Experimental investigation of adsorption materials for the mitigation of civilian radioxenon releases

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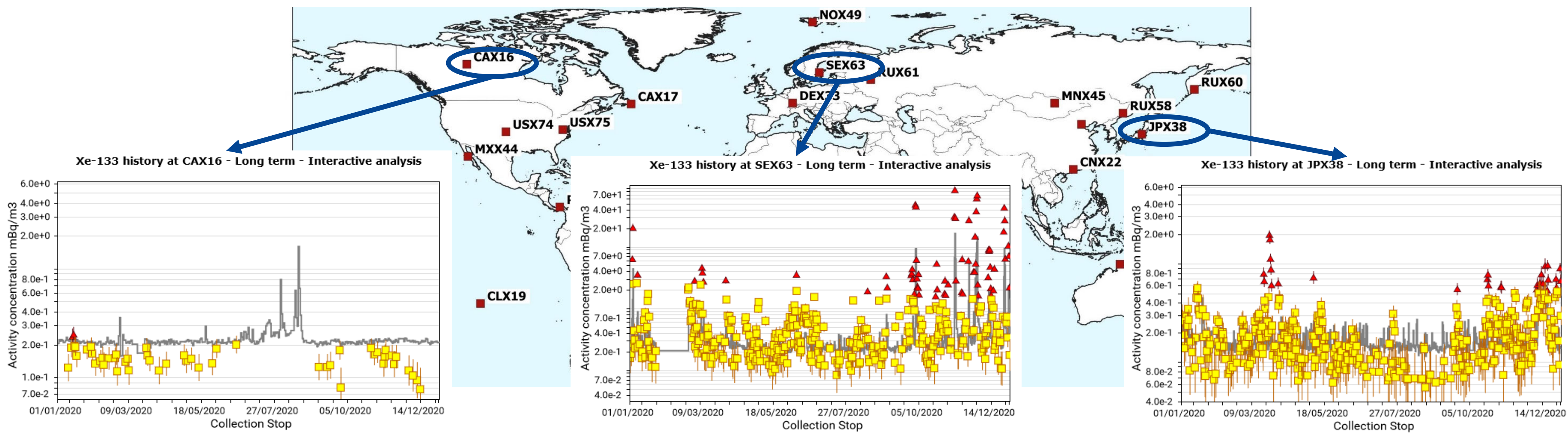
Introduction

- Radioxenon is a key component for the verification of the CTBT
- Detection capability of the IMS noble gas component depends on
  - Number and distribution of stations (31/40)
  - Minimum Detectable Concentration (< 1mBq/m^3 for Xe-133)
  - Background level from civilian sources at individual stations



Introduction

- Current Xe adsorption materials used for Xe mitigation
  - "Noble gas" activated carbons
    - Large volumes or chilled, risk of ignition

- Reasonable upper release level of 5 GBq/day proposed by Bowyer et al. 2013
- Reduction to 5 GBq/day = huge challenge for existing facilities
- **Silver-doped zeolites ?**

➔ How can new Xe adsorption materials support such a reduction ?

Bowyer, T.W., Kephart, R., Eslinger, P.W., et al. 2013. Maximum reasonable radioxenon releases from medical isotope production facilities and their effect on monitoring nuclear explosions. J Environ Radioactiv 115, 192-200.

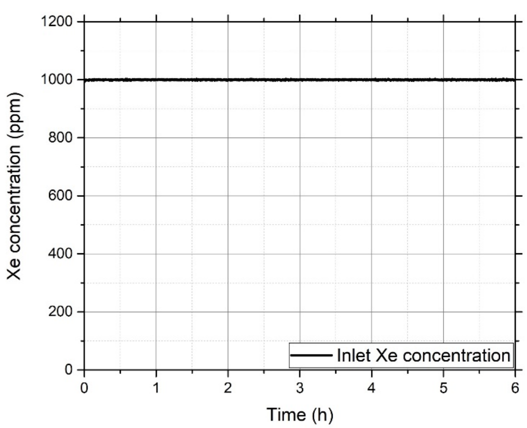
Experimental set-up

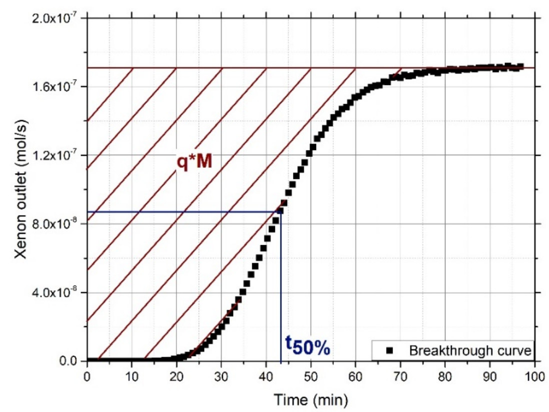
- Collection of Xe breakthrough curves on adsorption materials in different conditions
  - Xe concentration, gas carrier, moisture content, flow rate, …

Inlet

Adsorbent

Outlet





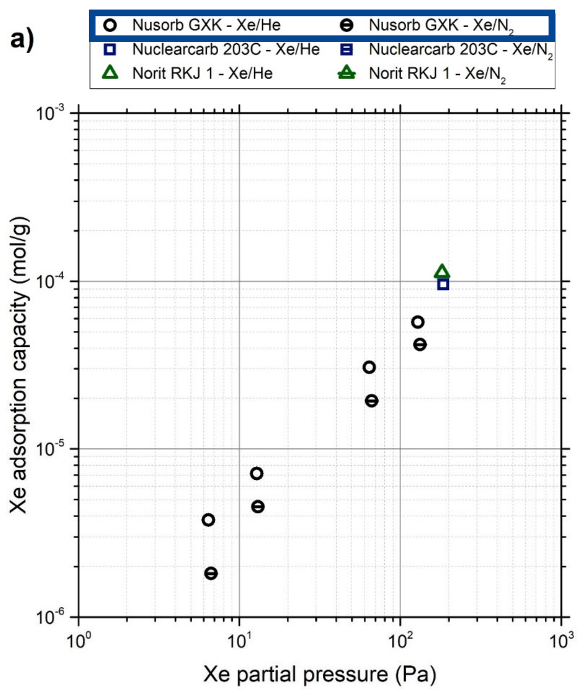
Selection of adsorption materials

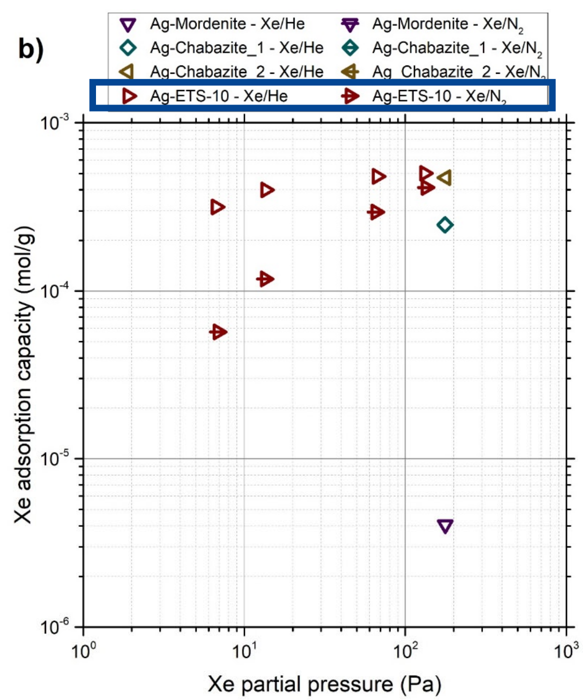
- 3 typical activated carbons as reference and 4 silver-doped zeolites for comparison

Supplier	Type of material	Material Name	Density (g/cm^3)	Ag (% in weight)
Cabot Norit Nederland B.V.	Activated carbon	NORIT RKJ 1	0.52	NA
NUCON International Inc.	**Activated carbon**	**NUSORB GXK**	**0.50**	**NA**
Chemviron Carbon	Activated carbon	NUCLEARCARB 203C	0.57	NA
Sigma Aldrich Co.	Silver-doped zeolite	Ag-Mordenite	1.07	10-15
Extraordinary Adsorbents	**Silver-doped zeolite**	**Ag-ETS-10**	**1.07**	**25-30**
Extraordinary Adsorbents	Silver-doped zeolite	Ag-Chabazite_1	0.57	10-15
Extraordinary Adsorbents	Silver-doped zeolite	Ag-Chabazite_2	0.63	25-30

Comparison of Xe adsorption capacity

- Xe adsorption capacity in He and N_2 *(work in progress)*
  - 50, 100, 500 and 1000 ppm Xe @ 1.3 bar, 23°C, 400 sccm, dry





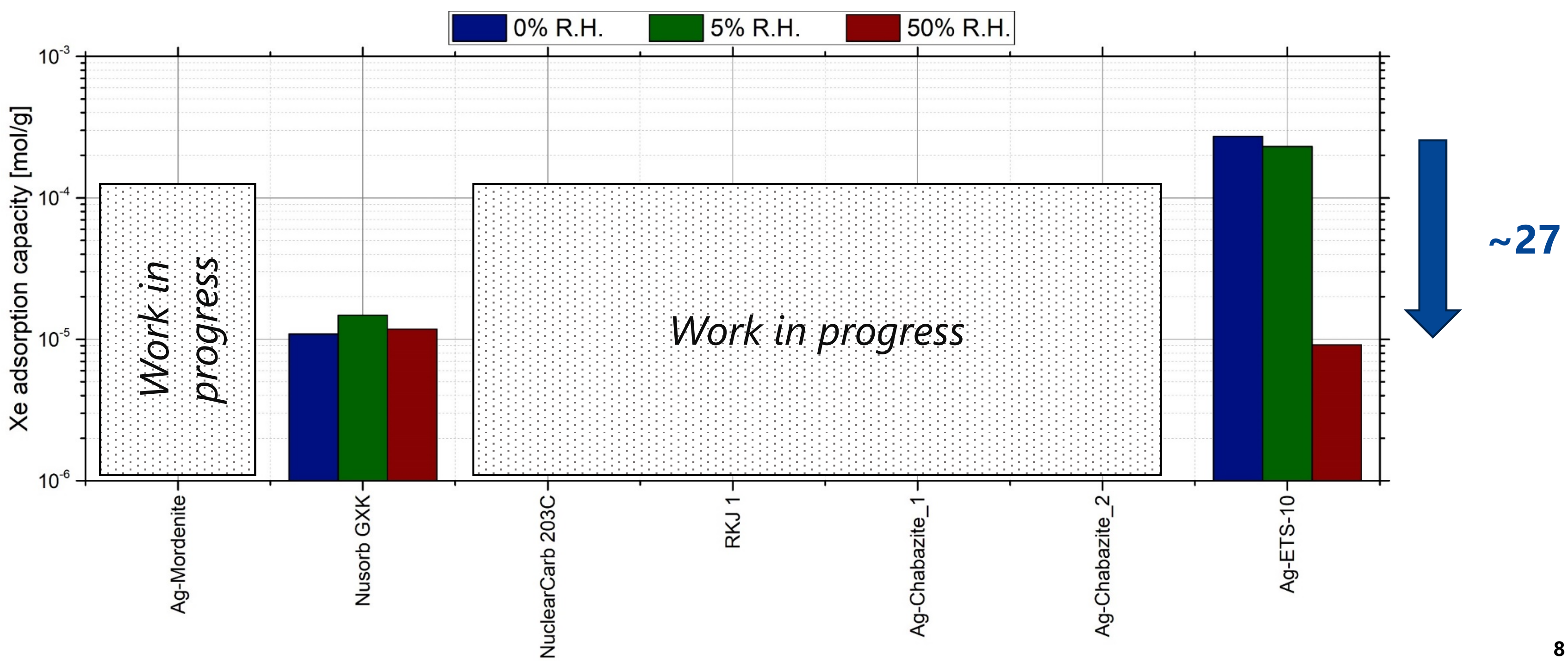
$$\frac{Ag - ETS - 10}{Nusorb\ GXK}$$

Xe conc. (ppm)	Carrier gas	
	He	N_2
50	83.6	31.5
100	55.8	26.1
500	15.7	15.3
1000	8.8	9.8

Volume ➔ X 2 !

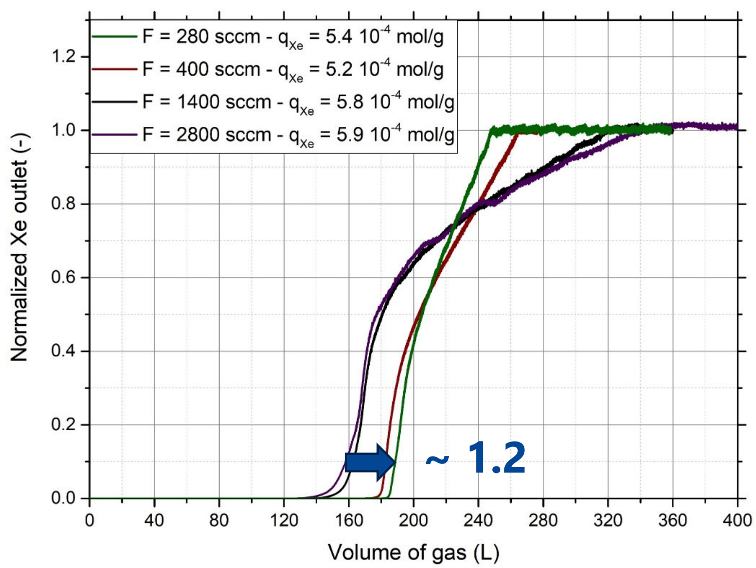
Comparison of Xe adsorption capacity

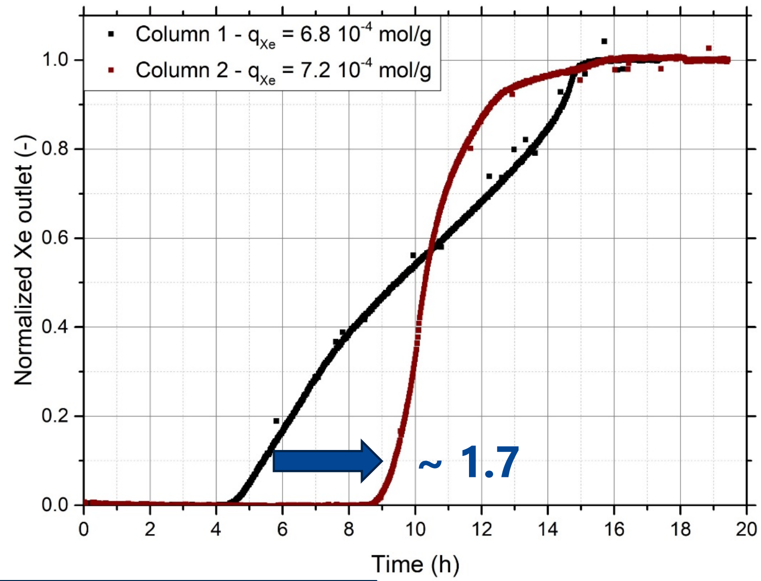
- Xe adsorption capacity in N_2 with different R.H. levels *(work in progress)*
  - dry, 5% R.H. and 50% R.H. @ 1.3 bar, 250 ppm Xe, 23°C, 400 sccm



Applicability of the Ag-ETS-10 zeolite

- Effect of flow rate and column geometry
  - 280, 400, 1400 and 2800 sccm @ 1.3 bar, 1000 ppm Xe in He, 23°C, dry
  - Column 1 (D = 3 cm L =3.3 cm) @ 400 sccm
  - Column 2 (D = 2 cm L = 7.6 cm) @ 400 sccm

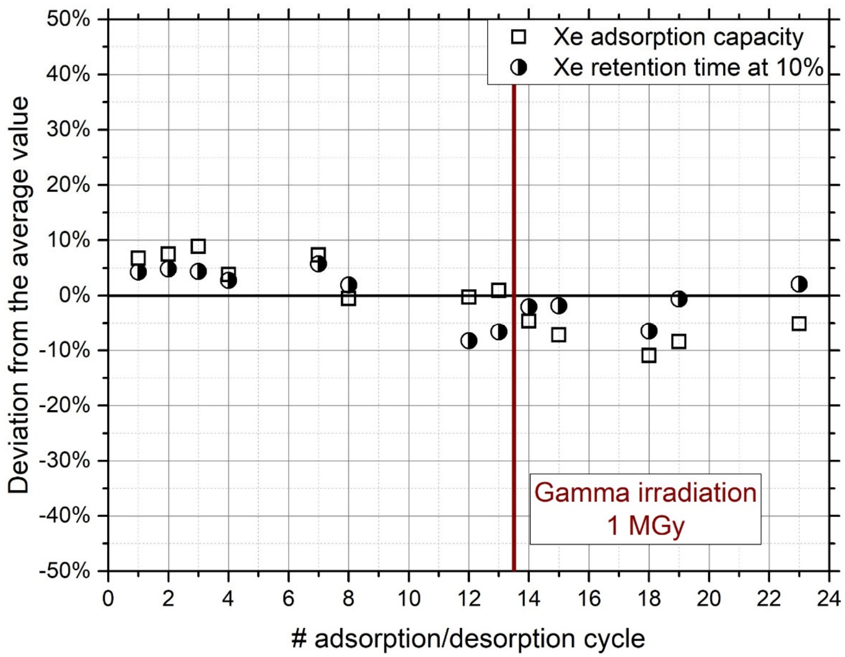




Optimization of the column design

Applicability of the Ag-ETS-10

- Durability against adsorption/desorption cycles ➔ 23 cycles
  - Adsorption with 1000 ppm Xe in He and desorption under He at ~ 200°C
- Exploration of the durability against gamma irradiation ➔ 1 MGy



No significant degradation observed

For 100 TBq of Xe-133 on 21.6 g of adsorbent ➔ 1 MGy / 3 h !!!

Conclusions

- Ag-ETS-10 has a significantly higher Xe adsorption capacity and retention time than AC at room temperature and for concentrations ≤ 1000 ppm
  - BUT sensitive to moisture !

- Applicability of the Ag-ETS-10
  - Column needs to be designed for the relevant conditions to maximize the retention time
  - No significant degradation after
    - 23 adsorption/desorption cycles
    - 1 MGy gamma absorbed dose