# **BTS ENVIRONNEMENT NUCLÉAIRE**

### E4 – MODÉLISATION ET CHOIX TECHNIQUES EN ENVIRONNEMENT NUCLÉAIRE

**U41** – Pré-étude et modélisation

SESSION 2021

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###### Durée : 4 heures

Coefficient : 3

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| **CORRIGÉ** |

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|  | **1/** | **Etude dosimétrique prévisionnelle** | | | |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  | **1-1/** | **Scénario 1** |  | **Document réponse n°1** | |  |  |  |  |  |  |
|  |  |  |  | **Phase** | **Service (s)** | **Activité** | **Nb. intervenants** | **Durée en h** | **Vol. de travail en H.h** | **Cexpo** | **H° en µSv/h** | **Eindividuelle en µSv** | **S en H.µSv** |
|  |  |  |  |
|  |  |  | idem scénario n°2 | 10 | Logisitique | Montage sas | 3 | 3,0 | 9,0 | 0,5 | 60 | 90 | 270 |
|  |  |  | 20 | Mécanique | Circuits fermés | 3 | 1,5 | 4,5 | 0,8 | 60 | 72 | 216 |
|  |  |  | 25 | Circuits ouverts | 3 | 2,0 | 6,0 | 0,8 | 115 | 184 | 552 |
|  |  |  | 30 | Logisitique | Déconta. sas | 2 | 1,5 | 3,0 | 0,9 | 115 | 155 | 311 |
|  |  |  | 35 | Démontage sas | 2 | 1,5 | 3,0 | 0,5 | 90 | 68 | 135 |
|  |  |  |  | 40 | Levage | Pose vinyle | 3 | 0,25 | 0,8 | 0,9 | 90 | 20 | 61 |
|  |  |  |  | 45 | Evac. échangeur | 3 | 2,0 | 6,0 | 0,7 | 90 | 126 | 378 |
|  |  |  |  | 50 | Lev. + Méca | Pose éch. | 5 | 2,0 | 10,0 | 0,7 | 3 | 4 | 21 |
|  |  |  |  | 60 | Mécanique | Raccord. Éch. | 3 | 4,0 | 12,0 | 0,8 | 3 | 10 | 29 |
|  |  |  |  |  | **Total** |  |  | 17,8 | 54,3 |  |  |  | 1 972 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  | WT = | 1 | car exposition globale | |  |  |  |  |  |  |
|  |  |  |  | E = | H°.t.Cexpo.WT |  |  |  |  |  |  |  |  |
|  |  |  |  | S = | Nombre intervenants | x Eindiv |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  | **Scénario 2** |  | **Document réponse n°2** | |  |  |  |  |  |  |
|  |  |  |  | **Phase** | **Service (s)** | **Activité** | **Nb. intervenants** | **Durée en h** | **Vol. de travail en H.h** | **Cexpo** | **H° en µSv/h** | **Eindividuelle en µSv** | **S en H.µSv** |
|  |  |  |  |
|  |  |  | idem scénario n°1 | 10 | Logisitique | Montage sas | 3 | 3,0 | 9,0 | 0,5 | 60 | 90 | 270 |
|  |  |  | 20 | Mécanique | Circuits fermés | 3 | 1,5 | 4,5 | 0,8 | 60 | 72 | 216 |
|  |  |  | 25 | Circuits ouverts | 3 | 2,0 | 6,0 | 0,8 | 115 | 184 | 552 |
|  |  |  | 30 | Logisitique | Déconta. sas | 2 | 1,5 | 3,0 | 0,9 | 115 | 155 | 311 |
|  |  |  | 35 | Démontage sas | 2 | 1,5 | 3,0 | 0,5 | 90 | 68 | 135 |
|  |  |  |  | 40 | Levage | Pose sarcophage | 2 | 0,5 | 1,0 | 0,5 | 90 | 23 | 45 |
|  |  |  |  | 45 | Evac. échangeur | 3 | 2,0 | 6,0 | 0,7 | 9 | 13 | 38 |
|  |  |  |  | 50 | Lev. + Méca | Pose éch. | 5 | 2,0 | 10,0 | 0,7 | 3 | 4 | 21 |
|  |  |  |  | 60 | Mécanique | Raccord. Éch. | 3 | 4,0 | 12,0 | 0,8 | 3 | 10 | 29 |
|  |  |  |  |  | **Total** |  |  | 18,0 | 54,5 |  |  |  | 1 616 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  | |  | | **1-2/** | | **Bilan** |  | | **Document réponse n°3** | | | |  | |  | |  | | |  | | |  | | |  | | |
|  | |  | |  | |  | | **Scénario** | **Durée en h** | | **Vol. de travail en H.h** | **Eindividuelle maximale pour un intervenant en µSv** | | | | | | **S en H.µSv** | | |  | | |  | | |  | | |
|  | |  | |  | |  | | **Logistique** | | **Mécanique** | | **Levage** | |  | | |  | | |  | | |
|  | |  | |  | |  | | 1 | 17,8 | | 54,3 | 313 | | 270 | | 150 | | 1 972 | | |  | | |  | | |  | | |
|  | |  | |  | |  | | 2 | 18,0 | | 54,5 | 313 | | 270 | | 39 | | 1 616 | | |  | | |  | | |  | | |
|  | |  | |  | |  | |  |  | |  |  | |  | |  | |  | | |  | | |  | | |  | | |
|  | |  | |  | |  | | Le scénario 2 n'est guère pénalisant en terme de temps mais présente un avantage dosimétrique pour les opérateurs de levage | | | | | | | | | | | | | | | | | |  | | |  | | |
|  | |  | |  | | Le coût financier du sarcophage, compte tenu des maigres gains dosimétriques, peut aussi sembler  déraisonnable auquel cas considérer le scénario 1 | | | | | | | | | | | | | | | | | | | | | | | |
|  | |  | |  | |  | |  |  | |  |  | |  | |  | |  | | |  | | |  | | |  | | |
|  | **2/** | | **Origine de la contamination** | | | | | | | |  | |  | |  | |  | | |  | | |  | | |
|  |  | |  | |  | |  | | |  |  | |  | |  | |  | | |  | | |  | | |
|  |  | |  | | **2-1/** | | activation | | |  |  | |  | |  | |  | | |  | | |  | | |
|  |  | |  | |  | | 5828Ni + 10n | | | 🡪 | 5827Co + 11p | |  | |  | |  | | |  | | |  | | |
|  |  | |  | |  | |  | | |  |  | |  | |  | |  | | |  | | |  | | |
|  |  | |  | | **2-2/** | | + car rayonnement d'annihilation à 511 keV | | | | | |  | |  | |  | | |  | | |  | | |
|  |  | |  | |  | |  | | |  |  | |  | |  | |  | | |  | | |  | | |
|  |  | |  | |  | | désintégration | | | |  | |  | |  | |  | | |  | | |  | | |
|  |  | |  | |  | | 5827Co | | | 🡪 | 5826Fe + 01e+ + 00 | | | |  | |  | | |  | | |  | | |
|  |  | |  | |  | |  | | |  |  | |  | |  | |  | | |  | | |  | | |
|  |  | |  | | **2-3/** | | activation | | |  |  | |  | |  | |  | | |  | | |  | | |
|  |  | |  | |  | | 5927Co + 10n | | | 🡪 | 6027Co + 00 | |  | |  | |  | | |  | | |  | | |
|  |  | |  | |  | |  | | |  |  | |  | |  | |  | | |  | | |  | | |
|  |  | |  | |  | | désintégration | | | |  | |  | |  | |  | | |  | | |  | | |
|  |  | |  | |  | | 6027Co | | | 🡪 | 6028Ni + 0-1e + | | | |  | |  | | |  | | |  | | |
|  |  | |  | |  | |  | | |  |  | |  | |  | |  | | |  | | |  | | |
|  |  | |  | | **2-4/** | | État métastable = état du noyau formé plus excité qu'à son état fondamental. | | | | | | | | | | | | |  | | |  | | |
|  |  | |  | |  | | Ici la désexcitation n'est pas instantanée. | | | | | |  | |  | |  | | |  | | |  | | |
|  |  | |  | |  | | TAg-110m = 250 j | | |  |  | |  | |  | |  | | |  | | |  | | |
|  |  | |  | |  | | On le prend donc en compte. | | | |  | |  | |  | |  | | |  | | |  | | |
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|  | **3/** | **Dimensionnement radiologique du sarcophage** | | | | |  | |  | |  | |  | |
|  |  |  |  |  |  |  | |  | |  | |  | |  | |
|  |  |  | **3-1/** | radionucléide le plus pénalisant = 110mAg | | |  | |  | |  | |  | |
|  |  |  |  | E = | 1 505 keV |  | |  | |  | |  | |  | |
|  |  |  |  | I = | 13 % |  | |  | |  | |  | |  | |
|  |  |  |  |  |  |  | |  | |  | |  | |  | |
|  |  |  | **3-2/** | µ/ = | 0,048 cm2/g |  | |  | |  | |  | |  | |
|  |  |  |  |  |  |  | |  | |  | |  | |  | |
|  |  |  | **3-3/** |  = | 7,86 g/cm3 |  | |  | |  | |  | |  | |
|  |  |  |  | µ = | 0,377 cm-1 |  | |  | |  | |  | |  | |
|  |  |  |  | Atténuation = | eµ.x |  | |  | |  | |  | |  | |
|  |  |  |  | = | 10 |  | |  | |  | |  | |  | |
|  |  |  |  | x = | 6,1 cm |  | |  | |  | |  | |  | |
|  |  |  |  |  |  |  | |  | |  | |  | |  | |
|  |  |  | **3-4/** | rayonnement le moins pénalisant = 58Co | | |  | |  | |  | |  | |
|  |  |  |  | E = | 511 keV |  | |  | |  | |  | |  | |
|  |  |  |  | I = | 30 % |  | |  | |  | |  | |  | |
|  |  |  |  | µ/ = | 0,080 cm2/g |  | |  | |  | |  | |  | |
|  |  |  |  | µ = | 0,629 cm-1 |  | |  | |  | |  | |  | |
|  |  |  |  | Atténuation = | 46 |  | |  | |  | |  | |  | |
|  |  |  |  |  |  |  | |  | |  | |  | |  | |
|  |  |  | **3-5/** | Les atténuations des énergies inférieures à Emax sont supérieures à 10. | | | | | | | |  | |  | |
|  |  |  |  | L'atténuation globale sera donc supérieure à 10. | | | | | |  | |  | |  | |
|  |  |  |  | Le DED mesuré sera inférieur à 90/10 µSv/h | | |  | |  | |  | |  | |
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|  | **4/** | **Contrôle du confinement** | | | |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | **4-1/** | **Contrôle du confinement** | | |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  | **4-1-1/** | U = | 2,64 V |  |  |  |  |  |  |
|  |  |  |  | k = | 3,40E-03 | V.min/tr |  |  |  |  |  |
|  |  |  |  | I = | 0 |  |  |  |  |  |  |
|  |  |  |  | E = | U |  |  |  |  |  |  |
|  |  |  |  | E = | 2,64 V |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  | n = | 776 tr/min |  |  |  |  |  |  |
|  |  |  |  |  | 12,9 tr/s |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  | **4-1-2/** | J = | 1,00E-06 | kg.m2 |  |  |  |  |  |
|  |  |  |  | w = | 81,3 rad/s |  |  |  |  |  |  |
|  |  |  |  | Ecinétique = | 0,0033 J |  |  |  |  |  |  |
|  |  |  |  |  | 3,3 mJ |  |  |  |  |  |  |
|  |  |  |  | t = | 1,0 s |  |  |  |  |  |  |
|  |  |  |  | Pcinétique = | 3,3 mW |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  | = | 80 % |  |  |  |  |  |  |
|  |  |  |  | Pair = | 4,1 mW |  |  |  |  |  |  |
|  |  |  |  |  | 0,0041 W |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  | **4-1-3/** | D = | 60 mm |  |  |  |  |  |  |
|  |  |  |  |  | 0,060 mm |  |  |  |  |  |  |
|  |  |  |  | v = | 1,58 m/s |  |  |  |  |  |  |
|  |  |  |  |  | > 1,5 m/s |  |  |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |  |  |
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|  |  |  | **4-1-4/** | Ils indiquent le sens d'écoulement de l'air : de l'extérieur vers l'intérieur du sas | | | | | |  | |
|  |  |  |  | puis donc de l'intérieur du sas en passant par le filtre THE du déprimogène. | | | | |  | |  | |
|  |  |  |  |  |  |  |  |  |  | |  | |
|  |  |  |  | Confinement conforme à l'attendu (vitesse et sens d'écoulement). | | | | |  | |  | |

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|  |  | **4-2/** | **Environnement bruyant** | | |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  | L1 = | 78 dB | au poste d’observation |  | |  |  |
|  |  |  |  | L2 = | 98 dB |  |  |  |  |  |
|  |  |  |  | d2 = | 50 cm |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  | **4-2-1/** | I2/I0 = | 6,31E+09 |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  | d'2 = | 300 cm |  |  |  |  |  |
|  |  |  |  | I'2/I0 = | 1,75E+08 |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  | I1/I0 = | 6,31E+07 |  |  |  |  |  |
|  |  |  | **4-2-2/** | I/I0 = | 2,38E+08 |  |  |  |  |  |
|  |  |  |  | L = | 84 dB |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  | **4-2-3/** | Pas de préjudice particulier sur une telle durée. | | | |  |  |  |
|  |  |  |  | Les protections auditives restent toutefois recommandées. | | | |  |  |  |

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|  | **5/** | **Mise en place du sarcophage et levage** | | | | |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  | **5-1/** | **Préparation** | |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  | ME = | 2 480 kg |  |  |  |  |  |
|  |  |  |  | L = | 2,920 m |  |  |  |  |  |
|  |  |  |  | D = | 0,922 m |  |  |  |  |  |
|  |  |  |  | e = | 60 mm |  |  |  |  |  |
|  |  |  |  |  | 0,060 m |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  | V = | D2.L/4 -(D-2e)2.(L-2e)/4 | |  |  |  |  |
|  |  |  |  |  | 0,535 m3 |  |  |  |  |  |
|  |  |  |  |  = | 7,86 g/cm3 |  |  |  |  |  |
|  |  |  |  |  | 7 860 kg/m3 |  |  |  |  |  |
|  |  |  | **5-1-1/** | MS = | 4 206 kg |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  | **5-1-2/** | M = | 6 686 kg |  |  |  |  |  |
|  |  |  |  | g = | 9,81 N/kg |  |  |  |  |  |
|  |  |  |  | F = | 65 586 N |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  | **5-2/** | **Aléa de levage** | |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  | **5-2-1/** | moteur |  |  |  |  |  |  |
|  |  |  |  | n = | 1 440 tr/min |  |  |  |  |  |
|  |  |  |  | réduction | 2 500 |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  | poulie |  |  |  |  |  |  |
|  |  |  |  | n = | 0,576 tr/min |  |  |  |  |  |
|  |  |  |  |  | 0,00960 tr/s |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  | D = | 160 mm |  |  |  |  |  |
|  |  |  |  | R = | 0,080 m |  |  |  |  |  |
|  |  |  |  | w = | 0,0603 rad/s |  |  |  |  |  |
|  |  |  |  | v = | 0,00483 m/s |  |  |  |  |  |
|  |  |  |  |  | 290 mm/min |  |  |  |  |  |
|  |  |  |  |  | ≤ 300 mm/min |  |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | **5-2-2/** | U = | | 400 V | |  | |  | |  | |  | |
|  |  |  |  | I = | | 6,5 A | |  | |  | |  | |  | |
|  |  |  |  | cos = | | 0,80 | |  | |  | |  | |  | |
|  |  |  |  | PA = | | 3 603 W | |  | |  | |  | |  | |
|  |  |  |  | moteur = | | 80 % | |  | |  | |  | |  | |
|  |  |  |  | réducteur = | | 90 % | |  | |  | |  | |  | |
|  |  |  |  | PU = | | 2 594 W | |  | |  | |  | |  | |
|  |  |  |  |  | |  | |  | |  | |  | |  | |
|  |  |  | **5-2-3/** | Fmax = | | 537 546 N | |  | |  | |  | |  | |
|  |  |  |  |  | |  | |  | |  | |  | |  | |
|  |  |  | **5-2-4/** | Cs = | | 8,2 | |  | |  | |  | |  | |
|  |  |  |  | | Cs ≥ 6 | |  | |  | |  | |  | |  | |
|  |  |  |  | | v ≤ 300 mm/min | | | |  | |  | |  | |  | |
|  |  |  |  | | Les 2 critères sont validés. | | | |  | |  | |  | |  | |
|  |  |  |  | | Situation acceptable. | | | |  | |  | |  | |  | |

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|  |  | **5-3/** | **Déplacement de la charge** | | |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  | **5-3-1/** |  | vitesses | |  |  |  |
|  |  |  |  | km/h | 0,054 | - |  |  |  |
|  |  |  |  | mm/s | - | 1,0 |  |  |  |
|  |  |  |  | m/s | 0,015 | 0,0010 |  |  |  |
|  |  |  |  | vH | vL |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  | **5-3-2/** | tréac = | 1 s |  |  |  |  |
|  |  |  |  | tballant = | 2 s |  |  |  |  |
|  |  |  |  | ttotal = | 3 s |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  | dmini = | 17 cm |  |  |  |  |
|  |  |  |  | dsécu = | 10 cm |  |  |  |  |
|  |  |  |  | dparcours = | 7 cm au max |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  | v en m/s | vL | vH |  |  |  |
|  |  |  |  | 0,0010 | 0,015 |  |  |  |
|  |  |  |  | dparcours en cm | 0,3 | 4,5 |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  | les deux vitesses sont autorisées | | |  |  |  |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **6/** | **Mauvaise surprise** | | |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  | **6-1/** | t = | 2,5 h |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  | **6-2/** | H = | dose équivalente à la peau | |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  | **6-3/** |  | A en kBq | µSv/h.Bq | t en h | H en mSv |  |
|  |  |  |  | 58CO | 38,5 | 2,8E-01 | 2,5 | 27,0 |  |
|  |  |  |  | 60Co | 276,5 | 7,8E-01 | 539,2 |  |
|  |  |  |  | 110mAg | 31,5 | 6,8E-01 | 53,6 |  |
|  |  |  |  |  |  |  |  | 620 |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  | **6-4/** | H > dose annuelle autorisée | |  |  |  |  |
|  |  |  |  | ESR classé INES (1 ou 2) | |  |  |  |  |
|  |  |  |  | déclaration à l'ASN | |  |  |  |  |