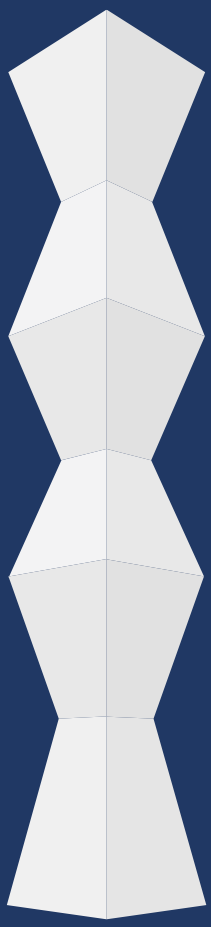
romania2019.eu
Romanian Presidency of the Council of the European Union

Non-power nuclear technologies and applications



Acknowledgements

This booklet is a collection of inspiring examples of good practices and ideas from different Member States across the European Union and from the European Commission – the Joint Research Centre. All the content used represents the contribution of the Member States delegations and is its purpose to support the discussions on the topic of non-power nuclear technologies and applications during the Romanian Presidency of the Council of the EU at the Atomic Questions Working Party level.

We thank all the Member States and the European Commission – the Joint Research Centre for their valuable contributions.

FOREWORD

Applications of nuclear science and technologies of today bring significant economic and societal opportunities that benefit to all Member States and European citizens. Breakthrough progress can only be achieved through fostering synergies between adjacent fields and through joint efforts.

Nicolae HURDUC, Minister of Research and Innovation of Romania

We need key-projects that boost contribution towards the achievement of the closely interlinked energy and climate goals. Mainstreaming the dimensions of energy security, innovation and research, will ensure access to affordable, reliable and sustainable energy for all.

Anton ANTON, Minister of Energy of Romania

There are many non-energy beneficial uses of nuclear and radiation technology that are prevalent in everyday use and provide solutions to some of Europe's most pressing societal challenges, for example in modern medicine (diagnosis and treatment of different diseases), in industry, in research, space, agriculture, culture, forensics, environment, food chain, water supply etc.

The benefits for a better and longer life, a more secure and healthy environment, for better conditions for workers and/or patients and more efficient ways of combatting climate change (through cleaner technologies, adaptation to and mitigation of the effects of climate change on the environment) are few of the strongest arguments for considering alternative uses of nuclear and radiation technologies.

This booklet intends to provide a broad overview of the state of affairs on the non-power nuclear technologies and applications in the European Union and aims to raise awareness on this topic.

I thank the Member States and the European Commission – the Joint Research Centre for their substantial contribution to this project.

Roxana Banu
Chair of the Atomic Questions Working Party
Council of the European Union

CONTENTS

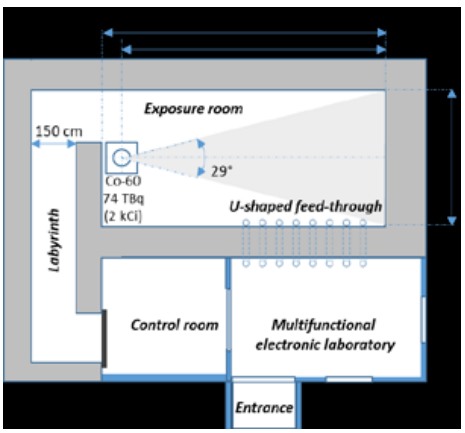
AUSTRIA

Radiation Hardness Assurance of Electronic Components

Description:

Electronic components and systems show degradation in their electrical performance when exposed to ionizing radiation. Affected are devices used in space, aviation, particle accelerators or in medical nuclear facilities. Radiation hardness assurance measures are needed to guarantee proper and save functionality. Due to the increasingly diminishing component structures radiation sensitivity is increased. Effects caused by cosmic radiation on the earth's surface become relevant for electronic devices even in terrestrial applications such as automotive. Electronic components and systems that are to be used in sensitive areas need to be qualified with respect to their radiation resistance. The corresponding test procedures are defined by international organizations such as the European Cooperation on Space Standardization (ECSS).

The TEC Laboratory, Seibersdorf Laboratories' novel testing site that was opened in 2016, is ideally equipped for such radiation hardness assurance measurements. It offers total ionizing dose (TID) exposure tests of electronics, systems and materials with a Cobalt-60 source. TID tests are of particular interest to electronic applications in space. The exposure of the device under test (DUT) is performed in accordance with accredited procedures that are compliant with the EN ISO/IEC 17025 standard for test labs. With its expertise, the team of Seibersdorf Laboratories supports ESA as well as numerous electronics and space applications manufacturers in Europe and worldwide.



Collaborators:

The partners Seibersdorf Laboratories, FOTEC / FH-Wiener Neustadt, AAC and MedAustron in Austria have joined forces within the framework of the Aerospace Testing Austria (ATA) Alliance to ensure that examinations and aerospace test campaigns are of high quality, economical and easily accessible as a one-stop-shop. The Austrian Aerospace Testing Alliance offers regional, national and global solutions for aerospace test campaigns. In addition, these capacities are available for applications in digitization, embedded electronics, and e-mobility.
Further dosimetry experiments with photons, electrons, neutrons, protons, and heavy ions are carried out at the following partner institutions:

- ATI - Vienna University of Technology (Vienna, Austria)
- CERN (Switzerland)
- DUBNA (Russia)
- Fraunhofer Institute INT (Germany)
- GSI – (Darmstadt, Germany)
- HIMAC (Chiba, Japan)
- INFN – (Legnaro, Italy)
- iThemba (Republic of South Africa)
- PTB – Physikalisch Technische Bundesanstalt (Braunschweig, Germany)
- RADEF (Jyväskylä, Finland)
- UCL - Université catholique de Louvain (Louvain, Belgium)
- University Padova (Italy)

Other:

Seibersdorf Laboratories:
https://www.seibersdorf-laboratories.at/en
TEC Laboratory:
https://www.seibersdorf-laboratories.at/en/products/ionizing-radiation/radiation-hardness-assurance/tec-laboratory

BULGARIA

Screening of cereal stress response in support of Bulgarian agriculture

Benefits:

The project is aimed to highlight the adaptive potential and enhance the involvement of wheat and barley in breeding programmes directed towards more sustainable, environmentally friendly and cost-effective agriculture. Work was focused on improvement of wheat for disease resistance, radiation-induced stress response in barley, nutrient use efficiency in wheat, characterization of abiotic stress response of wheat and barley through DNA fingerprinting and functional analyses of stress-related genes as well as on crucial physiological and biochemical parameters under stress conditions. High and low LET ionizing radiations (gamma-rays and ion beams) are utilized for screening the radiation induced mutation effects and induced genomic instability in wheat and barley.

Challenges:

Over the past 10 years the yield from the major cereals in Bulgaria - wheat, maize and barley, was subjected to fluctuations due to the increased vulnerability of the climatic conditions. Previous intensive agricultural and breeding practices directed towards increase of productivity have been accompanied with diminishing of the overall stress resistance. This tendency was also coupled with deteriorating ability of cereal crops to express their full genetic potential. Knowledge on the abiotic stress tolerance and combined tolerance to abiotic stress factors allows more flexible farm management, environmentally friendly production, lower herbicide costs and utilization energy requirements as well as efficient moisture. Unravelling the mechanisms underlying frost, drought and salinity tolerance is a prerequisite for improvement of current breeding practices and development of new valuable genotypes for Bulgarian agriculture.

Achievements/Good practice:

The obtained complex knowledge on distinct molecular, biochemical and physiological characteristics of wheat and barley stress response enables further development of effective national breeding strategies and practices aimed towards alleviation of the harmful impact of various biotic and abiotic stress factors on the productive capacity of wheat and barley. The list of ultimate end-users includes various breeding and production-oriented institutions as well as public and private entities dealing with cereal seed production, storage and dissemination. Potential beneficiaries can be also small and medium sized farms as well as rural communities maintaining arable land in areas lacking sufficient irrigation and/or burdened with industrial pollutions.

The project was implemented under the IAEA TC Programme (TC Project Bul5/014).

CROATIA (1)

IAEA RER7009 "Enhancing Coastal Management in the Adriatic and the Black Sea by Using Nuclear Analytical Techniques" (2018-2019) - Dr. Jasmina Obhodas, Head of Laboratory for Nuclear Analytical Methods, Department of Experimental Physics at Ruđer Bošković Institute in Zagreb, is the Lead Project Coordinator

Description:

The increasing exploitation of coastal areas poses serious environmental problems and requires science-based policies for a sustainable management of the marine ecosystems and resources. Nuclear and nuclear related techniques when applied together in analysis and dating of environmental archives such as sediments and corals can provide information on spatial and temporal trends of pollutants. They can also be used as a record of historical temperature variations and fate of carbon in sediments, thus enabling carbon storage assessment and evaluation of positive and negative synergies between pollution loading and the potential of sediments to sequester carbon. By the recognition of spatial patterns and temporal trends in pollutant levels and isotope ratios in environmental archives, the future predictions of changes in marine processes and adaptation measures may be proposed.

The regional IAEA project RER7009 is unique in the sense that it brings together countries bordering the Adriatic and the Black Sea, to jointly evaluate, compare and demonstrate processes in changing marine environment. This has formed a strong collaborative network of analytical laboratories and experts, and has facilitated the harmonization of methodologies. During the first RER7009 workshop held in Varna, Bulgaria in in September 25-27, 2018, a large data gap for sediments in the Black and the Adriatic Seas was identified in the IAEA hosted MARiS data inventory. The project will enable the establishment of the on-line, easily accessible data inventory for sediments in the Adriatic and the Black sea, including distribution maps of pollutants and other selected elements and parameters of importance for comparing and assessing respond of marine processes to pollution and climate changes in closed and semi-closed seas.

The database will be supplemental to the IAEA MARiS inventory of radionuclides measured in water and sediments The outcome of the project is expected to assist decision makers to adopt and synchronize future environmental protection policies to ensure the sustainable management of these very special environments.

Collaborators:

Albania, Bosnia and Herzegovina, Bulgaria, Georgia, Italy, Montenegro, Romania, Russian Federation, Slovenia, Turkey and Ukraine


Photo: During the RER7009 “Regional workshop on identification of data gaps in the Adriatic and the Black Sea and harmonization of field sampling strategies for strengthening regional capacities in coastal management “ held in Varna, Bulgaria, from 25 to 27 September, 2018, a one-day cruise expedition in Varna bay on board of R/V “Academic” has been organized by the Institute of Oceanology “Fridtjof Nansen” in Varna, Bulgaria in cooperation with the GeoEcoMar Institute, Constanta, Romania. Collected samples were distributed among the RER7009 project participants for further analysis and methodologies validation

CROATIA (2)

Radiation research, dosimetry, and processing in Croatia using gamma radiation of cobalt-60

Description:

The Radiation Chemistry and Dosimetry Laboratory (RCDL) at the Ruđer Bošković Institute has remained until the present day the only unit in the country pursuing both basic and applied scientific research in the fields of radiation chemistry, dosimetry and radiation processing.

Radiation processing activities include very lively:
- research of microbiological and chemical aspects of radiation treatment of materials;
- providing irradiation services on a commercial basis for sterilization, pasteurization and decontamination of medical supplies, pharmaceuticals, foods, cosmetics and toiletries, packaging, etc., as well as disinfestation and desinsection of cultural heritage artefacts.

Routine dosimetry monitoring has been performed by using ethanol – chlorobenzene dosimetry system (ISO/ASTM 51538) founded by RCDL scientists. The QMS according to the ISO 13485:2016 standard was established.

There are some challenges in the radiation processing. Recently the RCDL scientists initiated: (1) the introduction of environmental radiation technologies (like waste water treatment) with research background, (2) food irradiation improvement from the point of view of human health, (3) the introduction of radiation technology in medical applications, (4) the safe operation of irradiation facilities, (5) education of new generations, (6) popularization of radiation research and applications in all segments (art, industry, health, environment).

The status of commercial food irradiation will remain unchanged if some regulation or directive from the EU does not change it and expand the list of foods approved for irradiation. Special good practice the RCDL has in irradiation of cultural heritage artefacts thanks to the essential cooperation between the RBI and the Croatian Conservation Institute, the Croatian State Archives and Department of Restoration of the Academy of Fine Arts, University of Zagreb. The RCDL is also involved in the IAEA Coordinated Research programs on this topic. Thanks to all above mentioned activities RCDL scientists found an source of additional funding for advancement and improving of their scientific research.

Collaborators:

Croatia is involved in many international collaborations (IAEA, EURADOS, Horizon 2020, VERIDIC etc.). As for radiation processing, the most important is cooperation with the IAEA, which gives us support in our research and application. Through several IAEA regional projects Croatia collborates with other countries: Azerbaian, Belarus, Bosnia and Herzegovina, Bulgaria, Czech Republic, Croatia, Estonia, Greece, Hungary, Kazakhstan, Latvia, Lithuania, Montenegro, Poland, Portugal, Romania, Russian Federation, Serbia, Slovakia, The former Yugoslav Republic of Macedonia, Turkey, Turkmenistan, Ukraine, Brasil, Argentina etc.). Almost all staff members took part in IAEA training courses and Workshops organized within the framework of TC projects.

Website:

https://www.irb.hr/Istrazivanja/Zavodi/Zavod-za-kemiju-materijala/Laboratorij-za-radijacijsku-kemiju-i-dozimetriju2

Photo: Simultaneously irradiation of different products in the panoramic gamma facility at the RBI

CROATIA (3)

INT5155 "Sharing Knowledge on the Sterile Insect and Related Techniques for the Integrated Area-Wide Management of Insect Pests and Human Disease Vectors" – national coordinator dr. sc. Mario Bjeliš

Previous projects: "Use of the Sterile insect technique for the control of the Mediterranean fruit fly in Neretva River valley"; "Use of the nuclear energy for the sterilisation of the laboratory reared pupaes of the mediterranean fruit fly - Ceratitis capitata"; "Reduction of the insecticide use by implementation of the area – wide concept that include SIT (sterile insect technique), reduction of pollution of protected wetlands, Neretva river and recognised protected areas and landscapes, reduction of the risk for the growers and end users".

Project description:

Background: Mediterranean fruit fly, Ceratitis capitata, is a pest of high economic importance in Neretva valley in Croatia.
In Neretva valley, C. capitata affects production of mandarins, Citrus reticulata mainly for export to EU and Russia, with annual yield valued to over 25 million euros. Beside infestation in mandarin fruits, medfly also cause problems to export due to quarantine and food safety regulations. The project covers 4000 hectares of fruit orchards, mainly mandarins.
Methods: Fly emergence and release facility was built and equipped in the city of Opuzen, with current packing capacity of up to 30 million of sterile flies per week. Releases of sterile males are performed mainly with two ground release machines mounted on vehicles, using chilled flies. Trapping system is set and geo-referenced over the whole SIT treated (4000 ha) and non-treated area of the valley (additional 4000 ha) with Tephri Traps using 3component lures as attractant. Captured flies are checked using fluorescent lamps to separate sterile from the wild flies and to provide information on the insect population levels. Routine fruit sampling is undertaken to evaluate fruit infestation and the consequent efficacy of the suppression methods.

Results:

Results of the application of sterile insect technique after two years of pilot project and during two years of suppression project showed that medfly population, measured as number of larvae per kg of fruit was significantly reduced. In comparison to non-treated area in the upper part of the valley, medfly population was reduced by 92.4% in figs, 73.9% in peaches and 96.8% in mandarins during 2012 and by 100% in figs, 57.3% in peach and 96.7% in mandarins during 2013.

For additional information, be free to contact dr. Mario Bjelis (mbjelis@unist.hr).

Collaborators:

IAEA, Regional level countries (Bosnia and Herzegovina), Montenegro

Other:

Mubarqui, Mexico

CYPRUS (1) & (2)

(1) Enhancing the Inventory of Aerosol Source Profiles Characterized by Nuclear Analytic Techniques in Support of Air Quality Management

Description:

The overall objective is to reduce air particulate matter pollution across Europe based on new knowledge of air pollution sources and transport.

This project will provide 1) updated and quality assured regional database of PM2.5 concentrations; 2) improved source profiling and identification in areas of interest for Member States; 3) raised awareness among the scientific community and regulatory agencies about air quality.

Collaborators:

The Cyprus Institute in collaboration with the Radiation Inspection and Control Service, Department of Labor Inspection as the contact point with the IAEA's TC Program.

Other:

Funded by the International Atomic Energy Agency (IAEA) under the Technical Cooperation (TC) "RER/7/011"

(2) Enhancing National capabilities for Early and Rapid Detection of Priority Vector Borne Diseases of Animals (Including Zoonoses) by Means of Molecular Diagnostic Tools - Regional Project

Description:

The aim of the project is to enhance the capabilities of European countries to perform early and rapid disease diagnosis of targeted VBDs using verified and standardized nuclear derived diagnostic procedures improved.

Collaborators:

Governmental Veterinary Services, in collaboration with the Radiation Inspection and Control Service, Department of Labor Inspection as the contact point with the IAEA's TC Program.

Other:

Funded by the International Atomic Energy Agency (IAEA) under the Technical Cooperation (TC). Program RE: RER5023

CZECHIA (1)

Best practices of non-power applications of nuclear technologies

Based on the Act No. 263/2016 Coll., atomic act, workplaces with sources of ionising radiation are classified in 4 categories.
Category I workplaces are the workplaces with the lowest risk, on the other hand category IV workplaces are potentially the most risky one.
Depending on the degree of risk to health and to the environment posed by ionising radiation, the sources of ionising radiation are categorised as insignificant, minor, simple, significant and very significant.

The number of sources and workplaces
There are 8 category IV workplaces in operation (those are either workplaces with a nuclear installation or workplaces with a radioactive waste disposal facility) and 127 category III workplaces (processing of uranium ore, production of sources, mines, industrial sources, radiotherapy).

Unsealed radionuclide sources are usually used at laboratory and research workplaces. Altogether, there are 14 licence holders and 20 category III workplaces with unsealed radionuclide source recorded and 53 licence holders and 82 category II workplaces with unsealed radionuclide source recorded.

Sealed radionuclide sources are mostly mounted in devices (for example devices for radiation defectoscopy or industrial measuring instruments). Altogether, there are 6044 sealed radionuclide sources recorded (those are either separate sources or sources fitted to devices). Among those 6044 sealed sources 3330 are actively used, 1396 are placed in working storages and 1318 are stored to be disposed.

The numbers of devices with sealed radionuclide sources

Area	Devices with sealed radionuclide sources categorised as "significant sources of ionising radiation"	Devices with sealed radionuclide sources categorised as "simple sources of ionising radiation"
Health sector	43	12
Industry and other applications	424	992
Total	467	1004

Following the Decree No. 422/2016 Coll., on radiation protection and security of a radioactive source, particular attention is given to high-activity radionuclide sources.

There are 2064 high-activity sources recorded in the List of sources of ionising radiation, among those 1007 sources are actively used and 1057 sources are stored or handed to be repaired.

The numbers of recorded radiation generators

Area	Significant sources of ionising radiation	Simple sources of ionising radiation
Health sector	3038	9689
Veterinary applications	0	1015
Industry	8	330
Other applications	14	124
Total	3060	11158

CZECHIA (2)

Device for determination of radon diffusion coefficient and the methodology for radon diffusion coefficient determination in waterproof materials

Description:

Radon diffusion coefficient is a parameter that determines the barrier properties of waterproof materials against the diffusive transport of radon. Applicability of the radon diffusion coefficient for radon-proof insulation can be prescribed by national building standards and codes (e.g. Czech standard ČSN 730601 Protection of buildings against radon from the soil). Requirements for radon-proof insulation as regards the durability, mechanical and physical properties and the maximum design value of the radon diffusion coefficient were specified based on the long term experience gained during the implementation of protection of buildings against radon in the Czech Republic within the framework of national Radon Program – Action Plan.

A unique device for radon diffusion coefficient in waterproof materials has been developed, tested and related European patent published under the Patent Cooperation Treaty, International publication number WO 2009/030182 A2.

Since no reference standards and reference materials have not been available for these types of materials and related values of radon diffusion coefficient, the metrological requirements regarding the determination of the performance of the different methods described in document ISO/TS 11665-13 (Measurement of radioactivity in the environment — Air: radon 222 —Part 13: Determination of the diffusion coefficient in waterproof materials: membrane two-side activity concentration test method) were specified as required by ISO/IEC 17025.

Collaborators:

There was an international collaboration on the Czech approach implementation in ISO standard document within the framework of Technical Committee ISO/TC 85, Nuclear energy, nuclear technologies and radiological protection, Subcommittee SC 2, Radiological protection.

Other:

www.iso.org.

CZECHIA (3)

Clinical audit in radiology

Description:

In the Czech Republic, periodical external clinical audits are conducted by certified institutions at five-year intervals at all institutions performing medical irradiations (diagnostic and interventional radiology, radiotherapy and nuclear medicine). In the meantime medical facilities conduct their own internal clinical audits on regular basis. Audits check whether departments operate according to its local radiological standards (extended standard operating procedures) based on National radiological standards, which have been developed by physicians and medical physicists under the auspices of the Ministry of Health, professional societies (including Czech Association of Medical Physicists) and regulatory authorities. National radiological standards and their updates are published via the website of the Ministry of Health of the Czech Republic.
Clinical audits serve as a tool to improve patient care by reviewing of medical irradiation procedures against constantly evolving standardized criteria.

Collaborators:

"Clinical audit in radiology" was not an international project.

Other:

http://www.mzcr.cz/Unie/obsah/narodni-radiologicke-standardy-_3050_3.html

DENMARK (1)

Radiotherapy and proton therapy for treatment of cancer

Description:

Ionizing irradiation is an important part of comprehensive cancer management. About 50% of all cancer patients will need radiotherapy during the course of their disease, and radiotherapy is responsible for about 40% of all cures for cancer. The goal of radiotherapy is to eradicate all cancer cells with a minimum of damage to the surrounding healthy tissues; the reduction of unwanted side effects, including radiation-induced secondary cancers, is a major issue in radiation oncology. The most common form of radiotherapy is external beam radiation therapy, where a linear accelerator delivers photons (high energy x-rays) to tumors. Recent advances including use of image guidance and computer algorithms have resulted in more conformal techniques, such as intensity-modulated radiotherapy and stereotactic radiotherapy. A more advanced form of ionizing radiotherapy is the use of charged particle beams. The most common is proton beams, which deposit most of the dose in a sharply defined point, enabling a much lower dose to nearby critical organs surrounding the tumor. Proton therapy is today used for treating tumors located close to vital organs and for radiotherapy in children where late side effects are of major concern. Protons are produced by a particle accelerator and sent through a beam line into heavy rotating gantries that steer the desired radiation dose to the tumor, at the precise angle prescribed by the physician.

Denmark has one of the most advanced and well-served radiotherapy services in Europe, with easy access to state-of-the-art radiotherapy equipment, and a newly established national Danish Center for Particle Therapy (DCPT). Denmark is also the country with most patients per capita included in large radiotherapy trials. The clinical radiotherapy service is highly centralized, 53 linear accelerators in seven radiotherapy departments at academic hospitals. A global overview of the impact of radiotherapy related research placed Denmark as No. 1 on all parameters evaluated (in front of USA and The Netherlands).

Collaborators:

Radiotherapy in Denmark is collaborating in the DCCC Radiotherapy network (www.dcccrt.dk) and proton therapy is offered at the national center in Aarhus (www.dcpt.dk). European collaboration is extensive especially through the European Society for Radiotherapy and Oncology (www.estro.org) and the European particle Therapy Network (EPTN). International clinical radiotherapy trials are conducted by the European Organization for the Research and Treatment of Cancer (EORTC).

Other:

www.dcpt.dk


varian

DENMARK (2)

Non-destructive testing (NDT)

Description:

Non-destructive testing (NDT) methods based on x-ray or isotope sources, in particular in the field of infrastructure development. Tests provide information on the structural integrity of loadbearing construction parts and assemblies, welding of piping etc.

For NDT purposes, isotopes with relatively short half-lives such as Ir-90, Se-75 and Co-60 are widely used as radiation sources to generate images for the detection of defects or imperfections in assemblies and materials. The development of the technique has enabled this compact and robust type of equipment to find use in locations where limited space, limited access to power supplies or fire hazard considerations prevent the use of similar X-ray based equipment.

Collaborators:

Not state-run. Mostly applied by the private sector.

Other:

More info at:
https://www.iaea.org/topics/industrial-radiography
https://www.iaea.org/newscenter/multimedia/videos/radiation-technologies-daily-life

DENMARK (3)

Positron Emission Tomography (PET)

Description:

Use of short-lived radioisotopes, e.g. F-18, in Positron Emission Tomography (PET) is a well - established and rapidly growing technology for different diagnostic purposes in nuclear medicine. PET is very important for instance in cancer diagnosis, staging and follow-up.

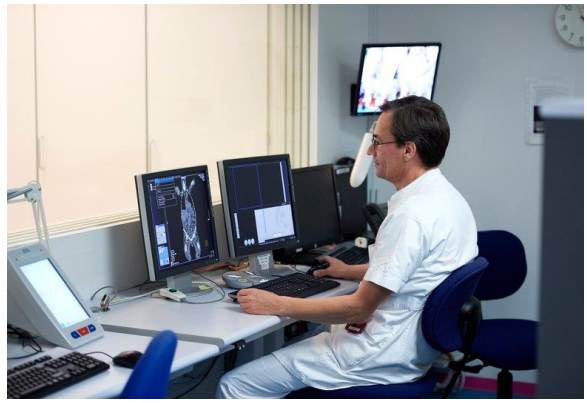
The development of this application is ongoing, after having passed the initial challenges of providing a sufficient distribution density of cyclotron facilities for the production of the short lived F-18 across the country. At some locations, the cyclotron facilities are on-site, eliminating the need for transport arrangements to PET centers, and in other cases, the proximity of isotope production facilities have significantly simplified the transport related logistics.

Collaborators:

Not state-run. Mostly applied by the private sector.

Other:

Additional info at:
https://www.rigshospitalet.dk/english/departments/centre-of-diagnostic-investigation/department-of-clinical-physiology-nuclear-medicine-and-pet/patient-information/Pages/what-is-clinical-physiology-and-nuclear-medicine.aspx



FINLAND

High-powered reactor for cancer treatment

Description:

Helsinki University Hospital (HUS) has now installed the world's first hospital-based Boron Neutron Capture Therapy device. The devise is used to treat patients with certain malignant tumors in body (head and neck areas first). Boron Neutron Capture Therapy is a form of radiation therapy that biologically targets cancer cells. It works by injecting patients with a drug carrying a boron compound designed to seek out cancerous growths. Following this, patients receive neutron radiation localized around the tumor being treated. The neutron source is produced by **2.6 MeV Electrostatic Proton Accelerator developed by company called** Neutron Therapeutics. The device is called nuBeam. If technical tests go well, the hospital can start the treatments for research purposes in winter 2019 or early 2020.

Between 1999 and 2012, the hospital delivered BNCT treatments using the research reactor housed

at VTT Technical Research Centre of Finland. However, the treatment ended in 2012 for non-therapeutic reasons but economics and the research reactor was also decided to be shut down in 2015. Basically, the treatment procedure is now the same as earlier although the neutron source is produced differently.

This is an innovation and a potential best practise, which uses radiation technologies for other uses than electricity production. There is also clear connection in capacity building nuclear energy uses and non-energy uses of nuclear and radiation technologies.

It should be noted that the nuclear waste management and disposal issues must be solved in both the regimes.

Website:
https://yle.fi/uutiset/osasto/news/finland_to_debut_new_high-powered_reactor_for_cancer_treatment/10061298

FRANCE (1)

Atoms for preserving our Heritage

Countries: France and Romania

Description:

Fragile and historically significant artefacts must undergo operations to strengthen and restore them for conservation and public exhibition. ARC-Nucléart, an original French laboratory mixing science and culture, has been providing its expertise on organic artefacts from all over Europe for more than 40 years.

Founded in 1967 following the development of a wood consolidation process using a radiation-cured resin ("Nucléart" treatment) to restore an 18th Century parquet floor in the old Town Hall of Grenoble, the ARC-Nucléart laboratory aims to preserve historical artefacts. Since then, the properties of gamma radiation have been routinely used by the laboratory to disinfect and/or consolidate organic materials (wood, leather, fibres) produced by humans. In addition, the scientists study deteriorated materials in order to develop new treatment methods, which may also be applicable to recent wood. During the 70s, this expertise was really useful on its most famous patient : the mummy of Pharaoh Ramses 2.

The activity of the workshop was subsequently extended to include other methods of treatment and restoration of archaeological, historical and ethnographic collections. This installation is located at the site of the CEA's research centre in Grenoble. In a 3,000 square meter facility of high tech equipment, a multidisciplinary team (chemists, physicists, technicians, restorers, conservators and administrative staff) works to preserve our physical heritage in museum collections and historical monuments. They also assist the archaeologists during excavations.

A yearly annual competition is open to French municipalities, helping them to consolidate and halt the deterioration of objects of high heritage value by resin impregnation and gamma irradiation.

This “Save your community heritage competition”, created in 2002, has already treated and restored 68 artworks out of a total of 610 applications and thus contributing to the preservation of our heritage not only present in our major museums.

However this facility is not only open to French artefacts. For instance, in 2015, the operation was extended to Romania as part of a collaboration between the IFIN-HH, the IFA and the CEA.

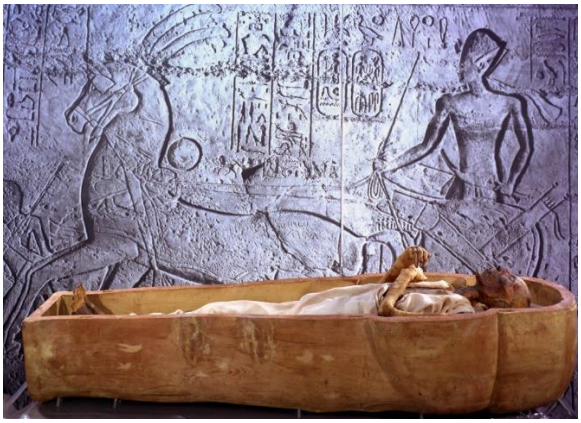
The CEA-Grenoble irradiator with the irradiator of the Stredoceské museum in Prague is the only facility in the world dedicated to heritage conservation.

Collaborators:

- The CEA (The French Alternative Energies and Atomic Energy Commission)
- IFIN-HH (Horia Hulubei National Institute for Physics and Nuclear Engineering)
- The IFA (Institute of Atomic Physics)

Website:

To learn more about ARC-Nucleart:
http://www.arc-nucleart.fr/



Placed in her sarcophagus, clothed in a linen sheet, the mummy of Ramses II just before his treatment in the irradiator Poseidon CEA / Saclay May 9, 1977. Suffering mainly from fungal damage, the mummy was exposed to a dose of 18 kGy of gamma radiation, killing fungal species and their spores. ©CEA/ARC-Nucleart

The CEA-Grenoble irradiator. ©Arc-Nucleart

FRANCE (2)

Fighting mosquitos with irradiation

Description:

On the La Réunion island, in the Indian Ocean, nuclear technologies are used to fight against the tiger mosquito, Aedes albopictus, one of the most invasive species in the world and vectors of diseases for humans such as the chikungunya virus and the dengue fever. For the last 10 years, researchers have been working on the "sterile insect technique" to reduce its population.

In laboratories, male mosquitoes are raised and being irradiated with X-rays to make them sterile. These males, which contrarily to females do not bite mammals and therefore humans, are then released en masse into the wild, to mate at the expense of wild males and thus control the growth of the mosquito population. Indeed, male mosquitoes sterilised by irradiation in the laboratory succeed in mating normally with the females. Then, during their few weeks lifespan, female continue to produce a large number of eggs, but they are non-fertilised and will thus produce no offspring.

For such a strategy to be effective, sterile males need to be produced by hundreds of thousands in laboratories but also be competitive enough with other wild males, which are fertile. That is why the researchers studied in details the effect of irradiation on sexual maturation and mating success of males in order to optimize both the calibration of the irradiation tools and the timing and amount of releases in the wild of sterile mosquitoes.

This technique, which has been used in agriculture for half a century, shows multiple advantages: the non-use of pesticides, the targeting of a single species of mosquito and the respect for the rest of the local biodiversity as no chemical or genetic modification are used.

The main challenge today lies in the population acceptability of this technique, which implies releasing an overwhelming number of mosquitoes, even if those have no effects on human health.

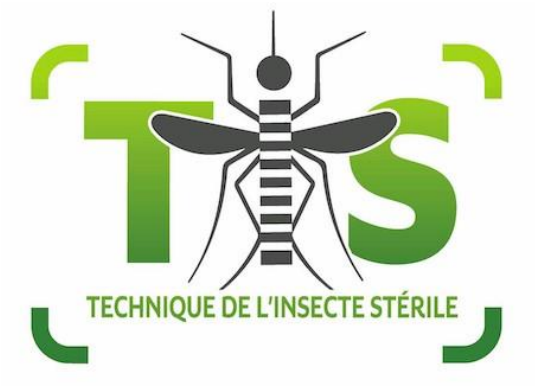
Releases in the wild, in specific areas, are now waiting the authorization of local authorities.

Collaborators:

IRD (Institut de Recherche et de Développement) and its national and international partners (Institut Pasteur, Université de la Réunion, CIRAD, CNRS, DRASS, CRVOI, AIEA, Oxytec, UKY, ILM, CAA « G Nicoli » Italy, ARS OI, DRRT, Préfecture et Conseil Régional de La Réunion).

Website:

To learn more on the project developments at La Réunion: http://www.la-reunion.ird.fr/recherche-et-missions/programmes-de-recherche-en-cours/programme-technique-de-l-insecte-sterile-2-tis-2



Logo of the project “Sterile Insect Technique”. ©IRD

An entomologist from the IRD checks traps for adult mosquitoes. © IRD/T. Vergoz

Inside a cage of the IRD laboratory breeding mosquitoes. © IRD/T. Vergoz

A blood-engorged female Aedes albopictus mosquito feeding on a human host. ©CDC

FRANCE (3)

Fighting cancer with lead-212

Description:

An innovative approach, known as targeted alpha therapy (TAT), recognizes and destroys cancer cells while limiting the impact on nearby healthy cells. To develop this new therapy against cancer, a unique laboratory in the world specialized in the production of lead-212 (^{212}Pb) has been set up in France. This radioactive isotope coming from thorium is very promising in alpha therapy, an innovative form of radiotherapy that limits the impact on healthy cells.

Based on an R&D program started in 2005, Orano Med, an affiliate of the Orano Group created in 2009, has developed new processes for producing high-purity lead-212 (^{212}Pb), a rare radioactive isotope coming from thorium. ^{212}Pb is currently at the heart of promising research projects in nuclear medicine to develop new treatments against cancer with the alpha therapy, an innovative form of radiotherapy that limits the impact on healthy cells.

To develop those powerful therapies to treat cancer, Orano Med works on 3 strategic actions:

- Produce high-purity ^{212}Pb to meet clinical development needs, and provide security of supply for ^{212}Pb for the development of targeted alpha therapeutics ;
- Develop innovative ^{212}Pb-based cancer treatments, thanks to an ability to perform quickly proof of concept studies with various vectors radiolabelled with 212Pb to support investigational new drug (IND) filing;
- Collaborate with scientific partners interested in ^{212}Pb. Orano Med has inaugurated in 2013 in France (in Bessines-sur-Gartempe) the first laboratory dedicated to the production of high-purity ^{12}Pb with 9 international scientific partners. A second production unit has been operating in Texas since 2016 due to the growing demand of the pharmaceutical industry and the medical community.

As a result, first clinical trials for ^{212}Pb have started between 2012 and 2014 when 18 patients were treated with TAT. The commercialization of such treatment is expected by mid-2020.

Collaborators:

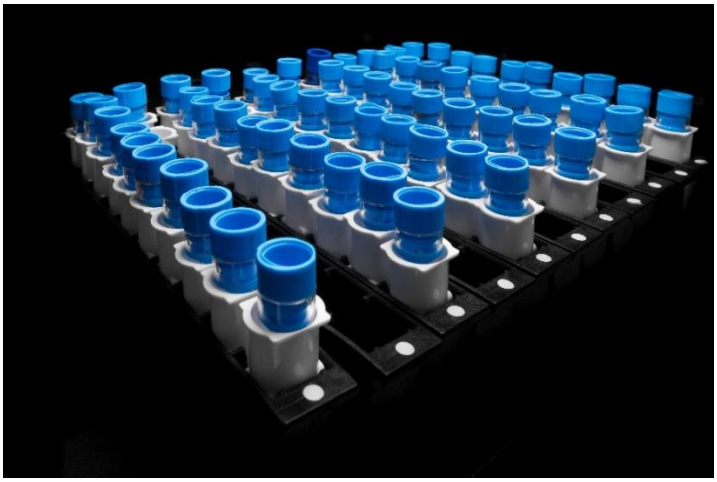
In addition to Orano Med, 9 partners from France, the USA, Norway and Switzerland are involved in these promising researches (Roche, Radiomedix, Morphotek, Nordic Nanovector, US National Cancer Institute, University of Cincinnati, French National Institute of Health and Medical Research, University of Alabama at Birmingham, Carat project).

To learn more on the research partners:
http://www.oranomed.com/EN/home-109/about-orano-med.html#tab=tab5

Website:

To learn more on this innovative approach:
https://www.orano.group/en/expertise/nuclear-medicine-against-cancer

To learn more on Orano Med:
http://www.oranomed.com/



Tubes, Arcolab, Orano Med in Bessines-sur-Gartempe, France © Eric Larrayadieu / Orano

Deposit on filter of a lead drop 212Pb, ArcoLab. Bessines, France © Eric Larrayadieu / Orano

Paul Jurek from laboratory Macrocyclics, Dallas, United-States © Warren Wright / Orano

GERMANY (1)

Technical University of Munich (TUM), Research Neutron Source Heinz Maier-Leibnitz (FRM II) in Garching

The FRM II is one of the most powerful and advanced neutron sources in the world. Using the nuclear fission of uranium, it produces more than 10^{14} free neutrons per square centimeter and second, which are used for research, industry and medicine.

Description:

At the Cutting Edge of Neutron Research The Heinz Maier-Leibnitz Zentrum (MLZ) is a leading center for cutting-edge research with neutrons and positrons. By offering a unique suite of high-performance neutron scattering instruments, scientists are encouraged and enabled to pursue state-of-the-art research in diverse fields as physics, chemistry, biology, earth sciences, engineering or material science.

Applied research: E.g. Stress in railway rails - A railway rail is examined for internal stresses at the neutron diffractometer STRESS-SPEC. Under strains, internal stresses in metals can increase to such an extent that cracks or fractures occur.

Industry: E.g. Silicon doping - Pure silicon is a very poor conductor of electricity. However, it is industrially viable for semiconductors when it contains a small amount of impurities (such as phosphorus). 15 t of silicon is homogeneously doped per year for the semiconductor industry at the FRM II. (e.g.: high voltage direct current transmission).

Medicine: Production of radioisotopes - The low-energy radioactive substance Lutetium (Lu-177) is used in a special molecule that binds to the prostate tumor according to the "key-lock principle". Due to the specific binding, radioactivity accumulates in the tumor tissue and irradiates it from the inside. (e.g.: approx. 2500 prostate cancer therapies per year).

Collaborators:

The scientific use with up to 1000 user visits per year is organized in the "Heinz Maier-Leibnitz Zentrum" (MLZ), a cooperation between TUM, Forschungszentrum Juelich and Helmholtz Zentrum Geesthacht with the participation of the Max Planck Society and nine other university groups. Furthermore, special services are offered to industrial customers in order to use the unique capabilities of neutron scattering for commercial applications.

Other:

www.frm2.tum.de; www.mlz-garching.de

The experimental hall at the FRM II/ TUM (Credits: Bernhard Ludewig)

The Research Neutron Source Heinz Maier-Leibnitz (FRM II)/ TUM (Credits: Astrid Eckert/ TUM)

GERMANY (2)

Proton Beam Therapy at West German Proton Therapy Centre Essen (WPE)

Description:

WPE is one of the leading institutions for proton beam therapy (PBT) in Europe and one of the most advanced proton therapy centres in the world.
PBT is a complex and highly innovative technique offering high-precision radiotherapy while minimizing damage to healthy tissue. Protons used in radiotherapy are positively charged particles of hydrogen atoms. Their path and depth of entry into the body can be easily controlled, varied according to tumour location and stopped precisely. PBT is increasingly used to enable safe and highly-effective irradiation for the most challenging scenarios like childhood cancer, treatment of tumours of the skull base or the central nervous system and other cancer types.
WPE does not only cover state-of-the-art technology with large capacity but also provides interdisciplinary care of a comprehensive cancer centre, representing an integral facility of the university medical campus in Essen and of the West German Cancer Centre. WPE is run by experienced clinical and technical experts. The centre offers 4 treatment rooms with 5 beam lines and 3 rotating gantries. PBT can be administered in various passive and active modes. Clinical care also involves psychological support and a thoughtful after-care programme. WPE offers treatment within multiple national and international clinical studies and is closely linked to various European and worldwide expert societies contributing to the progress of radiotherapy in cancer treatment.

WPE runs Europe's largest paediatric patient programme with 250 children treated annually. A major focus is the treatment of infant cancer in patients younger than 2 years, who deserve highest quality of care. WPE uniquely takes advantage of high-end technological innovations embedded into a university medical campus. Experience and data generated will expand evidence of proton beam therapy and promote the wider distribution of this promising technology in order to minimize the burden of cancer therapy in the future.

Collaborators:

The manufacturer and operator of the proton beam technique is IBA from Belgium.

The Oncology Information System (OIS) comes from the Swedish manufacturer Electa.

Other:

https://www.wpe-uk.de/

https://www.wpe-uk.de/en/

GERMANY (3)

AiNT GmbH in Aachen, Germany

Description:

AiNT has developed measurement systems based on the prompt and delayed gamma neutron activation analysis (P&DGNAA). This innovative analysis technique poses the advantages of being non-destructive, fast and universal. AiNT´s primary focus is on environmental and hazardous substance analyses, however, the technique´s characteristics allow samples of any kind. For heterogeneous or even bulk material no sample preparation is required. High volume samples may be analyzed in total, and this even through a sealed container. By P&DGNAA, the samples´ elemental compositions (mass fractions of all elements of the periodic system) are determined and the chemical composition is derived.

Besides professional training in the broad field of nuclear technology, its civil use and the required framework, AiNT provides consultancy services on matters covering the whole nuclear fuel cycle.

Its own R&D activities have led to three publicly supported R&D projects:

ZEBRA:

The ZEBRA system determines the composition of samples having a volume of up to 4.5 liters. The primary focus is to identify contents of heavy metals in comparably large samples within minutes without the need of representative sampling.

QUANTOM:

QUANTOM aims for non-destructive analyses of 200 liters waste drums containing radioactive waste. The P&DGNAA are highly beneficial for this field of application, since, in certain cases, costly openings are avoided that would otherwise be required in order to determine the unknown content of waste drums. However, QUANTOM is able to analyze any type of high-volume samples.

SoNDEx:

By SoNDEx, AiNT has developed a method to detect unexploded ordnances, which is typically done by identifying metallic cases onsite. Beyond this, SoNDEx provides non-destructive determination of a possible chemical composition and therefore can detect explosives by identifying certain elements. With more than 5.500 unexploded ordnances being defused in Germany every year, efforts, risks and costs can be reduced by SoNDEx.

Collaborators:

ZEBRA:

In cooperation with Karlsruhe Institute of Technology

funded by European Regional Development Fund (ERDF, Funding: EFRE-0800541)

QUANTOM:

In cooperation with: Framatome GmbH

Fraunhofer-Institut für Naturwissenschaftlich-Technische Trendanalysen INT

funded by Federal Ministry of Education and Research

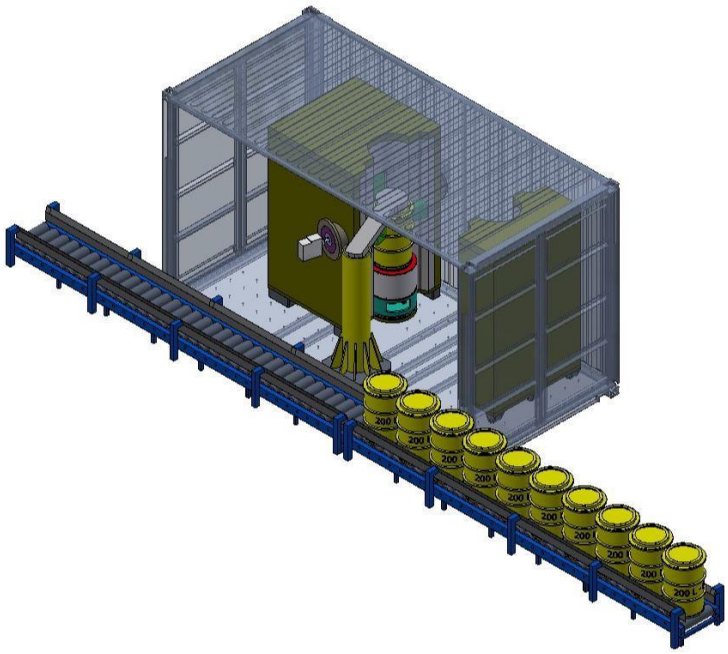
SoNDEx:

In cooperation with P-H-Röhll NRW GmbH, FH Aachen University of Applied Sciences

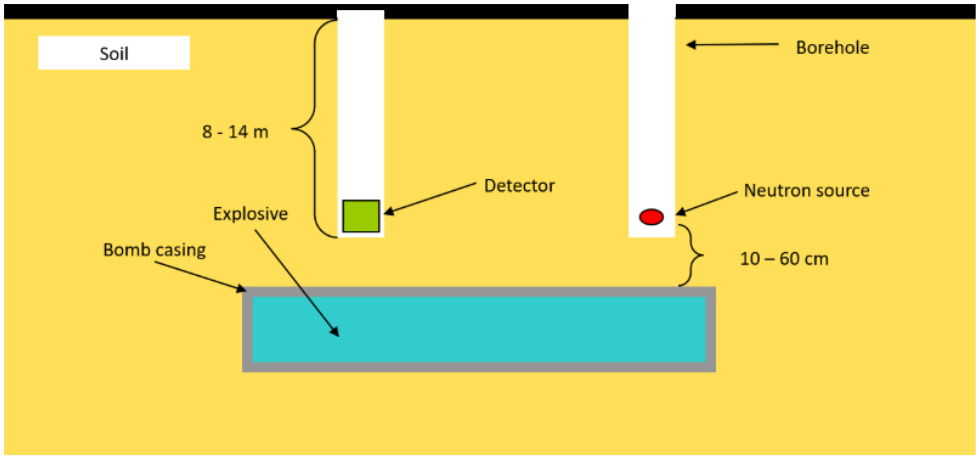
funded by Federal Ministry of Education and Research associated with Ministry of the Interior of North-Rhine Westphalia

Other:

https://www.nuclear-training.de/research.html



QUANTOM Measurement Device



Concept of SoNDEx

GREECE (1) & (2)

(1) Control Programmes for Aedes Invasive Mosquitoes in the European region

Description:

The aim of the project is the control of the Asiatic mosquito populations through the sterilization with radiation of male mosquitoes (Sterile Insect Technique, SIT) and their release to the environment.

The pilot implementation of this new method for the management of the mosquito populations and more specifically of the species Aedes albopictus has already started in Greece (Vravrona region).

Collaborators:

The Benaki Phytopathological Institute and the University of Thessaly cooperate for the project management with the support of the Greek Atomic Energy Commission (EEAE) as the contact point with the IAEA's TC Program

Other:

Funded by the International Atomic Energy Agency (IAEA) under the Technical Cooperation (TC) Program

(2) XRF analysis and MA-XRF imaging of Mycenaean wall-painting pigments from the Palace of Nestor at Pylos

Description:

The aim of the project is the non-destructive elemental analysis of the inorganic pigments from the Nestor's Palace wall-paintings, carried out by means of different X-ray fluorescence (XRF) techniques and Macroscopic X-ray Fluorescence (MA-XRF) imaging. Although MA-XRF is well-established for non-invasive analysis of historical or contemporary painted artworks it has hitherto been applied in a few cases only regarding the study of ancient polychromy. The present project has investigated the application of the MA-XRF imaging on selected wall painting fragments from the Palace of Nestor and evaluated the capabilities of this technique in identifying the composition of pigments and their spatial distribution within heavily deteriorated pictorial layers, and in revealing invisible iconographic information to the naked eye. The results of the MA-XRF imaging allows a critical re-consideration of previous artistic reconstructions, providing significant evidence on the painting techniques and materials used by Late Bronze Age painters.

Collaborators:

Aristotle University of Thessaloniki and NCSR "Demokritos"

Other:

The project runs within a post graduate thesis

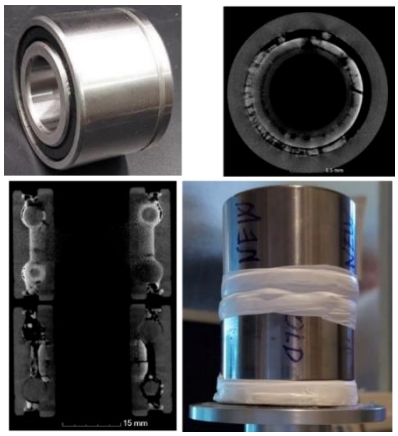
HUNGARY (1)

Non-destructive material analysis at the Budapest Research Reactor

Description:

At the Budapest Research Reactor, X-rays, gamma-rays and neutrons are routinely used to non-destructively characterize materials for scientific and industrial applications.
Digital neutron and X-ray tomography at the RAD station provides high-definition 3D visualization of objects. Neutrons can outperform X-rays in imaging if the sample is bulky (e.g. 3D imaging of the 'Budapest and Rider sculpture' attributed to Leonardo), made of high-Z material (density mapping of tungsten carbide industrial cutting inserts), or contains both organic and metallic materials (measurement of damaged ball bearings). The joint use of the two modalities offers enhanced discrimination power between materials. Quantitative assessment of pores (size, shape, orientation) or casting defects are achieved via state-of-the-art image processing software.

Elemental compositions can be determined with a handheld X-ray Fluorescence spectrometer, as well as by neutron irradiation in the reactor core (Neutron Activation Analysis) or in a guided beam of cold neutrons (Prompt-gamma activation analysis). MTA EK was pioneer in integrating neutron-based position-sensitive element analysis and imaging (PGAI-NT method) to analyze inhomogeneous objects: the NIPS-NORMA station is the only permanent user facility of this kind worldwide. These techniques offer high metrological value and can non-destructively analyze almost any element in the periodic table, including several uncommon elements (H, B, rare earth elements).
Imaging, element analysis and neutron diffraction techniques can be even combined to solve complex material science problems.



A comparative neutron imaging study of a new and a damaged ball bearing at the RAD station revealed the importance of proper lubrication. (Credits: Zoltán Kis, László Szentmiklósi, László Rosta; Rogante Engineering Office, Italy)

HUNGARY (2) & (3)

(2)Verification of measurement devices

In Hungary, radiation measurement devices as well as active and passive dosimeters should undergo a type-examination, following which they will be verified. The verification procedure is regulated by the law, carried out by an authority, meaning that the devices will be authorized to carry out measurements having legal effect.

(3)Type approval of medical radiological equipment

The objective of the type approval of medical radiological equipment is to provide inspectors, specialists, radiation protection experts with adequate information about the most important parameters of the equipment. This is of great importance, because in other countries it can happen that experts never encounter the equipment mentioned before the first on-site inspection. It is a major challenge for experts to find out in the field what the equipment is suitable for or able to do, which in many cases is not possible.

ITALY (1)

Detection Systems

a. **Radiation technology for radiation protection of the environment and the people**
b. **"Dirty bombs"**

Description:

a. Ionizing radiation sources can be applied to calibrate equipment and test the methods for radioactivity measurements on environmental and bioassay samples, as well as for direct measurements of internal contamination. ENEA can provide services for radioactivity measurements on various samples for different radionuclides, including NORM (e.g. ^{3}H, ^{60}Co, ^{131}I, ^{137}Cs, ^{90}Sr, ^{226}Ra, ^{241}Am, U and Pu isotopes), relying on high quality and most up-to-date techniques, in compliance with the highest radiation protection standards and recommendations:
• X-α and α spectrometry,
• liquid scintillation
• gross α and β counting
• ICP-MS spectrometry.
Whole body and organ counting (low and high energy) for in vivo measurements, while in vitro bioassay techniques (on urines, faeces, nasal mucus) are applied for detecting internal contamination.
Calibration of radiation detection equipment is also provided.

b. Description of the best practice
The NAI (Neutron Active Interrogation system) device to fight CBRN risks is based on the combined detection of explosives and radioactive materials in suspect objects by means of a neutron interrogation source and gamma and neutron detector systems.

Name of the project
NAI-Project

Description of the benefits
The system identifies fissile materials, explosives and radioactive sources with response times in the order a few seconds.
The industrial version can be implemented in ports, airports, customs, intermodal transfer points, for routine check combined with the baggage handling lines, to containers or suspect packages control.

The system is composed of a high performance fissile material detection tool operable for preventing illicit trafficking of U and Pu containing materials in compliance with international safeguard treaties.

Description of possible barriers, challenges
The industrialization process has to optimize radiation protection aspects and achievement of sufficiently low detection limits.
Strategies to involve private companies to setup an optimized business plan to obtain a fully industrialized product.

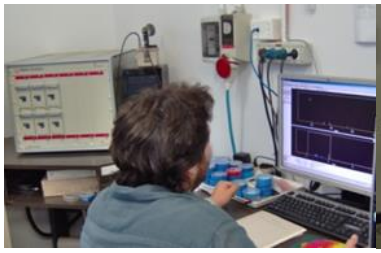
Collaborators:

a. IAEA Almera Network, PROCORAD association, EURADOS
b. None

Other:

a. http://www.enea.it/en/research-development/safety-and-health



ITALY (2)

^{99}Mo/^{99m}Tc production by means of

a. **TRIGA RC-1 research Reactor**
b. **Alternative route via 14 MeV fusion neutrons**

Description:

Description of the best practice

a. The ^{98}Mo(n,□)^{99}Mo has been experimentally demonstrated as an alternative route for the production of ^{99}Mo
b. The ^{100}Mo(n,2n)^{99}Mo is under investigation as an alternative route for the production of ^{99}Mo

For nuclear medicine applications (SPECT)

Name of the project

a. MOLY-Project
b. SORGENTINA-RF

Description of the benefits

Extensive production of ^{99}Mo using:

a. 1 MWth RR as neutron source without using LE/HEU targets (no-proliferation issues)
   The irradiated target manipulation is easier as the absence of α-contamination
   The radioactive waste eventually produced are LLW or Free release
b. High brilliance 14 MeV accelerator-driven neutron source (ADNS), without any use of ^{235}U targets presently irradiated at research fission reactors (nuclear waste reduction)
   An ADNS is less expensive than a reactor
   An ADNS 14 MeV is a welcome alternative solution to reactors, suffering around the world by problems of aging

The final product is cleaner as compared to the presently used LEU/HEU targets based production because the impurities levels in ^{98}Mo targets could be extremely low.

Description of possible barriers, challenges

a. High costs for procuring Molybdenum enriched in ^{98}Mo isotope (natural occurrence of ^{98}Mo is about 24% and could be too low for medical application)
b. Finding of proper funds to perform in the short-period some experimental tests on a mock-up of the main component of the neutron source (the target).

Strategies to involve private companies operating in the market to setup an optimized business plan to cover operation costs of the facility and finding the selling price for full cost recovery.

Collaborators:

a. PERMA-FIX Environmental inc. (USA), MoU and Non-disclosure agreement signed, co-funded project ongoing
   RATEN (Romania) in preparation
b. None at present

ENEA TRIGA RC1 Research Reactor

ITALY (3)

Radiation technology in

a. **research, culture, forensics fields**

b. **modern medicine for cancer's treatment**

a. The analysis of the matter, by investigating the characteristic radiation emitted by specimen elements, allows us to know its details and to reconstruct its characteristics and origin without damage.
Low-energy section of a pulsed proton accelerator is used for Particle Induced X-ray Emission (PIXE) stratigraphic spectroscopy analysis.
Elemental characterization studies are carried out on artifacts of the cultural heritage of Rome for the ADAMO Project (ENEA-Regione Lazio).
This investigation technique is totally non-destructive also in forensic science and analysis of environmental particulate (tens of μm of depth w/o sample perturbation).
Laboratory analyses are limited to a few mm^2 surface, studying miniaturized details at high resolution.

b. Ionizing radiation is used to treat cancer. The hadron therapy uses accelerated proton beams for a much better treatment, investing more selectively the patient target tissue: the particles penetrate to the desired depth by setting their right energy releasing the maximum dose only in the target (the tumor) without damaging the surrounding healthy tissues.
Modern medicine project is TOP-IMPLART (Oncological Therapy with Protons - Intensity Modulated Proton Linear Accelerator for Radiotherapy): first prototype of a linear proton accelerator for clinical proton therapy being developed (ENEA).
The compact machine will supply 150 MeV proton beams (first phase) for the treatment of pediatric and semi-deep tumors (230 MeV for deep tumors second phase) with active delivering technique.
The innovative accelerator operates at high radiofrequency. It is designed for intensity and energy beam modulation, pulse by pulse.
The operating technology minimizes radiative losses and secondary radiation affecting the healthy tissues or the workers' health.
TOP-IMPLART machine will occupy a very small space and have less construction and maintenance costs than circular accelerators, also considering the reduction on the radiation protection structures.

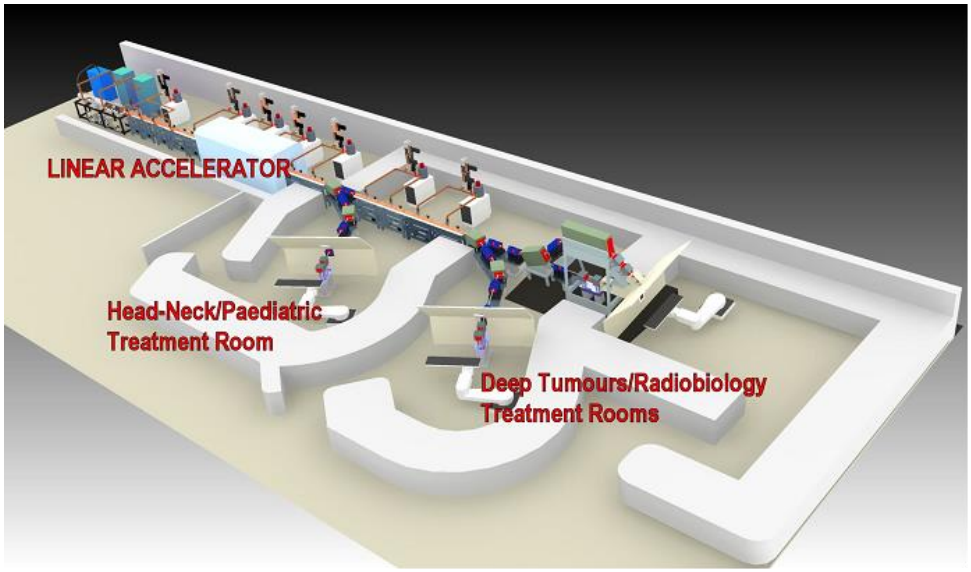
Currently the linear accelerator delivers pre-clinical particles for radiobiology studies on characterization of high intensity pulsed beams and models validation.

Collaborators:

No other countries or international/European organisations are involved.

a. http://progettoadamo.enea.it/

b. http://www.frascati.enea.it/accelerators/Sito/TopImplartMAIN/TopImplartMAIN.htm



JRC best practices on non-power and novel applications of nuclear technology

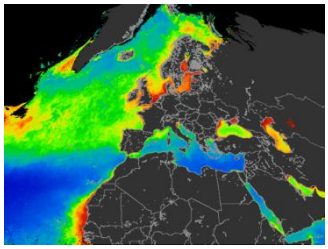
The JRC is active in supporting the development, safety and sustainability of nuclear science applications, which have an important impact on our societies' development and well-being. Nuclear and radiation-based applications create jobs in health, industry and research fields for a highly educated and well-trained work force. In the EU-28 member states over 1,000,000 people have an occupation directly linked to ionising radiation. The health sector alone accounts for over 700,000 of such workers. In addition, thousands of jobs in smaller equipment-manufacturing companies, different types of industry, laboratories, and research centres depend directly or indirectly upon these technologies.

Description:

The JRC works in close cooperation with EU Member States and disposes of excellent nuclear infrastructures, located in different EU member states, which are at the service of the Euratom community, and which are shared in an Open Access policy of research collaboration. The efficient use of these facilities combined with the expertise of the core research staff (more than 80% with doctoral qualifications) enables the array of different activities of the JRC in the different fields of nuclear science applications. For example, neutron resonance spectroscopy supported by the GELINA Neutron time-of-flight facility for high-resolution neutron measurements in the JRC Geel site can be used for a variety of applications in diverse fields, such as archeological studies, determination of the fissile content of nuclear material for nuclear safeguards and security, characterisation of reference materials for cross section measurements and of organic samples in the biomedical field, combatting illicit traffic by detection of drugs and explosives, temperature measurements, and the study of fundamental properties of materials.

Some of the ongoing JRC activities in nuclear science are listed below.

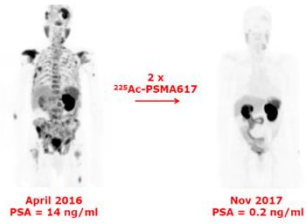
- **Nuclear techniques for cultural heritage**: the JRC is supporting the authentication and preservation of cultural heritage through the application of non-destructive analysis of historical artefacts, allowing for probing a variety of issues in Heritage Science: from the correct determination of historical and cultural time-frame of artefacts, to their location and method of production, to the choice of best treatments and environmental conditions for their restoration. In the recent years, the JRC has supported for example the analysis of genuine and fake Etruscan copper alloy statuettes, Roman bronze water taps and bronze-age weapons.



- **Tracer studies sustaining the understanding of climate change and its impact**: technical developments in radioactivity measurements enable new science based evidence pointing to improved climate modelling and effects of global warming and to the natural mechanism behind it. Examples include studies elucidating subduction in ocean streams, the study of plumes from hydrothermal vents in the oceans and detailed investigation of natural archives (e.g. water corals and Greenland ice cores).

- **The role of the JRC's low-level underground laboratory HADES** for radioactivity measurements is crucial for some of these analyses. This JRC facility collaborates extensively with a European network of underground laboratories in measurements of radionuclides with broad applications to environmental science, reference materials characterisation, materials science and astro-particle physics, among others. For example, the HADES lab capacities are often used to measure U-238 concentrations in ample matrices from NORM industry, by-products and radioactive waste of natural origin by means of gamma-ray spectrometry.

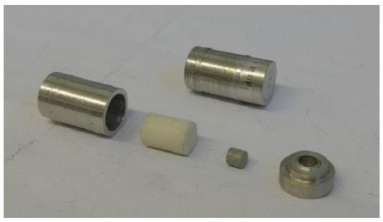
- **Protecting citizens from radioactivity**: verifying measurement capacity of member states through proficiency testing targeted at incident relevant radionuclides in air, water, soil, food and feed is an important support to the implementation of Article 35 of the Euratom Treaty. Radionuclide metrology capabilities at JRC are instrumental for the confidence in the reference materials produced and/or characterized by JRC for these proficiency tests.



- **Medical applications in radioisotope therapy**: The JRC has a long standing programme of research in the health applications of nuclear science, including the development and knowledge transfer of targeted immunotherapy with alpha radiation - a possible novel, highly effective treatment option for prostate cancer. The compound 225Actinium-PSMA617 was first synthesized and characterized at the JRC in Karlsruhe, followed by clinical testing in collaboration with hospitals in Germany and South Africa. To date, more than 250 patients have been treated worldwide with 225Ac-PSMA617. This work has been awarded the Marie Curie Award 2017 of the European Association of Nuclear Medicine, and could be used for the treatment of other cancers (e.g. breast or brain tumours).

- The need for **sustainability of production of the medical radioisotopes** poses challenges in the medium to long term, to ensure a reliable and robust supply from raw material to end-user ready product. Concerns about this supply chain have been materialised by the setup, in 2012, of an European Observatory on the Supply of Medical Radioisotopes, with JRC's active participation. The JRC is also coordinating a study under the title “Sustainable and Resilient Supply of Medical Radioisotopes in Europe", looking at the medical radionuclide production and availability in Europe. These actions are complementary to the SAMIRA initiative which seeks to identify cross-cutting actions that the European Commission can take in collaboration with stakeholders to maximize the societal benefits of nuclear and radiation technologies, whilst maintaining the highest achievable level of quality and safety to provide reassurance to citizens.
  Further information is available on: https://ec.europa.eu/energy/en/topics/nuclear-energy/radiation-protection/radiation-medical-use.

- **Collaboration on food authenticity and food fraud detection**: the JRC supports the Authent-Net: Food Authenticity Research Network and develops studies in collaboration with global partners, including capacity building activities and sharing of analytical expertise. The JRC developed for example, a new maize proficiency test material (for Cs-137 and I-131). The JRC works also in the harmonization/standardization of definitions of key terms and concepts related to food authenticity, and recommendations for best practices for compilation in a European CEN Workshop Agreement (CWA).
- **Supporting space exploration:** The JRC is developing a partnership with the European Space Agency on Am-221 batteries. Nuclear power is essential for electricity generation as well as for thermal regulation, as we venture further into the outer Solar system or to further explore the Earth's moon.



Collaborators:

Recognising the need to join efforts and find synergies with partners for supporting innovation in nuclear science applications, the JRC signed, on behalf of the European Commission, practical arrangements with the IAEA on February 2017 in Brussels. These arrangements include the following thematic areas: soil sciences, earth observation, food safety, health applications, traceability and authenticity, ocean science, environmental monitoring, emergency preparedness and water management.

In conclusion, given the economic importance and the added value of nuclear and radiation science and applications for societal well-being and progress, the European Commission through its JRC is actively supporting research, technological development and sharing of good practices in several related fields. These areas will continue to be a priority of the JRC, supported by a development strategy bringing together the global research community, policymakers and the civil society.

Website:

https://ec.europa.eu/jrc/en

NETHERLANDS (1)

Atoms for cultural heritage; analysis, inspection, (scientific) research and conservation of art objects with ionizing radiation

Description:

- X-ray examination reveals that the painting Walkers in a park (Paris, 1886) by Van Gogh appears to be an overpainting of a portrait. In the van Gogh museum, about twenty painted-over paintings were brought to light. Usually they are landscapes or preliminary studies of the final painting.
- Make a painting temporarily radioactive, and the original colors, substrates and painting technique become visible. This is interesting for art historians, but also of great importance for the restorer who starts working on the painting that has changed considerably over the centuries. An example is the painting The Saint Luke by Hendrick ter Brugghen, a seventeenth-century painter. This painting was irradiated in the low-flux reactor (LFR) in Petten.
- Making underpainting visible makes it possible to investigate the painting technique in order to discover the authenticity of a painting and e.g. to decide whether or not the painting is really painted by Rembrandt.
- Because we can measure the radioactive decay of each object over time, nuclear technology allows us to trace the age of an art object or archaeological find. And in this way, the same technology also makes it possible to expose art fakes.
- Age-old art objects are often in poor condition. Just think of old manuscripts that were exposed to water damage at a certain moment, or wooden objects in which a woodworm causes great damage. By irradiating age-old art objects with a nuclear technique, harmful organisms can be killed and important works of art can be saved.

Collaborators:

Last November 2018, France, Brazil, Egypt and the Netherlands organized a common side-event dedicated to cultural heritage, in the margin of the IAEA ministerial conference on Nuclear Science and Technology. Objective of this event (called “Atoms for Heritage”) was to highlight the role of nuclear techniques towards the history, interpretation, diagnosis and preservation of cultural heritage and natural history objects.

Experts from the four countries presented original novel nuclear imaging approaches (such as X-rays) to study paintings, or in paleoanthropology to look inside and beyond fossils and radiation-based methods, to consolidate old materials such a as linen or papyrus. The large attendance to this event confirmed the growing interest for the use of nuclear techniques in cultural heritage, which is a topic of broad international impact related to history, tourism, creative industries and sustainability.

In May 2019, the four countries (+co-sponsoring countries) will also have a joint statement on this topic during the Non-Proliferation Treaty Preparatory Committee in New York, under the agenda item on peaceful uses of nuclear energy.

NETHERLANDS (2)

Research in Food Safety

Description:

The RIKILT Institute for Food Safety, Part of Wageningen University and Research, carries out independent research into the safety and reliability of food. The RIKILT Institute performs the EURL tasks for mycotoxins & plant toxins in food and feed since March 1, 2018.

The RIKILT also works together with the Food and Environmental Protection Laboratory (FEPL) of the joint FAO/IAEA Programme. In this project, RIKILT contributes to the research of veterinary drug residues in foods by providing training and expertise.

FEPL's work centers on the traceability and authenticity of food products, and the control of food contaminants such as mycotoxins and residues of veterinary drugs and pesticides, and environmental factors related to food safety. FEPL targets critical points within the food supply chain where isotopic and related techniques provide added value, whilst encouraging and fostering the involvement of all stakeholders to promote sustainability.

Training is mainly focused on enhancing the capabilities of analytical laboratories and subjects include: Food traceability and authenticity techniques, Veterinary drug residues in animal derived foods, Pesticide residues in food and Laboratory Quality Assurance.

Collaborators:

FAO/IAEA Joint Programme

Other:

EURL Task RIKILT Institute:
https://www.wur.nl/en/Research-Results/Research-Institutes/rikilt/Reference-laboratory/European-Union-Reference-Laboratory-1/EURL-mycotoxins-plant-toxins.htm
FEPL:

http://www-naweb.iaea.org/nafa/fep/fep-laboratory.html

NETHERLANDS (3)

Atoms for health - nuclear medicine, Combination of therapy and diagnostics, the so-called "theranostics"

Description:

Annually 48 million medical isotopes are used. Most of these medical isotopes are made in Europe, in six nuclear reactors. All but one reactor are advanced in age and sooner or later they will have to be closed. Each day 30.000 patients receive a diagnosis treatment for a serious illnesses such as cancer and cardiovascular disease using radio-pharmaceuticals that have been irradiated in the High Flux Reactor (HFR) in Petten, the Netherlands. This makes the Netherlands the market leader when it comes to irradiating raw materials that are needed for nuclear medicine.

The European Nuclear reactors produce mainly Mo-99, which is supplied to deliver Tc-99m to hospitals. Mo-99 and Tc-99m generator supplies are sensitive to distribution efficiency because of their short half-lives. Tc-99m is the medical isotope used in patients for several diagnostic procedures like bone, thyroid, parathyroid and renal imaging, myocardial and lung perfusion studies. Tc-99m is used in approximately 80-85% of the diagnostic imaging procedures with nuclear medicines. Most of the medical isotopes are used for diagnoses, a smaller part for therapy. For these patients diagnosis or treatment with radioactive isotopes is the best type of care. Without isotopes, their diagnosis and therapy would be less good or non-existent. This would mean that their lives would be shortened and they would experience more side effects and pain. The demand for radiotherapy facilities is steadily increasing by new developments.

During the Ministerial Conference on Nuclear Science and Technology in 2018, organized by the International Atomic Energy Agency (IAEA) in Vienna, the Netherlands, Belgium and Australia co-organized a side-event on this topic. Three leading nuclear medicine producers from the three respective countries discussed the importance of reactor-based production to securing the nuclear medicine supply chain, new opportunities and innovations, and efforts to eliminate proliferation risks, followed by an interactive panel discussion.

A very promising emerging application of radioactive isotopes is the combination of therapy and diagnostics, the so-called "theranostics". These "theranostics" consists of binding an imaging radionuclide to a non-radioactive molecule ('the tracer') that specifically targets the cancer cells. This makes accurate screening and characterization of the tumor possible. The same tracer can be bound to a therapeutic radioisotope that emits radiation that can destroy the tumor. The use of the tracer guarantees the same absorption pattern for both diagnostic and therapeutic applications. A final scan allows checking the results.
Examples of this are diagnostics and therapy using the molecule PSMA. The diagnostic gallium-67 bound to the molecule makes the cancer cells visible. PSMA linked to lutetium-177 then irradiates only those sites that are visible on the scan, and can destroy the cancer cell from within with radiation. Lutetium-177-PSMA is now used for patients with prostate cancer, who have had all other treatment already. So far the treatment has been very successful and the life expectancy of the patients increases.
In the Dutch medical central UMC Utrecht a lot of research has been done into neuroendocrine tumors. Over the coming months they will start with a new experimental application. Whereas lutetium -177-PSMA is normally injection through a vein, they are planning to insert it direct into the prostate cancer itself, by inserting a tube via the groin directly into the blood vessel towards the prostate. This treatment will be used for patients who are diagnosed with early-stage prostate cancer, in which the tumor has not yet metastasized. The expectation is that in this way it is possible to strike a major blow to the tumor, and unpleasant side effects can be avoided.
Overall the combination of therapy and diagnostics means that nuclear medicines can make an great contribution to personalized medicine.

Collaborators:

Together, Australia, Belgium and the Netherlands supply 75% of the world's medical isotope Mo-99, which is used in the vast majority of nuclear

medicine procedures worldwide, e.g. for cancer diagnosis and treatment.

Other:

https://www.nrg.eu/en/products-services/controller/Product/action/showSubcategory/subcategorie/medische-isotopen.html?L=1&cHash=cd1b3f00d383d6fadda3d64bd41c6104

'Focus on Pallas 2018', page 18-19
https://www.pallasreactor.com/media/jaaroverzicht-pallas-2/

POLAND (1)

Electron beam flue gas treatment

Description:

The pollutants are emitted to the atmosphere with off-gases from industry, power stations, residential heating systems vehicles and ship engines. During the combustion process different pollutants as fly ash, sulfur oxides SO_x, nitrogen oxides NO_x, VOC & PAH, mercury are emitted. The air pollution control technologies have to be applied. Electron beam technology is among the most promising advanced technologies of a new generation, which allows simultaneous treatment of different pollutants. The high efficiency of SO_x , NO_x and VOC removal was achieved. Additionally the byproduct is a good fertilizer. After pilot tests an industrial plant has been constructed at coal fired power plant in northwest Poland. The next step in technology development was construction of pilot installation of heavy oil fired power plant at Aramco , Jeddah Refinery.

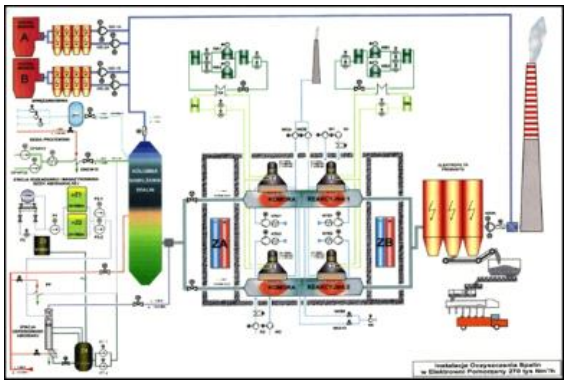
Project: Industry based orders. EU H2020 ARIES Project

The benefits. The technology enables a significant reduction of both pollutants (SOx and NOx) and good quality fertilizer is thde byproduct. The eb process demonstrated the possibility of destroying Polyaromatic Hydrocarbons (PAH) like benzo[a]pyrene as well.

Possible barriers, challenges. The main barier is related to the availabilty of high power electron accelerators.

Collaborators:

Other countries or international/European organisations involved: CERN, Geneva, Switzerland; Biopolinex, Lublin, Poland; Kazakhstan



POLAND (2)

Hybrid electron accelerator system for the treatment of marine diesel exhaust gases

Description:

Around 15% of global NO_X and 5-8% of SO_X emissions are attributable to ocean-going ships. According to International Maritime Organization regulations (MARPOL Annex VI), there are two sets of emission and fuel quality requirements: global (progressive reduction in global emissions of SOx, NOx and particulate matter) and more restrictive requirements dedicated to ships in deliberately established zones – Emission Control Areas (ECA). A new, hybrid technology is based on the concept of combining two methods used to clean up the exhaust gases: Electron Beam (EB) and Wet Scrubbing.

Project: Proof of Concept Project „ Accelerator system for the treatment of marine exhaust gases" in the frame EU H2020 „ARIES" and Polish Project – Tango 2.

The benefits. The hybrid eb method enables a significant reduction of both pollutants with limited reagent consumption and may assure organic pollutant destruction, which may be required by new standards in the future. The eb process demonstrated the possibility of destroying Polyaromatic Hydrocarbons (PAH) like benzo[a]pyrene.

Possible barriers, challenges. The hybrid eb method has a great potential to solve the emerging problem of marine industry and, although it still requires research, its development is now at the level 4 in the Technology Readiness Level. This means that the technology has been optimized at the laboratory level and is in the medium development phase.

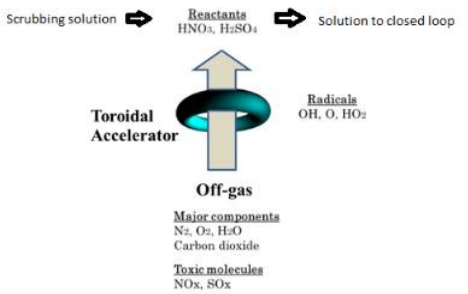
Collaborators:

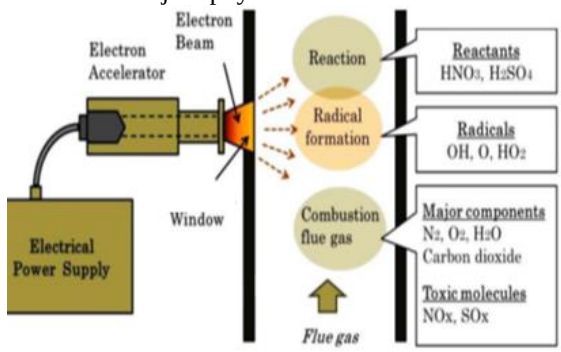
Other countries or international/European organisations involved: RTU, Riga, Latvia; INCT,Warsaw, Poland:Fraunhofer FEP, Dresden, Germany; CERN, Geneva, Switzerland; Remontowa, Gdańsk, Poland; RKB, Riga, Latvia; Biopolinex, Lublin, Poland.

Other:

1. Siwek M., Chmielewski A.G.,(2018), Process engineering aspects of diesel engine off gases treatment, INCT Report B, 2/18, Warsaw, http://www.ichtj.waw.pl/ichtj/publ/b_report/b2018_02.htm

2.Chmielewski A.G., Zwolińska E., Licki J., Yongxia Sun, Zimek Z., Bułka S., (2018), A hybrid plasma-chemical system for high-NOx flue gas treatment, Rad. Phys. Chem. 144, 1-7 DOI: 10.1016/j.radphyschem.2017.11.005





Principle of off gases treatment by electron beam, wet srubber is the second stage

POLAND (3)

“Zero energy” sludge hygenization electron beam technology

Description:

Nowadays municipal sewage is being cleaned mostly with the use of the method of activated sludge. Excess of activated sludge constitutes biomass which can be utilized to produce energy and at the same time has a value as a fertilizer. However, the problem is that the sludge is microbiologically contaminated by human and animal parasites, their eggs, and also pathogenic bacteria. According to the invention, biomass originating from waste prior to its fermentation or digestate derived in the process of methane fermentation is irradiated with electron beams that use energies from 1 MeV to 10 MeV, preferably 1-3 MeV. For a digestate derived in the process of fermenting biomass originating from waste and having a liquid form with the content of dry matter less than 5%, the radiation dose is from 1 kGy to 5 kGy, whereas for a digestate from which the aqueous phase has been filtered out and which has a dry matter content up to 30%, the radiation dose is from 5 to 20 kGy.

The benefits.

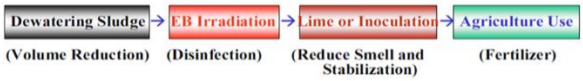
The advantage of the method according to the invention consists in the fact that the energy is generated from renewable waste material which is widely available. The method according to the invention does not require energy from external sources and, thanks to the fact that irradiated digestate is utilized as a fertilizer, does not generate waste. The method allows pathogens to be eliminated from sludge and does not have a negative impact on the environment. The plant due to own electricity source may be installed in a remote site, providing electricity for accelerator, wastewater treatment plant and village. The heat from cogenerator may be used for fertilizer drying.

Possible barriers, challenges.

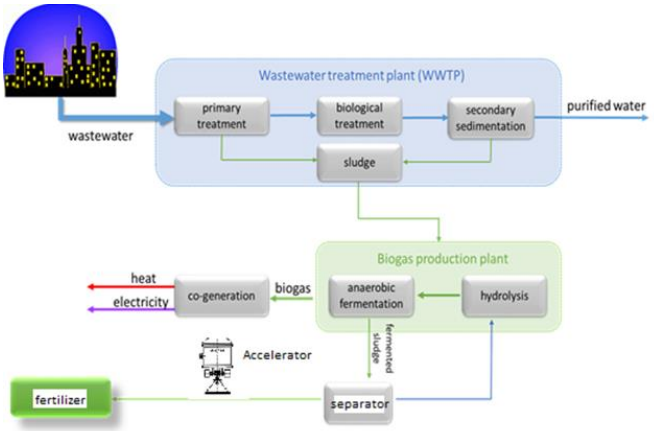
Accelerators cost , necesity to construct demonstration facility

Collaborators:

INCT, Warsaw, Poland; Biopolinex, Lublin , Poland



Layout of eb hygenization line



Scheme of biogas and eb plant for safe organic fertilizer manufacturing.
A.G.Chmielewski, Electron Accelerators for Environmental Protection, January 2011,Reviews of Accelerator Science and Technology 4:147–159
DOI: 10.1142/9789814383998_0007

ROMANIA (1)

Ion beam applications in natural, technical and social sciences

Description:

The Tandem Complex (DAT) at Horia Hulubei National Laboratory for Physics and Nuclear Engineering had an early start in 1972 when the 7.5 MV High Voltage FN Tandem was installed. The machine was later upgraded to 9 MV. In 2012 the DAT laboratory was equipped with two state of the art High Voltage Tandetrons for ion beam applications, while the old Tandem remained focused on nuclear structure and reactions as fundamental physics research. The new Tandetrons opened a wide range of ion beam applications in Accelerator Mass Spectrometry (AMS) and Ion Beam Analysis (IBA) studies with implications in all the spheres of the environment, from biosphere to techno sphere.

At the RoAMS Centre we run several studies regarding paleo morphology of the Romanian relief as well as paleoclimatology using radiocarbon dating and isotopic ratios like $^{26}Al/^{27}Al$ and $^{10}Be/^{9}Be$ to determine the glaciation periods in the Carpathian Mountains and floods episodes for the Romanian rivers. The ^{129}I was successfully used to monitor the Fukushima impact on some parts of the Indian Ocean and also to determine the enrichment of the Danube waters in this isotope. The multi-isotopic character of our 1 MV AMS system allowed us to undergo measurements in the actinides region for environmental monitoring and nuclear forensics investigations. In this area the species of interest are $^{239,240,242,244}Pu$, ^{236}U, ^{237}Np, etc. Radiocarbon dating has also an important impact in archaeology and cultural heritage. The age information of different artefacts is of a great importance for authentication and forgery identifications. For this purpose, and to further obtain relevant information one can take advantage of the IBA methods (i.e., PIXE) employed at the Romanian Centre for Ion Beam Applications (RoCIBA). As mentioned earlier, RoCIBA is primarily dedicated to applicative and fundamental research on ion–solid interaction, ion beam analysis, ion beam modification, and other basic and applied research on irradiation effects in a wide range of materials.

The RoCIBA is currently equipped with two ion sources connected to a 3 MV Tandetron™ accelerator, three beamlines and three end stations. The first beam line is dedicated to ion beam analysis (IBA) techniques: Rutherford Backscattering Spectrometry (RBS), Rutherford Backscattering Spectrometry in channelling conditions (RBS/C), Non-Rutherford backscattering spectroscopy (NRBS), Nuclear Reaction Analysis (NRA), foil - Elastic Recoil Detection Analysis (ERDA), Particle Induced X-ray and γ-ray Emission (PIXE), Particle Induced Gamma-ray Emission (PIGE), and micro-beam experiments (μ-PIXE). The second beam line is dedicated to high energy ion implantation experiments and the third beam line was designed mainly for nuclear cross-sections measurements used in nuclear astrophysics.

Since the beginning of operation in 2012, irradiations and measurements are conducted to meet increasing demands from national/international academic community, and high-tech industry. For example, combining NRBS and foil-ERDA, the H, C, N, and O contaminations were detected in thin films provided by Merck GmbH.

The 3 MV HVE Tandetron™ accelerator and three high-energy research beamlines (with L1 on the right, L2 in the middle, and L3 on the left) of RoCIBA

Collaborators:

ETH Zurich, TUM Munich, ICER Atomki, CNA Seville, CSNSM Orsay, UT Knoxville, IMP Lanzhou, CIAE Beijing, Merck

Other:

www.tandem.nipne.ro

ROMANIA (2)

Technological irradiation and beyond

Description:

IRASM is a Radiation Processing Centre both client and R&D oriented hosting two gamma irradiators and a number of laboratories dedicated to specific tests for dosimetry, microbiology or physical & chemical tests to measure the modifications induced by gamma irradiation.

Its activity started in 2001 by commissioning a multipurpose facility engaged to support the sterilization of medical devices, food microbiological control and any other application of gamma irradiation. Fulfillment of the main tasks is an everyday activity based on direct actions focused on possible end-users (common R&D projects, demo treatments, knowledge transfer, publications) but means also actions for improving the socio-economical frame (translation of specific standards, common projects with health regulatory bodies). Implementation and certification of a performing Quality Management System (QMS) since 2002 was the best argument for the economic activity. QMS conformity is extended to the standards important to industrial end-users - ISO 9001 (general management), ISO 13485 (manufacturing of medical devices) and ISO 11137 (validation of irradiation sterilization). Certifications covers all IRASM activities, including R&D. Laboratories have various proves of competence recognition; for instance the Dosimetry Lab is traceable at High Dose Reference Lab RISO - Denmark; the Microbiological Lab is authorized by national health authority and accredited cf. ISO 17025 by RENAR – Romanian competent authority.

Constant attention is given to prove radiation processing utility at the country and international level. IRASM is the technical facility in Romanian market survey for detection of irradiated foodstuffs. Also the Center maintains constant relations with International Atomic Energy Agency by active participations at IAEA projects in terms of offering experts or hosting workshops, training schools, fellowships or scientific visits.

Irradiation conservation of cultural heritage artifacts is another good example. In a context where nuclear applications are considered with suspicion by public opinion, in Romania this application is accepted and used by museums, archives, monasteries, churches or the Deputy Chamber.

Collaborators:

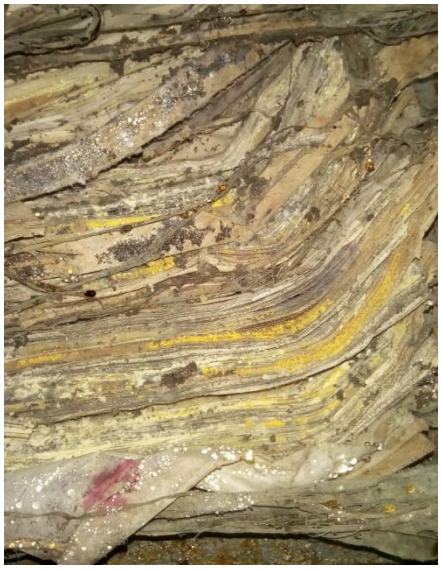
Manufacturers of medical devices, Health Ministry, stakeholders of cultural heritage artefacts.

Other:

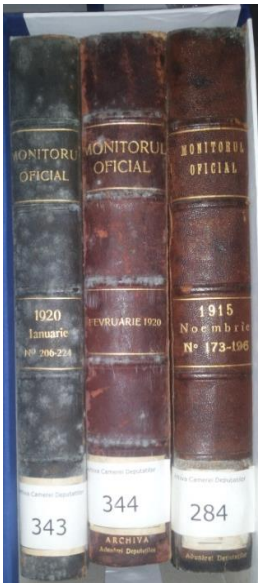
IAEA - Vienna, Austria;

ARC NUCLEART – Grenoble, France

The iconostasis of "The Spring of Healing" Church, Izvoarele - Prahova county , Romania treated at IRASM facility for stopping of woodworms attack (2005)



Documents from "Sahia Film" archive Bucharest, Romania (2016)



Leather book covers *Parliament of Romania (2014)*

ROMANIA (3)

Radiopharmaceutical research and development

Description:

Radiopharmaceuticals are drugs that contain radioactive materials called radioisotopes. They may be put into a vein, taken by mouth, or placed in a body cavity. Depending on the drug and how it's given, these materials travel to various parts of the body to image pathological processes, treat cancer or relieve its symptoms.

Once radiopharmaceuticals enter the body and travel to a specific organ, they interact with the processes of that organ. The radioactivity is picked up by camera and map the process resulting in functional imaging. The amount of radiation a patient is subjected to is about the same as a normal X-ray, but the information gathered is significantly different. The most commonly used nuclear imaging techniques are PET and SPECT scans, using radioisotopes emitting positrons or gamma radiation. For treatment purposes, different types of radiation are used, employing the highly destructive effect of alpha and beta emitters delivered locally, at cellular or intracellular level, while sparring surrounding normal cells.

Molecular imaging is playing an increasingly important role in early diagnosis of cancer, functional imaging in cardiology and neurodegenerative diseases. It uses radiopharmaceuticals to target and non-invasively quantify individual biochemical parameters such as hypoxia, angiogenesis, receptor expression and metabolism, which are some of the most important biochemical pathways involved in early development of a pathological state.

The Radiopharmaceuticals Research Centre (CCR: http://ccr.nipne.ro/) - a complex system comprising a versatile cyclotron (variable energy 14-19 MeV), radiochemistry and analytical laboratories, automated synthesis units, and a micro PET, represents a state of the art experimental facility, dedicated to research in the fields of radiochemistry, radio pharmacy and nuclear physics applications, facilitating a modern and efficient application of nuclear technology in life sciences.

CCR is a state of the art facility in radiopharmaceutical development, where new radiotracers are designed, aimed for early diagnosis of cancer, imaging of pathologies in cardiology and neurology, and also to more specific and individualized follow-up and therapeutic agents At CCR we develop radiopharmaceuticals, from basic research and preclinical testing to clinical applications. The radioisotopes are produced in a cyclotron or by generators and linked to biologically active molecules of interest. The successful candidates, evaluated pre-clinically, in the laboratory, are transferred to a pharmaceutical production line (EU-GMP) and further clinical investigations are conducted in patients.

Collaborators:

Nuclear Medicine Departments in public and private hospitals.

Similar Reasearch Centers in Europe: European Institute of Oncology Milan, Italy; Institute of Nuclear Sciences Applied to Health, University of Coimbra, Portugal; Nuclear Medicine Department of Medical University Innsbruck, Austria; National Centre for Scientific Research "Demokritos", Athens, Greece; National Centre for Nuclear Research, Otwock, Poland.

SLOVAKIA (1)

Ion beam technologies in natural, technical, biomedical and social sciences

Description:

A Centre for Nuclear and Accelerator Technologies (CENTA) was created in 2013 at the Faculty of Mathematics, Physics and Informatics of the Comenius University in Bratislava as a part of the Centre of Excellence of the Physics of Complex Systems, supported by the European Union in the framework of the European Structural Funds. The project has also been supported by the Technical Cooperation program of the International Atomic Energy Agency. The CENTA represents a modern state-of-the-art scientific and educational centre of excellence for ion beam technologies and their applications in many branches of science and cultural heritage. The most important part of the CENTA is the Tandem Accelerator Laboratory, which is equipped with the most recent accelerator technology from USA, consisting of two ion sources for gas and solid targets, injection system of ions, tandem accelerator (Pelletron), and high energy analyzers. The CENTA represents a unique laboratory for research in ion beam technologies, focusing on applications of AMS (Accelerator Mass Spectrometry), IBA (Ion Beam Analysis), NRA (Nuclear Reaction Analysis), and IBM (Ion Beam Modification of materials) for environmental, life and material sciences.

Specific AMS issues included protection of the total environment against contamination by radionuclides, climate change studies using isotopes as tracers of environmental processes, applications in geochemistry, geology, and space physics, in protection of groundwater against pollution, and development of new dating methods. The IBA issues focused on applications of RBS (Rutherford Back Scattering), PIXE (Particle Induced X-ray Emission) and PIGE (Particle Induced Gamma-ray Emission) techniques in atmospheric pollution studies, in nanotechnologies and biomedical investigations. Applications in biomedicine included impact studies of electromagnetic radiation on animals, formations of heavy metal clusters in brains, etc.). The IBM issues included radiation damage studies of construction materials by light and heavy ions.

Collaborators:

International Atomic Energy Agency (Vienna), international projects SupeNEMO, CRESST, LEGEND and about 50 scientific institutions worldwide.

Other:

www.centa.sk

CENTA team in the Tandem accelerator laboratory

SLOVAKIA (2)

Investigation of environmental friendly dichlorination of polychlorinated biphenyls (PBC) in Slovakia by electron beam treatment

Description:

Polychlorinated biphenyls (PCB) are toxic and potentially carcinogenic compounds. They were wide used in industry for their dielectric and thermal properties. Although their use was banned more than 20 years ago, PCB is still a big environmental load in Slovakia. Therefore its disposal is an important task for environment protection.

In the Slovakia the PCBs were produced until 1984 in Chemko Strážske. A large part of eastern Slovakia an area of 40×70 km^2 with over 250 000 permanent residents and a reservoir Zemplínska Šírava are heavily polluted with PCBs on level exceeding the limit more than by factor 5. The most massive source of contamination at eastern Slovakia unambiguously was and still is the canal Strážske. The concentration of PCBs in the sediments of the canal exceeds permitted limit thousand-times.

In Slovakia a detailed spatial screening of PCB contamination in the environment together with extensive studies on negative health effects of contaminated environment on population, mostly the children, were done in the past. The effect of the contamination level at particular areas was investigated as well.

An estimation based on the studies says that cleaning the source of contamination, the canal, will stop the input of new PCBs into the environment and in the course of five years their concentration in the environment of eastern Slovakia will drop by 30%.

There are some ways to defuse PCBs. The incineration is mostly used, but it causes hazardous emission. Biotechnological processes are inefficient and very slow. The most hopeful way is dichlorination of PCBs by electron beam because the process of radiation degradation PCB is without hazardous emission and for application in environment a relocatable irradiation unit can be used. Since 2015, we have been systematically developing the technique to increase the effectiveness of radiation degradation of PCBs at our facility with electron beam accelerator. The chemical pretreatment of sediment samples, the energy of accelerated electrons together with the geometry of sample irradiation were optimized.

The decrease of PCB congener concentration to 50% by radiation degradation was achieved irradiating sediment samples by a dose of 200 kGy. Parallelly, we are designing technical parameters of transportable irradiator based on electron beam accelerator, which on the contrary to the movable ones will not have such power limit, would be more reliable and operate with lower costs.

Collaborators:

In our effort the participation in the International Atomic Energy Agency (IAEA) TC projects is very helpful for us as we can consult the problematics with foreign experts in radiation processing.

Other:

Video with pictures and good practices about the project has been performed by IAEA specialists and can be downloaded from the link below:
https://iaea.wistia.com/medias/ootam7mpxv

SLOVAKIA (3)

Reduction of fecundity and trypanosomiasis control of tsetse flies by the application of sterile insect techniques and molecular methods

Description:

Tsetse flies (Diptera:Glossinidae) are vectors of African trypanosomes, which are of medical and economic importance, causing the Human African Trypanosomiasis (HAT) and Animal African Trypanosomiasis (AAT). Their vectoral capacity results in major public health emergency and vast economic losses in sub-Saharan Africa. Despite the fact that trypanosomes are one of the best-studied organisms, mammalian vaccines are not available and HAT treatment relies on dangerous and expensive drugs hardly delivered in remote areas of sub-Sahara, also trypanosomes are increasingly becoming resistant to the drugs. Population reduction methods based upon pesticides effectively reduce tsetse densities and disease transmission. However, the use of pesticides has side effects as mammalian toxicity, impact on non-target organisms and development of insecticide resistance. Genetic and non-pesticide based methods are thus highly desirable.

One of the most effective method and also cost-effective sustainable method for the suppression or elimination of target pest populations is the Sterile Insect Technique (SIT). This technique is an environmentally friendly method using area-wide mass release of sterile males to reduce reproduction in a field population. It is species-specific and has no effect on other 'non-target' species. Within our applied research we introduce the new type of SIT technology to various parts of Africa with the occurrence of tsetse populations. There are several tsetse fly habitats in sub-Saharan Africa, where a sustainable removal of the tsetse and trypanosomiasis (T&T) problem necessitates the involvement of SIT component as part of area-wide integrated pest management (AW-IPM) measures. In order to improve the effectiveness and efficiency of tsetse SIT, the development of new methods for mass production of sterile male tsetse flies and the shipment of 'seed' tsetse pupae and sterile males to tsetse mass-rearing centre in Senegal was conducted.

First use of the chilled adult aerial release technique

with tsetse in Senegal. The release machine is on board a gyrocopter of the Kalahari aerodrome.

Collaborators:

Institute of Zoology, Slovak Academy of Sciences, Scientica, s. r. o.,
International Atomic Energy Agency, Vienna, Austria.

Tsetse fly

SLOVENIA (1)

Dating of Early Medieval Glass Beads

Description:

Migrations of early Slavs are documented in their graveyards and precise dating of the graves is important. In western Slovenia, traditional dating of the graves from the so called Köttlach culture was into the seventh century, which was a century or two earlier than dating in the central Europe. A useful item to date the graves was discovered in glass beads, which are frequently found among the grave inventory. A significant time marker in glass technology occurred around 800 AD with the change of the glass flux. Until then, glass was produced from the siliceous sand whose melting temperature was reduced with the alkalis from the dry sediments of the Egyptian lakes, known as natron. Due to various events in the East, natron was no more easily accessible and after 800 AD it was gradually replaced by the ash of halophytic plants.

The two types of glass are easily distinguishable according to their chemical composition, as natron appears much purer than the plant ash. The glass beads are precious archaeological artefact, and therefore it is highly desirable that the analysis is done in a non-destructive way. The task is easily executed by nuclear-based methods available at charged-particle accelerators: the methods of proton induced X-rays (PIXE) and gamma-rays (PIGE), which can analyse all important glass elements in the form of oxides and several significant trace elements. For distinction between the natron and plant ash glass it is enough to determine the concentrations of potassium and magnesium. Both elements emit X-rays with a high enough energy to be detected, however, for our measurements at the Jožef Stefan Institute in Ljubljana we preferred to detect magnesium according to its gamma ray energy at 585 keV. The analysis showed that quite many graves from the western Slovenia contained glass beads made of plant ash, which can be dated after the second half of the eighth c. AD. This dating is consistent with the central-European dating.

Collaborators:

Jožef Stefan Institute, Slovenian National Museum

SLOVENIA (2)

Improving Water Quality in Ground Water Bodies

Description:

Establishing technologies for improved water quality are necessary. Nuclear techniques provide an innovative and unique methodology to trace and monitor the movement of nitrates from organic and inorganic fertilizers from the soil to ground and surface waters. Different fertilization and irrigation methods influence the nitrate leaching under the vegetable field above a shallow aquifer in Slovenia have. These methods gave been analysed to address the problem of groundwater pollution and have been studied within the IAEA technical cooperation project "Protecting Groundwater and Soil Against Pollutants Using Nuclear Techniques" (IAEA SLO/05/002) in coordination with national projects (e.g. L1-7079, "Nitrate Migration in a Plant-Soil-Groundwater System", and L1-0437, "Natural Hydro-Chemical Background and Dynamics of Groundwater in Slovenia).

The case study about measures for sustainable plant production in the Ljubljansko polje area has been performed. The outcomes of the project successfully provided the guidelines for water quality improvement, and application of improved farming practices in plant production in central Slovenia.

Good drinking water quality needs to be ensured to population, if the country wants to comply with the goals of the Water Framework Directive.

Collaborators:

Slovenian Agriculture Institute, National Research Agency, IAEA

SLOVENIA (3)

Supporting the Development of Ga-68 Labelled Biomolecules for PET Imaging of Neuroendocrine Tumours

Description:

The Department of Nuclear Medicine of University Medical Centre (UMC) Ljubljana is the leading Slovenian institution in the field of nuclear medicine. One of the most important outcomes from very fruitful cooperation with the IAEA in the past is the new laboratory that was equipped and (re)built within the framework of technical cooperation (TC) project, "Supporting the Development of Ga-68 Labelled Biomolecules for PET Imaging of Neuroendocrine Tumours".

The new laboratory enables safe production of radiopharmaceuticals labelled with positron and beta emitters. It enabled the start of routine production of gallium-68 radiopharmaceuticals for the management of neuroendocrine neoplasms. Being the only centre in Slovenia capable of producing PET and therapeutic radiopharmaceuticals such achievement is of utmost importance for the clinical needs of the Slovenian patients.

Today a team of radio pharmacists produces gallium-68 radiopharmaceuticals, designed to identify the presence and asses the spread of the disease on a daily basis. The production of radiopharmaceutical is technologically demanding process using advanced analytical technology which enables the appropriate quality of the radiopharmaceuticals for clinical use. The new PET/CT examination with gallium-68 radiopharmaceutical has significantly higher sensitivity than all the diagnostic tests used by now and it allows monitoring the effectiveness of treatment and planning the best treatment options for the patient.

Due to the cooperation with the IAEA, the patients and referral doctors have access to the best possible diagnostic examination for neuroendocrine neoplasms, so there is no need to send patients to foreign centres.

Collaborators:

University Medical Centre Ljubljana, IAEA

UNITED KINGDOM (1)

A novel power source for future space missions

Description:

Nuclear power in the form of radioisotope power systems (RPSs) - has been used to power many of the most significant space missions during the last 50 years. For example, Voyager, Cassini and Mars Science Laboratory (MSL) to name just a few. These would have been impossible without RPSs, since the alternative of solar power does not work in the distant locations that these missions explored.

RPSs contain a radioactive material (a radioisotope) which decays, producing heat, and this heat is then converted into electricity. For almost all the missions to date this radioisotope has been Plutonium 238. However Plutonium 238 is very expensive and difficult to make and the worldwide availability is so limited (with none in Europe) that missions using it can only be considered occasionally.

There is an alternative. In the UK used nuclear fuel has been reprocessed for many years and the plutonium which comes from this process has been stored for future use in nuclear reactors. When the plutonium is stored, over many years some of it decays to form another radioisotope - Americium 241, which by the conventional nuclear industry is considered a waste. However, the Americium 241 is a heat producing radioisotope that has similar properties to the Plutonium 238 used in RPSs.

NNL have developed a process to safely extract the Americium 241 from the UK plutonium stocks, and to use it as a fuel in a European designed RPS. This takes what would otherwise be a waste material from the nuclear industry and uses it to power future science exploration missions in outer space.

The UK's provision of RPSs to support space exploration has generated a range of fascinating STEM roles for the brightest nuclear graduates. These roles, within industry and academia, nurture and grow skills in research and development which can be applied to other sectors across Europe.

Collaborators:

UK National Nuclear Laboratory (NNL), The University of Leicester, Airbus defence and space, Lockheed Martin UK. There is also collaboration across Europe supporting this activity, including the Joint Research Centre in Karlsruhe, and with Airbus Safran Launchers in France.

UNITED KINGDOM (2)

The use of stabilised isotopes to measure malnutrition

Description:

The UK academic community is undertaking research on nutrition using stable isotopic echniques and deuterium, which allows for improved understanding of energy expenditure and body composition and enables tailored support to help against malnutrition. This work demonstrates how the UK's world-class scientists, through our research institutes and national laboratories, continue to discover new ways of harnessing the peaceful uses of nuclear technologies to alleviate the socio-economic issues of low and middle-income countries.

Stable isotopes are non-radioactive, safe and are applied for various purposes in human health assessment in trace amounts that minimally disturb normal physiology. The International Atomic Energy Agency supports the use of stable isotope techniques to design and evaluate interventions addressing malnutrition in all its forms with focus on infant and young child feeding; maternal and adolescent nutrition; diet quality; prevention and control of non-communicable diseases; healthy ageing and gut function. These techniques can be used to objectively measure: (1) Amount of human milk consumed and whether an infant is exclusively breastfed; (2) Body composition in the context of re-feeding programmes for moderate and severe acute malnutrition and as an indicator of the risk for obesity; (3) Bioavailability and bioconversion of pro-vitamin A and vitamin A body stores following vitamin A intervention programmes; (4) Absorption and retention of iron, zinc and protein; (5) Total energy expenditure for validation of physical activity measurement and dietary assessment tools and (6) Diagnosis of Helicobacter pylori. Stable isotopic techniques will be invaluable in the tracking of global targets on exclusive breast-feeding childhood obesity and anaemia among women. Efforts are underway to make nuclear techniques more affordable, field-friendly and less invasive, and to develop less sophisticated but precise equipment.

The UK offer technical expertise in the form of consultancy and attendance at relevant Technical Meetings and International fora organised by the IAEA in Vienna.

Collaborators:

London School of Hygiene and Tropical Medicine, Kings College London and the University of Cambridge, University College London and Department for International Development

Other:

https://www.cambridge.org/core/journals/proceedings-of-the-nutritionsociety/article/using-stable-isotope-techniques-in-nutrition-assessmentsand-tracking-of-global-targetspost2015/8E0A549E17DBD01C8F94A12E1A32AC1A/core-reader

UNITED KINGDOM (3)

A comprehensive radioanalytical service including radiological monitoring, dose assessment and control for a wide range of food, environment and effluent samples.

Description:

The Centre for Environment, Fisheries and Aquaculture Science (Cefas) is a world leader in marine science and technology, providing innovative solutions for the aquatic environment, biodiversity and food security.

Managing the risk from radioactivity requires the accurate measurement of activity concentrations in the environment. Cefas routinely perform qualitative and quantitative analysis for alpha-, beta- and gamma-emitting radionuclides on a large number of samples for a number of national and international customers. Cefas offer a range of services from the initial design and implementation of complex sampling and radioanalytical programmes to the final interpretation of derived dose assessments.

Cefas is experienced in the collection, preparation and radioanalysis across a wide range of sample matrices in both the aquatic and terrestrial environments, including soil and sediment, rain, river, lake, drinking and groundwaters, plant and animal tissue, milk and food products and effluents.

The radioanalytical data produced by Cefas are amongst the most reliable produced by expert laboratories anywhere in the world. Their Standard Operating Procedures and quality control programmes (both internal and external) are prepared to UKAS standards. Their high precision and accuracy are to recognised national and international levels. They also regularly participate in international and national inter-comparison proficiency schemes led by organisations such as the International Atomic Energy Agency and the UK National Physics Laboratory.

Collaborators:

The Centre for Environment, Fisheries and Aquaculture Science

Other:

https://www.cefas.co.uk/

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