NEWSLETTER 5

The nature and effects of the processes and events used to assess the safety of a geological 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 timescales. Confidence depends on the quality and presentation of the research executed. This newsletter is one of a series of newsletters which are intended to inform stakeholders with a general interest in the CAST project.

CAST (Carbon-14 Source Term) is a 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 CAST consortium brings together 33 organisations from 14 countries in the EU, Switzerland, Ukraine and Japan. The involvement of waste management organisations ensures that the project is aligned to European geological disposal programmes and that end results are of use in the safety assessments.

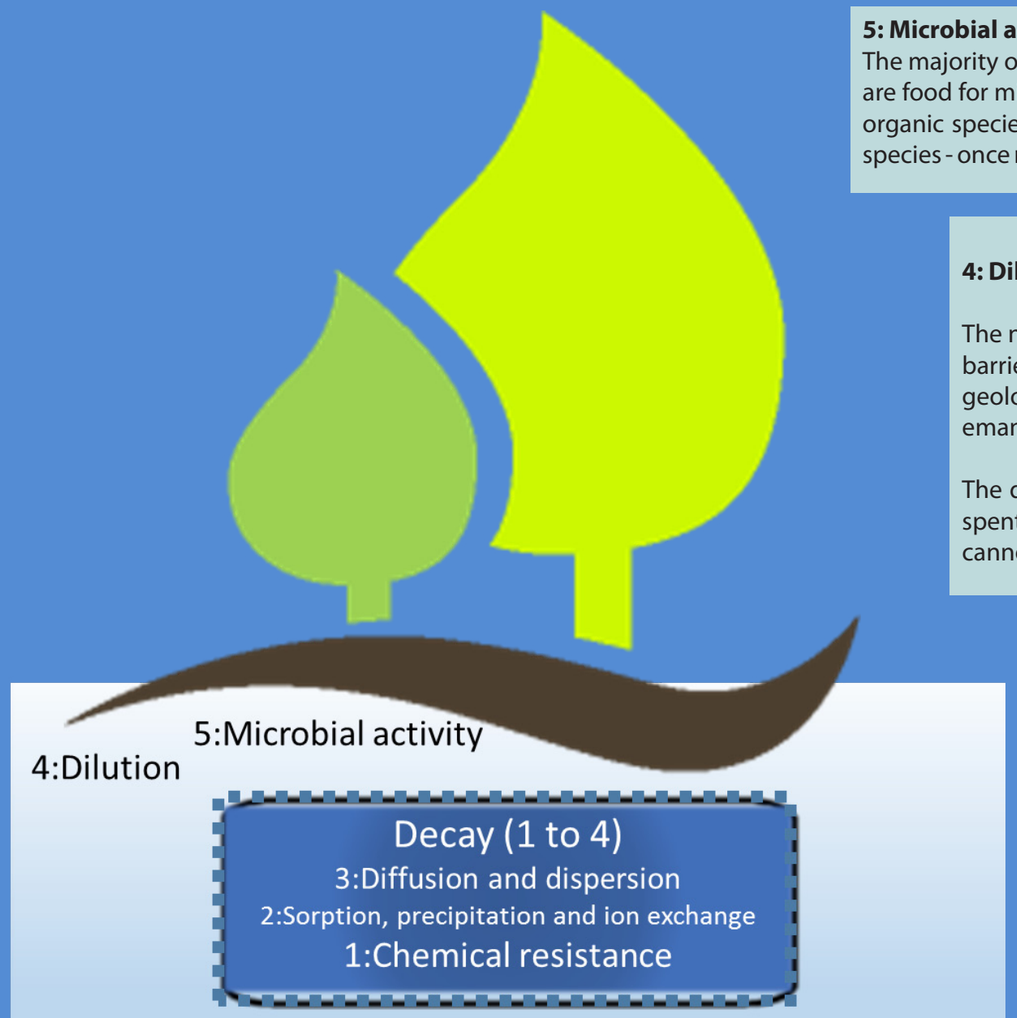
The progress of CAST is visualised in a digital growing tree and continuously updated on the website of CAST www.projectcast.eu

Carbon-14

The health related impact of disposal of waste is investigated in a safety assessment. The main exposure path for natural carbon-14 is ingestion. Carbon-14 is concentrated in food such as crops and animals that eat carbon-14 containing grass and algae.

The potential artificial $^{14}CO_2$ release rate into air can be compared with the natural emanation rate from soil in order to put the carbon-14 hazard potential from disposal of the waste in perspective with the natural carbon-14 exposure. A daily flux of CO_2 released by the soil is 2 to 13 gram per m^2. Cosmogenic generated carbon-14 is present as an impurity with a concentration of about 1 to 1.5 out of 10^{12} non-radioactive carbon atoms. The natural $^{14}CO_2$ flux from the soil into air is in the order of 10^9 atoms per cm^2 per year using a daily flux of 2 gram per m^2. The potential additional carbon-14 exposure from carbon-14 containing waste can be considered negligible if the calculated $^{14}CO_2$ from the disposal facility into our atmosphere is small compared to the natural carbon-14 flux. Why carbon-14 released from waste is expected to enter as $^{14}CO_2$ into air is described in this Newsletter.

Decay, dispersion, diffusion and dilution will cause a reduction in the radionuclide flux from the waste into our living environment. In this Newsletter, the extent of the reductions in the waste forms, engineered and natural barriers is described.



5: Microbial activity

The majority of released carbon species investigated in CAST was not measured to be $^{14}CO_2$ but organic carbon species. Organic carbon species are food for microbes. The University of Nottingham has investigated the extent of conversion of radioactive methane i.e. the fastest migrating organic species, into radioactive carbon dioxide. The measured conversion was almost 100%. It is therefore assumed that organic carbon-14 species - once released from the disposal system - will be converted into $^{14}CO_2$ by microbes before this artificial carbon-14 reaches our atmosphere.

4: Dilution

The natural barriers are the host rock that hosts the disposal facility and the rock formations surrounding the host rock. These natural barriers are in orders in magnitude larger in terms of volume than the disposal facility. Common values for dilution are 10^4 for deep geological disposal. The carbon-14 flux - with waste as an origin - into our living environment becomes a fraction of the carbon-14 emanation rate from soil when dilution is included. Decay can also reduce the carbon-14 flux when the travel time of species is included.

The designated end-point for the types of waste investigated in CAST is not for all countries deep geological disposal; conditioned spent ion exchange resins are disposed in near surface facilities in Sweden, Finland, Slovenia, Spain and France. A dilution value of 10^4 cannot be used in case of near surface disposal but there are other processes that reduces the articificial carbon-14 flux.

3: Diffusion and dispersion

The pore water in natural barriers such as clay and salt as host rocks and engineered barriers such as bentonite and concrete is stagnant. Diffusion can assumed to be the main migrating process for radionuclides within these barriers. The travel time of diffusing species can be increased orders in magnitude when retention mechanisms are allowed to be included. The carbon-14 flux is further reduced in these barriers by dispersion. The period in time to pass the host rock by diffusion may take several half-lives of carbon-14 i.e. the majority of carbon-14 is decayed within the host rock.

An example of the carbon-14 flux reduction in clay as a host rock is presented in the integration of CAST results to safety case and safety assessment, CAST report D 6.4.

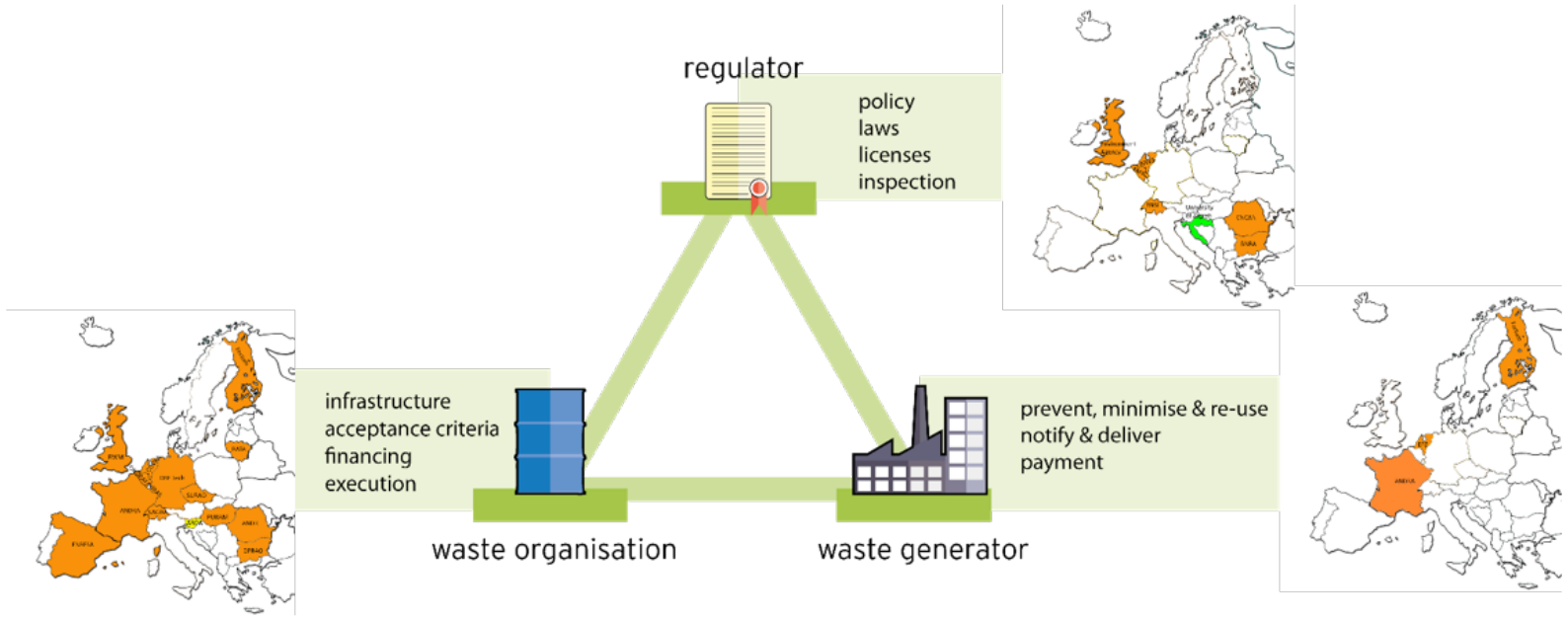
1: Chemical resistance

Carbon-14 is contained in a waste form at start of disposal. In CAST, the mass loss of waste forms when encapsulated in concrete has been investigated, because the irradiated metals and spent ion exchange resins are frequently processed with cementitious materials. The corrosion rate of neutron irradiated steel and neutron irradiated Zircaloy are limited due to the presence of a metal-oxide layer between concrete pore water and waste form that is thermodynamically stable in these alkaline conditions. The chemical resistance of Zircaloy is higher than steel due to the lower solubility product compared to iron-oxide. The chemical resistance of spent resins and neutron irradiated graphite is so high that chemical degradation rates has not been measured yet. Radiolytic corrosion rates of graphite are smaller than chemical corrosion rates of Zircaloy. Most of carbon-14 contained in these waste forms are therefore expected to decay within the waste form and is not released into barriers. The maximum in carbon-14 source term is at start of disposal: 10^{11} carbon-14 molecules per cm^2 per year from neutron irradiated steel i.e. two orders in magnitude larger than the carbon-14 emanation rate from soil.

Other quantifications of the source term can be found in 7.23 Final Overview of CAST. The corrosion rates of the neutron irradiated materials investigated in CAST can be found in the state art reports of the art reports D 2.1 for steel, D 3.1 for Zircaloy and D 5.5 for graphite. Corrosion rates verified in CAST for steel and Zircaloy are presented in the final reports D2.18 and D 3.20.

2: Sorption, precipitation and ion exchange

Some carbon-14 species can be retarded in engineered and natural barriers. Carbon-14 species can exist as neutral compounds and as anionic compounds i.e. these carbon-14 species are present as negatively charged compounds in these barriers. Only a part of the porosity is accessible for diffusion of anionic compounds and potential retention mechanisms are sorption, precipitation and ion exchange.
Cementitious materials are frequently used for processing and packaging of radioactive waste and sorption of inorganic carbon-14 species is a familiar process that reduces the carbon-14 flux from waste packages. Positively charged cementitious minerals can also contain organic carbon species for example acetate.
Cementitious pore water has a high calcium content and the solubility of some calcium-carbon compounds is very small i.e. these compounds are insoluble. Examples of carbon-14 species that are fixed in concrete by precipitation are carbonate and oxalate, an organic carbon species.
Ettringite is a cementitious mineral that exchanges its sulphate group with formate, also an organic carbon species.
Spent ion exchange resins can only contain anionic carbon-14 compounds. Disposal of waste packages with spent ion exchange resins processed with cementitious materials in near surface facilities is safe since anionic organic and inorganic carbon will be retarded by retention mechanisms in concrete if any carbon-14 contained by these resins would be released.



Two workshops have been held for participants with a responsibility in the management of waste. The institutional arrangement of these responsibilities can be viewed in a triangle in which regulators, waste management organisations and waste generators have clearly defined roles. The image above shows the participation of each group in the first workshop held in the Netherlands. The second workshop was held in France in conjunction with the CAST Final Symposium.

The CAST project is finished. The Proceedings of both workshops and all other CAST reports can be downloaded until 2023 from the public CAST website www.projectcast.eu.

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