

Supporting information for:

Direct analysis of radium-226 in sediment by ICP-MS after a simple acidic digestion: an analytical challenge?

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ICP-MS multi-element measurement procedure:

Elemental measurements (Li, Be, Na, Mg, Al, P, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Rb, Sr, Y, Mo, Rh, Ag, Cd, In, Sb, Te, Cs, Ba, La, Ce, Eu, Tb, Ho, Lu, W, Pt, Hg, Tl, Pb, Bi, Th and U) were realized in sediment digest on our ICP-MS instrument with a conventional Peltier-cooled cyclonic spray chamber as an introduction system. Polyatomic and isobaric interferences were minimized using the collision cell configuration of the kinetic energy discrimination (KED) mode of the instrument with He as a collision gas. Internal standard solution used for that purpose was Indium ^{115}In ($5 \mu\text{g L}^{-1}$) in 2% v/v HNO_3 . Measurements of these elements were validated using certified reference materials: IAEA-158, IAEA-314, HISS-1 and PACS-2. Recoveries of all elements of interest in certified reference material were comprised between 80% and 111%.

Table SI-1. Concentrations ($\mu\text{g g}^{-1}$) of all elements of interest in the five sediments of this study. Results given in brackets are % recovery compared to certified values.

Element	IAEA-314	IAEA-158	KB-5	RSC	Kaštela
Li, lithium	14.15	30.32 (93)	31.82	53.31	59.42
Be, beryllium	1.60	1.81	1.36	1.87	2.15
Na, sodium	789	22 682 (95)	12 154	17 760	18 164
Mg, magnesium	2 303	10 074 (97)	8 998	10 265	27 456
Al, aluminium	87 629	47 100 (91)	61 362	59 620	56 999
P, phosphorus	600	963	754	619	729
K, potassium	14 138	19 393 (97)	14 407	20 014	7 830
Ca, calcium	1 860	66 989 (103)	12 678	3 439	118 050
Sc, scandium	16.19	7.69 (92)	12.59	11.15	10.08
Ti, titanium	5 283	3 382 (97)	4 787	5 162	2 835
V, vanadium	169.1	72.5 (99)	99.7	86.1	234.1
Cr, chromium	82.8	69.5 (93)	100.9	58.7	110.4
Mn, manganese	128.2	348.8 (98)	914.7	436.7	408.5
Fe, iron	29 282	25 937 (99)	39 812	39 801	37 990
Co, cobalt	18.46	8.43 (92)	13.27	12.55	11.57
Ni, nickel	49.57	28.81 (95)	39.79	32.54	83.01
Cu, copper	44.7	43.8 (91)	33.5	21.0	52.8
Zn, zinc	75	142 (101)	104	92	173
As, arsenic	18.60	10.39 (90)	8.74	9.74	25.54
Rb, rubidium	90.5	77.1 (94)	63.5	92.3	50.9
Sr, strontium	25	468 (99)	133	88	487
Y, yttrium	24.91	15.52	27.11	22.32	22.18
Mo, molybdenum	32.12	4.75		5.79	17.00
Rh, rhodium	<0.04	<0.04	<0.04	<0.04	<0.04
Ag, silver	0.07	0.20 (111)	0.11	0.12	0.26
Cd, cadmium	0.080	0.370 (100)	0.399	0.467	2.771
In, indium	0.026	0.162	0.048	0.049	0.082
Sb, antimony	0.42	1.43 (107)	0.51	0.66	3.29
Te, tellurium	0.119	0.040	0.037	0.033	0.100
Cs, caesium	3.44	3.28 (88)	2.48	4.66	6.44
Ba, barium	208.7	1 013.5 (99)	389.3	277.3	359.1
La, lanthanum	119.84	27.29 (90)	30.24	31.11	28.67
Ce, cerium	222.8	55.1 (90)	72.1	66.6	53.9

Eu, europium	1.744	0.977 (91)	1.451	1.259	0.993
Tb, terbium	1.594	0.560 (89)	0.914	0.789	0.672
Ho, holmium	1.2155	0.6551	1.1440	0.9560	0.7538
Lu, lutetium	0.444	0.243 (80)	0.453	0.366	0.337
W, tungsten	5.0	1.1	2.3	1.3	1.2
Pt, platinum	< 0.07	< 0.07	< 0.07	< 0.07	< 0.07
Hg, mercury	-	0.132	-	-	-
Tl, thallium	0.37	0.59		0.58	1.58
Pb, lead	15.7	40.6 (102)	20.1	20.4	66.7
Bi, bismuth	0.229	0.232	0.132	0.194	0.399
Th, thorium	15.91 (89)	7.36 (83)	8.39	8.67	9.70
U, uranium	50.396 (89)	2.242 (93)	2.787	4.605	41.388

IAEA-158: Marine sediment, International Atomic Energy Agency (Vienna, Austria)

IAEA-314: Stream sediment, International Atomic Energy Agency (Vienna, Austria)

Table SI-2. Concentrations ($\mu\text{g L}^{-1}$) of all elements of interest of the five sediments of this study if 0.10 g sediment was digested to V=50 mL and then 5-fold diluted before ICP-MS analysis.

Element	IAEA-314	IAEA-158	KB-5	RSC	Kaštela
Li, lithium	5.66	12.13	12.73	21.32	23.77
Be, beryllium	0.64	0.72	0.54	0.75	0.86
Na, sodium	316	9073	4862	7104	7266
Mg, magnesium	921	4030	3599	4106	10982
Al, aluminium	35052	18840	24545	23848	22800
P, phosphorus	240	385	302	248	292
K, potassium	5655	7757	5763	8006	3132
Ca, calcium	744	26796	5071	1376	47220
Sc, scandium	6.48	3.08	5.04	4.46	4.03
Ti, titanium	2113	1353	1915	2065	1134
V, vanadium	67.6	29.0	39.9	34.4	93.6
Cr, chromium	33.1	27.8	40.4	23.5	44.2
Mn, manganese	51.3	139.5	365.9	174.7	163.4
Fe, iron	11713	10375	15925	15920	15196
Co, cobalt	7.38	3.37	5.31	5.02	4.63
Ni, nickel	19.83	11.52	15.92	13.02	33.20
Cu, copper	17.9	17.5	13.4	8.4	21.1
Zn, zinc	30	56.8	41.6	36.8	69.2

As, arsenic	7.44	4.156	3.496	3.896	10.216
Rb, rubidium	36.2	30.84	25.4	36.92	20.36
Sr, strontium	10	187.2	53.2	35.2	194.8
Y, yttrium	9.96	6.21	10.84	8.93	8.87
Mo, molybdenum	12.85	1.90	-	2.32	6.80
Rh, rhodium	<0.02	<0.02	<0.02	<0.02	<0.02
Ag, silver	0.03	0.08	0.04	0.05	0.10
Cd, cadmium	0.032	0.148	0.1596	0.1868	1.1084
In, indium	0.010	0.065	0.019	0.020	0.033
Sb, antimony	0.17	0.57	0.20	0.26	1.32
Te, tellurium	0.048	0.016	0.015	0.013	0.040
Cs, caesium	1.38	1.31	0.99	1.86	2.58
Ba, barium	83.5	405.4	155.7	110.9	143.6
La, lanthanum	47.94	10.92	12.10	12.44	11.47
Ce, cerium	89.1	22.0	28.8	26.6	21.6
Eu, europium	0.698	0.391	0.580	0.504	0.397
Tb, terbium	0.638	0.224	0.366	0.316	0.269
Ho, holmium	0.4862	0.26204	0.4576	0.3824	0.30152
Lu, lutetium	0.178	0.097	0.181	0.146	0.135
W, tungsten	2.0	0.4	0.9	0.5	0.5
Pt, platinum	<0.03	<0.03	<0.03	<0.03	<0.03
Hg, mercury	-	0.053	-	-	-
Tl, thallium	0.15	0.24	0.00	0.23	0.63
Pb, lead	6.3	16.2	8.0	8.2	26.7
Bi, bismuth	0.092	0.093	0.053	0.078	0.160
Th, thorium	6.36 (89)	2.94	3.36	3.47	3.88
U, uranium	20.158 (89)	0.897	1.115	1.842	16.555

IAEA-158: Marine sediment, International Atomic Energy Agency (Vienna, Austria)

IAEA-314: Stream sediment, International Atomic Energy Agency (Vienna, Austria)

Table SI-3. Instrumental operating conditions of the iCAP-Q ICP-MS and the sample introduction system Apex-Q for radium analysis.

<i>Instrumental parameters</i>	
Cool gas flow	14.00 L min ⁻¹
Auxiliary gas	0.80 L min ⁻¹
RF-power	1550 W

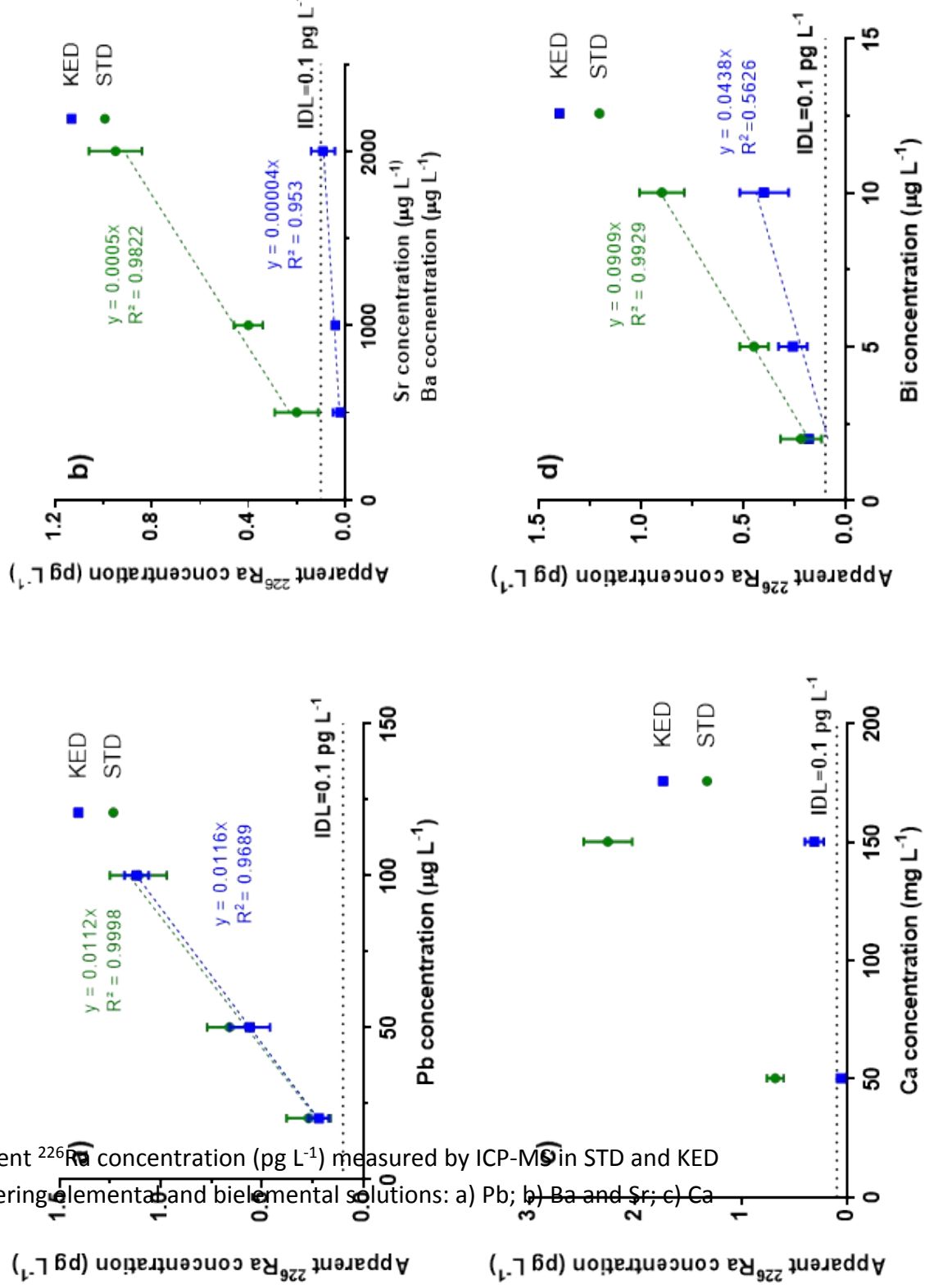
Interface cones	Nickel
<i>Ra - Acquisition parameters</i>	
Acquisition runs	5
Number of sweeps	28
Integration time per sweep	2 seconds
Total acquisition time	280 seconds
<i>Ra - Apex-Q parameters</i>	
Heated Cyclonic Spray Chamber	100°C
Peltier Cooled Multipass Condenser	2°C
He flow rate	
STD mode	0 mL min ⁻¹
KED mode	4.2 mL min ⁻¹
Nitrogen. N ₂	Off
Sample uptake rate	0.37 mL min ⁻¹
Internal standard uptake rate	0.19 mL min ⁻¹

Table SI-4. Relative standard deviation (RSD) on ²²⁶Ra concentration measured by ICP-MS in STD and KED mode using ¹¹⁵In as internal standard based on n sediment replicate mineralization and a matrix matched correction for polyatomic interference.

	STD		KED	
sediment	n	RSD (%)	n	RSD (%)

IAEA-314	5	4.6	9	4.3
Kaštela	3	4.5	3	5.1
RSC	-	-	3	16.7
IAEA-158	3	15.2	-	-

Figure SI-1. Apparent ^{226}Ra concentration (pg L^{-1}) measured by ICP-MS in STD and KED modes from interfering elemental and bi elemental solutions: a) Pb; b) Ba and Sr; c) Ca and W; and d) Bi



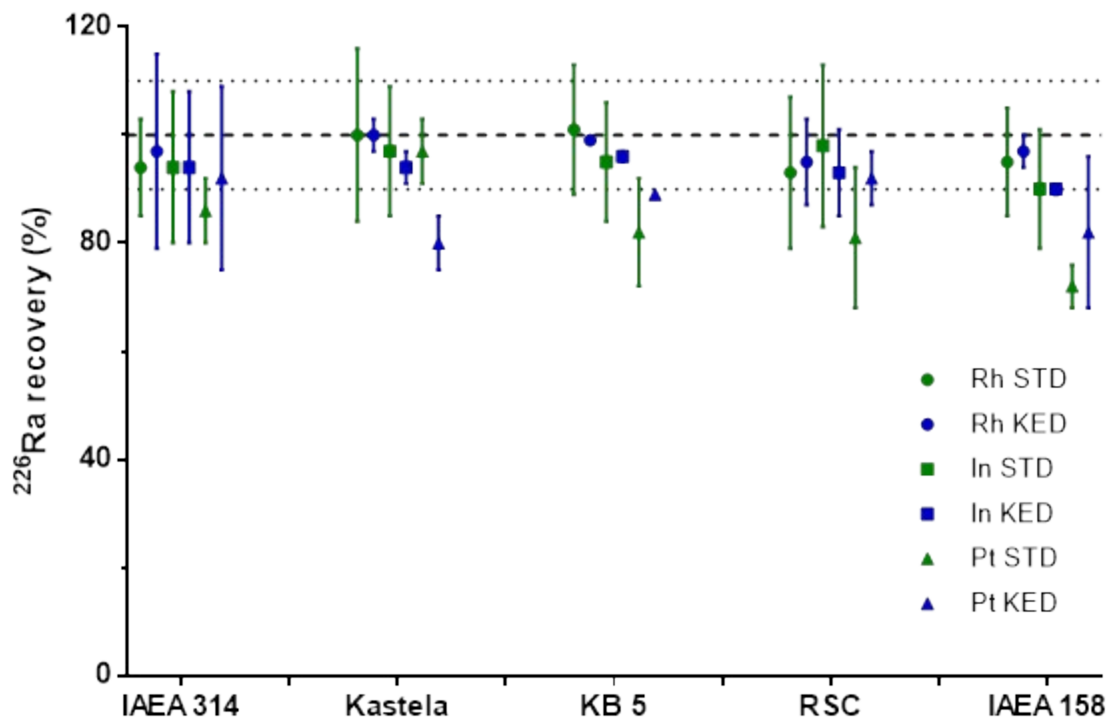


Figure SI-2. ²²⁶Ra spike recoveries (% mean ± 1 SD; n = 2 -3) measured in both STD and KED modes using ¹⁰³Rh, ¹¹⁵In or ¹⁹⁵Pt as internal standards after sediment mineralization.