted, devices for measuring flow volumes failed and needed to be repaired). A protocol was prepared to check the equipment before the test execution, therefore, these problems were overcome in time.

The labour of processing and interpreting all the results collected during the two phases and numerous injections of the LIFE SURFING test has been one of the hardest task of the project.

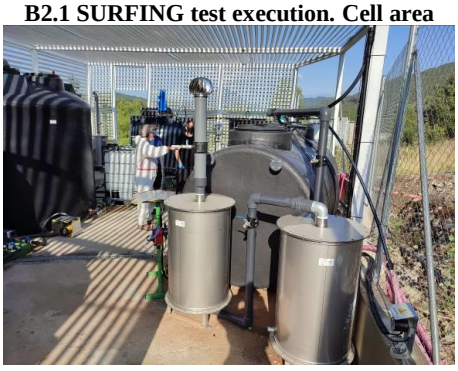
Is has lasted more than one year, since it is very important for the Government of Aragon to have all information in written for its future use.

B2.1 SURFING test execution. Injection area

B2.1 SURFING test execution. Cell area - measurements

B2.1 SURFING test execution. Cell area

B2.1 SURFING test execution. Data collection



B2.1 On-site treatment area

B2.1 Barrier area – soda injection

B2.1 Barrier facilities

B2.1 Barrier boreholes for aeration

Deliverables:

Detailed information about this action can be consulted in:

- D7_B2 “On -site SEAR-oxidation results report”
- D9_B2 SURFING Test Final Report (this deliverable includes the “SEAR results report” as well as the D7_B2 “S-ISCO results report”.

B3 SURFING FULL-SCALE APPLICABILITY PRELIMINARY DESIGN

Foreseen start date: 06/2023 Actual start date: 06/2023
Foreseen end date: 12/2023 Actual (or anticipated) end date: 12/2023

Activities undertaken and outputs achieved:
The aim of this action is to prepare a preliminary methodology for the future application of the SURFING test to the Bailin site. This preliminary methodology has been elaborated by the Government of Aragon, with the support of the company that develops the hydrogeological monitoring in Bailin site, as it is the one that will implement the full-scale application of the technique. The costs of this support have been assumed by own means of the Government of Aragon, outside the LIFE SURFING project costs.

Compare with planned output and time schedule:
Actions have been developed as planned, according to the time schedule of the project extension.

Modifications: No modifications have occurred.

Major problems / drawbacks encountered, delays, including consequences for other actions
No problems have been encountered.

Deliverables:
The full-scale methodology can be consulted in deliverable Dx_B3 "SURFING full-scale applicability preliminary design".

B4 REPLICABILITY AND TRANSFERABILITY

Foreseen start date:
B4.1: 07/2019 | B4.2: 10/2021
Actual start date:
B4.1: 07/2019 | B4.2: 04/2022
Foreseen end date:
B4.1: 12/2021 | B4.2: 06/2023.
Actual (or anticipated) end date:
B4.1: 06/2022 | B4.2: 12/2023

Activities undertaken and outputs achieved:

B4.1 Replicability and Transferability Test.
B4.1 objective is to investigate the application of the SURFING test in other contaminants and other hydrogeological conditions. The following actions have been developed to that aim:

- Literature review to identify relevant compounds and hydrogeological conditions.
- Development of the methodology for sampling and doing analytical measurements.
- Conduction of laboratory experiments to determine the kinetics of various contaminants in surfactant solutions.
- Degradation tests on the pollutant surfactant mixtures (Fenton's Reagent, persulfate and permanganate), together with an investigation on the suitable concentration ratios between surfactant and oxidant.
- Development of a concept column and 2D experiments considering the previous works (Figure 1).
- Conduction of column experiments where contaminated material was filled into a precolumn and a surfactant solution was injected.
- Experimental setup for testing S-ISCO on a 2D approach at mid-scale (1 m x 0.7 m x 0.12 m), including contaminated material and a simulated constant groundwater flow using two hydraulic heads.

B4.2: Replicability and Transferability assessment.
The LIFE SURFING test has been transferred to another site in Aragon, called "Sardas landfill", also polluted with HCH and containing DNAPL. The DNAPL existing in Sardas landfill is present in completely different geological materials than the case of Bailin. LIFE

SURFING technique in the case of Sardas has been applied in sandy gravels, granular sediments of alluvial deposits.
The UCM has published three scientific articles of the tests developed in Sardas landfill thanks to the transference of the LIFE SURFING project 589 kg of DNAPL have been removed up to now in Sardas landfill, an amount even higher than the one of Bailin landfill (240 kg).

Compare with planned output and time schedule:
B4.1: The action has been developed as planned.
B4.2: Replicability has been done earlier than planned and with great results.

Major problems / drawbacks encountered, delays, including consequences for other actions
B4.1: On-site work at the USTUTT has been restricted since March 2020 due to COVID-19, as by regulative infection control workplaces may only be partially occupied. Nevertheless, these inconveniences have been overcome satisfactory.
B4.2: No problems have been encountered, but advantages.

Deliverables: Detailed information of both subactions 4.1 and 4.2 can be consulted in deliverable D12_B4 "SURFING Replicability and Transferability Plan".

Photographs and schemes:

Figure 1: S-ISCO column test setup. Left: Flow scheme. Rigth: Sampling with gas traps and outflow bottles.

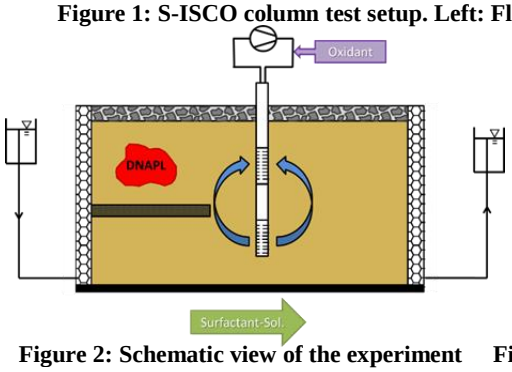


Figure 2: Schematic view of the experiment

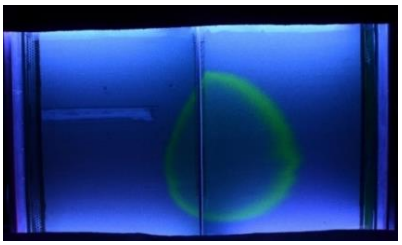


Figure 3: Tracer test visualization of flow regime in 2D experiment.

C1 PREVIOUS TEST MONITORING.

Foreseen start date:
C1.1: 07/2019 | C1.2: 07/2019 |C1.3: 07/2019

Actual start date:
C1.1: 04/2021 | C1.2: 08/2020|C1.3: 05/2020

Foreseen end date:
C1.1: 06/2022 | C1.2: 06/2022|C1.3: 06/2022

Actual (or anticipated) end date:
C1.1: 06/2022 | C1.2: 06/2022|C1.3: 06/2023

Activities undertaken and outputs achieved:
This action is closely linked with B1.3 action.

C1.1 Initial toxicity-biodegradability.

The tests on initial toxicity and biodegradability have been done outside the LIFE SURFING project, within an external contract of the Government of Aragon.

C1.2 Pumping and Tracer test monitoring.

The hydrogeological tests were carried out from March 2020 to September 2020. 7 pumping tests were carried out. The tests made it possible to establish the admissible flows to avoid cross

flows, the upstream and downstream zone of influence, approximate times of arrival at the barrier zone and to advance a conceptual model of hydrogeological operation in detail and response to injections and pumping. Levels and vertical profiles of temperature and conductivity were monitored during the test

During the last week of November and March 2021, five tracer tests were executed. The monitoring has been carried out by means of fixed level and conductivity probes, making vertical profiles of conductivity and temperature and by means of discrete sampling in boreholes at different levels and of the pumped flows. The samples have been analysed (conductivity, bromide and heptanol) in the Bailín and UCM laboratories.

In November 2021, 1 trial test was performed in the barrier area to evaluate the degradation of the injected surfactant with the oxidant.

In March 2022, an additional tracer test was carried out in the barrier area, to complete the knowledge of the aquifer behaviour at that area, once the two new control boreholes (P222, P223) were drilled.

C1.3 Pre-operational situation (baseline).

The aquifer conditions concerning levels, the concentration of contaminants and DNAPL distribution are changeable.

Before addressing any action, several campaigns for measuring levels and conductivity profiles have been performed in the existing boreholes of the M layer. Several campaigns for sampling and measuring VOCs have also been developed.

In a tentative way, during the borehole drilling POP extractions were done in fracture planes every meter of depth (MERC tests) to get an image of the DNAPL distribution in the new boreholes.

Additionally, before any injection was carried out for the previous tests (action B1.3) or for the field tests (action B2), the baseline situation of the aquifer was measured (field measures and sampling).

Compare with planned output and time schedule:

C1.1: Although the initial toxicity-biodegradability was measured, the study will continue after the LIFE SURFING project, at it is not related with the project objectives.

C1.2: The pumping and tracer test monitoring was more intense than foreseen, due to the increase of the number of previous tests carried out.

C1.3: Conductivities and GW levels in some boreholes were found different than expected according to the initial assumptions, which was essential to define the cell flow model.

Major problems / drawbacks encountered, delays, including consequences for other actions

The need of developing more previous tests than foreseen made it necessary to dedicate higher resources to the C1 action than initially foreseen (increase of measurements, sampling, laboratory analysis and data collection. Thus more time was required for interpretation).

Compare with planned output and time schedule:

This sub-action is strongly linked to sub-action B1.3 running in parallel to it. Thus, the same as for B1.3 is applicable to C1.2.

Major problems / drawbacks encountered, delays, including consequences for other actions

This sub-action is strongly linked to sub-action B1.3 running in parallel to it. Thus, the same than for B1.3 is applicable to C1.2.

Deliverables: Detailed information can be consulted in deliverables D13_C1 “Baseline conditions final report”.

C2 SURFING TEST MONITORING

Foreseen start date: C1.1: 06/2022 |C1.2: 06/2019 C1.3: 07/2019	Actual start date: C1.1: 05/2022 |C1.2: 01/2020 C1.3: 07/2019
Foreseen end date: C1.1: 12/2022 |C1.2: 12/2023 C1.3: 12/2021	Actual (or anticipated) end date: C1.1: 12/2022 |C1.2: 12/2023 C1.3: 06/2022

Activities undertaken and outputs achieved:

C2.1 SURFING Test monitoring.

The SURFING test monitoring consists in performing field measurements, sampling and laboratory analysis, with the aim of providing information before, during and after the execution of Phases 1 and 2 of the action B2.

The procedure of monitoring, control points and sampling schedule was planned and written beforehand in the field test protocols, which were used for the organisation of equipment and the personnel involved in the test execution.

A total of 811 field measurements have been carried out on field and 1069 laboratory analysis have been undertaken in the Bailin and Pirenarium laboratories of the Government of Aragon, operated by SARGA. Additionally, more than 400 samples have been analysed in the UCM laboratory.

C2.2 Environmental impact monitoring.

A new point called "(P11) Río Gallego aguas arriba de Ontinar de Salz (EEC LIFE – ONTINAR)" was included since 2020 (2 years before the test implementation) to monitor the NATURA 2000 area located in the low part of the Gallego river. No changes have been observed in this point during the LIFE SURFING project.

C2.3: Replicability and Transferability Test monitoring

This action has consisted in the monitoring of B4.1 Action (sampling, measurements and laboratory analysis to control the tests and to obtain its results).

Compare with planned output and time schedule:

C2.1 action is directly linked with B2.1 action. All changes in the time schedule have been conditioned to the ones of the B2.1 action.

C2.2 had no relevant changes in the time schedule.

C2.3 time schedule is linked to the B4.1 action.

Major problems / drawbacks encountered, delays, including consequences for other actions

The major problem related to the **2.1** has been that the volume of samples taken to ensure the development of the test in safety conditions has been much higher than expected. An important part of the human resources and reagents needed for this extra effort has been paid by own means of SARGA and the Government of Aragon.

No problems have occurred in **C2.2** and **C2.3** sub-actions.

Deliverables:

Detailed information on these actions can be consulted in the following deliverables:

- D14_C2 "Environmental Impact Monitoring Report"
- D15_C2 "SURFING test monitoring report"

Photos:

B2.1 Laboratory tests

B2.1 Laboratory tests

B2.2 Environmental monitoring

C3 ASSESSMENT OF THE SOCIOECONOMIC IMPACT

Foreseen start date:
C3.1: 06/2019 | C3.2: 06/2019

Actual start date:
C3.1: 06/2021 | C3.2: 06/2021

Foreseen end date:
C3.1: 12/2023 |C3.2: 12/2023

Actual (or anticipated) end date:
C3.1: 12/2023 | C3.2: 12/2023

Activities undertaken and outputs achieved:

C3.1 Assessment of the impact on Stakeholders.

The following visits, seminars, attendance to congresses and surveys have been carried out:

- 11 sessions for the general public
- 25 sessions of groups of experts
- 20 partner meetings
- 6 Committees of HCH (Social and Institutional)

In 4 of the information sessions (Kick off of the project (04/10/2019); EU Water Innovation Conference 2019 (12/11/2019); 14th International HCH and Pesticides Forum (02/21-24/2023) and Event final closing ceremony of Life Surfing (11/28/2023)), optional surveys have been distributed to attendees. Evaluations have been obtained from 114 people.

C3.2: Assessment of the socioeconomic impact:

Once results from the field tests have been obtained, a study regarding the socio-economic impact of the project at local and regional levels has been developed.

The socio-economic impact of LIFE SURFING Project has been done through a cost-benefit analysis. The SURFING test has resulted beneficiary in a short term scenario. For a long term scenario, the full scale application of LIFE SURFING has been analysed, being more profitable than any other alternative.

Compare with planned output and time schedule:

Less polls than initially planned have been distributed in **C1.3**, since they were prepared for face-to-face events. **C3.2** was accomplished as planned.

Deliverables:
More details can be consulted in deliverables D5_A3 “Report on outputs of stakeholder´s involvement activities” and D16_C3 “Assessment on socio-economic impact”.

C4 LIFE PERFORMANCE INDICATORS

Foreseen start date: 09/2019 Actual start date: 09/2019
Foreseen end date: 12/2023 Actual (or anticipated) end date: 12/2023

Activities undertaken and outputs achieved:
The baseline for the performance indicators was uploaded at the KPI 2.0 online platform in September 2019.
The indicators were reviewed in October 2020 and the final foreseen values were submitted.
The Final performance indicators have been uploaded at the KPI 2.0 online platform before the submission of the Final Report.

Compare with planned output and time schedule:
Activity has been developed according to plan.

Major problems encountered: No major problems have occurred.

C5 LIFE CYCLE ASSESSMENT

Foreseen start date: 07/2023 Actual start date: 07/2023
Foreseen end date: 12/2023 Actual (or anticipated) end date: 12/2023

Activities undertaken and outputs achieved:
The Life Cycle Assessment of the phases of the "LIFE SURFING" has consisted in the evaluation of the environmental impacts associated with the relevant processes and objectives of the project. Evaluation has been conducted in four stages:

1) Definition of objectives and scope of the surfing test and phases
2) Analysis of representative processes carried out, by describing relevant inputs (infrastructures and test phases) and outputs
3) Assessment of the impact of inputs and outputs with Leopold Matrix
4) Interpretation and conclusions to reduce negative environmental effects

Compare with planned output and time schedule:
Inputs and outputs have been analysed to processes (instead of considering products and by products), to reduce the number of data feeding the model and to make it more easy to handle.

Major problems / drawbacks encountered: No major problems have occurred.

D1 COMMUNICATION, DISSEMINATION AND RAISE AWARENESS ACTIONS

Foreseen start date: 01/2019 Actual start date: 01/2019
Foreseen end date: 12/2023 Actual (or anticipated) end date: 12/2023

Activities undertaken and outputs achieved:

D1.1: COMMUNICATION AND DISSEMINATION PACK

LIFE SURFING logo was created on 29/03/2019.
The website was launched in January 2020, at the site www.lifesurfing.eu.
A hagstag #lifesurfing_hch, #lifesurfing has been created and shared in the partner’s social networks to share news on the LIFE SURFING project.
The Communication Plan was submitted to all partners for comments in October 2019.
An informative notice board design has been elaborated outlining the scope of the project. Two informative boards have been printed and placed, one in the Government of Aragon offices and

another one in Bailin facilities. Additionally, two posters and one roll-up of the project have been printed to present them in events.

D.1.2 LAYMAN REPORT. to be reviewed and completed by GA

The Layman Report was completed on November 2023, on the occasion of the project Closing Session.

D.1.3 OPEN AND CLOSING SESSIONS

The Open Session was held in Zaragoza on 10/04/2019.
The Clossing Session was held in Zaragoza on 28/11/2023.

D.1.4. INFORMATIVE MATERIALS, SEMINARS AND VISITS

Partners have included the project information in their websites:

- Government of Aragon: https://descontaminacionlindano.aragon.es/proyectos/life-discovered-surfing/
- **UCM and CARESOIL:**
  - *https://www.ucm.es/inproquima*
  - *https://www.ucm.es/caresoil/*
  - *https://www.ucm.es/fundacion/noticias-grupo-investigacion-inproquima-ucm-participa-como-socio-en-proyecto-europeo-life-surfing*
- University of Stuttgart:
  - *https://www.iws.uni-stuttgart.de/en/institute/research/projects/research-project_166.html*
- SARGA: *http://www.sarga.es/noticias.aspx?id=268*
- The DGA organized 15 visits to the site during the whole project duration LIFE SURFING project has been explained on the occasion of these visits (LIFE SURFING partners on 17/06/2019, LINDANET project partners on 27/11/2019, students from IES Huesca on 19/12/2019, general public visits on 01/03/2020 and 08/03/2020, experts from the project HCH in EU in 18/05/2021, Students of the University of Saragossa on 17/09/2021, Experts from University of Castilla la Mancha, University of La Coruña and Autonomous University of Barcelona on 10/11/2021, Institutional and Social Committees for the HCH monitoring on 01/04/2022, Students of the Polytechnic University of Huesca on 06/05/2022, students from the Polytechnic University of Madrid – Ms of Mining on 25/01/2023, visit Life Surfing on the occasion of the 14th International HCH & Pesticides Forum on 24/02/2023, visit of 1st IES Barbastro on 17/03/2023, visit of Slovak Ministry of the Environment on 10-11/05/2023, students of the University of Saragossa on 15/09/2023).
- A project brochure was created on November 2021.
- The LIFE SURFING project has been presented by the UCM at the following 8 seminars: “Workshop CARESOIL 2019”, “European Night of Researchers 2019”, “XIX SCIENCE WEEK November 4-17, 2019”, “LIFE Platform Meeting on Chemicals 2019”, “EU Water Innovation Conference 2019”, “Workshop CARESOIL 2022”, “Scuola di Alta Formazione sulla Bonifica di Siti Contaminati. Labelab 2023”, “European Researchers' Night 2023”.

D.1.5: INTERACTIVE VIDEO

An interactive video of the project has been produced on the occasion of the 14th HCH and Pesticides Forum. There is a long version as well as separated in short videos.
Videos are available in English and Spanish in the LIFE SURFING Youtube video channel: https://www.youtube.com/watch?v=0BY4JjFIWsU

Compare with planned output and time schedule:
Outputs and time schedule have been fully accomplished.

Major problems/drawbacks encountered, delays, including consequences for other actions
The suspension of face-to-face events delayed the production of dissemination materials at the beginning of the project. This fact was overcome during the life of the project.

Deliverables:
Deliverables of action D1 collect the detail information and images of all dissemination materials:

- Deliverable D21_D22_D1 collects the notice boards leaflets and posters
- Deliverable D23_D1 collects the video information.
- Deliverable D24_D1 consists in the Layman report

D2 PARTICIPATION AND ORGANIZATION OF NETWORKING AND INFORMATION PLATFORMS RELATED TO THE PROJECT OBJECTIVES

Foreseen start date: 01/2019 Actual start date: 01/2019
Foreseen end date: 12/2023 Actual (or anticipated) end date: 12/2023

Activities undertaken and outputs achieved:

D.2.1 LIFE networking exchange group.

The project has exchanged information with the following EU Projects:

- LIFE POPWAT (LIFE Programme)
- LINDANET (Interreg Europe)
- AMIIGA (Interreg Central Europe)
- HCH in EU (European Commission Pilot Project)

Details on some of the sessions shared with the mentioned project can be consulted on deliverable D26_D2

D.2.2 Networking and transferability to other technical Stakeholders.

- The UCM has carried out presentations of LIFE SURFING projects in 8 seminars: "Workshop CARESOIL 2019", "European Night of Researchers 2019", "XIX SCIENCE WEEK November 4-17, 2019", "LIFE Platform Meeting on Chemicals 2019", "EU Water Innovation Conference 2019", "Workshop CARESOIL 2022", "Scuola di Alta Formazione sulla Bonifica di Siti Contaminati. Labelab 2023", "European Researchers' Night 2023".
- The UCM has also sent 9 abstracts for posters and oral presentations in soil remediation congresses: 2 abstracts for poster presentations at "Aquaconsoil 2019", 1 abstract for an oral presentation at "Aquaconsoil 2021" (together with USTUTT), 1 abstract for oral presentation at "7th International Conference on Industrial and Hazardous Waste Management. CRETE 2021", 1 abstract for poster presentation at "XIV Spanish Congress on Water Treatment. META", 1 abstract for oral presentation at "XXXIX Biennial Meeting of Chemistry. 2023", 1 abstract for poster presentation at "XXXVIII Reunion Bienal RSEQ 2022", 1 abstract for oral presentation at "Reunion Bienal RSEQ 2022", 1 abstract for oral presentation at "Aquaconsoil 2023".
- VEGAS (USTUTT) participated at the DECHEMA Symposium on strategies for soil and groundwater remediation in Frankfurt on 23 and 24/11/2020. The conference was held completely online due to Covid 19. Benjamin Herzog held a presentation about the Life-SURFING project and the S-ISCO technology, VEGAS tasks within the project and some of the results achieved up to that point. The DECHEMA Symposium is an annual event attended by representatives from industry, research, stakeholders and authorities from all over Germany. Current topics and news from the field of contaminated site remediation and management are presented and discussed.

D.2.3. Newsletter and Specialized publications

Newsletter: Websites, mailing and social networks have been used instead of the e-Newsletter. Main communications have been done once the field test development has been completed and field results were interpreted. Due to the time extension needed for the development of B1 and B2 action, this occurred late in the project, at the time that the 14th Forum was being organised. That is why, the progress of the project and the most relevant news for citizens have been disseminated through the project website (lifesurfing.eu/en/news-and-events), the 14th Forum website (www. hchforum.com) and the Forum social networks.
A large distribution list with more than 400 email accounts of stakeholders and HCH and pesticides experts has been used for informing about the 14th Forum and its outputs.
Specialized publications:

- 3 articles have been published in RETAMA specialized journal.
- 10 scientific articles related to the project technical outcomes have been published scientific journals of excellence (see deliverable D26_D2)
- 130 scientific articles were presented at the 14th International HCH and Pesticides Forum (see deliverables D27_D3).

D.2.4: INTERVENTION IN AN INTERNATIONAL EVENT (Brussels)
LIFE SURFING project was presented by the Government of Aragon at the "Final workshop of the HCH in EU project" in Brussels, that took place days 16 and 17 November 2021. The event was hosted by members of the EU Parliament and the European Commission.
The 'HCH in EU' project was initiated by the European Commission, by request of the European Parliament. One of the HCH in EU objectives was to map out the legacy of Lindane and technical HCH production in Europe. The LIFE SURFING presentation was part of a discussion related to how permanently resolve the legacy of HCH in the EU. SARGA and IHPA also participated at this event.
The LIFE SURFING project was also presented in the EU Water Innovation Conference 2019 celebrated in Zaragoza on 11/12/2019, at the side event "Remediation of Lindane manufacturing waste". UCM, IHPA, SARGA and DGA partners participated and made several presentations of the project.
An exhibitor with the project main information was installed during the two days of the event, and polls and information were distributed to visitors and participants.

Compare with planned output and time schedule:
D2.1: Groups contacted come from different EU Programmes (not only LIFE).
D2.2: Accomplished as foreseen.
D2.3: 10 scientific articles have been published in journals of excellence (vs, 2 planned)
D2.4: LIFE SURFING has been presented in 2 international events (vs. 1 planned)

Modifications:
D2.1: Groups contacted are different than the initially planned in the proposal, due to the reduced number of LIFE projects related to soil and water remediation. The new HCH remediation projects that arose in 2018 and 2019 in other EU Programmes, motivated the creation of networking groups among these HCH projects instead of the initially planned.
D2.3: Initially, the project planned the delivery of a periodic e-newsletter. Nevertheless, due to the project extension, the long period required for obtaining results from B1 and B2 actions, news generated were not enough to publish a periodic e-newsletter since the beginning. That is why, the e-newsletter was discarded and mailing, websites and social networks were used instead.
D2.4: Apart from the Brussels international event of 16-17/11/2021, the LIFE SURFING project has been presented in second international event (EU Water Innovation, 11/12/2019).

Major problems encountered: No major problems have been encountered.

Perspectives for continuing the action after the end of the project:
D2.1: LINDANET project (Interreg Europe) created a network of lindane waste affected regions. A project with an increased network (NATUREM) is planned to be presented to the 2024 call of Interreg Europe Programme, to continue with the European networking among resgions.

Complementary actions outside LIFE:
D.2.3: Some additional works, carried out with UCM own funds, were accomplished in the meantime before the LIFE proposal was approved and the beginning of the project. All these results were used in the A.1.1 section.

Deliverables:
Detailed information about the most outstanding aspects reached by the experts group to be delivered during the last semester of the project can be found in **deliverable D25_D2**. This outcome was culminated during the 14th International HCH and Pesticides Forum (Action D3). Deliverable D26_D2 collects the communications, specialized publications and posters generated for the D2 action.

D3 14TH HCH & PESTICIDES FORUM

Foreseen start date: 06/2021 Actual start date: 06/2022
Foreseen end date: 12/2023 Actual (or anticipated) end date: 12/2023

Activities undertaken and outputs achieved:
The work plan of the forum organization, started in March 2022, based on an intensive regular communication among IHPA, SARGA and DGA.
The website of the 14th HCH Forum (https://www.hchforum.com/) was elaborated and published by the IHPA, with the support of the Government of Aragón and SARGA. Website was published on July 2023. Social networks specifically dedicated to the Forum have been created (Facebook, Twitter/X, Linked-in), being Linked-in the one with higher interactions.
The 14th HCH Forum was announced in September 2022 with definitive date 21-24 February 2023, at Caja Rural in Zaragoza. The Call for Papers was also in September. The Forum theme was "*How the European Union is managing the Legacy of Lindane and HCH waste. What are the "Lessons learned" and what is the "Way forward"".*
Received abstracts were reviewed and selected during November and December to elaborate the final program, which was published on the forum website on the 1st of February 2023.
The Forum was organised in a 4-day conference, hosted by the Government of Aragon.
A Press Conference for presenting the 14th International HCH and Pesticides Forum,was held on 6 February 2023 in Zaragoza: with presentations of the Government of Aragón by:

- Mr. Carlos Gamarra Ezquerra – Former Managing Director of Climate Change and Environmental Education of the Government of Aragon
- Ms. Elena Cano - Head of Service of Contaminated Soils of the Government of Aragon
- Mr. John Vijgen, Managing Director, International HCH and Pesticides Association

Link of Press Conference: https://www.youtube.com/watch?v=b5hpIe174Yc with videos of the presentations
A total of 361 scientists and technical experts from 68 countries and 191 organizations attended the Forum in Zaragoza. 161 participants made use of the on-line conference platform.
Presentations and videos of all forum sessions are available in the website: https://www.hchforum.com/presentations/

Compare with planned output and time schedule:
The Forum had a high impact in the international community of HCH and pesticides experts. Time schedule took place as planned.

Modifications:
The event was finally hybrid (in-person / online) for the following purposes:

- To allow the online attendance of people with travel costs restrictions
- To maximize the impact of the Forum and very specially of the PFAs session.

Major problems / drawbacks encountered, delays, including consequences for other actions
The personnel dedication was higher than expected. Apart from that, no major problems were encountered.

Deliverables:
Deliverable D27_E1 "Forum Book" details all the Forum information and outputs.

E1 PROJECT MANAGEMENT.

Foreseen start date: 01/2019 Actual start date: 01/2019
Foreseen end date: 12/2023 Actual (or anticipated) end date: 12/2023

Activities undertaken and outputs achieved:

- The Project structure was established during the first quarter of the project.
- Partnership Agreements were signed between June and July 2019.
- The 1st Steering Committee meeting and the 1st Technical Committee meeting were held in Zaragoza on April 2019, on the occasion of the Opening Session.
- The 2nd, 3rd and 4th Steering Committees were held online days 04/05/2020, 09/01/2021 and 04/04/2022 respectively, together with the 2nd 3rd and 4th Technical Committees. The agenda separated coordination and administrative issues from the technical issues.
- The last Steering Committee was held on 28/11/2023, on the occasion of the Closing Session.

Compare with planned output and time schedule:
Outputs and time schedule are being successfully accomplished.

Major problems / drawbacks encountered, delays, including consequences for other actions
The need of extension of the project was discussed and agreed among project partners in coordinating meetings of 09/01/2021 and 04/04/2022.
At the monitoring visit of 8 November 2021, the coordinating beneficiary confirmed to the monitoring the need of extension of the project duration, due to a delay of approximately one year in the start of the SURFING test. In letter of 22/12/2021, the CINEA agreed with the approach and reminded the need of submitting a request of extension.
The request of extension was submitted on the 6th of May 2022. The approval of the project extension (amendment Nr. 1 to Grant Agreement) was received on 08/06/2022.

Deliverables:
More detailed information can be found in deliverable D28_D29_E2 "Coordinating Protocol" and "Monitoring Protocol".

E2 MONITORING THE PROJECT PROGRESS

Foreseen start date: 01/2019 Actual start date: 01/2019
Foreseen end date: 12/2023 Actual (or anticipated) end date: 12/2022

Activities undertaken and outputs achieved:

- Task E2.1: The project monitoring protocol, which consists in an Excel file that includes the schedule of all actions, as well as a checklist of deliverables and milestones, was

prepared at the beginning of the project and has being periodically updated during the project development until the end of the project.

- Task E.2.2:
    - 5 management meetings have been held during the course of the project, once per year (09/04/2019, 04/08/2020, 19/01/2021, 04/04/2022, 28/11/2023). Additionally, periodical meetings have been held before and during the development of actions B1 (hydrogeological and tracer tests), B2 (field test) and D3 (XIV Forum).
    - 3 monitoring reports have been prepared (Progress Report 30/09/2019, Mid Term Report 31/01/2021, Progress Report 30/09/2022).
- Task E2.3: A Google Drive folder was created to upload the project Deliverables during the life of the project, at draft and final stage. All project final Deliverables have been uploaded into the Butler Platform.
- Task E2.4: all the monitoring reports have been discussed either in the management meetings either in other monitoring meetings.

Compare with planned output and time schedule:
One more management meeting than planned has been held (5 meetings vs. 4), due to the project extension.
The rest of the tasks have been completed as planned.
Time schedule has been successfully accomplished.

Modifications:
Some management meetings have been online (14/05/2020, 19/01/2021, 16/12/2022) instead of in-person, due to covid travel restrictions and due to the after-covid meeting habits.

Major problems / drawbacks encountered, delays, including consequences for other actions: N/A

Deliverables:
More detailed information can be found in deliverables:

- D28_D29_E2 “Coordinating Protocol” and “Monitoring Protocol”
- D30_E2 “4 project management meeting minutes to be held once a year during the course of the project”

E3 EXTERNAL ECONOMIC AUDIT

Not applicable to LIFE SURFING project according to the Programme conditions.

E4 AFTER LIFE COMMUNICATION PLAN

Foreseen start date: 09/2023 Actual start date: 09/2023
Foreseen end date: 12/2023 Actual (or anticipated) end date: 12/2023

Activities undertaken and outputs achieved:
A compilation of the results and dissemination actions related to them has been carried out within this activity. As a product, an After-LIFE dissemination plan has been prepared, with realistic commitments and goals to undertake by all project partners.

Compare with planned output and time schedule:
Action has been accomplished as planned.

Major problems / drawbacks encountered, delays: No problems have been encountered.

5.2. Evaluation of Project Implementation

Methodology applied:

The methodology foreseen in the proposal refer to the SURFING Test implementation (action B2), which started in May 2022. According to the project proposal, the methodology consisted in the following phases:

- Phase 1: SEAR-on site treatment: this phase does not contemplate the direct in situ application of oxidant but the injection and extraction of a surfactant aqueous solution. After the separation of extracted DNAPL not dissolved (as drops), the aqueous phase containing surfactant and solubilized DNAPL will be treated on site using three techniques in parallel: Fenton, hidrooxidation-areation and retention in activated carbon. This methodology was strictly followed, although two SEAR injections were done instead of one, to optimize the test performance and the DNAPL extraction.
- Phase 2: S-ISCO. Once the available fraction of DNAPL has been removed with SEAR, Phase 2 contemplates the co-application of oxidant and surfactant, to abate in situ the residual DNAPL and avoid rebounds in the groundwater plume in the final ISCO treatment. This methodology was strictly followed.
- Phase 3: assessment of the rebound effect. The monitoring of the evolution of the contamination for few months immediately after phase 2 will determine whether a significant increase of the contamination due to diffusion from matrix is happening. In case a rebound effect had occurred, a new injection of S-ISCO or just ISCO (in situ chemical oxidation) could be applied. Finally, results obtained after the project shown that concentrations remained low for several months after the field test execution, and therefore, no additional injections (not S-ISCO nor ISCO) were needed.

Results achieved against the objectives:

The results and methodology foreseen in the proposal refer to the SURFING Test implementation (action B and C) and dissemination (action D), the latter one also strongly linked to the Test implementation.

The results to be obtained throughout the project are included in the following table:

Action	*Foreseen in the proposal*	*Achieved*	*Evaluation*
B2	*Objectives:* *To DEMONSTRATE the applicability of the SURFING test for the removal and decontamination of DNAPL and the transferability of the already performed laboratory test to field.* *Results:* *-Execution of the test and assessment of its effectiveness* *-Dosage evaluation and quantification, employed agents, limitations and conditions and field applicability* *-Rebound effect assessment, quantifying the concentration of contaminants at the site's dissolved plume*	*Yes*	*Results very relevant. The technique has been proven applicable and highly effective*

B2	*<u>Objectives:</u> To reduce the risk for the health and the environment, generated by the persistent organic pollutants (POPs) existing at the site, by means of the removal of the residual DNAPL at the demonstration project area.* *<u>Expected results:</u>* *-1,800Kg of DNAPL removed (mass that may pollute 10,000 hm3)* *-€/Kg of HCH removed per year compared to other alternatives. An estimate of 1,800Kg of DNAPL exits in the test area (equivalent to 600 Kg of HCH). Current annual treatment cost of Bailin leachates is 14,000€/Kg of HCH. Considering that SURFING test cost 1 million €, annual cost would be:* • *for a 100% performance (1,800 Kg DNAPL removed): 1,660 €/Kg of HCH* • *for a 50% DNAPL recovery: 3,330 €/Kg HCH DNAPL removal by pumping is in similar values in 2017 but increasing each year* *-Reduced timeframe of groundwater remediation (see OB-3 Result 1)*	*Yes*	*The amount of kg of DNAPL removed have been less than expected. But this is not due to the lack of effectiveness of the technique, but due to the fact that the major part of DNAPL remaining in Bailin is located downstream of the test cell area.* *Additionally, transferability of the test has allow to remove 589 kg of DNAPL in other polluted site next to Bailín.*
C3	*<u>Objectives:</u> To guarantee the reduction of the environmental risks and to analyse the full scale applicability of the technique from a technical, economic and environmental point of view, as well as to evaluate the reduction of the pollution for the health and the environment in case of a future full-scale implementation, considering the information gathered during the monitoring of the demonstration test.* *<u>Expected results:</u>* *-Assessment of human health risk reduction, using:* *1)annual mass eliminated (27.47kg using current methods. A 100% performance would be 73 times this annual mass)* *2)years needed for the aquifer remediation, both compared to current treatments* *-Incorporation of ES2430077 Bajo Gallego to the river Gallego HCH ecological control network* *-Assessment of technical and economic feasibility for a full scale implementation*	*Yes*	*In the overall tests, 240 kg of DNAPL have been removed from the aquifer (pumped or eliminated in situ).* *The removed contaminant load could disable 2400 Hm3 of water for potable use.* *With this technique, and only considering the HCH contained in the DNAPL mass removed from the aquifer, the tested layer has been prevented from discharging under the most unfavorable conditions, the mass equivalent of a period of 500 years of natural discharge into the Gállego river.*

D1	*<u>Objectives:</u> To disseminate the results of the project to stakeholders, as well as the raising of a general public awareness of to the problem of such type of contamination to the, paying special attention to the project surrounding area, affected by the contamination.* *<u>Expected results:</u>* *-Environmental awareness of the affected population including dissemination of materials, guided tours, open days* *-Positive response in the territory for the project development, evaluated according to direct and indirect impacts*	*Yes*	*11 Sessions for the general public* *25 Sessions for groups of experts* *20 Project partner meetings* *The Committees of HCH, were informed about the project start by email.* *An update explanation about LIFE SURFING progress was given in 6 annual Committees of HCH.* *Dissemination material (website, brochures, poster, videos) have been prepared and uploaded for the general public.*
D2	*<u>Objectives:</u> To innovate the application of the surfactant-enhanced chemical oxidation technology in DNAPL contaminants.* *<u>Expected results:</u>* *-Publication and presentation of 4 technical papers*	*Yes*	*3 articles have been published in RETAMA specialized journal.* *10 scientific articles related to the project technical outcomes have been published scientific journals of excellence, and another one is in process of approval.* *130 scientific articles were presented at the 14th International HCH and Pesticides Forum.*

B4	*<u>Objectives</u>: To analyse the replicability and transferability of the technique to other locations, by the definition of a strategy that allows to multiply the impact of the results obtained for their use in other locations.* *<u>Expected results:</u>* *-Replicability and Transferability Plan and Test, to assure the transferability to other sites with similar environmental problems* *-For optimal results, collaboration among stakeholders will take place: 6 governments with similar problems will be contacted*	*Yes*	*A replicability Plan has been elaborated thanks to the experiments carried out by the University of Stuttgart within action B4.1.* *Transferability of the test has allow to remove 589 kg of DNAPL in other polluted site next to Bailín.*
D2 and D3	*<u>Objectives</u>: To create a network to share, interchange and transfer knowledge and experiences for projects related to sites affected by other pesticides soil contamination.* *<u>Expected results:</u>* *-Networking at national and international level, including seminars, forums, conferences attendance and scientific papers* *-Contact with 5 similar projects* *-Hosting of the 15th Int. HCH&Pesticides Forum in Aragón (expected attendance: >300 experts)*	*Yes*	*A network called NATUREM (12 regional authorities with HCH pollution problems) has been generate thanks to the networking with the European projects LIFE SURFING, LIFE POPWAT, LINDANET and HCH in EU.* *The 14th HCH Forum was announced in September 2022 with definitive date 21-24 February 2023, at Caja Rural in Zaragoza. A total of 361 scientists and technical experts from 68 countries and 191 organizations attended the Forum*

5.3. Analysis of benefits

However, the following main benefits have been obtained after the end of the project:

<u>Environmental benefits</u>

- Removal of 240 Kg of DNAPL in Bailín (mass that may pollute 2,400 hm3)
- Perfect knowledge of the methodology to follow in Bailin landfill to remove all the DNAPL and residual DNAPL whose extraction needs the drilling of new boreholes (already under performance), as it has been proven that the main volume of remaining DNAPL in Bailin is located downstream of the LIFE SURFING test cell area.
- Removal of 589 kg of DNAPL in Sardas landfill, also in Sabiñánigo town and managed by the Government of Aragon, as a result of the transferability of the LIFE SURFING technology.
- Reduced timeframe of groundwater remediation.

Economic benefits:

- Reduction in the annual treatment cost of Bailin leachates.

Social benefits:

- Generation of employment for the development of the project, as well as for the future full-scale application of the SURFING test.
- Awareness raising in local population and the general public through the dissemination actions
- Replicability, transferability, cooperation:
    - Replication to other European sites with DNAPL of organochlorinated compounds, thanks to the transferability study.
    - New cooperation opportunities with other public entities managing HCH polluted sites have been created as a product of the project networking and of the 14th International HCH and Pesticides Forum.

Policy implications:

- Increased visibility of the HCH contamination problem through the dissemination activities.

6. Index of Deliverables

Internal Code	Number of action	Name of the Deliverable	Description
D1	A 1	SURFING Test experimental design	Includes Variables for defining the implementation of the hydrogeological and tracer tests, SEAR, and S-ISCO techniques
D2	A 1	SURFING Test engineering design	Includes the design of the construction works, facilities and equipment needed for the LIFE SURFING test
D3	A 2	Copy of the letters to the Ebro River Basin Authority and other organizations	Deliverable includes the official publications
D4	A 3	Copy of the OBA (Official Bulletin of Aragón) Publication	Official publication of the LIFE SURFING project
D5	A 3	Report on outputs of stakeholder´s involvement activities	Summary of the means of involvement of project stakeholders
D6	B 1	Borehole core-logging geological report	Report on the results of the boreholes drilled for the test development
D7	B 2	On -site SEAR-oxidation results report	Report on the development and results of the on-site treatment of Phase 1 of LIFE SURFING test
D8	B 2	S-ISCO results report	Initially, it was planned as a report on the development and results of the S-ISCO test (Phase 2). Finally, Phase 1 (SEAR tests) have also been included in the same Report, as one phase cannot been understood without the other, therefore, its content is coincident with the SURFING test final report.
D9	B 2	SURFING Test Final Report	It includes Phase 1 (S-ISCO) and Phase 2 (SEAR) test development and results
D10	B 3	SURFING Full Scale applicability preliminary design	analysis of the situation related to the existence of the dense phase (DNAPL) in Bailin site, in order to stablish a methodology for applying the SURFING technology at real scale
D12	B 4	Replicability and transferability Plan	Description of the measures to enable the transfer of the S-ISCO remediation method that has been developed in the course of the Life Surfing project
D13	C 1	Baseline conditions final report	It includes a description and the results of the previous test, developed for the preparation of the LIFE SURFING test, which includes hydrogeological and tracer tests.
D14	C 2	Environmental impact monitoring report	Report on the ecological state of the Gállego River basin during the LIFE SURFING project duration. A new monitoring point of Natura 2000 area, was included with the purpose of the LIFE SURFING project
D15	C 2	SURFING Test monitoring report	Report that gathers the field and laboratory data of the LIFE SURFING test development
D16	C 3	Assessment on socio-economic impact report	Analysis of the project benefices, not only from the environmental but also from the social point of view
D17	C 4	Starting LIFE Performance Indicators	Uploaded in the KPI platform
D18	C 4	Finish LIFE Performance Indicators	Uploaded in the KPI platform
D19	C 5	Life Cycle Assessment study	Life Cycle Assessment (LCA) of the phases of the LIFE SURFING test to evaluate the environmental impacts associated with the relevant processes and objectives of the project
D20	D 1	Communication Plan	Definition of the elements of the LIFE SURFING communication strategy

D21	D 1	Notice Boards	Report that gathers the information materials produced to inform the stakeholders and general public. Notice boards, leaflets and posters have been included in an only deliverable
D22	D 1	Leaflets (500), Posters(20),	
D23	D 1	Video/App	Report that gathers a list of videos produced during the project
D24	D 1	Layman Report	Dissemination document created to inform about the project development, objectives and final results
D25	D 2	1 Memorandum with the most outstanding aspects reached by the experts group to be delivered during the last semester of the project.	Overview of the highlights achieved by the Expert Group during the last period of the LIFE SURFING project
D26	D 2	4 Newsletters, 2 Articles in specialised journals and 2 scientific articles	Report that gathers the list of the scientific publications released during the project duration
D27	D 3	FORUM BOOK	Book that contains all the information shared during the 14th International HCH and Pesticides Forum. The deliverable includes links to the information, due to the huge size of the complete document
D28	E 1	Coordinating Protocol	Both deliverables have been included in the same document, for coherent reasons. It includes all the control documents used for the project monitoring
D29	E 2	Monitoring protocol, which includes a checklist	
D30	E 2	4 Project Management meeting minutes to be held once a year during the course of the project.	Report that gathers the MoMs
D32	E 4	After Life Communication Plan	Communication plan carried out by LIFE SURFING partners after the project completion