DELIVERABLE B.5.2.2

End-User Experience - The case of Principality of Asturias

Delivery Date: 31/03/2022

Partner in charge: Fundació Universitària Balmes

CONTENT

1. INTRODUCTION

The Principality of Asturias, in north-western Spain, is a region with a long mining tradition, and coal mining has been the economic motor of the area for centuries. However, nowadays, around 200 mines are abandoned. Many of these mines were abandoned long before the introduction of any environmental regulations to control metal release. Consequently, the natural environment in Asturias is affected by the existence of these abandoned mines, as high metal concentrations have been commonly found in soils and waters. Despite the substantial efforts made by the Government of the Principality of Asturias (PRAS), abandoned mines still are one of the most significant pollution threats in this Spanish region, causing environmental problems and health risks for the local population.

The DEMINE technology may offer an efficient and innovative solution to face this environmental problem since results obtained until the date from the two demonstration sites have indicated high metal removal efficiencies from mining effluents. One of the main objectives of the LIFE DEMINE project, in the framework of Action B.5, is to ensure the replication and transferability of the DEMINE technology by promoting its market introduction and implementation in other European areas facing the same environmental problem. Therefore, the DEMINE technology could be promoted and ideally implemented in Asturias, especially considering that PRAS is part of LIFE DEMINE project as a partner that supports the technology implementation.

Introducing an innovative technology into the market and society requires a long process. The launch stage, which includes the **adoption of this technology**, can be critical, and it is often not sufficiently considered. The technology adoption lifecycle has been widely studied, and it is represented as a sociological model that describes the adoption or acceptance of a new technology according to the demographic and psychological characteristics of different defined adopter groups[1]. This model is often broken into different costumer profiles according to how they accept an innovation: innovators, early adopters, early majority, late majority and laggards (Figure 1).

[1] Rogers, Everett (2003). Diffusion of Innovations, 5th Edition. Simon and Schuster. ISBN 978-0-7432-5823-4

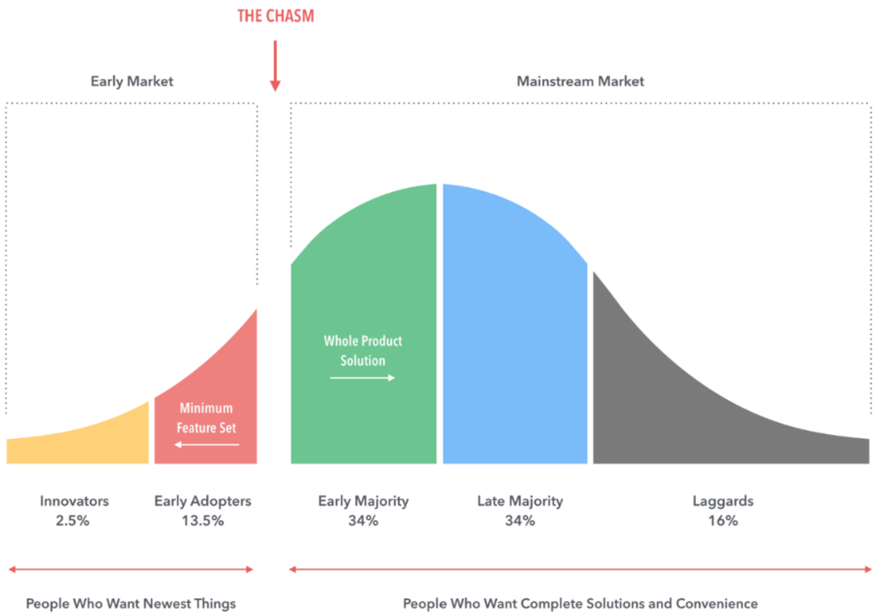


Figure 1. Technology Adoption Lifecycle, adapted from Rogers (2003) and Moore (1991).

According to Moore[2], the marketer should focus on one group of customers at a time, using each group as a base for marketing to the next group. The most challenging step is transitioning between visionaries (early adopters) and pragmatists (early majority). Therefore, the gap between early adopters and the early majority is the chasm, which makes up the start of the mainstream market. According to this model, early adopters are an important target group for transferring innovation.

The early-adopters are the second fastest category of individuals who adopt an innovation. These individuals have the highest degree of opinion leadership among the other adopter categories. Early adopters are typically young, have a higher social status, have more financial lucidity, advanced education, and are more socially forward than late adopters. More discrete in adoption choices than innovators. Realizing informed choice of adoption will help them maintain a central communication position. Therefore, it is critical to reach early-adopters within a community to promote the adoption of a new technology.

At the same time, the adoption of a new technology (i.e., acceptance, integration, and use of new technology) is a critical step that can fail as a result of a lack of local involvement and community participation. In fact, community engagement has been recognised as an important factor in the successful introduction and adoption of new technologies. To get the early-adopters and community engagement, education and communication is an essential and needed initial stage in the technology adoption process.

Considering these points, the end-user experience in the LIFE DEMINE project focused on the adoption of the DEMINE technology in Asturias, starting with the engagement and education of young students from the region. These students, have the capability to communicate with their families, local businesses and the communities in which they live, will be early adopters of the DEMINE technology. Therefore, using the knowledge and results provided by the LIFE DEMINE

[2] Moore, G. A. (1991). Crossing the chasm: Marketing and selling technology products to mainstream customers. New York: Harper Business.

project and the local knowledge provided by PRAS, a didactic activity was designed and developed to introduce these young students to the environmental problem targeted and to evaluate the potential benefits of implementing the DEMINE technology in their region, severely affected by pollution from abandoned mines.

Specifically, this didactic activity consisted of two practical sessions about the environmental problem targeted, the LIFE DEMINE project and the potential benefits of applying the DEMINE technology on an abandoned mine called “Soterraña Mine”. This activity was addressed to students from a high school located in Pola de Lena (Asturias), a small village near the Soterraña Mine. Throughout these practical sessions carried out by the DEMINE partners, students from Pola de Lena participated in a practical case study to assess the environmental impacts caused by a real abandoned mine and the potential contribution of the DEMINE technology in reducing these impacts.

2. MAIN OBJECTIVES

The main objective of this task was to design and develop a didactic activity addressed to students from a high school located near the Soterraña abandoned mine to raise awareness of the environmental problem caused by abandoned mines, with a special focus on those impacts occurring in freshwater ecosystems, especially in Asturias.

At the same time, these activities also aimed to inform about the restoration and treatment strategies currently available to address this problem, including the technology developed in the framework of the LIFE DEMINE project.

Finally, the didactical activity also aimed to give all the necessary information to the students so that they could assess by themselves the potential environmental benefits of applying the DEMINE technology to restore the Soterraña abandoned mine.

3. STUDY SITE

3.1. La Soterraña abandoned mine

“La Soterraña” is an abandoned mercury mine causing high arsenic concentrations in waters downstream from the mine. To date, no major intervention measures have been applied in this mine. La Soterraña abandoned mine is close to the village of Pola de Lena (Figure 2), on the northern slope of a deep valley drained by a small stream (La Soterraña Stream) that enters the Lena River, a tributary of the Caudal River. It began operating in 1844, obtaining arsenic and mercury, and ceased activity on April, 1974. Besides all the human harm as a result of mercury poisoning, this abandoned industrial activity produced serious damage in the perimeter of the facilities, such as the accumulation of useless and harmful residues, the ground deterioration, the plummeting water quality, the biodiversity harms, the visual impact damage and many other consequences that still have not been remedied. In this regard, this abandoned mine is identified as a priority area by the Spanish and PRAS Government for remediation. This mine is located 5 kilometers to the north-west of Pola de Lena, where there is located the high-school involved in the didactic activity proposed here.

The area occupied by the abandoned mining and metallurgical installations, including the spoil heap, is estimated to be 72.000 m^2. The spoil heap has not been stabilised and covers an area of about 17.000 m^2. This area is very permeable, which greatly accelerates the process of infiltration. Considering climate and geology features, potential infiltrated rainwater entering in contact with mine wastes is assessed as being 104 m^3 $year^{-1}$. This water transports pollutants in solution to groundwater and/or to surface watercourses. The impact of La Soterraña Mine into the water environment is mainly evidenced by the presence of high levels of arsenic (As) downstream of the mine operations[3]. To date, no major intervention measures have been applied in this mine.

The specific composition of the mining effluent generated in this abandoned mine was obtained in the framework of Action A1 and it is included in the LIFE DEMINE mining effluent database:

Table 1. Chemical composition of the mining effluent from "La Soterraña" abandoned mine.

c(As)	c(Ca)	c(Cl)	c(Mg)	c(Na)	c(SO4)
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
229.2000	353.0	20.6	55.7	160.0	14.7

3.2. IES Santa Cristina de Lena, Pola De Lena, Asturias

Asturias is known as one of the largest Hg producers worldwide and the main Hg deposits are in Mieres and Pola de Lena (the La Peña-Terronal and La Soterraña mining districts, respectively). Although this long-term mining activity has certainly promoted the economic growth of the region, it can also be identified as the primary source of several environmental issues, including the pollution of surface and ground waters. Pola de Lena is located only 5 km from the Soterraña abandoned mine (Figure 2).

The didactic activity proposed here was addressed to students (16 years old; 20 students) from Santa Cristina de Lena high-school, located in Pola de Lena, a small town in Asturias, close to the "Soterraña" abandoned mine.

Figure 2. *Location of the Soterraña abandoned mine and the Santa Cristina de Lena high-school, in Pola de Lena (Asturias, Spain).*

[3] Loredo, J., Petit-Domínguez, M. D., Ordóñez, A., Galán, M. P., Fernández-Martínez, R., Alvarez, R., & Rucandio, M. I. (2010). Surface water monitoring in the mercury mining district of Asturias (Spain). *Journal of hazardous materials*, *176*(1-3), 323-332

4. METHODOLOGY

The didactic activity was developed by PRAS, ELENTEC and UVIC, with the collaboration and supervision of the teaching staff from Santa Cristina de Lena High-School. The didactical activity was divided into two sessions, each one including a theoretical and a practical part:

SESSION 1: ABANDONED MINES: AN ENVIRONMENTAL PROBLEM

Specific objectives:

- To review the main environmental impacts caused by abandoned mines in Asturias, and the different remediation strategies applied in this region to face them.
- To review the impacts of mine water from abandoned mines in freshwater ecosystems.
- To know the specific case of La Soterraña abandoned mine.

Proposed activities:

- A seminar given by technical staff from the Government of PRAS about abandoned mines in Asturias.
- A seminar given by researchers from the BETA Technological Center (UVIC-UCC) about the ecological impacts of mining effluents on freshwater ecosystems.
- A field trip to La Soterraña abandoned mine in Asturias by experts from PRAS.

SESSION 2. Remediation strategies: The LIFE DEMINE technology

Specific objectives:

- To review the current remediation techniques available to reduce the adverse effects of mining effluents on the environment, including the DEMINE technology.
- To assess the potential environmental benefits of applying the DEMINE technology to reduce the impact caused by the Soterraña abandoned mine in downstream water bodies.

Proposed activities:

- A seminar given by technical staff from ELENTEC about the current remediation technologies available to treat mining effluents, including a detailed description of the DEMINE technology.
- Technical assessment of the potential application of the DEMINE technology to treat the specific effluent from Soterraña abandoned mine, using a small-scale DEMINE technology training system developed by ELENTEC.
- Sustainability assessment of the potential application of the DEMINE technology in La Soterraña abandoned mine, using a simplified LCA and LCA tool developed by UVIC.

The detailed program of the activities proposed provided to the high-school before the didactic activity is available as Annex I at the end of this document.

5. RESULTS

5.1 Description of the activities developed

This didactical activity was performed in two consecutive days (9 and 10 November 2021). Details of the specific development of each session can be found below:

SESSION 1: ABANDONED MINES: AN ENVIRONMENTAL PROBLEM

During the first session, Pablo Luis Álvarez Cabrero, General Director on Environmental Quality and Climate Change from PRAS, introduced the activity and gave a seminar on the environmental problem caused by abandoned mines in Asturias. During this seminar, he explained the current situation in Asturias, and how PRAS is dealing with this environmental problem. He reviewed different real case studies of abandoned mines across Asturias, and showed some photos before and after some restoration works performed on them. Finally, he introduced the specific case of La Soterraña abandoned mine. Some students noted that they had relatives who had worked in this mine before its closure.

After that, Meritxell Abril from BETA Technological Center (UVIC-UCC) explained the main ecological impacts caused by metal mining effluents from abandoned mines in freshwater ecosystems. After reviewing the scientific evidence about these impacts, she also explained the main results obtained in the framework of the LIFE DEMINE project in this field, including the relevance of using aquatic biofilms as ecological indicators of this impact in streams and laboratory tests.

Then, students performed a practical exercise that consisted of reviewing different scientific articles that included the specific water chemical composition of rivers affected or not by mining effluents, including a study performed in La Soterraña stream. They compared the metal concentrations described in these studies with the current legal thresholds defined in the Spanish legislation to assess the water quality of surface waters. In this way, they could clearly notice those metal concentrations were far above these limits in some of these rivers, including La Soterraña stream, compromising its ecological quality. The materials used to perform this practical exercise can be found in Annex II.

Finally, students visited the Soterraña abandoned mine, where experts from PRAS explained its history and legacy pollution and the difficulties of restoring them. During this visit, students collected water samples from two water courses downstream of the mine. The first sampling site was located just below the spoil head of the mine, while the second was situated on Soterraña stream, approximately 500 meters from the mine. Water samples were kept under cool conditions on the high-school’s laboratory until their analysis during the second session of the didactic activity.

Figure 3. Students participating in practical activities during Session 1.

<u>SESSION 2. Remediation strategies: The LIFE DEMINE technology</u>

During the second day, the <u>water samples collected during the visit to the "Soterraña" mine were analysed</u> in the high-school's lab. The total arsenic concentration and the water temperature and conductivity were determined by the students, using multiparametric probes and testing kits. Results from these analyses revealed high conductivity (aprox. 1256 µS/cm; pH 7.5) and arsenic concentration (aprox. 60 mg/L) in water samples collected at the first sampling site, near the spoil head of the mine, while these values decreased downstream (300 µS/cm; pH 7; 2 mg/L As). Using the information provided during the Session 1, students were able to observe that the As concentration in the first sampling sites exceeded the established legal thresholds for this metal in surface waters.

Figure 4. Students analysing water samples collected at watercourses downstream Soterraña abandoned mine.

Then, using the same water samples collected and analysed, ELENTEC tested the efficiency of the DEMINE technology in reducing the metal concentration on them. To do that, ELENTEC constructed a small prototype of the technology, where the different steps involved in it were clearly evidenced in order to show students its functioning and the metal removal throughout the process. Specifically, this prototype comprised:

- A Watson Marlow peristaltic pump for pumping the mine waste water through the system.
- A power supply to provide up to 10 amps to the electrode cell
- 2 perspex electrode cells with steel (ferric) and aluminium electrode plate packs – 1 for the working trial, the other to hand round so that the students could see the construction.
- A flow meter to regulate flow.
- A stirring platform to agitate the mine waste water following electrocoagulation.

Figure 5. Demonstration of the DEMINE technology functioning using a small-prototype.

Using this prototype and the water samples collected, different trials were performed at different flow rates and currents applied to establish the most effective treatment conditions.

We collected the treated waste following electrocoagulation and stirring in glass beakers, following each adjustment in the system set up so that students could see the different changes taking place as the coagulation occurred. We then filtered each sample using funnels and Whatman filter papers to represent the separation stage in the DEMINE technology.

The water samples obtained at the end of this process were analysed again using the sampling kits and a clear arsenic removal (95%) was observed, proving the efficiency of the DEMINE technology to treat this effluent from “La Soterraña” abandoned mine. ELENTEC noticed that, with optimisation of the system, greater reductions would be achieved.

Finally, Nancy Peña, a researcher from the UVIC, explained online the method used in the DEMINE project to assess and guarantee the overall sustainability of the technology. Together with the students, and using the results obtained during the session, the DEMINE tool was applied to assess the sustainability benefits provided by the technology in the specific case of treating the mining effluent from “La Soterraña” abandoned mine.

Figure 6. Students during the presentation of Nancy Peña from UVIC explaining the sustainability assessment of the DEMINE technology and the functioning of the DEMINE tool.

The DEMINE tool consists of a simplified life cycle assessment (LCA) of the DEMINE technology to quantify the potential environmental impacts of the mining effluent treatment process in different water streams where the technology could be installed. It is an excel running tool that models the potential benefits of installing the DEMINE technology in a given area by comparing the environmental burdens of 3 scenarios: i) adopting the technology, ii) adopting the technology and using only green energy, and iii) not adopting the technology and keeping the pollution source. Furthermore, it also shows the potential metal removal using the technology and compares the results with current regulatory limits for metals in water bodies and water for human consumption. For the End-User experience with the high school, a didactical version of the tool was developed for the students (see Annex 3).

The data collected and analyzed by the students were introduced to the tool to model the environmental impacts of climate change and ecotoxicity in the specific case of treating the mining effluent from “La Soterraña” abandoned mine. The modelled results showed that adopting DEMINE technology in “La Soterraña” could contribute to 0.39 kg CO2eq per m^3 treated or 0.009 kg CO2eq per m^3 treated in the green energy case, with an average of 90% of Arsenic removal. To put these results into perspective with the students, the tool shows the climate change impacts of driving a car for 100km (14.3kg CO2 eq) (see also Annex 3 for images of the tool). In the case of ecotoxicity, the results showed potential benefits for the water bodies, and the organisms on them, from treating the abandoned mine effluent (Figure 7).

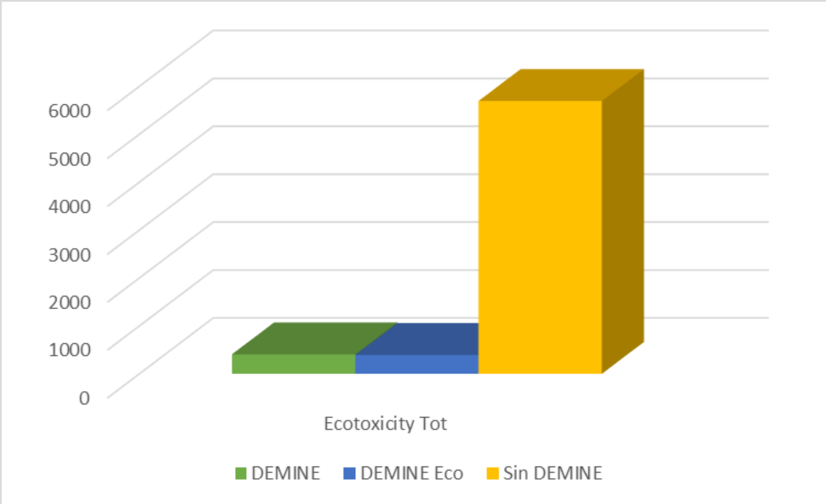


Figure 7. Results for ecotoxicity impacts of “la Soterraña” samples modelled by the DEMINE tool and discussed with the students.

Finally, we discussed with the students the trade-offs that can occur by adopting a new technology and possibly contributing with small impacts on climate change but obtaining a great benefit by reducing metal pollution and hence reducing the ecotoxicity of water bodies near abandoned mines.

6. CONCLUSIONS

The End-User Experience proposed here, within the framework of the LIFE DEMINE project, contributed to raise awareness of the environmental problem caused by abandoned mines in freshwater ecosystems, especially in Asturias. In general, the students from Santa Cristina High-School involved in this action were not familiar with this environmental problem despite the fact that their village is close to an abandoned mine (Soterraña mine) and some of them had relatives who had worked in this mine before its closure. This activity allowed them to realise the environmental impacts caused by this mine and the urgent need to address them. Specifically, after analysing the water samples collected during the visit to the “Soterraña”, students were able to observe by themselves that the arsenic concentration in some water courses downstream of the mine exceeded the established legal thresholds for this metal in surface waters. Finally, the same water samples were treated with a prototype of the DEMINE technology, reaching high arsenic removal (95%) rates, and its overall sustainability performance was evaluated using the DEMINE tool. It proved the potential efficiency of the DEMINE technology as a sustainable remediation action to be applied in “La Soterraña” abandoned mine to treat this effluent in order to reduce the environmental impacts that it is currently causing on water courses.

ANNEX 1. Detailed program of the activities proposed provided to the high-school before the didactic activity

JORNADA DE DIVULGACIÓN EN EL MARCO DEL PROYECTO LIFE DEMINE:

"Las minas abandonadas y su impacto ecológico: el caso de la mina abandonada La Soterraña y el potencial de la tecnología DEMINE para su rehabilitación"

IES Santa Cristina de Lena (Pola de Lena, Asturias)

9 y 10 de noviembre

INTRODUCCIÓN: El proyecto LIFE DEMINE

El objetivo principal del proyecto LIFE DEMINE es reducir el impacto de las explotaciones mineras abandonadas sobre los ecosistemas acuáticos. Para ello, el proyecto ha desarrollado una nueva tecnología de tratamiento de efluentes mineros procedentes de minas abandonadas con altas concentraciones de metales o sales. Esta tecnología innovadora combina procesos de tratamiento basados en electrocoagulación y membranas. A lo largo del proyecto, se ha diseñado y puesto a punto una planta piloto que incluye estos procesos de tratamiento en dos emplazamientos mineros abandonados, una de minería metálica situado en Gales (Reino Unido) que genera un efluente con altas concentraciones de metales, y otro de potasa localizada en Alemania que produce un efluente hipersalino.

Este proyecto, cofinanciado por la Unión Europea a través de su programa medioambiental LIFE, se lleva a cabo des del año 2017, y actualmente se encuentra en el último año de ejecución. Los resultados obtenidos hasta el momento han demostrado la eficiencia de la tecnología desarrollada para reducir la contaminación y el impacto ambiental asociado a estos efluentes mineros.

El consorcio del proyecto LIFE DEMINE está formado por la Universidad de Vic (Cataluña), la Universidad de Swansea (Reino Unido), la empresa ELENTEC Ltd (Reino Unido), el Centro de Estudios de Aguas Subterráneas de Dresden (Alemania) y el Gobierno del Principado de Asturias.

- Página web del proyecto: https://mon.uvic.cat/life-demine/
- Vídeo del proyecto: https://youtu.be/FGhsBMkYrw4

JORNADA DE DIVULGACIÓN:

Centro: IES SANTA CRISTINA DE LENA (Pola de Lena, Asturias)

Objetivo principal: El objetivo principal de les actividades prácticas propuestas es que los estudiantes se familiaricen con el problema ambiental relacionado con minas las abandonadas, con un enfoque especial en aquellos impactos que se producen en los ecosistemas de agua dulce, y en especial en Asturias y en su entorno más cercano. Al mismo tiempo, estas actividades también pretenden informar sobre las estrategias de restauración y tratamiento actualmente disponibles para abordar esta problemática, incluida la tecnología desarrollada en el marco del proyecto LIFE DEMINE. También se espera que los estudiantes, una vez conocida la tecnología propuesta, puedan evaluar por ellos mismos si es adecuada para el tratamiento de los efluentes generados en la mina de "La Soterraña", y en ese caso, cuál sería el beneficio ambiental resultante de su aplicación en esta mina abandonada

Nivel Académico: 1º Bachillerato, modalidad científica

Número de estudiantes: 20

Fechas y horario: 9 y 10 de noviembre**,** dos mañanas consecutivas de 8.30 a 14.30h.

Estructura: Se plantea la realización de 2 actividades eminentemente prácticas implementadas por los socios del proyecto LIFE DEMINE en colaboración con el profesorado, durante dos mañanas consecutivas.

Práctica 1. Minas abandonadas: impacto ambiental

Objetivos específicos: Introducir la problemática ambiental relacionada con las minas abandonadas, y revisar la situación actual al respeto en Asturias.

Actividad:

- *8:30 – 8:45h* **Presentación** de la jornada por parte del Gobierno del Asturias. [Twitter: #DEMINE_Asturias]

- *8.45 – 9.15h* **Seminario** impartido por técnicos del Gobierno del Asturias sobre minas abandonadas y la problemática ambiental relacionada con ellas en Asturias.

- *9.15 – 9.30h* **Seminario** impartido por investigadores de la UVIC sobre la **c**ontaminación del agua por minas abandonadas e impactos en ecosistemas acuáticos

- *9.30 – 10.00h* **Actividades múltiples**:
  - Relacionar fotos de minas abandonas y restauradas de Asturias.
  - Comparar composiciones de agua de río limpias y ríos afectados por minas abandonadas (comparar con legislación)

- *10.00 – 14.30h* **Visita** a la mina abandonada de La Soterraña:
  - La mina abandonada de la Soterraña: historia y situación actual.
  - Recogida de muestras de agua del efluente minero y el río receptor (Grupos de 5, 5 x 4 grupos)

Práctica 2. Estrategias de remediación: La tecnología LIFE DEMINE

Objetivos específicos: Revisar las opciones de tratamiento disponibles y valorar el potencial de la tecnología LIFE DEMINE para reducir el impacto ambiental en la mina abandonada de "La Soterraña".

Actividad:

 8.30 – 9.30h **Análisis** de las muestras de agua recogidas en La Soterraña y el río receptor. Comparación con los límites establecidos y posibles impactos en el medio (UVIC) – Análisis con sonda multiparamétrica, y realización de dilución para determinación de concentración de As con kits.

 9.30 – 10.00h Descanso

 10:00 – 12.00h La **tecnología DEMINE**. Ingenieros de la compañía ELENTEC explicarán la tecnología del DEMINE.

- Pase del vídeo del proyecto LIFE DEMINE
- Prototipo: Se utilizará un prototipo de la tecnología LIFE DEMINE a pequeña escala con fines didácticos para ayudar a los estudiantes a comprender los diferentes procesos incluidos en esta tecnología.
- Se utilizarán las muestras de agua recogidas el día anterior para testar *in-situ* la eficiencia de la tecnología con el prototipo.

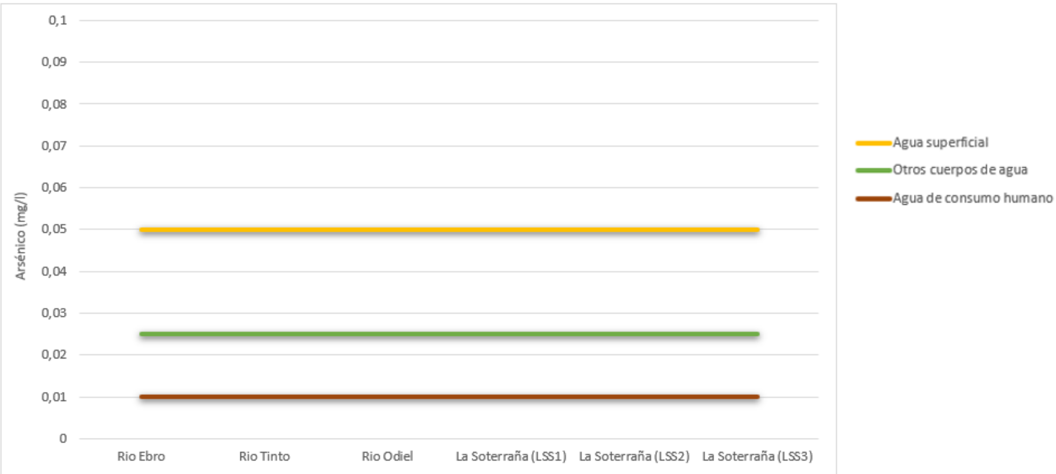
 12:00 – 13.00h **Valoración** ¿es la tecnología DEMINE una opción adecuada? El Análisis de Ciclo de vida como herramienta para evaluar el potencial de la tecnología DEMINE en el caso de La Soterraña (UVIC).

ANNEX 2. Session I – Practical exercise

Registro de Análisis Fisicoquímicos

Centro Tecnológico BETA
Universidad de Vic- UCC
LIFE DEMINE

Grupo: ____________________ Fecha __________



Comentarios:

Acid mine drainage pollution in the Tinto and Odiel rivers (Iberian Pyrite Belt, SW Spain) and bioavailability of the transported metals to the Huelva Estuary.

Nieto, J. M., Sarmiento, A. M., Olías, M., Canovas, C. R., Riba, I., Kalman, J., & Delvalls, T. A. (2007). Acid mine drainage pollution in the Tinto and Odiel rivers (Iberian Pyrite Belt, SW Spain) and bioavailability of the transported metals to the Huelva Estuary. *Environment International*, *33*(4), 445-455.

Table 1
Results obtained in the Tinto and Odiel rivers from the weekly sampling (February 2002 to September 2004)

	Tinto River				Odiel River			
	Mean	Minimum	Maximum	S.D.	Mean	Minimum	Maximum	S.D.
pH	2.89	2.22	5.01	0.60	3.76	2.95	5.05	0.50
EC (mS/cm)	2.26	0.43	8.22	1.20	1.00	0.23	3.88	0.50
SO_4 (mg/L)	1221	150	5547	894	643	110	2379	395
Ca (mg/L)	73.9	11.1	225.5	50.9	45.7	11.9	161.0	26.5
Mg (mg/L)	64.1	8.9	363	47.4	70.5	10.1	224.1	45.2
Na (mg/L)	38.2	6.7	97.2	23.3	17.3	7.9	32.7	5.7
K (mg/L)	3.6	1.0	23.6	2.7	2.4	0.2	37.3	3.7
SiO_2 (mg/L)	19.3	2.8	111.5	22.8	20.4	10.4	83.6	18.7
Al (mg/L)	66.5	0.03	434.4	60.4	32.8	0.58	175.8	26.1
Fe (mg/L)	123	0.07	2804	307	4.9	0.31	23.5	4.9
Cu (mg/L)	15.7	0.2	84.3	11.9	5.4	0.5	17.1	3.2
Mn (mg/L)	6.8	0.7	39.2	5.4	8.1	0.9	32.1	6.1
Zn (mg/L)	24.1	2.2	152.3	22.2	11.5	1.3	36.4	7.1
As (µg/L)	147	<3	2290	416	4	<3	22	5
Ba (µg/L)	15	5	57	9	21	<1	42	9
Cd (µg/L)	107	11	532	82	52	5	176	37
Co (µg/L)	476	52	3754	456	269	33	938	178
Cr (µg/L)	11	<2	86	13	5	<2	16	4
Li (µg/L)	113	<1	403	83	58	<1	217	37
Ni (µg/L)	135	16	742	105	145	19	500	113
Pb (µg/L)	121	<7	698	103	45	<7	267	42
Sr (µg/L)	257	60	673	149	114	30	237	47

S.D.: standard deviation.

Environmental Concentrations of Metals in the Catalan

Stretch of the Ebro River, Spain: Assessment of Temporal Trends

Vilavert, L., Sisteré, C., Schuhmacher, M., Nadal, M., & Domingo, J. L. (2015). Environmental concentrations of metals in the catalan stretch of the ebro river, Spain: assessment of temporal trends. Biological trace element research, 163(1), 48-57.

Table 2 Metal concentrations in drinking water (μg/L), river water (μg/L), and soil (μg/g) according to sampling areas (north and south)

	LOD	North				South				
		Mean±SD	Median	Min	Max	Mean±SD	Median	Min	Max	*p* value
Drinking water 2014										
As	0.20	0.55±0.18	0.59	0.24	0.73	0.41±0.34	0.30	ND	0.94	NS
Cd	0.05	ND				ND				–
Cr	0.50	4.70±1.77	4.39	3.14	7.59	8.43±1.45	8.85	6.92	10.4	<0.05
Cu	0.20	12.8±8.0	18.40	1.68	18.5	23.9±28.0	5.93	4.45	68.1	NS
Hg	0.20	ND				ND				–
Mn	0.10	0.84±1.07	0.36	ND	2.63	0.24±0.34	0.12	ND	0.84	NS
Ni	0.20	1.87±1.60	1.67	ND	4.48	1.46±1.43	1.08	ND	3.78	NS
Pb	0.05	0.47±0.24	0.61	0.20	0.67	1.39±1.75	0.53	0.22	4.35	NS
River water 2014										
As	0.20	0.83±0.01	0.83	0.82	0.84	0.81±0.02	0.81	0.79	0.83	NS
Cd	0.05	ND				ND				–
Cr	0.50	6.97±0.78	7.27	5.61	7.49	7.10±1.53	7.63	4.44	8.34	NS
Cu	0.20	6.63±2.58	5.52	3.85	10.40	6.17±1.66	5.62	4.47	8.87	NS
Hg	0.20	ND				ND				–
Mn	0.10	8.39±0.97	8.76	7.35	9.47	7.87±0.76	7.45	7.29	9.03	NS
Ni	0.20	1.65±0.18	1.69	1.39	1.89	1.57±0.18	1.65	1.38	1.77	NS
Pb	0.05	0.52±0.25	0.4	0.34	0.92	0.56±0.15	0.48	0.46	0.82	NS
Soil 2011										
As	0.10	5.14±1.01	4.99	3.39	7.06	5.33±2.43	4.28	3.07	10.4	NS
Cd	0.03	0.20±0.07	0.19	0.13	0.36	0.26±0.13	0.22	0.15	0.58	NS
Cr	0.25	8.68±1.93	8.63	4.56	11.83	11.6±5.78	9.97	4.74	23.0	NS
Cu	0.10	16.0±5.85	14.3	8.02	26.0	12.6±3.02	13.3	6.56	16.3	NS
Hg	0.10	0.16±0.24	0.03	ND	0.74	ND				NS
Mn	0.01	207±45.9	208	133	305	202±56.7	198	106	303	NS
Ni	0.10	7.81±2.82	8.70	3.16	11.4	7.91±2.53	8.70	3.88	11.2	NS
Pb	0.03	21.8±20.3	16.5	7.25	72.0	22.2±13.30	16.3	8.69	48.2	NS

LOD limit of detection, *SD* standard deviation, *ND* not detected, *NS* not statistically significant ($p>0.05$)

Arsenic input into the catchment of the River Caudal (Northwestern Spain) from abandoned Hg mining works: effect on water quality

Ordoñez, A., Silva, V., Galán, P., Loredo, J., & Rucandio, I. (2014). Arsenic input into the catchment of the River Caudal (Northwestern Spain) from abandoned Hg mining works: effect on water quality. Environmental geochemistry and health, 36(2), 271-284.

Environ Geochem Health (2014) 36:271–284 273

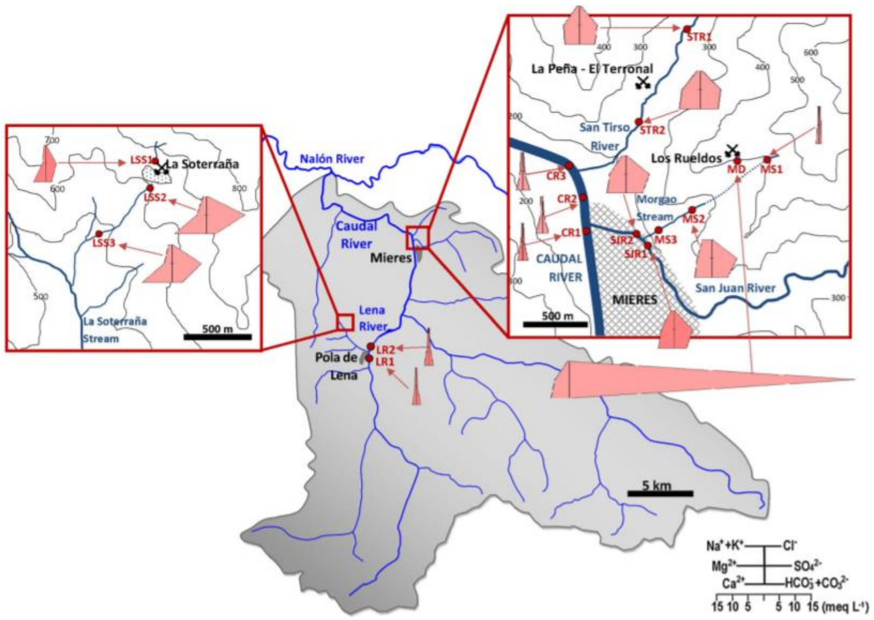


Fig. 1 Caudal River drainage basin showing the location of mine sites and water sampling points. Stiff diagrams of water sampled at those points, represented at the same scale

La Soterraña stream, upstream (LSS1) and downstream of the mine (LSS2 and LSS3), and the River Lena, upstream (LR1) and downstream (LR2) of the mouth of its tributary, La Soterraña stream.

Table 1 Average elemental concentrations and in situ measured parameters in the sampled waters

	La Soterraña			Los Rueldos						El Terronal	
	LSS1	LSS2	LSS3	MS1	MD	MS2	MS3	SJR1	SJR2	STR1	STR2
n	14	20	20	17	16	7	17	5	5	15	18
SC	462	1,366	1,133	211	5,248	1,228	1,107	914	988	1,105	886
pH	7.5	7.7	7.8	6.6	4.2	8.0	7.9	7.8	8.2	7.7	7.8
ORP	307	300	307	392	548	435	383	281	209	329	335
DO	6.6	7.3	6.8	7.9	5.5	11.7	7.4	8.2	8.9	8.2	6.8
Turb.	34.5	43.4	57.0	47.0	30.9	49.8	51.3	10.5	9.5	38.4	33.4
TOC	–	4.3	4.1	6.9	5.7	–	2.5	2.3	3.0	20.3	17.9
SO_4^{2-}	75.0	613	405	37.0	4,200	300	351	324	334	255	222
Cl^-	10.0	18.4	16.8	14.0	6.85	15.0	14.6	10.3	10.8	13.6	13.2
Al	0.08	0.03	0.03	0.13	141	0.87	0.50	0.72	0.08	nd	0.05
As	0.10	39	34	nd	7.2	1.01	0.13	nd	0.04	0.15	3.16
B	nd	nd	nd	nd	0.04	nd	nd	nd	nd	nd	0.03
Ca	69	225	177	25	134	111	105	114	111	102	101
Co	nd	nd	nd	nd	0.15	nd	nd	nd	nd	nd	nd
Cr	nd	nd	nd	nd	0.11	nd	nd	nd	nd	nd	nd
Cu	nd	nd	nd	nd	0.35	nd	nd	nd	nd	nd	nd
Fe	nd	0.06	0.05	0.49	716	4.0	2.07	1.21	0.39	0.05	0.20
K	2.44	12.16	11.10	1.05	2.66	5.01	4.60	4.50	4.20	6.03	5.89
Mg	14.8	41.7	29.5	5.5	59.5	52.6	53.6	54.0	53.5	56.6	52.3
Mn	nd	nd	nd	nd	1.9	0.26	0.08	0.05	0.06	nd	0.03
Ni	nd	nd	nd	nd	0.88	nd	nd	nd	nd	nd	nd
Na	4.5	15.8	16.2	5.4	7.4	50.7	54.3	29.0	28.5	10.7	14.9
Pb	nd	nd	nd	nd	0.03	nd	nd	nd	nd	nd	nd
Sr	0.17	2.94	1.83	0.08	0.27	0.58	0.62	0.59	0.59	0.34	0.37
Zn	nd	nd	nd	nd	6.2	nd	nd	nd	nd	nd	nd

All contents in mg L^{-1}; number of samples (n), specific conductance (SC) in µS cm^{-1}, ORP in mV, turbidity in NTU and temperature in °C; *nd* non-detected (below quantification limit = 0.03 mg L^{-1})

La Soterraña mine site

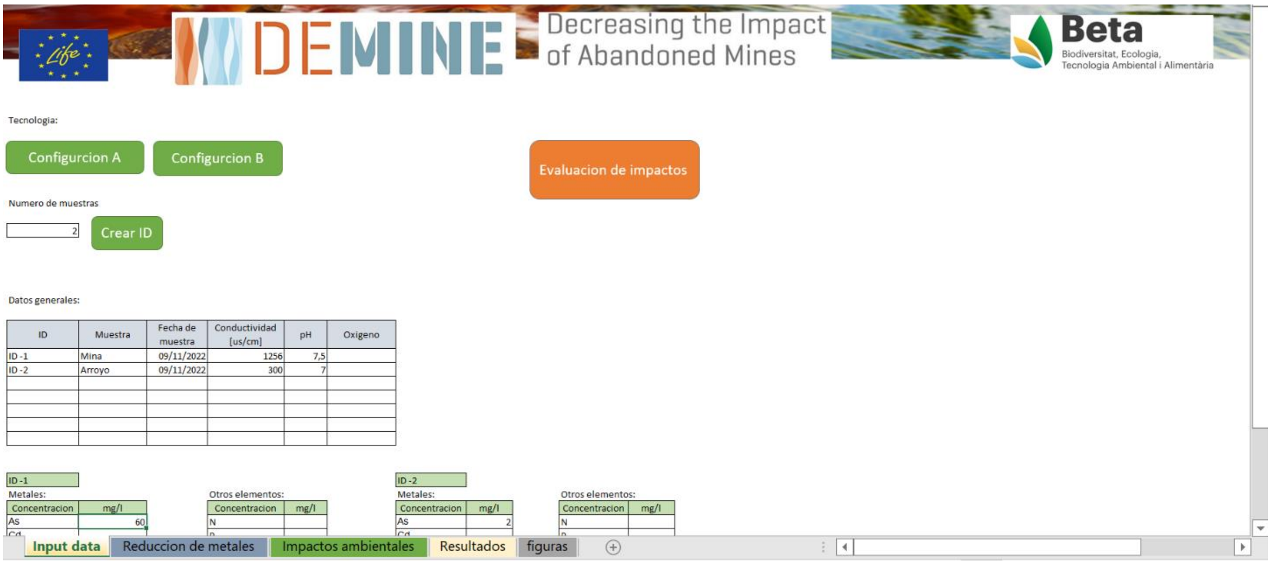
Total As concentrations in surface water upstream of La Soterraña mine are typically below the analytical quantification limit (0.03 mg L^{-1}). However, the impact of the mining activity in the area is evidenced by the extremely high As concentrations found downstream of the site (up to 171 mg L^{-1} at LSS2). This can be considered as a clear indication that water flowing through the spoil heap mobilizes a large quantity of this metalloid. If a comparison is made with the circumstances of the other two sites, in this case, there is a higher volume of wastes exposed to weathering and rainfall leaching (El Terronal spoil heap is now encapsulated and Los Rueldos spoil heap occupies 13 times less area than La Soterraña spoil heap). Additionally, in the ore exploited on this site, As sulphides, such orpiment and realgar, are more frequent than in the other two mineralizations, although As-rich pyrite also exists. All this, together with the alkaline pH, explains why waters in this site have a higher As/Fe ratio, despite the previous co-precipitation of the two elements. The increase in sulphate content downstream of the mine indicates that part of the leaching of As may be caused by the oxidation of sulphur minerals. The Stiff diagrams (Fig. 1) show that the samples taken at this site are of the calcium sulphate type, but those collected immediately downstream of the site are more mineralized than those taken upstream of the site.

Total As concentrations do not decrease significantly with the distance from the spoil heap, since water samples collected at LSS2 and LSS3 have similar concentrations. Surface watercourses are not affected by acidic mine drainage (AMD) at this site, since at LSS2, the pH is alkaline (6.9–9.1) with oxidizing values of redox potential (60–450 mV). Consequently, dissolution of heavy metals is not as significant as it could be, whereas specific conductance reaches a maximum of 2,027 µS cm^{-1}at LSS2. Figure 2a shows the evolution of As content in La Soterraña Stream during the sampled period, compared to its flow. It can be seen that As concentrations downstream of the site decrease when flow increases. These waters finally enter the River Lena, whose previous As concentration at LR1 is undetectable; after receiving them, the average concentration at LR2 is 0.09 mg L^{-1}. Once the River Lena becomes the River Caudal, having gained much flow (at CR1; Fig. 1), As concentrations are found below the quantification limit.

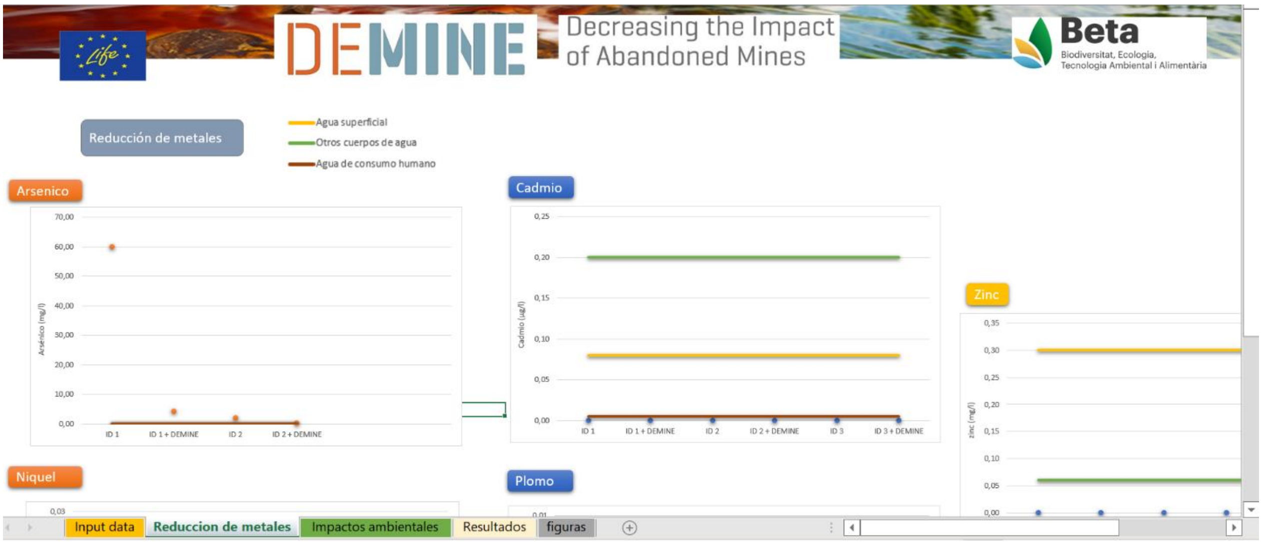
Cluster analysis of the analytical results show that Ca, Mg, K, Sr and Na (major elements) are associated with As (Fig. 3a). The contents of these elements, together with pH, increase after the waters have traversed the mine site.

ANNEX 3. Session 2 – Practical exercise DEMINE tool

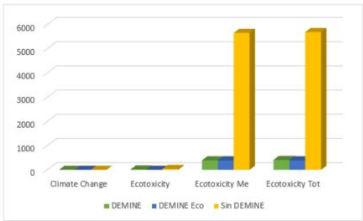
Front page for input data:



Results for metal remotion and comparison with current regulation:



Results by impact category:



	DEMINE	DEMINE Eco	Sin DEMINE
Climate Change	0,391	0,00958	0
Ecotoxicity	13,9	0,624	33,6
Ecotoxicity Me	391,82051	391,82051	5660,2229
Ecotoxicity Tot	405,72051	392,44451	5693,8229

0,39 → 14,3