A Method for the Replacement of ^{137}Cs with ^{40}K for Open-Source Ion Exchange Research Applications in Hot Cells.

Andrew Parker, Prof. Colin Boxall & Prof. Malcolm Joyce

a.parker4@lancaster.ac.uk
Engineering Department, Lancaster University, Lancaster, LA1 4YR

Presentation Outline

- Background,
- Connection to Hot Cells and Radiation Protection,
- Potassium and Ion Exchange,
- Method Development of ^{40}K as an Analogue of ^{137}Cs,
- Hot Cell Context & Conclusions.

Background

First generation Magnox storage pond, (FGMSP)

^{137}Cs is one of the principal contaminants in many nuclear facilities being decommissioned, e.g. FGMSP, concrete lined Hot Cells.

Weathering and erosion of external facilities causes the leaching of radioactive material into the concrete structure. **External surface at 9 Sv/h!**

The remediation is to take place through the development of a "*nuclear elastoplast*" using ion exchange materials and electrokinetic methods.

Hot Cells and Worker Protection

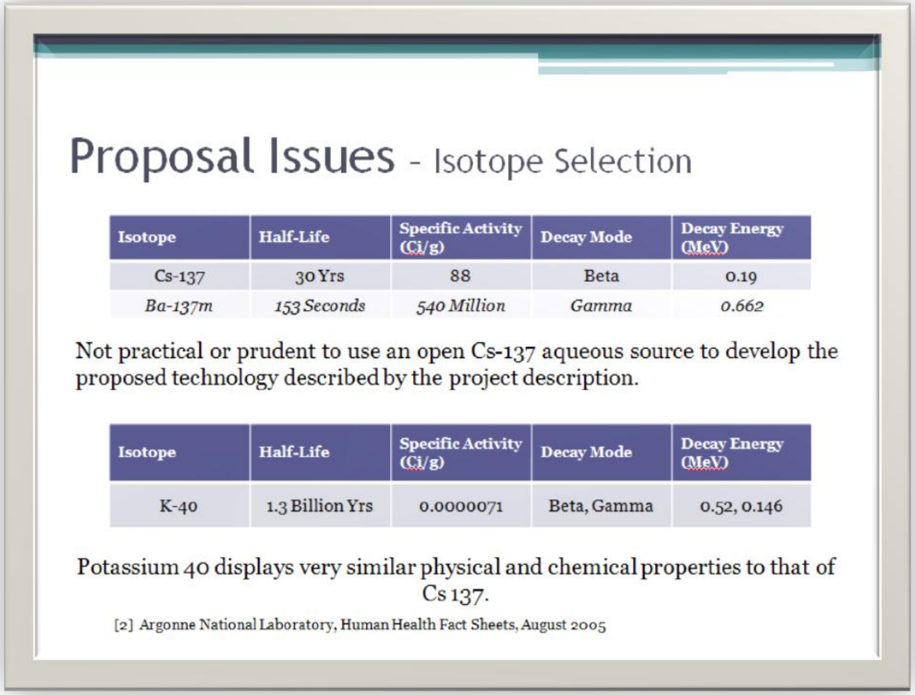
Post Irradiation Examination facility at PIED, Bhaba Atomic Research Centre, India.

Caesium cations:

- Two radioactive Cs isotopes,
- Significant safety management,
- Highly soluble,
- Migrates readily with water,
- Difficult to immobilise.

Insoluble salts and carbonates on external pond-concrete surfaces require analytical study.

Potassium Calibration



Proposal Issues - Isotope Selection

Isotope	Half-Life	Specific Activity (Ci/g)	Decay Mode	Decay Energy (MeV)
Cs-137	30 Yrs	88	Beta	0.19
Ba-137m	*153 Seconds*	*540 Million*	*Gamma*	*0.662*

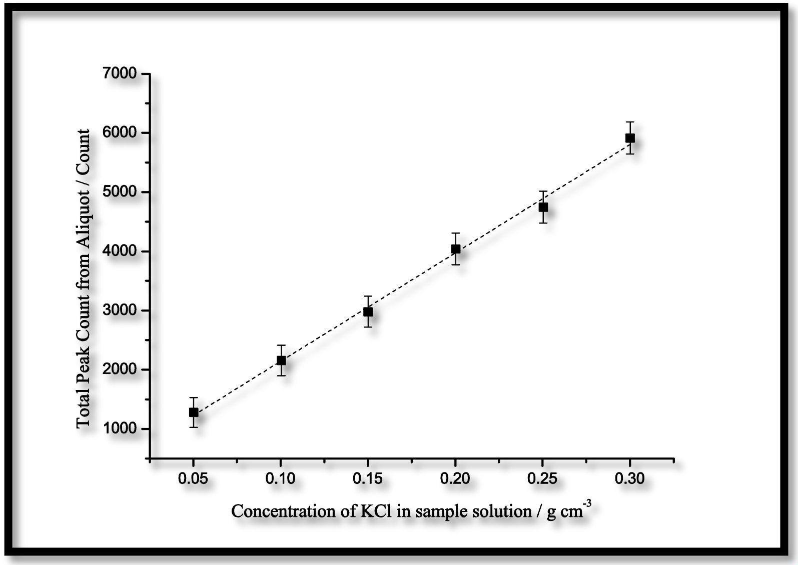
Not practical or prudent to use an open Cs-137 aqueous source to develop the proposed technology described by the project description.

Isotope	Half-Life	Specific Activity (Ci/g)	Decay Mode	Decay Energy (MeV)
K-40	1.3 Billion Yrs	0.0000071	Beta, Gamma	0.52, 0.146

Potassium 40 displays very similar physical and chemical properties to that of Cs 137.

[2] Argonne National Laboratory, Human Health Fact Sheets, August 2005

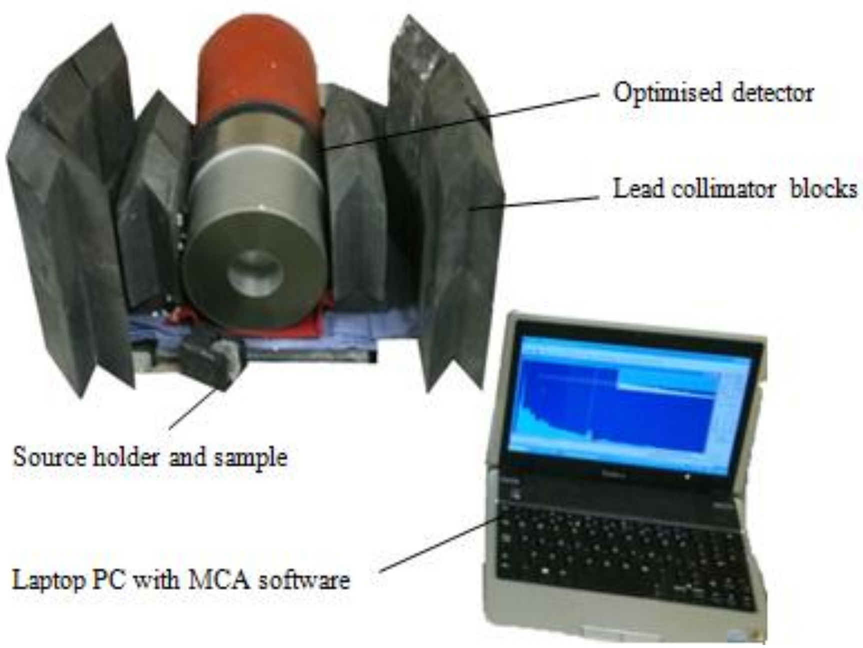
Established a linear relationship between the concentration of KCl in solution and the associated count detected.

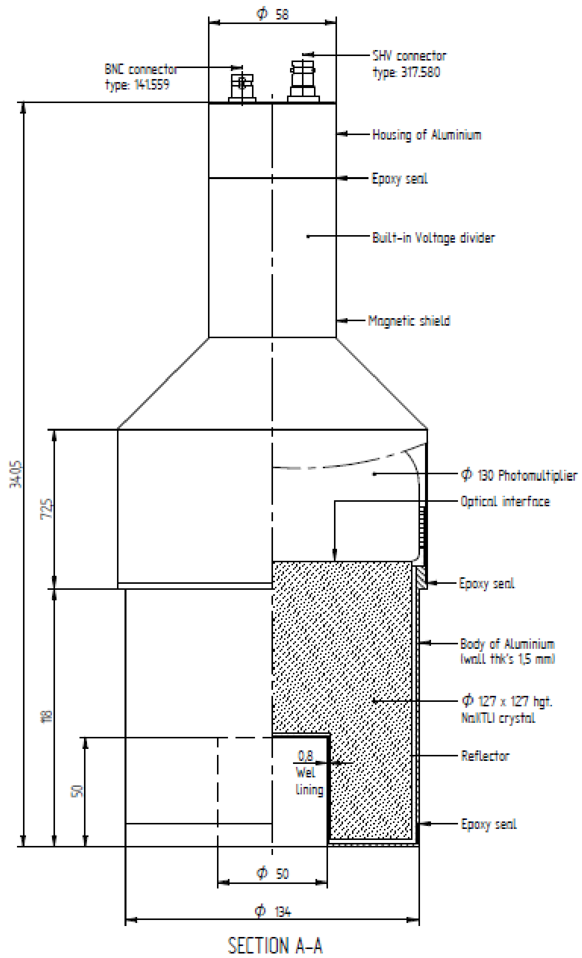


Our current laboratory facilities are not sufficient to be able to handle open-source radioactive caesium. So we have used potassium.

Detection Apparatus

Radiometric measurement provides a versatile and consistent means of quantifying concentrations and masses of radionuclides, both *in situ* and in the laboratory.

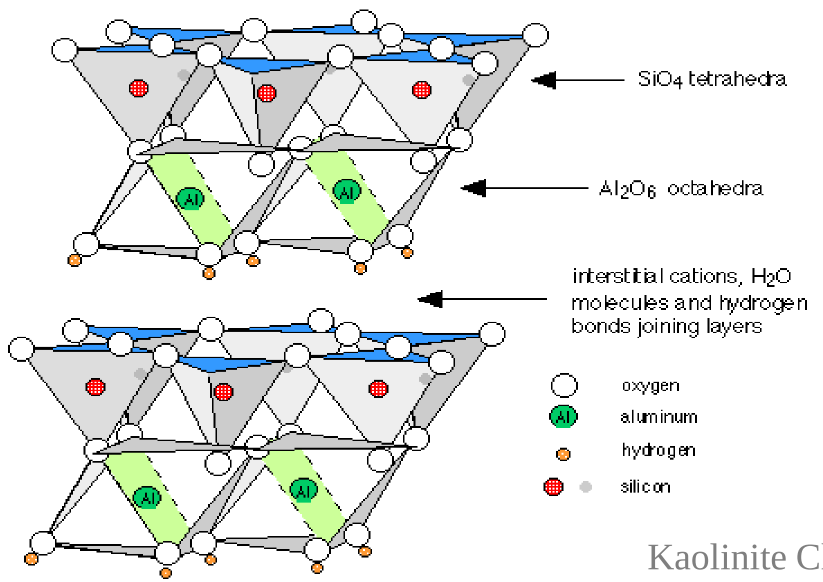




Ion Exchange Approach

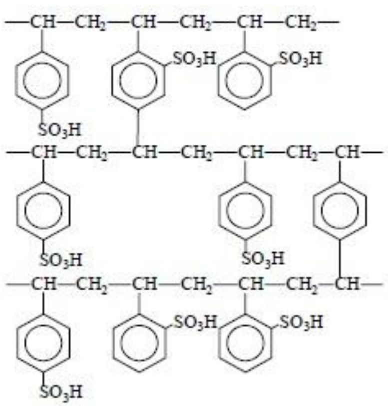
$$M^{-}A^{+} + B^{+} \leftrightarrow M^{-}B^{+} + A^{+}$$ [1]

Where M is the ion exchange material carrying the A^+ ions and B^+ are the counter ions in an aqueous phase. It should be noted that this reaction can be reversible.



Kaolinite Clay

Ion Exchange Resins



[1] Ion Exchange: Theory and Practice, 2nd Edition, C.E. Harland

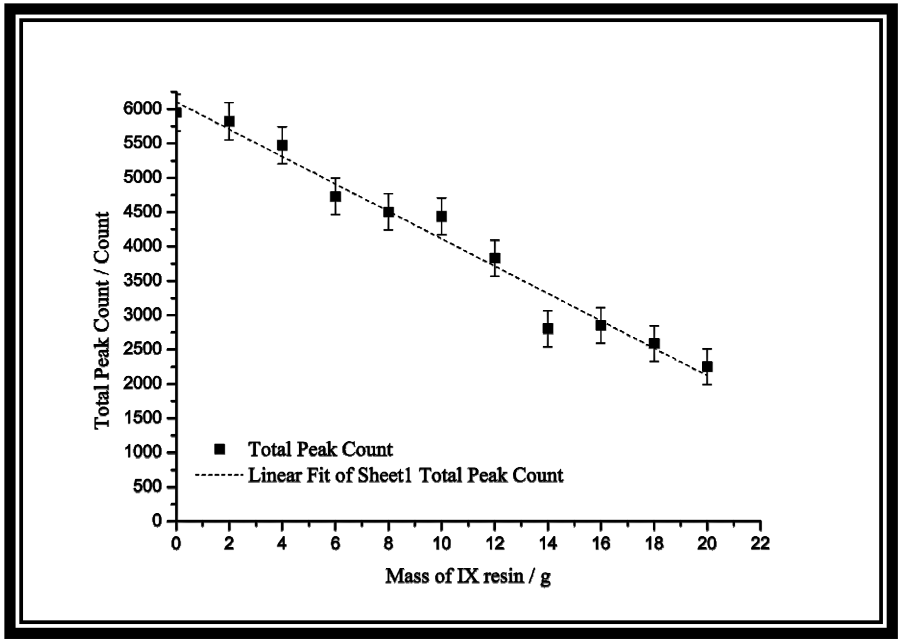
Potassium Adsorption Studies

Determining the plausibility of measuring an ion exchange reaction radiometrically using ^{40}K.

$$M^{-}H^{+} + K^{+} \leftrightarrow M^{-}K^{+} + H^{+}$$

Batch Experiments

- 5.62g of KCl
- 20mL of water
- Lewatit resin added [2]
- Stirred for 2 hours
- 7mL aliquots taken
- Detected for 20 hours
- 0g – 20g resin used



The linear relationship between number of counts, N, and mass of IX is given by N = A - B[IX]. A = 6103 ± 151, B = -199 ± 12

[2] Ion Exchange Resin: Monoplus S 108 KR

Potassium Adsorption Isotherms

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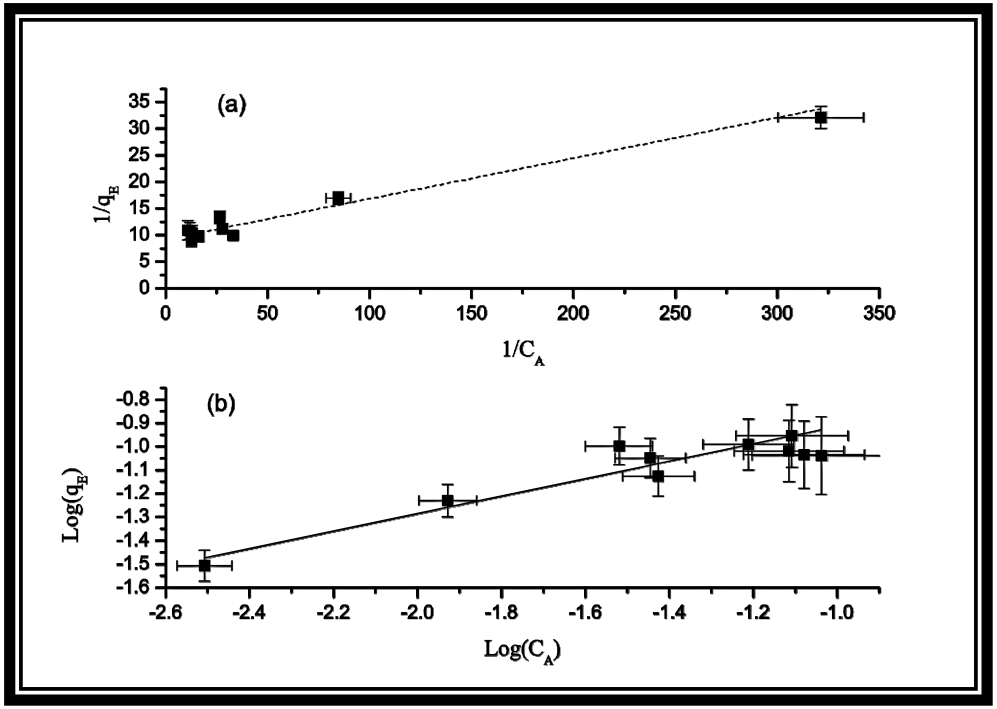
Linear Isotherms

(a) $$\frac{1}{q_E} = \left(\frac{1}{bQ^0}\right)\frac{1}{C_A} + \frac{1}{Q^0}$$

Langmuir

(b) $$\log(q_E) = \log(K_f) + 1/n \log(C_A)$$

Freundlich



Linear Langmuir (a) and Freundlich (b) relationships.

K_f, $1/n$ = Freundlich Constants

b, Q^0 = Langmuir Constants

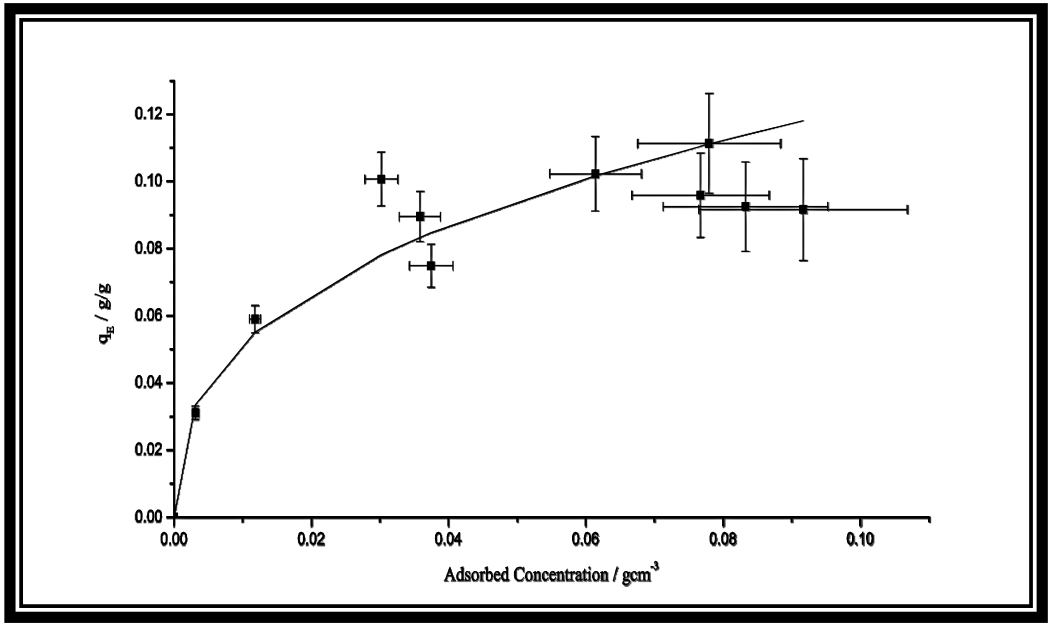
q_E = Grams of cation adsorbed per gram of resin

C_A = Adsorbed Concentration

HOT LAB

Potassium Adsorption Isotherms

	Freundlich Model			Langmuir Model			Resin
	K_f	1/n	χ_v^2	Q^o	*b*	χ_v^2	Total K^+ Capacity
Empirical	**0.286**	0.371	0.491	**0.109**	120.039	1.525	*0.1*



Non-Linear Freundlich isotherm plotted against experimental data.

Non-Linear

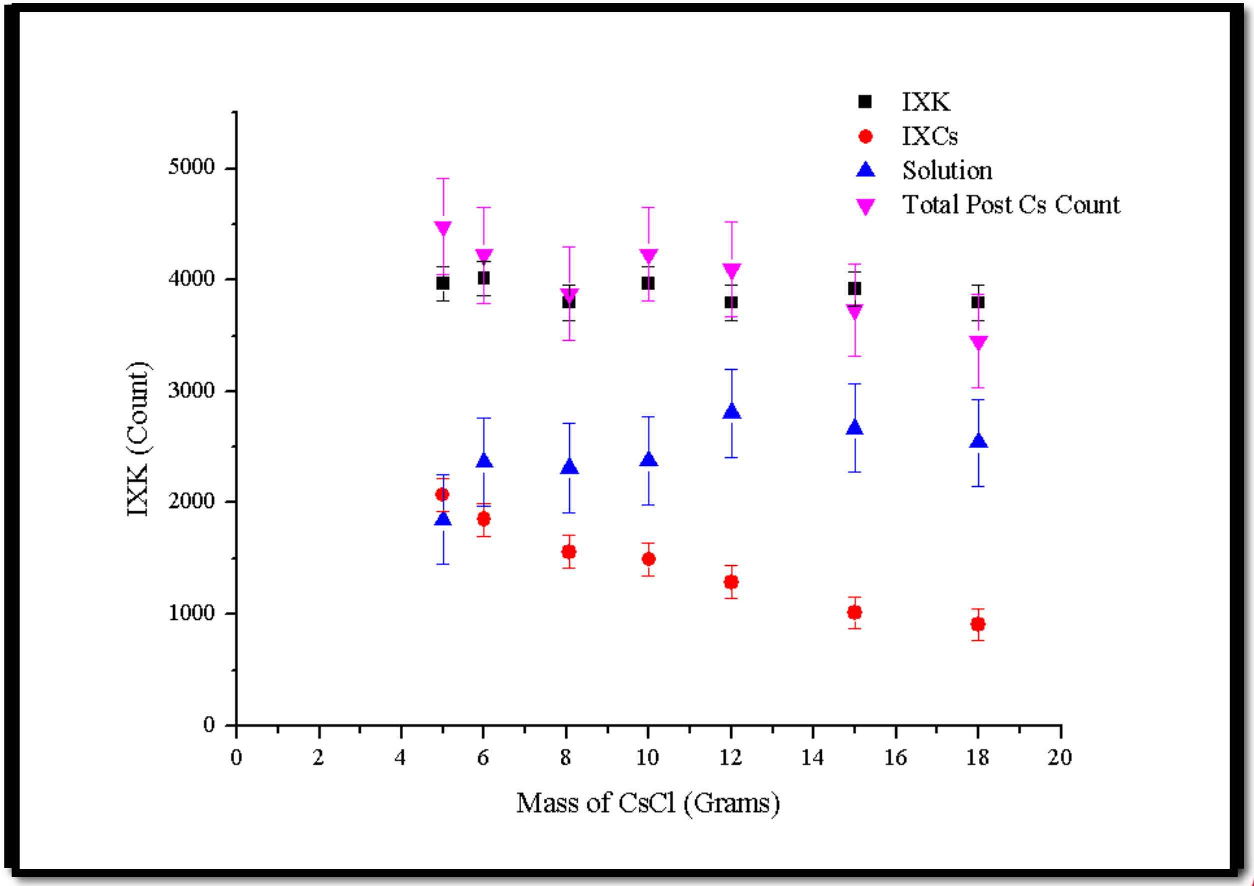
$$q_E = K_f C_A^{\frac{1}{n}}$$

Freundlich

$$q_E = (C_0 - C_E)\frac{V}{W}$$

Caesium Adsorption

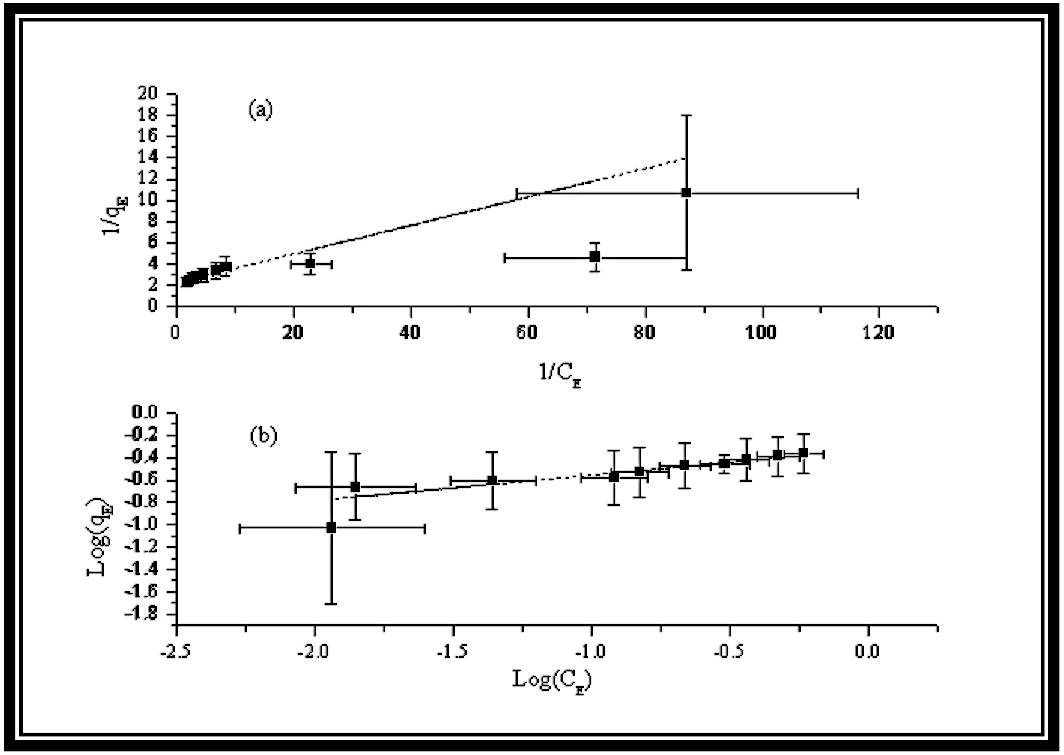
- ≈ 6 grams of washed & dried K^+ form resin;
- 20 ml DW;
- Varying masses of non-active CsCl added;
- Mixed for two hours;
- Aliquot of solution taken and detected;
- New Cs^+ form resin is washed, dried, and detected.



Counts detected: $IXCs^+$ + Solution = Total Post Cs ≈ IXK^+

$$M^-K^+ + Cs^+ \leftrightarrow M^-Cs^+ + K^+$$

Caesium Adsorption Isotherms



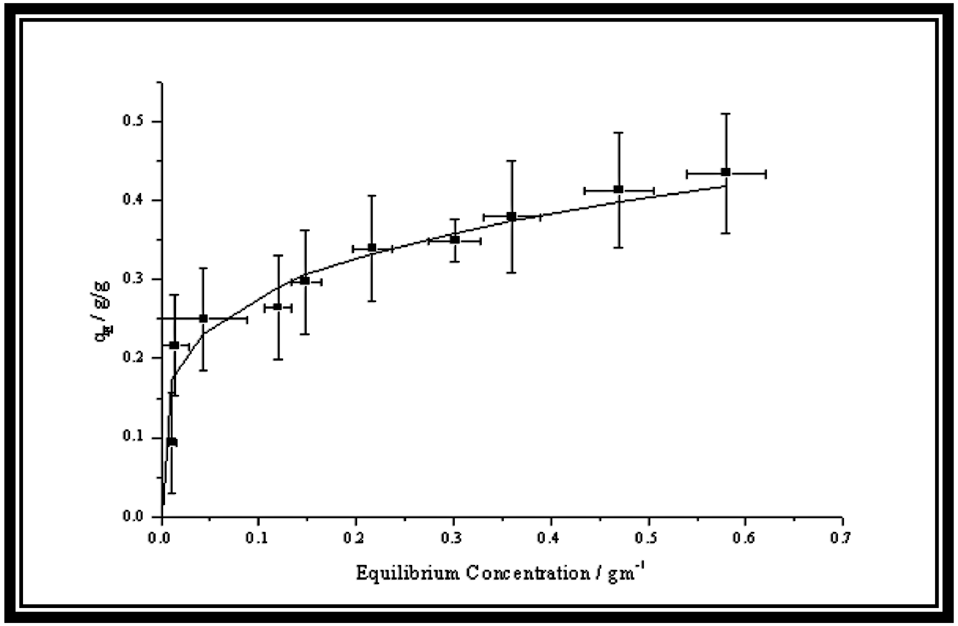
Linear Langmuir (a) and Freundlich (b) relationships.

Using the detected count from the displaced potassium Freundlich and Langmuir relationships were derived describing the caesium adsorption.

q_E = grams of Cs adsorbed per gram of resin & C_E = Equilibrium Concentration

Caesium Adsorption Isotherms

	Freundlich Model			Langmuir Model			Resin
	K_f	$1/n$	χ_v^2	Q^0	b	χ_v^2	Total Cs^+ Capacity
Empirical	**0.472**	0.228	0.04	**0.442**	16.879	3.872	***0.35***



Non-Linear Freundlich isotherm plotted against experimental data.

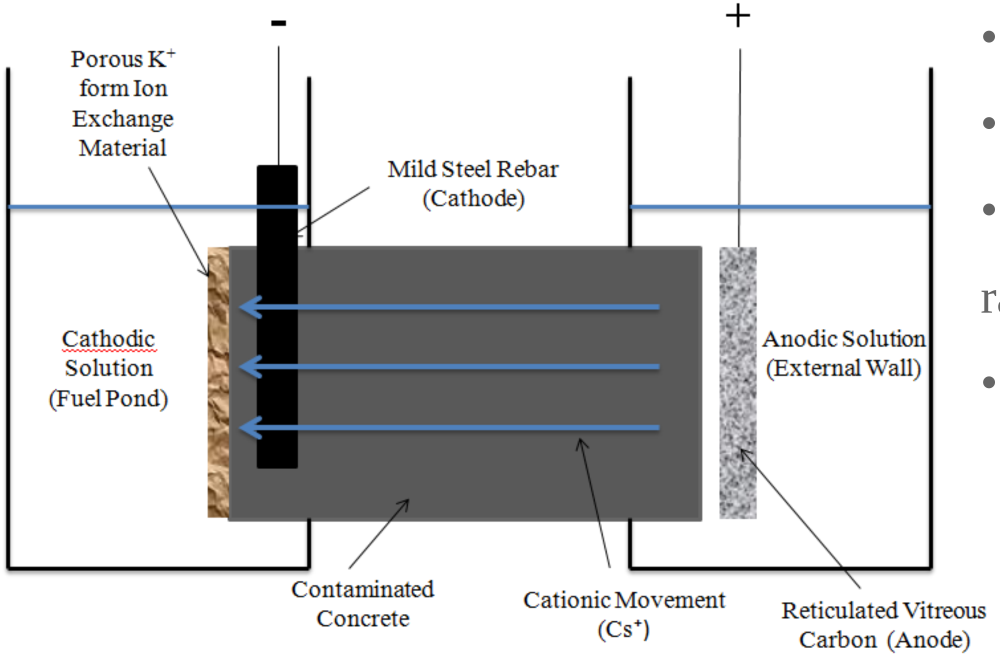
Non-Linear Freundlich

$$q_E = K_f C_A^{\frac{1}{n}}$$

The experimental data from the caesium adsorption study is consistent with the previous potassium adsorption study and the resin manufacturers data.

Context of Results I

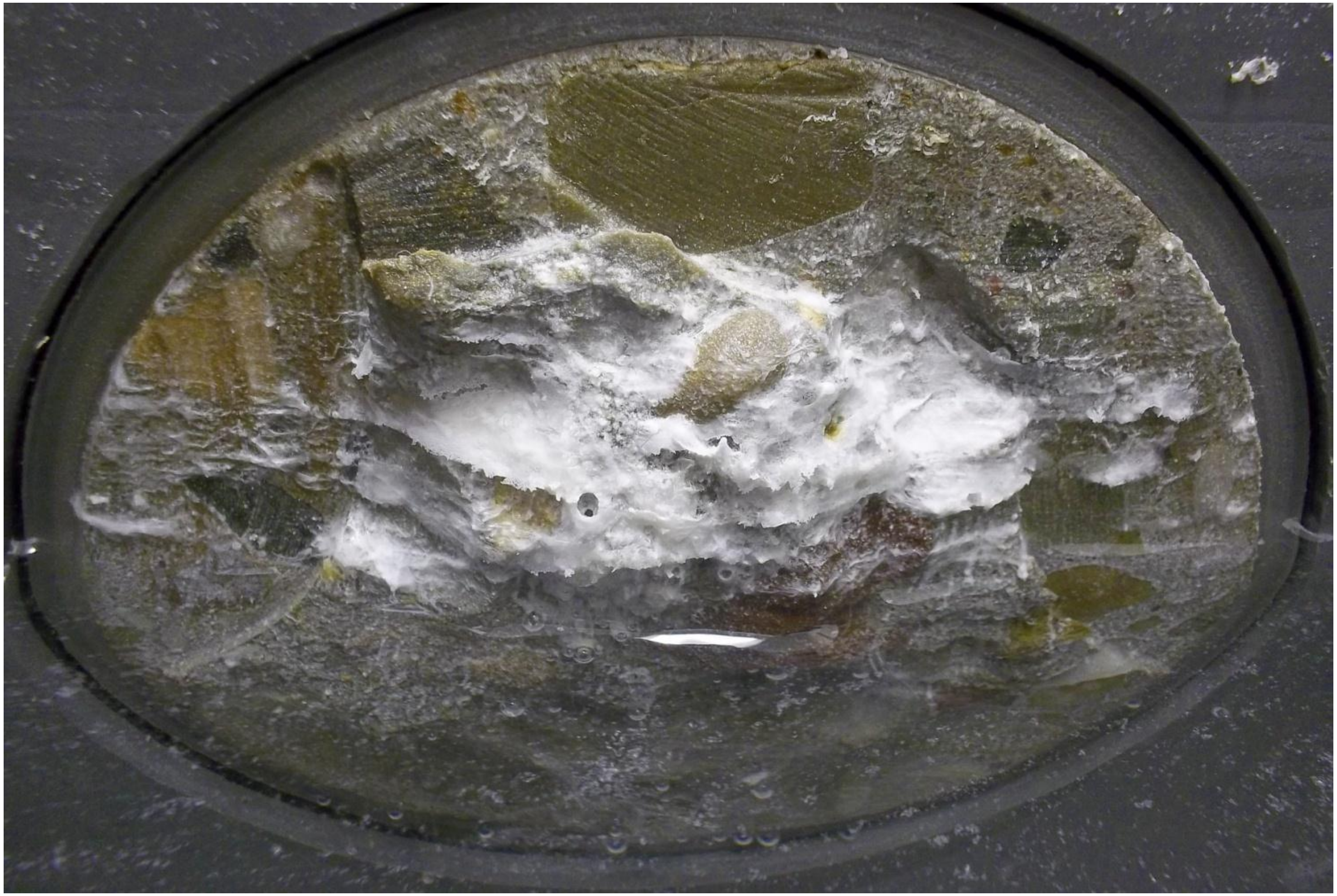
e.g. Electromigration



- No radiation concerns,
- No special equipment required,
- Allows safe method development,
- Uses same technique as *in situ* radiation detection,
- Simulate real-world concentrations.

The use of a K^+ form ion exchange medium can be used in migration studies of non-active Caesium, as a marker.

Context of Results II



Conclusions

- Demonstrated the novel use of ^{40}K as a radiometric source,
- This is shown in the development of an empirical adsorption isotherm from radiometric data,
- We can monitor non-active Cs^{+} adsorption through the radiometric measurement of displaced K^{+} in ion exchange media,
- This allows work to be carried out without the radiological concerns of more dangerous isotopes and the use of Hot Cells, thereby allowing potassium to be used as a non-active analogue of ^{137}Cs.

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Thank you for your attention,
any questions?