Evaluation of radioactive concentration produced in electric equipments and materials on the decommissioning of nuclear power plants

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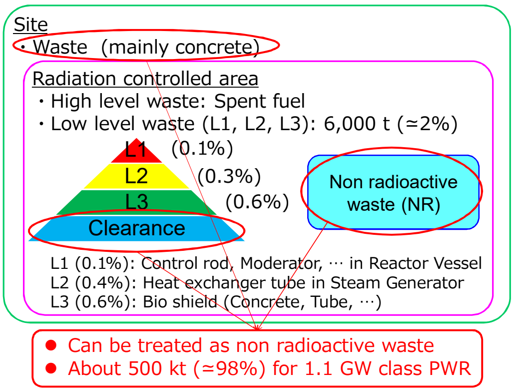
1. Introduction

- ✓ The aging nuclear power plants will increase in the coming decades, and most of them are expected to be decommissioning
- ✓ If the part of waste generated in the decommissioning could be treated as non-radioactive wastes, the amount of radioactive waste could be reduced
- ✓ Furthermore, valuable resources such as copper which used in electric equipments can be recycled, and that contributes to the efficient use of resources
- ✓ Activation of copper materials used in electric equipments have not been evaluated



2. Objective

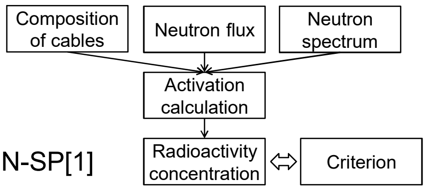
- ✓ Evaluate the radioactive concentration produced in copper material

3. Method

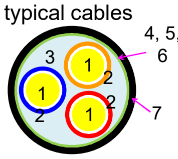
(1) Analysis of target material composition
- ✓ SEM/EDX and ICP-OES analysis for principal component
- ✓ Activation analysis for minor component at UTR-KINKI

(2) Estimation of neutron spectrum and flux at target position
- ✓ Focused on thermal neutron

(3) Evaluation of radioactivity concentration using PHITS3.17/DCHAIN-SP[1]
- ✓ Screening the radioisotopes to be evaluate



Cross sectional view of typical cables



1. **Conductor (Copper)** 2. Insulator 3. Jute 4. Tape 5. Shield 6. Tape 7. Sheath

Variable resource expected to be recycled

4. Results

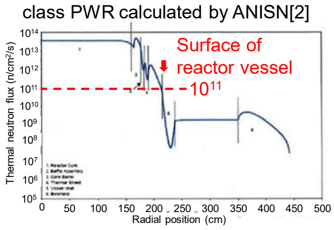
(1) Analysis of material composition
- ✓ Principal component of conductor: Cu
- ✓ Detected Ca and Sn as trace element

Composition of conductor

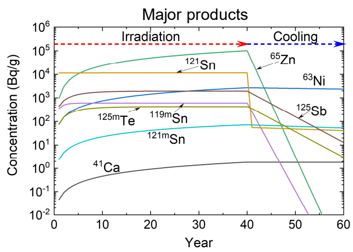
Element	Composition (wt%)
Cu	99.95
Ca	1.192×10^{-3}
Sn	0.051

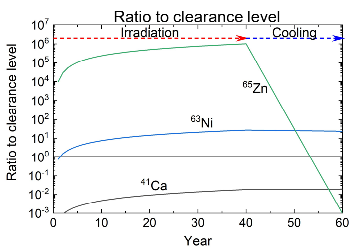
(2) Estimation of neutron spectrum and flux at target position
- ✓ Most of cables are located outside reactor vessel in PWR
  ➔ Focused on thermal neutron
- ✓ Refer to a typical neutron flux
  ➔ 10^{11} n/cm²/s EPRI report[2] (most conservative evaluation)

Radial thermal neutron flux of 1 GW class PWR calculated by ANISN[2]



(3) Evaluation of radioactivity concentration
- ✓ ^{41}Ca, ^{63}Ni and ^{65}Zn was generated ($^{119,\,121,\,121m}$Sn, ^{125}Sb, ^{125m}Te are excluded from clearance)
- ✓ Radioactive concentration of ^{63}Ni and ^{65}Zn are greater than the clearance criterion at 40 years





Target	$T_{1/2}$	CL (Bq/g)	40 y	50 y	60 y
^{41}Ca	1.03×10^{5} y	100	1.85	1.85	1.85
^{63}Ni	101.2 y	100	2.71×10^{3}	2.53×10^{3}	2.36×10^{3}
^{65}Zn	244.06 d	0.1	1.02×10^{5}	3.16	9.81×10^{-5}

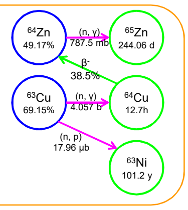
5. Discussion

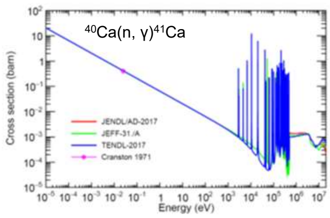
- ✓ Calculation results of PHITS3.17/DCHAIN-SP agree with analytical calculation
- ✓ ^{63}Ni is dominant in the residual radioactivity after 10 years from reactor shutdown
- ✓ Direct measurement of ^{63}Ni is difficult due to the low energy beta ray emission ➔ Calculation based evaluation
- ✓ Uncertainty evaluation of activation cross section is important
- ✓ The cross section of ^{63}Cu(n, p)^{63}Ni have large difference between libraries ➔ Important to uncertainty evaluation

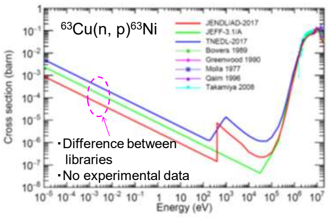
Product	Concentration (Bq/g) PHITS3.17/ DCHAIN-SP	Analytical solution
^{41}Ca	1.85	1.90
^{63}Ni	2.71×10^{3}	2.85×10^{3}
^{65}Zn	1.02×10^{5}	1.06×10^{5}

$$A=\frac{c_i N_A}{M}\Phi\sigma\left(1-e^{-\lambda t}\right)$$

M: Atomic mass of target
C_i: Isotopic composition
N_A: Avogadro constant
λ: Decay constant of product
t: Irradiation time







6. Conclusion

- ✓ Radioactive concentration of ^{63}Ni and ^{65}Zn in the cable near the reactor vessel may exceed the clearance criterion
- ✓ To improve the evaluation of radioactivity concentration, the uncertainty evaluation of activation cross section will be important

Reference

[1] T. Sato, et. al., J. Nucl. Sci. Technol. 55, p.684-690 (2018).
[2] A. Freitag, et. al., EPRI 1008018, (2003).
[3] K.Shibata, et. al., JAEA-Conf 2016-004, p.47-52, (2016).