

Nature Communications

“Stand-off nuclear reactor monitoring
with neutron
detectors for safeguards and
non-proliferation
applications”

BM van der Ende, L Li, D Godin, B Sur.
Canadian Nuclear Laboratories
Del Vecchio Barrón Carlo Roberto

Medidas de vigilancia

- Plantas de fisión
 - Sello indicador de manipulación
 - Monitoreo por videocámaras
 - Inventario físico
- Reactores de investigación
 - Uranio altamente enriquecido
 - Mayor preocupación

Modelo

$$n_{\text{det}} \propto n_{\text{pop}} \propto \frac{\langle \phi \rangle}{\langle \nu \rangle} V$$

$$P_{\text{tot}} = V \langle \phi \rangle \sum_i \langle \Sigma_{f,i} \rangle E_{f,i} = V \langle \phi \rangle \sum_i N_i \langle \sigma_{f,i} \rangle E_{f,i}$$

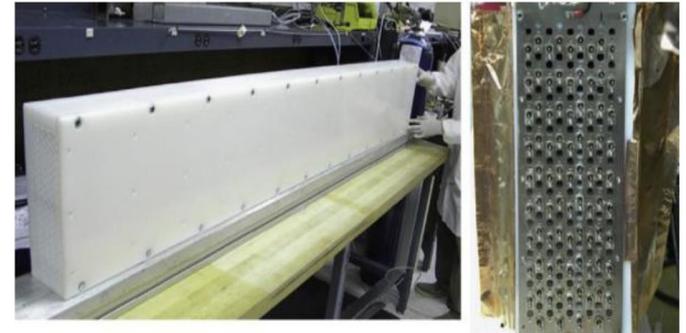
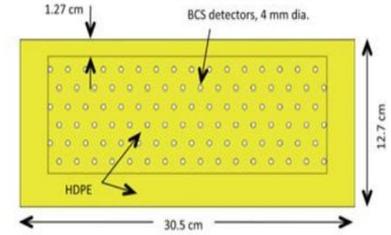


Table 1 Properties of key reactor isotopes

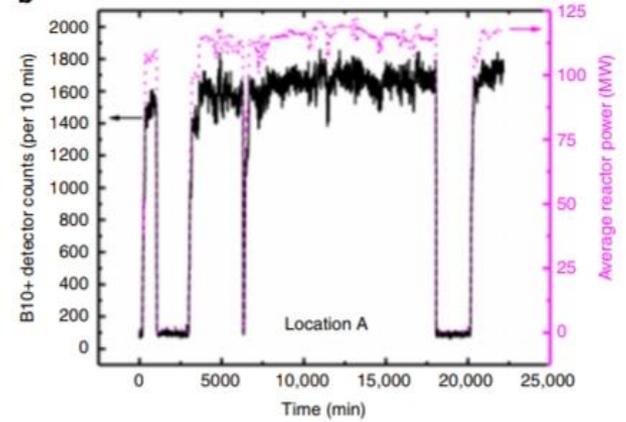
Property	U-235	U-238	Pu-239	Pu-241
Thermal (0.0253 eV) neutron induced fission cross-section ²⁰	582.6 ± 1.1 barns	0.000003 barns	748.1 ± 2.0 barns	1011.1 ± 6.2 barns
Thermal energy per fission ²¹	201.7 ± 0.6 MeV	205.0 ± 0.9 MeV	210.0 ± 0.9 MeV	212.4 ± 1.0 MeV

Resultados

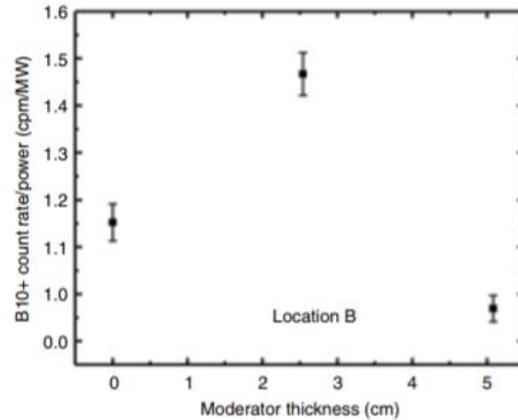
a



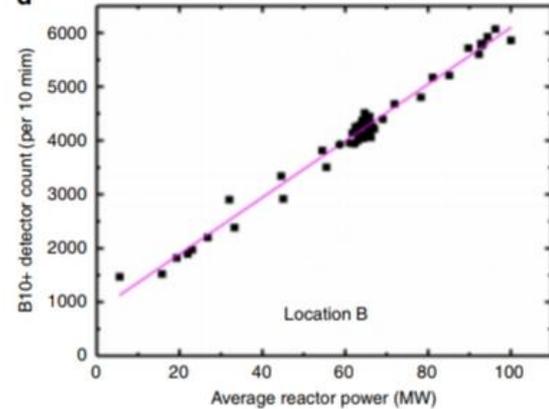
b



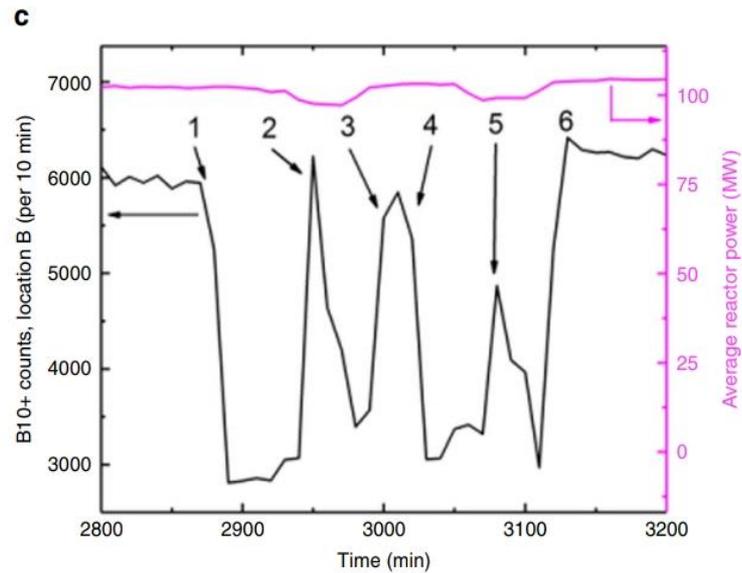
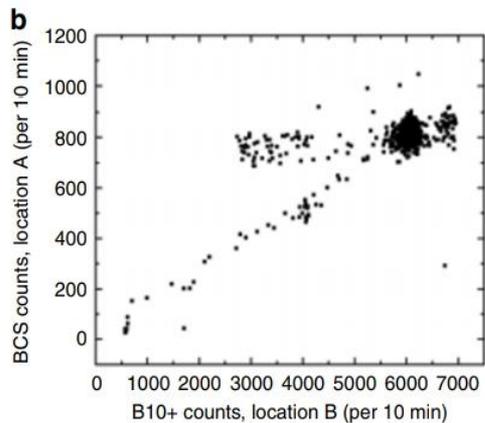
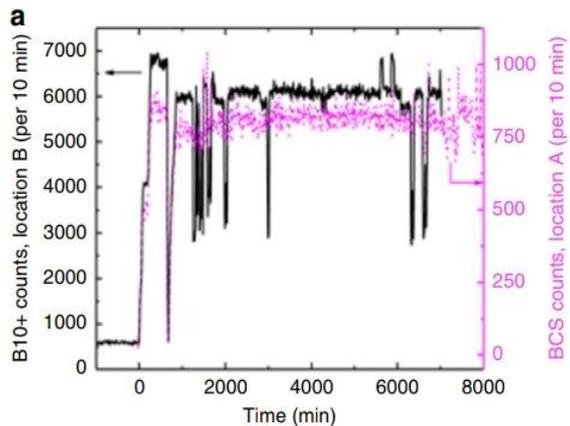
c



d



Resultados



Resultados

Table 3 Average masses of fissile isotopes for the time periods indicated in Fig. 2a, b

a							
Time Period	U-235 (g)	Pu-239 (g)	U-238 (g)	Pu-241 (g)	Relative calculated $\langle \phi \rangle / P_{tot}$	Relative measured count rate/power	Percentage difference (%) $[meas - calc / (meas + calc) / 2]$
11/2014 to 12/2014	23045.49	434.74	182879.33	32.20	1	1	0.0
04/2016	+ 3223.14 (13.98%)	+ 36.55 (8.41%)	+ 73842.34 (40.38%)	-11.06 (-34.35%)	0.879	0.843	4.3
07/2016 to 08/2016	+ 2634.01 (11.43%)	+ 107.11 (24.64%)	+ 77463.17 (42.36%)	-8.77 (-27.24%)	0.895	0.920	2.7
b							
Time Period	U-235 (g)	Pu-239 (g)	U-238 (g)	Pu-241 (g)	Relative calculated $\langle \phi \rangle / P_{tot}$	Relative measured count rate/power	Percentage difference (%) $[meas - calc / (meas + calc) / 2]$
09/2016 to 10/2016	+ 1857.57 (8.06%)	+ 620.66 (142.76%)	+ 290566.29 (158.88%)	+ 41.98 (130.37%)	0.896	0.896	0.0
10/2016 to 11/2016	+ 2386.76 (10.36%)	+ 793.51 (182.53%)	+ 277483.17 (151.73%)	+ 80.94 (251.37%)	0.868	0.837	3.6

Using Eq. (3), the relative neutron flux per unit reactor power is estimated from masses of fissile isotopes which contribute greater than 99.9% of the neutron flux in the reactor core. The estimated relative neutron flux is compared against the average relative detector count rate per unit reactor power for the corresponding time period, measured with (a) the BCS detector at location A, and (b) the B10 + detector at location B. All changes in mass amounts (and corresponding percentage changes indicated in parentheses) are relative to the 2014/11 to 2014/12 time period

Conclusiones

- Se obtuvo una mayor detección en el punto B (fuera del edificio) que en el punto A (dentro del edificio) a pesar de estar más lejano, debido al concreto en el techo del punto A
- Aunque el error en las mediciones del conteo es alto, la precisión es suficiente para detectar concentraciones anómalas de material de fisión
- Debido a la efectividad y facilidad de instalación, los detectores de neutrones demuestran ser un buen candidato como apoyo de monitoreo contra la proliferación nuclear

Referencias

- BM van der Ende, et. al. 2019 “Stand-off nuclear reactor monitoring with neutron detectors for safeguards and non-proliferation applications”. Nature Communications
- Karen Guzmán, 2017. “CARACTERIZACIÓN TEÓRICO-EXPERIMENTAL DE NUEVOS SISTEMAS DE DETECCIÓN DE NEUTRONES PARA EL CONTROL DE MERCANCÍAS EN FRONTERAS Y PUNTOS CRÍTICOS”. Univerisad Politécnica de Madrid