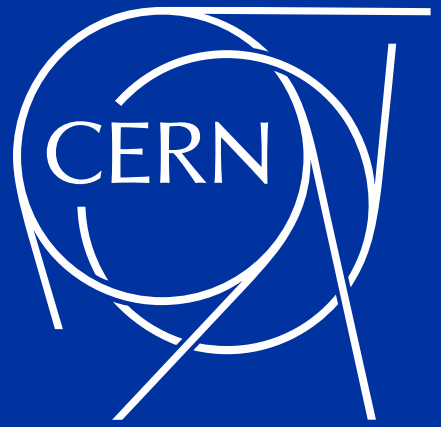

Radionuclide inventory of burnable radioactive waste contaminated with artificial alpha-emitters

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Contents

Radioactive waste at CERN

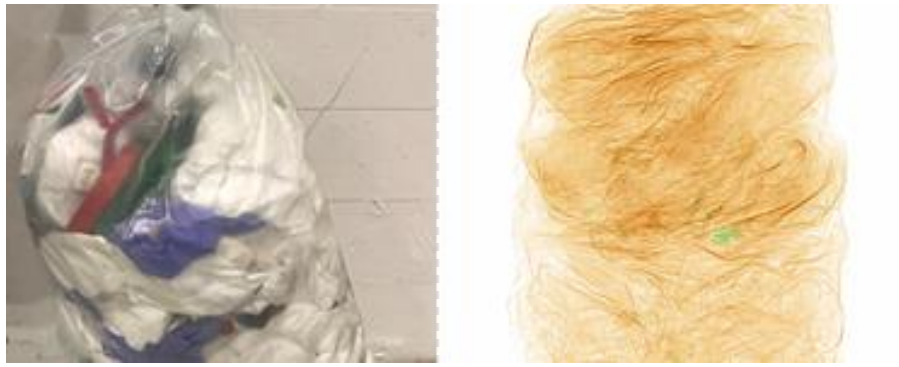
CERN's RW Classification		Elimination pathways
Clearance candidates - CL (Candidats à la Liberation inconditionnelle)	Release from regulatory control in **Switzerland** (Clearance <> "free-release")	AMAL, EVA, B-FREE, PLATAN, CRANES, etc.
Very Low-Level Waste - TFA (Très Faibles Activités)	Surface disposal in **France.** As defined by the acceptance criteria of the ANDRA CIRES repository	**BEEP-ABG**, BEEP-BG, ELICA, ELMA, SHERPA, ELFI, etc.
Intermediate & Low-Level Waste - FMA-VC (Faibles et Moyennes Activités à Vies Courtes)	Surface disposal in **France** Half life $T_{1/2}$ < 30y As defined by acceptance criteria in ANDRA CSA repository	ABEILLE, MAST, etc.
Intermediate & Low-Level Waste - FA-MA (Faibles Activités et Moyennes Activités)	Disposal in **Switzerland** When FMA-VC acceptance criteria (half-life, activity level) are not met	STEP-1, ITEP, STEP-2, etc.

93% in volume of the waste stored at CERN belongs to the category of TFA

Burnable radioactive waste

Type of waste

- Mostly personal protection equipment
  - Gloves, fabrics, Over-shows, etc.
- ventilation filters.



BEEP-Free

- Elimination with free release in Switzerland

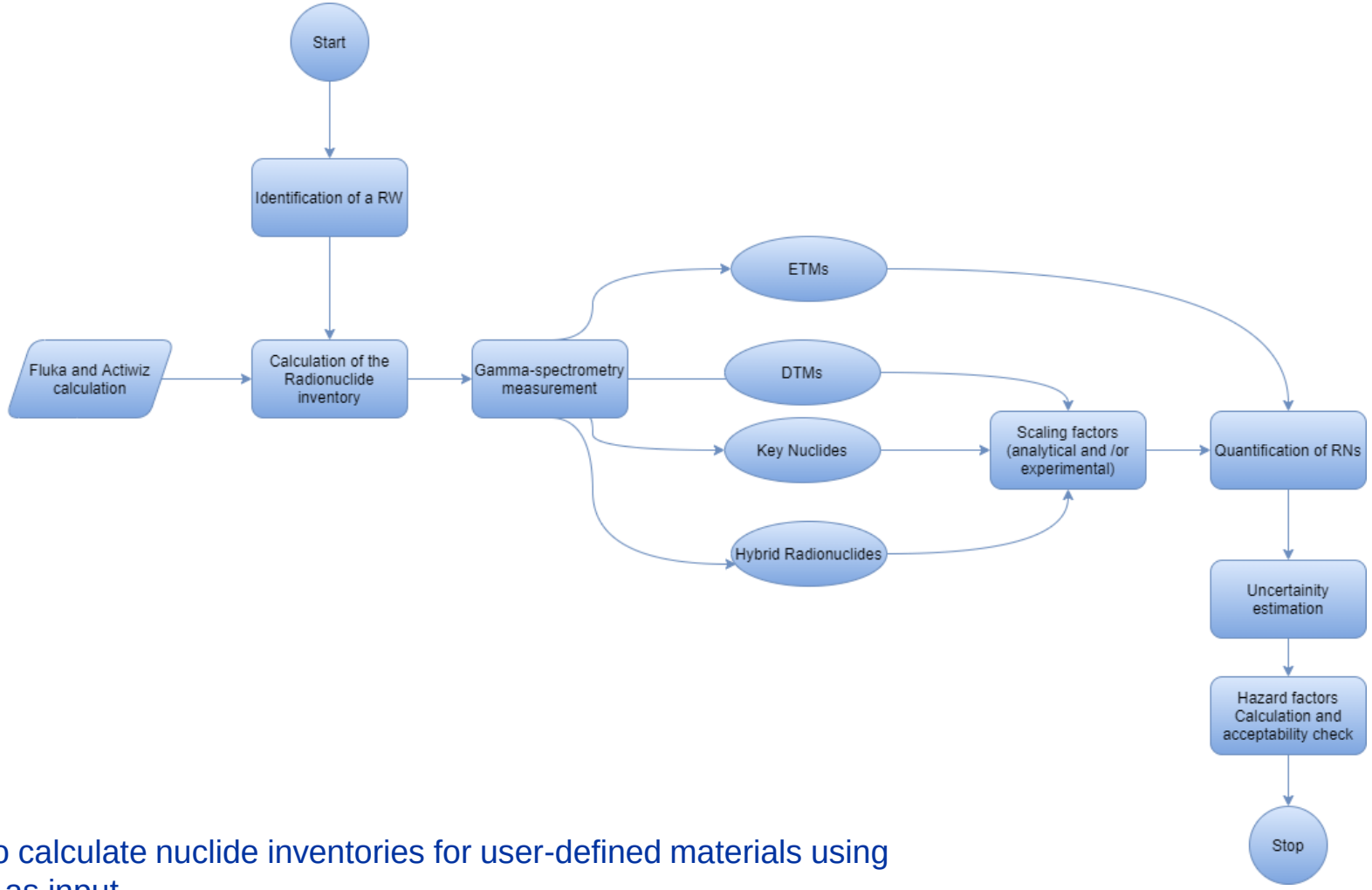
BEEP-BG

- Contamination by activated metallic particulates or concrete dust

BEEP-ABG

- Contamination in the manufacturing and handling of spallation targets (n_TOF) and ISOLDE

Characterization of TFA



Actiwiz creator allows to calculate nuclide inventories for user-defined materials using particle fluence spectra as input

Courtesy of B. Zaffora, M. Magistris

Challenges for predicting BEEP-ABG RN inventory

- **Wide range of activation scenarios**
  - Targets of ISOLDE and n_TOF facilities – target core and structural materials
- **A sampling strategy is not adequate given the heterogeneity of the waste**
  - Hence relying only on FLUKA simulation and analytical calculation
- **A longer list of DTMs**
  - Targets made of actinides produces virtually any radionuclide from nuclides table.
  - Alpha emitters DTMs: Gd-148, Po-210, etc.

ISOLDE and n_TOF

- **n_TOF targets**
  - Made of lead block
  - Kept together by stainless steel frame (target1) , or in aluminum (target2)
  - Alpha emitters come from direct contamination
  - n_TOF target #1 : 2000-2004
  - n_TOF target #2 : 2008-2018
- **ISOLDE targets**
  - Different targets materials
  - Potential alpha emitters come from Uranium, Lead and Tantalum targets
  - Targets are irradiated from few days up to couple of weeks

N-TOF

ISOLDE

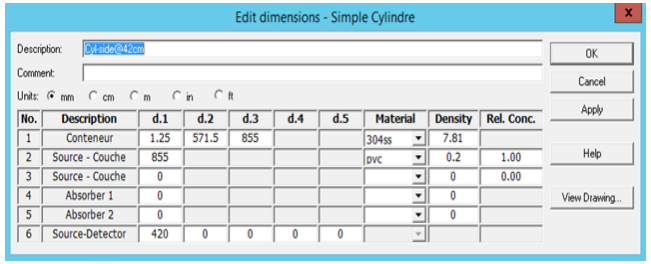
Radionuclide inventory

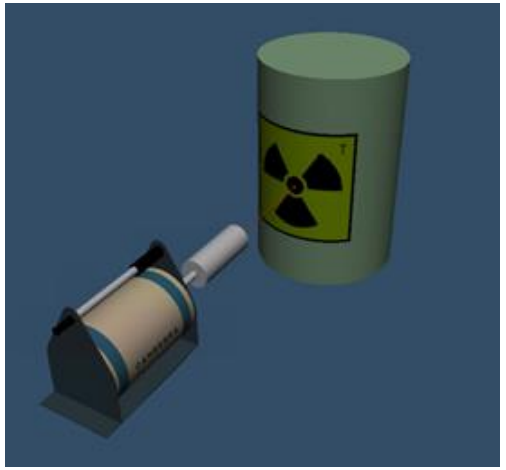
- **Predicting Fluence spectra for the targets – FLUKA simulation**
- **Establishing the full list of radionuclide inventory – using Actiwiz**
  - For most relevant targets
  - For different irradiation times
  - For cooling times ranges from, 6 month – 30 years
- **Reduced radionuclide list – (under certain criteria and assumptions)**
  - Ex: Normalization to hazard factor IRAS = 10.
  - Half-life > 6 months
  - Excluded radionuclides (natural radionuclides): Th-232, Ra-226 and K-40.
- **typical radionuclides of uranium contamination were added – associated with target production**

Radionuclide	ETM/DTM/Hybrid
Mo-93	DTM
Nb-93m	DTM
Tc-99	DTM
Cd-113m	DTM
Sn-119m	DTM
Cs-137	ETM
Ce-144	ETM
Pm-145	ETM
Sm-145	ETM
Pm-147	DTM
Gd-153	ETM
Tb-157	DTM
Lu-174	ETM
Hf-178n	ETM
Po-208	DTM
Po-209	DTM
Pb-210	DTM
Ac-227	DTM
Ra-228	DTM
Th-228	DTM
Pa-231	DTM
U-232	DTM
U-234	DTM
U-235	Hybrid
Pu-236	DTM
Np-237	DTM
Pu-238	DTM
U-238	ETM
Pu-239	DTM

Gamma spectrometry Analysis

- **Gamma spectrometry to quantify MDA for each radionuclide**
- **Based on the MDA value, a radionuclide can be classified to**
  - ETM – MDA < 0.5 declaration threshold (criteria set by waste repository)
  - Hybrid – 0.5DT<MDA < DT
  - DTM – MDA > DT, or no MDA (not a gamma emitter)
- **Measurement set-up specifications**
  - 42 cm between the drum and the detector,
  - 1800 seconds counting time,
  - Geometry is standardized,
  - Double measurements every 20 drums (random quality controls),





Scaling Factors

- **Analytical scaling factors**
  - Obtained by a ratio between specific activity of KN and DTM/hybrid
- **Experimental Scaling factors**
  - Obtained by radiochemical analysis of samples
  - For BEEP-ABG
    - Experimental SFs were only included for structural material of the target, taken from SHERPA
    - For target core, only analytical scaling factors were considered
- **relying exclusively on Monte Carlo and analytical calculations (for contamination with alpha)**
- **Agreement between analytical and experimental SFs were shown in previous studies**

	6 months to 3 years					
KN	Ru-106	Bi-207	Hf-172	U-238	Na-22	Co-60
DTM/Hybrid						
H-3	1.8	306.7	1.4		3.3	2.7
Be-10						
C-14					3.9E-03	
Cl-36						
Ar-39						
Ca-41					9.2E-04	
V-49						3.2
Fe-55					17.7	43.2
Ni-63						1.1
Zn-65	3.7E-03	0.4	3.0E-03			
Ge-68	9.1E-04	0.2	9.5E-04			
Kr-85	2.8E-02	0.6				
Sr-90	0.1	0.8				
Mo-93		1.2E-03				
Nb-93m						
Tc-99						
Ag-108m	2.7E-04	4.8E-03	5.3E-06			
Cd-113m						
Sn-119m	0.3					
Sb-125	0.3	0.1				
Pm-147	0.2					
Gd-148	2.7E-04	0.3	1.4E-02			
Eu-152						
Tb-157						
Ta-179	3.3E-02	25	3.1			
Pt-193		10				
Au-195	2.5E-02	80				
Pb-202						
Tl-204		184.1				
Po-208	0.1					
Po-209						
Pb-210	7.1E-03					

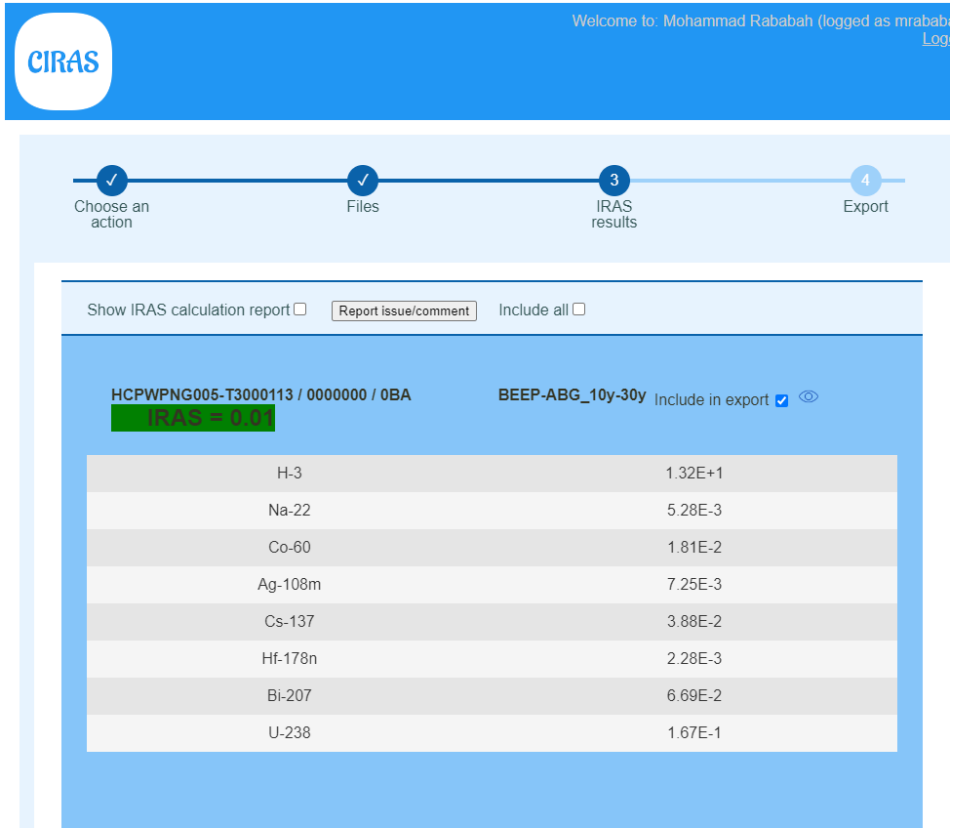
Calculation of hazard factor - IRAS

- **Extracts from gamma-spec**
  - Meta data, Detected radionuclides, MDA
- **Apply the criteria**
- **calculate activities**
  - Activities of ETMs
  - Activities of DTMs/Hybrid
- **Calculate IRAS**
  - $IRAS = \sum_i \frac{a_i}{L_i}$,
  - a_i is the specific activity and L_i the reference activity limit for the radionuclide *I*

Example of different criterion for different RN type	
Radionuclide	Radionuclide
ETM	• activity contributes to IRAS if it is > DT(ANDRA) • activity maybe reported activity or MDA
Hybrid	• detected activity, • if not, calculated activity(KN_activity, SF_KN)
DTM	always calculated activity with SFs (analytical or experimental)

CIRAS

- **To calculate the IRAS factor of a waste package**
  - **from the results of the gamma spectrometry reports and**
  - **from a set of scaling factors,**
- **To establish the list of radionuclides and their activities**
- **User friendly**
- **Possibility to add new elimination pathways and modify input data**

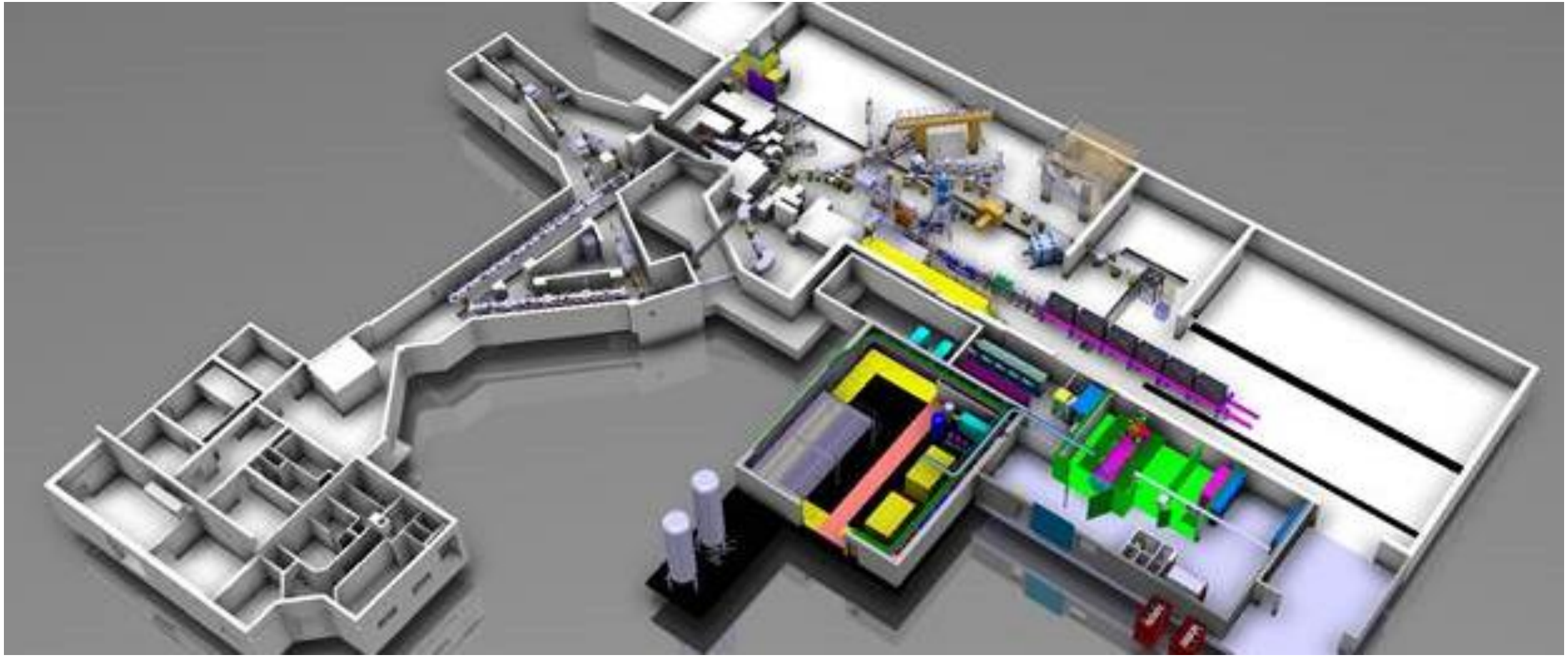


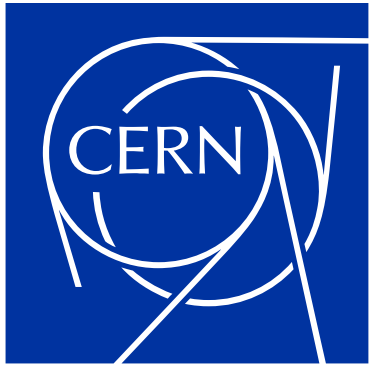
Acknowledgement to Xavier Eric Ouvrard, the software developer.

Conclusion

- **The methodology comprised several steps**
  - Monte-Carlo Fluka simulation
  - Actiwiz calculation
  - Gamma-spectrometry analysis
  - Criteria application
  - Establishing final radionuclide inventory, activities, IRAS.
- **This methodology can be extended to other waste produced at similar facilities or research laboratories**

Questions





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