TRAINING COURSE 2

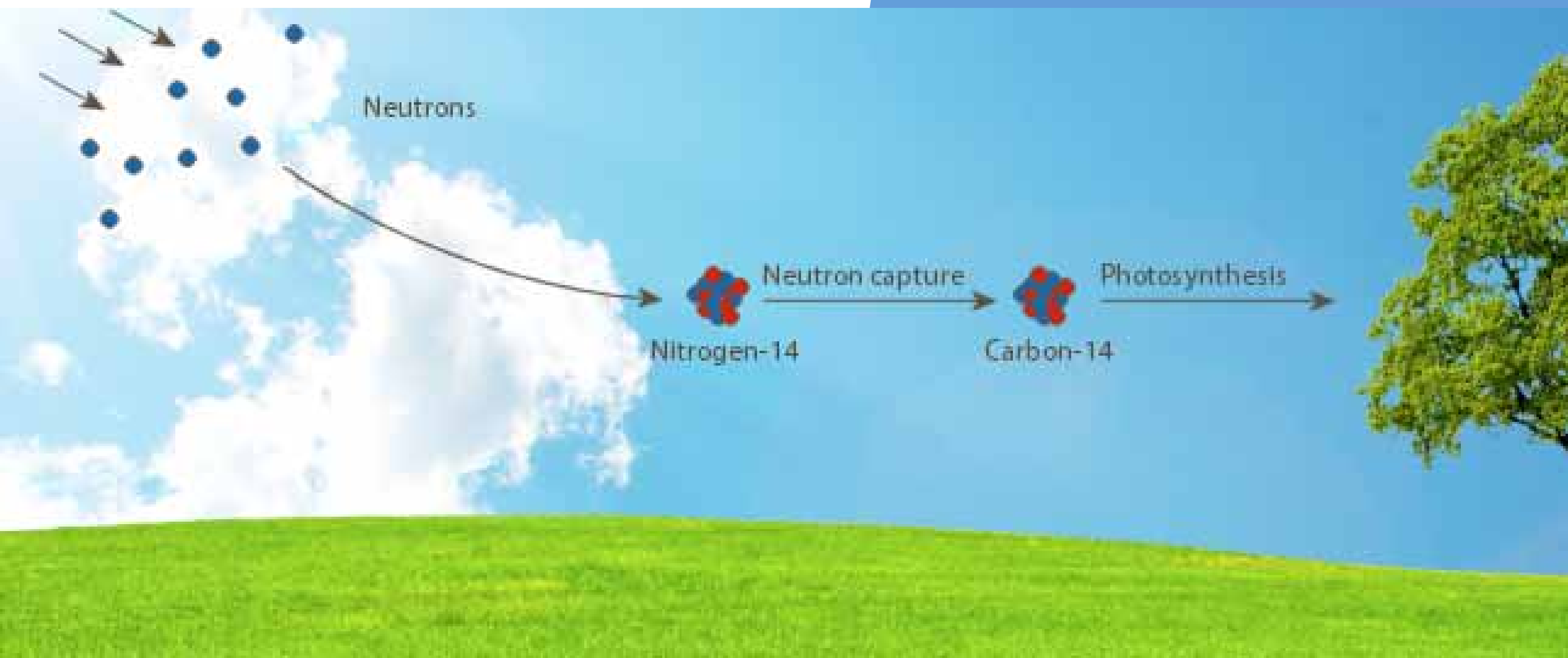
CAST (Carbon-14 Source Term) is an EU research project that aims to develop understanding of the potential release of carbon-14 from radioactive waste materials under conditions relevant to waste packaging and disposal to underground geological disposal facilities. The project focusses on the release of carbon-14 as dissolved and gaseous species from irradiated metals (steels, Zircaloys), irradiated graphite and spent ion-exchange resins.

The nature and effects of the processes and events used to assess the safety of a geological disposal disposal facility must be considered for timescales of hundreds of thousands of years. One of the main issues is the ability to assess these events and processes with sufficient confidence over these long time scales. The use of available knowledge of natural analogues can provide confidence that the potential effects are correctly included in an assessment. The health related effect of artificial and natural carbon-14 can be calculated with the same exposure model. The modelling of the generation of natural and artificial carbon-14 is similar only the parameter values to model their generation rates are different e.g. the thermal neutron flux.

Two training courses are envisaged in CAST for early-stage researchers i.e. Master and PhD students with background in (nuclear) engineering, geology, chemistry and mathematics. Bachelor students with these backgrounds that are in their third year are also welcome. The courses are envisaged to gain knowledge and develop skills to address waste management issues associated with carbon-14 containing waste from the point of view of experimental investigations or from a modelling and performance assessment perspective. There is no fee for the training courses.

The first training course was held in Karlsruhe in 2016. The lecture notes are published on the CAST website.

The types of waste investigated in CAST can be viewed in storage facilities in the second training course. Storage is an interim solution for radioactive waste and disposal of the stored waste is foreseen. Some types of waste investigated in CAST are already disposed in Europe e.g. in Spain.



The second training course takes place in the Netherlands at COVRA's premises because the waste investigated in CAST can be viewed at a single location and is therefore beneficial to become acquainted with the executed research in this EU research project. This EU project is in a finishing stage and all published materials will remain accessible till 2023 at the CAST website www.projectcast.eu.

The photo on the left is the HABOG facility; one of the storage facilities at COVRA's premises. The facility contains heat-generating High Level Waste and also irradiated Zircaloy. The potential carbon-14 release from the waste contained in this building is monitored.

Steels

Steel is frequently used in nuclear reactors, and the largest structural material is the reactor vessel. The carbon steel wall thickness can be several decimetres thick. The inside of this vessel consist of several millimetres of stainless steel to prevent corrosion of the vessel. Other structural materials include components to assemble fuel elements and ducts to transport heated water. Irradiated steel can become radioactive waste. At COVRA, irradiated steel is expected to be conditioned in concrete. Storage to allow decay of mainly cobalt-60 to facilitate the conditioning is one of the options and shown on the left in the yellow temporary containers.

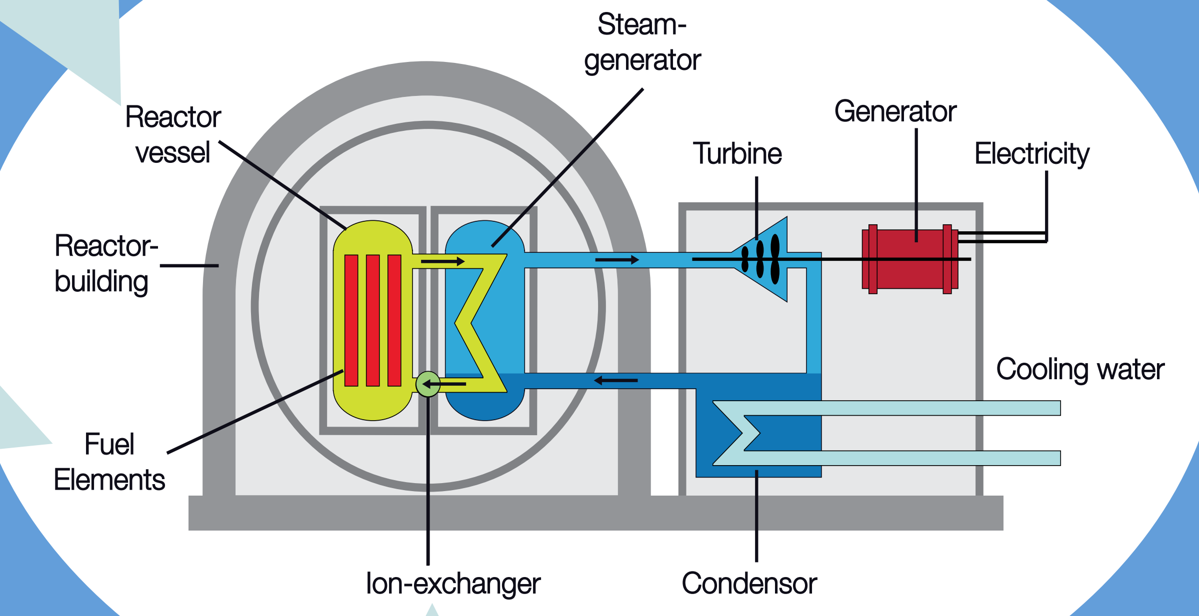
Natural carbon-14

Natural carbon-14 is a neutron activated product. Neutrons are present in our living environment. Outides the Earth's atmosphere, high energetic particles e.g. protons are generated. A cascade of secondary cosmic rays is made by collisions with these high energetic protons (primary cosmic rays). The Earths' magnetic field and atmosphere provide protection against cosmic radiation. A part of these secondary rays are neutrons. The energy of neutrons resulting from collisions with high energetic protons can be 1 GeV. Hydrogen atoms are most effective in reducing the energy of neutrons. The neutron flux at altitudes typical for intercontinental flights is about 10 neutrons $cm^{-2}\ s^{-1}$. There is more shielding against cosmic radiation at the Earth's surface and consequently the environmental neutron flux is smaller i.e. about 10^{-3} neutrons $cm^{-2}\ s^{-1}$.

The neutron reaction to carbon-14 cross sections of the precursors of carbon-14, their chemical content, the temperature and energy dependent neutron flux are needed as input determine the carbon-14 generation rate in air. For scoping, frequently the thermal cross sections are used. Nitrogen-14 has the largest thermal cross section. Carbon-13 and oxygen-17 have, respectively, an almost three and four orders in magnitude smaller cross section than nitrogen-14 . The natural abundances of nitrogen-14, carbon-13 and oxygen-17 are 99.64%, 1.07% and 0.038%, respectively. The air that we breathe is made up of 80% nitrogen. The natural abundance of nitrogen-14 and neutron cross section are the reasons why the main origin of carbon-14 is nitrogen i.e. other precursors and processes can be neglected.

Zircaloy

The cladding of fuel elements is normally made of Zircaloy. The thickness of these claddings is usually less than 1 mm. Fuel elements are replaced several times during the lifetime of a reactor. Spent fuel can be reprocessed: carbon-14 is released from irradiated metal-oxide fuel during the fuel dissolution process. The claddings are not dissolved during reprocessing and become waste. At COVRA, this waste is stored in the 'HABOG' facility.



Graphite waste

Some types of reactors use graphite moderators and reflectors, instead of water. This produces irradiated graphite, which may release carbon-14 under geological disposal conditions.

Ion-Exchange Resins

Carbon-14 is filtered from water with an ion exchanger. These exchangers are frequently replaced and become waste. In the Netherlands, spent-ion exchange resins are together with sludge mixed with cementituous mortar in a drum. Each drum is contained in a reinforced concrete vessel for permanent additional shielding.

19 February 2018	21 February 2018
With University College Roosevelt	With University College Roosevelt
Bus to COVRA's premises leaves at 12:45 from Lange Noordstraat 1 Middelburg 13:00 Coffee and tea	Bus to COVRA's premises leaves at 8:15 from Lange Noordstraat 1, Middelburg 8:45 Coffee and tea
13:15-14:00 Generation radionuclides in general, disposal radioactive waste, specific details carbon-14, natural analogue. COVRA - Dutch WMO - Erika Neeft	9:00-10:00 Spanish disposal facility El Cabril Radiochemical analysis of carbon-14 in spent ion exchange resins, irradiated graphite and sludge (TBC) or visit waste processing facility
14:00-15:00 Radiocarbon dating, monitoring activity around nuclear facilities and modelling carbon-14 in the environment Hungarian Akademy of Sciences - Molnár Mihály	10:00-11:15 Visit storage facility LOG Irradiated steel Processed spent ion exchange resins
15:15 Coffee and tea	11:15 Coffee and tea
15:15-16:30 3D-Movie, nebula room and exhibition centre Visit storage facility HABOG Irradiated Zircaloy	11:30-12:30 Nuclear power plant decommissioning and infer into suitable waste form ENRESA - Spanish WMO - Jose Luis Leganés Nieto
16:45 Back to Middelburg	12:30 Back to Middelburg

20 February 2018

Bus leaves at 9:00 from Lange Noordstraat 1, Middelburg

The knowledge and understanding of carbon-14 release needs to be integrated in a conceptual model to calculate the health related effect of disposal of waste in a safety assessment. For the second training course of CAST, a conceptual model for each type of waste investigated in CAST, is presented for a geological disposal setting. These models are intended to be implemented in COMSOL. COMSOL is used since this software tool is one of those preferred by the Nuclear Energy Agency (NEA) Safety Case Integration Group as published in the outcomes of the NEA MeSA - Methods for Safety Assessment of Geological Disposal Facilities for Radioactive Waste - initiative in 2012.

19:00 Dinner in Kloveniersdoelen, Middelburg

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CAST
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