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SEVENTH FRAMEWORK PROGRAMME

CARBOWASTE

Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste

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1st Periodic Report

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CARBOWASTE		
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- 1st Periodic Report -

Executive summary

The CARBOWASTE project was officially started on First of April 2008 with a ‘fixed starting date’. The Grant Agreement was signed on April 25, 2008. The Kick-Off Meeting took place at Forschungszentrum Juelich on 6 and 7 of May 2008.

The Grant Agreement was countersigned on May 30, 2008 by the European Commission and received on June 10, 2008, with a total budget of 6 million EUR funding. The Pre-financing has been received on July 3, 2008. 1 487 688 EUR have been transferred to the partners, on August, 26, 2008.

Some delay occurred due to the administrative process, problems in hiring e.g. candidates for PhD, identification of adequate sample material, transport issues, ordering / commissioning of experimental facilities etc.

Meanwhile, all WPs are active and first results become available.

Several workshops and conferences have been used to disseminate information on the project objectives.

Revisions

Rev.	Date	Short description	Author(s)	Internal Review	WP Leaders	Coordinator
00	dd/mm/yyyy	Issue	Name, Organisation	Name, Organisation *Signature*	Name, Organisation *Signature*	Name, Organisation *Signature*
01	20/05/2009	First issue	WP-Leaders/ Coordinator	Vulpius FZJ Vu		W. von Lensa
02	29/05/2009	2nd Issue	WP-Leaders/ Coordinator	Vu		W. von Lensa

Declaration by the scientific representative of the project coordinator

I, as scientific representative of the coordinator of this project and in line with the obligations as stated in Article II.2.3 of the Grant Agreement declare that:

- The attached periodic report represents an accurate description of the work carried out in this project for this reporting period;
- The project (tick as appropriate):

  ☐ has fully achieved its objectives and technical goals for the period;
  X has achieved most of its objectives and technical goals for the period with relatively minor deviations[1];
  ☐ has failed to achieve critical objectives and/or is not at all on schedule[2].

- The public website is up to date.
- To my best knowledge, the financial statements which are being submitted as part of this report are in line with the actual work carried out and are consistent with the report on the resources used for the project (section 6) and if applicable with the certificate on financial statement.
- All beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, research organisations and SMEs, have declared to have verified their legal status. Any changes have been reported under section 5 (Project Management) in accordance with Article II.3.f of the Grant Agreement.

Name of scientific representative of the Coordinator: Dr. Werner von Lensa

Date: 29/ 05/ 2009

Signature of scientific representative of the Coordinator: ....

[1] If either of these boxes is ticked, the report should reflect these and any remedial actions taken.
[2] If either of these boxes is ticked, the report should reflect these and any remedial actions taken.

1 Publishable summary

CARBOWASTE

Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste

The objective of the CARBOWASTE project is the development of best practices in the retrieval, treatment and disposal of irradiated graphite and other carbonaceous waste like structural material e.g. non-graphitised carbon bricks or fuel coatings (pyrocarbon, silicon carbide). It addresses both legacy waste as well as waste from future generations of graphite-based nuclear fuel.

After defining the various targets for an integrated waste management, comprehensive analysis of the key stages from in-reactor storage to final disposal will then be undertaken with regard to the most economic, environmental and sustainable options. This will be supported by a characterisation programme to localize the contamination in the microstructure of the irradiated graphite and so more to better understand their origin and the release mechanisms during treatment and disposal.

It has been discovered that a significant part of the contamination (including ^{14}C) can be removed by thermal, chemical or even microbiological treatment. The feasibility of the associated processes will be experimentally investigated to determine and optimise the decontamination factors. Reuse of the purified material will also be addressed to close the ‘Graphite Cycle’ for future graphite moderated reactors. The disposal behaviour of graphite and carbonaceous wastes and the improvement of suitable waste packages will be another focus of the programme.

During the first year of the CARBOWASTE project, Work Package 1 activities have focussed on developing a thorough understanding of the current world wide knowledge on irradiated graphite and the issues associated with the development of an ‘integrated approach to waste management‘.

The main focus has been on the production of a review volume describing the irradiated graphite position in various countries and regions, and the development of a route map identifying the key factors and data that influence and inform waste management strategy. Subsequently, efforts have focused on identification of key data gaps.

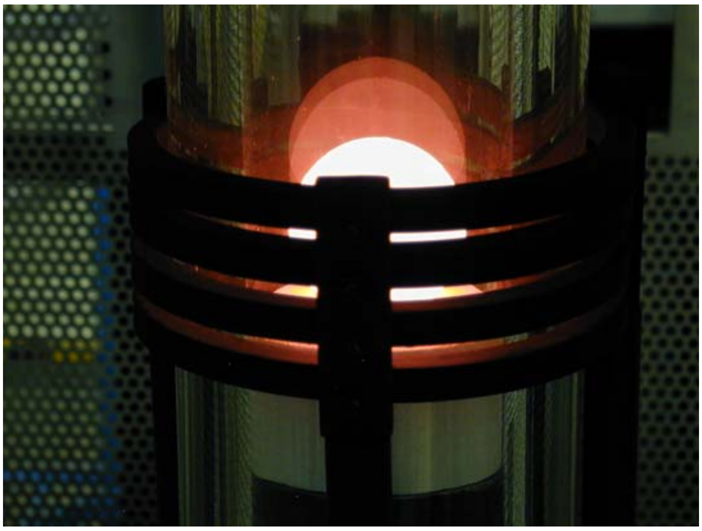
A review has been carried out of Multi Criteria Decision Analysis (MCDA) techniques, and the identification of suitable options for deployment in the second and third years of the project. MCDA is an important component in the CARBOWASTE toolbox of techniques.

Work Package 2 covers the retrieval and segregation of i-graphite predominantly from the cores of nuclear reactors at the decommissioning stage. The elaborated reports contain information on input data, R&D gaps and retrieval strategies including numerical modelling of retrieval procedures to support the toolbox.

High-Temperature Reactor (HTR) fuel needs specific segregation techniques to separate the coated particles from the moderator graphite. New equipment for pulsed power fragmentation of HTR fuel compacts have been constructed and put into operation. Complementary work is performed by the South African Partners applying chemical, electrochemical deconsolidation and molten salt methods.

The progress on Work Package 3 shows basically the setting-up of the characterisation, structural and radioanalytical methodologies in order to face the needs of the project in this field for inventory determination, for qualification of the treatment methodologies and for demonstrating the behaviour of i-graphite in repository conditions. The work performed is based on the virgin and irradiated samples available in each lab due to the fact that the sample management is not finished at the end of the period. Sample transports will be started, soon. Round Robin Tests (RRT) are foreseen to compare the capabilities of different analytical methods. The characterisation and homogenisation of identical samples for all participating labs has been finished. RRT rules have been established and will be sent to the partners together with the sample material.

Methods for removal of radioactive contamination (incl. ^{14}C) from irradiated nuclear graphite are being developed in Work Package 4. One option is based on the selective oxidation of ^{14}C whereby the graphite matrix remains widely unaffected. Consequently, it was concluded that ^{14}C in the graphite matrix is not on regular places in the graphite lattice, but rather adsorbed on inner surfaces of the porous graphite structure or between the crystal planes or in a chemical form which is easier to oxidise compared to the ^{12}C of the graphite matrix. Presently an investigation of the chemical form and of the binding relations of ^{14}C is in progress.



Graphite Ball (6cm diameter) at 1000°C

A new facility with an inductive furnace has been built to remove radioactive contamination by heating up to 2500°C, under injection of reactive gases (see figure above).

Work Package 5 is concerned with the recycle and reuse of irradiated graphite. The activities during the first year of the project have been mainly concerned with reviewing existing experience relevant to potential recycling activities. A full report has been produced covering this. Discussions have been held with the graphite manufacturers (including visits to their facilities) enabling them to define their experimental work programmes and so to commence production of trial simulated recycled materials. Work on isotope separation was started. Significant progress has also been made on the use of recycled graphite as a means of decontaminating solutions.

In Work Package 6, the performed activities are characterised by bibliographic studies, compilation of previous results, and by design and setup of first experiments. Sample lists were prepared for active and inactive samples. Sample characterisation has started. First important observations are that ^{36}Cl is bound in graphite both in organic and inorganic bonding, that leaching of this ^{36}Cl may vary between 10 and 90% of the original inventory and that water transport in graphite is very fast. The retention of ^{36}Cl on cementitous barrier materials was found to be relatively low. New matrices for confinement of graphite powders were characterised.

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2 Project objectives for the period

In **Work Package 1**, the work in the first year has focussed on the following activities,

- the preparation of review volume (issue 1);
- development of the CARBOWASTE route map for irradiated graphite;
- identification of data gaps;
- evaluation of Multi Criteria Decision Analysis (MCDA) techniques;
- identification of high tier retrieval criteria;

In addition to these activities a WP1 workshop was planned to encourage interaction, facilitate communication and to allow the review of documents by all participants.

Work Package 2 was required to liaise with Work Package 1 with a key milestone being the issue of a technical review report being required to address the i-graphite configuration and environment, and associated constraints and requirements for a range of reactor types. Of particular interest are radiological, reactor design, and graphite mechanical integrity considerations and the input of "route map" issues derived in WP1 activities and workshops. A Data Pack aimed to identify gaps in knowledge and information relevant to retrieval and segregation. Another part of this work package was devoted to the segregation of i-graphite from High-Temperature Reactor Fuel and the removal of coatings from the coated particles.

The objectives of **Work Package 3** were basically directed to the setting-up of the methodologies of characterisation, structural and radioanalytical in order to face the needs of the project in this field for inventory and structure determination. This supports the qualification of the treatment methodologies and the demonstration of the behaviour of i-graphite in repository conditions. The work addresses virgin and irradiated samples available in each lab due as long as the sample transports are not yet performed. The Round Robin Test (RRT) rules and sampling had to be established and the transport had to be prepared.

The main objective of **Work Package 4** is to develop procedures for efficient decontamination of used reactor graphite, e.g. the separation of radioactive contamination and especially of ^{14}C, tritium, ^{36}Cl etc. from the graphite matrix by thermal, chemical and micro-biological treatment. A successful separation could reduce the radiotoxicity of the graphite waste and offer a more favourable disposal or reuse strategy. The activities in the first year are directed to the construction of experimental facilities and first experimental confirmations.

Work Package 5 is dealing with the good environmental practice that disposal of waste should be the last resort selected only after preferable alternatives have been considered. These alternatives include minimisation of waste generation, reuse of the materials in their current form or recycling the materials through appropriate processing to form new products. This work package is concerned with creating opportunities to reuse or recycle graphite, or constituents of graphite such as ^{14}C. It is thought that the major opportunities will be associated with recycling rather than reuse, but any opportunities identified to reuse graphite in its existing form will be included.

The overall objective of **Work Package 6** is the assessment of disposal properties of graphite and other carbonaceous wastes. In the reporting period, the objective of the work performed in WP6 is of preparatory nature: to provide a sound knowledge base on the present state of the art using bibliographic studies and a compilation of previous results, and to design, setup and start first experiments. Lists of active or inactive samples should be prepared and sample transport to different laboratories should be initiated and sample characterisation to be started.

3 Work progress and achievements during the period

3.1 Work Package 1: Integrated Waste Management Approach

3.1.1 Preparation of the Review Volume (Task 1.1)

A "Review Volume" or Summary Report has been collated to describe the current position internationally regarding the management of irradiated graphite. Nine of the CARBOWASTE participants have been involved in the preparation of fifteen chapters and an extended summary that comprise the Review Volume.

The volume is broken down into a series of chapters (15); following on from an *introduction* and *Nuclear Graphite Overview*, most chapters are regionally focussed, describing the situation in one or more counties. Two further chapters will focus on the disposal and leaching of irradiated graphite, and carbon dioxide sequestration.

"Regional" based chapters
Asia
France
Germany
Italy/Spain
Japan
Lithuania
Other Member States
PBMR
Russia
UK
US

Each of the 'Regional' chapters considers (where applicable) the following subject areas as outlined in the Specification Document, issued in May 08.

- Legislative and regulatory framework;
- Policy objectives of decommissioning;
- Compliance with international guidelines and regulations;
- Decommissioning of nuclear reactors – current situation;
- Graphite characteristics;
- I-graphite/carbonaceous wastes retrieval options;
- Treatment/conditioning techniques/processes used on retrieved irradiated graphite.

On average the chapters are about 35 pages in length, and collectively make the document a most comprehensive irradiated graphite review of this nature. This is a live document and will undergo annual review to ensure during the latter three years of the CARBOWASTE project that new data/information made available from the project and/or elsewhere is considered. These annual reviews will probably be stand alone shorter documents.

Further to the original scope, an extended summary is in preparation, which identifies key features of the individual chapters, to allow readers to quickly appreciate the irradiated graphite waste management challenge and the current gaps in knowledge.

The irradiated graphite position varies widely from country to country; for example, in terms of inventory, reactor type and in the availability of data. Indeed, some chapters contain significant irradiated graphite data (predicted and measured) of the radionuclide composition, in particular the C-14 and Cl-36 values, whilst others rely on predicted values and some with little or no details.

Some Member States are now re-evaluating the predicted data.

There is a paucity of decommissioning and irradiated graphite retrieval information. With the exception of three significant examples (GLEEP, WAGR and Fort St Vrain), containing about 1000 tonnes of irradiated graphite in total, there has been no graphite moderated commercial reactor that has undergone stage 3 decommissioning. The techniques and procedures employed for these smaller reactors have largely been influenced by the design, operational mode and final destination of the retrieved graphite.

PBMR has evaluated a number of internal PBMR reports detailing the take of the company on the handling and management of carbonaceous waste once the pebble bed reactor becomes operational. Included is a number of international (including IAEA) reports. A summary report detailing PBMR's waste strategy as well as expected characteristics of PBMR waste was generated and made available to the WP1 Lead. A request made during the Avignon Steering Committee Meeting during April 2009 with respect to the availability of the PBMR internal reference documents was taken up with the PBMR Chief Technology Officer. This request was approved and these documents will be made available to the WP1 Lead in due course.

Some regional chapters describe techniques for the treatment of graphite to reduce/remove the C-14 content, largely to either re-classify the irradiated graphite or make disposal easier. The techniques evaluated have either been at laboratory scale and in a few cases at demonstration / pilot scale.

As expected the whole review exercise has identified some major knowledge/data gaps and also provides some clear indications on where other work packages should concentrate their efforts.

3.1.2 CARBOWASTE route map (Task 1.2)

A key task within the CARBOWASTE project is the development of an irradiated graphite road/route map. The purpose of this map is to identify the factors and data that will influence the development of integrated waste management strategies. The CARBOWASTE route map has been developed through workshops and issued to all WP 1 participants and work package leaders for input and comments. The map was presented and reviewed by participants in the work package 1 workshop (Feb 09) and also outlined at the 2nd CARBOWASTE Steering Committee Meeting (April 2009).

The route map comprises of 6 major stages viz:

- Identify magnitude of problem and other major considerations
- Retrieval of irradiated graphite and/or other options
- Interim storage/considerations prior to treatment selection
- Irradiated graphite treatment options
- Re-use/recycle
- Disposal

Some of the required information has already been secured from the review exercise whilst many more questions will be answered by the CARBOWASTE project. The route map is also considered a living document and will potentially be updated as further considerations emerge from the project.

The route map complements the review exercise and vice-versa. It is also underpins the retrieval criteria and helps to direct the research/activities of the other Work Packages.

3.1.3 Identification of Data Gaps (Task 1.3)

As described earlier, task 1.1 – the review volume has focussed on collating a knowledge base on world wide irradiated graphite, whilst task 1.2 has focussed on identification of information that influences the selection of waste management strategies. These two exercises have been used to identify the data gaps. One session of the Work Package 1 workshop was aimed at identification of information gaps with work package 1 participants, and this is reported in the workshop minutes.

Following the steering group meeting where work package leaders described their work programmes, consideration is now being given to how other work packages may help to fulfil these data requirements.

3.1.4 Review of Multi Criteria Decision Analysis Techniques (Task 1.4)

An extensive review of MCDA techniques has been carried out and reported (T1.4.1). There are a very large number of MCDA tools and techniques reported in the literature and this report was kept to a manageable size by drawing heavily on a number of previous reviews of decision making tools and techniques. Several of these have been carried out at national and European levels. The report then describes the MCDA tools and techniques that are prominent in use and in the literature, starting with the most basic ‘elementary’ techniques and progressing to the more sophisticated and flexible methods.

The inherent strengths and weaknesses of the main methods were considered. There is a range of techniques which are suitable for deployment on the CARBOWASTE project, depending on the precise application, and these will be considered further in the next phase of work (D1.4.2)

3.1.5 Undertake MCDA at key stages of the road map (Task 1.5)

No activities were yet foreseen in this period.

3.1.6 Identification of high tier retrieval criteria (Task 1.6)

Although the bulk of the work on retrieval of irradiated graphite falls within WP2, the NNL in collaboration with the leader of the retrieval tasks/deliverables (Doosan-Babcock) agreed to identify the key considerations for selection of a retrieval method. Several meetings involving the appropriate experts within the NNL and meetings with other WP1 participants (Doosan-Babcock and AMEC) considered these high tier and lower tier criteria. The resulting criteria were distributed to all WP 1 participants and other Work Package Leaders for consideration.

A similar tiered approach to the development of the route map was conceived, as the high tier criteria had to be sufficiently broad to accommodate all CARBOWASTE participants’ needs and relevant to future graphite moderated reactors. The lower tier considerations/criteria will then be developed to accommodate requirements for specific reactor designs.

The higher tier criteria were judged to be:

- Stakeholder requirements;
- Environmental impact;
- Risk assessment.

This approach to the development of high level criteria fits with the major CARBOWASTE deliverable 'a European irradiated graphite waste management Tool Box that all stakeholders can employ to develop the most appropriate solution for their country'.

3.2 Work Package 2: Retrieval & Segregation

WP2 activity is integrated with WP1 as it is important that the Retrieval and Segregation analysis takes account of existing practice, anticipated i-graphite location and condition and the potential route map options for i-graphite. Consequently, work on WP2 only commenced in earnest following significant activity in working with NNL on WP1 as follows.

The key activities of relevance to WP2 were:

- contribute to the development of step 2 of the route map,
- contribute to chapters describing the status of i-graphite retrieval and segregation arising from prior UK experience
- identify the properties of i-graphite that would be relevant to retrieval and segregation (this activity is on-going into period 2)

3.2.1 Radiological, reactor design and graphite mechanical integrity considerations (Task 2.1)

Doosan Babcock, working closely with NNL and AMEC derived criteria and other issues relevant to the retrieval and segregation process including a workshop. Doosan Babcock developed this further and reported it in T-2.1.1 Data Pack technical report.

As WP1 reached an appropriate point of publishing information for the review report specification of the contents of the Data Pack Technical Report T-2.1.1 was initiated and facilitated by organisation of a WP2 day added on to a WP1 workshop in Manchester. This was an additional opportunity not originally planned and proved of great assistance for Doosan Babcock to then produce and issue on SINTER the Data Pack. The review chapters of WP1 to identify information are of specific interest to WP2 Task 2.2.

Technical Report T-2.1.1 was issued in draft to beneficiaries for comment in March 2009. This document is a working document as it is intended to promote knowledge transfer and not act as a major constraint.

3.2.2 Examination of retrieval and segregation options (Task 2.2)

The Data Pack has identified as inputs to the planned workshop under task 2.2:

- the proposed retrieval and segregation process
- the key issues (processes/working environment, access routes, graphite detail, and preliminary waste route) that will constrain potential solutions
- assumptions, constraints and exclusions that will impact on the development of solutions
- a review of the source data produced in WP1
- a gap analysis in the information needed for Retrieval and Segregation
- a review of the reactor designs, i-graphite and other influential components/geometries that may be encountered

- an analysis of the influence of waste routes
- proposals as to the value and use of the toolbox
- initial examination of criteria, risk and hazard issues
- a list of actions for WP2 beneficiaries to consider before at the workshop has been produced.

3.2.3 Diagnostic and modelling activities

No activities were foreseen in the current reporting period.

3.2.4 Conditioning of HTR-waste (Task 2.4)

3.2.4.1 Fragmentation of HTR compacts by pulsed power

The new pulsed power equipment is operational since November 2008 after many preliminary tests and safety demonstration (figure 3.2.1).

A parametric study has started with non-irradiated compacts. The different parameters are the energy, the frequency and the number of the pulse, the liquid medium into the reactor and the number of compact per run.

The compacts contain different amount of inert TRISO-particles (0 %, 10 % and 20 %).

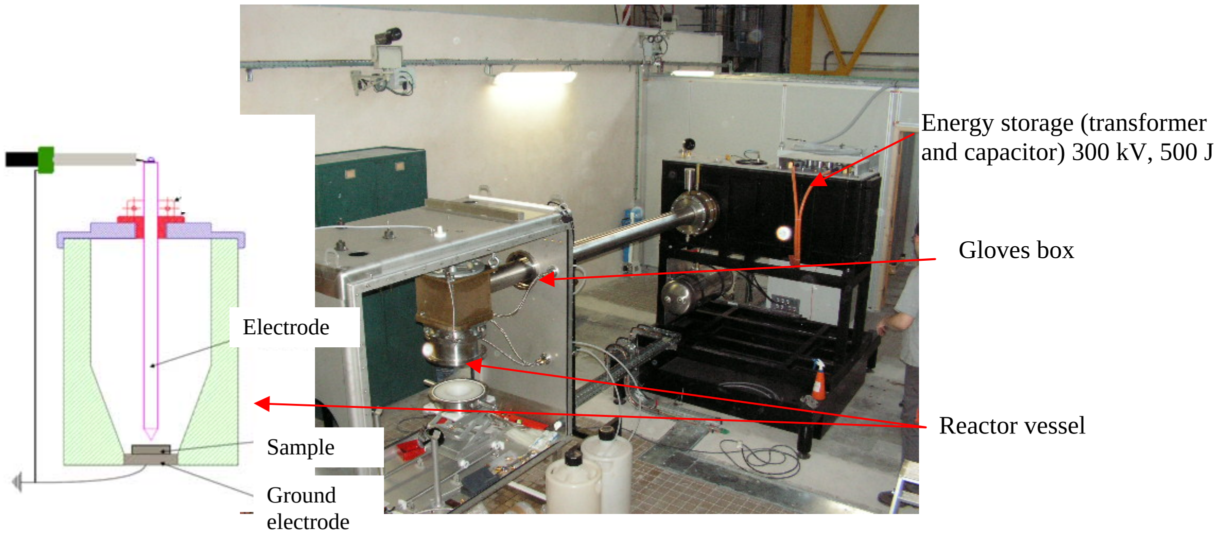

Figure 3.2.1: Pulsed power fragmentation facility at CEA Marcoule

These runs are made with energy of 3.4 kJ / pulse. The diameter of the Triso particle is about 700 µm. Preliminary results are very promising. The results indicate that after 3 pulses, 75 % of particles are released from the graphite and the coating. Two values of energy (0.5 kJ/pulse and 3.4 kJ/pulse) were tested. Fragmentation is more efficient for a high value of energy by pulse. But the production of undersize is more important.

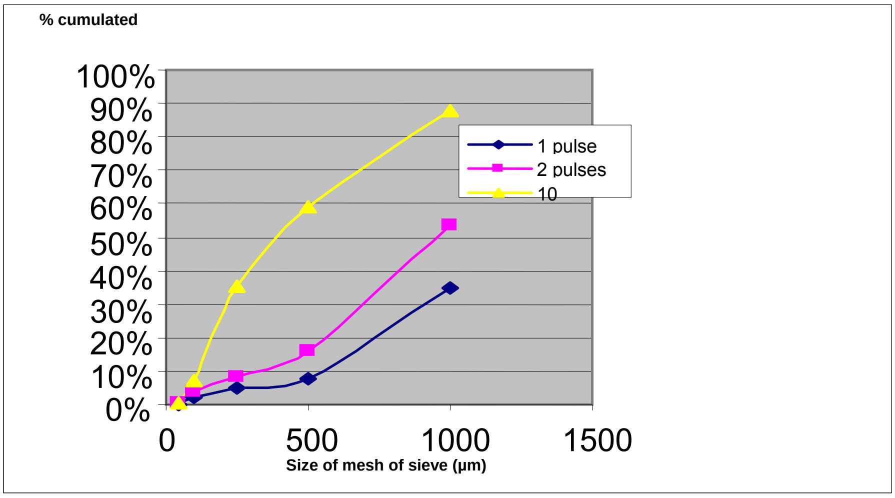

Figure 3.2.2: fragmentation of 1 compact (pulse of 3.4 kJ)

Compacts with particles are more easily broken than compacts without particles. This fact is known because the fragmentation is done generally at the interface. Compared with compact without particle, an amount of 20% of particles in the compact divides by 2 the energy for fragmentation. In addition, irradiation will create failure and will weaken the interface.

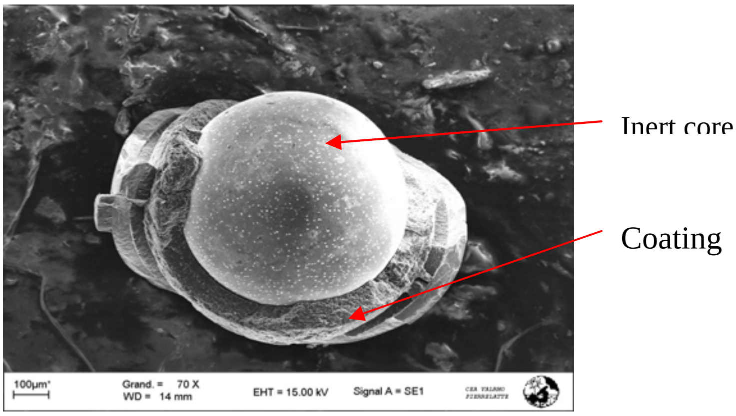

Figure 3.2.3: Triso particle after fragmentation test at 3,4 kJ

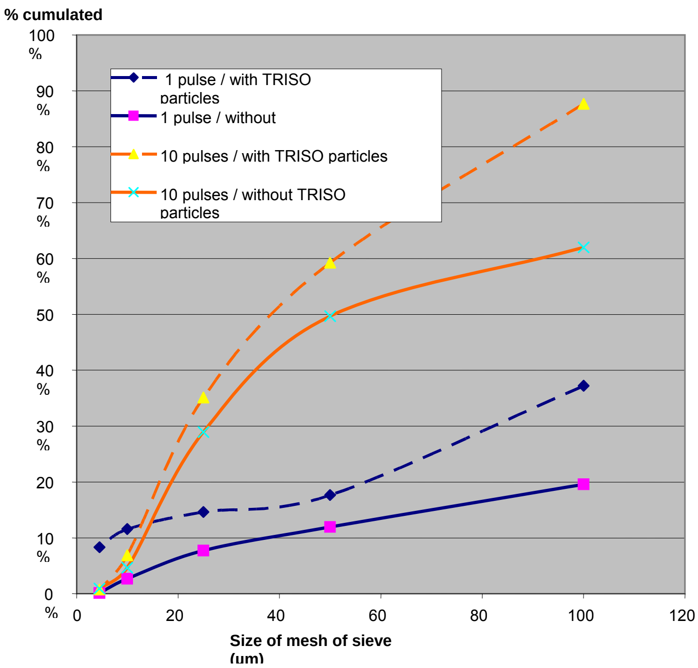

Figure 3.2.4: Influence of Triso particles amount in compact

The deliverable D-2.4.1 will be elaborated with a short shift in June. The delay is due to the delayed availability of the samples and the intensive safety procedures.

An optimization of the process will be necessary. The objective is in first time the separation of particles from graphite, and in second time the separation of particle kernels from the coating. In 2009, the parametric study will be continued and a new reactor will be installed on the pulsed power equipment. The undersize are screening by a sieving operation during the fragmentation.

3.2.4.2 Deconsolidation of HTR fuel by chemicals

The use of chemicals to selectively destroy the binder material in a PBMR fuel sphere, thereby inducing deconsolidation of the fuel sphere into graphite and coated particles, was investigated. In this study mineral acids, alkaline solutions, dissolved oxidising agents, organic washing detergents and such combinations were studied. The results of this study indicated two possible means to deconsolidate the fuel. The first is a mild combination solution that destroys the binder material (resin) and dissolves a minimal amount of graphite, resulting in the deconsolidation of the fuel sphere. The second solution, based on electrochemical technology, is an aggressive one that not only destroys the binder material (resin) and dissolves graphite, but also results in the destruction of the fuel sphere. As this was done on non-irradiated PBMR fuel, experimentation will continue on irradiated graphite.

3.2.4.3 Deconsolidation of HTR fuel by electrochemical technology

The NFC group in NECSA did the initial experimentation to deconsolidate the fuel sphere. The equipment, based on an original German design, was built at NECSA and tested as indicated in Figure 3.2.6. The test results show that it is possible to deconsolidate the PBMR fuel by this technology, but the process is unfortunately very slow and generates huge volumes of secondary waste. Research continues into the influence of other electrolytes on the deconsolidation time and reduction of secondary waste volume generated.

Fig. 3.2.5

3.2.4.4 Deconsolidation of HTR fuel by molten salt technology

The use of molten salt technology to deconsolidate a PBMR fuel sphere by selectively destroying the binder material in the sphere was investigated. The initial study was based on using a salt mixture at 350 ^{O}C. During the initial dissolving phase, no dissolution of the fuel was observed to have taken place. However, by adding a chemical to the molten salt, the structure of the sphere collapses as indicated in Figure 3.2.6.

Research is continuing on using this technology to deconsolidate spent fuel.

Figure 3.2.6

3.2.4.5 Deconsolidation of HTR Fuel by Homogeneous Oxidation

FZJ has established a draft report on homogeneous oxidation of matrix graphite pebbles. The report will be delivered with a short delay till July due to the necessity to produce additional figures and illustrations.

3.2.5 Removal of Coating Layers from TRISO Particles (Task 2.5)

3.2.5.1 Combustions of Coatings

This process involves controlled combustion of the outer layers of graphite of a TRISO particle inside a plasma.

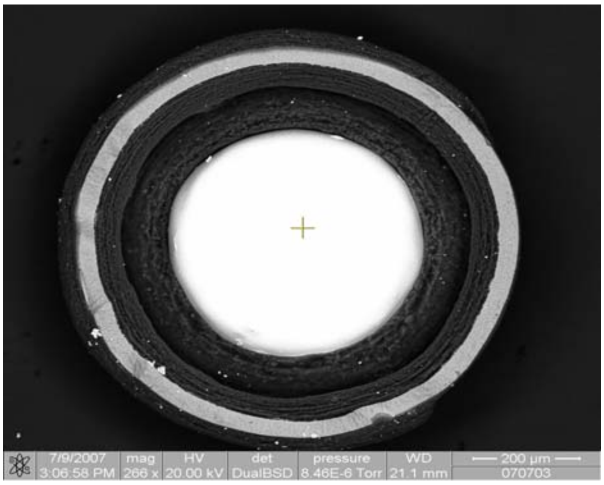

Figure 3.2.7: SiC layer in a TRISO particle

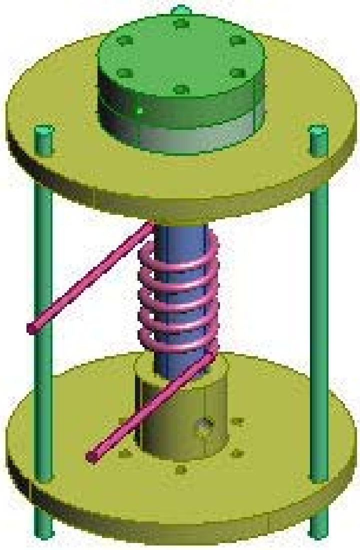

Figure 3.2.8: RF heated controlled oxidation reactor

By performing the oxidation in a controlled manner, the total graphite component could be selectively removed up to the SiC layer. If the removal can be done without damaging the inside protective SiC layer, the loss of hazardous or radioactive materials in the off-gas would be minimal. A high-temperature small-scale spouted-bed radio frequency (RF) heated reactor was designed and successfully commissioned wherein the pyrolytic carbon and SiC layers are exposed in a CF_4 plasma (Figure 3.2.8).

Preliminary results are very promising and the results in Figure 3.2.9 indicated that the graphite layers surrounding the SiC protective layer can be controllably removed. The SiC surface that remains after removing the graphite layers implies no loss of hazardous or radioactive materials from this protective layer. The components of the off-gas measured by GC-MS indicate that the graphite oxidised to carbon dioxide and water.

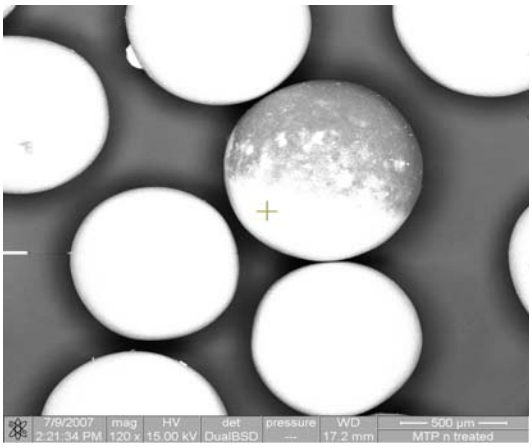

Figure 3.2.9: Step-wise removal of graphite layers

Approval has been given by the internal Necsa IP committee to explore the patentability of this process. A provisional patent has subsequently been filed.

The technology is in the process of optimising the process conditions (applied power, the time of exposure to the CF plasma and the distance of the static bed from the glow discharge) for the removal of graphite material from the PBMR coated particles.

3.2.5.2 Oxidation of SiC layers by Plasma

The aim of these experiments was to treat the silicon carbide layer in a cold plasma that was generated in a reactor with a 1.3 kW RF power supply. In this case, CF_4 was ionized and reacted with silicon carbide.

Firstly the raw coated particles (4 layers) were heated at 1 000°C for 24 hrs at atmospheric conditions in a muffle oven to remove the outer carbon layer and to expose the silicon carbide layer. A glass tube was filled with approximately 0,5 g of these particles which were loaded on a porous PTFE insert supported by redundant PTFE wool and placed at different heights below the coil. Different current readings were set for each height to determine the most efficient setting for the reaction of silicon carbide and the CF_4 radicals. After the reactor was placed inside the coil and the system closed, the reactor was evacuated to –80 kPa $_{(g)}$ and the CF_4 gas was opened to flush the system.

The induction power is switched on to ionise CF_4 to form $CF_3^{\cdot}$ and $F^{\cdot}$ radicals, which reacts with silicon carbide and SiO_2 from the glass to form different products. Pressure, current and voltage readings were recorded during the experiment, as well as the mass loss of the coated particles.

At the beginning of the experiment, a U-tube was placed in liquid nitrogen to freeze the gaseous products, which were sent for analysis after the experiment

3.2.5.3 Conditioning process for the Triso particles layers

CEA develops a conditioning process for the Triso particles layers. SiC-glass composites from glass frit ‘FNOC77’ will be realized. Fundamental data have been gathered. Elaboration process and first composites have been defined.

a. Measurement of the properties of SiC and glass powders acting as waste flux: viscosity vs T°, granulometry, specific surface, SEM observation, flowability of the powders. The waste SiC flux is simulated by a 88µm angular-shaped powder.
b. Comprehension of SiC-glass reactivity (bubbling) : thermodynamical approach and experiences (DTA)
c. Understanding of the co-milling of a blend of SiC and glass powders (XRD spectra and specific surface evolution)
d. Dilatometry test on first composites and validation of the elaboration process

These preliminary tests allow to design and understand a solid elaboration process focussing on the key parameters.

CEA hase lead a parametric study where the min and max range of selected experimental parameters have been determined such as glass granulometry, temperature, length and atmosphere of the densification thermal treatment. The selection criterion is the higher relative density for the higher SiC charge ratio.

CEA has realized dense composites at 95% with 30%wt of SiC. In 2009, test the leachability of the composites will start. Other less viscous glass frit in order to design two composites types with their own SiC charge and densification ratios will also be tried. Assuming that the contamination and/or activation of the SiC are not known yet, there is the need to investigate and then propose different immobilization routes. In 2010, it is foreseen to study the influence of the HUP (Hot Uniaxial Pressure) process for densification.

3.3 Work Package 3:

3.3.1 Intercomparison Test and Sample Management (Task 3.1.1)

In order to organise the sample distribution from different suppliers and to several receiving labs a questionnaire was prepared by **CIEMAT** and distributed among the beneficiaries of WP3&4 in order to know not only the abilities of the lab's and the results to be supplied to the data base but the needs of testing samples of real waste graphite to fulfil the objectives of the project.

Virgin and Irradiated graphite double entrance table (**Reactor type/ Contributors**) fill-in with the amounts available to deliver or required were performed according to the questionnaires answers received. With this table and by consensus three suppliers corresponding to the three main reactors types were selected: UNGG graphite supplied by EDF, presently the work of sample preparation is almost finish, MTR graphite supplied by INR almost prepared and Magnox graphite supplied by Magnox South thought out **University of Manchester** at the time of finishing the period is in progress the sampling. Additional amounts of graphite are available (as G2 graphite offered by **CEA**, RBMK graphite by **FI**, or MTR graphite by **FZJ**)

The **UoM** have identified key sources of U.K graphite waste for Round Robin Testing (RRT) and sample management, the UoM contacted various parties concerned and are now waiting for the retrieval of Magnox graphite from the National Nuclear Laboratory.

The RRT is now organised in detail. **CIEMAT** will evaluate the results according to international standards on the field. The chosen scheme is the "split-level" distributing two samples per participant of approximately 2g of real i-graphite for a homogeneous sample testing with ANOVA test of gamma emitting nuclides, in the original sample. The nuclides to be determined are gamma emitting species like ^{60}Co, ^{14}C, ^{3}H, ^{36}Cl, ^{63}Ni & voluntarily $^{154/152}$Eu, ^{137}Cs, and ^{90}Sr. All the labs evolved were supplied the information needed and tuning up the procedures.

Each lab will receive the excel file to complete with the analytical data. The file has and will have all the information about the characterisation of the samples according to an individual "reference value" supplied in the file. The uncertainty estimation will be performed according to ISO/TS 21748.

CIEMAT has prepared the samples for distributing and transportation as well as develop the transport concept through the collaboration with the transport company **ETSA**.

3.3.2 Structural Changes by Irradiation and Treatment (Task 3.2)

Characterisation of the structure and property changes unirradiated PGA, Gilsocarbon and EDF graphite (Pechiney) undertaken at the **UoM** using optical, SEM, FIB-SEM, TEM, Tomography, RAMAN, XRD and EDXS. Preliminary characterisation of structure and property changes of irradiated British graphites using Tomography, RAMAN, autoradiography and optical microscopy and high resolution Synchrotron x-ray tomography. Set-up facilities to examine irradiated graphite using SEM with EDXS facilities for elemental analysis. Synchrotron x-ray tomography experiments in November 2008 and June 2009, examining the i-graphite before and after WP4 leaching at the Paul Scherrer Institute, Swiss Light Source, to perform i-graphite experiments in order to characterise and identify the microstructure and location of impurities within i-graphite and calculate the volume fraction attributed to porosity. The **UoM** have also advertised PhD student place for WP3 across the EU, to date this place is still vacant.

The contribution of **CEA/LPCMI** concerns the evolution of physical and structural properties of virgin and irradiated graphite from G2 CEA reactor. The typical characterizations performed were bulk and hydrostatic densities, porosity determinations, XRD analysis and Raman spectroscopy.

Non irradiated graphite from G2 reactor was characterized. All the samples were cut out from a brick corresponding to ones located in the moderator part of the reactor core. Thus, it is expected that this graphite is made from "A special" coke. Samples were taken in the so-called "with grain" (WG) and "against grain" (AG) directions in order to study the eventual anisotropy evolution of G2 graphite under irradiation. Results obtained for bulk density lead to values quite smaller than those expected. Helium pycnometry measurements lead to total porosity. XRD characterizations lead to "a" cell parameter very close to those of perfect graphite (HOPG). For "c" crystallographic direction, there is a quite important difference between G2 graphite and HOPG. Raman acquisitions did not exhibit large difference between different samples from the brick studied. For all samples, spectra show the graphite "G" band as well as defects bands D1, D2 and D3. An interesting result is that two types of spectra were obtained: when the acquisition was performed inside a coke grain, a high crystalline degree is shown. In the other hand, acquisitions performed on the surface of the coke grain shows a very low crystalline degree probably associated to pitch impregnation that is not so easy to graphitize than coke grains..

CEA Cadarache contributions in this task 3.2 were devoted to compiling a state-of-the-art review which was used to design the tests for both virgin and irradiated graphite samples. The bibliographic analysis made it possible to summarize all existing results, to propose several research programs, and to define the experimental conditions to implement as part of the study on the behaviour of ^{36}Cl during graphite leaching.

This analysis revealed that the data on graphite (type of coke, impurities, radionuclide activities, etc.) and the data on its behaviour during leaching vary in a wide range.

Experimental sample preparation work was performed on two types of graphite taken from the G2 and SLA2 UNGG reactors, choosing four core samples coming from different heights in the stack in order to check the influence of the thermal history and/or neutron flux on chlorine releases. Six core samples were also taken from two channels (different areas of irradiation) and at three different heights (different temperatures) in the SLA2 reactor.The mercury porosimetry measurements of G2 and SLA2 inactive graphite samples revealed the existence of two types of pores in the mesoporosity range. Microporosity is difficult to detect with this technique owing to the high mercury pressure applied in order to penetrate small-sized pores (< 50 nm).

To determine the water saturation kinetics of graphite, a technique is put in operation that involves measuring the mass of liquid impregnating the graphite samples as a function of time. These tests may be performed using various liquids with different surface tensions under several pressure conditions, to extend the displacement of air in the open porosity in the way to increase water penetration to be used to determine the water impregnation rate in leaching tests. The results of G2 and SLA2 graphites correlate with the porosity measurements shows that water fills lower percentage (13%) in the G2 graphite (in 15 days) than in the SLA2 graphite (28%) of the porosity in 7 days. Based on the assumption that the biggest pores are the first to be filled, it was calculated that water penetrates up to 10 μm for G2 and up to 3.5 μm for SLA2 pores.

The work performed by **ENS** in this period concerns the structural characterization of virgin and irradiated UNGG graphites by Raman Microspectrometry (RMS) and Transmission Electron Microscopy (TEM) starting on the characterisation of ^{37}Cl implanted graphite.

In a well defined and adequate conditions Raman spectra were recorded. As expected, Raman microspectrometry allows a pertinent structural study of heterogeneous materials such as carbon-carbon composites (as nuclear ‘graphites’ are). A single crystal of graphite was first selected as a reference.

^{37}Cl (around 4 ppm) has been implanted into polycrystalline moderator graphite brick samples. As a consequence, Raman spectra show that this ionic implantation produces an important structural change. A Tuinstra and Koenig diagram was plotted based on the spectra obtained in order to highlight the implantation effect on the graphite structure. Based on these results it should expect a strong decrease of the crystallites size following the implantation. Furthermore, to follow the evolution of the structural defects in-depth, graphite sample were cutting into two parts and its section was analyzed. The analyses of Raman Spectra is use to check a “clear” transition from an ordered virgin graphite structure to that of disordered one being in the side of implanted face.

To compare previous results obtained by RMS with those obtained by TEM, several techniques were applied to explore the implanted graphite.

UoM has started with examination of structure and property changes unirradiated and irradiated graphite using different techniques (FIB SEM, TEM, Tomography, RAMAN and optical spectroscopy). Written experimental proposal for i-graphite and had accepted experimental time at the Paul Scherrer Institute, Swiss Light Source, to perform i-graphite experiments using high resolution X-ray tomography. First data are being produced for this period.

3.3.3 Localisation of Impurities and Isotopes before & after Treatment (Task 3.3)

During this period, **CIEMAT** has designed and tested the characterisation process for the graphite samples for both determination of inventory and the evaluation of the effectiveness of the treatment to be applied (for WP4 duties). The process for 1st step characterisation consist on gross alpha/beta determination, gamma spectrometry of powder samples in a special geometry, and 3H/14C determination by catalytic oxidizer. The full characterisation is based on the solubilisation process and low energy gamma emitting nuclides, alpha emitters and pure beta emitting determination.

Solubilisation process has been developed using microwaves system by acid treatment with H_2SO_4, HNO_3 and $HClO_4$, obtaining a final solution for analysing non volatile radionuclides. For volatile materials analyses (^{36}Cl, ^{99}Tc and ^{129}I) a study on the methodology has been put in operation. ^{36}Cl is analysed using a specific procedure in which it is not necessary to dissolve the sample previously. Up to now, 0.25 g of virgin graphite is digested in 5 ml of concentrated nitric acid and 20 ml of sulphuric acid for 50 minutes at 260ºC. In these first studies, the procedure was developed on different standard samples prepared from virgin graphite on which were poured ^{99}Tc and ^{129}I standard, in order to determine its chemical yield. With respect to ^{129}I a chemical yield of 99% has been found. The measurement was performed by low energy gamma spectrometry. Presently, we are studying the chemical yield of the process for ^{99}Tc. In this case, a problem has been observed because in the H_2SO_4 medium which is obtained at the end of the process, when the corresponding reagents are added in order to separate ^{99}Tc, an important reaction occurs and in this point it is losing a big percentage of ^{99}Tc. Probably, the procedure to dissolve graphite must be modified, in order to obtain a diluted sulphuric medium and in this way to avoid the ^{99}Tc losses.

In order to isolate ^{36}Cl from the other radionuclides present in the sample an acidic treatment with HNO_3, $HClO_4$ and H_2SO_4 conc., bubbled with N_2 and refluxed is undertaken. Determination by LSC was studied in order to optimise the activity results and separation factors for the main beta

ENEA contribution in the period was focused in the negotiation and signature of the contract with **Nucleco**, in which laboratories the analytical analyses on irradiated graphite will be performed. The effort in this period has been dedicated to prepare the equipments in the laboratory for the experimental activities with virgin graphite. ENEA has collected irradiated graphite samples from the Latina Magnox plant.

ENRESA began the compilation of required information on distribution of impurities of virgin graphite of Vandellos I sleeves. Analysis of the impurities tests carried out in order to determine their distributions inside the graphite matrix, and the degree of correlation with the radioactive isotopes detected. Also the distribution of impurities of virgin graphite of the MTR JEN-1 CIEMAT reactor (thermal shield) was measured.

NRI contribution in this task was concentrated on the development and application determination method for ^{14}C content in graphite waste from a MTR reactor. The method consist on two process steps: Graphite combustion using an oxidizer oven and LSC counting. The combustion method provided accurate results, the ^{14}C recovery was 98.49 % and the ^{14}C memory was 0.07%. The radioactivity of graphite waste was generated by a ^{14}C content of $1.09{\cdot}10^3$ Bq/g. The measuring statistical precision of the graphite samples was $2\sigma\% = 0.5\ \%$.

It is intended to develop and apply a total beta activity determination method for i-graphite on MTR graphite samples by proportional counter.

3.3.4 Modelling the Behaviour of Impurities and Isotopes in Graphite (Task 3.4)

The lead partner of this subtask is UoM.

The **UoM** has identified and purchased suitable activation code packages to examine radionuclide production in i-graphite and has undergone FISPACT training in February 2009, Modelling of the origin of isotopes is now underway.

The **UoM** has performed extensive literature review on leaching procures for the immobilisation of graphite waste and the Chemical decontamination of i-graphite using reactive gases.

LEI has started (in January 2009) updating of the computer model (MCNP-5) for modelling of the neutron fluxes in the core of the RBMK-1500 reactor.

Institute of Physics has collected unirradiated samples of graphite sleeves, metal samples from upper, middle, and bottom parts of fuel channels of RBMK-1500 reactor of Ignalina NPP. Collection and analysis of data on characteristics of materials used in RBMK-1500 reactor has been done. Critical nuclides in these materials to be additionally analysed have been determined. Trace element analysis of materials of the fuel channels has started. Collection of data on operational history of the reactor necessary to define the irradiation conditions of the fuel and the reactor history has been done. Creation of the reactor model for radionuclide inventory calculation in graphite from the reactor has started.

3.3.5 Correlation with Existing Data on graphite Wastes (Task 3.5)

No activities yet in this reporting period

3.4 Work Package 4:

3.4.1 Mechanistic Background of Impurity Removal (Task 4.1)

A literature review investigating the mechanistic background of impurity removal of irradiated graphite waste has been undertaken.

The UoM will develop a mechanistic model for impurity removal using statistical pattern recognition. The aim is to develop a statistical pattern recognition model based on quantitative results which will enable the results to be analysed in terms of classification and discrimination. This will highlight trends with regards to impurity removal and identify key relationships and will give confidence in the statistical analysis.

An examination of structure and property relationships of un-irradiated graphite using FIB-SEM, EDX, TEM, Tomography, RAMAN and optical spectroscopy has been undertaken.

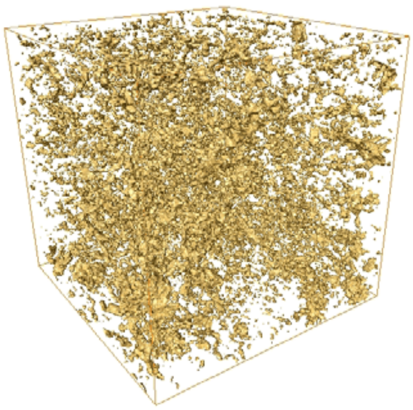

Fig. 3.4.1: 3D reconstruction of the microstructure of a graphite sample

Fig. 3.4.1 shows the 3D reconstruction of the microstructure of a graphite sample. The high porosity of graphite is in evidence.

3.4.2 Graphite Decontamination by Physical Treatment (Task 4.2)

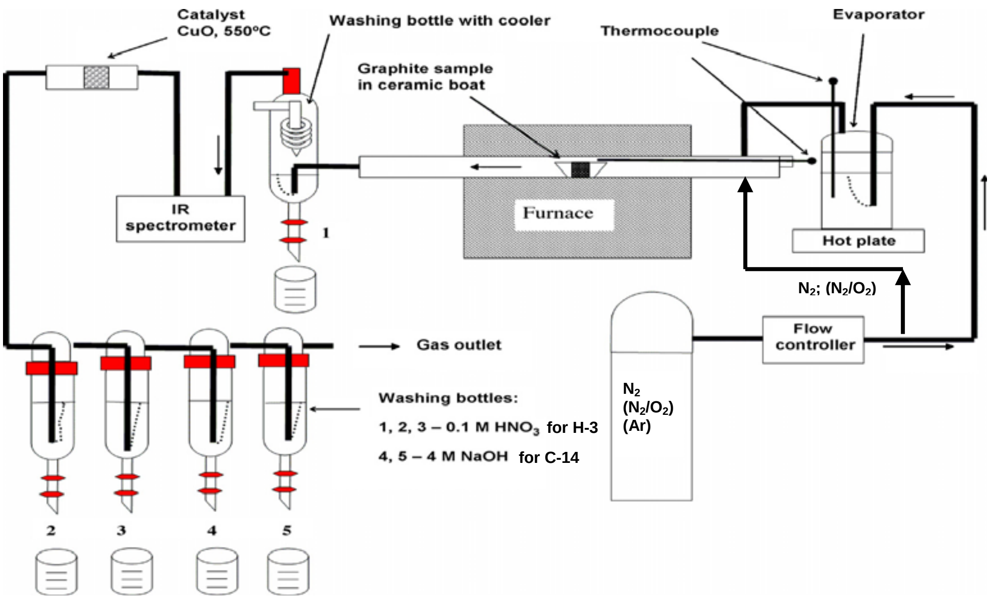

Fig. 3.4.2: Experimental set-up for the thermal treatment

At FZJ irradiated graphite samples of the decommissioned German nuclear reactors AVR and MERLIN were heated up to a temperature of 1300 °C in a nitrogen atmosphere (for experimental details see Fig. 3.4.2). Under these conditions H-3 can be released from the graphite matrix up to nearly 100 % (see Fig. 3.4.3). However, C-14 is released only up to 20 %. The difference between both release mechanisms may be that H-3 is released only on a physical way, but C-14 on a chemical way. The explanation of this effect may be the following: On the graphite surface gases like oxygen or water steam are adsorbed. These gases react with the loosely bonded C-14 and release it as CO or CO_2. When the oxidising gases are consumed, the release of C-14 stops.

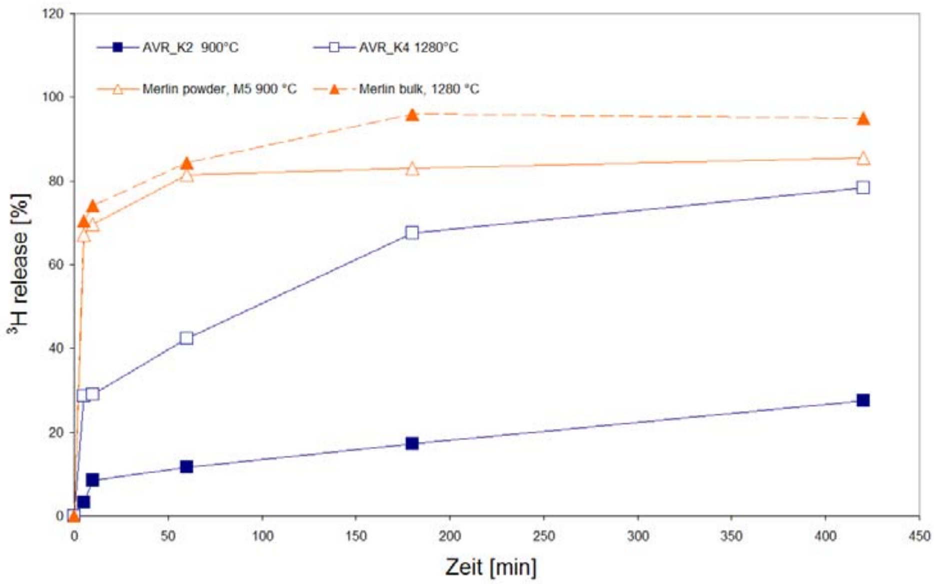

Fig. 3.4.3: Release of tritium in nitrogen

3.4.3 Graphite Decontamination by Chemical Treatment (Task 4.3)

UoM: An extensive literature review of technical methods for graphite purification using reactive gases is underway. Facilities for the chemical treatment of irradiated graphite using oxygen treatment are set up. Chemical leaching treatment with irradiated graphite using British Experimental Pile Grade Zero as foundation study has commenced. An examination of structure and property relationships of irradiated British graphites before chemical treatment using Tomography, RAMAN, autoradiography, optical spectroscopy and shortly active SEM has been undertaken and the graphite has been characterised in terms of crystal structure, orientation, pore size and impurity location.

FZJ: The chemical treatment was performed in the same way as described under Task 4.2. Nitrogen was used as carrier gas. In addition, the carrier gas contained either oxygen (max. 1.2 vol.-%) or water steam as oxidising agents. The results demonstrate that the main part of the C-14 inventory can be removed from the graphite matrix by selective oxidation. In oxygen, a C-14 release of maximum 79 % with a mass loss of the matrix of 2.9 % within 3 hours was determined. In water steam a C-14 release of maximum 93 % with a mass loss of the matrix of 5.4 % within 7 hours could be detected. Fig. 3.4.4 and Fig. 3.4.5 show the corresponding graphs.

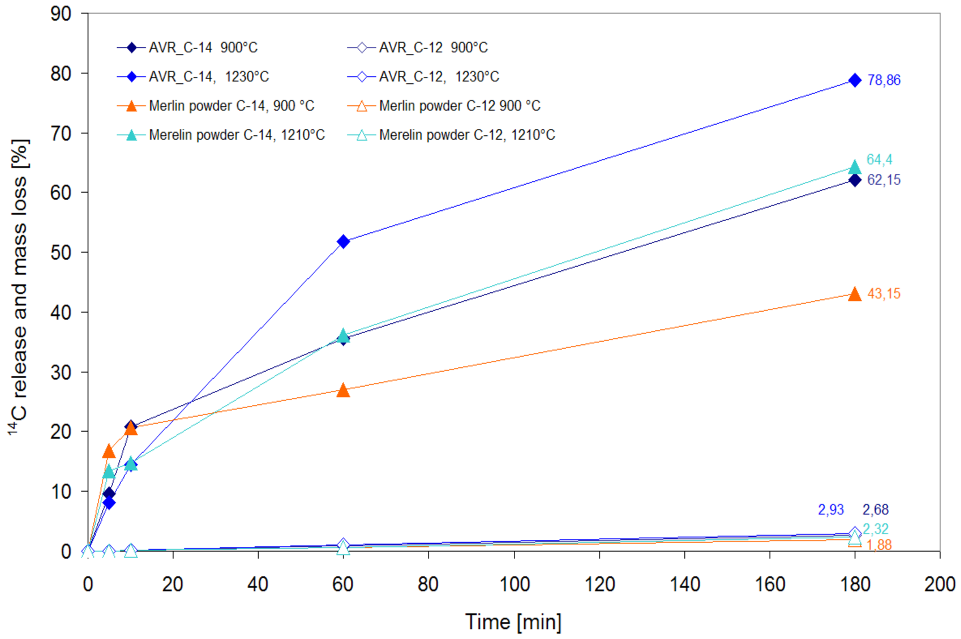

Fig. 3.4.4: *Release of C-14 in oxygen (max. 1.2 vol.-%)*

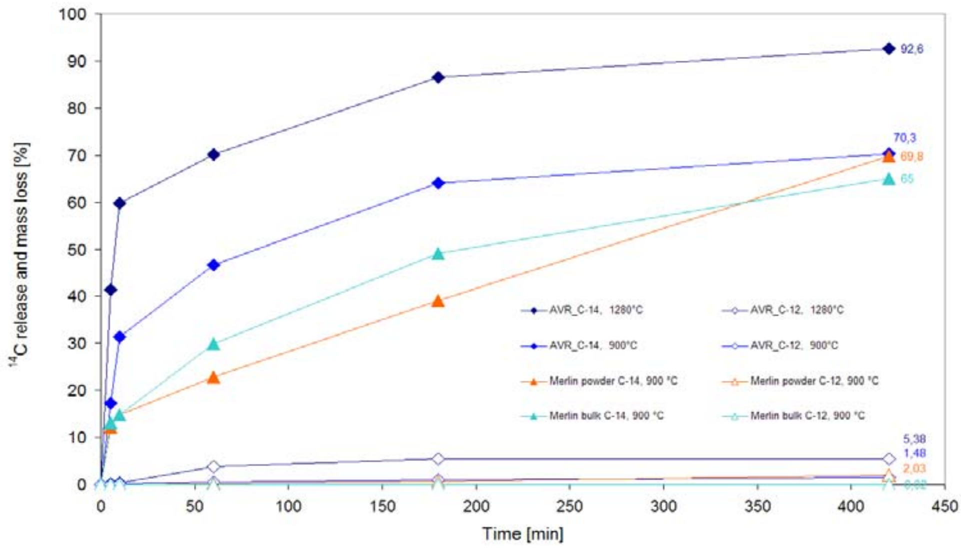

Fig. 3.4.5: *Release of C-14 in water steam*

In view of the equality of chemical behaviour of isotopes (in this case C-12 and C-14) these results lead to the question: Why C-14 can be easier oxidised compared to C-12 from the same material? It can be conclude that the C-14 is not integral part of the graphite lattice, but it is (chemically) attached to the surface of the graphite crystallites or loosely adsorbed between the graphite lattice planes. These suppositions have to be investigated by future experimental work.

In addition, the laboratory experiments have to be transferred into a half-technical grade. For this purpose an induction furnace was purchased to obtain temperatures up to 2500 °C coupled to a mass spectrometer for the analysis of the flue gases. Furthermore, it is intended to extend the method for decontamination of radioactive metal nuclides (e.g. Fe-55, Co-60, Ni-63 and Cs-137) by converting them to their volatile chlorides at temperatures higher than 1500 °C. The first test run with the new furnace is shown in Fig. 3.4.6 using a non-irradiated AVR graphite pebble at 1000 °C.

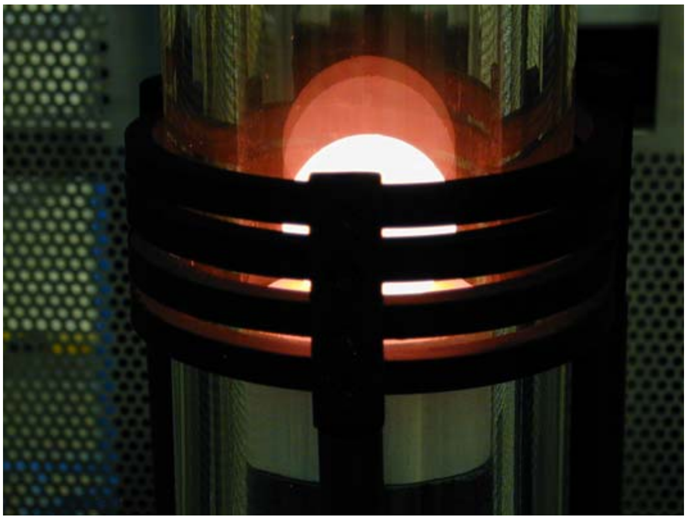

Fig. 3.4.6 AVR graphite pebble at 1000 °C

3.4.4 Graphite Decontamination by Microbiological Treatment (Task 4.4)

PBMR: A literature study of separating isotopes via microorganisms has been completed.

Furthermore, a scoping study with the following objectives to determine has been undertaken:

- Bacterial species that will work best,
- Bacterial growth in the presence of graphite and
- Need for supplemental nutrients.

The bacterial growth on graphite chunks has been analysed via SEM. Best results were achieved with Styriakova media in glucose. Fig. 3.4.7 shows an example.

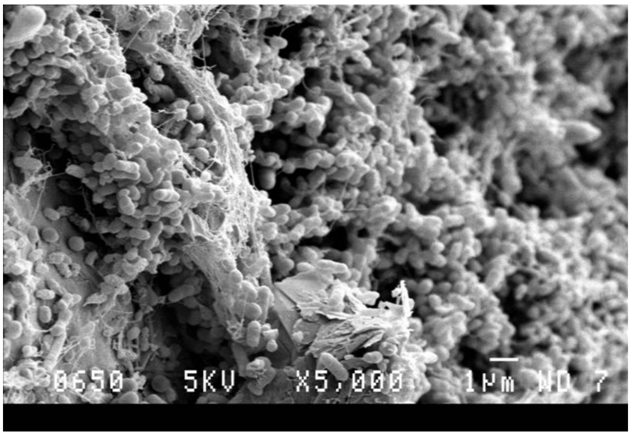

Fig. 3.4.7: SEM micrograph of Styriakova media on a graphite surface

The last year was spent setting up laboratories on the campus of the University of Pretoria. This includes full refurbishment (civil) of the laboratories to ensure that they comply with the South African Department of Health’s Class B License (Authority to possess and use radioactive nuclides) that is required for the initial work that would include work with bacteria, low-activity (commercial) Carbon-14 as well as purchasing of new equipment. Equipment included an Atomic Absorption Spectrometer, Gas Chromatograph Mass Spectrometer and a Liquid Scintillation Analyzer. In addition the necessary Carbon-14 material was acquired. The research group has done extensive work on the bacteria itself, this included an extensive literature study, running DNA analysis to aid identification of organisms, initial laboratory analysis to verify that the chosen organisms do in fact show a preference for graphite material (non-Carbon-14). The results to date are promising though of course it needs further work. The next tasks will include work with actual Carbon-14-containing samples. In order to be certain that the research team members (which include a number of post-graduate students and interns) are able to comply to safety requirements of the laboratory license PBMR ensured that all completed both a Radiation Worker and Chemical Worker course presented by NECSA.

3.5 Work Package 5:

3.5.1 Review Existing Experience Relevant to Recycling (Task 5.1)

This task is essentially complete. A report has been produced which is a review of existing experience relevant to the recycling of graphite. Work Package 5 is concerned with establishing ways of recycling graphite and the objectives can only be met by considering all the steps between irradiated graphite arising as waste and its supply in new products. Due to the limited experience with recycling and reusing irradiated graphite it was decided to widen the scope of the review to include a discussion of those pathways for graphite management which hold the most potential, but require further work before they can be proven valid.

Initially the report considers the properties of irradiated graphite in as far as they will affect the subsequent steps of recycle. The report then goes on to consider the steps necessary to prepare graphite for recycle, such as the appropriate removal (by decontamination) of radioactivity. This may involve conversion of the graphite to the gas phase and re-deposition as carbon. The potential value of "roasting" is considered, which can separate graphite into isotope-rich and isotope-lean fractions. Graphite manufacturing techniques are then considered to discuss what types of product or processes might be applicable. Other types of recycled product are then considered, including the sale of ^{14}C as a product. This option will almost certainly require separation of carbon isotopes, and the techniques for accomplishing this are discussed.

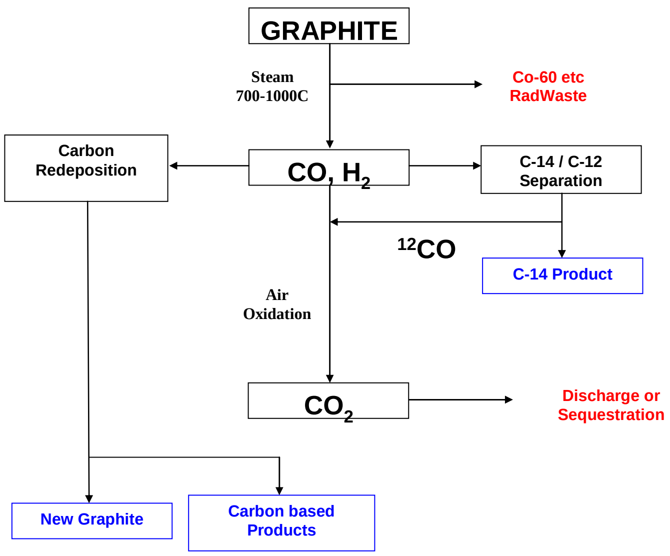

Figure 3.5.1: Graphite Recycling Diagram

Manufacturers of recycled products would face considerable challenges in trying to produce materials with fully active irradiated graphite. Most candidate materials are currently produced in a non-radioactive environment. In order to provide effective potential pathways to manufacture of new products an appropriate decontamination and processing pathway is needed to prepare the graphite for recycle. As a result of discussions during the early part of the programme, graphite manufacturers have expressed a preference for using starting material such as carbon black, which has been well decontaminated and is produced by carbon re-deposition from the gas phase (as shown in Figure 3.5.1). This diagram also shows how ^{14}C could be concentrated as part of the same overall processing route for the production of this product.

Although the review has been prepared principally by Bradtec, other organisations involved in Work Package 5 have contributed information for the report and provided comments on its contents.

The South African Government has published a National Nuclear Waste Management Strategy during 2008. This sets out (for the first time) a national strategy for South Africa. A result of this would be the creation of a South African Nuclear Waste Management Organization (possibly to be known as the South African Nuclear Waste Institute). A direct result of this strategy's release was a number of workshops n this topic hosted by ESKOM (the South African Electricity Generation Utility) and NECSA during October 2008. Both of these were attended by PBMR and culminated in two follow-up workshops hosted by NECSA. A particular topic is now the possible re-use of irradiated graphite in future. PBMR should be in a position to contribute a report detailing the company's internal views in this regard during 2009.

3.5.2 Identification and Making of New Products (Task 5.2)

Meetings have been held with the graphite manufacturers (including visits to their premises) to discuss the approach which they will take to recycling graphite. Notes of the meetings have been produced. It is clear that any recycle route will need to be undertaken with slightly radioactive material, and hence it is important that recycle procedures involve only simple manufacturing methods. As stated above, the graphite manufacturers have indicated a preference for working with carbon black as an intermediate material, although other possible intermediates have not been ruled out.

The type of product manufacturing process which could be undertaken to incorporate recycled carbon black is GrafTech's "Fast Process". This process could potentially be used to produce electrodes for radioactive waste vitrification. Investigation of this possibility will now form a part of the forward programme.

The outcome of deliverable T-5.2.1 is that future work will be directed towards use of carbon black as the primary intermediate for recycle. The reasons for this are discussed in the review, Chapter 3 "Preparing Graphite for Recycling", Chapter 4 "Graphite Manufacturing Processes and Adaptation for Recycle and Chapter 5 "Potential Recycled Products used by Nuclear Industry.

Significant results have been reported by NECSA covering the use of irradiated graphite as an absorbent for radionuclides, and a report on these activities has been produced. For example, Kd values have been determined for the absorption of Ag-110m and I-131 onto graphite from blasting solutions and demin water as a function of pH. Powerful absorption (Kd values between 1,000 and 100,000) has been observed. Similarly, effective release of bound silver contamination has been observed in nitric acid and hydrogen peroxide solutions. This represents a promising start to the overall experimental programme.

3.5.3 ***Separation & Recycle of Radiocarbon (Task 5.3)***

This work is in its early stages, but Studsvik is undertaking work on modelling the PSA isotope separation process and a subcontract has been placed with URENCO to examine the use of gas centrifuge.

3.5.4 ***Task 5.4: Products Evaluation***

There has been no progress with this task, which is due to be undertaken towards the end of the project.

During the next period SGL, GrafTech and NRG will be manufacturing trial products. An initial report on these activities is due during the next period (23 months). GrafTech will concentrate on "Fast Process" to produce vitrification electrodes. Isotope separation work will also be continuing at Studsvik and URENCO with and initial report due during the next period (18 months).

NECSA has developed a full forward programme and its report on graphite use for decontamination is due at 18 months. The programme includes:

e. Irradiated graphite as absorbent
f. Irradiated graphite as gas absorbent
g. Irradiated graphite as electrodes to dissolve spent fuel
h. Irradiated graphite as crucible material to dissolve spent fuel
i. Irradiated graphite as nanotube technology to immobilise radioactive waste

Additional parts of the programme which will be addressed during the next period include contacts with GE Healthcare concerning ^{14}C recycle and a visit to NRG re Silicon Carbide production.

3.6 Work Package 6:

3.6.1 Disposal behaviour for Graphite Wastes (Task 6.1)

The lead partner of this subtask is CEA.

The disposal behaviour of graphite is characterized by the release of its radionuclide inventories upon groundwater contact. A bibliographic analysis has been carried out by CEA, revealing that the data on graphite (type of coke, impurities, irradiation history, radionuclide activities, etc.) and the data on its behaviour during leaching vary in a wide range, making comparison of leach results difficult. The release of radionuclides contained in the dissolved irradiated graphite depends on

1) the water impregnation rate of graphite,
2) the chemical form of chlorine and its distribution in the material, and
3) the diffusion of soluble species in the graphite porosities.

The dissolution of radionuclides such as ^{36}Cl in the graphite does not only depend on the type of chemical bonds, but also on the accessibility of water to the different sites ^{36}Cl, and therefore on the chlorine distribution in graphite porosity. In the porosity accessible to water, the dissolution kinetics will mainly depend on the type of bonds between chlorine and graphite, which are conditioned by the graphite manufacturing methods and the behaviour of ^{35}Cl and then ^{36}Cl formed by activation under the effect of the reactor temperature and irradiation.

Contribution of EDF

A detailed list of samples of both virgin and irradiated graphite has been prepared from various French reactors to be shipped both to French and other European partners.

Contribution of ANDRA

A first draft of the report on the behaviour of radionuclides in UNGG graphite in aqueous media has been delivered for the WP1 and WP6 (2). The report provides a state-of-the-art knowledge review on graphite leaching. The final version will be provided by May or June.

Following main results have been obtained by IPNL:

1) To study the effect of reactor operation on Cl binding sites in the graphite ^{37}Cl has been implanted into polished nuclear graphite samples in order to simulate ^{36}Cl displacement from its original structural site through recoil effects. The implantations have been performed at a fluence of $5x10^{13}$ at·cm^{-2} and at an energy of 250 keV. The projected range Rp is centred around 200 nm and results in a maximum atomic concentration around 50 ppm. The implantation fluence was chosen to reduce the creation of defects and to avoid effects due to release and / or trapping usually observed at higher fluences for volatile elements. The value of displaced atoms at the maximum of the defect profile in the implanted volume, calculated with SRIM, is around 0.02 dpa (displacement per atom). ^{37}Cl profiles and repartition has been followed by SIMS. The results show that ^{37}Cl begins to release at temperatures as low as 200°C. For annealing durations of 4 hours and at 500°C (representative of mean operating temperatures), around 20% of the initial amount of ^{37}Cl is released. The activation energy of the release is very low (<0.5 eV) and shows that the loss process is almost athermal. For longer annealing times (8 and 12 hours), the release reaches a plateau around 30%. Moreover, the investigation of two kind of samples, cut in the same block but implanted along two different directions (respectively along and perpendicularly to the spinning axis), allowed to outline the role played by open porosities with respect to chlorine loss.

Raman microspectroscopy has been performed at each step of the thermal treatment. The results show that the introduction of ^{37}Cl results in defect bands. These bands anneal with increasing temperature and ^{37}Cl loss and but the original structure is not completely recovered even at 800°C.

2) Previous results have been completed by analyses of virgin nuclear graphite samples carried out at a macroscopic scale, in order to describe the chemical forms of chlorine in nuclear graphite and during thermal release . Temperature programmed desorption studies show that the main released form of chlorine is hydrogen chloride. The results are in agreement with the microscopic level findings. The desorption starts at 200°C. A peak around 350°C is followed by a shoulder around 450°C. These two desorption peaks were interpreted as a signature of two chemical forms of chlorine. In order to identify these forms, complementary X-Ray Photoelectron Spectroscopy (XPS) has been carried out on virgin and annealed samples splitted under vacuum: two chemical chlorine forms have been identified. An inorganic form corresponds to oxychlorinated groups like ClO_2^-, ClO_3^- and ClO_4^- (around 30%). The second identified form corresponds to organic chlorine (around 70%), i.e. chlorine atoms covalently bound to sp2 carbons of aromatic rings. The contribution of the inorganic chlorine disappears with annealing (since 200°C), whereas the contribution of the organic chlorine remains until 1000°C.

Contribution of CEA

An experimental study of the dissolution kinetics has started in CEA-Cadarache, using graphite taken from the G2 and SLA2 reactors. These graphites have different characteristics, e.g. type of coke, neutron flux, thermal histories, etc. The main issue with G2 was reconstituting the full 9.4 m core sample that was removed in 1989. Four core samples were prepared, coming from different heights in the stack in order to check the influence of the thermal history on chlorine releases. Six core samples were also taken from two channels (different areas of irradiation) and at three different heights (different temperatures) in the SLA2 reactor.

The results were obtained from preliminary studies on G2 and Bugey reactor graphites showing for G2 good reproducibility chlorine releases to reach about 80% with no effect of leachant composition on releases. In the case of the Bugey graphite, the samples came from several cores removed from different positions in the stack. The dissolved chlorine releases vary between 10% and 90%. This disparity seems to result from the different thermal histories of the graphite core samples in relation to their position in the stack. New experiments are on going both on G2 and St Laurent A2 graphite.

Contribution of ARMINES/SUBATECH

The open and closed porosity of non-irradiated graphite has been determined. A percolation test has been set up: a non-irradiated graphite sample of 22% porosity and 32 mm diameter and 25mm length from the G2 reactor has been embedded in a resin inside a stainless steel reactor, allowing to pass water across the sample by means of an HPLC pump. The Darcy law has been validated controlling water transport through the graphite with a permeability coefficient of $1 \cdot 10^{-9}$m/s. Experiments for HTO migration in the graphite core have been started. Modelling of the results is underway.

Preparations for electrochemical assessment of graphite corrosion and C14 release are under way. Graphite rods have been embedded in resin and electrode samples have been cut for use in a rotating disk electrode.

Contribution of FZJ

The water uptake and the diffusion of radioactive tracers across the graphite will be investigated. The effective diffusivity will be determined by the through-diffusion method. The apparatus used for the diffusion experiments is shown in Fig. 3.6.1.

The graphite sample (denoted as AVR-354-2) for the diffusion experiments was cut from ruptured parts of the bottom reflector of an experimental HTR (AVR). The sample's diameter was 11.2 mm, and thickness was about 5.6 mm, mass – 0.9509 g. The sample was eight times washed in 20 ml distilled water during 30 minutes in ultrasonic bath.

Fig. 3.6.1 Diffusion Cell

The density of the graphite disk was measured by the geometrical method; the value of density equals 1.724 g/cm3. The sample was mounted in between two 20 ml Teflon containers with rubber O-rings as sealing (see Fig. 3.6.1). Left and right containers were initially filled with distilled water. The left container will then be filled with the radioactive tracers Brine-2 base solution, right container – pure Brine-2 solution. The diffusion experiment will be started in April 2009 and will take approximately three months. The water uptake will be measured afterwards.

3.6.2 <u>Disposal behaviour of other carbonaceous wastes (Task 6.2)</u>

The lead partner of this subtask is NRG. In this task disposal behaviour of carbonaceous waste are studied by leaching experiments. Ceramics materials synthesized from virgin and irradiated graphite (from WP5) will be leached in the chosen leachant at the temperature of 25 ºC. Long term leaching will be performed within the Hot Cells Laboratories at NRG. Sampling will take place at defined intervals. Materials will be tested in the form of powders and pellets. Concentration of C-14 in leachants will be measured by liquid scintillation counting method. Samples will be measured by gamma spectroscopy. Microstructure of the pellets before and after leaching will be studied by SEM. Preparation work to execute the experiment are running and containers design are under discussion. Experiment execution would start after materials to be leached (made /prepared in WP 5) are available.

3.6.3 <u>Waste Packages (Task 6.3)</u>

The lead partner of this subtask is CEA. The disposal behaviour of highly radioactive graphite and other carbonaceous wastes (concentrate residues from graphite treatment, pyrolytic coatings of the fuel particles or whole graphite matrices of fuel elements from GCR reactors) can be improved by a design of appropriate waste packages. An important concern is the mobility of radionuclides in the waste package and its surrounding under repository conditions prior to and after water access. Access of water to the pore space in graphite containing waste packages is studied as first step for the release of radionuclides, as well as corrosion of the graphite matrix and diffusion of radionuclides and the retention on engineered barrier materials such as cement.

Contribution form ENRESA

Different graphite tests (leaching, adsorption desorption, organic inorganic content) were compiled and results are evaluated. A report is going to be written before the end of 2009.

Graphite-concrete/mortar barrier compatibility test (matrix degradation) were started. The work consists in the fabrication of 6 cylindrical samples according to a recipe used at El Cabril, considering curing for 30 days. Three of them have been put in contact in an immersion test to crushed graphite and the other three samples will be used as reference.

The next step will be to test the compression stress for the six samples.

Contribution from CEA

CEA studied the retention properties of cement for ^{36}Cl. ^{36}Cl is the major contributor to a potential dose resulting from disposal of i-graphite and concrete is envisaged to be used as packages for this kind of waste. Cement waste packages are going to be altered during the storage due to leaching by natural water entering the system. The retention properties of such a package depend on the cement paste's composition, its alteration and the conditions of water geochemistry. Studies have been carried out using a well characterised fresh (pH~13), deteriorated (pH~12.4) and degraded (pH~12) CEM-V cement paste, investigating the kinetics of uptake, and effect of stable chloride ions present in groundwater.

Classical batch experiments were then performed to calculate distribution ratios of $^{36}Cl^-$ between solid and solution (Rd). The results show that Rd slowly increases during the first 20 days of contact between cement powder and water, and then, whatever the case, there is no evolution of Rd values measured beyond one month. Rd values are relatively low (max: 30 ml/g). They depend on the alteration rate of the cement paste and isotherms show that they strongly depend on the stable chloride concentration in water. A single deliverable gathering D-6.3.2 and D-6.3.3 will present all the results, and is planned at the end of 2009.

Contribution of NECSA

The encapsulation of graphite dust into a cementitious matrix is problematic, as the graphite dust does not "wet" easily Grouts (cement) were developed for encapsulating radioactive graphite dust studying structural integrity, porosity, water uptake and radiation properties of these matrices. To improve the leaching resistance of the cement matrices manufactured with OPC (Ordinary Portland Cement), different percentages of different admixtures were added to these matrices. Since the usefulness of cement (grout) solidification appears to be limited for encapsulation of ^{99}Tc, ^{129}I, ^{14}C etc. NECSA is currently developing alternative waste forms (cement glass, low temperature ceramic material and vitrification). In particular, iron, zinc, iron/magnesium and magnesium/potassium phosphate ceramics seems suitable. Results indicate that immobilisation of 40% graphite dust (depending on particle size) in a special matrix has the following properties:

- Thermal stability between 5ºC and 65ºC (Temperature fluctuations at Vaalputs repository)
- Average total porosity of 4%
- Average water uptake rate of less than 1.5 grams/hour

Above results will be confirmed with irradiated graphite. Current research is on the encapsulation of graphite and coated particles from a HTR reactor into cement, cold-ceramics and glass. Due to radionuclide volatility, the high temperatures that occur during the manufacture of any glass matrix for the encapsulation of radionuclides must be controlled. For research purposes, a new induction-heating mantle was recently installed in a glove box and the equipment was tested for manufacturing glass.

3.6.4 ***Performance analyses (Task 6.4)***

The lead partner of this subtask is SUBATECH/ARMINES.

Contribution of ANDRA

Environmental conditions to be taken into account for the studies on irradiated graphite behaviour have been defined.

Contribution of INR

The preliminary safety analysis of the future LIL waste repository Saligny in Romania emphasized the important contribution of C-14 to the total annual individual dose, both for normal (reference scenario) and abnormal evolutions [1]. C-14 inventories are governed by CANDU reactor wastes and are only slowly increased by graphite waste. In the case of the residence scenario, a major contribution is given by the inhalation of the C-14 released in the atmosphere through gas migration pathway. For this reason, a special attention should be given to the gas phase migration simulation of the volatile radionuclides from the repository (especially C-14, I-129, Cl-36, H-3) and better models and accurate experimental data are needed. A model for permeabilities of loess soil with little clay contents has been developed describing both gas and water permeability as a function of water saturation.

Preparations for gas migration experiments on cover materials are ongoing, using CO_2. Experiments will be run under constant pressure gradient, on cylindrical samples (60mm diameter, 50 – 100mm high) for different water contents (S = 0-0.3). The out-gas flux will be measured and the relative permeability of the gas phase as function of saturation degree. Preliminary calculations indicated that for a permeability range of 10^{-15} -10^{-10} m^2 and for a pressure gradient of 0.25 atm/cm, the gas flux should range between 10^{-4} and 10 m/s (meaning a flow rate between 10^{-3} and 10^2 m^3/h). For low permeable samples, gas fluxes will be calculated as function of volume variation at constant pressure, while for samples with large permeability, the flow rate measurement would be more suitable.

Contribution of ENRESA

The behaviours of C-14 and Cl-36 in a near-surface repository were modelled. A Spanish national project started 2008 (outside Carbowaste project) which consists in the revision of the total radiological capacity of El Cabril. The project is expected to extend 2 years. The Carbowaste contribution will be a compilation of C-14 and Cl-36 results of this project.

Contribution of SUBATECH/ARMINES

Modelling for pore water composition in graphite as function of irradiation has been started. The model is based on H_2O_2 production by radiolysis and a quantitative relation between H2O2 concentration and graphite dissolution rates leading to accumulation and transport of carbonate and organic molecules in the pore water. A more detailed modelling depends on the knowledge of exact dose rate evolutions as a function of time.

Contribution of NDA

NDA RWMD effort has focussed on Task 6.4, with some of the work also being relevant to the organisation's Task 6.3 contribution. A project entitled "Near-surface Disposal of Graphite: A Modelling Exercise to Determine Acceptable Release Rates to the Biosphere" has been launched, and is still on going. In the context of this project, "near surface" means disposal of graphite at a depth of order 100m below the ground, rather than disposal at a surface facility with an engineered cap subsequently covering the waste. The model used in this project can readily be modified to consider disposal at greater depths, something that will be investigated further at a later stage of the project.

The project considers a range of barrier containment functions potentially relevant to irradiated graphite itself, any encapsulant, the waste packaging, other engineered barriers, and the geosphere. The behaviour in the biosphere of two radionuclides of key concern for irradiated graphite - carbon 14 and chlorine 36 - is considered in some detail. The UK ILW irradiated graphite inventory is considered as an example inventory, and doses calculated by the model are compared with a Guidance Level relevant to UK regulations. Preliminary results to date from this project report an investigation of how calculated dose varies as the behaviour of the respective containment functions of each of the barriers varies: the containment function afforded by the geosphere is noted to be particularly significant. Further work on this project is planned into Year 2 of the CARBOWASTE project.

NDA RWMD attended the WP1 meeting undertaken as part of the EPRI meeting in Lyon, October 2008, as well as the WP6 meeting in Karlsruhe in March 2009. At both meetings NDA RWMD made presentations: of work to date (at the WP6 meeting), and how the organisation sees the output from CARBOWASTE being more widely considered in the on-going development of its safety case (at the EPRI meeting).

4 Deliverables and milestones tables

Deliverables (excluding the periodic and final reports)

Del. no.[26]	Deliverable name	WP no.	Lead	Nat.	Diss. level	Delivery date	De-livered	Fore-cast	Comments
T-1.1.1	Access appropriate reports, papers either via databases on public display e.g. IAEA, journals, www. etc and from partners	1	20	R	PP	3	Part of D-1.1.4	Task complete	Initial literature review completed following kick off meeting and key documents identified. Now superseded and reported in the individual chapter "Reference" sections of the Review Volume (D-1.1.4)
T-1.1.2	Analysis of information deciding on key issues	1	20	R	PP	3	Yes	Task complete	Specification document produced for summary document (Review volume).
T-1.1.3	Ascertain from partners and user group if other information exists to complement [1] above	1	20	R	PP	4	Part of D-1.1.4	Task complete	Additional information identified and reported in the production of the chapters of the review volume (D-1.1.4), and reported in reference sections
D-1.1.4*	Production of summary report of the various options identifying key issues. Summary report on Work Package n°1	1	20	R	CO	6	draft	Feb 09 Jun 09	1st draft of the review chapters with the exception of PBMR chapter ready for the WP 1 workshop (Feb 09) chapter. Update following workshop comments and steering group (Apr 09) currently being incorporated.
T-1.2.1	Decision on the key stages of the road map and report to user group	1	20	R	PP	4	Yes	Sept 08	First draft of roadmap issued September identified the key stages, issued by email Subsequent revision to the route map following discussion at the Feb workshop. Final version of route map produced and distributed
T-1.2.2	Identification of end point for each key stage and compare with previous similar exercises undertaken either by the consortium and/or others	1	20	R	PP	5	Yes	Task Complete	First draft of roadmap issued September Since publication of the route map on the 7 September 08 no information identified by WP 1 partners that comparable route/road maps exist. This position confirmed at the WP 1 workshop (Feb 09) and document reissued

D-1.2.3	The report from [1] and [2] presented to consortium.	1	20	R	PP	6	draft	Feb 09	Review volume and route map presented at Work Package 1 meeting; with key points recorded in workshop slides and minutes. Also outlined at Steering group meeting April 2009, (see presentations)
T-1.3.1	Identification of end-point gaps in data/information	1	20	R	PP	7	yes	20/04/09	High level gaps identified at workshop. Reported in workshop minutes
T-1.3.2	Assessment of the impact of the lack and/or inferior quality of data/information on the project deliverable.	1	20	R	PP	10	draft	May 09	The Executive Summary identifies the gaps. The lack of information will be discussed at the WP2 workshop (June/July 09) and note issued to all participants for consideration/comment.'
D-1.3.3	Consideration if other WPs can deliver the absent information and recommend to consortium modifications to work programmes	1	20	R	PP	12	no	Jun 09	In preparation following steering group meeting (Apr 09)
T-1.4.1	Review the various MCDA tools/methodologies previously employed and relevance to this project.	1	20	6	PP	9	Yes	Dec 08 Feb 09	Report 1st issue Presentation of MCDA techniques and case studies presented at WP 1 workshop.
D-1.4.2	Selection of appropriate MCDA tool/methodology	1	20	R	PP	12	Yes	Apr 09	Report of MCDA techniques and selection of candidates
T-1.6.1	Agree assessment criteria for retrieval	1	20	R	PP	6	Yes	Complete 05/03/09 01/04/09	Following several NNL meetings and meetings with Doosan-Babcock and AMEC overview Note presented to workshop. Distributed to WP 1 participants for comment. Agreed criteria
D-1.6.2*	Assessed retrieval options against above criteria	1	20	R	CO	9	no		Output from workshop and record of NNL meetings. Further meeting with WP 2 leader
T-1.6.3	Feed back information into sub-tasks 1.3 and 1.4	1	20	R	PP	9	no	29/03/09	Ongoing activity facilitated through workshop output, WP 1 meeting and subsequent meeting with WP2 leader
D-1.7.1	Organisation and management of User Group (CUG)	1	20	O	PP	9	Yes	8	Combined with EPRI Workshop
T-1.7.2	Collation of data/information from other WPs	1	20	O	PP	Cont.			
D-2.4.1*	Separation of particles from matrix: synthesis of parametric study of pulsed power fragmentation with unirriadiated compacts (report)	2	8	R	CO	12	Yes		
T-2.1.1	Dissemination of data information for WP2	2	9	R	PP	11	no	14	
D-2.4.3*	Literature compilation on homogeneous oxidation of matrix graphite pebbles	2	1	R	CO	12	Draft	15	New drawings necessary
T-3.1.1	Proposal for graphite samples distribution	3	7	R	CO	3	Yes	9	Transports delayed
T-3.1.2	Sample management plan	3	7	R	CO	6	Yes	9	

T-3.1.3	RRT. Participation rules	3	7	R	CO	6	Yes		
D-4.2.1	Decontamination factors obtained by thermal treatment in an inert atmosphere	4	1	R	CO	36		36	PhD Thesis (in German) completed on first exploratory experiments.
T-5.1.1*	Review existing graphite waste-management methods	5	6	R	CO	12	Yes	March 2009	
T-5.2.1	Identification of requirements for intermediates needed for new products synthesis	5	6	R	PP	9	Yes	March 2009	
T-6.3.1	Compilation of waste package concepts as envisioned for the ANTARES project	6	5	R	CO	12	no	15	
T-6.4.1	Report on pore water model adaptation for organic/inorg. ^{14}C release	6	26	O	RE	12	no	15	
D-0.1.1	Detailed GANTT Chart	0	1	O	CO	2	Yes	1	Separate for each WP
T-0.1.2	CARBOWASTE Quality Plan	0	1	R	CO	3	Yes	2	Part of report template
D-0.2.1	CARBOWASTE Dissemination Plan	0	1	R	CO	3	Yes	6	Part of Periodic Report
T-0.2.2	CARBOWASTE Homepage (basic version)	0	1	O	PU	9	Yes	10	Fully in operation

Table 2: Milestones

Milestone no.	Milestone name	WP no	Lead	Delivery date	Achieved Yes/No	Actual / Forecast achievement date	Comments
M-1.1.1	Identifying key issues of the various options	1	NNL	6 months from start date	Yes	See comments for explanation of completion dates	First iteration of key issues achieved according to delivery date. Further refinements involving WP2 have occurred and now complete
M-1.3.1	Review of other WP activities to secure additional information	1	NNL	12 months from start date	Yes largely. (see comments)	By month 15	Throughout the project the other WP leaders have been made aware of the progress with the route map and graphite properties portfolio. Discussion will take place at the 2nd Steering group, to finalise what is required from other WPs.
M-2.1.1*	Data pack describing key reactor/graphite status and configuration	2	9	10	Yes		
M-2.4.1	First results for pulsed power separation of particles	2	CEA	9	Yes		
M-3.2.1	Tuning-up structural characterisation methologies & start of experimental work	3	UoM	7	Yes		
M-3.5.1*	Definition of DATABASE design	3	7	12	No	18	
M-4.1.1	Collection of data and identification of modelling packages finalised	4	27	6	Yes		
M-4.1.2	Statistical analysis & Tomography and SIMS evaluation of benchmarked virgin samples	4	27	12	No	18	
M-4.2.1*	Set up of the experimental devices	4	1,18	12	Yes		Sample Transport delayed
M-5.1.1*	Existing experience reviewed	5	6	12	Yes	March 2009	
M-5.2.1	Identification of requirements for recycled products	5	6	12	Yes	March 2009	
M-6.1.1*	Choice of Samples	6	10	12	yes	12	
M-6.1.2	UNGG samples prepared	6	8	6	yes	6	
M-6.1.3	Microtome device installed	6	26	12	no	15	
M-6.1.4	Percolation cell test set-up(s)	6	26	18	yes	11	
M-6.3.1	Concrete samples prepared	6	8	12	yes	12	

5 Project management

Task 0.1: Project Management & Support

The Work Package Leaders provided detailed work plans to specify the expected input by the partners. These work plans have been presented during the Kick-Off Meeting and have been upgraded in the specific Work Package Meetings.

The NNL (former name: Nexia Solution) organised a three day workshop in Manchester during February (16/18th). All WP1 European participant organisations attended. The review chapters, route map, retrieval criteria and graphite portfolio were addressed and many of the deliverables were reviewed and subsequently refined. Two sessions were devoted to the use and value of Multi Criteria Decision Analysis (MCDA) and retrieval criteria for WP2. The MCDA session was included as this activity will represent a significant contribution by the NNL for years 2 and 3 and forms a significant component of CARBOWASTE. It also allowed the NNL experts to introduce MCDA techniques/expectations to other WP1 participants.

Further to work package 1, the key linkages to Work Package 2 were noted and Doosan-Babcock described the current plan and scope for WP2 Retrieval and Segregation; illustrating current knowledge based on experience from the decommissioning of GLEEP and WAGR in the UK.

The workshop further cemented working relationships and an appreciation of the way forward for WP1.

As engineering lead of WP2 legacy waste aspects, Doosan Babcock worked particularly closely with National Nuclear Laboratory in WP1 holding regular progress and workshop meetings in the UK (at typically monthly intervals).

A combined WP3&4 Workshop was held in Berlin in January, 2009. The workshop was organised by FZJ. The main topics were: organisation of the round-robin test and of the exchange of graphite samples between the project partners, presentation and discussion of first scientific results and coordination of the further works.

There is a change in the position of the WP4 Leader as Dr. J. Fachinger left FZJ and is now working with FNAG, Grenoble. This company is also working in the field of graphite technology. His position is provisionally taken over by the coordinator, Dr. W. von Lensa, supported by Dr. D. Vulpius from FZJ-IEF6, who works on WP4 issues since beginning of 2009 as Post-Doc.

The 1st WP6 workshop was held with 22 participants (in presence of WP1 coordinator and project coordinator) at JRC-ITU, Karlsruhe from 23 March to 24 March, 2009. The presentations were characterized by national programmes for graphite waste management and by preparation work of many partners. Some interesting results have already been achieved and the planning of the work has been presented.

Beneficiary ‘Nexia Solutions Ltd.’ was renamed into ‘National Nuclear Laboratory’. Contract amendments to cope with this change are under preparation.

Task 0.2: Dissemination

The CARBOWASTE project has been formally presented the 9th of October 2008 in the course of the Audition by the CNE, the French “Commission Nationale d’Evaluation” of the program on long-lived low-level wastes of French nuclear waste management agency ANDRA.

A paper on CARBOWASTE was submitted to the HTR 2008 Conference in Washington.

In addition to the above, there was a separate CARBOWASTE session at the 7th EPRI International Decommissioning and Radioactive Waste Workshop in Lyon, France, on 29 October 2008. This session also addressed potential users of CARBOWASTE results. The Coordinator and the WP Leaders as well as utilities and waste management authorities provided presentations to this event.

A flyer has been produced providing a short overview on the CARBOWASTE project. A URL has been fixed for the homepage of the CARBOWASTE project (www.carbowaste.eu). The homepage is operable since Beginning of March 2009.

Further publications and presentations are collected in the 'Dissemination Plan'. The next 'User Group Meeting' will again be co-organised with the EPRI Workshop, which will be held in Hamburg, Germany, in October 2009.

A patent has been applied at the German Patentamt by FZJ on 19.12.2008 concerning 'In-Situ Purification of Contaminated Graphite' (10 2008 063 941.9-54). The invention proposes to inject reactive gases into graphite-moderated reactors during the final operation period to remove a part of the volatile contamination before retrieval, treatment and disposal.

Task 0.4: Education and training

A yet incomplete list of PhD students and post Docs with contact details has been collected, including 1 in IPNL and 1 at SUBATECH and 1 at FZJ. As planned, a post-doc fellow was recruited at ENS for 24 months and at UoM. Another Post-Doc has started at FZJ, Beginning of 2009. A PhD thesis has been finalised at FZJ and another will be started Mid of 2009 to understand better the physical and chemical background of C-14 removal. SCK.CEN performs a PhD thesis on characterisation and immobilisation of BR1 graphite.

The UK NNL have organised a PhD at B/ham University to study the C-14 distribution in Magnox reactors on the waste management of i-graphite. Other offending radionuclides will be part of the three year study that will also accommodate other reactor types. This PhD is being part funded by the Engineering and Physical Sciences Research Council (EPSRC) one of the UK's research councils. The title of the thesis is 'The implications of i-graphite activation product distribution in nuclear reactors on decommissioning and disposal strategies'.

This linkage of national research interests with EURATOM research will be further developed within CARBOWASTE.

A Nuclear Graphite Technology Course was held in Manchester in March, 2009. The course was organised by the School of Mechanical, Aerospace and Civil Engineering of the UoM together with CARBOWASTE. 34 participants were present from which the majority were partners of the CARBOWASTE project. The course covered all aspects of the nuclear graphite cycle that means the production, the characterisation and the final disposal of nuclear graphite.

A second training and education workshop is in the planning state. The workshop shall be open to scientists from graphite related national programs. A provisional suggestion has been made to hold the workshop in France somewhere in the second half of 2009, considering the large number of French participants, in the project.

The young researchers in CARBOWASTE are organizing a workshop on their research activities for September 2009 at JRC-ISPRA in Italy.

List of CARBOWASTE Venues:

Kick-Off Meeting (1. SCM): 6-7 May 2008, Juelich, DE

1. User Group Meeting: 29 October 2008, Lyon; FR

WP5 Meeting: 10-11 December 2008, Meitingen, DE

1. WP3&4 Meeting: 20-21. January 2009, Berlin, DE

1. WP1&2 Workshop: 15-19 February 2009, Manchester, UK

1. Graphite Course: 10-13 March 2009, Manchester, UK

1. WP6 Meeting: 22-24 March 2009, Karlsruhe,DE

2. Steering Committee Meeting (2. SCM): 21-21. April, Marcoule, FR

2. WP3&4 Workshop: 9-10 June 2009, Madrid, Spain

6 Explanation of the use of the resources

Partner 1: FZJ

Table 3.1 Personnel, subcontracting and other major Direct cost items for Beneficiary FZJ for the period

Work Package	Item description	Amount	Explanations
1	Personnel costs	75.076,54 €	0,2 PM Scientists
2	Personnel costs		0,2 PM Scientists
3	Personnel costs		0,9 PM Scientists; 4 PM Technician, (4 PM PHD)*
4	Personnel costs		1,2 PM Scientists, 2 PM Post-Doc 5,5 PM Technician, (6PM PHD)*
5	Personnel costs		0,1 PM Scientists
6	Personnel costs		0,2 PM Scientists, 3,3 PM Technician
0	Personnel costs		0,4 PM Scientist
	Subcontracting	431,00	Service for Microscope
	Major cost items	1850,95	Depreciation on following facilities: Frequency transformers for Induction Furnace Data loggers
	Consumables	1.295,97 €	Chemicals, radioisotopes, labware
	Travel & Subsistence	15.942,66 €	Kick-Off Meeting: 6-7 May 2008, Juelich, DE Conference: 27-31.October 2008, Wuerzburg, DE EPRI Workshop 27-30 October 2008, Lyon; F WP5-Meeting: 10-11 December 2008, Meitingen, DE WP3&4 Meeting: 20-21. January 2009, Berlin, DE WP1&2 Workshop: 15-19 February 2009, Manchester, UK Graphite Course: 10-13 March 2009, Manchester, UK WP6 Meeting: 22-24 March 2009, Karlsruhe,DE
	Remaining direct costs	3.657,13 €	
	TOTAL DIRECT COSTS	98.254,25 €	

** PHD from own FZJ resources – no charge to CARBOWASTE*

Partner 2: AMEC-NNC

Table 3.2 Personnel, subcontracting and other major Direct cost items for Beneficiary AMEC-NNC for the period

Work Package	Item description	Amount	Explanations
1,2	Personnel costs	2978.02€	Time of personnel to attend meetings etc.
	Subcontracting		
	Major cost item 'X'		
	Major cost item 'Y' ………..		
1,2	Remaining direct costs	995.53€	Travel costs
	TOTAL DIRECT COSTS	3973.55	

Partner 3: ANDRA

TABLE 3.3 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY ANDRA FOR THE PERIOD 1			
Work Package	Item description	Amount	Explanations
1,6	Personnel costs	14 832,47	Salaries of 3 persons for 0,9 month, 0,6 month and 0,2 month
	Subcontracting		
1,3,6	Travel & Subsistence	2 014,71	2 meetings for 2 persons (kick off meeting) 2 meetings for one person (WP2/3 and WP6)
	Consumables & Supplies		
	Durable Equipment		
	Remaining direct costs		
	TOTAL DIRECT COSTS	16 847,18	

Partner 4: NECSA (see Partner number 29)

Partner 5: AREVA NP

TABLE 3.5: PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY AREVA NP FOR THE PERIOD 1			
Work Package	Item description	Amount	Explanations
	Personnel costs	6780.13	
	Subcontracting		
	Travel & Subsistence	1178.24	Kick-off meeting in FZJ + WP3-WP4 meeting in Berlin
	Consumables & Supplies		
	Durable Equipment		
	Remaining direct costs		
	TOTAL DIRECT COSTS	7958.37	

Partner 6: BRADTEC

TABLE 3.1 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY BRADTEC FOR THE PERIOD APRIL 2008 – MARCH 2009			
Work Package	Item description	Amount	Explanations
5	Personnel costs (RTD)	*34,654 €*	393 Hours D Bradbury and 165 Hours G Elder per timesheets. Principal activities - production of review report and visits, discussions
5	Personnel costs (Other Activities)	*5,459 €*	66 Hours D Bradbury and 21 Hours G Elder per timesheets, principal activity training J Goodwin to join CARBOWASTE programme in 2nd year.
5	Travel Costs	*2,861 €*	D Bradbury travel to Jülich (plenary mtg, May 2008) to Graftech, Parma, Ohio, (August 2008) and SGL, Germany (December 2008)
	TOTAL DIRECT COSTS[3]	*42,974 €*	

Partner 7: CIEMAT

TABLE 3.7 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY CIEMAT FOR THE PERIOD			
Work Package	Item description	Amount	Explanations
3	Personnel costs	*34482 €*	*6.6 P-month SS, 2.8 P·,month T & 0.8 P·month medium T*
4	Personnel costs	*12172 €*	*2.2 P-month SS, 1.6 P·,month T*
0	Personnel costs	*1642 €*	*0.4P. month SS (management)*
0, 3,4,	Travel & subsistence	*2854 €*	*SCM and WP meetings*
	TOTAL DIRECT COSTS[3]	*51150 €**	

Partner 8: CEA

TABLE 3.8 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY CEA FOR THE PERIOD 1			
Work Package	Item description	Amount	Explanations
WP2	PERSONNEL	9 018 €	*1,75 PM*
WP3	PERSONNEL	16 385 €	*3,2 PM*
WP6	PERSONNEL	39 636 €	*7,7 PM*
	Consumables	*934 €*	*labware*
	Other Cost	*2.724€*	*Travel etc.*
	TOTAL DIRECT COST	68.697,71 €	

3 Total direct costs have to be coherent with the directs costs claimed in Form C

Partner 9: DOOSAN BABCOCK

TABLE 3.9 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY DOOSAN BABCOCK FOR THE PERIOD			
Work Package	Item description	Amount	Explanations
WP1 WP2	Personnel costs	*38816€*	*Salaries of Senior Engineers*
	Subcontracting	*0€*	
	Major cost item 'X'	*0€*	
	Major cost item 'Y' ………..	*0€*	
	Remaining direct costs	*1859€*	*Travel and Subsistence in UK and to European meetings*
	TOTAL DIRECT COSTS[4]	*40675€*	

Partner 10: EDF

TABLE 3.10 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY EDF FOR THE PERIOD 1			
Work Package	Item description	Amount	Explanations
1,2,3,6	Personnel costs	28,557.92	Salaries of 2 persons for 2.5 month and 1 month
	Subcontracting		
1,2,3,6	Travel & Subsistance	3,277.48	2 meetings for 2 persons (kick off meeting) 4 meetings for one person (WP1,2,3,6)
	TOTAL DIRECT COSTS	31,835.40	

Partner 11: ENS

TABLE 3.11: PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY ENS FOR THE PERIOD 1			
Work Package	Item description	Amount	Explanations
3.2	Personnel costs	29 222.36€	Salaries of 1Postdoctoral for 6 months and one lab technician for 12 months each
	Subcontracting		
3.2	Travel & Subsistance	3 837.39€	Project Meetings (Lyon, St. Laurent des Eaux, Saclay, Lille, Evry, Berlin, Montpellier)
3.2	Consumables & Supplies	2 037.30€	Labware
	Durable Equipment		
	Remaining direct costs		
	TOTAL DIRECT COSTS	35 097.05€	

[4] Total direct costs have to be coherent with the directs costs claimed in Form C

Partner12: ENEA

TABLE 3.12 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY ENEA FOR THE PERIOD 1			
Work Package	Item description	Amount	Explanations
WPs 3.1, 3.3, 4.3	Personnel costs	27000 €	Salaries of 2 researchers and 1 responsible for 6.5 months, 3 months each and 0.5 months respectively (*to this amount has to be added an amount of 25000 € for personnel indirect cost*)
	Subcontracting		
Steering Committee	Travel & Subsistence	2700 €	Participation of 2 people at the 1st Steering Committe Meeting (Juelich)
WPs 3.1, 3.3, 4.3	Consumables & Supplies	2500 €	Chemicals for preparing experiments
	Durable Equipment		
	Remaining direct costs		
	TOTAL DIRECT COSTS	32200	

Partner 13: ENRESA

TABLE 3.13: PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY ENRESA FOR THE PERIOD 1			
Work Package	Item description	Amount	Explanations
1	Personnel costs	12446	1,89 person-month
1	Travel & Subsistence	5346	Kick-Off Meeting & WP1&2 Meeting in Manchester
2	Personnel costs	471	0,07 person-month
3	Personnel costs	3139	0,51 person-month
6	Personnel costs	1569	0.26 person-month
6	Subcontracting	0.0	
6	Travel & Subsistence	2058	
6	Consumables & Supplies	0.0	
6	Durable Equipment	0.0	
6	Remaining direct costs		
	TOTAL DIRECT COSTS	25,029	

Partner 14: GRAFTECH

TABLE 3.14: PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY UCAR-GRAFTECH FOR THE PERIOD 1			
Work Package	Item description	Amount	Explanations
4 & 5	Personnel costs	10 637	1 month worth for one employee
	Subcontracting		
4 & 5	Travel & Subsistence	1 306	Train/rent car/other
	Consumables & Supplies		
	Durable Equipment		
	Remaining direct costs		
	TOTAL DIRECT COSTS	11 943	

Partner 15: FI

TABLE 3.15 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY FI FOR THE PERIOD 1			
Work Package	Item description	Amount	Explanations
WP1 (tasks 1.1, 1.2, 1.3), WP3 (tasks 3.1, 3.4)	Personnel costs	20649,74 €	Salaries of 6 researchers for 6 months each, salaries of 3 researchers for 3 months each Salaries of 2 engineers for 6 months each
WP3 (task 3.1)	Subcontracting	19346,62 €	Advanced payment to subcontractor for taking graphite samples from RBMK-1500 reactor of Ignalina NPP
WP1 (tasks 1.1, 1.2, 1.3), WP3 (tasks 3.1, 3.4)	Travel & Subsistence	4728,44 €	Participation of 1 person at Project meetings in Julich, Lyon, Berlin, and Manchester
	Remaining direct costs		
	TOTAL DIRECT COSTS	447248,80 €	

Partner 16: INR

TABLE 3.16 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY INR FOR THE PERIOD 1			
Work Package	Item description	Amount	Explanations
W1.1, 3.3, 4.3, 6.4	Personnel costs	5979.20	Salaries of 10 researchers for 0.2 months, 2.2 months, 0.2 months & 2 months respectively. Salaries of two lab technicians for 0.5 months each.
	Subcontracting		
WP1.1, WP3.3, WP4.3, WP6.4	Travel & Subsistence	4148.17	Participation of 5 persons in Carbowaste meetings (Kick off meeting, WP1 meeting, WP6 meeting)
WP3.3	Consumables & Supplies	617.16	Materials for laboratory experimental set-up
	Durable Equipment		
W1.1, 3.3, 4.3, 6.4	Remaining direct costs	665.15	Other direct costs connected to the working activity
	TOTAL DIRECT COSTS	11409.68	

Partner 17: IPNL

TABLE 3.17 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY IPNL FOR THE PERIOD			
Work Package	Item description	Amount	Explanations
WP6	Personnel costs	7.385,22	Permanent scientific staff
	Subcontracting		
	Consumables	7.430,30	Manufacturing of a gold deposit on the internal walls of the irradiation cell, gas mixture for the irradiation experiments, ion microprobe analysis, diamond pastes for polishing, nickel foils
	Travel	778,00	Winter School on Radiolysis (November 11-14, 2008)
	Remaining direct costs		
	TOTAL DIRECT COSTS	15.593,52	

Partner 18: JRC

TABLE 3.18: PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY JRC FOR THE PERIOD			
Work Package	Item description	Amount	Explanations
Ex: 4.2	Personnel costs	*25541,37 €*	Salaries of researchers
	Subcontracting		*
	Major cost items	*nil*	*
	Remaining direct costs		
	TOTAL DIRECT COSTS	*25541,37€*	

Partner 19: LEI

TABLE 3.19 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY LEI FOR THE PERIOD 1			
Work Package	Item description	Amount	Explanations
D1.1.1, D1.1.2, D1.2.2, D1.6.1, D1.1.1, WP2/2.1, WP/3.4	Personnel costs	15167,67 €	Salaries of 3 researchers for 1,7 month, 0,5 months, 1,1 months respectively.
-	Subcontracting	-	
WP1, WP2, WP3, WP6 WP1, WP2	Travel & Subsistence	636,71 € 1198,91 €	Participation of one person in the opening meeting of the project. Participation of one person in the meeting (WP1-WP2) of the project
-	Consumables & Supplies	-	-
-	Durable Equipment	-	-
-	Remaining direct costs	-	-
	TOTAL DIRECT COSTS	17003,29 €	-

Partner 20: NNL

TABLE 3.20: PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY NATIONAL NUCLEAR LABORATORY FOR THE PERIOD 1			
Work Package	Item description	Amount	Explanations
WP1,WP2 & Training	Personnel costs	€197,357.11	Work Package 1 – 19.7 man months. Effort has been focused on the following tasks. 1 preparation of review document (issue 1); 2 development of the CARBOWASTE route map; 3 identification of high tier retrieval criteria; 4 production of graphite properties/characteristics portfolio; 5 organisation of WP1 workshop. (4 main technical experts have carried out the bulk of the work and a number of key specialists have been brought in for input to workshops and key decision points). Work Package 2 – 1.2 man months (2 x technical experts – familiarisation with WP2 and attendance at workshops). Work Package 6 – 0.5 man months (2 technical experts - familiarisation with WP6 and attendance at WP6 meeting). Training - 0.46 man months (2 x junior staffs time for attending nuclear graphite technology course at Manchester University. 1 x staff attendance at EU training course).
	Subcontracting	-	

WP1,WP2 & Training	Travel & Subsistence	€19,422.94	May 2008 - Attendance at project kick of meeting x 3 people October 2008 Carbowaste User Group, Lyon x 1 person October 2008 WP 1 meeting x 3 people. February 20009 Presentation of Paper at Waste Management 2009, USA 1 x person. March 2009 - WP 6 meeting, Germany x 2 attendees May – March 2009 – T&S associated with attendance of internal workshops and meetings for WP1 (approx 3 trips per month). May – March 2009 – T&S associated with attendance at preliminary workshops for as part of WP2.
WP1,WP2 & Training	Consumables & Supplies		
	Durable Equipment		
WP1,WP2 & Training	Remaining direct costs	€6,611.07	March 2009 – Course Fees for the nuclear graphite technology course at Manchester University for 2 junior members of staff. October 2008 – Course Fees for the Financial Reporting & Auditing of EU Funded Projects Training Course for 1 person. May – March 2009 – Conferences facilities & fees (waste management, EPRI, & WP1 meeting).
TOTAL DIRECT COSTS		€223,391.12	

Partner 21: NDA-RWMD

TABLE 3.21 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY NDA RWMD FOR THE PERIOD

Work Package	Item description	Amount	Explanations
6.4	Personnel costs	*13432,17 €**	*Input to task looking at post-closure implications of irradiated graphite, and participation in CARBOWASTE meetings at Lyon (in association with EPRI) and Karlsruhe (WP6)*
6.4	Indirect costs	*2686,43 €**	*At agreed flat rate*
TOTAL DIRECT COSTS		*13432,17€**	

Partner 22: NRG

TABLE 3.22 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY NRG FOR THE PERIOD 1			
Work Package	Item description	Amount	Explanations
WP3.1, WP 5.2 WP6.2	Personnel costs	8.002,95	Salary of researcher
	Subcontracting		
WP3.1, WP 5.2 WP6.2	Travel & Subsistence	1.546,42	Participating to the kick-off meeting and WP3 and WP6 meetings
	Consumables & Supplies		
	Durable Equipment		
WP3.1, WP 5.2 WP6.2	Remaining direct costs	31,30	Chemicals
	TOTAL DIRECT COSTS	9.580,67	

Partner 23: SCK.CEN

TABLE 3.23 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY SCK.CEN FOR THE PERIOD 01/04/2008 – 31/03/2009			
Work Package	Item description	Amount	Explanations
3, 4	Personnel costs	*10,388.44 €*	*Labour costs (preparation of the analyses in both WP's, coordination)*
4	Other direct costs	*1,031.30 €*	*Purchase of a membrane pump (as part of the thermal analyzer), other small items*
	TOTAL DIRECT COSTS	*11,419.74 €*	

Partner 24: SGLGROUP

TABLE 3.24: PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY SGL FOR THE PERIOD 1			
Work Package	Item description	Amount	Explanations
WP3.2 WP4.1, 4.3 WP5.1, 5.2, 5.4	Personnel costs	16735 €	Consulting to WPs 3/4, WP Meetings 3/4 and 5, Activities in WP5 (Survey, technical discussions, work plan): total 1.5 PM scientists
	Subcontracting	0 €	
WP3.2 WP4.1, 4.3	Travel & Subsistence	362	Travel Costs Kickoff Jülich, WP 3/4 Meeting Berlin
	Consumables & Supplies	0 €	
	Durable Equipment	0 €	
	Remaining direct costs	0 €	
	TOTAL DIRECT COSTS	17097 €	

Partner 25: STUDSVIK

No activities, yet

Partner 26: ARMINES

TABLE 3.26A PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY 26 –ENSMN FOR THE PERIOD			
Work Package	Item description	Amount	Explanations
6	Personnel costs	58806.25	Coordination of WP6, start of experiments
	Subcontracting		
	Major cost item 'X'		
	Major cost item 'Y' ………..		
	Remaining direct costs		
	TOTAL DIRECT COSTS	58806.25	

TABLE 3.26B PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY 26-ENSMP FOR THE PERIOD			
Work Package	Item description	Amount	Explanations
0	Personnel costs	4789.43	Organisation of teaching and training activities
	Subcontracting		
	Major cost item 'X'		
	Major cost item 'Y' ………..		
	Remaining direct costs		
	TOTAL DIRECT COSTS	4789.43	

TABLE 3.26C PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY 26-ARMINES FOR THE PERIOD			
Work Package	Item description	Amount	Explanations
6	Personnel costs		
	Subcontracting		
	Major cost item 'X'		
	Major cost item 'Y' ………..		
	Remaining direct costs	4676.87	Travel to kickoff+ wp meetings, consumables
	TOTAL DIRECT COSTS	4676.87	

TABLE 3.26D PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY 26 –ARMINES FOR THE PERIOD			
Work Package	Item description	Amount	Explanations
0	Personnel costs		
	Subcontracting		
	Major cost item 'X'		
	Major cost item 'Y' ………..		
	Remaining direct costs	2667.75	Travel to training workshop, Manchester
	TOTAL DIRECT COSTS	2667.75	

Partner 27: UNIMAN

TABLE 3.27: PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY UNIMAN FOR THE PERIOD 1			
Work Package	Item description	Amount	Explanations
3,4,5,6	Personnel costs	€20,881.81 €7,215.08 €57.03 €71.76	WP3 – 7.6 mm (includes 1.75 mm ac partner own-staff) WP4 – 3 mm (includes 0.75 mm ac partner own-staff) WP5 – 0.01 mm WP6 – 0.01 mm
	Subcontracting		
3,4,5,6	Travel & Subsistence	€4,152.88	€460.82 – INGSM-9 conference: Netherlands, Sep 08 €718.81 – Research trip: Switzerland, Nov 08 €910.95 – CARBOWASTE meeting: Germany, Jan 09 €1,369.48 – CARBOWASTE conference: France, Oct 08 €345.97 – UNTF conference: UK, Mar 09 €346.85 – Miscellaneous travel costs, Apr 08 – Mar 09
3,4,5,6	Consumables & Supplies	€5,431.24 €63.09	Computer code software Miscellaneous consumables
	Durable Equipment		
	Remaining direct costs		
	TOTAL DIRECT COSTS	€37,872.89	

Partner 28: PBMR

No EU-Funding

TABLE 3.28: PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY PBMR FOR THE PERIOD 1			
Work Package	Item description	Amount	Explanations
WP1.1, WP4.4, WP5.1	Personnel costs	149833	Direct PBMR staff salaries (One fulltime researcher, one 20% manager, two interns, four masters degree students under PBMR funding)
WP4.4	Subcontracting	61760	Specialist support (microbiology), University of Pretoria; under management of PBMR
WP1.1, WP4.4, WP5.1	Travel & Subsistence	22087	Two persons, FZJ meeting April 2008; Three persons EPRI meeting, Oct 2008; One person Berlin meeting Febr 2009
WP4.4	Consumables & Supplies	23605	Graphite, C14, bacteria & general laboratory consumables
WP4.4	Durable Equipment	235376	New laboratory equipment for use in university laboratories (ownership remains with PBMR), equipment used by PBMR personnel (fulltime staff & interns)
WP4.4	Remaining direct costs	61224	Training costs, laboratory infrastructure (security, licensing, etc.)
	TOTAL DIRECT COSTS	553885	

Partner 29: NECSA

No EU-Funding

TABLE 3.29 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY NECSA FOR THE PERIOD APRIL 2008-APRIL2009			
Work Package	Item description	Amount	Explanations
2,4,5,6	Personnel costs	*250000 €**	Salaries of: 1 permanent employee(registered postdoctoral student) 3 permanent employees(Registered Masters students) 2 Necsa Scientists 2 University students (Masters)
	Subcontracting	*0 €**	
2, 4	Major cost item 'X'	*30 000 €**	*Rf induction oven system*
2,4	Major cost item 'Y' ………..	*70 000€**	*Electrochemical apparatus*
2,4	Major cost item 'Y'	*30 000€**	*Instalment and upgrading of Nd-Yag Laser*
5, 6	Remaining direct costs	*96 000€**	*Other equipment (glove box, blasting system, analysis) and managing costs*
	TOTAL DIRECT COSTS	*476 000€**	

7 Financial statements – Form C and Summary financial report

Please submit a separate financial statement from each beneficiary (if Special Clause 10 applies to your Grant Agreement, please include a separate financial statement from each third party as well) together with a summary financial report which consolidates the claimed Community contribution of all the beneficiaries in an aggregate form, based on the information provided in Form C (Annex VI) by each beneficiary.

When applicable, certificates on financial statements shall be submitted by the concerned beneficiaries according to Article II.4.4 of the Grant Agreement.

IMPORTANT:

Form C varies with the funding scheme used. Please make sure that you use the correct form corresponding to your project. Templates for Form C are provided in Annex VI of the Grant Agreement. An example for collaborative projects is enclosed hereafter. A Web-based online tool for completing and submitting the forms C is under preparation. If you have to submit forms C before the tool becomes available, please ask your Commission project officer for an Excel version of the form.

If some beneficiaries in security research have two different rates of funding (part of the funding may reach 75% in reference with Article 33.1 of the EC rules for participation - REGULATION (EC) No 1906/2006) then two separate financial statements should be filled by the concerned beneficiaries and two lines should be entered for these beneficiaries in the summary financial report.

The Financial Statements are attached in the Annex

8 Certificates

Beneficiary	Short Name	Certificate provided	Comments, if certificate is not provided
1	FZJ	No	Expenditure threshold not reached
2	AMEC-NNC	No	Expenditure threshold not reached
3	ANDRA	No	Expenditure threshold not reached
4*	NECSA	No	Expenditure threshold not reached
5	AREVA NP	No	Expenditure threshold not reached
6	BRADTEC	No	Expenditure threshold not reached
7	CIEMAT	No	Expenditure threshold not reached
8	CEA	No	Expenditure threshold not reached
9	DOOSAN BABCOCK	No	Expenditure threshold not reached
10	EDF	No	Expenditure threshold not reached
11	ENS	No	Expenditure threshold not reached
12	ENEA	No	Expenditure threshold not reached
13	ENRESA	No	Expenditure threshold not reached
14	GRAFTECH	No	Expenditure threshold not reached
15	FI	No	Expenditure threshold not reached
16	INR	No	Expenditure threshold not reached
17	IPNL	No	Expenditure threshold not reached
18	JRC	No	Expenditure threshold not reached
19	LEI	No	Expenditure threshold not reached
20	NNL (NEXIA)	No	Expenditure threshold not reached
21	NDA-RWMD	No	Expenditure threshold not reached
22	NRG	No	Expenditure threshold not reached
23	SCK.CEN	No	Expenditure threshold not reached
24	SGLGROUP	No	Expenditure threshold not reached
25	STUDSVIK	No	Expenditure threshold not reached
26	ARMINES	No	Expenditure threshold not reached
27	UNIMAN	No	Expenditure threshold not reached
28	PBMR	No	Expenditure threshold not reached
29	NECSA	No	Expenditure threshold not reached

** NB: Partner 4 (NECSA, RSA) is identical with the former partner 29, as still listed in the GPF*

Dissemination Plan

All CARBOWASTE partners have been active to promote the CARBOWASTE project in public, also indicating the EURATOM support. To date, the following steps have been undertaken:

[1] Article for Nuclear Futures entitled 'CARBOWASTE - An Integrated Approach to Irradiated Graphite'

[2] Presentation at the Nuclear Decommissioning Conference, Sept. 09 Liverpool University, Presentation entitled 'CARBOWASTE - An integrated Waste Management Approach to Irradiated Graphite'.

[3] Presentation at the Securing the Safe Performance of Graphite Reactor Cores conference, Nottingham 24/26 Nov 08, presentation entitled 'UK's Irradiated Magnox Graphite - Is It Intermediate Level Waste?'

[4] Paper accepted for the Tucson 09 Nuclear Waste Management conference. Paper 'Strategic options for the management of waste irradiated graphite nears completion'.

[5] Paper for the 4th International Topical Meeting on High-Temperature Reactor Technology, HTR2008, September 28 - October 1, 2008, Washington D.C., USA, CARBOWASTE: New EURATOM Project on 'Treatment and Disposal of Irradiated Graphite and other Carbonaceous Waste', HTR2008-58280

[6] A flyer has been produced providing a short overview on the CARBOWASTE project. About 200 exemplars have been distributed, to date.

[7] - J.N. ROUZAUD, C.E. VAUDEY, N. TOULHOAT, N. MONCOFFRE. Characterization of nuclear graphite by Raman microspectrometry and TEM. 9th International Nuclear Graphite Specialists Meeting, Petten, Holland, 14-17 September 2008.

[8] Presentations during the EPRI Workshop in Lyon on October 29, 2008

[9] M.R. AMMAR, C.E. VAUDEY, J.N. ROUZAUD, N. TOULHOAT, N. MONCOFFRE. Structural characterization of raw and implanted nuclear graphite by Raman microspectrometry and Transmission Electron Microscopy, Biarritz, France, 14-19 June 2009.

[10] M.R. AMMAR, C.E. VAUDEY, J.N. ROUZAUD, N. TOULHOAT, N. MONCOFFRE. Structural study of implanted nuclear graphite used to simulate irradiation effects.10th International Nuclear Graphite Specialists Meeting, West Yellowstone, Montana, 28-30 September 2009.

[11] Paper at the International High-Level Waste Conference, September 7 – September 11, 2008, Las Vegas, USA: ALTERNATIVE USE OF IRRADIATED GRAPHITE WASTE - .CARBOWASTE, Published Paper no. 195968

[12] The **CARBOWASTE Homepage** is active since March 2009

[13] Paper at the 33 rd International Material Research Society Symposium, May 24 – May 29, 2009, St Petersburg, Russia, TREATMENT OF RADIOACTIVE GRAPHITE TO MINIMIZE DISPOSAL VOLUME, Paper no. A7

9 Annex 3: List of Acronyms

AGR	Advanced Gas-cooled Reactor
ALARA	principle in radiation protection „As Low As Reasonably Achievable”
AVR	Arbeitsgemeinschaft-Versuchs-Reaktor
BET	Brunauer, Emmett und Teller (Surface area and porosity method)
BPM	Best Practical Means
C	Contributor
$D_{25,50,75}$	Duration in years between de-fuelling and retrieval of graphite
DESCA	DEvelopment of a Simplified Consortium Agreement in FP7
EDAX	Energy Dispersive X-ray analysis
EDX	Energy Dispersive X-ray analysis, is a valuable tool for qualitative and quantitative element analysis
EELS	Electron Energy Loss Spectroscopy
EPRI	Electric Power Research Institute
ERA	European Research Area
FIB	Focussed Ion Beam
FRJ I	Research Reactor Juelich I
FTIR	Fourier Transformation Infra-Red Spectroskopy
GC	Gas Chromatography
GCR	Gas Cooled Reactor
GIF	Generation International Forum
GLEEP UK	Graphite Low Energy Experimental Pile**,** was a long-lived experimental British Nuclear Reactor
HLW	High-Level-Waste
HPLC	High Performance Liquid Chromatography
HRTEM	High Resolution Transmission Electron Microscopy
HTR	High Temperature Reactor
IAEA	The International Atomic Energy Agency
IEF	Institute of Energy Research within FZJ
ILW	Intermediate-Level-Waste
IPR	Intellectual Property Rights
INL	Idaho National Laboratory
Konrad	Final Repository for Radioactive Waste in Germany
LEU	Low Enriched Uranium
LLW	Low-Level-Waste

LWR	Light Water Reactor
MAGNOX	Pressurised Reactors, carbon dioxide-cooled, graphite-moderated using natural Uranium as fuel and Magnox alloy as fuel cladding
MCDA	Multiple Criteria Decision Analysis
MOX	Mixed oxide
MSR	Molten-Salt Reactor
MTR	Material Test Reactor
ND-YAG	neodymium-doped yttrium aluminium garnet laser
PBMR	Pebble Bed Modular Reactor
PSA	Pressure Swing Absorption
RBMK	Reaktor Bolshoy Moshchnosti Kanalniy (reactor of high power channel)
R&D	Research & Development
RN	Radionuclides
RSA	Republic of South Africa
RTD	Research and Technology Development
RWTH	Rheinisch-Westfälische Hochschule Aachen (Technical University of Aachen)
SEM	Scanning Electron Microscope
SIMS	Secondary-Ion-Mass-Spectroscopy
TG-MS	Thermogravimetric Analyser linked to Mass Spectrometer
TL	Task Leader
TRISO	Coated Particle-type thorium carbide (ThC),uranium carbide (UC)
QA	Quality Assurance
UKAEA	United Kingdom Atomic Energy Authority
UNGG Plant	Uranium Naturel Graphite Gaz
WAGR	Windscale Advanced Gas-cooled Reactor
WP	Work Package
WPL	Work Package Leader
VHTR	Very High Temperature Reactor (Generation IV reactor)
XRD	X-ray Diffraction Analysis