Application of Extraction Chromatography for Determination of Radionuclides (U, Th, Ra, Pb Isotopes and ^{210}Po) in Drinking Water Samples

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1. Introduction

- **The advantage of the extraction chromatographic methods:**

- **(1) Better selectivity if compared with the liquid-liquid extraction method.**
- **(2) There is a wide variety of comercially available products served for different analytical purposes.**
- **(3) Beside the comercially available products, it can easily be prepared in laboratory with the extractants and the inert support.**

- **Prof. C. Testa is a pioneer in the application of the extraction chromatographic methods for radionuclide analyses, not only in Italy, but also in the world. His research activities can be traced back to 1960's.**

1. Introduction

- The National Institute of Environmental Protection and Research (ISPRA) has successfully used the extraction chromatographic methods for separation and determination of the fission products, rare-earth elements, and trans-uranic elements, including ^{144}Ce, ^{90}Sr-^{90}Y, ^{210}Po, ^{210}Pb, ^{238}U, ^{234}U, ^{232}Th, ^{230}Th, ^{228}Th, ^{226}Ra, ^{228}Ra, $^{239+240}Pu$, ^{241}Am in environmental and biological samples, for examples:

- Microthene-TNOA: For determination of Pu isotopes;
- Microthene-TOPO: For determination of U and Ra isotopes;
- Microthene-TOPO: For determination of Th isotopes;
- Microthene-HDEHP: For determination of ^{90}Sr and ^{241}Am.
- The anion-exchange resin, BIO-RAD-AG 1-X4, for Ra analyses.
- The cation-exchange resin, AG-50W-X8, for Pb analyses.

2. Materials

- **2.1 Inert support:**
- **Microthene (microporous polyethylene or polypropylene, 60 - 140 mesh): which are the products of petrochemistry industry.**

- **There are three main advantages of using Microthene:**
- **(1) It is an easily available material.**
- **(2) Its cost is very low if compared with that of Kel-F and other similar products.**
- **(3) After impregnating with different organic extractants, such as TOPO, HDEHP, TNOA, TBP etc, it can easily be prepared into columns with different capacity for different analytical purposes.**

2.2 Stationary phase used in Lab. of the ISPRA:

The organic extractants can be:

- **TOPO (tri-octyl-phosphine oxide);**
- **HDEHP (di(2-ethyhexyl)phosphoric acid);**
- **TNOA (Tri-n-octylamine);**
- **TBP (tri-n-butyl phosphate), etc.**

- **2.3 Mobile phase:**
- **Feeding solution: acid solution (HCl, HNO_3, H_2SO_4).**

2.4 Column preparation

- **A certain amount of TOPO or TNOA or HDEHP was dissolved or diluted in about 100 ml of cyclohexane or toluene in a beaker. A certain amount of Microthene was added. The mixture was stirred for several minutes until homogeneous, and was then evaporated to eliminate cyclohexane or toluene at 50 °C.**

- **The porous powder thus obtained contained about 10-20% of TOPO or TNOA or HDEHP.**

- **A portion of the powder, slurred with 3 ml of concentrated HCl and some water, was transferred to a chromatographic column. After conditioning, the column was ready for use.**

2.5 Chromatographic column.

3 Methods

3.1 Procedure for determination of uranium isotopes in water samples by α-spectrometry.

Water (1-2 litres)

⇓

Addition of 40 mg Fe^{3+}, 0.03 Bq ^{232}U and 20 ml HNO_3; Uranium coprecipitation at pH 9.5-10

⇓

Precipitate dissolution and mineralization with HNO_3, H_2O_2 and HF

⇓

Leaching solution in 2 M HNO_3, passing through a Microthene-TOPO column

⇓

Washing with 30 ml 6 M HNO_3 and 50 ml 1 M HCl

⇓

Elution with 30 ml of 0.025 M $(NH_3)_2C_2O_4$

⇓

Electrodeposition uranium on a stainless steel disk at pH 1.0-1.5 (400 mA cm^{-2}, 4 h).

⇓

Counting by α–spectrometry

Uranium alpha-spectra obtained from a water sample by using the recommended procedure for uranium.

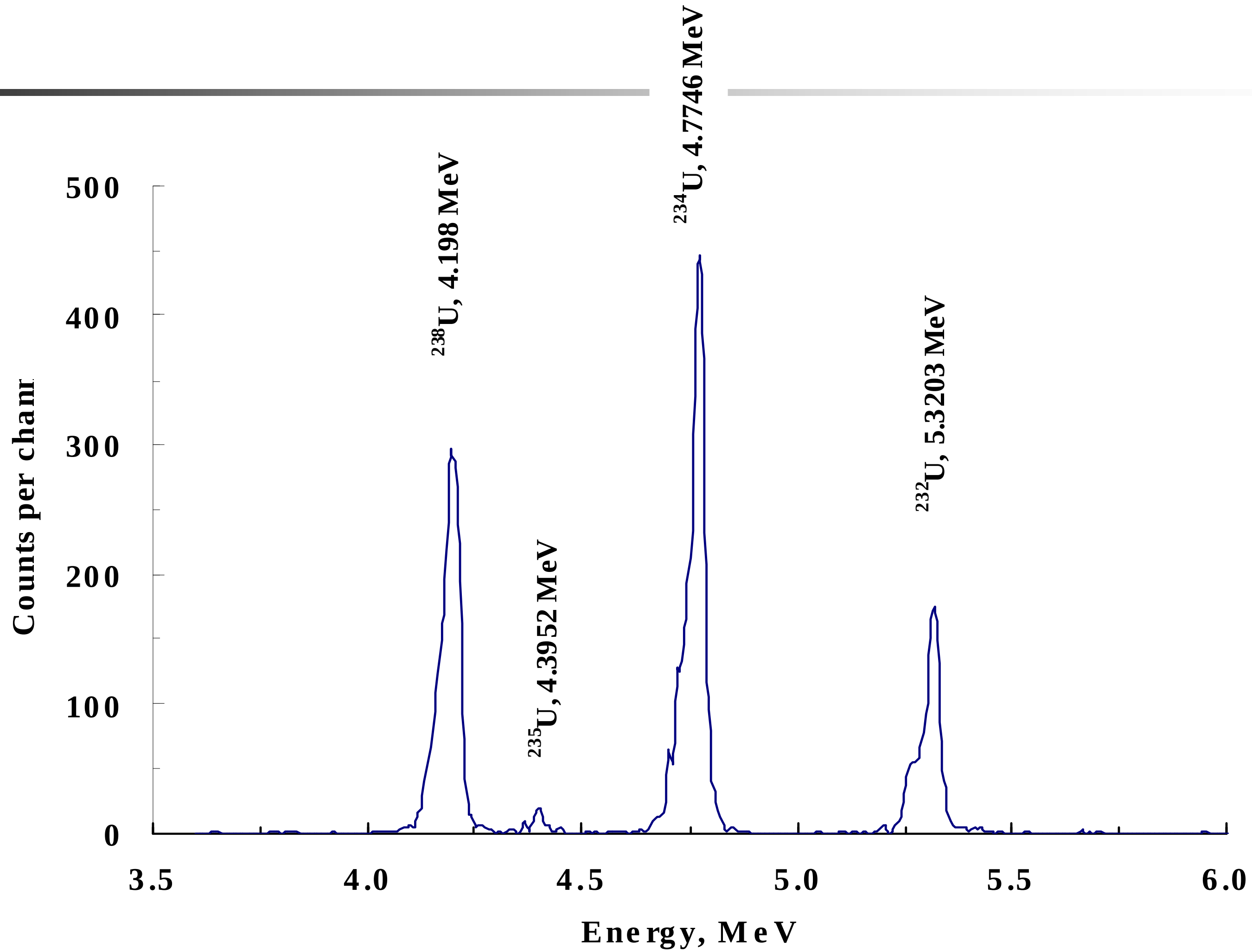

Fig. A10U894a. Uranium alpha-spectra obtained from a water sample by using the recommended procedure.

3.2 Procedure for determination of thorium isotopes in water samples by alpha-spectrometry.

Water (100 litres)

⇓

Addition of 160 mg Fe^{3+}, 0.0116 Bq ^{229}Th and 100 ml HNO_3; Uranium coprecipitation at pH 9.5-10

⇓

Precipitate dissolution and mineralization with HNO_3 and H_2O_2

⇓

Leaching solution in 2 M HNO_3, passing through a Microthene-TOPO column

⇓

Washing with 40 ml 6 M HNO_3 and 30 ml water

⇓

Elution with 80 ml of 1 M HCl, evaporate to dry

⇓

Transfer to sell with 0.025 M $H_2C_2O_4$+0.15 M HMO_3, electrodeposition Th on a stainless steel disk at pH 1.0-1.5

⇓

Counting by α–spectrometry

Thorium alpha-spectra obtained from a soil sample by using the recommended procedure for thorium.

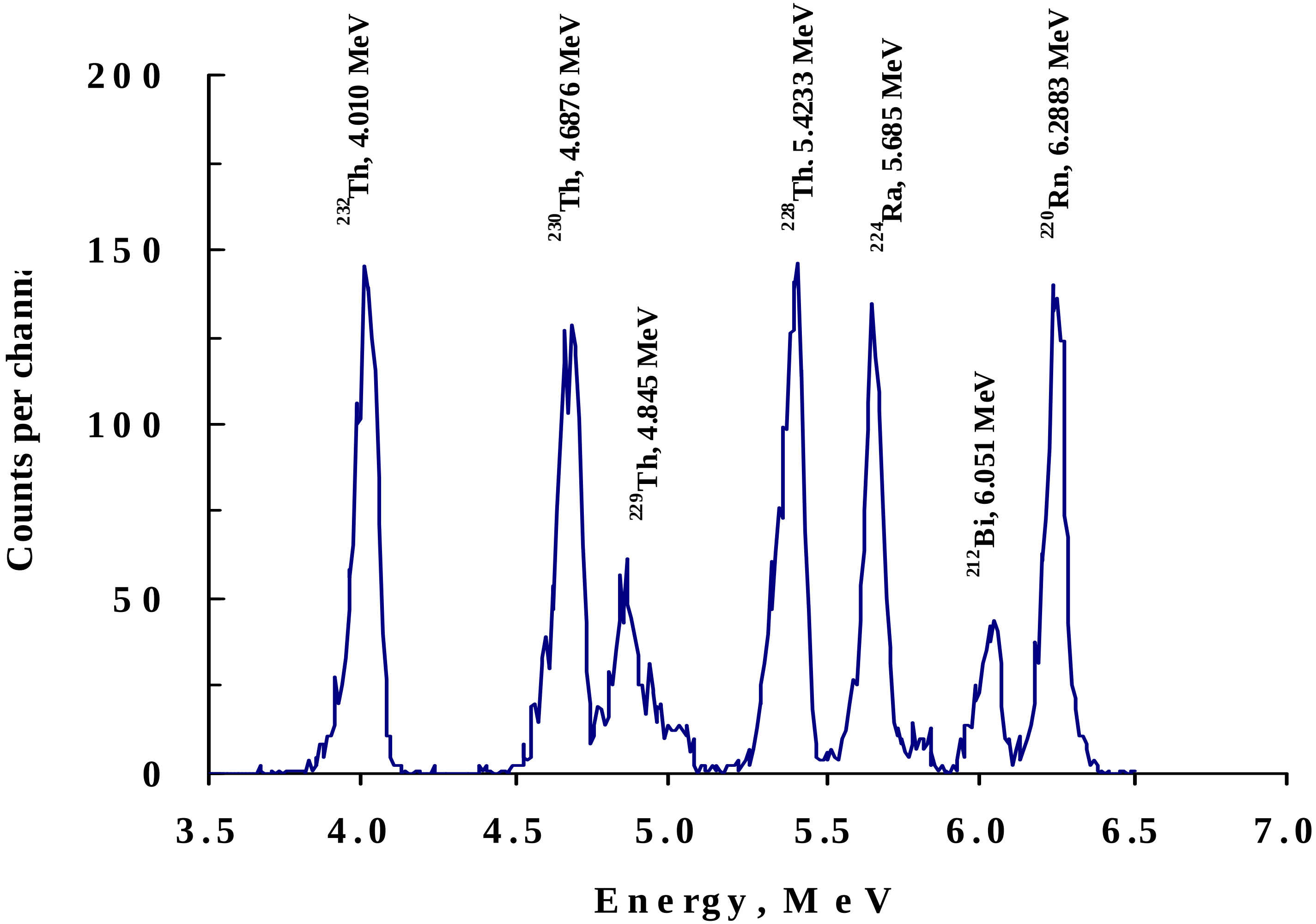

Fig. 1. Alpha-spectra of thorium isotopes and their daughters obtained from a sample (IAEA-326 soil) by using the recommended procedure (T=5681 min).

3.3 Procedure for determination of radium isotopes in water samples by alpha-spectrometry.

Water (2 litres)

⇓

Addition 2 mg Fe^{3+}, 10 mg Ba^{2+}, 0.053 Bq $^{229}Th/^{225}Ra$ and 10 ml HCl; Radium coprecipitation as sulfate at pH 3

⇓

Precipitate dissolution with 8 M HCl

⇓

Passing the leaching solution through a Microthene-TOPO column to separate Ra/Th

⇓

After drying the effluent, the residue is dissolved with 0.05 M CyDTA at pH 5-6

⇓

Separation of Ra/Ba with cation-exchange resin (AG-50W-X8) column

⇓

Washing with 0.05 M CyDTA at pH 8.5, elution with 3 M HNO_3, evaporate to dryness

⇓

Transfer to sell with 0.17 M $(NH4)_2C_2O_4$, electrodeposition Ra on a stainless steel disk at pH 2.6

⇓

Counting by α–spectrometry

Radium alpha-spectra obtained from a water sample by using the recommended procedure for radium.

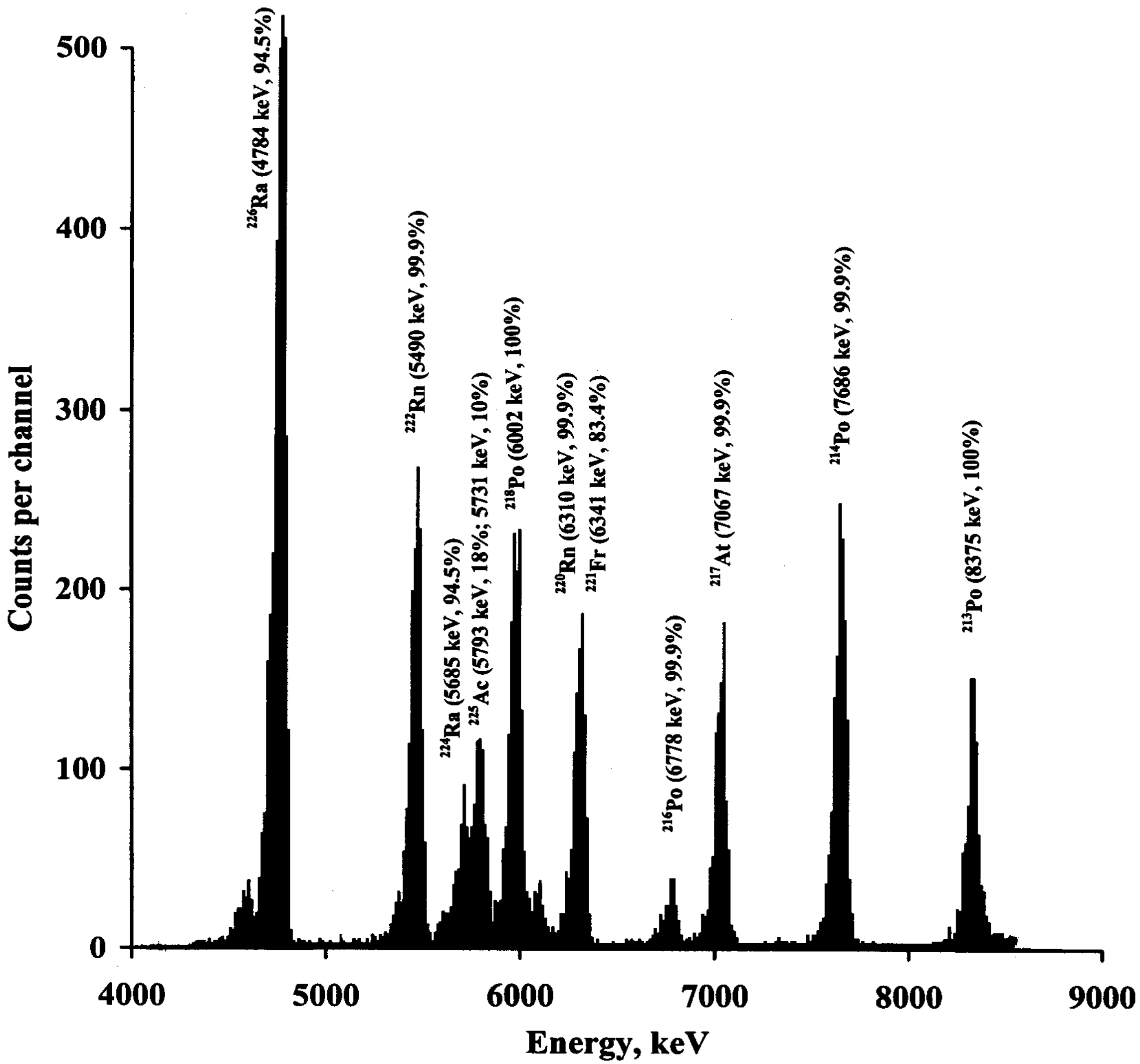

Fig. 7. Alpha-spectra of radium and thier daughters obtained from a water sample by using the recommended procedure.

3.4 Procedure for determination of ^{210}Po, ^{210}Pb and ^{212}Pb in water samples.

Water (50 litres)

↓

Addition 50 ml HCl 40 mg Fe^{3+}, 0.050 Bq ^{209}Po and 25 mg Pb^{2+} ; Coprecipitation as hydroxides and carbonates at pH 9-10 with ammonia; The precipitate is dissolved in 1.5 M HCl

↓

10% leaching solution

↓

Adding 1.0 g $NH_2OH \cdot HCl$, 1.25 g sodium citrate

↓

Deposition Po on a Ag disk at pH 1.5 and 90 °C for 4 h

↓

Counting ^{209}Po and ^{210}Po by α-spectrometry

90% leaching solution

↓

Passed through a BIO-RAD-AG 1-×4 anion-exchange resin column

↓

After washing with 1.5 M HCl, elution Pb with water

↓

Purified as PbS by using Na_2S solution

↓

Source preparation as $PbSO_4$

↓

Counting by low background β-counter for ^{212}Pb and ^{210}Pb determination

Polonium alpha-spectra obtained from a water sample by using the recommended procedure for Po.

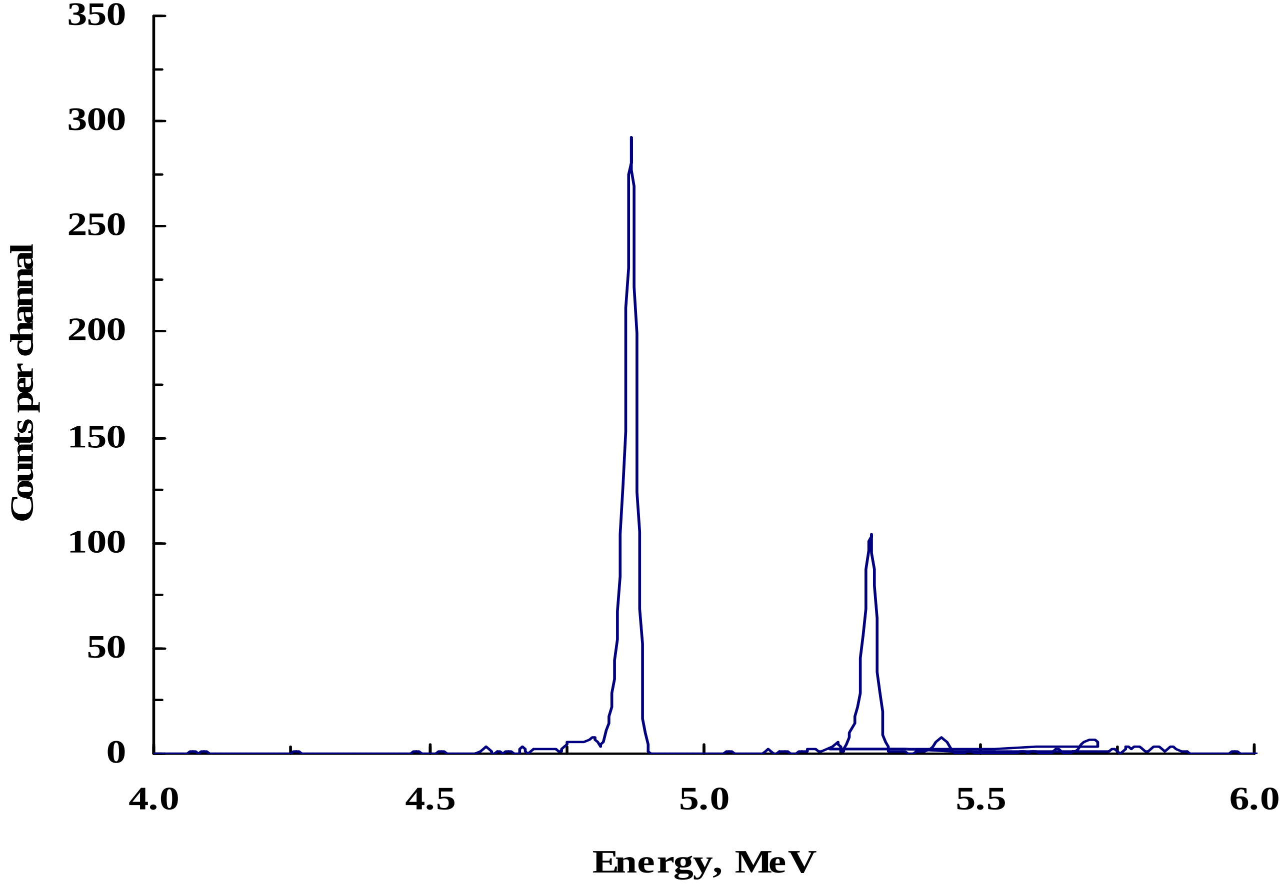

Fig. 2. Alpha-spectra of ^{209}Po (tracer) and ^{210}Po obtained from a water sample using the recommemded procedure.

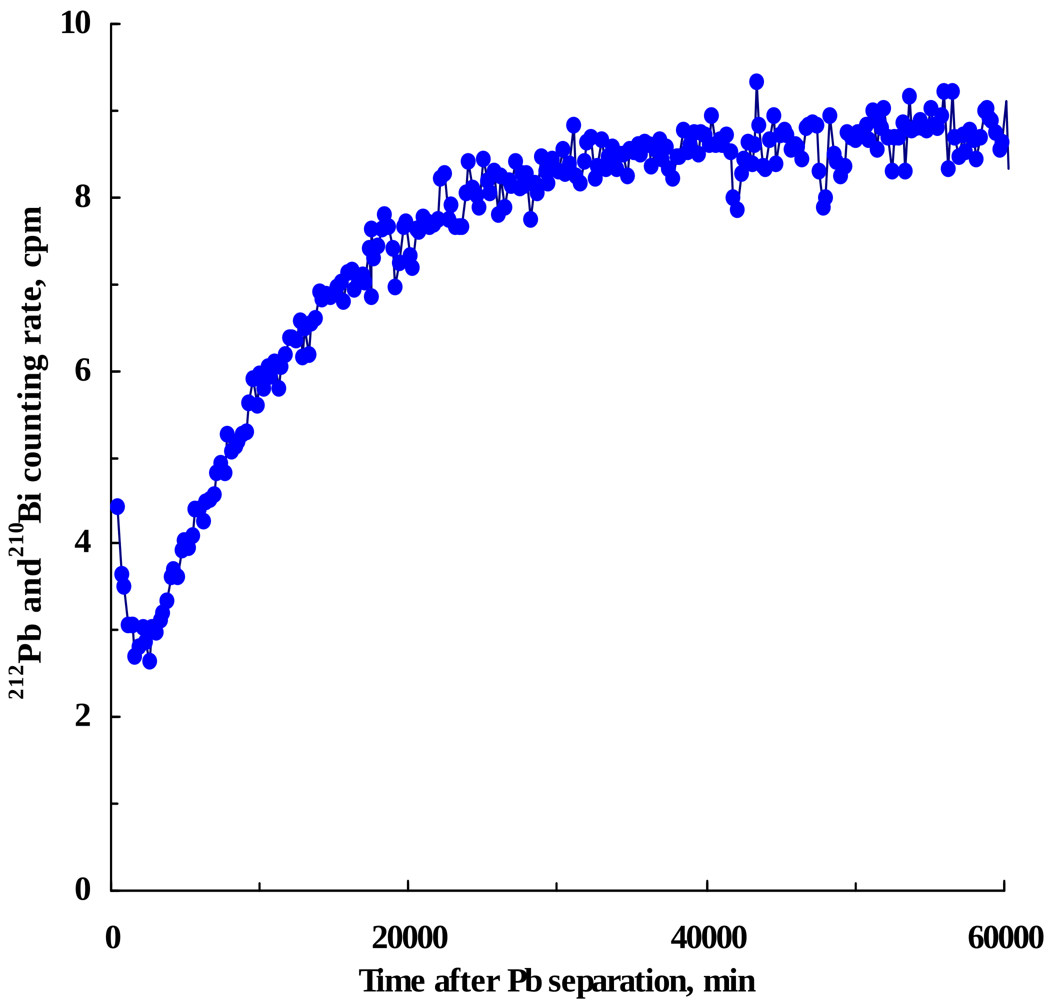

Fig. 1. The ^{212}Pb decay and ^{210}Bi ingrowth curve of a Pb source obtained from a portable water sample collected in Italy.

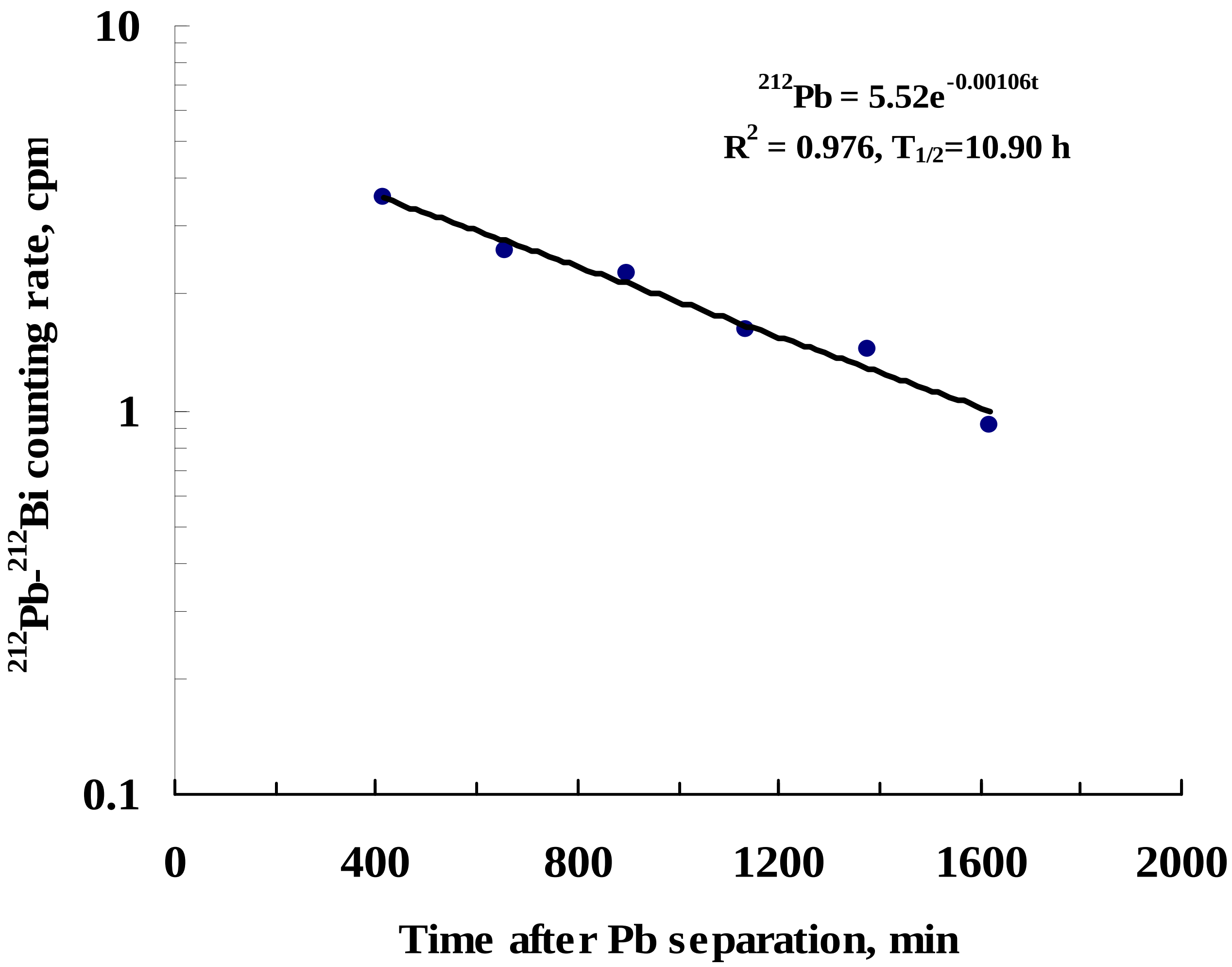

Fig. 2. The ^{212}Pb-^{212}Bi decay curve of a Pb source obtained from a potable water sample (same water as shown in Fig. 1) collected in Italy.

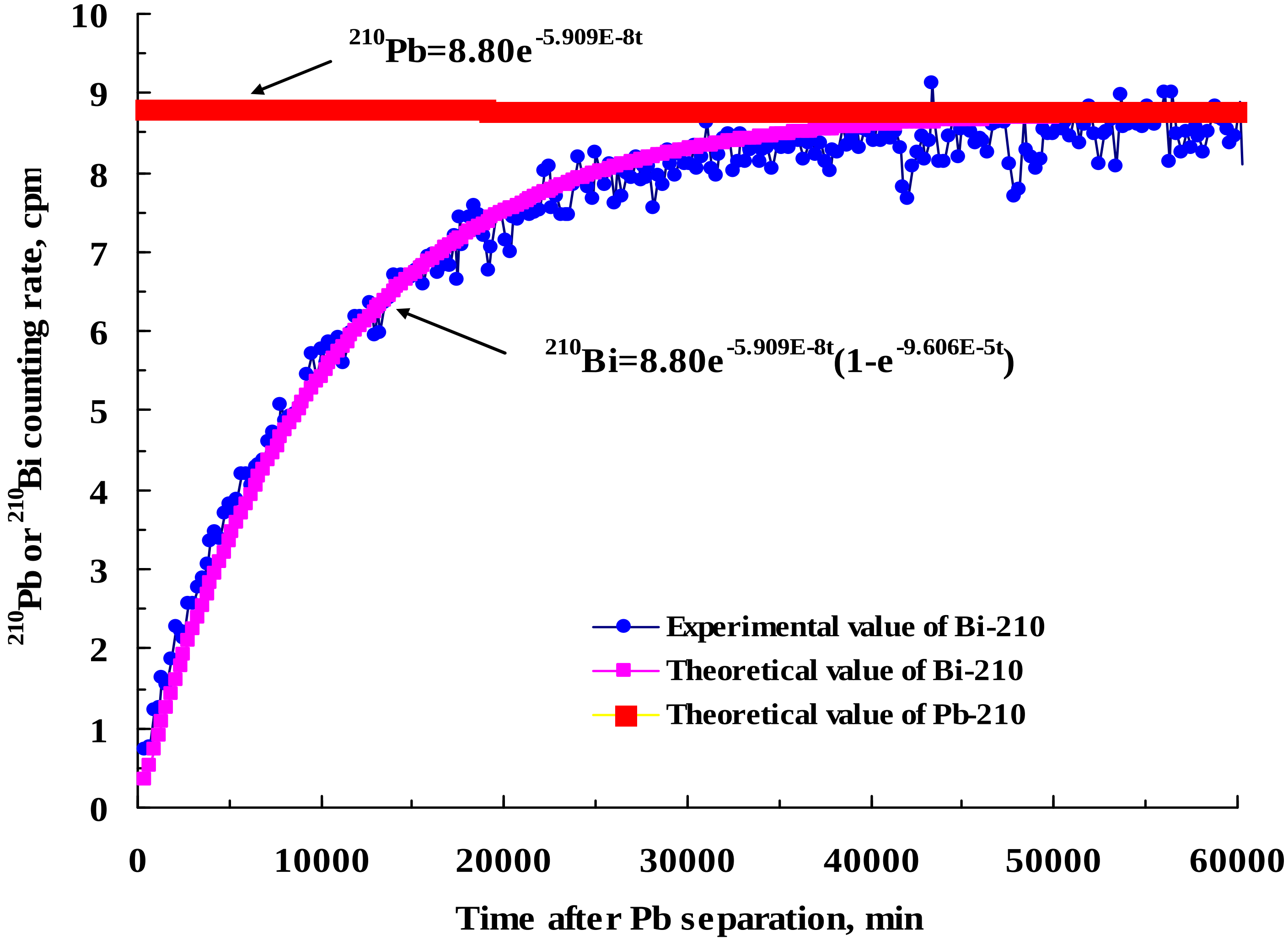

Fig. 3. The ^{210}Pb decay and ^{210}Bi ingrowth curves (after subtracting the ^{212}Pb contribution) of a Pb source obtained from a potable water sample (same water as shown in Fig. 1) collected in Italy.

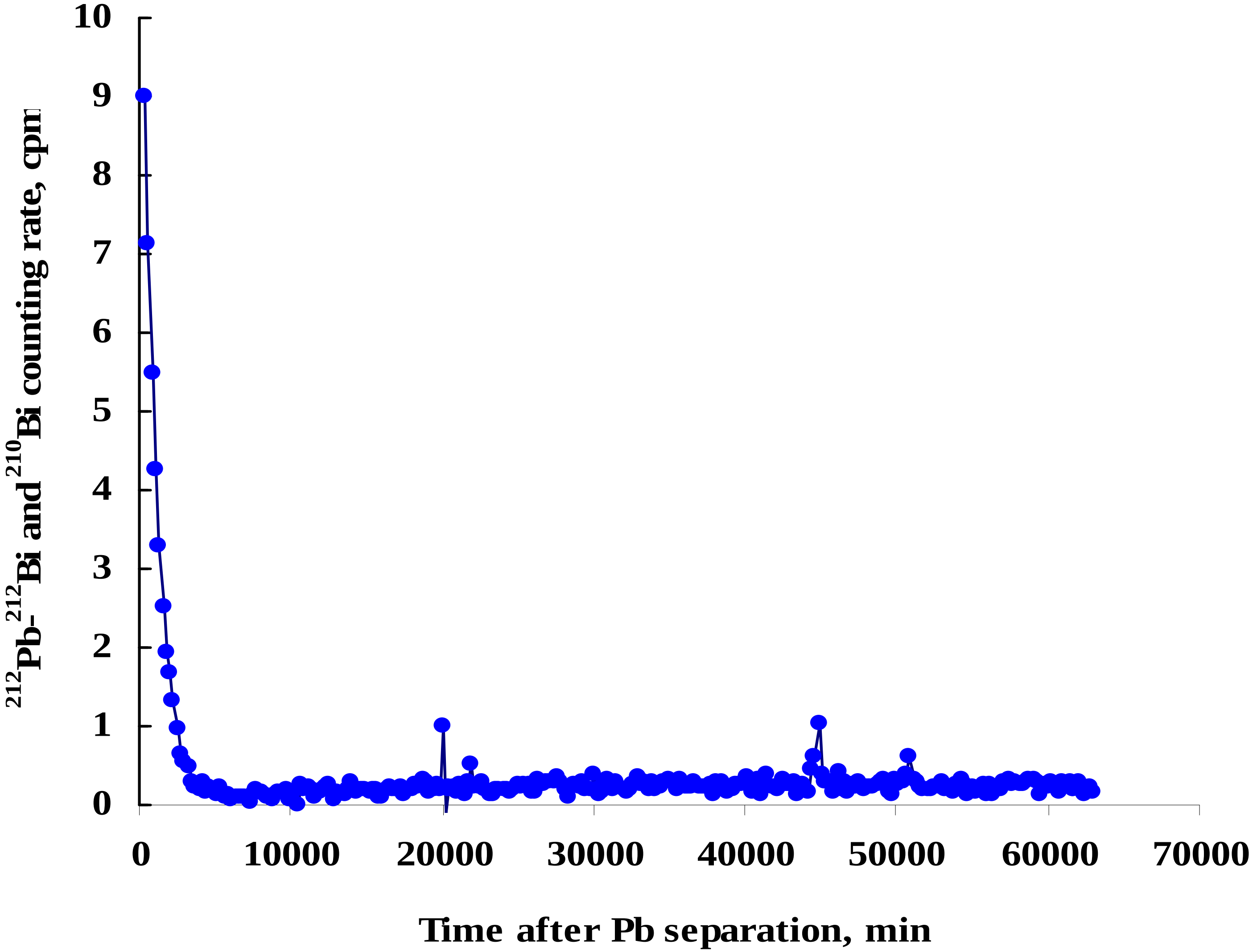

Fig. 4. The ^{212}Pb-^{212}Bi decay and ^{210}Bi ingrowth curve of a Pb source obtained from a tap water sample collected in Italy.

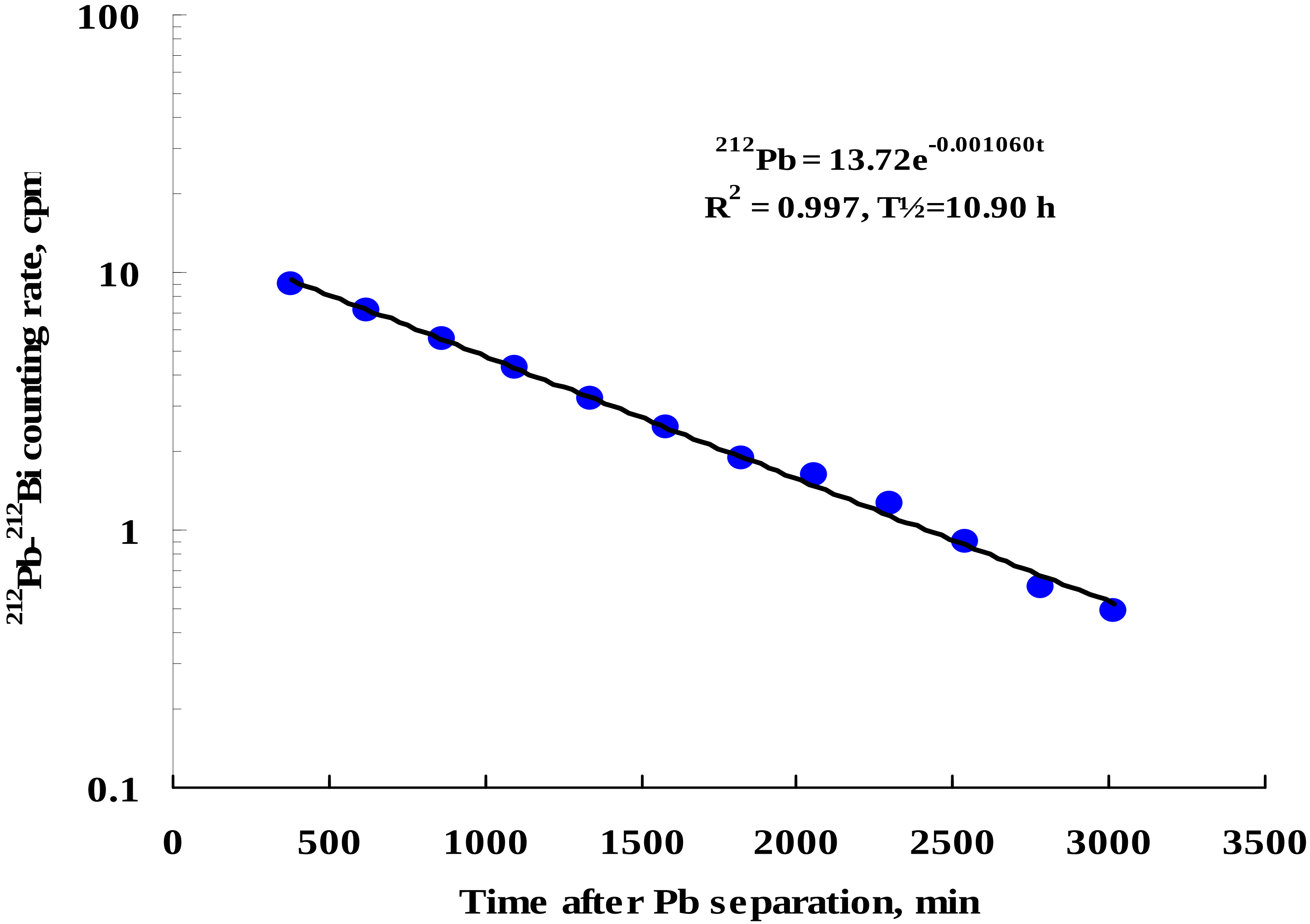

Fig. 5. The ^{212}Pb-^{212}Bi decay curve of a Pb source obtained from a typical tap water sample (same water as shown in Fig. 4) collected in Italy.

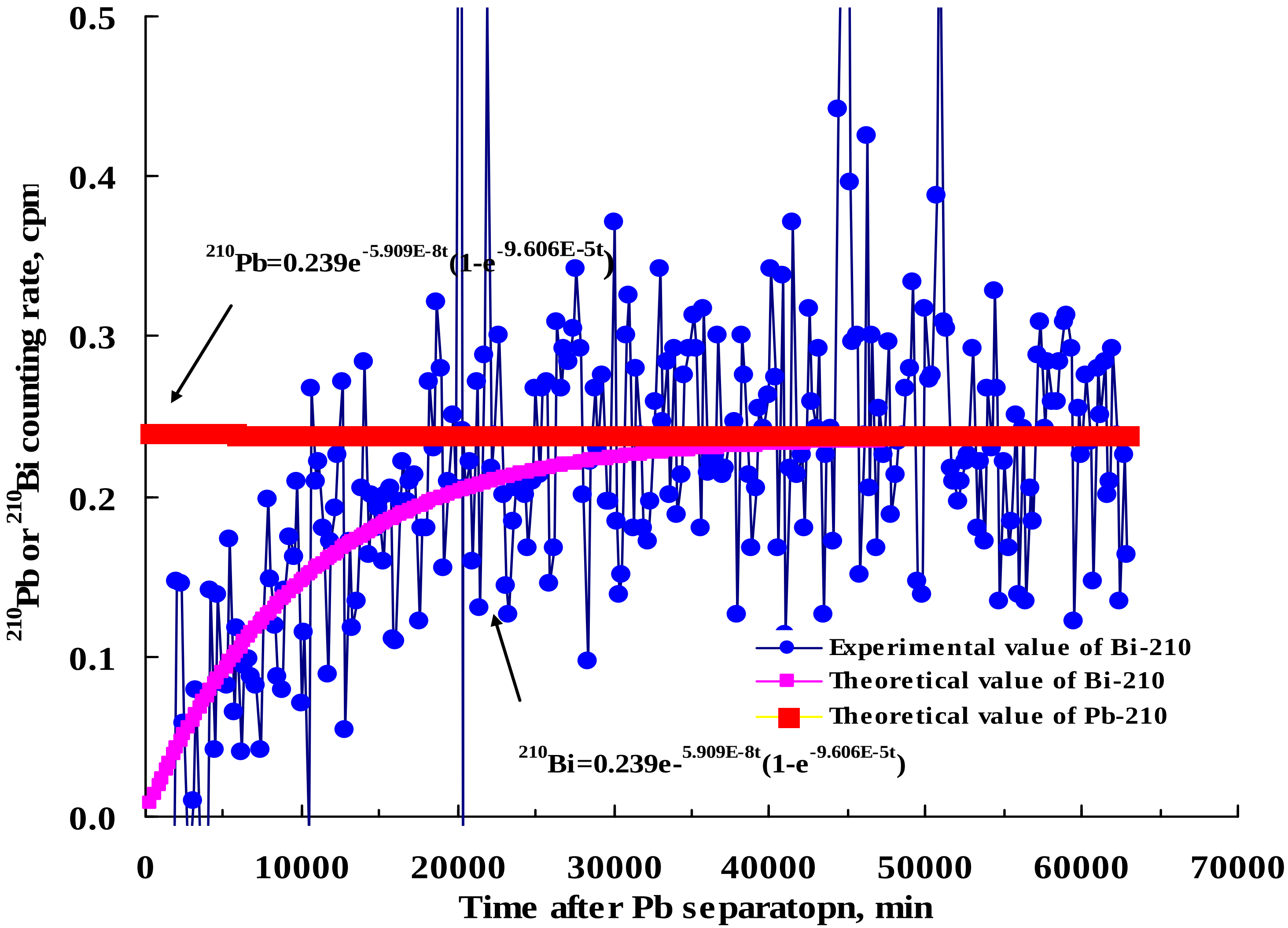

Fig. 6. The ^{210}Pb decay and ^{210}Bi ingrowth curves (after subtracting the ^{212}Pb contribution) of a Pb source obtained from a tap water sample (same water as shown in Fig. 4) collected in Italy.

3.5 The minimum detectable activity (MDA) of the methods for the radionuclides determined (counting time: about 10 days for alpha-emitters and 3 days for beta-emitters).

Radionuclide	Blank counts, cps	Counting efficiency, %	Yield, %	Sample volume, L	MDA, mBq L^{-1}
^{238}U	0.000085±0.000017	30.06	75.4±9.0	1.00	0.22
^{234}U	0.000085±0.000017	30.06	75.4±9.0	1.00	0.22
^{235}U	0.0000065±0.0000046	30.06	75.4±9.0	1.00	0.061
^{232}Th	0.0000091±0.0000034	31.08	74.7±14.2	100	0.00044
^{230}Th	0.000033±0.000006	31.08	74.7±14.2	100	0.00080
^{228}Th	0.000053±0.000008	31.08	74.7±14.2	100	0.0010
^{226}Ra	0.00014±0.00002	31.77	86.2±6.5	2.00	0.11
^{224}Ra	0.00014±0.00002	31.77	86.2±6.5	2.00	0.11
^{228}Ra	0.00014±0.00002	31.77	86.2±6.5	2.00	0.11
^{210}Po	0.000031±0.000007	28.77	94.8 ± 3.8	5.00	0.016
$^{210}Pb(^{210}Bi)$	0.00607±0.00027	48.16	88.8 ± 5.5	48.0	0.039
$^{212}Pb(^{212}Bi)$	0.00607±0.00027	88.36	88.8 ± 5.5	48.0	0.033

4.0 Results and discussion

4.1 The ^{238}U, ^{234}U, ^{235}U, ^{232}Th, ^{230}Th, ^{228}Th activity concentrations (in mBq L^{-1}) in drinking water samples collected in Italy.

ample code	Commercial name	^{238}U	^{234}U	^{235}U	^{234}U/^{238}U	^{235}U/^{238}U	^{232}Th	^{230}Th	^{228}Th	^{230}Th/^{232}Th	^{228}Th/^{232}Th
1	Blues Aura	16.8±0.9	17.1±0.9	0.86±0.17	1.02	0.051	0.0011±0.0002	0.0021±0.0003	0.100±0.004	1.85	88.1
2	Egeria	59.8±2.4	84.4±3.3	3.31±0.33	1.41	0.055	0.0019±0.0004	0.0053±0.0007	0.927±0.057	2.7	479
3	Guizza	6.14±0.29	6.43±0.30	0.29±0.05	1.05	0.047	0.0010±0.0003	0.0006±0.0004	0.0048±0.0014	0.62	4.84
4	Panna	7.21±0.38	13.2±0.6	0.35±0.08	1.83	0.048	0.0012±0.0003	0.0033±0.0006	0.0674±0.0032	2.7	54.7
5	Rocchetta Brioblu	2.33±0.15	3.37±0.19	0.16±0.04	1.44	0.070	0.0019±0.0013	0.0075±0.0023	0.0830±0.0067	3.9	43.2
6	Lete	20.5±1.2	23.3±1.3	0.98±0.21	1.14	0.048	0.0007±0.0002	0.0026±0.0003	0.176±0.006	3.7	248
7	Vitasnella	78.5±4.2	71.4±3.8	4.10±0.54	0.910	0.052	0.0008±0.0002	0.0015±0.0004	0.166±0.006	1.9	203
8	San Gemini	14.2±0.7	13.4±0.7	0.42±0.11	0.947	0.030	0.0008±0.0003	0.0033±0.0007	0.0653±0.0037	3.9	77.2
9	B-Rocchetta	1.39±0.20	2.09±0.23	0.08±0.05	1.51	0.054	0.0008±0.0004	0.0008±0.0007	0.0449±0.0033	1.1	58.6
10	Vera	12.0±0.8	15.3±1.0	0.99±0.21	1.28	0.083	0.0007±0.0002	≤ 0.0008	0.0068±0.0008	≤ 1.1	9.67
11	San Benedetto	12.4±0.7	21.6±1.0	0.68±0.14	1.75	0.055	0.0014±0.0004	≤ 0.0008	0.325±0.013	≤ 0.57	232
12	Lieve	2.91±0.18	5.02±0.24	0.20±0.05	1.72	0.069	0.0013±0.0002	0.0014±0.0003	0.0307±0.0016	1.1	24.4
13	Ferrarelle	16.0±0.8	20.7±1.0	1.22±0.18	1.30	0.077	0.0018±0.0003	0.0017±0.0005	1.32±0.05	0.92	717
14	Uliveto	4.13±0.23	8.29±0.37	0.27±0.05	2.01	0.065	0.0027±0.0014	0.0036±0.0032	0.897±0.031	1.3	328
15	Capannelle	103±3	135±4	3.48±0.41	1.31	0.034	0.0019±0.0004	0.0023±0.0006	0.219±0.008	1.2	114
16	CSM tap water	0.206±0.064	0.249±0.066	<MDA	1.21	ND*	0.0011±0.0003	0.0010±0.0005	0.0649±0.0030	0.88	58.3
17	Magliana tap water	7.22±0.36	7.55±0.37	0.51±0.10	1.05	0.071	0.0013±0.0004	0.0012±0.0007	0.0014±0.0010	0.95	1.06
an±SD		21.4 ±29.7	26.4±36.3	1.12±1.30	1.35±0.33	0.053±0.020	0.0013±0.0006	0.0023±0.0019	0.265±0.393	1.7±1.2	161±194
ange		0.206-103	0.249-135	<MDA-4.10	0.910-2.01	ND-0.083	0.0007- 0.0027	0.0008-0.0075	0.0014-1.32	≤ 0.57-3.9	1.06-717

4.2 The ^{226}Ra, ^{228}Ra, ^{224}Ra, ^{210}Po, ^{210}Pb and ^{212}Pb activity concentrations (in mBq L^{-1}) in drinking water samples collected in Italy.

ple code	Commercial name (Origin)	^{226}Ra	^{228}Ra	^{224}Ra	^{228}Ra/^{226}Ra	^{224}Ra/^{226}Ra	^{210}Po	^{210}Pb	^{212}Pb	^{212}Pb/^{210}Pb
1	Blues Aura (Umbria)	4.76±0.23	1.50±0.18	0.64±0.24	0.315	0.135	0.40±0.04	0.327±0.018	1.17±0.07	3.57
2	Egeria (Roma)	3.56±0.25	10.2±0.9	2.17±0.36	2.85	0.610	11.3±0.5	10.2±0.4	3.22±0.18	0.317
3	Guizza (Pescara)	1.19±0.10	1.23±0.24	1.12±0.23	1.03	0.941	0.50±0.04	3.62±0.15	1.12±0.08	0.308
4	Panna (Firenze)	2.49±0.17	1.95±0.27	0.35±0.16	0.782	0.141	3.39±0.20	5.11±0.21	1.77±0.11	0.346
5	Rocchetta (Perugia)	2.72±0.20	1.18±0.21	0.73±0.21	0.432	0.267	1.01±0.06	1.78±0.08	2.82±0.15	1.58
6	Lete (Caserta)	3.07±0.21	2.92±0.38	0.90±0.24	0.949	0.292	1.37±0.11	3.26±0.14	1.67±0.11	0.512
7	Vitasnella (Brescia)	26.6±1.2	5.01±0.41	0.93±0.16	0.189	0.035	7.37±0.45	8.65±0.36	3.17±0.18	0.367
8	Sangemini (Terni)	8.74±0.47	3.47±0.33	0.64±0.19	0.397	0.073	1.29±0.10	1.80±0.08	3.14±0.17	1.74
9	Brioblu Rocceetta (Perugia)	1.61±0.11	0.74±0.22	0.53±0.26	0.461	0.327	5.93±0.36	1.44±0.06	2.79±0.15	1.94
10	Vera (Padova)	0.50±0.06	0.55±0.11	0.46±0.17	1.09	0.912	1.48±0.09	6.66±0.28	1.93±0.11	0.289
11	San Benedetto (Vinece)	0.52±0.06	0.10±0.14	<MDA	0.200	ND	2.71±0.19	3.69±0.15	1.63±0.10	0.442
12	Lieve (Perugia)	2.95±0.20	2.54±0.27	1.11±0.28	0.862	0.378	0.32±0.03	0.806±0.036	4.03±0.20	5.01
13	Ferrarelle (Caserta)	60.8±2.3	25.7±1.9	3.17±0.45	0.422	0.052	10.7±0.6	4.27±0.18	3.26±0.18	0.764
14	Uliveto (Pisa)	14.4±0.7	6.19±0.63	1.34±0.35	0.430	0.093	0.61±0.06	0.458±0.024	2.48±0.14	5.41
15	Capannelle (Roma)	1.11±0.22	4.95±0.86	1.01±0.44	4.45	0.905	6.55±0.36	15.1±0.6	5.77±0.30	0.383
16	CSM tap water (Roma)	10.8±0.6	11.8±1.1	7.97±1.12	1.10	0.741	0.13±0.01	0.191±0.12	3.22±0.19	16.9
17	Magliana tap water (Roma)	4.97±0.28	1.53±0.25	1.53±0.61	0.308	0.308	0.15±0.01	0.562±0.028	2.27±0.13	4.05
n±SD		8.87±14.9	4.80±6.32	1.45±1.84	0.957±1.097	0.371±0.324	3.25±3.72	3.99±4.11	2.67±1.15	2.58±4.08
ge		0.50 - 60.8	0.10–25.7	<MDA-7.97	0.189-4.45	ND – 0.941	0.13 – 11.3	0.191 – 15.1	1.12–5.77	0.289-16.9

4.3 The committed effective doses (μSv yr^{-1}) to an adult in Italy from intake of naturally occurring radionuclides in the sampled drinking waters.

Sample code	^{238}U	^{234}U	^{235}U	^{232}Th	^{230}Th	^{228}Th	^{226}Ra	^{228}Ra	^{224}Ra	^{210}Po	^{210}Pb	^{212}Pb	Total dose, μSv yr^{-1}
1	0.551	0.613	0.029	0.00019	0.00032	0.00523	0.973	0.755	0.031	0.351	0.165	0.0051	3.48
2	1.96	3.02	0.113	0.00032	0.00081	0.04874	0.728	5.12	0.103	9.87	5.12	0.0141	26.2
3	0.202	0.230	0.010	0.00017	0.00009	0.00025	0.243	0.619	0.053	0.442	1.82	0.0049	3.63
4	0.237	0.472	0.012	0.00021	0.00051	0.00354	0.510	0.983	0.017	2.97	2.57	0.0077	7.79
5	0.077	0.121	0.006	0.00032	0.00115	0.00436	0.556	0.592	0.034	0.885	0.895	0.0123	3.19
6	0.673	0.834	0.034	0.00012	0.00040	0.00925	0.628	1.47	0.043	1.20	1.64	0.0073	6.55
7	2.58	2.556	0.141	0.00014	0.00023	0.00874	5.43	2.53	0.044	6.45	4.36	0.0139	24.1
8	0.466	0.480	0.015	0.00014	0.00050	0.00343	1.79	1.75	0.030	1.13	0.908	0.0138	6.59
9	0.046	0.075	0.003	0.00013	0.00013	0.00236	0.329	0.374	0.025	5.20	0.724	0.0122	6.79
10	0.393	0.547	0.034	0.00012	0.00001	0.00036	0.103	0.276	0.022	1.30	3.35	0.0084	6.03
11	0.406	0.774	0.023	0.00024	0.00006	0.01710	0.107	0.053	0.003	2.37	1.86	0.0072	5.64
12	0.096	0.180	0.007	0.00021	0.00021	0.00161	0.603	1.280	0.053	0.285	0.406	0.0177	2.93
13	0.524	0.741	0.042	0.00031	0.00026	0.06953	12.4	12.9	0.150	9.35	2.15	0.0143	38.5
14	0.136	0.296	0.009	0.00046	0.00056	0.04713	2.94	3.12	0.063	0.535	0.231	0.0109	7.44
15	3.38	4.82	0.119	0.00032	0.00035	0.01149	0.227	2.49	0.048	5.74	7.59	0.0253	24.5
16	0.007	0.009	ND	0.00019	0.00015	0.00341	2.20	5.97	0.378	0.110	0.096	0.0141	8.79
17	0.237	0.270	0.017	0.00021	0.00019	0.00007	1.02	0.771	0.073	0.130	0.283	0.0100	2.81
Mean±SD	0.704±0.976	0.944±1.30	0.036±0.044	0.00022±0.00009	0.00035±0.00029	0.0139±0.0206	1.81±3.05	2.42±3.18	0.069±0.087	2.84±3.26	2.13±2.08	0.0121±0.0049	10.87±10.55
Range	0.007-3.38	0.009-4.82	ND-0.141	0.00012-0.00046	0.00001-0.00115	0.0001-0.0695	0.103-12.4	0.053-12.9	0.003-0.378	0.110-9.87	0.096-7.59	0.0049-0.0253	2.81-38.5

The mean activity concentrations ($mBq\ L^{-1}$) of the radionuclides in the analysed drinking water samples were almost in the order:

26±36 (^{234}U) > 21±30 (^{238}U) > 8.9±15 (^{226}Ra) > 4.8±6.3 (^{228}Ra) > 4.0±4.1 (^{210}Pb) > 3.2±3.7(^{210}Po) 2.7±1.2 (^{212}Pb) > 1.4±1.8 (^{224}Ra) > 1.1±1.3 (^{235}U) > 0.26±0.39 (^{228}Th) > 0.0023±0.0009 (^{230}Th) > 0.0013±0.0006 (^{232}Th).

4.4 The dose contribution from radionuclides of uranium, thorium, radium, lead and polonium.

Table 4. The dose contribution fractions from radionuclides of uranium, thorium, radium, polonium and lead.

Sample code	Commercial name (Origin)	Dose fraction from uranium, %	Dose fraction from thorium, %	Dose fraction from radium, %	Dose fraction from polonium, %	Dose fraction from lead, %
1	Blues Aura (Umbria)	34.2	0.17	50.5	10.1	4.88
2	Egeria (Roma)	19.5	0.19	22.7	37.8	19.6
3	Guizza (Pescara)	12.2	0.01	25.2	12.2	50.4
4	Panna (Firenze)	9.25	0.05	19.4	38.1	33.1
5	Rocchetta (Perugia)	6.36	0.18	37.1	27.7	28.4
6	Lete (Caserta)	23.5	0.15	32.7	18.3	25.2
7	Vitasnella (Brescia)	21.9	0.04	33.2	26.8	18.1
8	Sangemini (Terni)	14.6	0.06	54.1	17.2	14.0
9	Brioblu Rocchetta (Perugia)	1.81	0.04	10.7	76.5	10.8
10	Vera (Padova)	16.1	0.01	6.64	21.5	55.7
11	San Benedetto (Vinece)	21.3	0.31	2.87	42.0	33.1
12	Lieve (Perugia)	9.63	0.08	66.1	9.70	14.5
13	Ferrarelle (Caserta)	3.40	0.18	66.3	24.3	5.62
14	Uliveto (Pisa)	5.93	0.65	82.3	7.20	3.25
15	Capannelle (Roma)	34.0	0.05	11.3	23.5	31.1
16	CSM tap water (Roma)	0.18	0.04	97.2	1.25	1.25
17	Magliana tap water (Roma)	18.7	0.02	66.2	4.63	10.4
Mean±SD		14.9±10.3	0.13±0.16	40.3±28.1	23.5±18.2	21.2±15.9
Range		0.18-36.0	0.01-0.65	2.87-97.2	1.25-76.5	1.25-55.7

It is shown that:

- As far as the measured radionuclides were concerned, the total doses for all the analysed drinking water were in the range of 2.81-38.5 μSv yr^{-1} with a mean value of 11±11 μSv yr^{-1}.

- All are well below the reference level of the committed effective dose (100 μSv yr^{-1}) recommended by the WHO for drinking water.

As far as each measured radionuclide was concerned, the mean dose (μSv yr^{-1}) from the drinking water intake were in the order:

- **2.8±3.3 (^{210}Po) > 2.4±3.2 (^{228}Ra) > 2.1±2.1 (^{210}Pb) > 1.8±3.1 (^{226}Ra) > 0.94±1.30 (^{234}U) > 0.70±0.98 (^{238}U) > 0.069±0.087 (^{224}Ra) > 0.036±0.044 (^{235}U) > 0.014±0.021 (^{228}Th) > 0.012±0.005 (^{212}Pb) > 0.00035±0.00029 (^{230}Th) > 0.00022±0.00009 (^{232}Th).**

5 Conclusion

- It is concluded that:
- The extraction chromatographic methods are selective, economic and accurate techniques in the field of radioanalytical analyses for environmental and biological samples, and is playing a very important role.

Thank you for your attention!