Oplegger bij Besluitnota en brief Creates

Afhandeling van de opmerkingen op vorige versie

<u>Opmerking op nota</u>

Hoe laten we aan EPZ en Orano weten dat we zo gaan doen? Dus nu kader naar TK en consultatie, missionair kabinet kan dan besluit over dit specifiek verzoek nemen

> Gelijktijdig met het verzenden van de brief aan de Tweede Kamer, worden EPZ en Orano per mail geïnformeerd door de DGMI. EPZ en Orano weten al dat eerst een toetsingskader aan de TK wordt gestuurd en dat er publieke consultatie plaatsvindt, en dat pas daarna een besluit over de aanvraag zelf wordt genomen op basis van het toetsingskader.

<u>Opmerkingen op de brief</u>

Toevoegen: (5)(2)

> Aanpassing doorgevoerd

Betreft het afval dat dus - ILT het hoger radioactieve afval dat we eigenlijk zouden ontvangen, niet in toekomst naar eindberging hoeft?

> Al het afval dat bij COVRA staat gaat in principe naar de eindberging, dus ook dit afval, ook is de stralingsbelasting minder. Dit is conform het huidige beleid.

Toevoegen: (5)(2)

> Aanpassing doorgevoerd

(5)(2)

> Aanpassing doorgevoerd

(5)(2)

> Aanpassing doorgevoerd

RESTRICTED AREVA

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TECHNICAL NOTE

CREATES
Integrated Toxic Potential
Description and calculation method

Rev.	Written by	Checked by	Approved by
A	(5)(1)(2e) / (5)(1)(2e) / (5)(1)(2e)	(5)(1)(2e) / (5)(1)(2e)	(5)(1)(2e) ATTESTATION DE SIGNATURE ELECTRONIQUE NOM : (5)(1)(2e) Le : 12/12/2016

REVISION RECORD SHEET

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CONTENTS

1 PURPOSE AND CONTEXT

In the framework of the management of residues from La Hague to Foreign clients AREVA is developing a Project for the Optimization of the conditioning of residues. In this framework an Equivalence Factor between different kinds of conditioned waste must be established and especially between Compacted Waste Standard Residue (CSD-C) and Vitrified Waste Standard Residue (CSD-V).

An equivalence criteria between CSD-C and CSD-V must, then be defined (1 CSD-V = x CSD-C) and a calculation tool must be developed in order to calculate this equivalence criteria.

Among existing methods developed to define a measure of equivalence for use in comparing radioactive wastes, AREVA NC held the "Integrated Toxic Potential" (ITP) approach.

The ITP method was first proposed by British Nuclear Fuels Limited (BNFL) in the 90s in order to optimize the return of residues towards overseas customers. NAC was, then, contracted by the Nuclear Decommissioning Authority (NDA) [1], responsible for ensuring that the implementation of substitution using ITP is executed correctly, to conduct an independent review of the waste substitution implementation proposals, including audits as appropriate on data and calculation processes.

The ITP method is described in a publication of the European Union emitted by the British National Radiological Protection Board [2]. Those principles are also exposed in several others publications [3], [4], [5] and [6].

The equivalence method is based on the calculation of the "Integrated Toxic Potential" representative of the waste package radiotoxicity.

This document aims to describe the ITP method and analyze the different ways to implement it in the calculation tool under development.

2 INTEGRATED TOXIC POTENTIAL AND BIBLIOGRAPHICAL ANALYSIS

2.1 BIBLIOGRAPHICAL ANALYSIS

The ITP method is described in several publications. The available publications have been reviewed in order to wright the correct mathematical expressions that describe the ITP.

The 1996 European Union publication emitted by the British National Radiological Protection Board [2] describes different methods such as ITP used to compare radioactive wastes.

ITP calculations were carried out with three types of wastes (High Level Wastes (HLW), Intermediate Level Wastes (ILW) and Low Level Wastes (LLW)) and for different integration periods. If the method seems to be globally relevant with the definition and the mathematical expression described in § 2.2, some of the calculated values in tables 5 and 6 of ref. [2] cannot be traced. Moreover, in appendix D dedicated to the ITP method:

- Numerical Toxic Potential (TP) values in table D1 cannot be traced ;
- ^{107}Pd and ^{147}Sm are considered with a null toxic potential value while possessing effective dose coefficients ;
- The calculation method for decay chains seems inadequate and does not consider all configurations.

The documents [4], [5] and [6], written by the same authors between 2001 and 2002, focus more on a comparison of waste package type from different waste streams or the influence of different factors than a calculation of equivalence between waste packages. Nevertheless, in each documents, the equations defining TP and ITP are well detailed and consistent with § 2.2.

It should be noted nevertheless that, in the documents [4] and [6], the unit of ALI_{ing} is inaccurate, given in $mSv.year^{-1}$ instead of $Bq.year^{-1}$.

The document [1], released in 2006 by NAC International upon request of NDA, reviews the BNG's TOXIC and WRiST softwares implementing ITP method. The audit validates the method and the tools after BNG responds fully to NAC's recommendations for corrective actions concerning constants databases, formal verification and validation documentation.

Appendixes A and E of this report detail the TP and ITP equations implemented in TOXIC. Bateman formulation is used to calculate the radionuclides activities as a function of time.

The TP values given in the table of the appendix D of ref. [1] for some radionuclides are consistent with § 2.2.

2.2 INTEGRATED TOXIC POTENTIAL

The equivalence principle is based on the calculation of a theoretical quantity named "Integrated Toxic Potential" (ITP). This quantity aims to assess the radiotoxicity of waste packages.

According to this method, at a time t, the radiotoxicity can be quantified by its "Toxic Potential" (TP) which is defined as "the volume of water into which 1 m^3 of waste must be diluted so that the annual ingestion of this water leads to an absorbed dose of 1 mSv".

Therefore, TP can be understood as an activity weighted by a coefficient depending of annual intake of the nuclide.

For a given nuclide, specific toxic potential, Φ_i, is calculated as:

$$\Phi_i(\mathrm{t}) = \frac{AWI\ .\ A_i(t)}{ALI_{ing}} = \frac{AWI\ .\ ECD_i\ .\ A_i(t)}{AAEDL} \quad (1)$$

With:

- $\Phi_i(t)$: specific toxic potential of a given nuclide i (m^3) ;
- *AWI* : average annual drinking water intake of ICRP reference man (0,712 $m^3.yr^{-1}$) ;
- ALI_{ing} : annual limit of intake by ingestion ($Bq.yr^{-1}$) ;
- $A_i(t)$: activity of given nuclide i as function of time (Bq) ;
- ECD_i : effective dose coefficient of given nuclide i ($Sv.Bq^{-1}$) ;
- *AAEDL* : annual average effective dose limit for members of the public (1 $mSv.yr^{-1}$).

The Average Annual Water Intake *(AWI)*, the Effective Dose Coefficients (ECD_i) and annual average effective dose limit *(AAEDL)* are defined by the International Commission on Radiological Protection [7]

The total Toxic Potential (m^3) of a waste package is defined as:

$$\Phi(\mathrm{t}) = \sum_i \Phi\mathrm{i}(\mathrm{t}) \quad (2)$$

The calculation of an instantaneous toxic potential is useful as it provides a measure of relative toxicities. However, it is a difficult measure by which to compare different back-end fuel cycle options because plots of toxic potential can vary, and in some cases cross, as the respective inventories evolve.

This variability of measure is mitigated by the integration of the toxic potential over a chosen time period. The Integrated Toxic Potential (ITP ($m^3.yr$)) is then given by:

$$ITP = \int_{t_1}^{t_2} \Phi(\mathrm{t})\, dt \quad (3)$$

Where t_1 and t_2 are the lower and upper time limits for which toxic consequences are considered. This period of time $[t_1; t_2]$ is called “integration period”.

3 CALCULATION METHODS AND SOFTWARE PRINCIPLE

In order to perform calculations of the ITP of a given waste container, the activity of each radionuclide $A_i(t)$ contained into the waste must be calculated.

The weighted activity must be then integrated over the chosen integration period $[t_1; t_2]$ to obtain the ITP described by equation (3).

Two different calculation methods have been evaluated and compared.

A description of the two methods, advantages and drawbacks of each in terms of ease of implementation, calculation time, calculation precision and accuracy are given in the following sections.

The evaluated ITP calculation methods are:

- a method called « numerical method »,
- a method called « analytical method ».

These two methods principles are presented in the following paragraphs 3.1 and 3.2.

A critical analysis and the orientation of the calculation tool to be developed are presented in the paragraph 3.3.

3.1 NUMERICAL METHOD

The numerical method of the waste package ITP calculation is based on a numerical integration of the activities of radionuclides contained into the waste package over a given integration period.

The evolution of the activity of each radionuclide is calculated by means of the AREVA's software code "CESAR 5.3" [8].

In order to avoid repeating time-consuming CESAR calculations for each waste package, some simplifications can be made on the basis of the definition and properties of the Integrated Toxic Potential and the properties of Integrals. This largely reduces the complexity of the problem and the computational effort needed.

From equations given in paragraph 2.2, the following observations can be made:

- the ITP of a given radionuclide is proportional to its initial activity (assuming it is not descended from another radionuclide but taking into account its descendants);
- the ITP of a given spectrum is equal to the sum of the ITP of each of its components;
- the ITP calculated over an integration period $[t_1; t_2]$ is equal to the ITP from 0 to t_2 minus the ITP from 0 to t_1.

These observations will be used to simplify the calculation tool.

The activity of each radionuclide initially present into the waste package is calculated once for a unitary initial activity (ex.1 TBq). The nuclides are aged to different given times (the choice of these times are discussed further away).

The calculation of the integrated activity between 0 and t is, then, performed for each nuclide (parents and daughter products). These integrated activities are then converted into ITP and added for each nuclide allowing the calculation of the ITP from 0 to t for each initial nuclides and considering an unitary initial activity (1 TBq).

The ITP calculation of the waste package, over *[t_1; t_2]*, is then performed by computing the ITP of each radionuclide in the waste package spectrum from t_1 to t_2 and by adding them according to their initial activities.

Integration method

The numerical integration of the activity is performed by means of the trapezoidal rule and a variable step. As the integration period for the ITP calculation varies from 0 up to 1 000 000 years, the aging times must be chosen wisely to represent as precisely as possible the variations of the activity (fast variation on first years becoming slower over years).

ITP calculation from 0 to any time t

The previous described method may only give a result for times for which the aging has been computed. If the given time is not part of the already calculated aging time, a linear interpolation of the ITP will be computed between the inferior and superior closest known time.

With this method, the calculation tool will contain the ITP, from 0 to t, for each radionuclide initially present in the waste package spectrum for each chosen time t. Then, the calculation tool will be able to compute the ITP of the whole spectrum over *[t_1; t_2]* using tabulated values.

3.2 ANALYTICAL METHOD

In the analytical method the evolution of the activity is calculated analytically. The CESAR code is no more used.

The analytical method of the waste package ITP calculation is based on the Bateman equation [9]. This equation provides, at a given time t, the activities of a couple of "parent and daughter" nuclides.

This equation has been generalized for decay chains with n isotopes [10].

The activity $A_n(t)$ of the n^{th} radionuclides of a decay chain, considering an initial activity A_0 for the radionuclide parent of the chain, is calculated by the following equation:

$$A_n(t) = A_0 \prod_{i=1}^{n} \lambda_i \sum_{i=0}^{n} \frac{e^{-\lambda_i t}}{\prod\limits_{\substack{j=0 \\ j \neq i}}^{n} (\lambda_j - \lambda_i)} \qquad (4)$$

where λ_i is the exponential decay constant of the i^{th} radionuclide of the decay chain.

From equations given in paragraph 2.2, the ITP of the radionuclide i is calculated by the expression:

$$ITP_i = \frac{AWI\ .\ ECD_i}{AAEDL} \int_{t_1}^{t_2} A_i(t)dt$$

By integrating (4), it becomes:

$$ITP_i = \frac{AWI\ .\ ECD_i}{AAEDL} A_{0,i} \prod_{j=1}^{i} \lambda_j \sum_{j=0}^{i} \frac{(e^{-\lambda_j t_1} - e^{-\lambda_j t_2})}{\lambda_j \prod_{\substack{k=0 \\ k \neq j}}^{i} (\lambda_k - \lambda_j)} \quad (5)$$

where $A_{0,i}$ is the initial activity of the radionuclide parent of the decay chain leading to the i^{th} radionuclide.

The waste package's ITP is then calculated by adding ITP of each radionuclide in the package.

The main goals of the developed calculation tool are therefore to:

- list all the radionuclides from the decay chains of the radionuclides parents declared in the waste package;
- calculate with (5) the contribution to the ITP of each radionuclide listed at the previous step;
- add all of the contributions to obtain the final ITP of the waste package.

3.3 CRITICAL ANALYSIS OF THE METHOD AND CALCULATION TOOL ORIENTATION

The two methods previously described show both advantages and drawbacks (sorted by order of importance):

- concerning the numerical method:
  - advantages:
    - as the evolution activity database is computed once for all the radionuclides (and a unitary activity), the only computation to be done by the calculation tool is to find the right step and perform an addition of products (unitary Toxic Potential x Activity), this operation will be very fast,
    - the aging is performed by CESAR 5.3 that considers every filiation including fission products from spontaneous fissions (even if it will certainly be negligible);
  - drawbacks:
    - the creation of the radionuclides decay database is time consuming and the generated database could be quite large;
    - the exponential decay constants are very different from a radionuclide to another. As a consequence, some radionuclides disappear after a few days (some fission products) whereas others have activities constant up to a billion years. The activity calculation must be chosen as wisely as possible to guarantee a good ITP computation.

- concerning the analytical method:
  - advantages:
    - as the only input data are the decay data (the filiation, the exponential decay constant and the branching ratiothe final calculation tool will be light and easy to update,
    - no previous calculations are needed to create the calculation tool with this method,
    - the integration over the chosen integration period is performed analytically so the ITP is accurately calculated;
  - drawbacks:
    - the Bateman equation does not take into account spontaneous fissions of actinides. Activities of fission products could therefore be miscalculated. However, the induced error is insignificant and has no impact on the ITP calculation.

In conclusion, the advantages of the numerical method are:

- to be very fast to compute but the analytical method shouldn't take more than a second,
- to use CESAR 5.3 as aging tool that is already qualified but the analytical method will be qualified using the CESAR code.

The advantages of the analytical method are:

- the tool can be updated very easily as the tool only needs physical data as entry data.

The disadvantage of the numerical method may be difficult to overcome without generating a huge database. Thus, the generation of the database will be time consuming and the tool might be slower.

The disadvantage of the analytical method has no real impact on the calculation as the induced error is insignificant.

According to these observations, the analytical method is chosen and will be implemented in the AREVA ITP calculation tool.

4 CONCLUSION

In the context of the CREATES project, this document details the Integrated Toxic Potential method allowing to establish an equivalence between different types of waste packages.

After a description of the equations describing the Integrated Toxic Potential, two methods for calculating the ITP for a given type of waste package from the initial activity of radionuclides contained into the waste package have been evaluated and their advantages and drawbacks compared: a numerical method and an analytical method.

Considering advantages and disadvantages of these two methods, the analytical method is selected to compute ITP.

The next steps of the Project are:

1. The implementation of the calculations tool on the basis of the equations described in § 3.2. The calculation tool is still under development.
2. The calculation of the ITP for a given set of waste packages (CSD-C and CSD-V). As described in § 3.1 and § 3.2 the Integration period can be adjusted. The proposed Integration Period is from 500 to 1 000 000 years.

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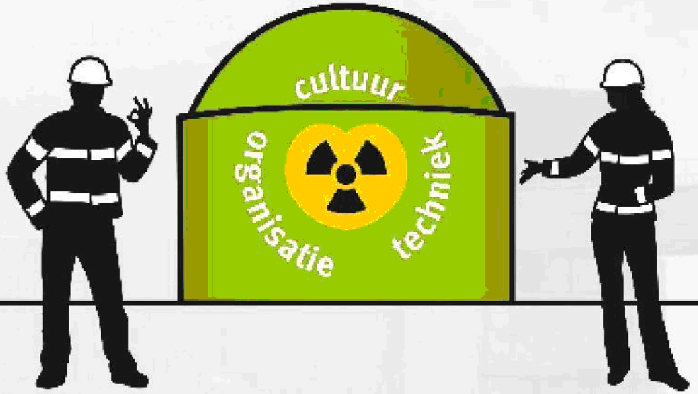
Jerzy Cetnar

Creates

Informatie uitwisseling
Infrastructuur en Waterstaat,
18 december 2020

Wat is nucleaire veiligheid?



Nucleaire veiligheid is het beschermen van mens en milieu tegen schadelijke effecten van radioactieve lozing en straling.

Bij EPZ doen wij dat door het voortdurend verbeteren van techniek, organisatie en cultuur.

EPZ voortdurend verbeteren

Informatie

- Wat doen we?
- Wat stelt Orano voor?
- Waarom willen we dit?

Opwerken van splijtstof

- EPZ laat sinds 1976 alle gebruikte splijtstof opwerken
- Opwerkingsfabriek in La Hague, Normandie
- Contract tussen EPZ en Orano (voorheen Areva, voorheen Cogema) tot einde bedrijfsvoering in 2034

Motief

- 95% herbruikbaar: 94% Uranium en 1% Plutonium
- Recycling van alle uranium en plutonium afkomstig uit Borssele
- Infrastructuur en regelgeving in NL uitsluitend opgezet voor opwerken

Voorwaarde

- Alle radioactieve residuen worden teruggebracht naar NL
- Franse regelgeving vereist goedkeuring door NL

Splijtstof

Activiteit

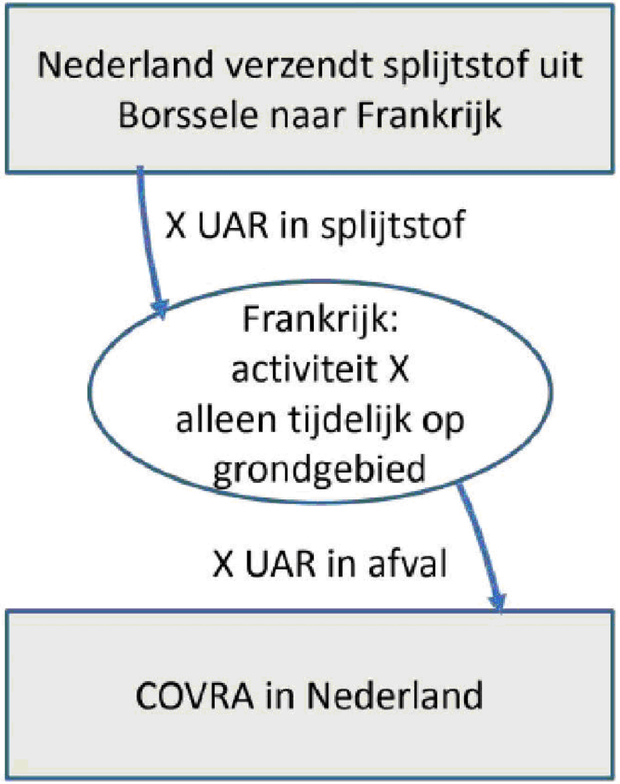
- Borssele element bevat 321 kg verrijkt UO2 of MOX
- 16 Kg hiervan (5%) wordt in de reactor omgezet in splijtingsproducten (is afval)

Transporten

- 9 Ton splijtstof per jaar naar Frankrijk voor opwerking
- De fracties Uranium en Plutonium worden hergebruikt en gelden niet als afval
- De radioactieve fractie die niet meer nuttig gebruikt wordt (5% afval) mag wettelijk niet in Frankrijk blijven

Franse regelgeving

- Equivalent van alle <u>activiteit</u> die Frankrijk binnenkomt moet terug naar land van herkomst
- Rekeneenheid is de UAR: "Unité d'Activité de Résidu"
- ORANO levert daarom verpakkingen met evenveel UAR aan EPZ terug



Twee soorten verpakking

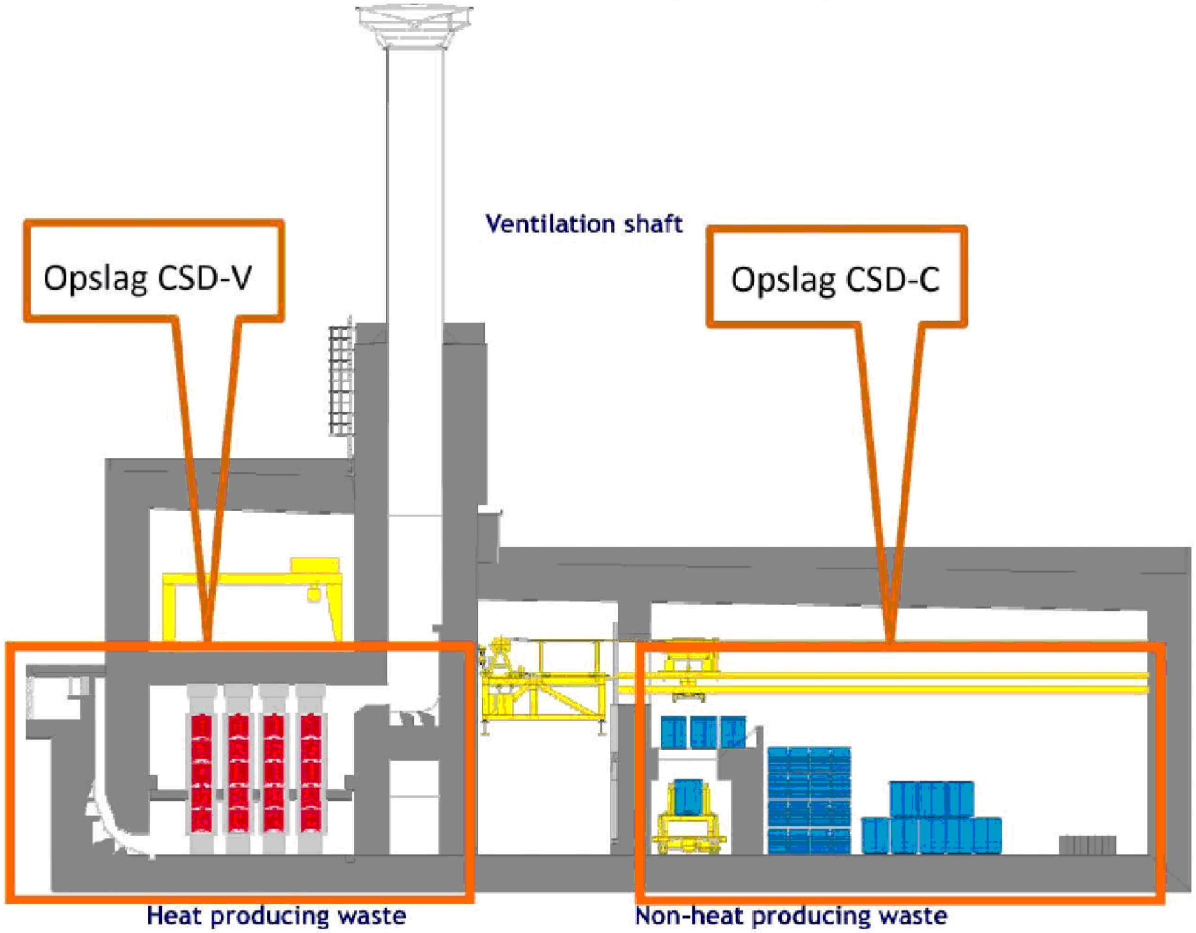
Conteneur Standard de Dechets Vitrifiees (CSD-V)

Glasblok met 80% glas en 20% splijtingsafval (hoog radioactief afval)

Conteneur Standard de Dechets Compactes (CSD-C)

Gecompacteerde metaaldelen (minder activiteit per verpakking)

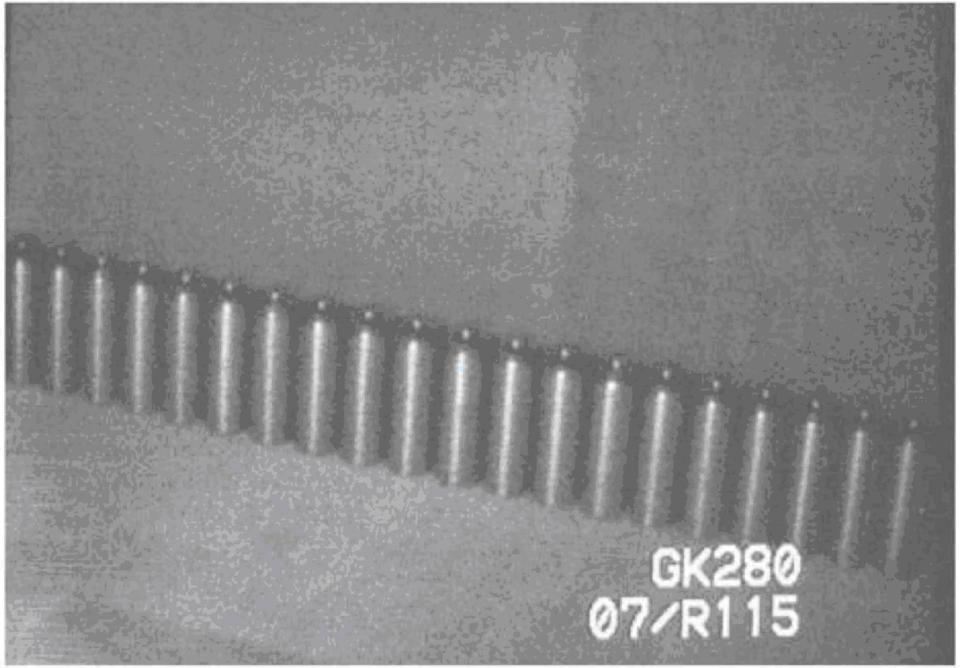
Habog opslaggebouw



Huidige Habog situatie

CSD-V
- 224 CSD-V van EPZ (+28 CSD-V van GKN) opgeslagen
- Capaciteit CSD-V wordt uitgebreid

CSD-C
- 322 CSD-C van EPZ opgeslagen
- Overcapaciteit voor CSD-C in HABOG



CSD-C worden op vloer van bunker vrij neergezet

Uitruil van residuen

pakketten afval zijn uitwisselbaar

- Afval pakketten zijn vermengde resten van alle splijtstof-elementen (fysieke oorsprong gaat verloren)
- UAR balans van binnenkomende en uitgevoerde activiteit moet eindigen met 0
- Voor balanceren kunnen alle soorten afval met activiteit gebruikt worden, de ene soort kan worden uitgeruild tegen een andere

Ervaringen met uitruil

- EPZ heeft in 1998 alle vaten beton met metaalafval geruild voor CSD-C
- GKN heeft in 2010 vaten beton met metaalafval geruild voor CSD-V

Voorstel uitruil

- ORANO is bereid EPZ en COVRA een financiële compensatie te geven voor het uitruilen van 20 CSD-V voor 1764 CSD-C
- Dit betekent dat EPZ een hoeveelheid "activiteit" toegewezen krijgt verpakt in de vorm van 1764 CSD-C equivalent aan de activiteit van 20 CSD-V verpakkingen die niet naar Nederland komen
- Qua radio-toxiciteit is de uitruil neutraal
- Volume niet-warmte producerend afval EPZ wordt groter
- Uitruil is nadrukkelijk toegelaten in Franse regelgeving mits het ontvangende land er mee instemt.

Voorgestelde verandering

Zonder uitruil, eindsituatie HABOG na 2034
- 550 CSD-V, 600 CSD-C nu

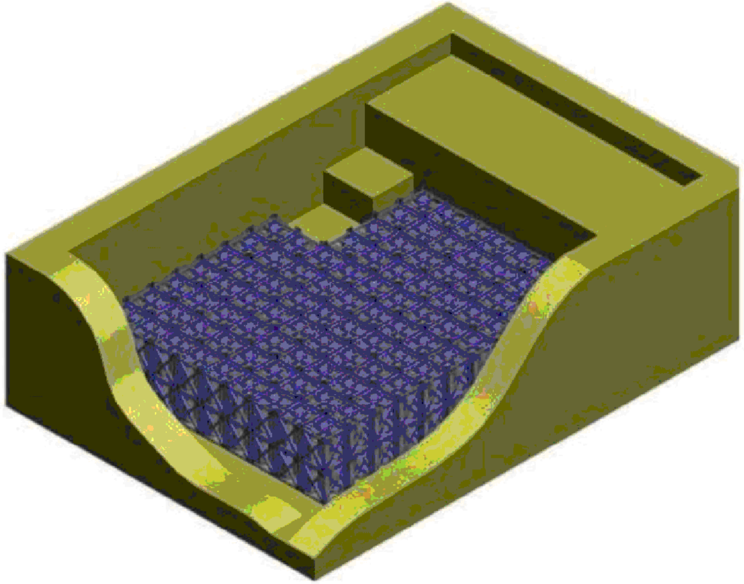
Met uitruil, eindsituatie HABOG na 2034
- 530 CSD-V, 2364 CSD-C

Radio toxiciteit ongewijzigd

- Aanpassing van logistiek nodig (per transport, 5 containers tegelijk, in plaats van 1 container zoals nu)
- Doorlooptijd van het project circa 10 jaar

Technische aanpassing

huidige praktijk van 1 laag CSD-C in HABOG bunker



mogelijke stapeling van CSD-C in meerdere lagen

Waarom?

Substantieel financieel voordeel voor

- Het NL afvalbeleid (b.v. eindberging wordt nauwelijks duurder of groter), (5)(1)(1c) wel extra middelen (5)(1)(1c) (5)(1)(1c)
- COVRA, een extra marge van circa 10 maal de jaarwinst
- EPZ, de mogelijkheid om het amoveringsfonds 4 jaar eerder volgestort te hebben (5)(1)(1c)

Minder warmte producerend afval naar Nederland

Vragen?

Aanvullende informatie na overleg 18.12 2020

Covra

Van: Jan Boelen < (5)(1)(2e) @covra.nl>
Verzonden: dinsdag 12 januari 2021 16:10
Aan: (5)(1)(2e) <(5)(1)(2e)@epz.nl>
CC: (5)(1)(2e) < (5)(1)(2e) @epz.nl>; Wolters C.F.C.M.M. < (5)(1)(2e) @epz.nl>
Onderwerp: RE: N.a.v. het overleg IenW-EPZ van 18 december

Beste (5)(1)(2e) ,
COVRA voorziet geen onoverkomelijke bezwaren voor de voorgestelde uitruil van CSD-V containers tegen CSD-C containers.

Het HABOG is uitgelegd voor de ontvangst, behandeling en opslag van zowel CSD-V als CSD-C containers. Wel zullen er enige aanpassingen doorgevoerd moeten worden door de veranderende aantallen.
Een recente scoping studie heeft aangetoond dat de opslag van voorziene aantallen CSD-C containers door middel van een stapelsysteem in rekken en/ of door uitbreiding van het HABOG gerealiseerd kan worden. Stapeling in rekken is al tijdens de bouw van het HABOG in 2003 door ORANO onderzocht en een soortgelijk systeem is in gebruik bij onze collega organisatie in België.

De uitruil van afval is in de nucleaire sector niet ongebruikelijk. Australië heeft bijvoorbeeld haar opgewerkte hoogradioactieve spijtstof in de UK uitgeruild tegen ILW (Intermediate-level waste), zodanig dat Australië geen HLW (High-level waste) meer bezit. Dit geeft enorme voordelen in de beheersing van dit afval.
Ook EPZ en GKN hebben in het verleden materiaal uitgeruild met Frankrijk en de UK om tot een meer beheersbaar portfolio aan afvalstoffen te komen.
De verwachting is dat het aantal transporten niet zal toenemen, alleen zullen de transporten uit meerdere containers bestaan, die na enige aanpassing van het spooremplacement op het COVRA terrein zelf, zonder problemen afgehandeld kunnen worden.
Door de aard van de uitruil zal de uitgeruilde hoeveelheid "radio-toxiciteit" gelijk zijn, conform de Intergouvernementele Overeenkomst en bestaande wet- en regelgeving in Nederland en Frankrijk.

Naast de dienstverlening aan EPZ, biedt de uitruil ook voordelen voor COVRA zelf.

- Het biedt extra werkgelegenheid, voor operators, technici en stafdiensten, voor een periode van meer dan 10 jaar. De uitruil vraagt een uitbreiding van de bezetting van het HABOG omdat er in meerdere ploegen gewerkt zal gaan worden.
- COVRA verwacht voor haar dienstverlening een extra bijdrage aan haar lange termijn opslag en eindbergingsfondsen te kunnen realiseren (5)(1)(1c) (5)(1)(1c)
- Door de uitruil wordt de voorziene hoeveelheid HLW verminderd ten faveure van het minder stralende ILW. De eindberging zal door de toename van het aantal CSD-C's in omvang wat groter worden, echter dit wordt gecompenseerd door lagere stralingsbelasting van de CSD-C's en de daaruit voortvloeiende eenvoudigere en mogelijk kleinere eindverpakkingen.

Met vriendelijke groet,
Jan

Ir. Jan Boelen
Directeur - Managing Director

Orano: IGA

Allimann Nicolas

À: (5)(1)(2e) (ORANO) ((5)(1)(2e) @orano.group)
Objet: CREATES

-----Message d'origine-----
De : (5)(1)(2e) - DGEC/DE/SD4/4C < (5)(1)(2e) @developpement-durable.gouv.fr>
Envoyé : mercredi 6 janvier 2021 19:18
À : (5)(1)(2e) (ORN-CORP) < (5)(1)(2e) @areva.com> Cc : (5)(1)(2e) - DGEC/DE/SD4 < (5)(1)(2e) @developpement-durable.gouv.fr>; (5)(1)(2e) - DGEC/DE/SD4/4C < (5)(1)(2e) @developpement-durable.gouv.fr>
Objet : CREATES

Bonjour (5)(1)(2e)

Je te confirme que nous estimons que le projet CREATES pourrait être réalisé sans modifier l'AIG entre France et Pays-Bas. En revanche, comme le prévoit la réglementation française et conformément aux directives européennes, il serait nécessaire de disposer de l'accord des Pays-Bas à la reprise des déchets résultant de l'opération d'attribution proposée.

Il est à noter que nous l'avons signalé aux Pays-Bas durant l'année 2020. C'est également dans ce contexte que nous leur avions fait part de questions et d'observations après réception de leur analyse du besoin de modification de l'AIG.

Cordialement,

--

(5)(1)(2e)

orano

To the attention to:
N.V. EPZ
(5)(1)(2e)
P.O. Box 130
4380 AC VLISSINGEN

Orano Recyclage

Ref. : DC 21-418

Object: Creates and applicable IGA's

Chatillon, the 12th of January 2021

Dear (5)(1)(2e)

Following our call on January 4, 2021 we confirm that to execute CREATES no new IGA between The Netherlands and France is needed. As we conceived it CREATES is fully complying with the provisions of the applicable IGA's between our countries.

The CREATES project consists in a modification of the initial Dutch waste allocation. Such operation is backed by the French regulatory framework (Décret no 2017-1309 du 29 août 2017 portant modification du décret no 2008-209 du 3 mars 2008 relatif aux procédures applicables au traitement des combustibles usés et des déchets radioactifs provenant de l'étranger). Based on the commonly accepted equivalence system (ITP), the activity and radiotoxicity of the waste to be returned to The Netherlands is the same as for the initial allocation (pursuant to the above-mentioned modification).

The European law stipulates that Member States shall bear the final responsibility for the waste resulting from reprocessing. CREATES fully respects this principle. The amount of waste is evaluated based on art.2 of Council Directive 2011/70 EURATOM of July 2011, which offers the possibility of returning "an agreed equivalent". Accordingly, the Kingdom of the Netherlands would only accept and take responsibility of "conditioned residues" returned to it in the framework of the current IGA (art 4).

This point of view is shared with our competent authority DGEC as you may see in the attached e-mail.

Sincerely yours,

(5)(1)(2e)

EPZ

Equivalentie modellen

Référence : DM2D NT 2020 0025		Orano Direction Maîtrise d'Ouvrage Démantèlement et Déchets	orano
Révision : 1	PAGE 1/16		
Numéro de projet :			

SUMMARY OF THE METHOD FOR COMPARING AND COMPUTING THE EQUIVALENCE OF WASTE PACKAGES

FOR REVIEW BY THE CONCERNED CUSTOMER OF THE CREATES PROJECT

	Nom	Dpt.	Visa
Approbateur	(5)(1)(2e)	DM2D	(5)(1)(2e) (5)(1)(2e)
Vérificateurs :	(5)(1)(2e)	OP	(5)(1)(2e)
	(5)(1)(2e)	DCSC	(5)(1)(2e)
Rédacteur	(5)(1)(2e)	DCSC	(5)(1)(2e) Signature numérique de (5)(1)(2e) DN : o=AREVA GROUP, (5)(1)(2e) Date : 2020.04.10 15:59:17 +02'00'

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Limitée	Diffusion limitée à
Normale	Diffusion aux destinataires et au sein d'Orano Cycle sans autorisation préalable de l'émetteur

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Siège social : 125, Avenue de Paris - 92320 Châtillon
Tél. : +33 (0)1 34 96 30 00 Fax : +33 (0)1 34 96 00 01
Orano Cycle - Société anonyme au capital de 99 229 077 € - 305 207 169 RCS Nanterre

Référence : DM2D NT 2020 0025		Orano Direction Maîtrise d'Ouvrage Démantèlement et Déchets TECHNICAL NOTE	orano
Révision : 0	PAGE 1/14		
Numéro de projet :		Date : 13/03/2020	

PRELIMINARY CALCULATIONS INTEGRATED TOXIC POTENTIAL CSD-V AND CSD-C

	Nom	Dpt.	Visa
Approbateur	(5)(1)(2e)	DM2D	(5)(1)(2e) (5)(1)(2e)
Vérificateurs :	(5)(1)(2e)	OP	(5)(1)(2e)
	(5)(1)(2e)	DCSC	(5)(1)(2e) (5)(1)(2e)
Rédacteur	(5)(1)(2e)	DCSC	(5)(1)(2e) Signature numérique de (5)(1)(2e) DN : o=AREVA GROUP, (5)(1)(2e) Date : 2020.03.13 17:39:20 +01'00'

orano
Siège social : 125, Avenue de Paris - 92320 Châtillon
Tél. : +33 (0)1 34 96 30 00 Fax : +33 (0)1 34 96 00 01
Orano Cycle - Société anonyme au capital de 99 229 077 € - 305 207 169 RCS Nanterre

Financiële impact

- Orano heeft de mogelijkheid om binnen het bestaande opwerkingscontract de hoeveelheden CSDV en CSDC aan te passen.
- In ruil voor deze aanpassing ontvangt EPZ een vergoeding (i.v.m. vertrouwelijkheid en de onderhandelingspositie doet EPZ geen mededelingen over de hoogte van deze vergoeding).
- (5)(1)(1c)

Samengevat:

- Uitgeruilde hoeveelheid qua radio-toxiciteit gelijk
- Geen negatieve effecten op veiligheid en operatie
- Geen (onoverkomelijke) blokkades in regelgeving
- Uitruilen wordt vaker toegepast
- Volledige vergoeding van extra kosten
- Mogelijkheid ontmantelingsfonds van EPZ eerder te vullen
- Extra werkgelegenheid Covra en dienstverleners
- Geen nadelige gevolgen eindberging
- Substantiële verbetering financiële positie staatsdeelneming COVRA

Onderwerp: Creates
Verzoek tot wijziging van het afvalpakket van het opwerkingsafval van Borssele

Directie: OenM

Aanwezig: (5)(1)(2e)
(5)(1)(2e)

Bijlage: Memo Creates met uiteenzetting van de casus

Doel:

- *Ervan uitgaande dat een volgend kabinet beslist over de casus Creates, een besluit nemen over verkenningen voor verdere ontwikkeling van opwerkingsbeleid.*

Advies:
- *U wordt geadviseerd om kennis te nemen van bijgaand Memo.*
- *U wordt geadviseerd om akkoord te gaan met het in gang zetten van de verkenningen zoals hieronder beschreven, als voorbereiding op de doorontwikkeling van het opwerkingsbeleid.*
- *Een besluit over Creates zelf wordt overgelaten aan een volgend kabinet.*
- *Een nadere uitwerking van het beleid voor het opwerken van verbruikte splijtstoffen vindt uiteindelijk plaats binnen de opkomende update van het Nationale programma voor het beheer van radioactief afval en verbruikte splijtstoffen (NPRA). U wordt over deze update later dit jaar geïnformeerd.*

Korte inhoud:

We voorzien de volgende stappen in de voorbereiding op de doorontwikkeling van het beleid voor de opwerking van verbruikte splijtstoffen:
1. *Toetsen van de rekenmethode van Orano (waarmee de gelijkwaardigheid van de afvalpakketten wordt bepaald) door de ANVS.*
2. *Onderzoeken welke stappen nodig zijn om aanvullende voorwaarden voor financiële zekerheidsstelling voor de ontmantelingskosten van de KCB te kunnen stellen.*
3. *Verkennen van de randvoorwaarden voor een instemmingsprocedure voor Frankrijk.*
4. *Verkennen van een nadere uitwerking van het opwerkingsbeleid, bijvoorbeeld: de Staat wel/niet betrekken in het besluit om verbruikte splijtstoffen op te werken, voorwaarden stellen aan de samenstelling of wisseling van afvalpakketten, procedures om daarover afspraken te maken, etc.*
5. *Verkennen van de consequenties voor het Verdrag met Frankrijk bij het verder uitwerken van het opwerkingsbeleid.*
6. *Nadenken over een verdere uitwerking van de duale strategie, bijvoorbeeld: welke mogelijke samenwerkingen met het buitenland voorzien we, welke vinden we wenselijk, hoe kan het geheel worden georganiseerd.*

To: (5)(1)(2e) - DGMI[(5)(1)(2e)@minienw.nl]
Cc: (5)(1)(2e) - ANVS[(5)(1)(2e)@anvs.nl]; (5)(1)(2e) ANVS[(5)(1)(2e)@anvs.nl]; (5)(1)(2e) - ANVS[(5)(1)(2e)@anvs.nl]
From: (5)(1)(2e) - ANVS
Sent: Fri 9/24/2021 9:18:36 AM
Subject: RE: Met toevoeging maatschappelijke participatie aan nota en brief Creates; geen bezwaar ANVS
Received: Fri 9/24/2021 9:18:37 AM

Ha (5)(1)(2e),

Wij zijn heel blij met de toevoeging van de parallelle publieke consultatie in zowel nota als brief. Daarmee wordt gelaagde besluitvorming zonder publieksparticipatie voorkomen. Publiek kan zich nu reeds uitspreken over de wenselijkheid van de uitruil. Dat is voor ons ook van belang bij de toekomstige vergunningverleningprocedures.

Verder hebben we al heel vaak over de stukken gesproken. Op dit moment gaan we geen nieuwe toevoegingen/wijzigingen voorstellen. Dus geen bezwaar.

Suc6 met de verdere afwikkeling.

Met vriendelijke groet,

(5)(1)(2e)

(5)(1)(2e)@anvs.nl
(5)(1)(2e)

-----Oorspronkelijk bericht-----
Van: (5)(1)(2e) - DGMI <(5)(1)(2e)@minienw.nl>
Verzonden: vrijdag 24 september 2021 09:12
Aan: (5)(1)(2e) - ANVS <(5)(1)(2e)@anvs.nl>; (5)(1)(2e) - ANVS <(5)(1)(2e)@anvs.nl>
CC: (5)(1)(2e) - ANVS <(5)(1)(2e)@anvs.nl>; (5)(1)(2e) - ANVS <(5)(1)(2e)@anvs.nl>
Onderwerp: Met toevoeging maatschappelijke participatie

------< Content Manager Record Informatie >------

Recordnummer: IENW/BSK-2021/254903
Titel: Brief TK Toetsingskader opwerkingsafval 20sept21

------< Content Manager Record Informatie >------

Recordnummer: IENW/BSK-2021/254901
Titel: Nota Creates (verzoek EPZ betreffende opwerkingsafval) v20sept21

Afvalvolume in verschillende scenario's					Volume afval		Indicatie opslag ruimtebeslag interim storage		warmte-producerend	niet warmte producerend
1. Directe opslag	222	opslagcontainers	18	m3 per container	4.000	m3	12.000	m3	100%	0%
2. Opwerken volgens de 1993 techniek					733	m3	2.000	m3	14%	86%
Voor warmteproducerend afval gelijk aan hieronder	105	m3								
Bitumen	120	drums	0,24	m3						
Hulls en ends	400	drums	1,5	m3						
Volume per verpakking	0,19	m3 per CSDV	0,19	m3 per CSDC						
Bouw en contract HABOG	270	CSDV oud	320	CSDC oud						
Volgens haalbaarheidstudie afgerond	280	CSDV nieuw	280	CSDC nieuw						
	550	CSDV totaal	600	CSDC totaal						
3. Opwerken volgens huidige contract	550	CSDV	600	CSDC						
	105	m3	116	m3	220	m3	1.000	m3	47%	53%
Totaal canisters na Creates	530	CSDV	2.364	CSDC						
4. Opwerken na Creates	101	m3	455	m3	556	m3	1.000	m3	18%	82%
Benodigde capaciteit HABOG gelijk aan bestaand HABOG (door mogelijkheid van stapeling ruimtebeslag geen extra m3)										

To: (5)(1)(2e) - DGMI[(5)(1)(2e) @minienw.nl]; (5)(1)(2e) - DGMI[(5)(1)(2e) @minienw.nl]
Cc: (5)(1)(2e) (5)(1)(2e)@epz.nl]
From: (5)(1)(2e)
Sent: Tue 9/28/2021 11:11:34 AM
Subject: RE: check Volume splijtstof vs afval
Received: Tue 9/28/2021 11:11:41 AM

Beste (5)(1)(2e),

De 550 canisters uit scenario 3 zijn maximale benodigde capaciteit bij maximale productie (95% beschikbaarheid van de kerncentrale over 60 jaar) destijds ingeschat bij de bouw van het HABOG. Daarnaast is er ook nog extra ruimte voor overpacks die nu niet ingepland zijn. De huidige produktieverwachting van de kerncentrale blijkt (minder dan 90%) lager, waardoor ook het aantal geproduceerde CSCV's lager zal zijn dan het maximum van 550.

Zo komen in het bestaande HABOG maar 242 CSDV canisters van EPZ (van de oorspronkelijk 270 geplande). Verder heeft EPZ in de uitbreiding van het HABOG nog recht op 270 posities, die bij de huidige produktieverwachtingen ook niet allemaal nodig zullen zijn. Daarnaast heeft EPZ nog rechten op 16 overpack posities (zijn gebouwd t.b.v. mogelijk beschadigde canisters die omgepakt moeten worden). Deze zijn vooralsnog niet in gebruik bij EPZ. Tevens heeft EPZ ook nog recht op momenteel 51 ongebruikte posities voor canisters met splijtstofelementen.

Vriendelijke groet
(5)(1)(2e)

Van: (5)(1)(2e) - DGMI <(5)(1)(2e) @minienw.nl>
Verzonden: maandag 27 september 2021 15:50
Aan: (5)(1)(2e) <(5)(1)(2e)@epz.nl>; (5)(1)(2e) - DGMI <(5)(1)(2e) @minienw.nl>
CC: (5)(1)(2e) <(5)(1)(2e)@epz.nl>
Onderwerp: RE: check Volume splijtstof vs afval

Beste (5)(1)(2e),

Dank hiervoor!

Dus eigenlijk met het "sparen" van 1 vault CSDV en 1 vault CSDC worden de capaciteiten:
540 CSDV en 2912 CSDC.

Hoe krijg je dan 550 CSDV passend als Creates er niet zou zijn?

Met groet,

(5)(1)(2e)

Van: (5)(1)(2e) <(5)(1)(2e)@epz.nl>
Verzonden: maandag 27 september 2021 15:40
Aan: (5)(1)(2e) - DGMI <(5)(1)(2e) @minienw.nl>; (5)(1)(2e) - DGMI <(5)(1)(2e) @minienw.nl>
CC: (5)(1)(2e) <(5)(1)(2e)@epz.nl>
Onderwerp: RE: check Volume splijtstof vs afval

Beste (5)(1)(2e),

Klopt idd, waarbij wel een van de drie als reserve dient te blijven worden aangemerkt.

Vriendelijke groet
(5)(1)(2e)

Van: (5)(1)(2e) - DGMI <(5)(1)(2e) @minienw.nl>
Verzonden: maandag 27 september 2021 15:03

Aan: (5)(1)(2e) <(5)(1)(2e)@epz.nl>; (5)(1)(2e) - DGMI < (5)(1)(2e) @minienw.nl>
CC: (5)(1)(2e) <(5)(1)(2e)@epz.nl>
Onderwerp: RE: check Volume splijtstof vs afval
Urgentie: Hoog

Ha (5)(1)(2e),

Zie nog vraag hieronder voor de check.

BVD en groet,

(5)(1)(2e)

Van: (5)(1)(2e) <(5)(1)(2e)@epz.nl>
Verzonden: vrijdag 18 juni 2021 11:01
Aan: (5)(1)(2e) - DGMI < (5)(1)(2e) @minienw.nl>; (5)(1)(2e) - DGMI < (5)(1)(2e) @minienw.nl>
CC: (5)(1)(2e) <(5)(1)(2e)@epz.nl>
Onderwerp: Volume splijtstof vs afval

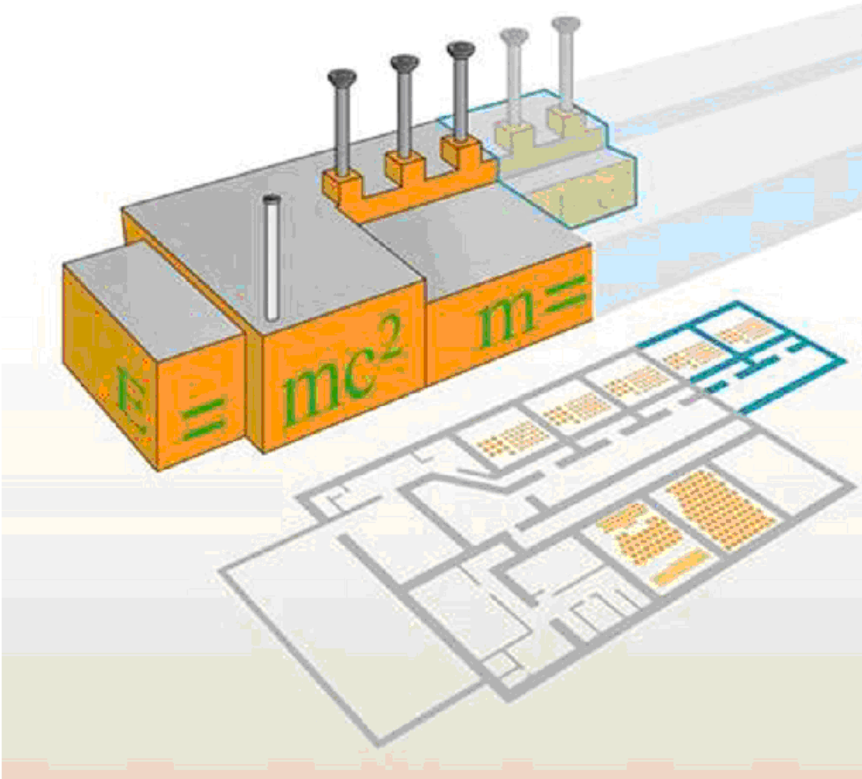
Beste (5)(1)(2e) en (5)(1)(2e)

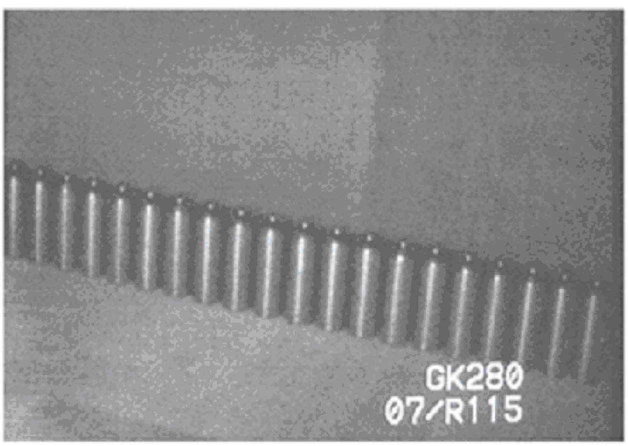
Hierbij naar aanleiding van ons gesprek gisteren de gevraagde toelichting op onderstaande tabel aangevuld met de andere gevraagde informatie.

- De vier geschetste scenario's zijn allen geëxtrapoleerd naar 1-op-1 vergelijkingen. Voor alle scenario's hebben we een indicatie gemaakt van alle back-end volumes die ontstaan bij een bedrijfsduur van 1973 tot en met 2033. In deze 60 jaar bedrijfsvoering zullen we ongeveer 2.000 brandstofelementen gebruiken.
  - In scenario 1 bij de keuze voor directe opslag zou dit hebben geleid tot 222 opslagcontainers van ieder 18m3 met gebruikte splijtstofelementen. Een totaalafvalvolume van ongeveer 4.000 m3 dat moet worden opgeslagen in een afvalopslaggebouw dat NL (door de keuze voor opwerking) niet kent en niet heeft met een capaciteit van ongeveer 3 keer het volume van de containers, dus 12.000m3.
  - In scenario 2 wordt het afval beperkt door opwerking. Hierbij was in 1993 de techniek zodanig dat naast de warmte producerende CSDV's niet warmteproducerende drums met bitumen afval en drums met hulls en ends zouden worden geproduceerd en aan NL worden geleverd.
  - In scenario 3 wordt de uiteindelijke keuze gepresenteerd, na de afspraken over het bouwen van het HABO in 2004. Alle afval uit Frankrijk over de gehele levensduur komt terug in CSDV en in plaats van bitumen en hulls en end drums in de vorm van CSDC met niet warmte producerend afval. Hiervoor is de huidige infrastructuur van HABOG ontwikkeld. In het plaatje hieronder zie je
    - de 5 vaults voor warmteproducerend afval, met ruimte voor EPZ voor 135 CSDV per vault (plus nog ruimte voor een aantal cannisters met overpack en splijtstof met overpack)
    - de 3 vaults voor niet warmteproducerend afval, met ruimte voor 600 CSDC per vault op de grond en bij opslag in rekken en stapeling ruimte voor 1456 CSDC. Dus totaal voor 3 vaults 4368 CSDC?
    - Het donker gekleurde deel is de (eerste) modulaire uitbouw die dit jaar is opgeleverd.
  - In de bedrijfsvoering van HABOG dient ten allen tijde in verband met mogelijke calamiteiten 1 vault CSDV en 1 vault voor CSDC leeg te blijven.
- Het HABOG bevat momenteel 224 CSDV en 302 CSDC van EPZ. In de loop van de tijd komen daar in scenario 4 nog 306 CSDV en 2084 CSDC bij
- Het afval van een eventuele bedrijfsduurverlenging past niet in de bestaande vaults en vergt een modulaire uitbreiding zoals ook dit jaar gerealiseerd is. Het scenario 4 heeft daar geen impact op.

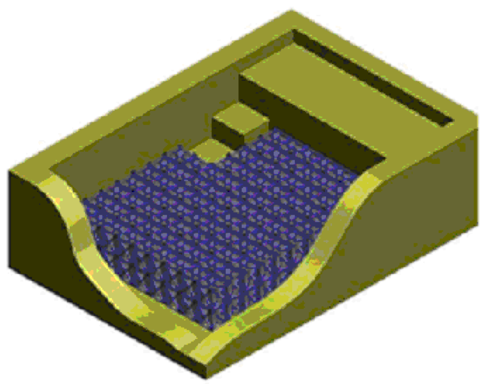
Mochten jullie nog vragen hebben of aanvullingen willen dan horen we dat graag.

Met vriendelijke groet
(5)(1)(2e)





CSD-C worden op vloer van bunker vrij neergezet



mogelijke stapeling van CSD-C in meerdere lagen

Van: (5)(1)(2e)
Verzonden: maandag 7 juni 2021 14:23
Aan: ' (5)(1)(2e) - DGMI' < (5)(1)(2e) @minienw.nl>
CC: (5)(1)(2e) - DGMI < (5)(1)(2e) @minienw.nl>; (5)(1)(2e) < (5)(1)(2e) @epz.nl>; (5)(1)(2e) - DGMI < (5)(1)(2e) @minienw.nl>
Onderwerp: RE: Volume splijtsof vs afval

Beste (5)(1)(2e)

Alles is gebaseerd op bedrijfsduur tot 31.12.2033 met circa 2.000 brandstofelementen en 9 elementen per opslagcontainer (grotere containers kunnen niet bij EPZ worden toegepast).

Mvrgr
(5)(1)(2e)

Van: (5)(1)(2e) - DGMI <(5)(1)(2e)@minienw.nl>
Verzonden: maandag 7 juni 2021 14:06
Aan: (5)(1)(2e) <(5)(1)(2e)@epz.nl>
CC: (5)(1)(2e) - DGMI <(5)(1)(2e)@minienw.nl>; (5)(1)(2e) <(5)(1)(2e)@epz.nl>; (5)(1)(2e) - DGMI <(5)(1)(2e)@minienw.nl>
Onderwerp: RE: Volume splijtsof vs afval

Dank (5)(1)(2e) voor dit overzicht.

De 222 opslagcontainers zonder opwerking: om welke periode/tijdsbestek gaat het?

Alvast bedankt!

Van: (5)(1)(2e) <(5)(1)(2e)@epz.nl>
Verzonden: maandag 7 juni 2021 12:33
Aan: (5)(1)(2e) - DGMI <(5)(1)(2e)@minienw.nl>
CC: (5)(1)(2e) - DGMI <(5)(1)(2e)@minienw.nl>; (5)(1)(2e) <(5)(1)(2e)@epz.nl>
Onderwerp: RE: Volume splijtsof vs afval

Goedemorgen (5)(1)(2e),

Hieronder zoals toegezegd de indicatie van de m3 verhoudingen. Het volume afval is het formaat maal de nu bekende hoeveelheid.
V.w.b. de opslagruimte: deze getallen zijn een zeer ruwe inschatting dus niet nauwkeurig.
Het gaat m.n. om het beeld dat Creates vooralsnog geen extra HABOG ruimte vergt.
Ik ben nog in overleg met COVRA voor meer specifieke uitwerking.

Met vriendelijke groet
(5)(1)(2e)

Afvalvolume in verschillende scenario's					Volume afval		Indicatie opslag ruimtebeslag interim storage		warmte-producerend	niet w produ
1. Directe opslag	222	opslagcontainers	18	m3 per container	4.000	m3	12.000	m3	100%	
2. Opwerken volgens de 1993 techniek					733	m3	2.000	m3	14%	
Voor warmteproducerend afval gelijk aan hieronder	105	m3								
Bitumen	120	drums	0,24	m3						
Hulls en ends	400	drums	1,5	m3						
Volume per verpakking	0,19	m3 per CSDV	0,19	m3 per CSDC						
Bouw en contract HABOG	270	CSDV oud	320	CSDC oud						
Volgens haalbaarheidstudie afgerond	280	CSDV nieuw	280	CSDC nieuw						
	550	CSDV totaal	600	CSDC totaal						
3. Opwerken volgens huidige contract	550	CSDV	600	CSDC						
	105	m3	116	m3	220	m3	1.000	m3	47%	
Totaal canisters na Creates	530	CSDV	2.364	CSDC						
4. Opwerken na Creates	101	m3	455	m3	556	m3	1.000	m3	18%	
Benodigde capaciteit HABOG gelijk aan bestaand HABOG (door mogelijkheid van stapeling ruimtebeslag geen extra m3)										

Van: (5)(1)(2e) - DGMI <(5)(1)(2e)@minienw.nl>
Verzonden: donderdag 3 juni 2021 16:47
Aan: (5)(1)(2e) <(5)(1)(2e)@epz.nl>

CC: (5)(1)(2e) - DGMI < (5)(1)(2e) @minienw.nl>
Onderwerp: Volume splijtsof vs afval

Beste (5)(1)(2e) ,

Ik heb in mijn archief het volgende gevonden:

Hoeveel m^3 verbruikte splijtstof gaat naar ORANO voor 20 canisters CSD-V? 75 splijtstofelementen, dat is 11,4 m^3. En hoeveel m^3 is 20 canisters CSD-V? 3,6 m^3. Hoeveel m^3 is 1764 canisters CSD-C? 317 m^3. Met andere woorden wat is het effect op het volume dat heen en weer getransporteerd en opgeslagen wordt? Voor het effect is de toxiciteit (gevaarstelling) relevant.

Dit is m.i. een deel van het antwoord.

Volgens het m.e.r. uit 2015 (MOX m.e.r.) komen er gemiddeld per jaar 8,5 canisters CSD-V en 8 canisters CSD-C (samen net onder 3 m3) terug. Er worden er gemiddeld 28 elementen opgewerkt (volume?)

Die verhouding zoek ik.

BVD en groet,

(5)(1)(2e)

Dit bericht kan informatie bevatten die niet voor u is bestemd. Indien u niet de geadresseerde bent of dit bericht abusievelijk aan u is toegezonden, wordt u verzocht dat aan de afzender te melden en het bericht te verwijderen. De Staat aanvaardt geen aansprakelijkheid voor schade, van welke aard ook, die verband houdt met risico's verbonden aan het elektronisch verzenden van berichten.
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To: (5)(1)(2e) - ANVS[(5)(1)(2e) @anvs.nl]
Cc: (5)(1)(2e) - ANVS[(5)(1)(2e) @anvs.nl]; (5)(1)(2e) - ANVS[(5)(1)(2e) @anvs.nl]; (5)(1)(2e) - ANVS[(5)(1)(2e) @anvs.nl]; (5)(1)(2e) (5)(1)(2e)- ANVS[(5)(1)(2e) @anvs.nl]; (5)(1)(2e) - DGMI[(5)(1)(2e) @minienw.nl]
From: (5)(1)(2e) - DGMI
Sent: Tue 9/28/2021 12:06:08 PM
Subject: RE: ITP rekenmethode
Received: Tue 9/28/2021 12:06:00 PM

Dank hiervoor. Ik bewaar dit goed. Nota en brief liggen dus bij(5)(1)(2e)en de opmerkingen die nu zijn gemaakt maken niet dat brief en nota teruggehaald zouden moeten worden (stralingsbelasting is m.i. een valide indicatie van risico's).
Als ik meer weet, horen jullie van mij.
Gr(5)(1)(2e)

Van: (5)(1)(2e) - ANVS
Verzonden: dinsdag 28 september 2021 12:31
Aan: (5)(1)(2e) - DGMI ; (5)(1)(2e) - DGMI
CC: (5)(1)(2e) - ANVS ; (5)(1)(2e) - ANVS ; (5)(1)(2e) - ANVS ; (5)(1)(2e) (5)(1)(2e) - ANVS
Onderwerp: ITP rekenmethode

Hallo (5)(1)(2e) en (5)(1)(2e)

Gisteren hebben we met een aantal ANVS-ers de rekenmethode van Orano verkend. Een observatie die we jullie nog willen meegeven (nu de brief nog niet bij de Kamer ligt) is dat de rekenmethode de 'integrated toxic potential' (ITP) berekent. ITP is wat anders dan 'radiotoxiciteit', het is meer een maat voor potentiële stralingsbelasting in plaats van effectieve volgdosis bij directe inname van de nucliden. Ook betekent een gelijkwaardige ITP niet automatisch dat de activiteiten van de afvalpakketten gelijkwaardig zijn. Wij twijfelen daardoor over de haalbaarheid van voorwaarde 2 (De twee afvalpakketten zijn aantoonbaar gelijkwaardig in radioactiviteit en radiotoxiciteit). Het is meer dat de ruil gebaseerd wordt op gelijkwaardigheid van potentiële stralingsbelasting van de pakketten.

Daarbij hebben we nog wat vragen over de tijdsintegratie die gebruikt wordt. Het lijkt erop dat de ITP berekend wordt tussen 500 en 1 000 000 jaar vanaf nu en dus niet voor de voorziene periode van bovengrondse opslag bij COVRA. Daar moet nog wat verder ingedoken worden en is misschien interessant om mee te geven aan NRG of TU Delft bij de validatie van de methode. Wellicht heeft dit namelijk consequenties voor de opslag bij COVRA, transport en eindberging(vereisten).

De rekenmethode gaat enkel over radiologische aspecten, daarnaast moet o.a. ook worden aangetoond dat de opslag van het te ontvangen afval ook chemisch geen gevaren oplevert en/of impact op het milieu heeft. Die veiligheid zal op een andere manier moeten worden aangetoond tijdens de vergunningsprocedure.

Groeten, (5)(1)(2e)

(5)(1)(2e)

....

Autoriteit Nucleaire Veiligheid en Stralingsbescherming (ANVS)
Team Stralingsbescherming, Afval en Ontmanteling
Koningskade 4 | 2596 AA | Den Haag
Postbus 16001 | 2500 BA | Den Haag

....

M (5)(1)(2e)
(5)(1)(2e) @anvs.nl
www.anvs.nl

....

Mijn werkdagen zijn maandag, dinsdag en donderdag.

To: (5)(1)(2e) - DGMI[(5)(1)(2e) @minienw.nl]; (5)(1)(2e) - DGMI[(5)(1)(2e) @minienw.nl]
From: (5)(1)(2e) (ORANO)
Sent: Wed 10/6/2021 3:36:23 PM
Subject: CM: RE: CPEN report, English version
Received: Wed 10/6/2021 3:36:32 PM
[CEPN NTE ITP - English Version - VF.pdf]

Dear (5)(1)(2e), thank you for the information.
Please find attached the English translation of CPEN's independent report "INTEGRATED TOXIC POTENTIAL: REVIEW AND ANALYSIS OF ORANO APPROACH".
Please allow me some remarks since I know that a decision of the Dutch authorities is in preparation.
From a technical standpoint, the proposed optimization respects the radioactive equivalency based on rules that were recently confirmed once more both in France and Germany. (It should be noted here that the method has been used by BNFL in the past and validated by several governments and authorities (UK, Japan, Germany, Switzerland and Italy) in the context of substitutions following the processing of spent fuel by BNFL. To my knowledge, these rules were also applied for the Dodewaard substitution.)
From a legal standpoint, the French administration confirmed in 2020 that there is no adjustment required to the intergovernmental agreement between our two countries relating to the matter.
The proposed agreement provides also very significant economic advantages for EPZ and the Dutch institutions in charge. Orano needs to know during this current autumn if our proposal can be accepted by the Dutch Government, at least on a political dialogue basis, with some additional time allowance until the turn of the year for written confirmation.
I am sorry to be so direct. I remain at your disposal for all discussions or meetings you may request.
Best regards,

(5)(1)(2e)
office : (5)(1)(2e)
cell : (5)(1)(2e)

De : (5)(1)(2e) - DGMI
Envoyé : mercredi 6 octobre 2021 12:02
À : (5)(1)(2e) (ORN-RE) ; (5)(1)(2e) - DGMI
Objet : RE: CPEN report, English version

Avertissement de sécurité: Sachez que ce message vous a été envoyé par un expéditeur externe.

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Dear (5)(1)(2e), dear (5)(1)(2e)
Thanks for this information. I am responding on behalf of (5)(1)(2e), because buiten reikwijdte verzoek.
Looking forward to the report,
Best regards,
(5)(1)(2e)

Best regards,

(5)(1)(2e)

....

Ministry of Infrastructure and Water Management

Environmental Safety & Risks Directorate
Visiting address: Rijnstraat 8 | 2515 XP Den Haag
PO Box 20904 | 2500 EX DEN HAAG
The Netherlands
[www.rijksoverheid.nl]
....
T (5)(1)(2e)

E (5)(1)(2e) @minienw.nl
………………………………………………………………………

Van: (5)(1)(2e) (ORANO) < (5)(1)(2e) @orano.group>
Verzonden: woensdag 6 oktober 2021 10:35
Aan: (5)(1)(2e) - DGMI < (5)(1)(2e) @minienw.nl>
CC: (5)(1)(2e) - DGMI < (5)(1)(2e) @minienw.nl>
Onderwerp: CPEN report, English version

Dear (5)(1)(2e) , I'd like to inform you that I received the translated CPEN report. I review it right now and will transmit it to you and (5)(1)(2e) this afternoon and I'll call you just in case you have questions.

Regards,

(5)(1)(2e)
office : (5)(1)(2e)
cell : (5)(1)(2e)

De : (5)(1)(2e) - DGMI < (5)(1)(2e) @minienw.nl>
Envoyé : lundi 27 septembre 2021 09:05
À : (5)(1)(2e) (ORN-RE) < (5)(1)(2e) @areva.com>
Cc : (5)(1)(2e) - DGMI < (5)(1)(2e) @minienw.nl>
Objet : Policy note and letter to parliament are at the secretary general of our ministry

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Dear (5)(1)(2e)

I saw you tried to call on Thursday. Unfortunately I was struggling with malfunctioning internet at that moment that I was trying to fix.

As you see in the title the note and letter are pretty far on the decision ladder.

I cannot tell more right now.

Best regards,

(5)(1)(2e)

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DE LA PROTECTION DANS LE DOMAINE NUCLEAIRE

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INTEGRATED TOXIC POTENTIAL:

REVIEW AND ANALYSIS OF ORANO APPROACH

Diffusion Free **X** Restricted : Orano RE : (5)(1)(2e)
Order number: 40105827

CEPN Reference: CEPN NTE 21/15		
Index	**Date**	**Version**
0	09/28/2021	V0
1	10/01/2021	V1 (including 09/30/2021 comments from Orano)

Author(s)	Reviewer	Authorisation
(5)(1)(2e) (5)(1)(2e) (5)(1)(2e) (5)(1)(2e)	(5)(1)(2e) (5)(1)(2e)	(5)(1)(2e) (5)(1)(2e)
September 28th 2021	September 28th 2021	September 28th 2021

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1. EXECUTIVE SUMMARY

Following a request form the French General Directorate for Energy and Climate (DGEC), CEPN (Nuclear Protection Evaluation Centre, www.cepn.asso.fr) carried out an in-depth analysis of the Integrated Toxic Potential (ITP) methodology. Introduced in the United Kingdom in the early 1990ies, the ITP is equal to the integral over time of the volume of water in which 1 m^3 of waste is to be diluted so that the annual intake of this water by a reference individual leads to an exposure of 1 mSv:

$$\mathrm{ITP} = \int_{t_1}^{t_2} \sum_i \frac{\mathrm{AWI.\,ECD_i.\,A_i(t)}}{\mathrm{AAEDL}} .\, dt$$

Where

- AWI is the average annual water consumption (in m^3 per year);
- ECDi is the effective dose coefficient for the radionuclide i (in $Sv.Bq^{-1}$);
- Ai(t) is the activity of the radionuclide i at time t (in Bq);
- AAEDL is the annual effective dose limit for the public (1 mSv per year).

In other words, ITP quantifies the hazard potential of a waste in terms of its radiotoxicity to humans considering ingestion pathway and over a long period of time, 500 to 100,000 years in the approach proposed by BNFL. BNFL. This methodology was developed for the purpose of radioactive waste substitution and endorsed by the UK Authorities and BNFL's overseas clients. It was actually implemented. While ITP does not depend on the final management option of the considered wastes. Based on the review and analysis presented in this report, CEPN considers that ITP is a robust indicator, built on numerical parameters which values are based on international consensus. Toxicity of radionuclides is assessed with ingestion dose coefficients as provided by the International Commission of Radiological Protection (ICRP). The approach is relevant since ingestion is the main pathway for human exposure from geological disposal. The review of literature achieved by CEPN did not highlight any indicator or methodology as robust and operational as ITP. These aspects are discussed in Chapters 3 and 4.

ITP does not directly address the protection of non-human biotas. However, taking into account the analysis of toxicity indicators for non-human biotas, CEPN agrees with National Decommissioning Authority (NDA) view that '*ITP is a reasonable measure of the effects that radioactive materials could cause to both humans and the environment*'. It should be noted, however, that this analysis remains qualitative and detailed calculations based for instance on the Erica approach were not performed within this work. Furthermore, ITP calculation does not address waste chemical toxicity. However, CEPN considers reasonable to assume that mass equivalence (in particular of heavy metals), as planned for the substitution project, induces (at least qualitatively) an equivalence in terms of chemical toxicity of the substituted waste. These elements are discussed in Chapter 4 of this report.

The CREATES software has been developed by Orano to perform ITP calculations based on the radiological characteristics of waste packages. The method to assess these characteristics (either by measurement or calculation) are certified by Bureau Veritas. The tests and calculations carried out by CEPN and analysis of the CREATES documentations allow to confirm that the software performs ITP calculations in accordance with its technical specifications and, therefore, the ITP methodology. The calculations performed by CEPN confirmed the results obtained by Orano. These calculations also made it possible to assess the impact of several uncertainties, in particular those related to the radiological inventory. These calculations show that CREATES software results are robust. Finally, it should be outlined that over the considered period, ITP final value appeared related to a limited number of radionuclides (^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{241}Am, ^{243}Am and ^{244}Cm) and their progenies (Chapter 5).

The methodology developed in the 1990ies by BNFL is based on an integration over 500 to 100,000 years of the waste toxicity potential. National agencies in charge of radioactive waste management are nowadays carrying out impact studies associated with geological disposal up to 1,000,000 years. By analogy, this value could be used for ITP calculations (e.g. from 500 to 1,000,000 years) while maintaining the lower bound which basically corresponds to the end of the institutional control period usually considered at the design stage of geological repository. Such calculations were achieved and analyzed within this work (Chapter 5).

To conclude, CEPN analysis confirms the broad environmental neutrality of the proposed substitution based on the ITP calculations and ratio. This methodology builds on an equivalence based on the radiotoxic potential of the waste to humans by considering dose factors for ingestion and long time period. The method is robust both in terms of the exposure route considered and the toxicity of the waste. It remains valid according to recent work in the field of quantification of the hazard potential of radioactive waste. Some alternative methods are based on qualitative assessment criteria based on expert judgement and therefore more open to question. A potential improvement to the methodology could be taken into account an upper bound equal to one million years by analogy with current practices for quantifying impacts from geological repositories. It should be noted here that the method has been used by BNFL in the past and validated by several governments and authorities (UK, Japan, Germany, Switzerland and Italy) in the context of substitutions following the processing of spent fuel by BNFL.

2. INTRODUCTION

The treatment of nuclear spent fuel at the Orano La Hague plant is based on a separation process which allows to recover valuable material (plutonium and uranium) from the spent fuel. The process induces various types of waste or residues which are conditioned and temporary stored on site before their final disposal in a dedicated facility. For foreign customers, these wastes are sent back to the owner of the spent fuel that was processed.

In order to facilitate the process of return of waste packages to foreign customers, Orano developed a method (and an associated tool) to assess the equivalence between different wastes. The method proposed by Orano is based on the Integrated Toxic Potential (ITP) methodology. This methodology was first developed and implemented in the United Kingdom.

Following a request from the French General Directorate for Energy and Climate (DGEC), CEPN achieved an in-depth review of Orano ITP based approach and the way it is implemented in order to build an equivalence between CSD-C and CSD-V packages. The CEPN review was focused on the following aspects which are developed in this report:

1. Analysis of scientific basis on which the ITP method is based and review of adequacy and accuracy of the various parameters. This evaluation is based on national and international documents describing the ITP methodology and a literature review. Additional indicators and aspects which could be taken into account in the equivalence process are also discussed.

2. The validity of the calculations and results (equivalence) obtained by Orano through the implementation of the ITP method is discussed. This task is based on documents provided by Orano and a technical review of Orano's calculations and results. A particular attention was paid to the quantification of radiological inventories of waste packages (representativeness and uncertainties). Discussions were held with a number of Orano representatives and independent calculations were performed.

3. INTEGRATED TOXIC POTENTIAL: ANALYSIS OF THE METHODOLOGY

3.1. Purpose

In the early 1990's, British Nuclear Fuel Limited (BNFL) proposed to the UK Government an approach for substituting low and intermediate level waste (LLW and ILW) belonging to overseas customers and temporary stored at Sellafield with an equivalent amount of high-level waste (HLW). The final objective of this approach was thus to send HLW to overseas customers while ILW and LLW would remain in the UK. Among other aspects, BNFL approach for substitution allowed for a significant decrease of shipments (particularly to Japan). BNFL's customers in Japan, Germany, Switzerland, Italy and the Netherlands did accept the substitution process but they also raised a number of questions related to health and environmental impacts over time associated with the substitution. The UK government also questioned the environmental detriment associated with the substitution [1]. BNFL work on the development of the Integrated Toxic Potential (ITP) method to provide an equivalent indicator for substitution process addressing these issues.

3.2. The ITP methodology

An equivalence between various waste packages could not be simply based on total activity comparison (or comparison in mass or volume). BNFL developed an indicator that weights the activity of each radionuclide in the waste package by a coefficient that takes into account its radiotoxicity, i.e. the effective dose coefficients for ingestion published by the International Commission on Radiological Protection (ICRP). ITP was defined as *'the volume of water in which 1 m^3 of waste must be diluted so that the annual ingestion of this water by a reference individual leads to an exposure of 1 mSv'*. This definition first appeared in a 1997 European Commission Report [3]. The Toxic Potential ϕ_i (in m^3) of a radionuclide i in the waste is written as:

$$\Phi_i(t) = \frac{\mathrm{AWI.\,ECD_i.\,A_i(t)}}{\mathrm{AAEDL}}$$

Where

- AWI average annual drinking water intake by a reference individual (in m^3 per year);
- ECD_i Effective Dose Coefficient for radionuclide i (in $Sv.Bq^{-1}$);
- $A_i(t)$ activity of radionuclide i at time t (in Bq);
- AAEDL Annual Average Effective Dose Limit for member of the public i.e. 1 mSv per year.

For a mixture of radionuclides, Toxic Potentials can be summed:

$$\Phi(t) = \sum_i \Phi_i(t)$$

Radionuclides activities (and so the radionuclide inventory of a waste package) evolves over long time periods associated with these wastes. Integrating $\Phi(t)$ over a time period from t_1 to t_2 allows takes into account these evolutions (between t_1 and t_2) and the Integrated Toxic Potential (ITP) is calculated as:

$$\mathrm{ITP} = \int_{t_1}^{t_2} \Phi(t).\,dt$$

The ITP quantifies the hazard potential of a given waste in terms of its radiotoxicity by ingestion (of water) for humans and over a long period of time. The Toxic Potential Factor, which are specific to each radionuclide, can also be introduced (TPF_i, in $m^3.TBq^{-1}$) so the ITP of a waste can be expressed as follows:

$$\mathrm{ITP} = \sum_i \frac{AWI.ECD_i}{AAEDL} \int_{t_1}^{t_2} A_i(t).dt = \sum_i TPF_i. \int_{t_1}^{t_2} \mathrm{A}_i(t).dt$$

Finally, a waste equivalence for substitution purposes can then be calculated with a comparison of the ITP of the considered wastes:

$$\mathrm{ITP}_{\mathrm{Waste\ 1}} = \mathbf{X}.\,\mathrm{ITP}_{\mathrm{Waste\ 2}}$$

The X ratio is used to evaluate the volumes of waste (ex. m^3) concerned by the substitution.

3.3. Implementation of the ITP methodology

In 1993, the government sought the advice of the Radioactive Waste Management Advisory Committee (RWMAC[1]) on BNFL's proposal for waste substitution based on the ITP method. The request to RWMAC was to ensure that the substitution was environmentally neutral and to analyze the basis of the ITP indicator [1]. The RWMAC gave a positive opinion on BNFL's approach and the neutrality of the substitution based on ITP:

> *'ITP provided a reasonable approximation for establishing radiological neutrality* [...] *RWMAC supported the use of ITP, despite its limitations as a means of quantifying substitution and agreed that broad environmental neutrality in terms of radiological impact can be expected for substitution based on ITP'* (§135 of [1])

In addition, the Nirex (Nuclear Industry Radioactive Waste Executive) informed the government that the amount of LLW and ILW involved in the substitution process was small with regards to the domestic production and could be stored with no actual issue in the UK storage repository (§ 138 of [1]). BNFL's proposal was accepted in 1994 by the UK government.

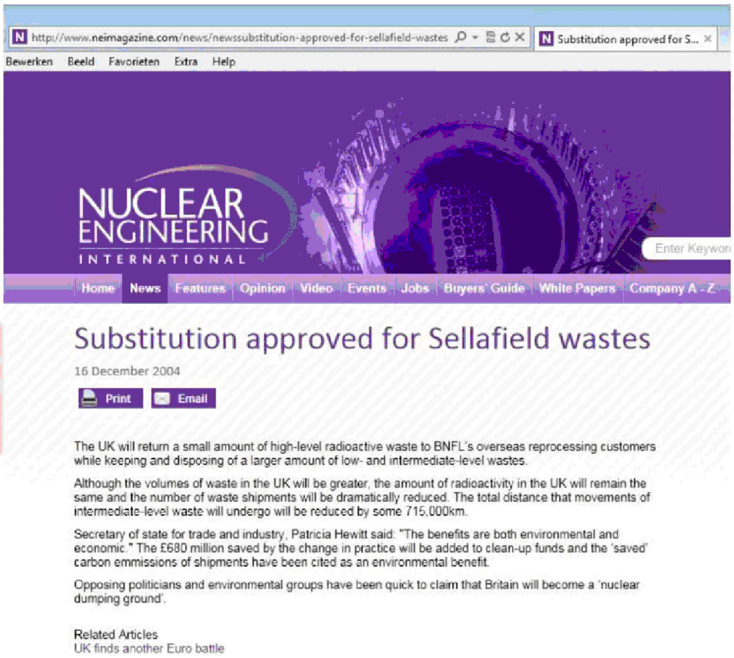
In the early 2000's, the national framework for radioactive waste management in the UK evolved. The new framework [4] reaffirmed the principle that waste from overseas utilities cannot remain on the UK territory and must be returned to their owners. The principle of substitution remains an option set out in the National Radioactive Waste Management Plan for Nirex in its 2003 version (§ 5.1 of [4]). The Nirex nevertheless considered it was appropriate to review the substitution procedure again in order to ensure its transparency and robustness:

> *'Nirex agrees that it is appropriate at this time to review the substitution proposals and links to the future availability of waste management facilities. The key issue for any decision-making process is that it should be transparent and based on a technically robust environmental impact assessment'* [4].

[1] RWMAC was founded in 1978 and brought together a group of experts from different background to provide technical and independent views on the UK strategy for radioactive waste management.

In 2006, the Nuclear Decommissioning Authority (NDA) contracted NAC International to audit the substitution method based on ITP methodology. NAC International achieved an audit [5] on the way British Nuclear Group (BNG, formerly BNFL) implement the ITP method with its TOXIC calculation code and the results obtained for different types of waste. In its report (§ 1.4 to § 1.6 of [5]), NAC International concluded that the use of ITP for substitution purposes was adequate, that the methodology was correctly implemented in the TOXIC calculation code and that the results of the TOXIC code were correct. On the basis of this report, the NDA approved the waste substitution method based on ITP.

Figure 1 shows an extract from the Nuclear Engineering website announcing the return of vitrified waste from Sellafield to the Netherlands instead of low and intermediate level waste (2003). Figure 2 shows an extract from the UK Radioactive Waste and Materials Inventory 2019 mentioning ongoing substitutions between the UK and several countries[2].



Substitution approved for Sellafield wastes

16 December 2004

The UK will return a small amount of high-level radioactive waste to BNFL's overseas reprocessing customers while keeping and disposing of a larger amount of low- and intermediate-level wastes.

Although the volumes of waste in the UK will be greater, the amount of radioactivity in the UK will remain the same and the number of waste shipments will be dramatically reduced. The total distance that movements of intermediate-level waste will undergo will be reduced by some 715,000km.

Secretary of state for trade and industry, Patricia Hewitt said: "The benefits are both environmental and economic." The £680 million saved by the change in practice will be added to clean-up funds and the 'saved' carbon emmissions of shipments have been cited as an environmental benefit.

Opposing politicians and environmental groups have been quick to claim that Britain will become a 'nuclear dumping ground'.

Related Articles
UK finds another Euro battle

Figure 1. Agreement for radioactive waste substitution between BNFL and its Dutch client

[2] https://ukinventory.nda.gov.uk/wp-content/uploads/2020/01/2019-Waste-Report-Final.pdf

2019 UK Radioactive Waste and Material Inventory
Radioactive Waste Inventory

14 WASTES FROM OVERSEAS MATERIALS

Key facts:

* Waste from reprocessing overseas spent fuel is returned to the country of origin.
* About 1,780 canisters of vitrified HLW and smaller quantities of other wastes will be exported.

A proportion of the waste from the Thorp and Magnox reprocessing plants at Sellafield results from reprocessing overseas spent fuel. All reprocessing contracts with overseas customers signed since 1976 include a provision to return packaged wastes or their equivalent (by internationally agreed substitution arrangements) back to the country of origin.

Government policy is that wastes resulting from the reprocessing of overseas spent fuel should be returned to the country of origin, and HLW should be returned as soon as practicable after vitrification. The policy allows "waste substitution" arrangements that ensure broad environmental neutrality for the UK. Waste substitution is the process whereby an additional amount of HLW from reprocessing would be returned, which is smaller in volume but equivalent in radiological terms to customers' ILW and LLW from reprocessing that would otherwise be returned.

Exports of vitrified HLW started in January 2010 and are planned to be completed by around 2025. In total about 1,780 canisters of vitrified HLW (about 267 m^3) are planned for export, and this volume assumes that substitution arrangements are implemented.

Future arisings of HLW reported in the Inventory are net of exports to overseas reprocessing customers, so that the total volume/number of containers reported represents only the HLW that is a UK liability.

During the 1990s materials test reactor fuel was reprocessed at Dounreay for customers in Belgium, Germany, the Netherlands and Australia. The contracts and regulatory authorisations required that the radioactive wastes produced be returned to the countries of origin within 25 years of reprocessing. The contracts are backed by inter-governmental letters. A total of 123 containers of cemented waste were returned to Belgium between 2012 and 2014. In 2012 the Scottish and UK governments agreed in principle to allow waste substitution and those arrangements are currently at various stages of implementation.

Figure 2. Excerpt from the UK inventory of radioactive waste and materials (2019)

3.4. ITP methodology: review of parameters values

The mathematical expression of the ITP and the values of the physical parameters were first given in [3]. They remained identical in the years 2000[3] (Annex 3 of NAC International report [5]). The following paragraphs discuss validity of these elements in the current context.

3.4.1. Average annual water consumption

The value of the average annual water consumption (AWI) used for the calculation of the ITP is 0.712 m^3 per year. This value is in line with current recommendations on the subject. For example, it is 2 L per day for a standard adult individual in the 2017 WHO guidelines [8].

3.4.2. Annual effective dose limit for the public

[3] *Modular simulation software for modelling the impacts of alternative spent fuel management practices in the nuclear power industry*, C. Robbins, C. Hoggett-Jones, Simulation Modelling Practice and Theory 10, 153–168, Annals of Nuclear Energy **29** (2002) 491–508, 2001.
Implications associated with the sensitivity analysis of fast flux transmutation system, C. Hoggett-Jones, C. Robbins, G. Gettinby, S. Blythe, Progress in Nuclear Energy, Vol.**19**, No. 3-4, pp. 353-366, 2001.
Modelling the inventory and impact assessment of partitioning and transmutation approaches to spent nuclear fuel management industry, C. Hoggett-Jones, C. Robbins, G. Gettinby, S. Blythe, Annals of Nuclear Energy **29**, 491–508, 2002.

1 mSv.year^{-1} (dose limit for a member of the public) is used for the calculation of the ITP. This value has not changed since 1993. The use of 1 mSv.yr^{-1} is in line with the latest ICRP general recommendations from 2007 [9] and with the current regulations for planned exposure situations.

Note. The values of the parameters AWI and AAEDL are constants: an equivalence based on a ITP ratio is the same regardless of the values chosen for AWI and AAEDL.

3.4.3. Dose coefficients

The effective dose coefficients (ECDi, Bq.Sv^{-1}) used to calculate the exposure of an individual member of the public by ingestion are taken from ICRP Publication 72 [10]. Dose coefficients published by the ICRP are internationally recognized and have not changed for members of the public since ICRP Publication 72. These coefficients are included in national regulations (e.g. in Table 1.3 of Arrêté du 1er septembre 2003[4] in France).

It should be noted that the ICRP is currently in the process of updating dose coefficients. New values have recently been published for workers[5] and work is underway to update the dose coefficients for the public[6]. It is not easy to foresee the evolution of dose coefficients for the public and potential impacts on ITP calculations results and ratios. The work of the ICRP is not expected to be completed for several years and current regulations will not change in the short term.

3.4.4. Waste package radiological inventory

Radiological inventory differs according to the type of waste and the activity values A_i for each radionuclide differ for each package within the same type (family: CSD-C, CSD-V) of waste package. In practice, the A_i values are based on measurements or calculations which are performed during the production process of each individual package. These values are part of the parameters that ensure that each waste package complies with technical specifications defined in agreement between Orano and waste owners or waste management agencies. Compliance with these specifications is required to ensure that waste package will be accepted and adequately managed.

3.4.5. Integration period

The integration period must be representative of the time scale over which the waste shows a hazard potential because of its radiotoxicity. Based on standards for impact assessment associated with a geological disposal facility and following the recommendations of RWMAC and the UK Department of the Environment, an integration period of 500 to 100,000 years (§ 4.5 of [4]) was adopted by BNFL[7]. The European Commission document [3] presents (in Annex D) the results of ITP calculations performed by BNG for several integration periods (covering 0 to 10^6 years) and concludes that '*the results show a large degree of sensitivity to the integration period*'. The sensitivity of the results to the integration period is further considered in this report (§ 5.7.1).

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[4] Arrêté du 01/09/03 définissant les modalités de calcul des doses efficaces et des doses équivalentes résultant de l'exposition des personnes aux rayonnements ionisants, Journal Officiel de la République Française, 262 du 13 novembre 2003.
[5] Publications 130 (2015), 134 (2016), 137 (2017) et 141 (2019).
[6] *"The schedule of work for Committee 2 and its task groups includes replacement of all currently available dose coefficients for ingestion and inhalation of radionuclides by members of the public"*, *Overview of ICRP Committee 2* , Doses from Radiation Exposure', J. Harrison, ICRP Proceedings, 2013.
[7] Dans *Review of Radioactive Waste Management Policy preliminary Conclusions*, Department of Environment Consultation Document, Août 1994 et l'Annexe E de *The Environmental Implications of BNFL's Proposals for Substitution*, RWMAC Advice to the Minister for the Environment and the Countryside, tous deux cités dans les références de l'Annexe D de [6].

3.5. Limitations of ITP methodology

The ITP method considers the ingestion pathways to quantify the hazard potential of a waste package. Qualitatively, in the context of deep geological repository and over long time period, impact assessment studies show that water is the main transfer pathway for radionuclides from the repository to the biosphere and that ingestion is the most penalizing exposure pathway. The ITP method appears as quite suitable and consistent for radioactive waste which are to be disposed of in geological repository (water, ingestion, integration period) and therefore, BNFL approach appears justified and robust. Nevertheless, a qualitative discussion on the inclusion of the inhalation pathway is proposed in this report (§5.8). The ITP method does not take into account (a priori) hazard potential of the waste with respect to non-human biotas (ecotoxicity). Also, the method does not take into account chemical toxicity of radioactive waste.

3.6. Summary

1. The ITP method was developed to support judgements on equivalence between different types of waste and for substitution purposes. The ITP is designed to justify environmental neutrality of substitution.

2. Equivalence are based on the radiotoxic potential of the waste to humans and over the long term.

3. The parameters of ITP are related to a physical and measurable reality (radiological inventory) and/or parameters that have been agreed upon and are included into national regulations (dose coefficients and dose limits). The latter parameters are still valid today.

4. The ITP method was reviewed and analyzed twice: in 1994 and 2006. Reviews confirmed that ITP provides a reasonable and robust approach to establish equivalence between different types of waste and supported the use of ITP for substitution purposes.

5. The method was actually used by BNFL to formalize agreements with foreign customers for radioactive waste substitution projects comparable with the substitution projects foreseen by Orano. The method was agreed upon by several governments: UK, Japan, Germany, Switzerland and Italy.

4. ALTERNATIVE METHODS TO ITP

4.1. Elements for assessing the equivalence between radioactive waste materials [3]

The European Commission document [3] provides an overview of the methods that have been developed in the 1990ies to compare radioactive materials or waste. It discusses several methods, including the ITP.

Among others methods, the report highlights a multi-criteria method (§ 4.2 in [3]) which integrates a wide range of criteria associated with both the nature of the waste and its foreseen management. The criteria are related to both radiological aspects - exposure pathways, critical groups, time period - and also economic aspects (transport and storage costs). Weighting factors are used to take into account views from experts or other stakeholders.

Discussion: the multi-criteria approach allows to take into account a wide range of criteria considered to be important in the context of substitution. However, it relies on qualitative factors and the weighting system is based on expert choices and judgements, which leads to questions about the robustness and transparency of equivalences based on such an approach.

Another method discussed in § 4.4 of [3] establishes an equivalence based on the maximum annual dose (peak dose) calculated for a waste and storage solution pair. Doses are calculated and averaged for each type of waste and the results are used to establish an equivalence ratio.

Discussion: this method considers the results of detailed impact studies and depend upon the characteristics of the storage (clay, salt dome, etc.). It does not reflect an equivalence of hazard potentials of the waste/materials themselves since it considers specific management methods.

The last method presented in § 4.6 of [3] calculates a toxicity factor for each radionuclide by dividing the mass activity of the radionuclide in the considered waste (in $Bq.g^{-1}$) by the exemption threshold recommended in the International Atomic Energy Agency (IAEA) standards. The toxicity factors are then summed and integrated over a time range of 0 to up to 800,000 years.

Discussion: this method proposes to use the exemption levels as reference values to reflect the hazard potential of a radionuclide. These values are derived from conservative scenarios which can differ from one radionuclide to another. An exemption level does not formally and neutrally reflect the hazard potential of a radionuclide and more generally of radioactive waste.

4.2. Recent developments

The NDA introduced in 2013 the Radiological Hazard Potential (RHP) [11]. The RHP is intended to measure the hazard potential of a radioactive material/waste arising from the decommissioning of a nuclear facility, based on its radiological and some of its physiochemical properties. For a given radioactive material/waste, the RHP is calculated as follows:

$$\text{RHP} = \text{Inventory} \times \frac{\text{Form factor}}{\text{Control factor}}$$

The inventory parameter answers the question *'how radioactive the material is and what is its radioactive hazard potential?'* It is in fact equal to the ITP.

The form factor answers the question 'how much of the substance would be released if the protection provided by the storage method disappeared for a short period of time, for example one day?'. This factor takes into account the physicochemical form of the radioactive substance: a gas or liquid has a greater chance of escaping, so the form factor takes the maximum value of 1, while a vitrified waste has a value of 10^{-6}. Powders have intermediate values.

The control factor should allow for an assessment of the difficulty of controlling the waste with respect to its characteristics: corrosive, flammable, temperature etc. (there is no exhaustive list). The control factor should answer the question: 'given the properties of the waste, its 'ideal' storage and the changes that are possible, what would be the frequency of inspection that an experienced consultant would consider necessary to allocate to monitoring the waste'. This frequency ranges from 1 hour to 10^5 hours.

Discussion: the form and control factors are assessed on the basis of expert judgement. The RHP thus seems less robust and less consensual (in terms of calculation parameters) than the ITP. Moreover, the RHP does not specifically aim to the equivalence of different types of waste but rather to compare radioactive substances from the decommissioning of installations in terms of their radiotoxicity, their hazard and the difficulty in storing them and therefore to anticipate the appropriate management methods. This objective differs from the ITP one, which aims to judge the equivalence of the hazard potentials of different types of waste independently of the management options.

In the document, the NDA's view of the impact of waste on the environment and non-human species should be highlighted: *'The inventory factor [ITP] has been derived with regard to the damage that the radioactive material could cause to human beings. However, it has been shown that this factor is also a good indicator of the damage that could be caused to plants and animals. In this sense, the ITP is a reasonable measure of the effects that radioactive materials could cause to both humans and the environment'*.

Also in 2013, an article [12] published by the State Scientific and Engineering Centre for Control System and Emergency Response (GNITS SCAR, a Ukrainian national company) focused on the development of a method to assess the equivalence of radioactive substances. The objective here was to compare VVER-400 spent fuel assemblies sent by Ukraine to the Russian Mayak complex with the waste returned from Russia to Ukraine after processing. The authors indicated that the equivalence criterion must meet the following conditions:

- Limit exposures of workers and the public during transport and storage of the waste,
- Limit exposures to the public associated with the storage of the waste until engineered barriers may fail, i.e. 1,000 years,
- Limit the volume of waste.

The authors define the criterion E as follows:

$$E = \sum_i B_i . A_i$$

Where for radionuclide i:

- B_i is the effective dose coefficient for ingestion as taken from ICRP Publication 72,
- A_i is the activity of i. 4 fission products (^{90}Sr, ^{90}Y, ^{137}Cs and ^{137m}Ba) and 8 actinides (^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{241}Am, ^{243}Am, ^{244}Cm) are considered.

The authors establish that the mentioned conditions are met if:

$$E_{spent\ fuel} = E_{waste\ packages}$$

This equivalence method has been incorporated into the Ukrainian and Russian legislations.

Discussion: this method is (kind of) a lighter version of the ITP approach. It considers only 12 radionuclides and a more limited time period. According to the authors, compliance with equivalence according to this method makes it possible to meet the different objectives. This would suggest that equivalence based on ITP would take into account other impacts (workers in particular) but, again, this is an expert judgement.

4.3. Waste ecotoxicity

ITP quantifies radioactive waste toxicity with regards to human health but is not directly related to . its toxicity for the environment and non-human biotas. From the beginning of the 2000ies, ICRP has gradually included the protection of the environment into the system of radiological protection. This system is presented in Figure 3 below.

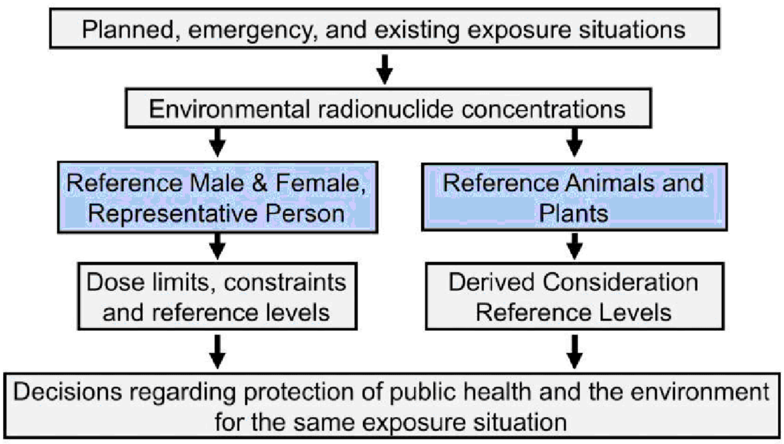

Figure 3. The ICRP System for Radiological Protection

Several ICRP Publications focusing on radiological protection of the environment have been published over the last decade. Exposure of Reference Animals and Plants (RAPs) is expressed in mGy per day (dose rate) and protection of RAPs is based on a reference dose rate value below which no effect on the target organism is expected: the DCRL (Derived Consideration Reference Levels). The DCRLs serve as guiding values below which measures are to be implemented to protect the environment.

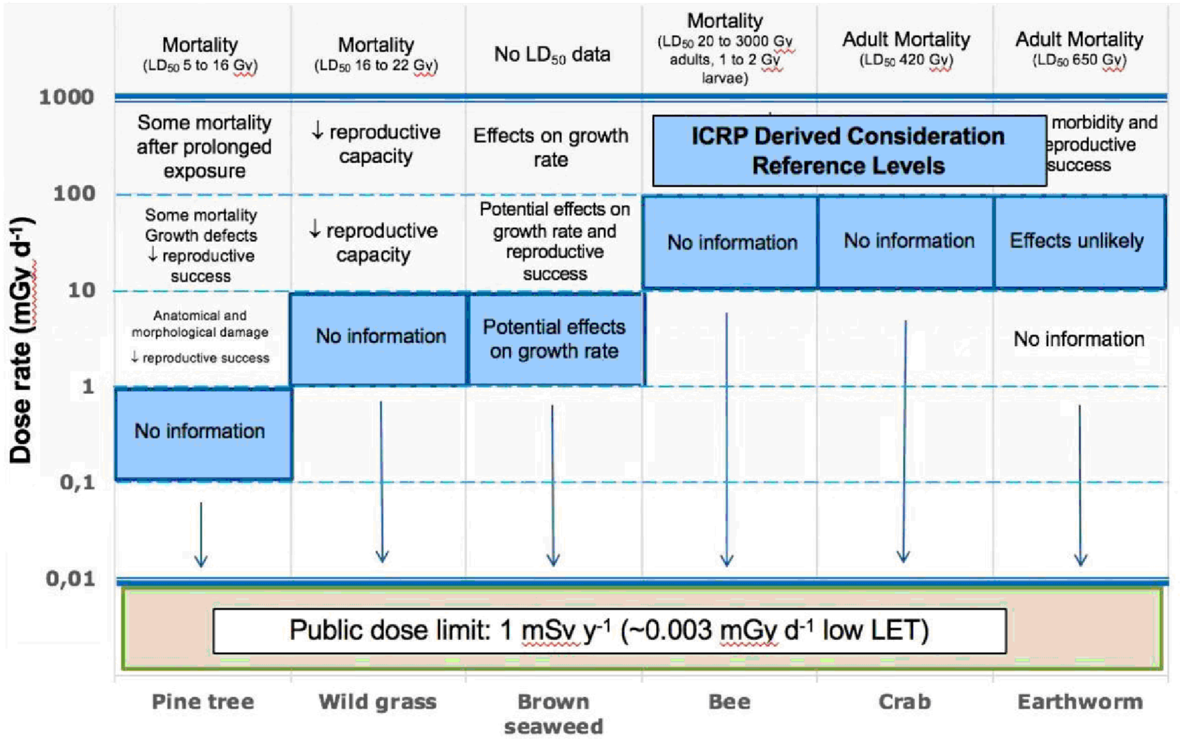

Figure 4. **Derived Consideration Reference Levels for Reference Animal and Plants and Public Dose Limit**

Figure 4 above allows to compare DCRLs and dose limit for the public (1 $mSv.year^{-1}$ or 0.003 mGy per day). It appears clearly that the dose limit for the public is reached at levels of exposure which are several orders of magnitude below DCRLs. In other words, the volume of water required to dilute a radioactive waste to reach 1 $mSv.yr^{-1}$ for exposure by ingestion by a member of the public is several orders of magnitude higher than the volume of water required to dilute a waste to a to reach a DCRL. This means that ITP as developed by BNFL and based on criteria related to human exposure is rather conservative with regards to an ITP that would be based on non-human biotas exposure. This point illustrates what NDA pointed out regarding ITP [11]:

'ITP has been derived with regard to the harm that the inventory of radioactive material could cause to humans. However, it has been shown that this factor is also a good indicator of the damage that could be caused to plants and animals. In this sense, ITP is a reasonable measure of the effects that radioactive materials could cause to both humans and to the environment'.

An ITP based on the toxicity of a waste to non-human biotas (for instance trout for consistency with the ITP approach based on water volume) could be calculated for different waste packages using an approach based on the Erica methodology (www.erica-tool.eu) in order to assess the neutrality of a substitution from the point of view of hazard potential for the environment only. Nevertheless, such calculations were not performed within this study. While highlighting the potential interest of such a work, CEPN recommends to rely on the position of the NDA: the neutrality of the substitution based on ITP ensures the neutrality of the substitution with regards to the environment.

4.4. Waste chemical and/or physical toxicity

ITP is an indicator related to the radiotoxicity of a waste or radioactive material for human beings. One could question the fact that toxicity associated with the presence of non-radioactive substances (such as heavy metals) is not taken into account.

For chemical substances, the main pathways of exposure are inhalation and ingestion and, to a lesser extent, skin absorption. Exposure is usually expressed as the mass of substances ingested by an individual per unit of body mass and per day ($mg.kg^{-1}.d^{-1}$). For chronic exposure to low doses, the considered toxic effects are generally carcinogenic, mutagenic and reprotoxic. Two types of dose-effect relationships can be distinguished:

- Non-threshold dose effect relationship, with an assumption of linearity: even a small increment in exposure leads to a proportional increase in risk, known as the no-threshold effect;
- Threshold dose effect relationship, no effect below an exposure value.

The objective of protection here is to prevent the occurrence of threshold effects and to minimize the risk of occurrence of non-threshold effects. In order to achieve this, exposures to chemical substances are to be compared with Toxicological Reference Values (TRVs).

For non-threshold effects, a quantitative protection objective should be defined, e.g. a level of risk that is considered 'acceptable'. The literature generally indicates acceptable lifetime risk values for anthropogenic environmental exposure in the range of 10^{-6} to 10^{-4}. TVRs are generally expressed as acceptable or tolerable daily intake (ADI/TDI) for threshold effects or as a unit excess risk (UER) for non-threshold effects.

The average daily exposure of an individual to a substance i (ADE_i) is assessed considering inhalation and ingestion pathways and different assumptions related for instance to the duration of exposure and on the calculation or measurement of the concentration of substance i in the different compartments of the environment. Exposure, together with TRVs, allow for the calculations of a risk ratio or an individual excess risk.

For a chemical substance which is toxic with regards to the ingestion pathway, it is in theory possible to calculate a volume of water in which to dilute a waste or material so that the consumption of that water does not exceed a standard or reference level. An accurate inventory of chemical substances in a waste package would allow to develop an indicator comparable to ITP for chemical substances, having in mind that toxic potential for chemical would globally not evolve with time. However, in the context of waste substitution involving also equality in terms of mass, CEPN estimates that most of chemical toxicity of the waste is first associated with heavy metals. In this context, considering an equivalence in terms of mass of substituted waste, CEPN considers it reasonable to state that the hazard potential for chemical toxicity is more or less similar.

4.5. References

[1] *Review of Radioactive Waste Management Policy, Final Conclusions*, Presented to Parliament by the Secretary of State for the environment by Command of Her Majesty, UK Stationery Office Limited, 1995

[2] *Considering Timescales in the Post-closure Safety of Geological Disposal of Radioactive Waste*; NEA/RWM/IGSC(2006)3, Nuclear Energy Agency, April 2006

[3] *Elements for assessing the equivalence between radioactive waste materials*, European Commission CRNA17241ENC_001, 1997.

[4] § 5.1 of *Nirex Report N/101, Summary of Nirex Experience and Expertise on Additional Waste Forms and Other Waste Management Option*, Nirex, ISBN 1 84029 346 2 Octobre 2003.

[5] *Review and Audit Report on Proposed Implementation of Radioactive Waste Substitution Arrangements Related to British Nuclear Group Overseas Reprocessing Contracts*, G. Varley, M. Kennard, prepared for Nuclear Decommissioning Authority (NDA), NAC International, NAC Worldwide Consulting, C-2006-16, Septembre 2006.

[6] ICRP, 1995. Age-dependent Doses to the Members of the Public from Intake of Radionuclides - Part 5 Compilation of Ingestion and Inhalation Coefficients. ICRP Publication 72. Ann. ICRP 26 (1).

[7] *Generalised Habit Data for Radiological Assessments*, Chilton, NRPB-N636 de 1996.

[8] Guidelines for Drinking-water Quality, 4th edition incorporating the first addendum, WHO (World Health Organization, 2011.

[9] ICRP, The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37 (2-4), 2007.

[10] ICRP, 1995. Age-dependent Doses to the Members of the Public from Intake of Radionuclides - Part 5 Compilation of Ingestion and Inhalation Coefficients. ICRP Publication 72. Ann. ICRP 26 (1).

[11] The "Radiological Hazard Potential" - Helping to make sense of cleaning up the UK's nuclear sites, R. Jarvis, Document No: EGR003

[12] Justification of equivalence criteria for high-level waste from VVER-440 spent fuel reprocessing, A.N. Masko, S.A. Kuznetsov, P.M. Rusynko, Nuclear Energy and the Environment, No. 2, 2013.

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[14] ICRP, 2009. Environmental Protection: Transfer Parameters for Reference Animals and Plants. ICRP Publication 114, Ann. ICRP 39(6).

[15] ICRP, 2014. Protection of the Environment under Different Exposure Situations. ICRP Publication 124. Ann. ICRP 43(1).

5. VERIFICATION OF ORANO METHOD FOR ITP CALCULATION AND IMPLEMENTATION

5.1. Approach

CEPN has been contracted by Orano to conduct an independent analysis of the implementation of the substitution based on the ITP methodology. To proceed, Orano provided to CEPN a set of technical notes describing the CREATES software and the characteristics of the waste packages bound for substitution: CSD-C ([6] to [12]) and CSD-V ([13] à [18]). Furthermore, four meetings were planned by Orano allowing CEPN to meet the developers and the users of CREATE[8] and to use the software to perform calculations[9].

The approach of CEPN has been completed as followed:

1. Analysis of the CREATES calculation method;
2. Verification of the constants and the parameters;
3. Analysis of the qualification note;
4. Comparison of the results of ITP calculation performed independently with results obtained by Orano.

The results of the audits are presented in the paragraphs below.

5.2. Overview of CREATES software and the calculation methodology

5.2.1. The CREATES software

In 2016, Orano Project started the development of a calculation tool running on PC to perform calculation of equivalence between different types of waste based on the ITP. The calculation tool, named CREATES is an executable Excel macro, described notably in [1] to [4].

In practice, the user selects from a browser a source file (Excel format) compiling all the parameters of the waste package - either guaranteed parameters and additional parameters. If the source file contains the parameters of more than one waste packages, the data are presented in lines: one line per package. The data and the source file are edited by Orano La Hague at the production of the waste package.
The user then enters the integration period and run the calculation; CREATES extracts the necessary data to make the calculation from the source file without further action from the user.

After the calculation time, CREATES creates an Excel file with 3 worksheets: the first one presents the initial activities of the radionuclides of the radiological spectrum extracted (or calculated) from the source file, the second the ITP (in $m^3.y$) of each radionuclides of the spectrum and the third the relative contribution (%) of each radionuclides of the spectrum to the total ITP of the package. If the source file contains the parameters of more than one waste package, these results will be presented on several lines: one line per package. Finally, the result files can be saved for post-treatment.

5.2.2. CREATES calculation method

[8] Meetings took place 18 and 21 January 2021 at Orano Châtillon premises.
[9] Meeting took place 8 and 19 February 2021 at Orano Châtillon premises.

The calculation of the toxic potential Φ_i for each radionuclide i of the initial radiological spectrum is the first step of the calculation. To reduce the number of operations for each run of, a "toxic potential unit" (TP, in m^3/TBq^{-1}) has been defined:

$\Phi_i(t) = TP_i . A_i(t)$ were $TP_i = \frac{AWI.ECD_i}{AAEDL}$, using the notations introduced in § 3.2.

The toxic potential unit is specific to each radionuclide and is not time-dependent.

The Integrated Toxic Potential (ITP, in $m^3.y$) of one radionuclide (and its progenies) is calculating for a period of integration from t_1 to t_2 entered by the user:

$$ITP_i = \int_{t_1}^{t_2} \Phi_i(t)\,dt = TP_i \int_{t_1}^{t_2} A_i(t)\,dt$$

Two methods were available to integrate the activities over time [1]:

- A numerical method, using the CESAR software 5.3[10] to calculate the evolutions of the activities of the radionuclides in the decay series for different time steps and integrate the activities for each time step.
- An analytical method taking advantage of the general solution of the Bateman's equations. This second method was selected by Orano because of its flexibility: the activity can be calculated whatever the integration period selected by the user and without building data bank of pre-calculated results as in the first method. Furthermore, the second method requires less time by calculation and is more precise: no approximation is needed in the calculation of the integrals.

The calculated ITP_i appearing on one line in the second worksheet are then summed to calculate the ITP of the waste package (which appear in the last column). The relative contributions (ITP_i/ITP, in %) are calculated and presented in line in the third worksheet.

A few notes

1. The analytical method using the solutions of the Bateman equations was already used by BNG in the TOXIC software. NAC International audited and validated the TOXIC software.
2. The Bateman equations do not take into account the activities of the spontaneous fission products. Orano has indicated (§ 3.3 [1] and § 5.1 [3]) that the error on the ITP will be 'negligible'[11].
3. CREATES calculates the ITP of a waste package (m^3.y/package) when the ITP (and the TOXIC software used by BNG) calculated the ITP of one m^3 of waste. This difference has no impact as long as the objective is to establish an equivalence between different types of package for substitution purposes, nonetheless, it prevented to compare the results obtained by CREATES and TOXIC.

[10] The CESAR software (Simplify Evolution Applied to the Retreatment Software) has been co-developed by CEA and AREVA in the 90's to perform calculation of the evolution of the radionuclides in burnt fuel, from its cooling phase to the storage/repository. CESAR is today the software in operation at Orano La Hague. The software has been validated with DARWIN, which is the reference tool in France for the calculation of the evolution of the fuel. Therefore, CESAR is fully qualified., https://www.cea.fr/Documents/monographies/La%20neutronique%20%20Les%20applications%20de%20la%20neutronique.pdf (in French).

[11] Orano did not present quantitative element in [1] and [3]. Nonetheless, the spontaneous fission is an extremely rare phenomenon: quantitatively, the probability of spontaneous fission of the elements in a waste package are less than 1.10^{-6} % per year and the half-life of the spontaneous fission of the radionuclides is far beyond one million year (ex. $7,8.10^{15}$ y for ^{239}Pu).

5.3. The constants, parameters and the input data

Considering the overview in § 5.2, the following parameters are inserted in the calculation model:
- The TP_i of the 473 radionuclides considered in CREATES;
- The decay times and the branching ratios for these radionuclides (used in Bateman equations).

The input data are:
- The activities of the radionuclides in the radiological spectrum in the waste-package (or the population of waste packages) in the source file selected by the user;
- The bounds of the integration period: t_1 and t_2 entered manually by the user.

5.3.1. The Toxic Potential Units

CEPN compared the TP_i of the 144 radionuclides in the TOXIC database presented in Annex D of the NAC Audit with the TP_i of the 473 radionuclides of the CREATES database presented Annex 3 of [3].

The results were that:

- For the 144 radionuclides for which a comparison was possible, the TP_i of 140 of them were identical in the two databases;
- The 75 radionuclides declared by Orano (either guaranteed or nominal parameters) for CSD-C) and the 36 radionuclides declared for CSD-V are included in these 140 radionuclides
- 330 radionuclides were not featured in the TOXIC database (which is less extended than CREATES database). Indeed, BNG h chosen not to include in TOXIC database:
    - the radionuclides with short half-life compared with the time scales under consideration for repository (from 500 à 100 000 years)
    - and/or limited alpha, beta or gamma energy spectrum
    - and/or low initial activities
    - and/or low TP_i.

  The contributions to the ITP of these radionuclides were judged marginal in the ITP. It should be highlighted that this judgement cannot be ascertain because the inventory of these radionuclides is not known and not asked by the French National Waste Management Agency (Andra) who establish its own acceptance criteria (however, this last point is also supporting the judgment that the contribution of these radionuclides to the ITP is negligible).
- 3 radionuclides in TOXIC database are not presented in CREATES database (^{138}La, ^{106m}Rh and ^{170}Tm).
- One value for ^{3}H was different ($1{,}28.10^4$ $m^3.TBq^{-1}$ in TOXIC and $2{,}9.10^4$ $m^3.TBq^{-1}$ in CREATES).

CEPN has informed Orano by email about these differences (27 January 2021) and the answer was received 8 February 2021. The ^{138}La, ^{106m}Rh and ^{170}Tm do not appear in CREATES because they are not declared by Orano in the initial radiological inventory, they are not progeny of radionuclides that are declared in the initial radiological inventory and do not appear in CESAR database. When it comes to tritium, the developers of CREATES had chosen the form of tritium with the highest radiotoxicity (in this case: Organically Bound Tritium).
Overall, CEPN considers that these differences have no significant impact on the results of the ITP calculations.

5.3.2. Nuclear data

The half-life (years) and the branching ratio (%) for each radionuclide in CREATES are coming from JEFF 3.3.1 (Joint Evaluated Fission File version 3.3.1, 2009) database. This database is published by the Nuclear Energy Agency (NEA), coordinating the work of several laboratories worldwide. The database is regularly updated and has no equivalent[12].

5.3.3. The activities of the radionuclides

The radiological inventory (in TBq/waste or g/waste) is established by Orano La Hague at the time of production of the waste. Depending on the radionuclide under consideration, the value is either a guaranteed or a nominal parameter, used for product quality control and to ensure the agreement of the waste package with the specifications.
These specifications are set to ensure that the compliance with transport and storage requirements are met, and are validated by the Nuclear Safety Authority. The specifications, the guaranteed and nominal parameters are listed in [6] to [18].

The methods to assess the guaranteed and nominal parameters (by direct measurement or by calculation) is verified, audited and validated by Bureau Veritas on behalf of the customers. On this ground, CEPN did not make an independent expertise of these methods.

Concretely, CREATES extracts from the source file:

- Of a CSD-C: the activities (TBq/package) of 75 radionuclides;
- Of a CSD-V: the activities (TBq/package) of 21 radionuclides and the masses (g/package) of 15 actinides (as well as their isotopic composition (%)).

The activities (and masses) might be affected by some uncertainties which are evaluated and integrated in the product quality control process. Concerning the influence of these uncertainties on the ITP, a sensitivity analysis is presented in § 5.7.

5.4. Qualification and validation of CREATES

Reference [4] describes the qualification process of CREATES, detailing the tests performed on CREATES version 1 and the modifications leading to version 1.1 in January 2020.

The qualification of CREATES a has been performed internally by Orano by comparing:

- The results of the calculations of $A_i(t)$ for 10 values of time[13] for the 473 radionuclides in the CREATES' database obtained from CREATES with the same calculations performed with CESAR 5.3. The maximum relative differences between the results were lower than 1 %.
- The results of the calculations of ITP for 4 radionuclides over the integration period [500-1,000,000] years[14] obtained with CREATES with the same calculations performed with CESAR and integrated (trapezoidal rule). The maximum relative differences between the results were lower than 0,25 %.
- The results of the calculations of ITP for 6 radionuclides (^{3}H,^{48}Ca,^{60}Co, ^{55}Fe,^{228}Th and ^{238}U) over [500-1,000,000] years from CREATES with the same calculations performed analytically ('by

[12] Plompen, A.J.M., Cabellos, O., De Saint Jean, C. et al. The joint evaluated fission and fusion nuclear data library, JEFF-3.3. European. Physics. Journal. A **56**, 181, 2020.
[13] Precisely t = 1, 5, 10, 50, 100, 500, 1 000, 10 000, 100 000 and 1 000 000 years.
[14] The comparison cannot be performed for t > 1.10^6 years because this is the time limit in CESAR.

hand'). The maximum relative differences between the results were lower than 2.3 %, coming from differences in the number of significant figures in the coefficient of the exponentials. The calculations with the higher precision come from CREATES (100 significant figures).

- The ten radionuclides mentioned in the two bullets above were chosen to cover a wide range of half-life and radionuclides with many progenies or not.

Finally, the results obtained from CREATES and CESAR (both using JEFF 3.1.1 database) were in very good agreement. The results obtained from CREATES and an analytical method were similarly in good agreement. These results provide confidence that CREATES indeed calculate ITP accurately.

Nonetheless, the description of the integration periods chosen for some validation calculations did not appear very clearly in [4]. Furthermore, other calculations could have been performed for validation purposes. CEPN sent to Orano by email a list of questions (27 January 2021) on these topics and the answers were received 8 February 2021 orally and by email. CEPN judges that the answers were satisfactory.

Besides, Orano informed CEPN orally (21 January 2021 meeting) that several parts of CREATES and results had also been validated and/or accepted by Orano's clients:

- The methodology of CREATES and the calculation;
- The orders of magnitude of the ITP;
- Some results of calculation.

All the results obtained by Orano and the clients for the integration period [500-100 000] years were in good agreement.

5.5. Synthesis on CREATES

- The calculation method of the ITP in CREATES is compliant with the calculation of ITP as it was developed by BNG and BNFL. A few differences in methodology and numerical values had been identified by CEPN but without impact on the ITP calculations and the ratio of equivalence.
- The approach of the tool is analytical, which is the most flexible and precise method. This choice is justified in a specific technical note ([1]).
- The analytical approach is based on Bateman equations to calculate the evolution of the activities with time. This is a state-of-the art approach.
- The methodology is well described ([1], [2]) and no remarks had been formulated by CEPN.
- On the ground of the documentation that had been send, the parameters of the ITP are well inserted in CREATES.
- On the ground of the documentation and the meetings with Orano, CEPN judged that the qualification process of CREATES over the period [500-1,000,000] years is robust.
- Globally, on the ground of this analysis, CEPN concluded that CREATES is fit-for-purpose to calculate correctly and accurately ITP over the [500-1,000,000] years period.

Suggestions

- Some clarifications could be added in CREATES qualification note [4].

- The JEFF was updated in November 2017[15]. Technically, the updated data will be integrated in CESAR in the normal update process of the software, then in CREATES. CEPN estimates that there is no pressing issue: the evolutions in JEFF will not have impact on ITP calculations.

5.6. Equivalence ratio with CREATES

5.6.1. Results from Orano

Equivalence ratio had been calculated by Orano with CREATES using a sample of 20 CSD-C packages and a mean activity spectrum of CSD-V package over the [500-100,000] years integration period. Table 1 presents the means ITP (arithmetical means) for each waste package type and the equivalence ratio.

Table 1. ITP_{means} and equivalence ratio from Orano

Type of package	ITP_{mean} (m^3.y/package)	Equivalence ratio
CSD-C	$1.97.10^{11}$	$R_{CSD\text{-}V/CSD\text{-}C} = 1.11.10^{13}/1.97.10^{11} = 56$
CSD-V	$1.11.10^{13}$	-

The objective of these calculation was to gain a first insight of an estimate of the equivalence ratio and an order of magnitude of the number of waste packages bound to substitution and transport.

5.6.2. Results from CEPN

Orano planned for CEPN a first working session with CREATES (8 February 2021). To prepare the session, CEPN informed Orano about its calculation plan and the source files that will be needed (message from 5 February 2021). After a meeting with DGEC/D4 (15 February 2021), a second working session with CREATES was planned (19 February 2021).

The file source at the disposal of CEPN represented:
- The data from a sample of 20 CSD-C;
- The data from 84 CSD-V.

The next paragraphs are based on the calculations and results from the two working sessions and a final technical meeting 23 March.

First, Figure 5 presents the relative contribution (%) to the total initial[16] of each radionuclide in the waste package.

[15] https://www.oecd-nea.org/dbdata/jeff/jeff33/index.html#decay_data

[16] At the moment of the measure and/or calculation at Orano La Hague.

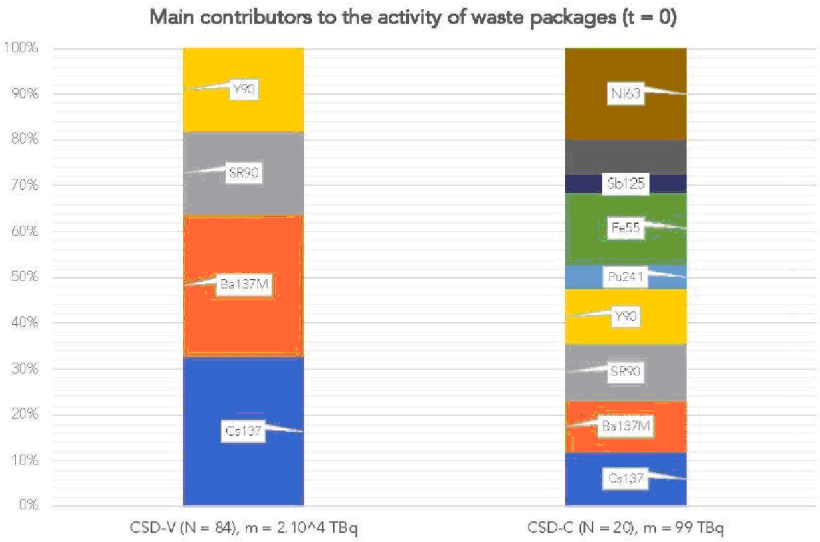

Figure 5. Main contributors to the initial activities of the CSD-V and CSD-C waste packages

The main contributors to the activity of the CSD-V packages are ^{137}Cs, ^{137m}Ba, ^{90}Sr et ^{90}Y (fission products), whereas the contributions from the radioactive isotopes of iron, steel, cobalt, antimony and nickel are dominant in CSD-C (composed of compacted structural elements, fuel rod parts and other metallic wastes [6]). It can be noted that the mean activity "m" of the CSD-V is two decades higher than the CSD-C mean activity.

The ITP_{mean} for the [500-100,000] years integration period and the equivalence ratio $R_{CSD\text{-}V/CSD\text{-}C}$ are presented in Table 2.

Table 2. ITP_{means} and equivalence ratio from CEPN.

Type of package	ITP_{mean} (m^3.y/package)	Equivalence ratio
CSD-C	$1.88.10^{11}$	$R_{CSD\text{-}V/CSD\text{-}C} = 9.68.10^{12}/1.88.10^{11} = 52$
CSD-V	$9.68.10^{12}$	-

The equivalence ratios obtained from Orano and CEPN are in good agreement.

5.7. Sensitivity analysis

The results of the calculations of ITP_{means} and the equivalence ratio can be affected by the choice of the integration period and by the uncertainties in the measurement/calculation of the initial activities. A sensitivity analysis has been completed to gain an insight of their respective influence on the results. In addition, and following DGEC/D4 request, the impact of the modification of the pathway of exposure (inhalation vs. ingestion) on the ratio has been qualitatively analysed.

5.7.1. Influence of the integration period

The integration period selected by BNFL was [500-100,000] years, and this was validated by RWMAC and the British Ministry of the Environment (§ 3.4.5). Orano used a similar integration period for its calculation with CREATES (Table 1). This period is in line with the timing of the environmental impact assessment that were considered in the 1990 for geologic repository.

Indeed, the lower bound relates to the end of the institutional control phase (i.e. the active monitoring phase of the site after the closure). This is also the time selected by the French Nuclear Safety Authority (p. 32 [19]). CEPN performed several calculations over the [1; 500] years integration period, but just for information purposes. Regarding the type of wastes and the type of repository, it is not recommended to lower the bound of the integration period below 500 years.

The upper bound is associated with the time scale conventionally used in the scenarios of environmental impact assessment. Nonetheless, the Nuclear Energy Agency stated in [20] that the timing can be extended to 1,000,000 years, giving the examples of France (cf. the Safety Report of Cigéo [21]) and in Germany. **On the ground of this elements, CEPN judges legitimate to integrate ITP over the [500-1,000,000] years period**.

5.7.1.1. First results

Figure 6 and Figure 7 present respectively the $ITP_{CSD\text{-}C,\ means}$ and the $ITP_{CSD\text{-}V,\ means}$ for different integration periods, ranging from 1 year to 1,000,000 years. Figure 8 and Figure 9 then presents respectively the $ITP_{CSD\text{-}C,\ means}$ et $ITP_{CSD\text{-}V,\ means}$ integrated for different integration periods, starting at 1 year or at 500 years.

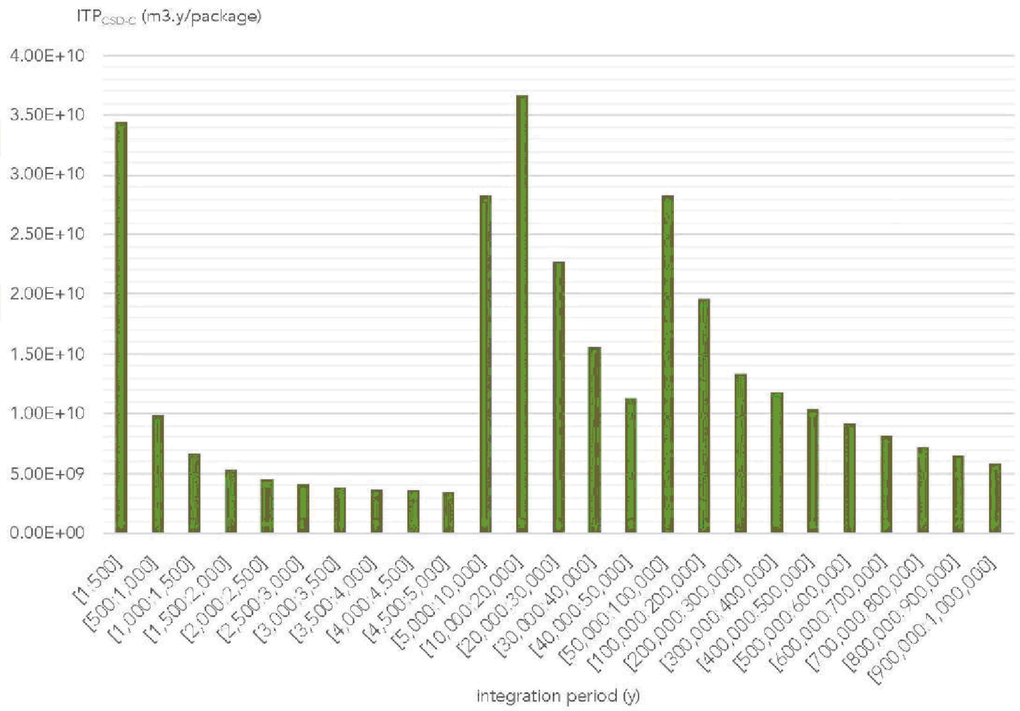

Figure 6. $ITP_{CSD\text{-}C,\ means}$ for several integration period from 1 year to 1,000,000 years

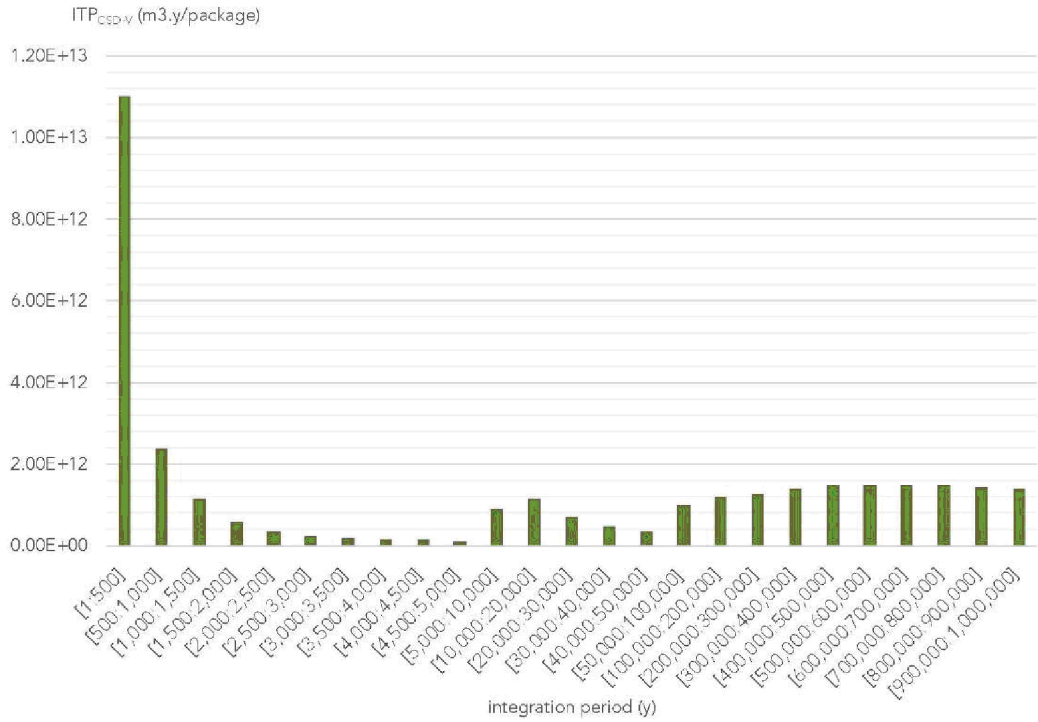

Figure 7. ITP$_{CSD-V,\ means}$ for several integration period from 1 year to 1,000,000 years

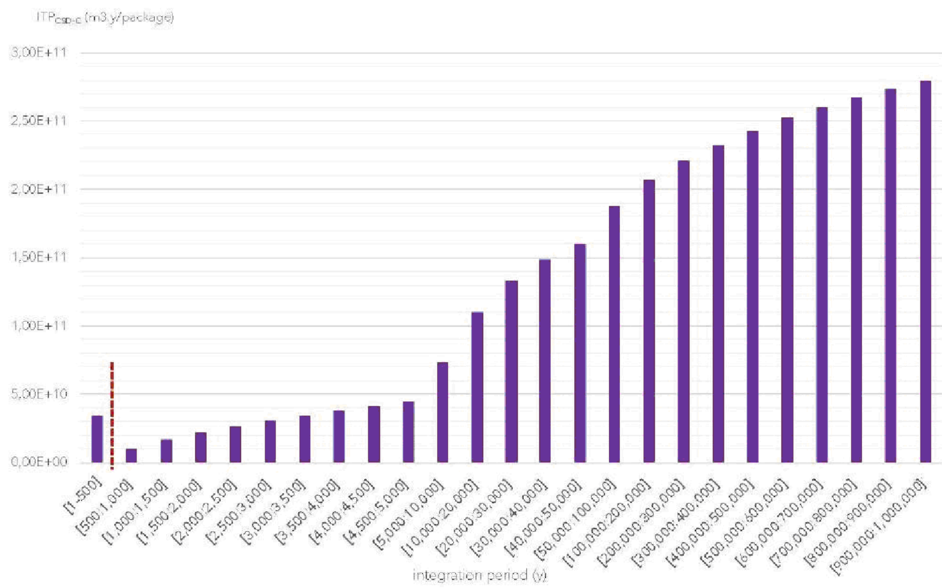

Figure 8. ITP$_{CSD-C,\ means}$ for several integration periods from [500-X] years

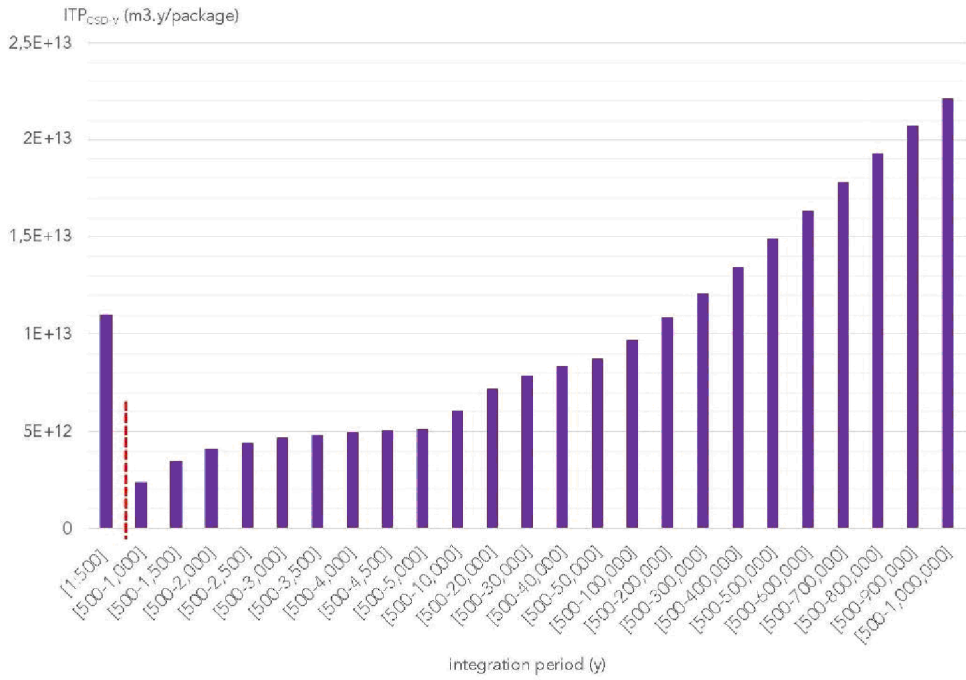

Figure 9. **$ITP_{CSD\text{-}V,\ means}$ for several integration periods from [500-X] years**

5.7.1.2. The case of the integration period [1-500] years

It is apparent on Figure 6 and Figure 7 that the ITP over the integration period [1-500] years are notably higher than the ITP over the integrations periods that come just after. That may be explained by the presence of the fission products (^{90}Sr, ^{90}Y, ^{137}Cs etc. cf. Figure 5) that contribute to ITP, then disappear after 200-300 years.

When using an [1-100,000] years integration period, the results are as follow:

– $ITP_{CSD\text{-}C,\ mean}$ is $2{,}22.10^{11}$ m^3.y/package (compared to $1{,}88.10^{11}$ m^3.y/package over the [500-100 000] years integration period, cf. Table 1).
– $ITP_{CSD\text{-}V\ mean}$ is $2{,}06.10^{13}$ m^3.an/package (compared to $9{,}68.10^{12}$ m^3.an/package over the [500-100,000], years integration period, cf. Table 1).

Therefore, the ITP on the [1-500] years period contributes to almost 50 % of the ITP on the [1-100,000] years period for CSD-V package and to around 25 % of the ITP for the CDS-C package.
These results are presented for information purpose only. **CEPN does not recommend to calculate equivalence ratio with the lower bound of the integration period below 500 years.**

5.7.1.3. Other integration periods and up to 1,000,000 years

Figure 10 synthetizes the results presented in the four graphics above by showing the evolutions of the equivalence ratio $R_{CSD\text{-}V/CSD\text{-}C}$ for different integration periods starting after 500 years.