Dose reconstruction after the overexposure of a nuclear diver handling mistakenly highly activated materials

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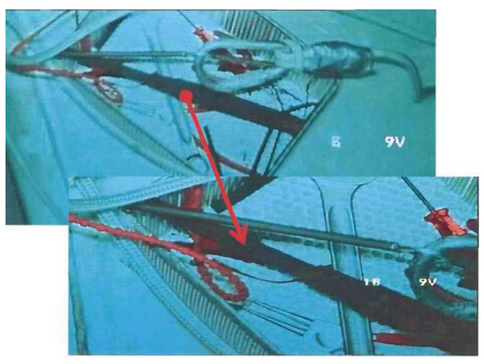
1. Introduction

- During the 2010 outage of the Leibstadt NPP, a diver performed maintenance work in the fuel transfer pool. After completing his work, he recovered a highly activated object.
- The diver's ring dosimeter measured $H_p(0.07)$ of 1.1 Sv to the right hand while whole body dosimeters indicated $H_p(10)$ values between 19 and 40 mSv.

Underwater picture of the object that was identified as a lost piece of a dry tube of 30 cm length that had been unnoticed in 2006 outage.



2. Objectives

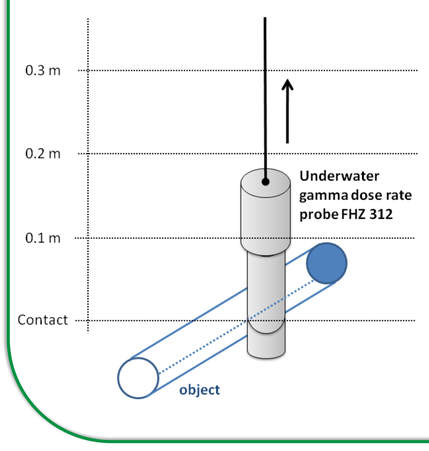
- This study aimed at assessing both diver's skin dose to the hand and effective dose by performing dose reconstructions based on analytical calculations and Monte Carlo (MC) simulations associated with numerical phantoms.

3. Materials and methods

1. Activity estimation

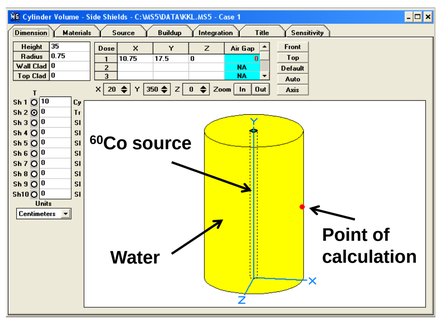
- The activity was estimated by comparing dose rate measurements at several distances of the object under water with dose rates per unit activity of ^{60}Co calculated in water using MicroShield® and MCNPX 2.5.0.

Geometrical configuration of underwater dose rate measurements at several distances

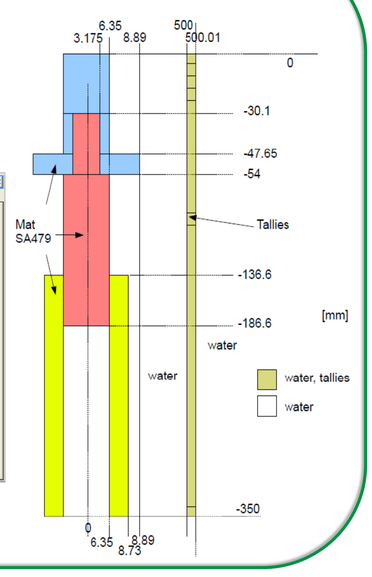


Geometrical description of the object for dose rate calculations using :

- MicroShield®-



- MCNPX -

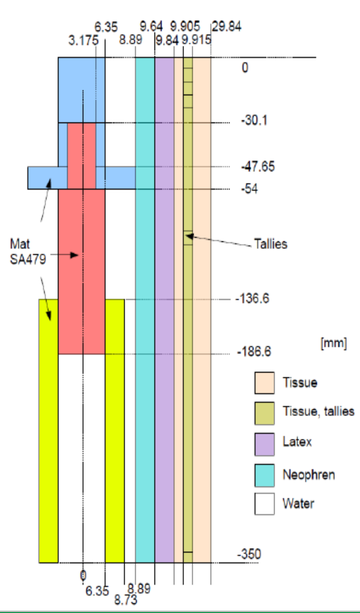


- The activity was also obtained through activation calculation using the estimated neutron fluence on the dry tubes after 22 years residence in the core, i.e. $2.9 \cdot 10^{13}$ cm^{-2}·s^{-1}.

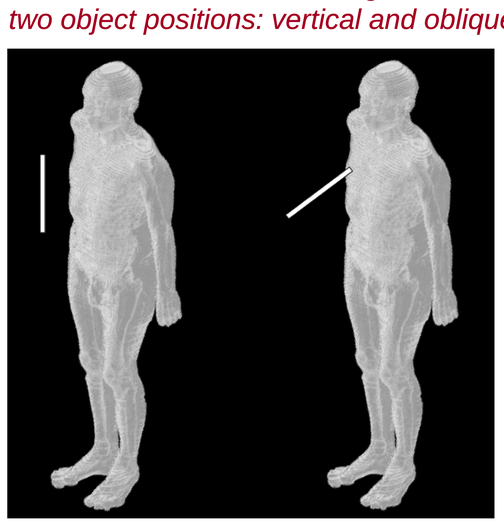
2. Personal dose estimation

- For the hand, the absorbed dose at 0.07 mm tissue depth was calculated with MC considering various distances between skin surface and object.
- The effective dose derived from dosimeter measurements was compared with the one obtained by MC using the ICRP reference voxel phantom and different positions of the objet relative to the phantom.

Geometrical description for hand dose calculations using MCNPX



Geometrical description for organ and effective dose calculations using MCNPX with two object positions: vertical and oblique



Results

1. Activity estimation

Dose rate measurements in water

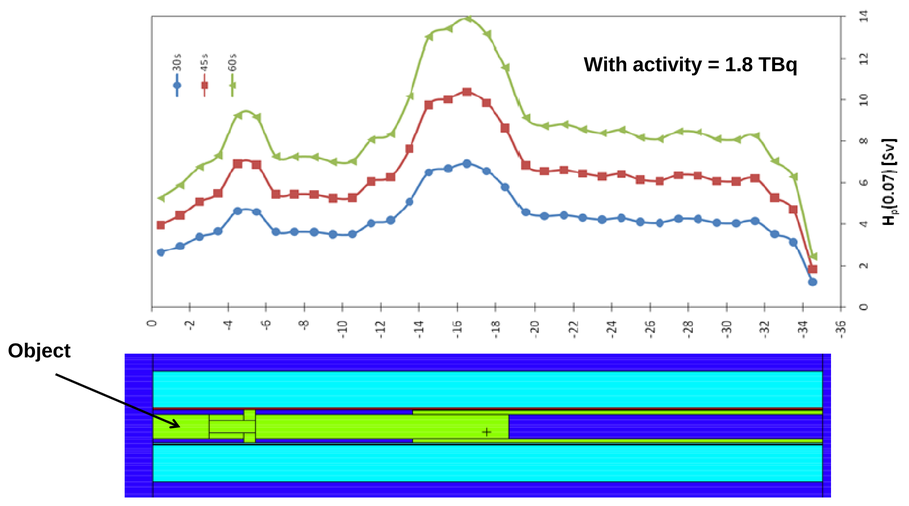
Calculations for 100 GBq of ^{60}Co

- The dose rate scaling approach gave 2.3 TBq.
- The neutron activation approach gave 1.2 TBq.
- The average activity of the object was 1.8 TBq (range, 0.9-2.8 TBq).

2. Personal dose estimation

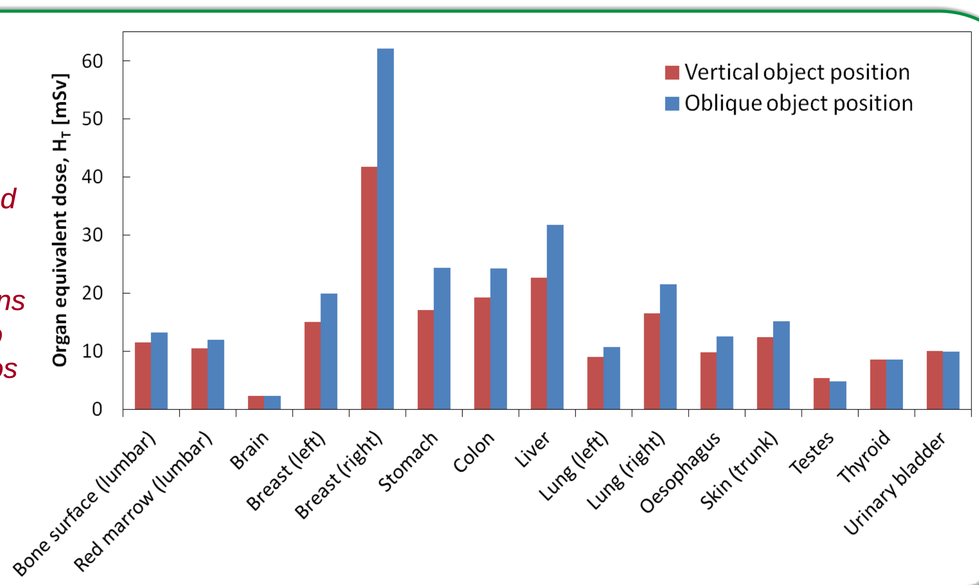
- The skin dose to the hand in contact with the object was calculated between 3.5 and 13.9 Sv depending on the scenarios.
- For a likely handling time of 45 s, the contact skin dose was 7.5 Sv (range, 5.3-10.4 Sv).
- If the object was not in contact but located at 2 cm from the ring dosimeter, the calculated dose is between 1.0 and 3.3 Sv. Those values are compatible with the measured $H_p(0.07)$ of 1.1 Sv.

MC-calculated doses to skin in contact with the object at different positions along the object length for three handling times (30, 45 and 60 seconds)



- The effective dose was estimated to 28 mSv combining dosimeters from routine monitoring and 14 mSv using MC simulations associated with the ICRP voxel phantom.

MC-calculated equivalent doses for selected organs according to both scenarios



Conclusions

- We retained a MC-calculated skin dose of 7.5 Sv for the hand, which corresponds to the most probable maximum dose.
- For the effective dose, the value of 28 mSv derived from individual routine monitoring was registered because the uncertainties related to the positions of the object during the diver's move make hard to obtain a better estimate using MC calculations.
- MC-based dose reconstructions provide valuable information when phantoms measurements are not feasible due to radiation safety limitations.