Gross Alpha and Beta Measurements of Water Samples from the Wonderfonteinspruit Catchment Area in the Gauteng Province (South Africa), using Liquid Scintillation Counting

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Aim of the study

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Aim:

To use the Quantulus 1220 ultra low level liquid scintillation spectrometer for the:

- **determination of the gross α- and β-activities directly on the raw water samples without extensive sample preparation**
- **semi-qualitative identification of the major NORM nuclides in environmental water collected from the Wonderfonteinspruit catchment area (WCA).**

Study area, WCA

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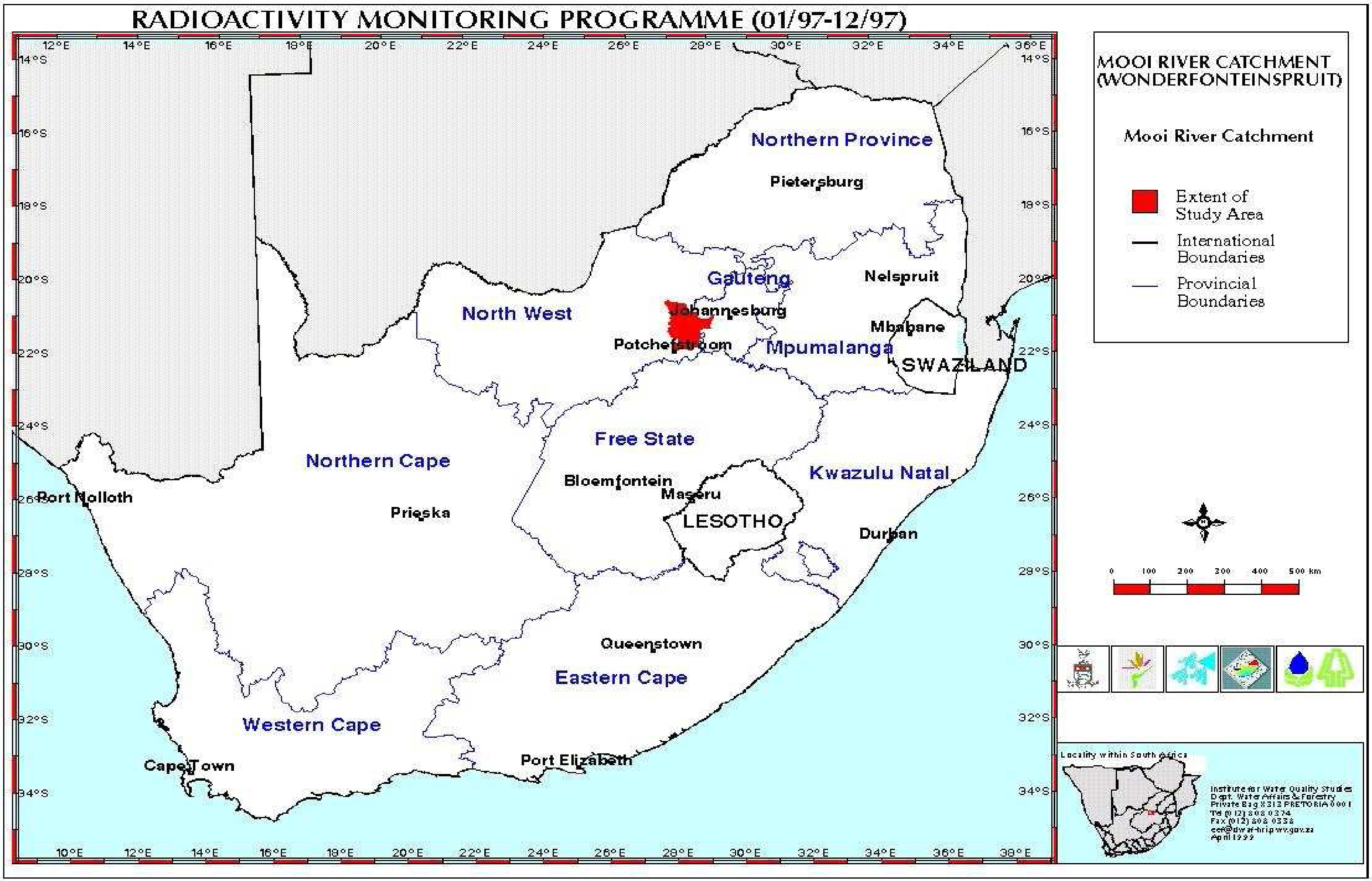
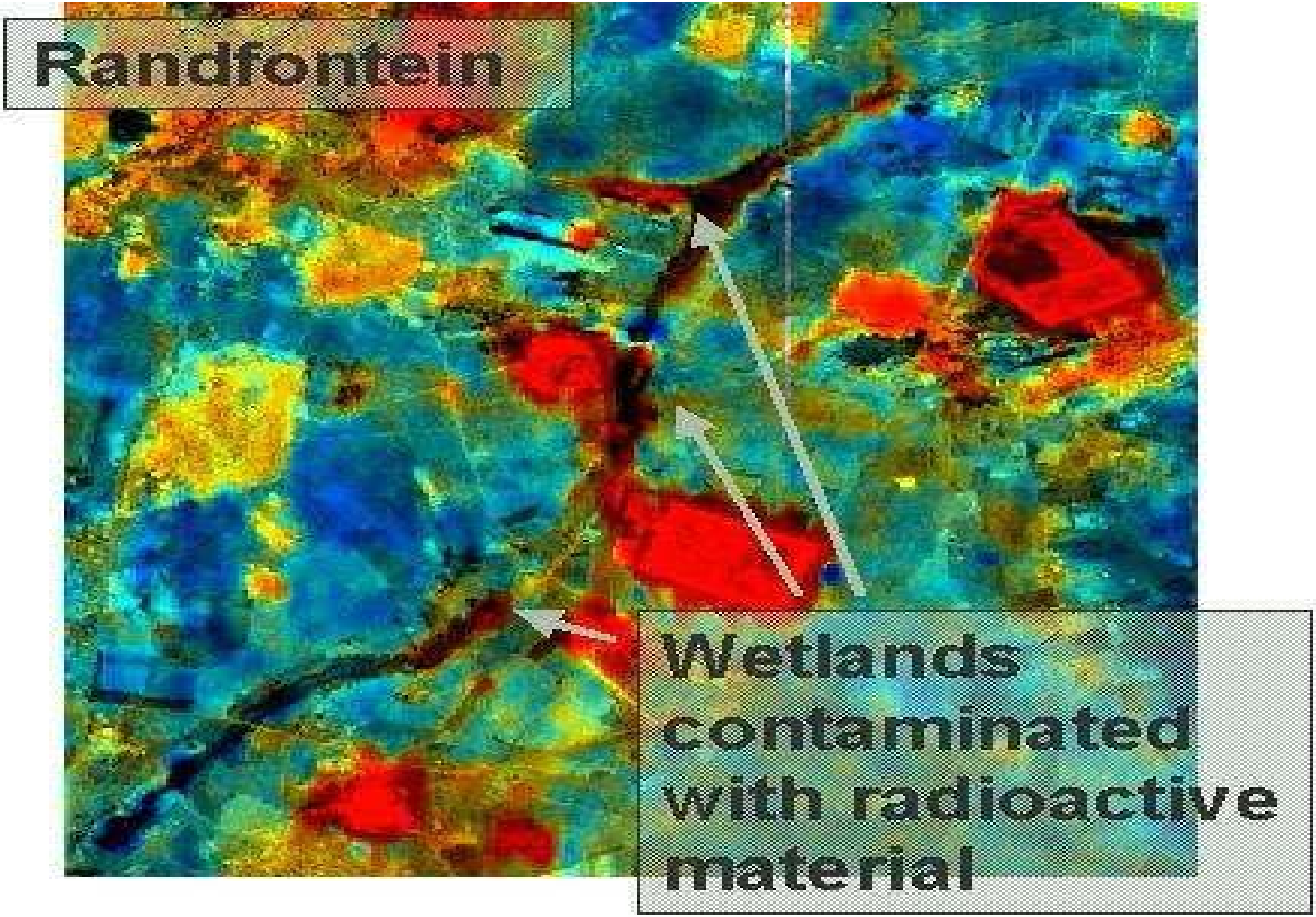


Study area, WCA Cont...



Materials and Methods

Optimal PSA setting

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Optimal PSA setting

- Different quench levels were obtained by preparing standards (^{241}Am and ^{90}Sr) with different volumes of distilled water and measured at various PSA values.

- The optimal PSA was established by calculating α-β spillovers at different PSA levels. The α-spillover (X_α) and and β-spillover (X_β) were calculated using the following equations;

$$X_\alpha = \frac{MCA\ 11}{MCA\ 12 + MCA\ 11} \qquad X_\beta = \frac{MCA\ 12}{MCA\ 12 + MCA\ 11}$$

Optimal PSA setting cont..

The following data were gathered from the above equations;

	1 ml		3 ml		5 ml		7ml	
PSA	α spillover	β spillover	α spillover	β spillover	α spillover	β spillover	α spillover	β spillover
30	0.00007	0.95951	0.00010	0.78426	0.00014	0.71249	0.00021	0.68979
40	0.00008	0.93051	0.00022	0.57384	0.00025	0.45515	0.00032	0.45061
50	0.00007	0.88665	0.00042	0.26639	0.00041	0.18309	0.00037	0.17624
55	0.00007	0.84015	0.00049	0.16931	0.00039	0.12045	0.00042	0.12270
60	0.00015	0.76395	0.00044	0.09533	0.00040	0.07370	**0.00039**	**0.07278**
65	0.00022	0.64888	0.00050	0.07182	0.00052	0.05960	0.00065	0.06096
70	0.00022	0.50795	0.00055	0.04105	**0.00049**	**0.03307**	0.00075	0.03630
75	0.00037	0.37124	0.00059	0.03954	0.00084	0.03488	0.00115	0.03838
80	0.00038	0.24262	**0.00057**	**0.02132**	0.00125	0.02028	0.00191	0.02199
90	0.00045	0.09625	0.00142	0.01382	0.00637	0.01531	0.00804	0.01646
100	0.00053	0.04085	0.00690	0.00910	0.02776	0.00956	0.03072	0.01142
110	0.00063	0.02050	0.03386	0.00817	0.08439	0.00772	0.08653	0.00932
120	**0.00058**	**0.01051**	0.10532	0.00583	0.19382	0.00705	0.18419	0.00689
130	0.00164	0.00739	0.23713	0.00499	0.33846	0.00462	0.31381	0.00679

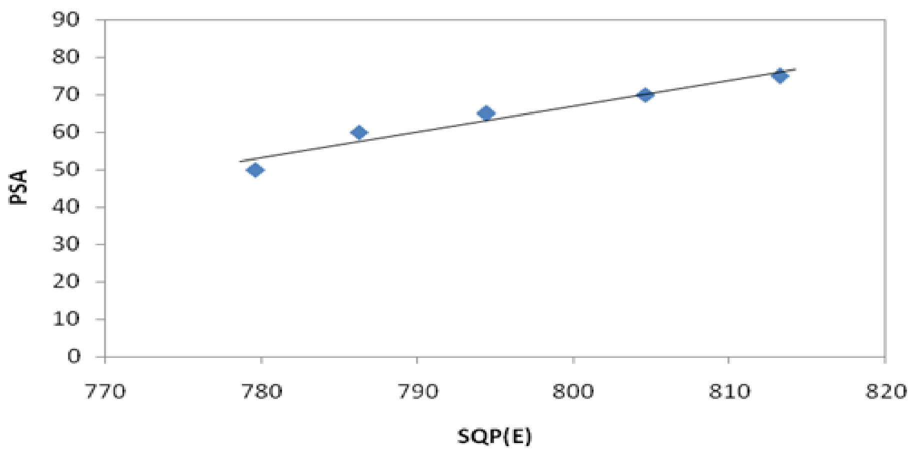
Optimal PSA setting cont..

The highlighted changeover values were used to construct a PSA calibration curve shown below and can be mathematically presented, through linear regression, by,

$$Y = 0.690x - 485.2$$

Where Y is the optimal PSA setting and x is the measured quench value/parameter (SQP(E)), ($r^2 = 0.95$).

This relationship makes it possible to find the optimum PSA setting once the quench value has been determined of each individual environmental sample (from an arbitrary PSA level).



Determination of gross α-β activity in water samples

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Twenty-five water samples collected from the WCA in the Gauteng Province were analysed. The water samples were prepared by taking a 5 ml portion of the water samples (using a pipette) and transferring them to a polyethylene counting vial after which 15 ml of the Ultima Gold AB cocktail was added and the mixture shaken vigorously. The background samples were prepared the same way as using distilled water. Gross α-β activities were calculated using two options; with and without spillover correction;

Without spillover:

$$A_{\alpha} = \frac{(MCA\,12_{G\alpha} - MCA\,12_{B\alpha})}{V \cdot T \cdot}$$

$$A_{\beta} = \frac{(MCA11_{G\beta} - MCA11_{B\beta})}{V \cdot T \cdot}$$

With spillover:

$$A_{\alpha} = \frac{(MCA12_{G\alpha} - MCA12_{B\alpha})(1 - X_{\beta}) - (MCA11_{G\beta} - MCA11_{B\beta})X_{\beta}}{(1 - X_{\alpha} - X_{\beta}) \cdot \varepsilon_{\alpha} \cdot V \cdot T \cdot}$$

$$A_{\beta} = \frac{(MCA11_{G\beta} - MCA11_{B\beta})(1 - X_{\alpha}) - (MCA12_{G\alpha} - MCA12_{B\alpha})X_{\alpha}}{(1 - X_{\alpha} - X_{\beta}) \cdot \varepsilon_{\beta} \cdot V \cdot T \cdot}$$

Results

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Code (WS)	Calculated values (Bq/ℓ)				Activity with spillover correction (Bq/ℓ)				Activity without spillover correction (Bq/ℓ)			
	Gross α	α unc	Gross β	β unc	Gross α	α unc	Gross β	β unc	Gross α	α unc	Gross β	β unc
1	7.46	0.07	7.01	0.06	9.46	0.23	8.69	0.09	9.77	0.23	8.15	0.08
2	6.14	0.06	5.96	0.06	6.40	0.17	7.51	0.08	6.70	0.18	7.02	0.07
3	10.77	0.11	10.79	0.12	11.5	0.26	12.9	0.13	12.1	0.26	12.0	0.12
4	2.19	0.07	1.97	0.05	2.18	0.08	2.88	0.03	2.31	0.08	2.67	0.03
5	12.42	0.14	12.10	0.14	12.9	0.28	13.2	0.13	13.5	0.28	12.2	0.12
6	3.56	0.07	3.56	0.07	4.07	0.13	5.47	0.06	4.29	0.13	5.12	0.05
7	1.02	0.04	0.68	0.03	0.84	0.04	2.27	0.02	0.94	0.04	2.10	0.02
8	14.03	0.10	11.74	0.09	13.7	0.29	12.5	0.13	14.2	0.29	11.6	0.12
9	6.99	0.06	7.23	0.06	7.59	0.19	7.90	0.08	7.87	0.20	7.42	0.08
10	6.05	0.14	6.12	0.12	6.50	0.18	9.98	0.10	6.83	0.18	9.44	0.10
11	12.90	0.08	11.26	0.08	14.1	0.29	11.4	0.12	14.5	0.30	10.7	0.11
12	11.06	0.12	10.97	0.12	12.3	0.27	12.2	0.12	12.8	0.27	11.4	0.12
13	3.56	0.05	3.35	0.04	3.42	0.11	14.5	0.14	3.93	0.12	13.7	0.14
14	0.30	0.02	0.20	0.01	1.06	0.04	1.53	0.02	1.13	0.04	1.42	0.02
15	14.17	0.09	13.87	0.09	15.8	0.32	13.8	0.14	16.3	0.32	12.9	0.13
16	6.64	0.09	6.59	0.07	7.37	0.19	9.59	0.10	7.71	0.19	9.03	0.09
17	13.27	0.09	13.34	0.09	13.5	0.29	14.2	0.14	14.1	0.29	13.3	0.13
18	7.28	0.08	6.51	0.07	9.82	0.23	4.95	0.05	9.96	0.23	4.39	0.05
19	34.38	0.29	33.25	0.28	44.8	0.60	33.4	0.30	46.1	0.61	29.3	0.26
20	8.55	0.08	6.95	0.08	13.08	0.28	7.44	0.08	13.3	0.28	6.56	0.07
21	12.41	0.09	12.67	0.09	14.5	0.30	11.7	0.12	15.0	0.30	10.2	0.10
22	41.22	0.30	37.05	0.29	54.1	0.67	44.0	0.37	55.9	0.68	38.5	0.33
23	32.36	0.30	30.79	0.28	38.4	0.37	54.1	0.56	46.4	0.45	37.0	0.38
24	344.46	2.84	181.46	2.02	5242	6.92	1172	3.94	5383	7.47	814	2.71
25	528.30	4.25	11.30	3.01	9638	5.43	7414	21.95	11404	10.9	1252	3.55

Semi-qualitative nuclide identification

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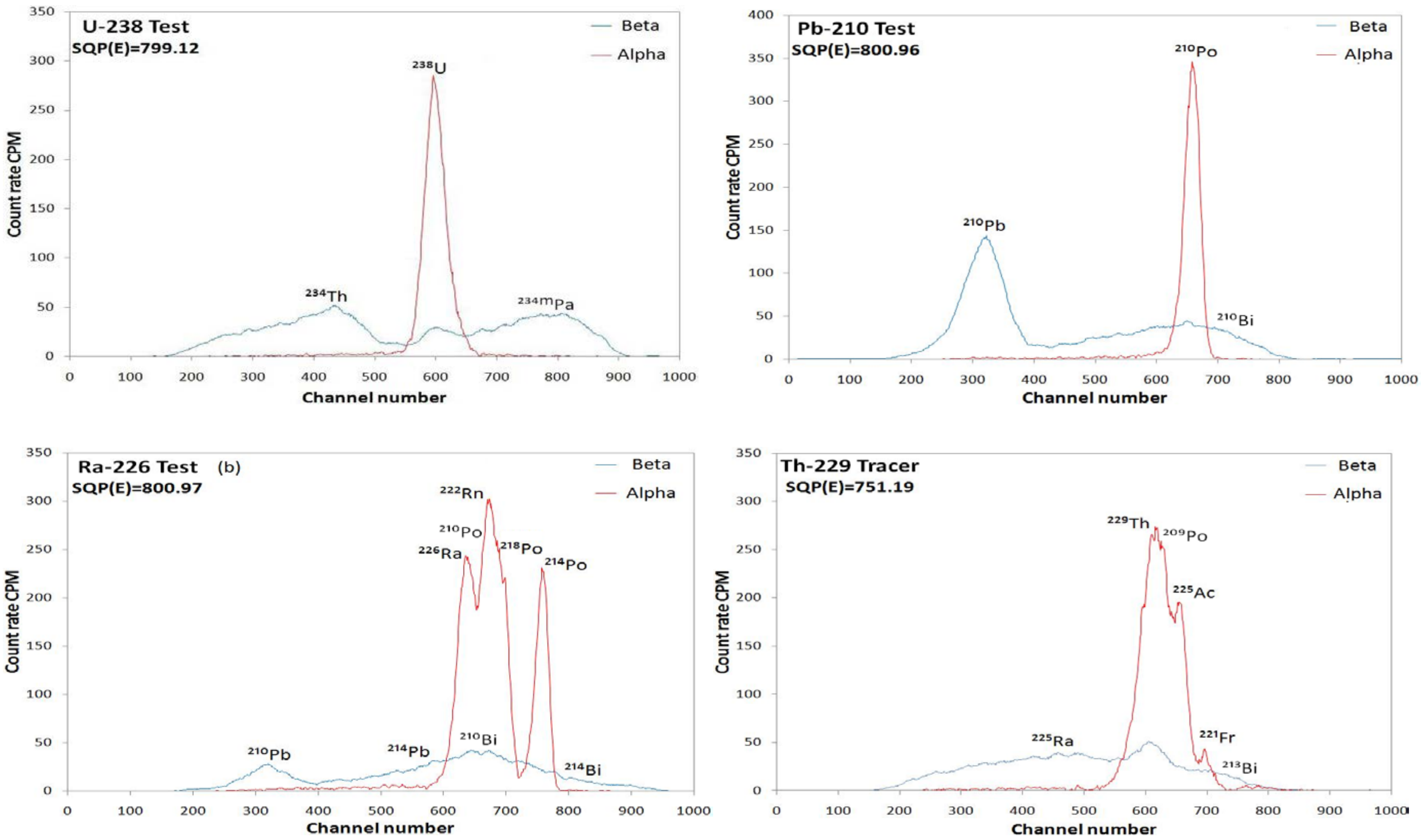

Figure 2. α-β spectra of standard reference solutions at optimal PSA settings.

Semi-qualitative nuclide identification cont...

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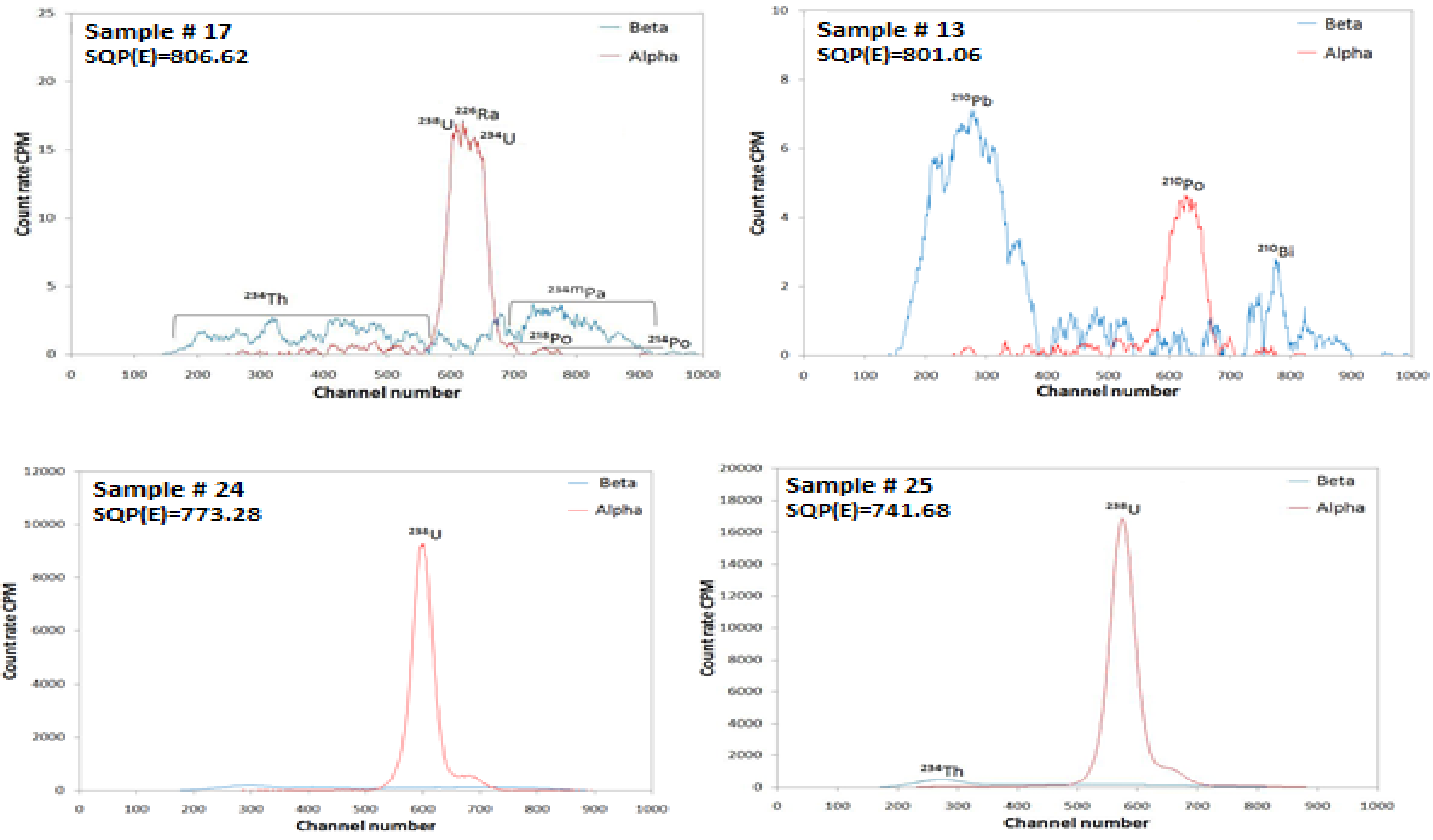

Figure 3: α-β spectra of four environmental water samples obtained with Quantulus 1220^{TM}.

Semi-qualitative nuclide identification cont..

The technique to semi-qualitative nuclide identification in LSC-spectra have been reported on previously. Without going into detail of every individual sample the following remarks can be made;

- Sample number 17 indicates that the α spectra (red spectra) reveals mainly uranium and minor amounts of ^{226}Ra.
- Sample number 13 is a typical example where the gross α and β activities cannot always be attributed to the uranium content of the sample as can be expected in the specific catchment área, but that in this case ^{210}Pb, and its progeny is the major activity in the water sample.
- Samples number 24 and 25 are the other extreme examples where the activity of uranium is so high that the spectra are distorted such that no real information can be reliably obtained.

Conclusion

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- Gross α-β activity analyses was performed for 25 environmental water samples.
- Before counting the samples, counting parameters were optimized and validated to obtain the best possible separation of α and β activities to assure the accuracy of the results.
- The results are in reasonable good agreement between the data obtained from LSC and those obtained from nuclide specific analyses.
- Our study showed that all values of water samples exceeded WHO limits, which indicate that the water is not safe for human consumption and further nuclide specific analyses and consumption/exposure rates of the communities concerned will be necessary to get a better insight in the potential radiological exposure to be expected within the specific catchment area.

Thank You...

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