

Supplementary information

Supplementary Table 1: Specifications and operating conditions of ICP-AES.

Instrumental specification	
Optical design	Paschen-Runge mounting, Circular design
Focal length	750 mm
Grating	Holographic
Groove density	1800 grooves/mm (1), 3600 grooves/mm (2)
Wave length range	130-800 nm
Entrance slit width	15 microns
Resolution (FWHM)	0.01 nm from 130-450 nm 0.02 nm from 450-800 nm
Thermal regulation	Controlled to $30 \pm 1^\circ\text{C}$
Frequency	27.12 MHz
Pump	Dual channel peristaltic pump
Detector	Linear arrays of CCD (3648 pixels/array)
Nebulizer	Cross flow
ICP-torch	Demountable, radial viewing
Operating condition	
Coolant flow	16 L/min
Auxiliary flow	0.5 L/min
Total time of measurement	26 s
Pump speed	28 Rpm
RF power out put	1.1 kW
Input power	230 V AC

Supplementary information on Isotherm models

Langmuir isotherm

The Langmuir model is the most widely used model which explains sorption by assuming an ideal gas behaviour of sorbate on the sorbent at isothermal conditions. The main assumptions involved are (i) all sites are equivalent (ii) the adsorbing surface possess homogeneity (iii) monolayer coverage i.e., each molecule can hold at most one molecule of adsorbate (iv) there exists dynamic equilibrium between the adsorbed and free adsorbate molecules (v) there are no interactions between adsorbate molecules on neighbouring sites [1]. It can be expressed as:

$$\frac{C_e}{q_e} = \frac{1}{q_0 b} + \frac{C_e}{q_0} \quad (1)$$

where, C_e – the equilibrium concentration of the Pu^{4+} or PuO_2^{2+} ion, q_e – the amount of metal ion adsorbed on AFMWCNT at equilibrium, q_0 – the sorption capacity of AFMWCNT for Pu^{4+} or PuO_2^{2+} ion and b is the sorption energy.

Dubinin–Radushkevich (D–R) isotherm

The Dubinin- Radushkevich isotherm is widely used for describing sorption of subcritical fluids in microporous solids such as activated carbon and Zeolites, originally was based on the Polanyi potential theory of adsorption. This model is based on the assumptions of a change in potential energy between the adsorbate and the adsorbed phases and a characteristic energy of a given solid [2]. It can be expressed as

$$\ln q_e = \ln X_m - \beta \varepsilon^2 \quad (2)$$

where, q_e – the amount of Pu ion adsorbed on the AFMWCNT at equilibrium, X_m – the maximum sorption capacity and β – the activity constant. The Polanyi potential, ε can be evaluated by

$$\varepsilon = RT \ln(1 + 1/C_e) \quad (3)$$

where, R– the universal gas constant (8.314 J mol⁻¹ K⁻¹), T- the absolute temperature and C_e– the equilibrium concentration of Pu ion. The energy (E) can be determined from β, slope of the ln q_e vs. ε² plot, expressed as

$$E = 1/(-2\beta)^{1/2} \quad (4)$$

Freundlich isotherm

Freundlich adsorption isotherm is an empirical relation between the concentrations of a solute on the surface of an adsorbent to the concentration of the solute in the liquid. This adsorption model is based on the following assumptions (i) the surface containing the adsorbing sites is heterogeneous (ii) possibility of multi-layer adsorption (iii) the active sites are non-uniform. The following equation holds good at low pressure

$$Q_e = K_f C_e^{1/n} \quad (5)$$

where, Q_e – the amount of plutonium ions adsorbed per gram of the AFMWCNT at equilibrium condition (mg g⁻¹), K_f – Freundlich isotherm constant (mg g⁻¹), C_e – the equilibrium concentration of plutonium (mg L⁻¹) and n – sorption intensity.

On linearization of equation, we have

$$\log Q_e = \log K_f + 1/n \log C_e \quad (6)$$

The constant K_f indicates the adsorption capacity, whereas the 1/n is a function of the strength of adsorption. If ‘n’ is unity, then the partition of metal ions between the solid phase and liquid phase are independent of the concentration of metal ion. ‘n’ value above unity indicates the normal sorption and ‘n’ value less than one implies that the sorption process is cooperative [3]. As the temperature increases, change in the constants K_f and n values indicate that the quantity adsorbed rises more slowly and higher pressure are required for saturation.

Temkin isotherm

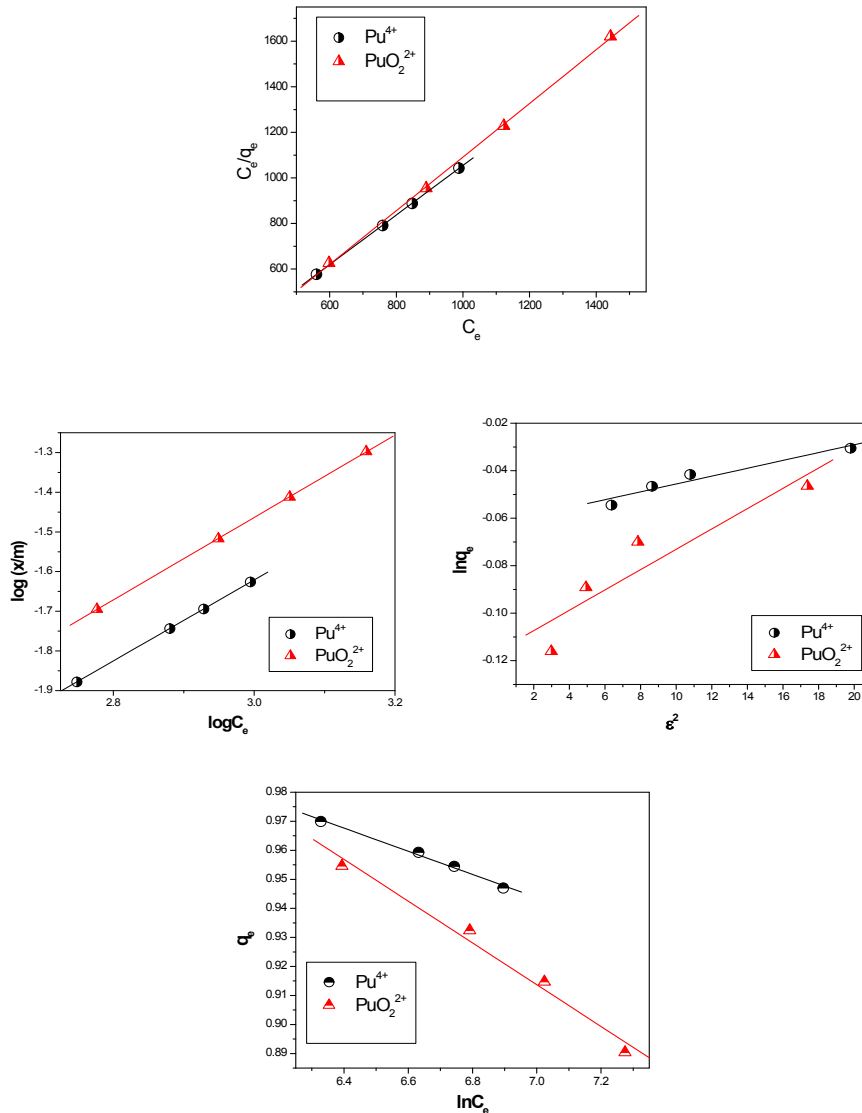
This model approach relies on the assumption that by ignoring the extremely low and high value of concentrations, the heat of adsorption (function of temperature) decreases linearly rather than

logarithm with increasing coverage. Parameters involved in Temkin isotherm model can be evaluated from the slope and intercept of q_e against $\ln C_e$ plot [4]. The model can be quantitatively expressed as

$$q_e = \frac{RT}{b} \ln (A_T C_e) \quad (7)$$

$$q_e = \frac{RT}{b} \ln A_T + \frac{RT}{b} \ln C_e \quad (8)$$

where, A_T – Temkin isotherm equilibrium binding constant ($L g^{-1}$), b – Temkin isotherm constant, R – universal gas constant ($8.314 J mol^{-1} K^{-1}$) and T – absolute temperature.



Supplementary Fig. 1: Langmuir, Freundlich, D–R and Temkin isotherms for Pu^{4+} and PuO_2^{2+} on AFMWCNT

References:

1. A.O. Dada, A.P. Olalekan, A.M. Olatunya and O. DADA, IOSR J. Appl. Chem., 2012, **3 (1)**, 38–45.
2. C. Nguyen, D.D. Do, Carbon, 2001, **39 (9)**, 1327–1336.
3. S. Mohan and J. Karthikeyan, Environ Pollut. 1997, **97(1-2)**, 183–187.
4. A.P. Olalekan, A. O. Dada and A.O. Okewale, Res. J. Chem. Env. Sci., 2013, **1 (5)**, 22–27.