GRAPHITE MANAGEMENT TO ENHANCE DISPOSABILITY BY ACHIEVING COMPLIANCE WITH LILW DISPOSAL WAC FOR EL CABRIL

Case Study from Spain

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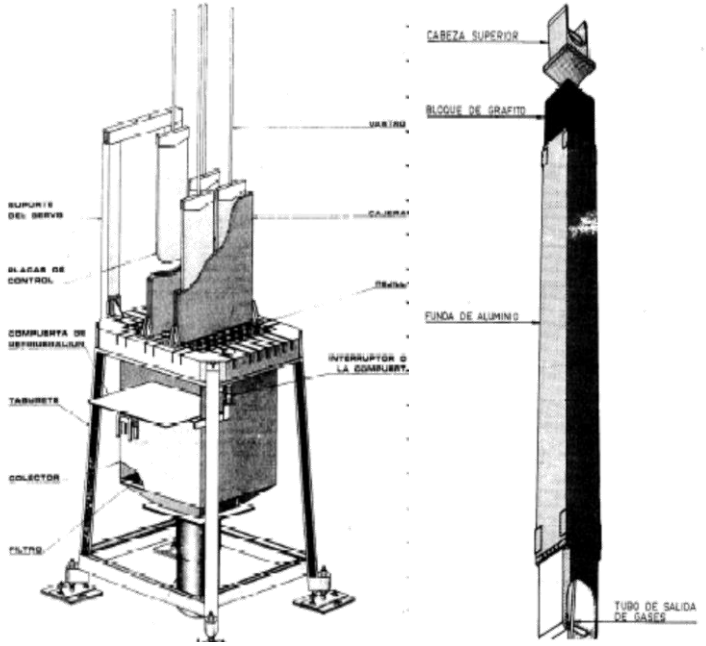
SPANISH IRRADIATED GRAPHITE. MANAGEMENT FOR FINAL DISPOSAL

- **Disposal at the El Cabril near-surface repository facility**
  - There are two main origins of irradiated graphite: In Spain:
    - JEN-1 MTR and
    - Vandellos-1 a UNGG gas cooled reactor.
  - The radiological inventory of graphite from the JEN-1 MTR (6.30E+00 Bq/g) allows its disposal without treatment; Even more an important amount of this graphite was managed as VLLW
  - However, the radiocarbon content of the ~3,600 tons of irradiated graphite from Vandellós 1 (5.62E+04 Bq/g) exceeds the maximum inventory of radiocarbon at the El Cabril near surface repository
  - Note that the WAC for disposal at El Cabril permit only relatively low activity concentrations from long-lived alpha emitters – this is relevant for disposal of graphite sleeves from Vandellós 1

ORIGIN OF JEN-1 GRAPHITE

- **Irradiated graphite waste arises from MTR JEN-1**
  - JEN-1 Material Testing Reactor
    - USA nuclear graphite origin (Unknow manufacture process)
  - Located at the CIEMAT research centre – reactor fuel enriched to 19.8% U-235
  - Virgin Graphite Characteristics
    - Graphite thermal shield (8 tons)
    - Porosity: about 26%
    - Density: 1.73 g/cm3.
    - Volatile content: 0.2% mass, mainly H2O, to a lesser extent CO_2, CO, hydrocarbons (methane, ethane, ethylene, propane, propylene, etc.).
    - Water adsorption: from 3.3% mass for graphite powder to 0.5% graphite pieces, intermediate values for grains.
    - H_2 adsorption: it has not been observed at ambient temperatures. A light weight loss of graphite observed at high temperatures (300º) due to H_2O formation.
    - Chemical impurities: N, Li, Mg, Al, Ca, Fe, Ti, Sn, Sr, Cd, Sb, Ag, Cl, Mn. Co, Ni, Be,Mo, Eu, In.



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CHARACTERIZATION OF JEN-1 IRRADIATED GRAPHITE

- Isotopic composition and mean activity of thermal shielding (01/01/2007)

Isotope	Content (%)	Mean Activity (Bq/g)
^{14}C	1,930	6.30E+00
^{55}Fe	0,267	8.72E-01
^{3}H	93,400	3.05E+02
^{63}Ni	0,512	1.67E+00
^{90}Sr	0,744	2.43E+00
^{60}Co	0.008	2.68E-02
^{152}Eu	3.050	9.96E+00
^{154}Eu	0.036	1.19E-01
Total	99.95	-

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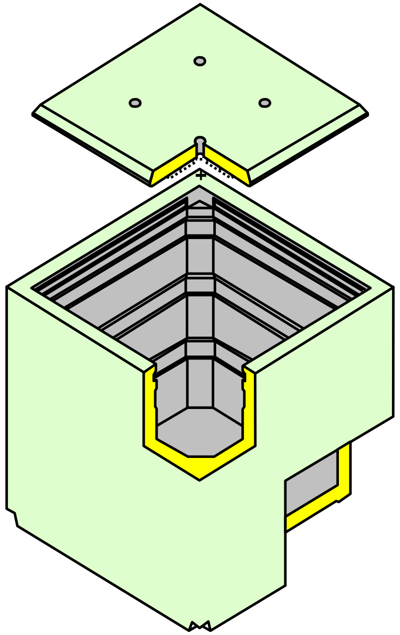
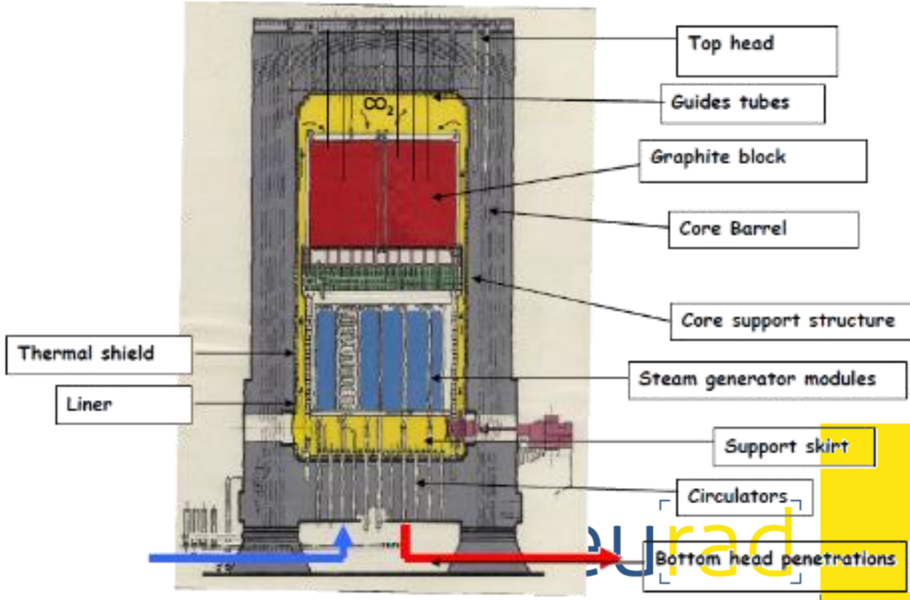
JEN 1 IRRADIATED GRAPHITE DISPOSAL



- **JEN 1**
  - Graphite from the thermal shield has been retrieved and placed in 6 cubic containers, which are disposed at El Cabril
  - The Disposal Units are concrete cells (C2-a and C2-b)
    - There are specific WAC for the C2a and C2b: external dimensions of 2.25 x 2.25 x 2.20 m.
- **WAC:**
  - **Concrete of CE2a/CE2b containers**
    - Compression strength after 28 days ≥41.3 MPa
    - Tensile strength after 28 days ≥ 3 Mpa
  - **Backfilling mortar**
    - Compression strength after 28 days: **≥ 3 Mpa**
  - **Sealing mortar**
    - Compression strength after 28 days: ≥ 25 MPa
    - Tensile strength after 28 days: ≥ 1 MPa

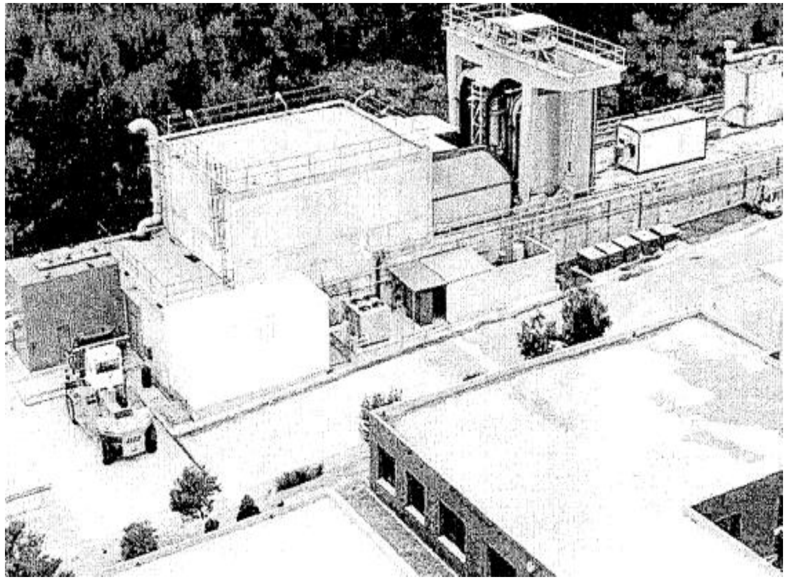
ORIGIN OF VANDELLOS 1 GRAPHITE

- **Irradiated graphite waste arises from UNGG VANDELLÓS I**
  - Vandellós 1 NPP – a Uranium Natural Graphite Gas (UNGG) reactor
    - *Pechiney Nuclear Graphite (France)*
    - Graphite was manufactured by Pechiney SA in France – the manufacturing method was not well defined but involved baking a paste made of oil, coke and pitch, which was then graphitised by electrical heating
  - Graphite moderated, cooled by carbon dioxide, fuelled with natural uranium metal
    - 186,000 graphite sleeves were used (1,000 tons)
    - Graphite pile moderator is a 2,680 ton cylinder
  - The Virgin graphite characteristics
    - Porosity: about 20%
    - Density: 1,8 g/cm3.
    - Volatile content: 0.18% mass, mainly H2O, to a lesser extent CO2, CO, hydrocarbons (methane, ethane, ethylene, propane, propylene, etc.).
    - Water adsorption: 2.2% mass for graphite powder.
    - H_2 adsorption: it has not been observed at ambient temperatures. A light weight loss of
    - graphite observed at high temperatures (300º) due to H_2O formation.
    - Chemical impurities: N, Li, Mg, Al, Ca, Fe, Ti, Sn, Sr, Cd, Sb, Ag, Cl, Mn. Co, Ni, Be,,Mo, Eu.



VANDELLÓS 1 GRAPHITE MANAGEMENT STEPS

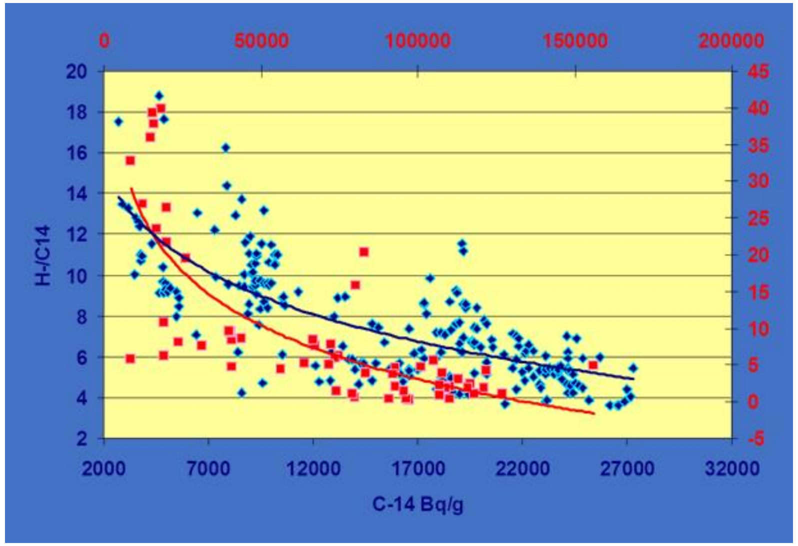
- The management steps to be investigate are:
  - Retrieval
  - Treatment (reduction of ^{14}C) to be categorized
  - Conditioning in appropriate matrix (to meet WAC)
  - Complete Characterization

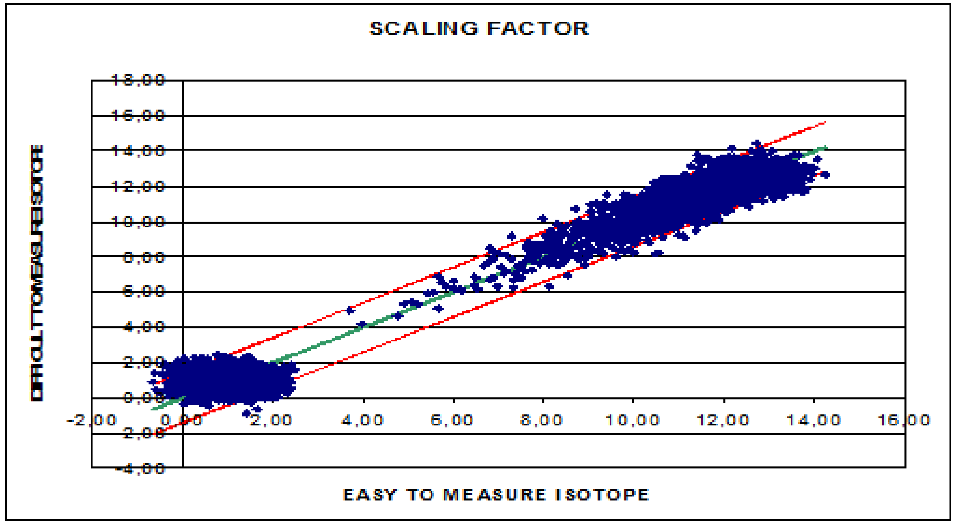


- The present Key uncertainties are
  - *Definition of retrieval method for blocs of the Pile*
  - *Reduction of [^{14}C)] [Available amount without corrosion]*
  - *Conditioning for Waste Minimization ➔ Achieving compliance with LILW disposal WAC for El Cabril*

CHARACTERISTICS OF VANDELLOS 1 IRRADIATED GRAPHITE

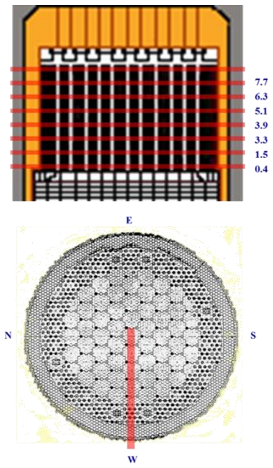
- **Radiological Characterization ➔ Development Nuclide vector**
  - Correlation of gamma emitters, pure beta emitters, and TRU with [^{60}Co]
  - Alpha emitting (TRU content) ^{238}Pu, ^{239,240}Pu, ^{241}Am, ^{242}Cm, ^{244}Cm, ^{234}U, ^{235}U and ^{238}U
  - Pure beta and beta-gamma emitters ^{60}Co, $^{152/154/155}$Eu, ^{133}Ba, $^{137/134}$Cs, $^{94/93m}$Nb, ^{241}Am: $^{41/45}$Ca, $^{55/59}$Fe, $^{63/59}$Ni, ^{90}Sr and ^{241}Pu
  - Non correlated nuclides: ^{3}H, ^{14}C and Long lived Volatile material ^{36}Cl, ^{99}Tc and ^{129}I
  - Validation methods by proficiency test

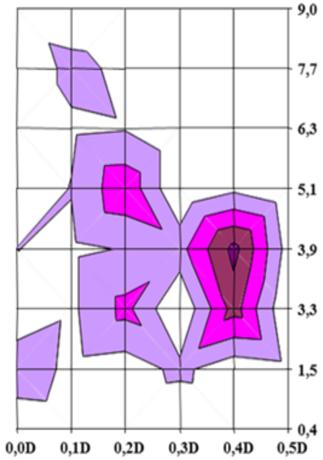




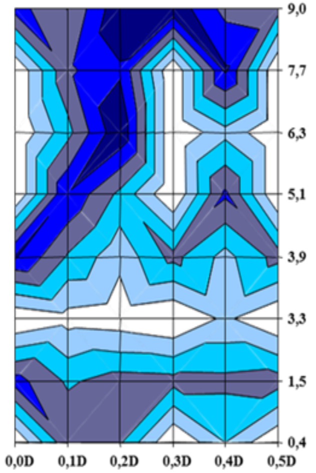
CHARACTERISTICS OF VANDELLOS 1 IRRADIATED GRAPHITE

- Mapping of nuclides distribution (Pile graphite)

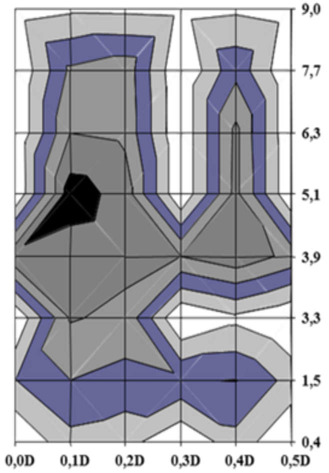




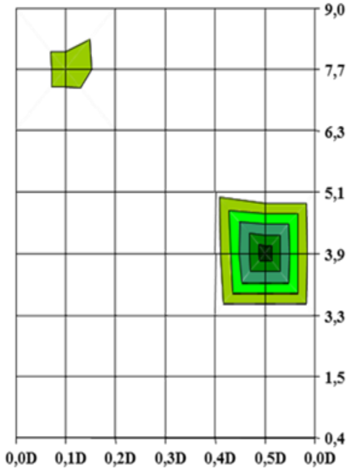
^{60}C



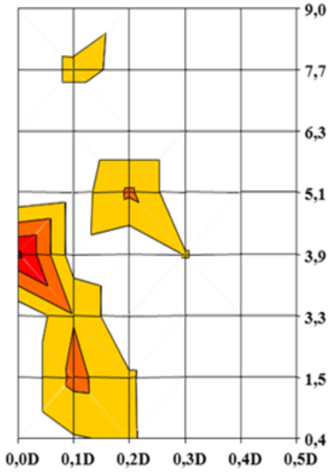
^{3}H



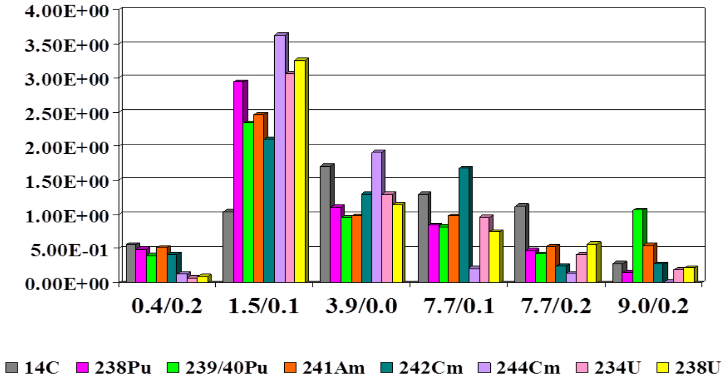
^{14}C



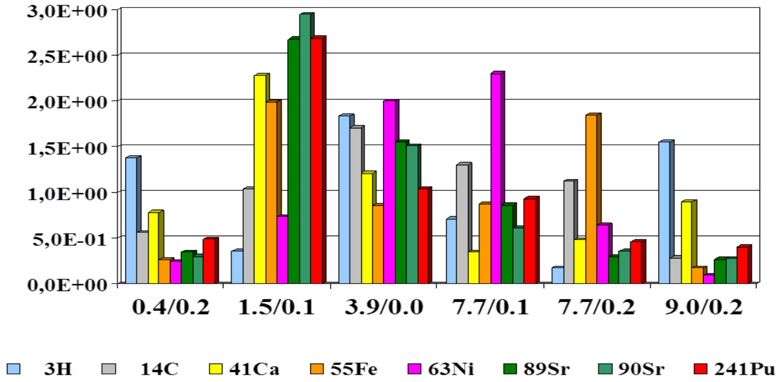
^{137}Cs



^{241}Am



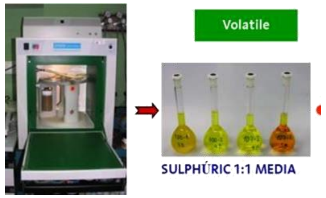
Alpha emitters distribution

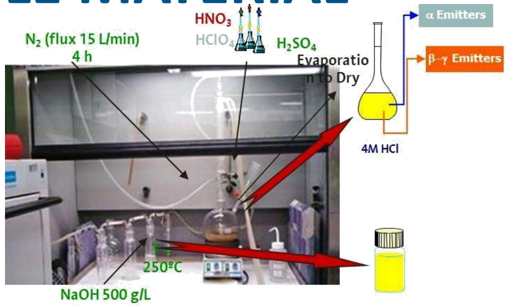


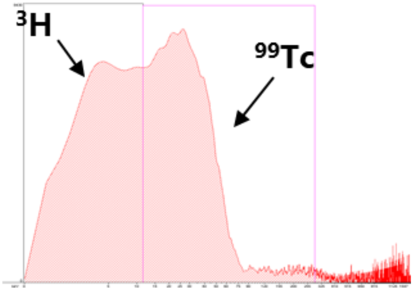
Pure beta emitters distribution

VANDELLOS 1 IRRADIATED GRAPHITE CHARACTERIZATION OF VOLATILE MATERIAL

- Acidic Digestion by Microwaves system for ^{99}Tc & ^{129}I.
- Conventional solubilization reflux Acidic Digestion for ^{36}Cl
- Radiochemical Determination (^{99}Tc, ^{36}Cl & ^{129}I)

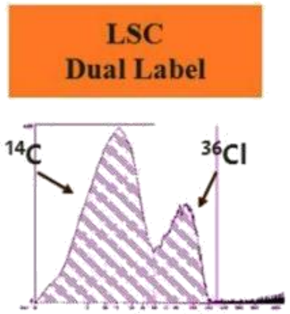






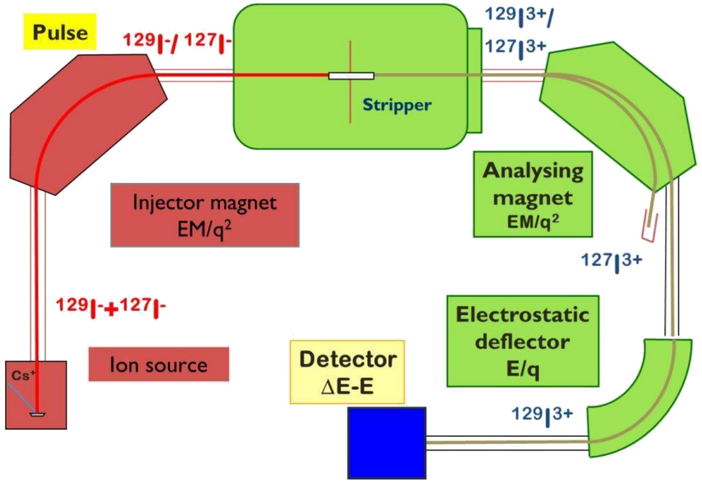
After Separation

Chemical Yield = 96%
MDA = 4 Bq/g
➔ 0.006 g/alíquot



After Separation

- Determination of ^{99}Tc, ^{36}Cl & ^{129}I by AMS



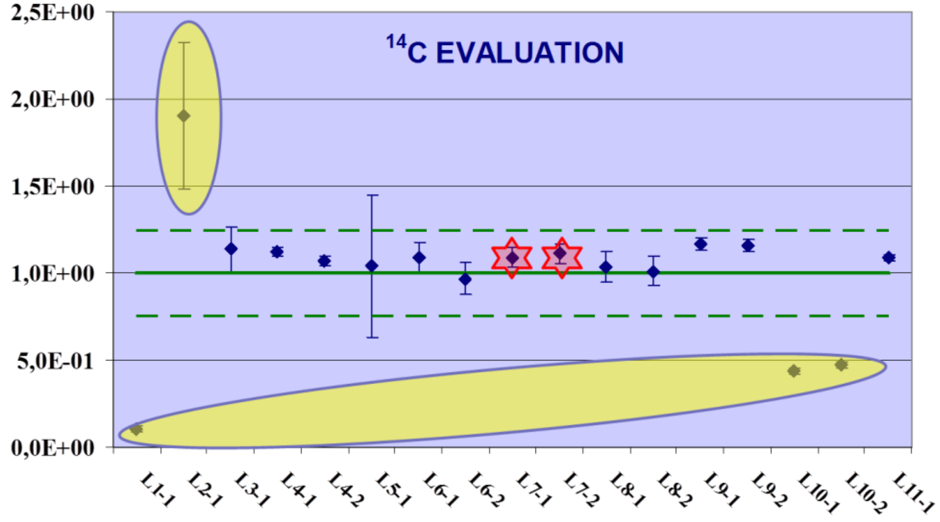
	Tc-99	I-129
Sample ID	Bq/g	Bq/g
GC-1 MEDIANO	< 3,62E+01	< 6,89E+00
GC-2 GRUESO	< 3,85E+01	< 8,62E+00
GC-3 FINO	< 4,01E+01	< 6,31E+00
GC-4 MUY FINO	< 5,03E+01	< 4,85E+00

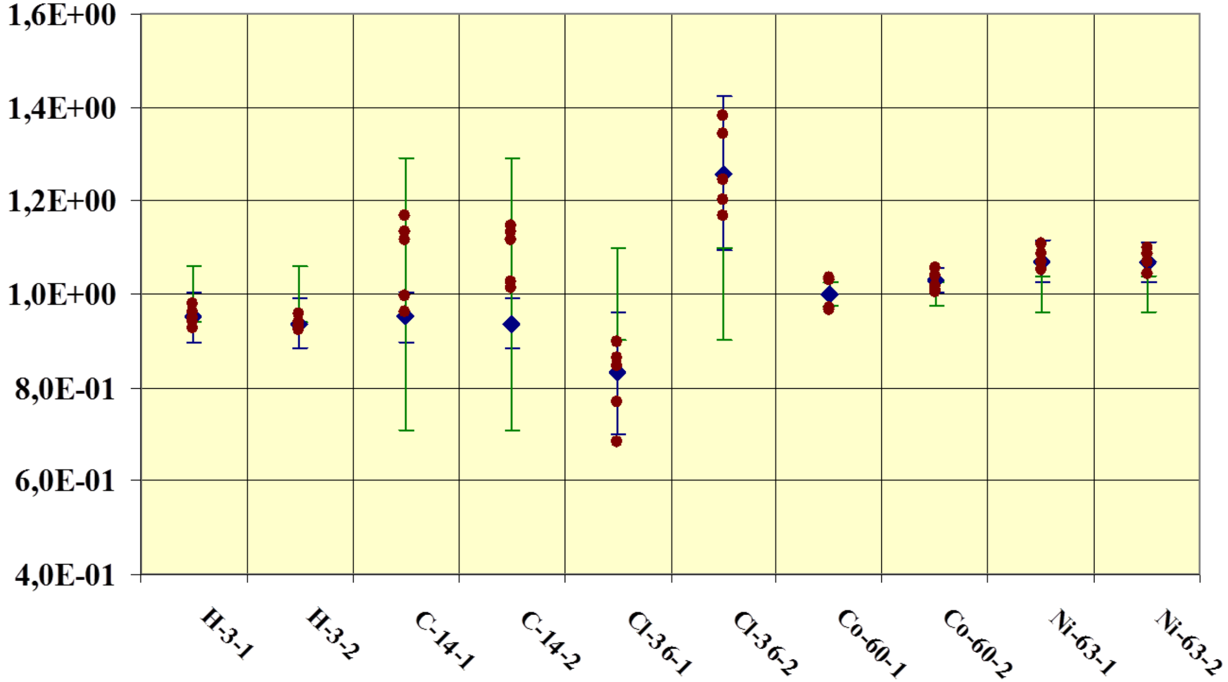
Sample	Description	^{129}I A (uBq/g)	Error (uBq/g)
CNAI-581	GC-1 MEDIANO	1,213	0,027
CNAI-582	GC-2 GRUESO	18,45	0,32
CNAI-583	GC-3 FINO	25,16	0,39
CNAI-584	GC-4 MUY FINO	1,208	0,035

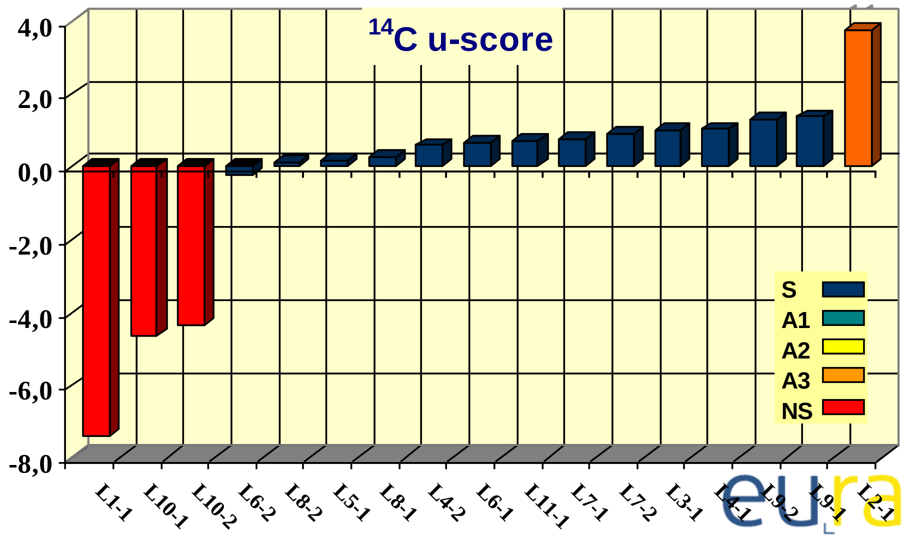
VANDELLOS 1 IRRADIATED GRAPHITE PROFICIENCY TEST

- 35 blind samples ⇒ 12 (11) Lab's
- 464 x 3 primary data generated
- 81 processed data evaluated
- Reference Values Calculation of 6 nuclides:

➔ ^{3}H, ^{14}C, ^{26}Cl, ^{60}Co, ^{63}Ni, ^{90}Sr & Extra γ emitters

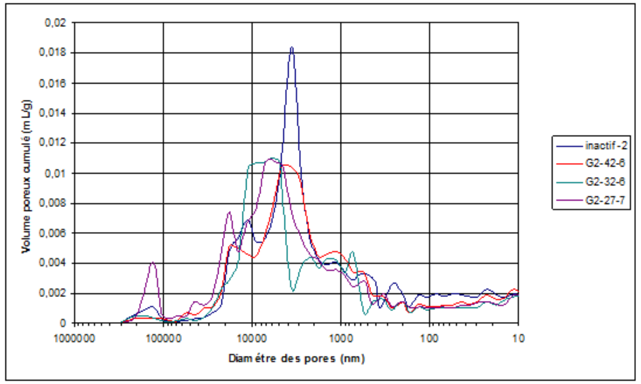


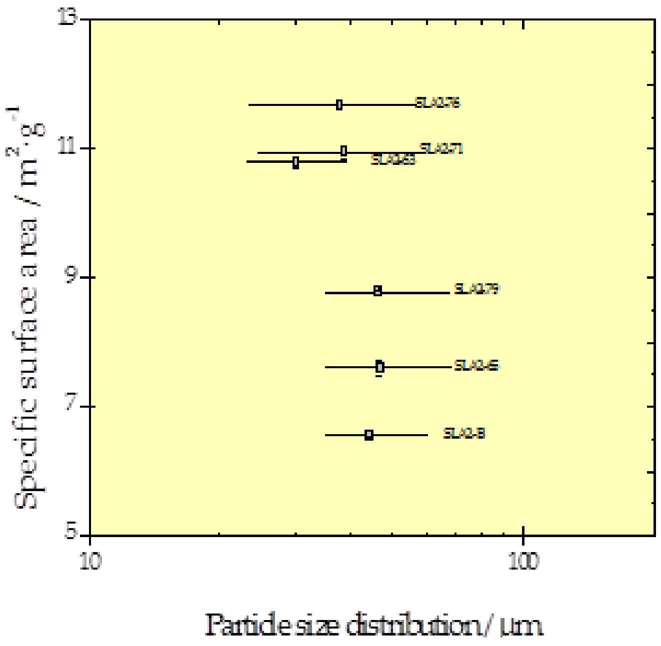


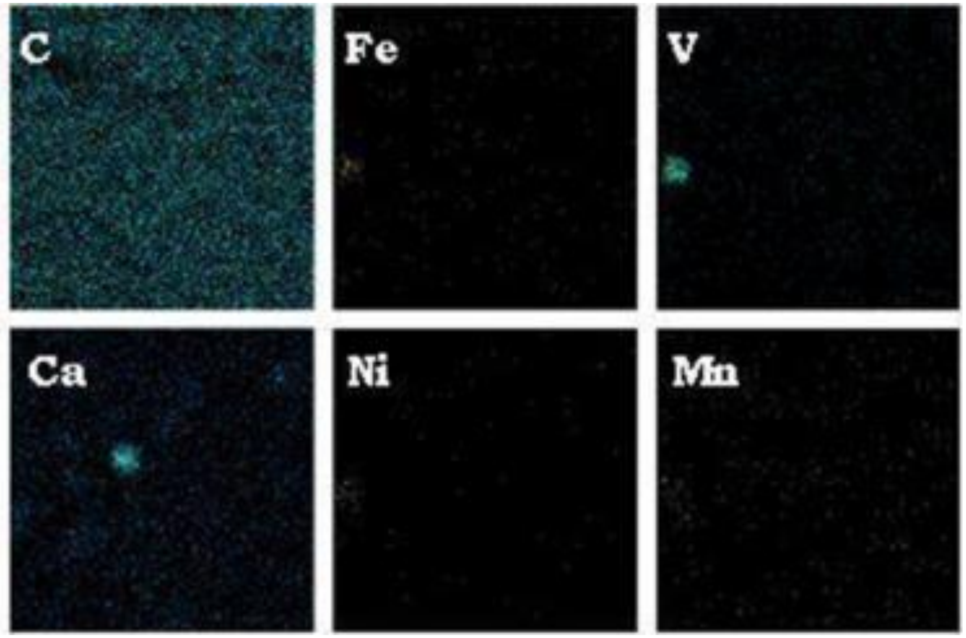


VANDELLOS 1 IRRADIATED GRAPHITE STRUCTURAL CHARACTERIZATION

- **Correlation structural parameters (CARBOWASTE)**
  - **XRD:** crystalline parameters
  - **BET:** Specific surface
  - **Laser diffraction**: Particle size
  - **Location of impurities:** Prompt-gamma NEUTRON ACTIVATION

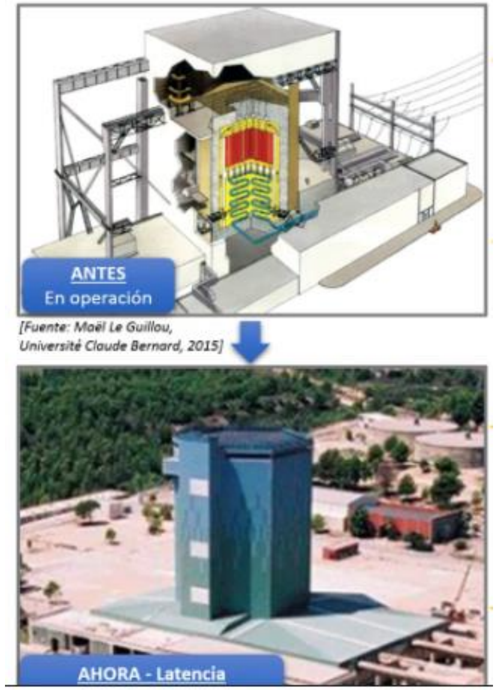






VANDELLÓS 1 GRAPHITE (SLEEVES) MANAGEMENT

- The graphite pile is currently located inside the reactor building in a safe enclosure (for 25 years).e sleeves)



- Graphite sleeves have been retrieved, pre-treated and are temporarily stored at Vandellós I in cubic containers; (the rest of this case study focuses primarily on these sleeves)
- The functions of conditioning systems were:
  - Processing of the graphite wastes and segregation of the support seal wires.
  - Packaging of the different stream of wastes
  - Transfer of the waste packages outside of the conditioning building
- Total amount of graphite, steel wires and miscellaneous wastes was packaged in 220,
  - CME type boxes "cubic containers" with 1054 ton of graphite,
  - 95 CBE type casks "cylindrical containers" with 19,7 ton of steel cylinders absorbents and wires
  - 11 CE2 type container with miscellaneous wastes, plus 875 drums with technological wastes generated during the retrieval process,

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VANDELLÓS 1 GRAPHITE MANAGEMENT OF SLEEVES

The original technical solution selected by the former owner for the interim storage of irradiated graphite sleeve waste generated during the operation of the Vandellos I plant consisted of the **direct dropping of the wastes into concrete silos** (three silos), which included about 1000 tonnes of graphite and seat wires. Each silo has dimensions of 24 m x 7.20 m x 8,70 m. Concrete walls are 0,75 m thick and upper and lower slabs are 0,80 m thick

The **sleeves were placed inside the reactor pool while removing the fuel**; this means that non-activation products like Cs-137, TRU, etc., have been absorbed from the pool.

Prior to the start of the **decommissioning** activities, the graphite **sleeves were removed from**

the silos and **conditioned into high integrity containers which were placed in a temporary storage**

facility **on site**.

- **Recovery the waste** from silos using and **Transfer** to the processing unit.
- **The Processing** consists on **crushing** graphite sleeves
- The **seat wires were separated** and graphite and wires were **placed in different containers.**
- **Transfer** of the **waste containers** to a **temporary store on site**. Final clean up of the silos.

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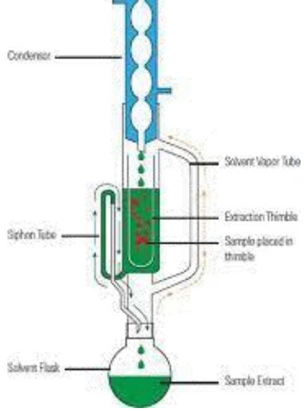
VANDELLÓS 1 GRAPHITE MANAGEMENT OF SLEEVES

- There are 240 cubic containers of 6,5 m^3 with the crushed graphite obtained from the segregation process carried out. The total mass of this waste is 1.1E+03 tons.
- There are 98 cylindrical containers 0,35 m^3 with the wires of the sleeves obtained from the segregation process. The total mass of this waste is 22 tons.
- The segregation was performed using continuous scanning by gamma ray detection.
- Total amount of graphite, steel wires and miscellaneous wastes was packaged in:
  - 240, CME type boxes "cubic containers" with 1,054 tons of graphite.
  - 95 CBE type casks "cylindrical containers" with 19.7 tons of steel cylinders, absorbents and wires.
  - 11 CE2a type container "El Cabril containers" with miscellaneous wastes → **DISPOSAL AT EL CABRIL.**
  - 875 drums with technological wastes generated during the retrieval process, → **DISPOSAL AT EL CABRIL**
- The average surface dose rate of the CME boxes was: 3.66 mSv/h contact and 0.68 mSv/h at 1 metre. For the CBE casks, the average surface dose rate was 0.06 mSv/h and 7.9 mSv/h at 1 metre.

CATEGORIZAION OF VANDELLOS 1 IRRADIATED GRAPHITE

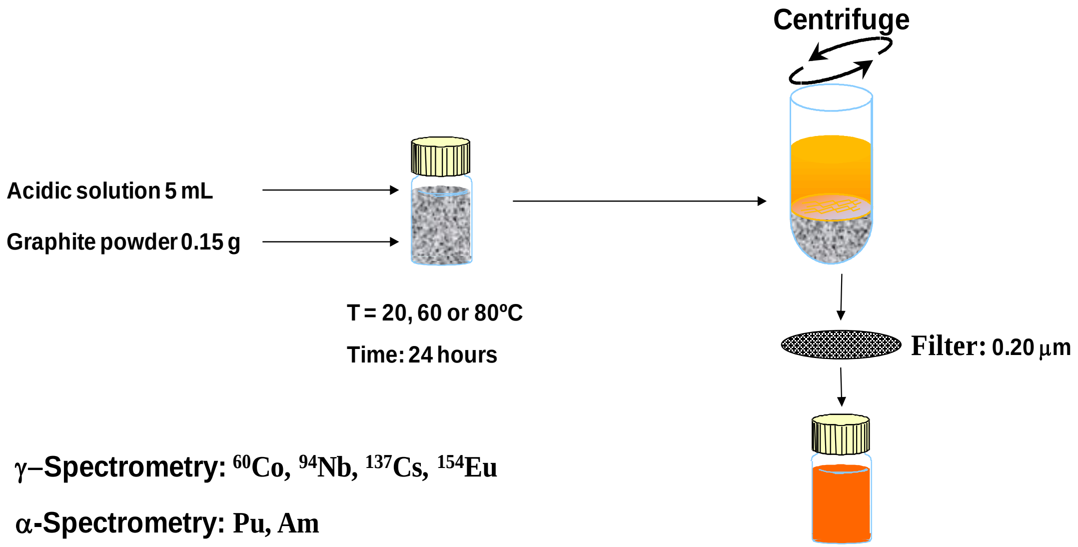
- *Spanish irradiated graphite is a special waste due to its radiological content and stability of the matrix can be considered L&ILW even more if a decontamination process can reduce the activity of macro components could be categorized as VLLW. It is, up to now, out of the categorization for the Spanish Near Surface Repository Initial characteristics of waste (general physical, chemical, radiological, as relevant)*
- *The challenge is to categorised the Spanish i-graphite as L&ILW by mean*
    - *Reduction of ^{14}C content by decontamination (keeping the graphite structure)*
        - *Chemical treatment (Including Soxhlet Extraction)➔ Ongoing Studies*
        - *Thermal Treatment (also ^{3}H and ^{36}Cl) ➔ Ongoing Studies*
        - *Electrochemistry in Molten salt ➔ To be start*
    - *Conditioning the irradiated graphite*
        - *As part of Backfilling mortar ➔ Ongoing Studies*
        - *Using innovative marices (Gedopolimeric) ➔ Ongoing Studies*
        - *Vtrification / IGM (Impermeable Graphite Matrix) ➔ Ongoing Studies*



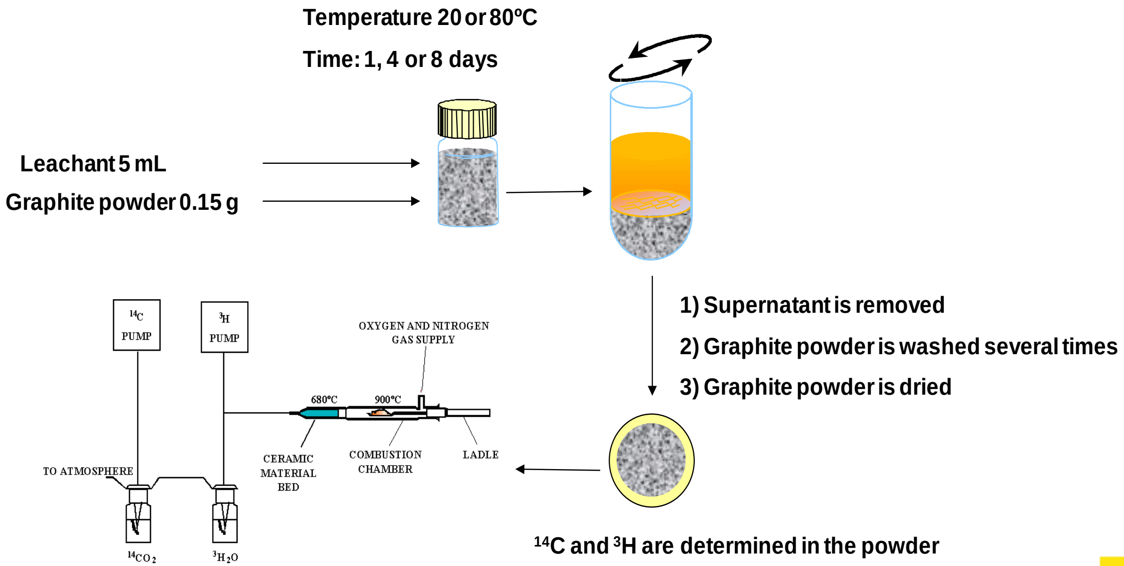
TREATMENT STUDIES OF VANDELLOS 1 IRRADIATED GRAPHITE. ACIDIC TREATMENT

- Studies on decontamination of i-graphite by Chemical Treatment have been carried out using several acids: nitric, chlorhidric, phosphoric, sulfuric, citric and oxalic, and mixtures of these acids.
- **Procedures**

Alpha, Beta-gamma



Tritium and Radiocarbon

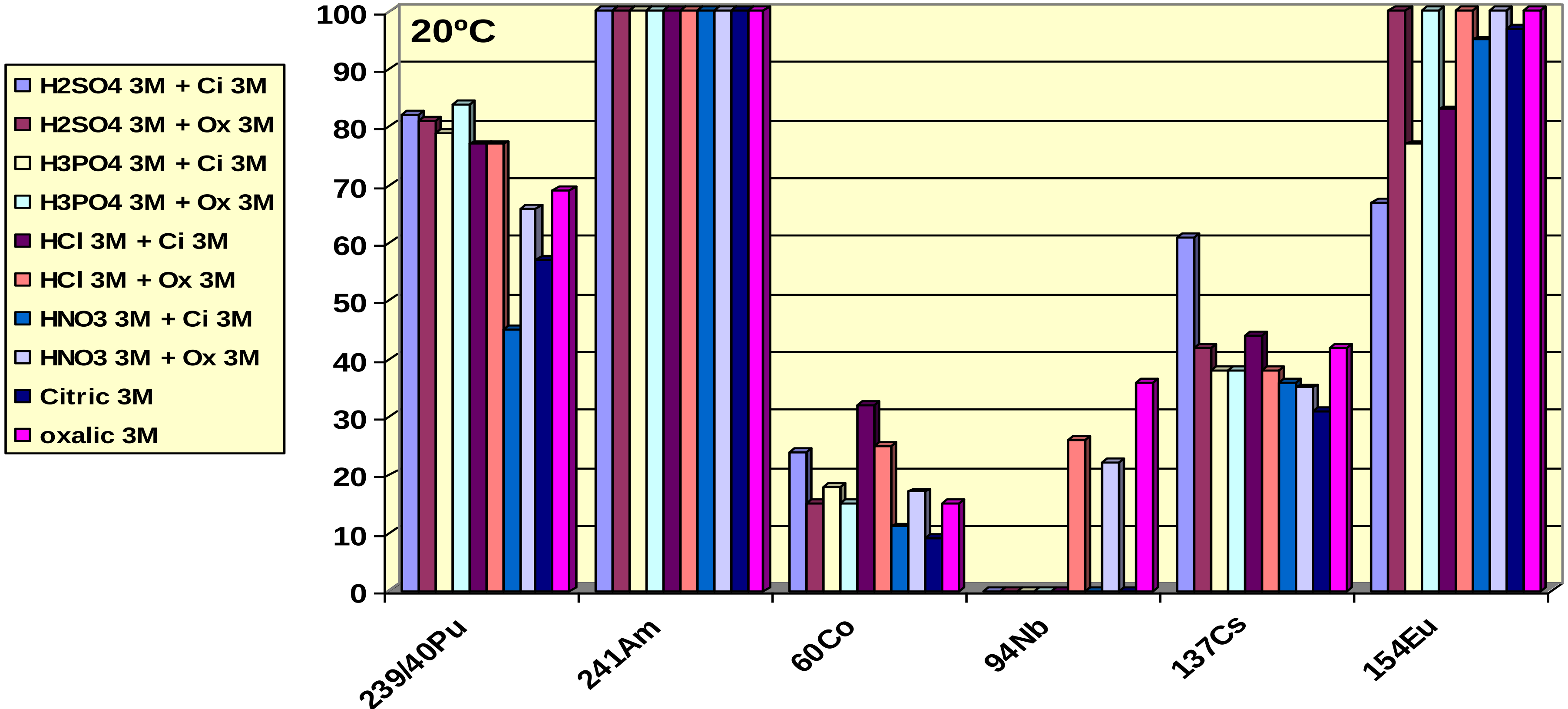


TREATMENT STUDIES OF VANDELLOS 1 GRAPHITE. ACIDIC TREATMENT RESULTS

- The best conditions for the leaching of ^{60}Co are 3M HCl at 80ºC

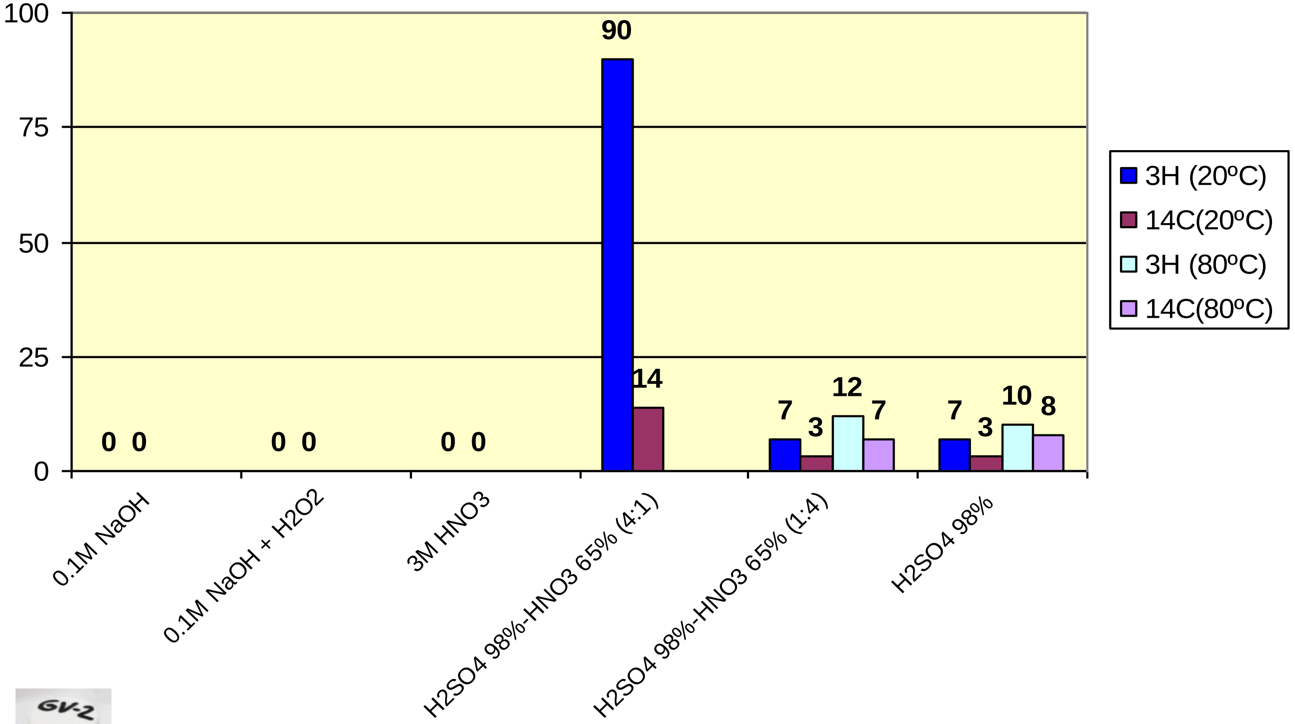
Leaching rate (%)				
$^{239/40}Pu$	^{241}Am	^{94}Nb	^{154}Eu	^{60}Co
87	100	77	84	96

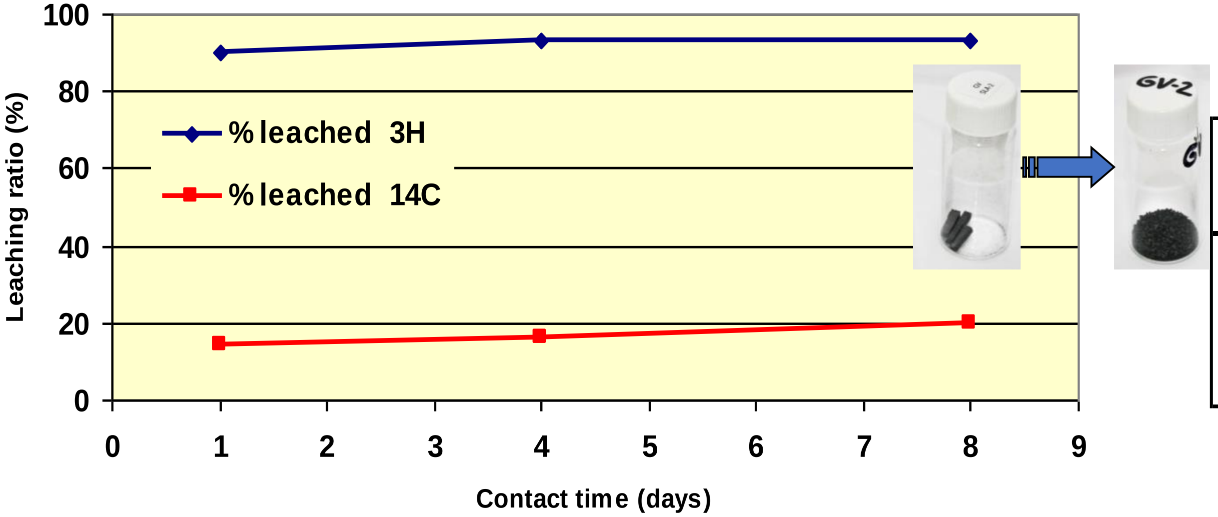
- When a complex agent like oxalic or citric acid is added, 100% of ^{241}Am is leached at 20 ºc and ^{154}Eu



TREATMENT STUDIES OF VANDELLOS 1 GRAPHITE. ACIDIC TREATMENT RESULTS ^{14}C & ^{3}H

Leachant	Temperature ºC	% leached	
		^{3}H	^{14}C
0.1M NaOH	20	0	0
0.1M NaOH + H_2O_2	20	0	0
3M HNO_3	20	0	0
H_2SO_4 98%-HNO_3 65% (4:1)	**20**	**90**	**14**
H_2SO_4 98%-HNO_3 65% (1:4)	20	7	3
H_2SO_4 98%	20	7	3
H_2SO_4 98%	80	10	8
HNO_3 65%-HCl 37% (1:3)	80	0	0
H_2SO_4 98%-HNO_3 65% (1:4)	80	12	7
H_2SO_4 98%-HNO_3 65% (4:1)	80	**Dissolved**	





Mixture	Time (days)	% leached	
		^{3}H	^{14}C
H_2SO_4 98%-HNO_3 65% (4:1)	1	90	14
	4	93	16
	8	93	20

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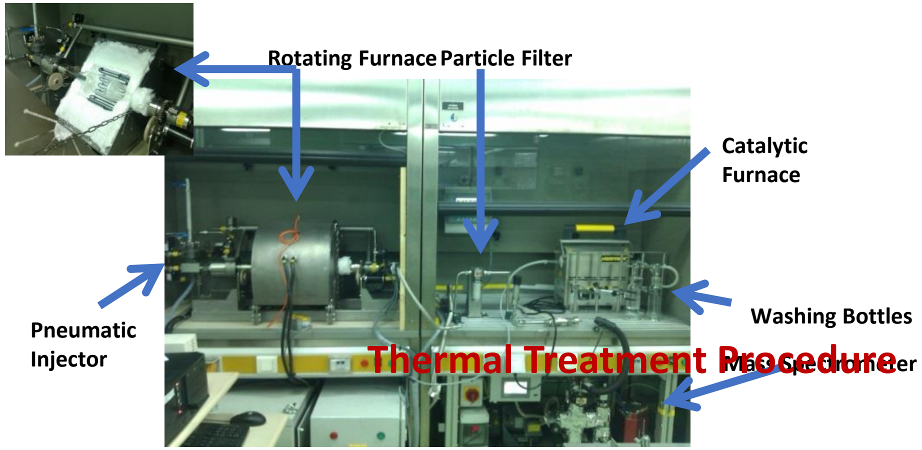
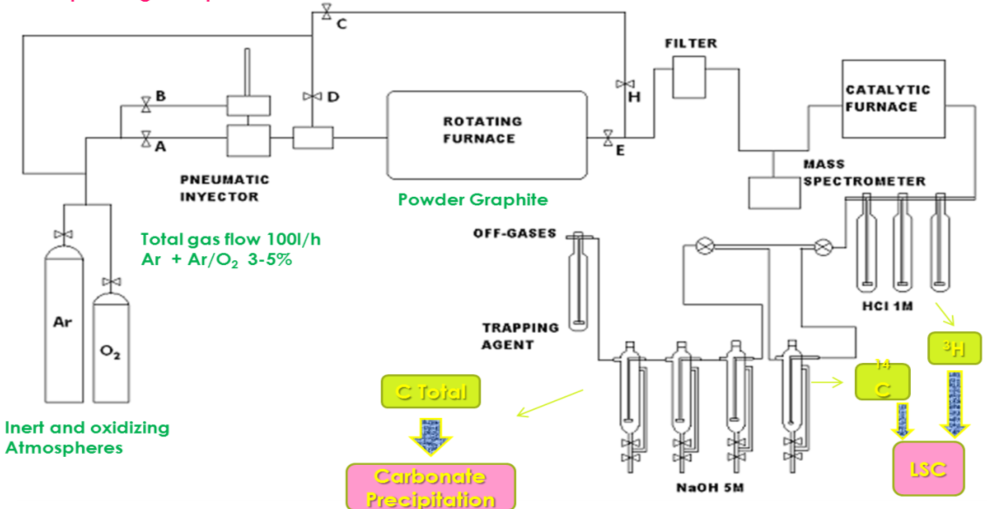
THERMAL TREATMENT STUDIES OF VANDELLOS 1 GRAPHITE.

GRAFEC project (ALD-France- ENRESA – CIEMAT)

Thermal Treatment Facility

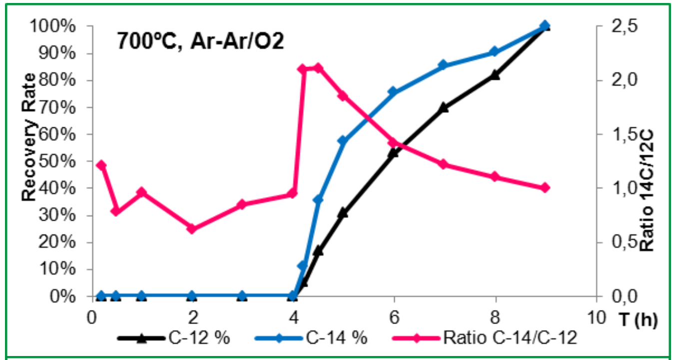


Thermal Treatment Procedure

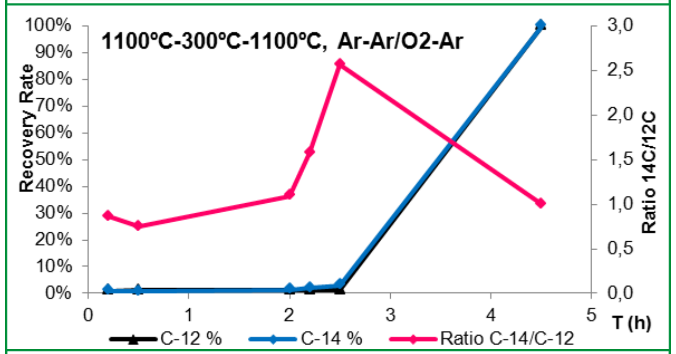


Results

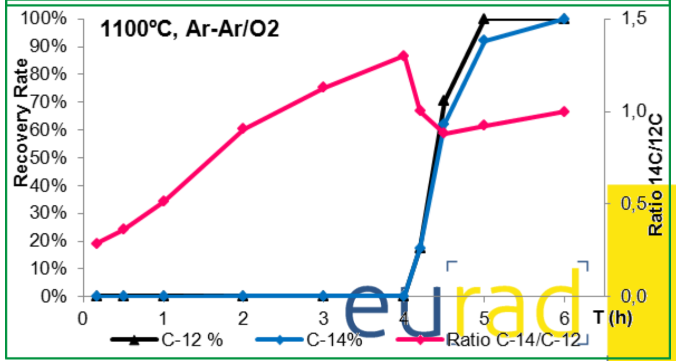
11% ^{14}C - 5% ^{12}C



3% ^{14}C - 1% ^{12}C



NO SELECTIVE SEPARATION

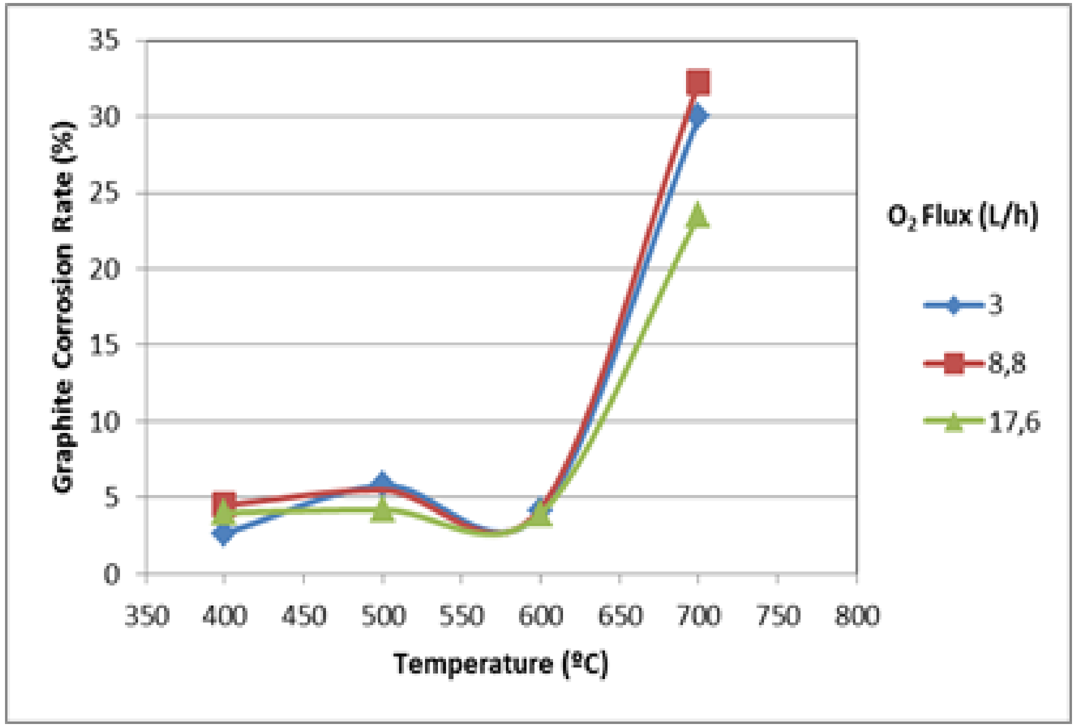


THERMAL TREATMENT STUDIES OF VANDELLOS 1 GRAPHITE. CORROSION RATE

- Corrosion rate for different fluxes vs treatment temperature
  - Behavior/Evolution of oxidation Vs O_2 flux and T ➔ to select conditions for: **minimum of corrosion and maximum of ^{14}C decontamination.**

- slope ≈0 for T < 600ºC . Corrosion rate ≈5%.

- Slopes ranging 0.20 - 0.28 for T > 600ºC. Corrosion rate 23%-33%. ➔ lower for higher flux (17.6 L/h).



THERMAL TREATMENT STUDIES OF VANDELLOS 1 GRAPHITE. DISCUSION POINTS

- **Lowest corrosion & highest ^{14}C decontamination factor**
  - ➔ T range [400ºC -600ºC]
  - ➔ O_2 flow rate < 9 l/h.
  - ⇧[CO_2] & [CO] [Ar atm. at 400ºC]
    - ➔ could be: O_2 chemisorbed in the surface and pore system, and the labile C (may be as CN groups) react ➔ without additional oxidant.
- **Decontamination ratio ^{14}C/Total C ➔ no WAC**
  - To be improved and tested
    - ➔ minimization of Corrosion rate probably kinetics of oxidation (particle size) ⇧ available ^{12}C (⇩grain size) ➔ corrosion kinetic
- **To scale up the system**
  - **Overpressure:** due to evaporation in the washing bottles (NaOH) ➔ precipitation and blocks the gas fluency.
  - ➔ additional washing bottle before ^{14}C trapping system
  - ➔ injection of new solution ^{14}C trapping system

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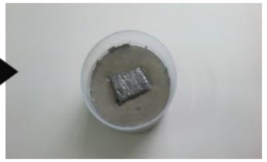
VANDELLOS 1 GRAPHITE. LEACHING

- Leaching Powder graphite. Drawbacks
  - Adsorption of powder in reactor teflon walls ➔ Static electricity
  - Supernatant of fine powder
    - ➔ avoid "quantitative" extraction of leachant
    - ➔ filtration: mass losses ~ 1 – 2 % per step
  - Difficult to adapt powder to ISO 6961("Monolithic Waste Form").

- Making volumetric sources

Select pieces (2 - 3 cm)

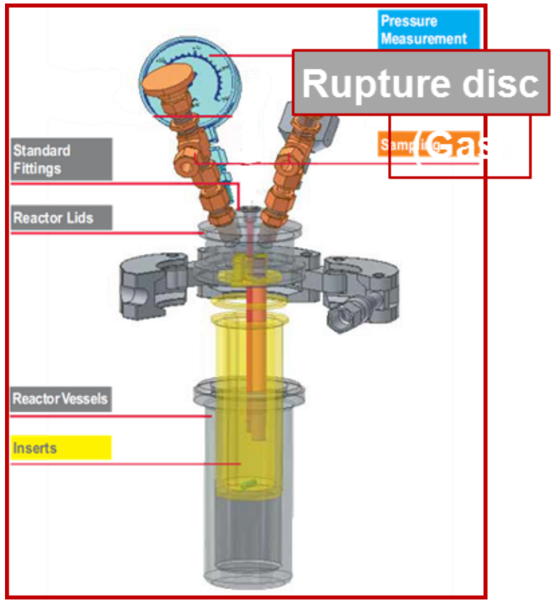


cementation

Drilling

VANDELLOS 1 GRAPHITE. LEACHING RESULTS & SPECIATION

- **METHOD – LEACHING PROCEDURE (Final Set Up).**
  - Leachants: NaOH 0,01 M, pH ~ 12, H_3PO_4 1 M, pH ~ 1



Gas sample is collected with a gas tight syringe and immediately injected into the GC-MS (speciation).

The container is opened and the leachate filtered and transferred to a PEHD bottle (filter paper and liquid are stored for ulterior analysis).

- pH & EC
- γ-spectrometry
- ^{14}C inventory
- GC-MS,ICspeciation)

The PFTE insert cleaned up with deionized water, refilled with fresh leachant and the reactor closed with its headspace purged with synthetic air.

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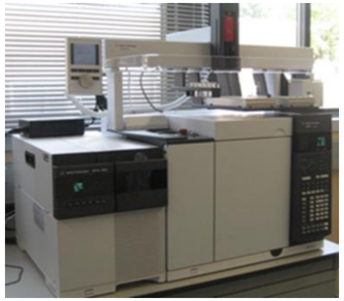
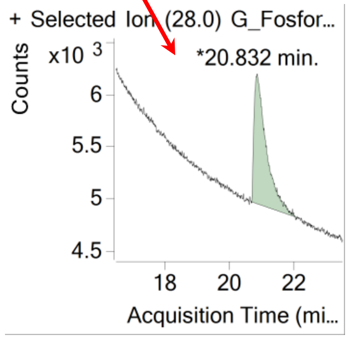
VANDELLOS 1 GRAPHITE. LEACHING RESULTS & SPECIATION

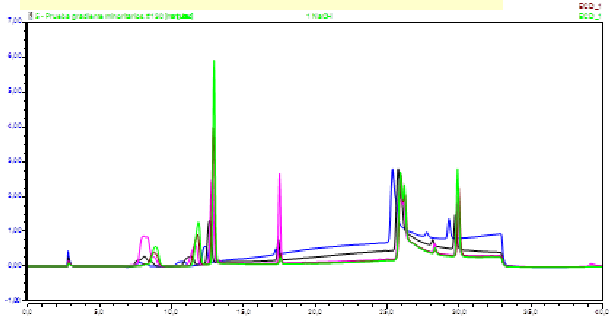
- Gases and volatile material speciation; No alcohols nor aldehydes detected in leachates
- CO detected >3.5 ppm (MDC) in gas ➔ no variation among leachiants
- **Ionic organic compounds ➔ IONIC CHROMATOGRAPHY**
  - **Oxalate compounds** found **in both media** although in **much higher concentration in H_3PO_4** (x10 – x30).
  - **Formate** was also detected **in NaOH**, not detected in H_3PO_4 because of the high phosphates concentration of this media -> higher detection limits

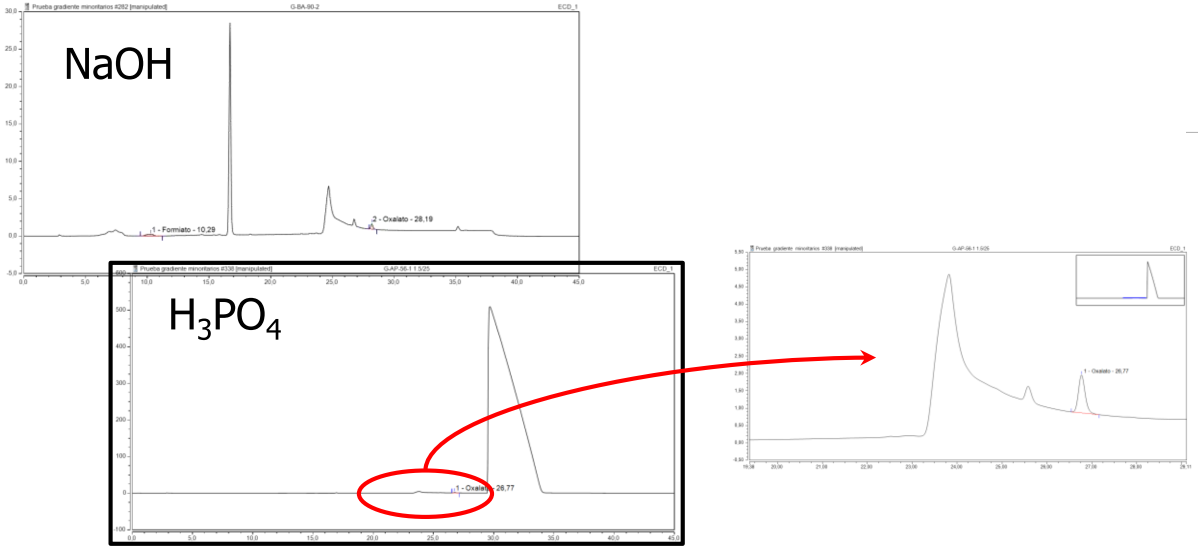


CO signal (91 leaching days in H_3PO_4)



Calibration Chromatogram Overlapping





VANDELLOS 1 GRAPHITE. LEACHING RESULTS & SPECIATION

- Initial Characterization

➔ $^{14}C \sim$ K mean

$\bar{A}$ =11 700 ± 1023 Bq/g

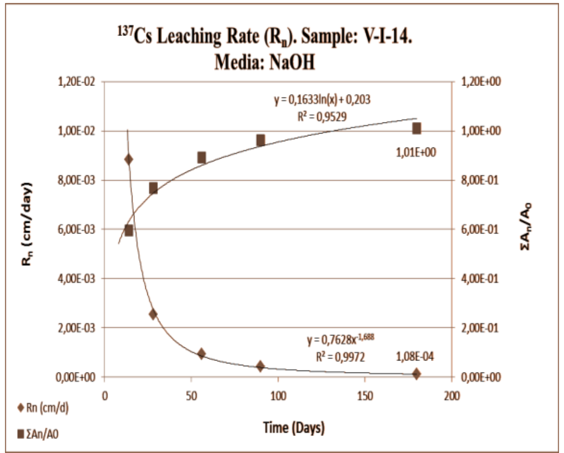
➔ heterogeneity ➔ β–γ emitters

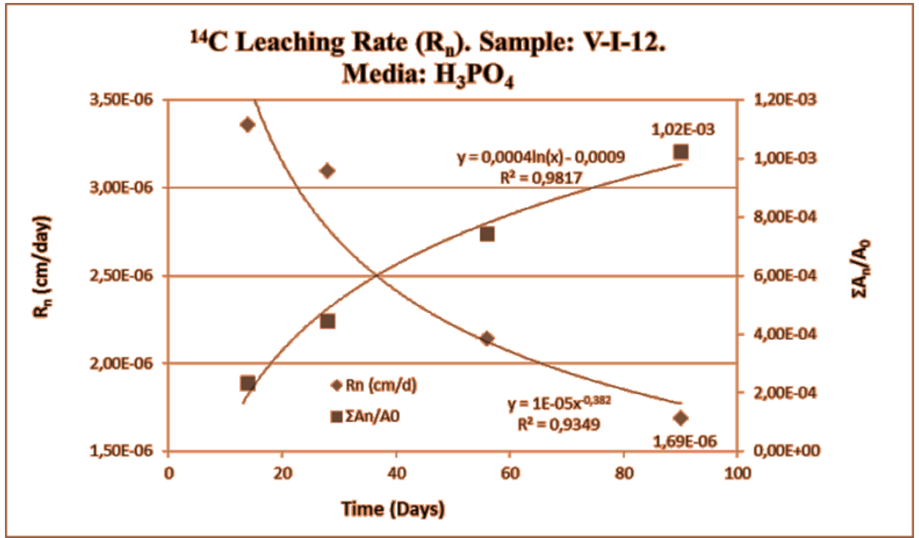
Sample	^{14}C (Bq/g)	^{60}Co (Bq/g)	^{137}Cs (Bq/g)
V-I-1	12 200	56	2 030
V-I-2	13 500	50	398
V-I-3	10 800	11	29
V-I-4	11 300	142	217
V-I-5	11 200	59	42
V-I-6	11 000	23	14

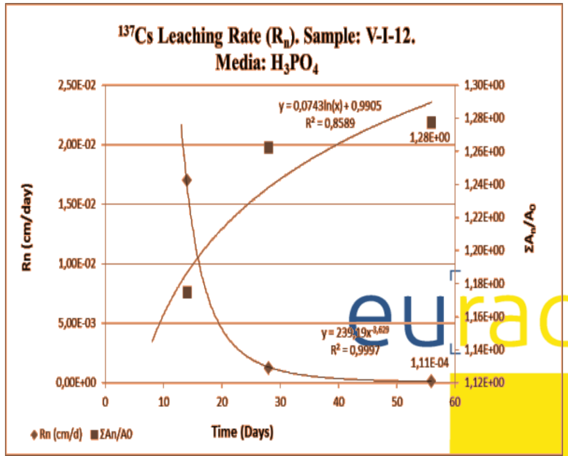
* All the uncertainties were below 10% at the 95% confidence.

H_3PO_4
2nd Stage(28 days)

- **Leaching rate**
- After 90 days ^{14}C leaching rate in acid reach 0,1 % c over the total (2E-06 cm/day).
- In basic media have not been possible to establish a leaching trend (^{14}C < MDA).







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CONDITIONING AS IGM OF VANDELLOS 1 GRAPHITE. THE SYSTEM

The method is based in the conversion of graphite into a impermeable material using an inorganic matrix (IGM). The objective is, “at least” the same final volume than graphite matrix.

- Vacuum Thermo-press to prepare IGM specimens

- Vacuum Thermo-press to prepare IGM specimens

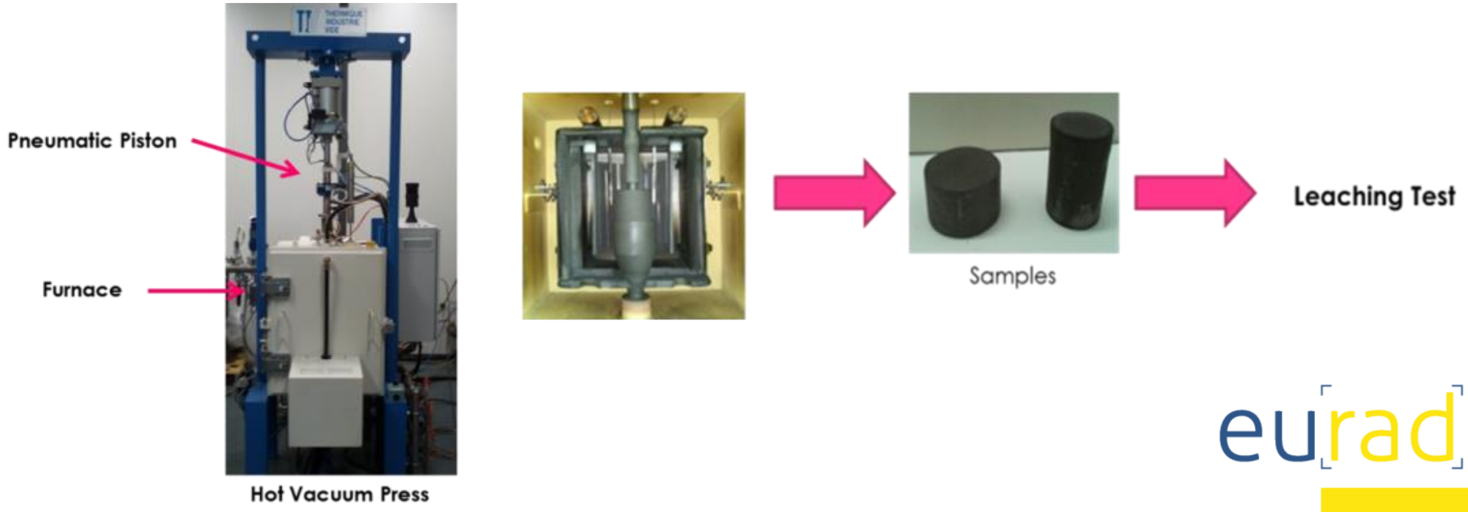
  - Assays with Virgin Graphite

Process Parameters Optimization to obtain IGM specimens with $r \geq 2.2$ g/cm.

  - Assays with Virgin Graphite

High density specimens for leaching test

- Granite-bentonite water
- Deionized water
- Acidic media (H_3PO_4)
- Alkaline media



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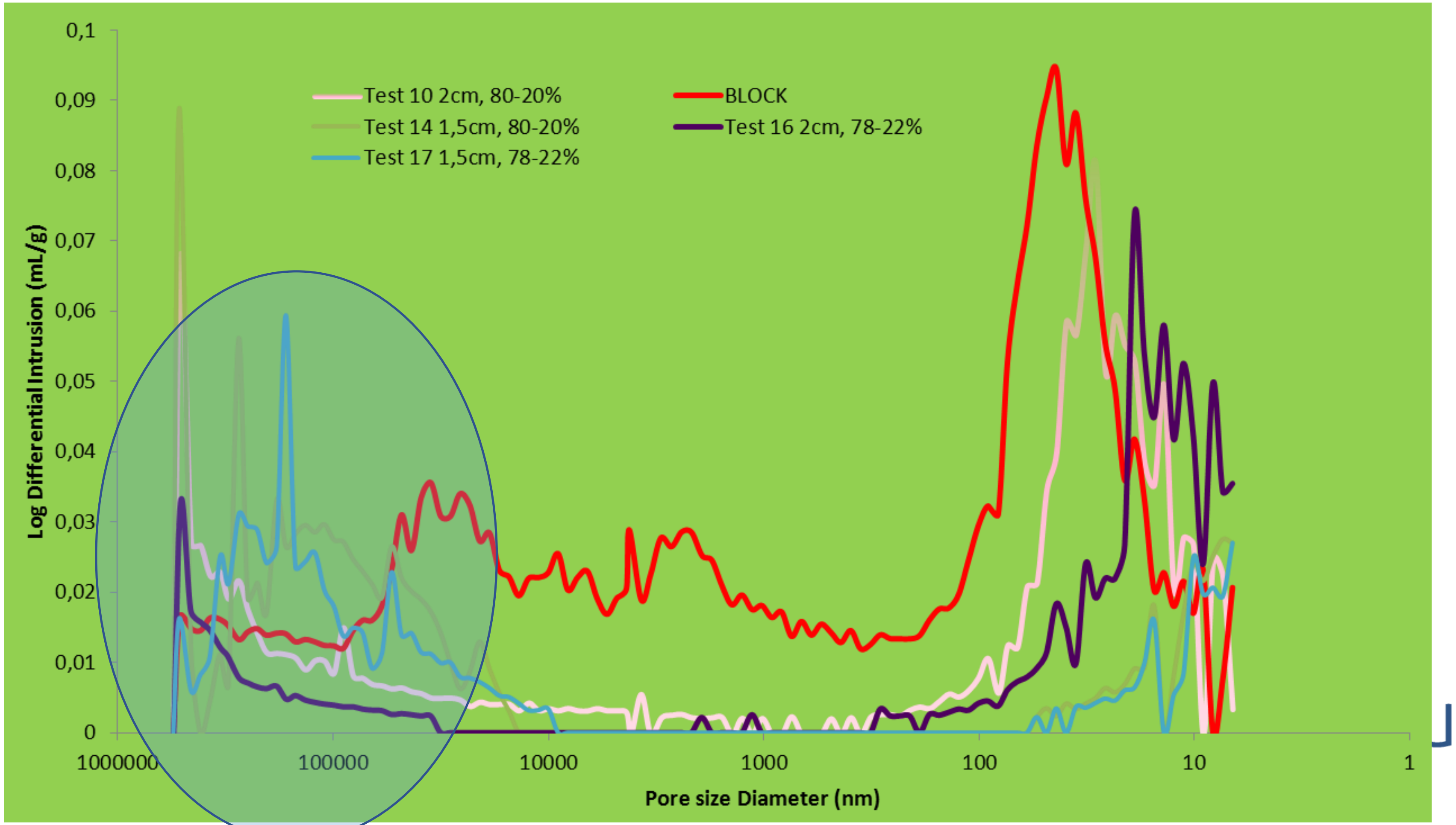
CONDITIONING AS IGM OF VANDELLOS 1 GRAPHITE. IGM CHARACTERIZATION

- **Mercury Porosity**

Decrease the pore system, close the open porosity (>50 nm)

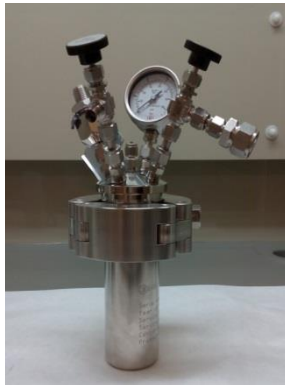
Samples

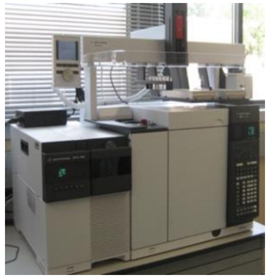


CONDITIONING AS IGM OF VANDELLOS 1 GRAPHITE. LEACHING

- Leaching test on gaseous and liquid to determine in i-graphite and IGM:
  - Long term C-14 release
  - C-14 species
- Leaching procedure ISO 6961. Leaching rate basis (cm/day). (Room temperature and oxidant atmosphere)

$$R_n = \frac{a_n}{a_o} \times \frac{V}{S} \times \frac{1}{t_n}$$





GC-MS

HPLC (IC)

Low backgr LSC

CONDITIONING AS IGM OF VANDELLOS 1 GRAPHITE. LEACHING

- Leaching media for i-graphite and IGM:
  - NaOH a pH = 12
  - H_3PO_4 pH = 1
  - Granite-Bentonitic water
  - Deionized Water

- Leaching Tests:
  - Whole leachant reposition (in each step). Dynamic ➔ CAST
  - Reposition of aliquot taken (in each step): Semi-dynamic ➔ GRAFEC

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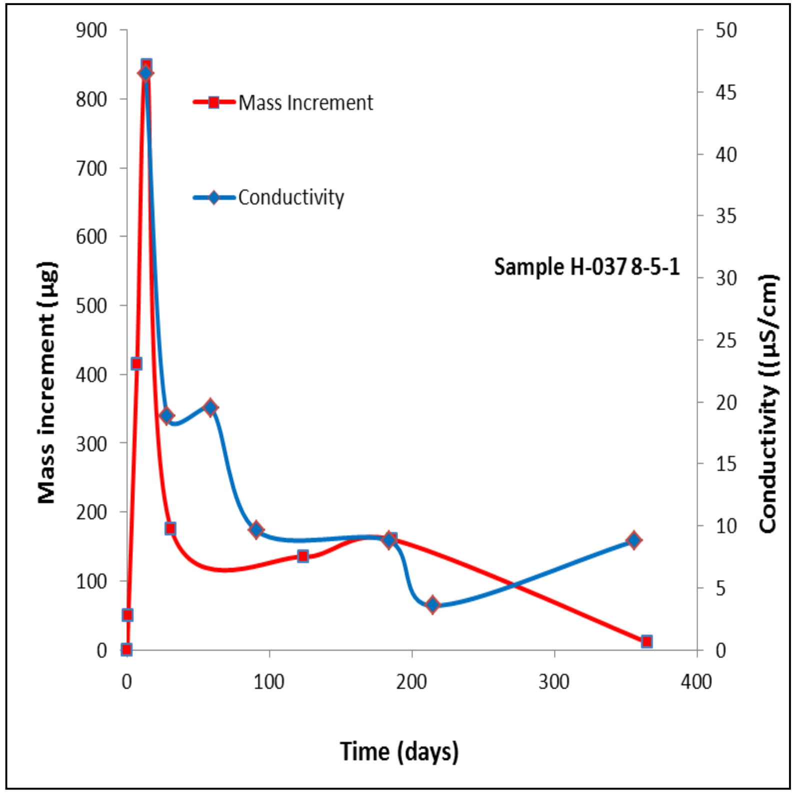
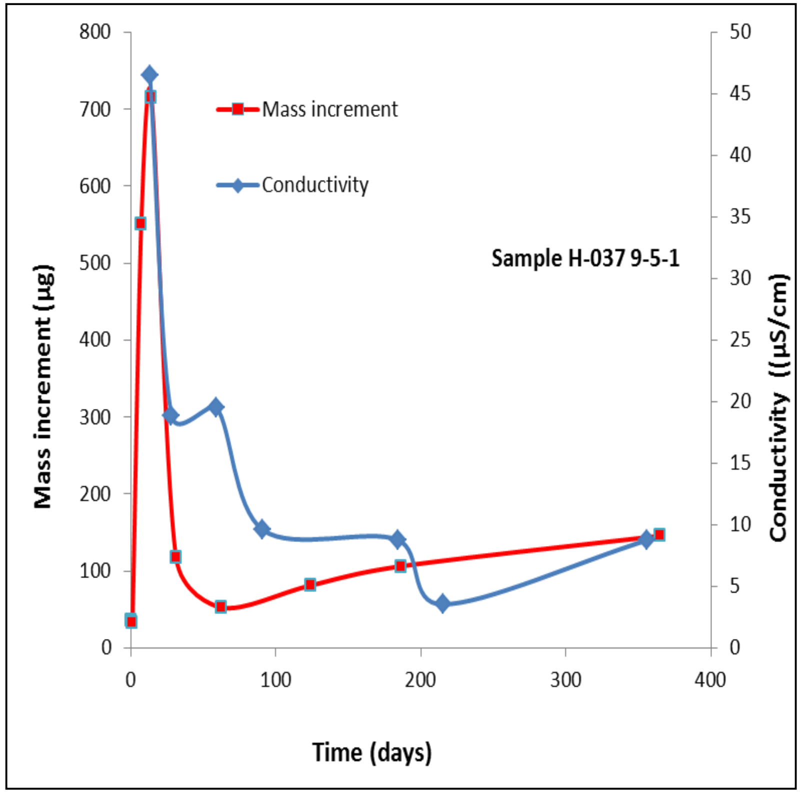
CONDITIONING AS IGM OF VANDELLOS 1 GRAPHITE. LEACHING

- The pH and EC profiles in function of leaching time, has been cross-checked with the total ion concentration found in the determination of IGM matrix corrosion behaviour
- is observed that the increase in conductivity coincides effectively with the presence of dissolved ions
- Dissolution from the glass matrix ➔ ⇧ EC ➔ ⇩secondary phases ➔ Encapsulation





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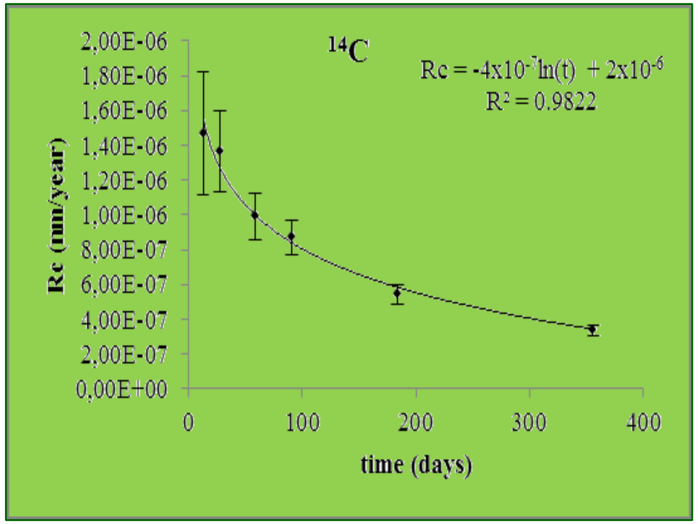
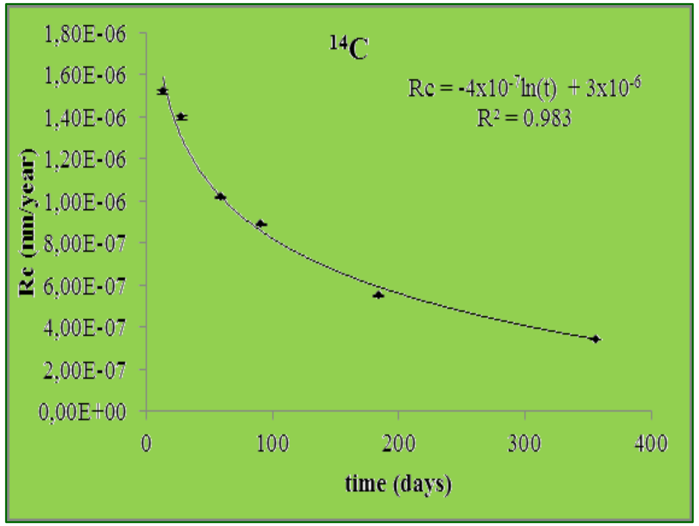
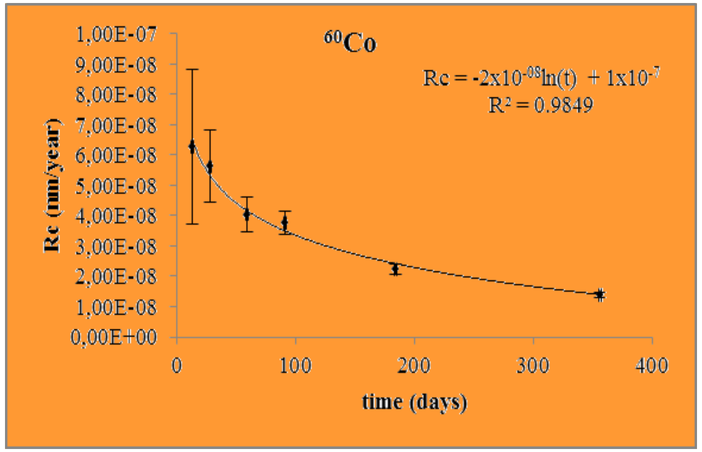
CONDITIONING AS IGM OF VANDELLOS 1 GRAPHITE. LEACHING RESULTS

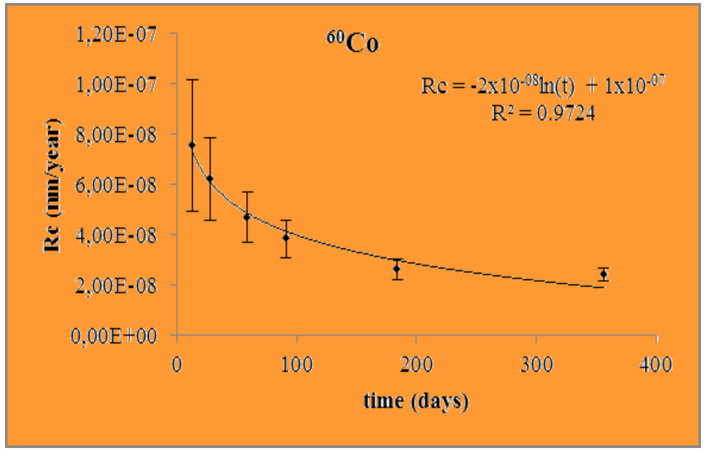
- **Corrosion rates of ^{14}C:** The corrosion rate decreases with time to a constant value.➔∀ [^{14}C] < MDA





- **Corrosion rates of β–γ emitters** The corrosion rate decreases leading by logarithmic trend.





CONDITIONING AS IGM OF VANDELLOS 1 GRAPHITE. LEACHING SPECIATION RESULTS

- **Gas and Leachate Volatile Species by GC-Mass Spectrometry**
  - Negligible amounts of leachant vaporization have been registered during the leaching time.
  - The assays to analyze alcohols and aldehydes. Both have not been detected in the leaching process, the absence of a signal ➔ Not enough time to form them

➔ No thermodynamic and kinetic conditions

  - CO was found in concentrations of 27.9 mg/l and 10.4 mg/l. This can be associated to the carbonate content in the leachate.
- **Corrosion rates of ^{14}C**
  - The corrosion rate decreases with time to a constant value.➔ **$\forall$ [^{14}C] < MDA**

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CONDITIONING AS IGM OF VANDELLOS 1 GRAPHITE. DISCUSSION

- A methodology has been established to manufacture IGM samples at laboratory scale.
- The durability of the IGM glass matrix has been validated by leaching experiments.
- It is possible to close the pore system in i-graphite without increasing the volume of the waste.
- **Conductivity and pH:**
- Deionized water : Increase, ➔ ions migrate from IGM into the leachant.
- **Organic carbon**
- Deionized water: formate (HCOO-) and oxalate (COO_2=).
- Volatile alcohols and aldehydes: No signal for volatile ➔ not enough formation time/ no thermodynamic and kinetics
- **CO**
- Negligible amounts of leachant vaporization have been registered
- Gas phase : First leaching period with deionized water, 33.9 mg/l
- First and second leaching period with granitic-bentonite water, 27.9 mg/l and 10.4 mg/l
- **^{14}C and ^{60}Co**
- Values < MDA, no correlation ➔ No scaling factor methodology.
- Leached amount of ^{14}C & ^{60}Co indicate the sealing capacity of IGM as final waste form..

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STRATEGY ACCORDING THE RESULTS

- The Route for the final disposal as L&ILW of Spanish i-graphite must be defined:
  - An in situ **RETRIEVAL** methodology to ensure the graphite-powder to ensure the treatment and conditioning
  - An in situ **TREATMENT** (decontamination) methodology to eliminate from the graphite structure the radiocarbon content (as much as possible)
  - An in situ **CONDITIONING** that ensure lomg term behavior of matrices:
    - Cemented graphite for the backfilled mortar
    - Geopolymeric Grafphyte for both backfilled and conditioned graphite in this "cementitious" matrix
    - Vitrifyed graphite in IGM as waste form as been established to manufacture IGM samples at laboratory scale.
- The fulfillment of WAC in this stage ensure the fulfillment of WAC in the VLLW and L&ILW repository
- If the radiological WAC can not be meet then a Intermediate Geoogival Disposal (medium deep) could be the alternative

THANKS FOR ATTENTION

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 847593.