Rapid Method for Low Level ^{90}Sr Determination in Seawater by Liquid Extraction Technique

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Problem statement and Challenges

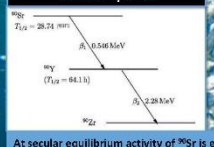
1. Presence of ^{90}Sr in Atmosphere and Ocean

- Waste discharge from generation nuclear energy
- Waste discharge from nuclear reprocessing facilities
- Nuclear accident occurring at power plants
- Nuclear weapon tests in the 1950s and 1960s

2. Toxicity and Hazard

- ^{90}Sr is concerned as a high hazardous radionuclide.
- ^{90}Sr is accumulated in bone like Ca.
- ^{90}Y (^{90}Sr's decay product having high energy) could cause damage to bone marrow and may cause Leukaemia and skeletal cancer

3. ^{90}Sr decay series



At secular equilibrium activity of ^{90}Sr is equal to ^{90}Y

4. Methods to Analyses ^{90}Sr

Radiochemical analysis

	Measurement technique
^{90}Sr	Gross beta particles by gas proportional counter
	Beta particles by liquid scintillation counter
^{90}Y	Gross beta particles by gas proportional counter
	Cherenkov light by liquid scintillation counter

5. Advantage of Liquid extraction technique to Analyses ^{90}Sr via ^{90}Y measurement in Cherenkov light

Fast // Simple // Economical // Easy for waste treatment

Method

Liquid extraction technique to Analyses ^{90}Sr via ^{90}Y measurement

Separation and purification 2 hr

- Seawater samples were added with yttrium carrier
- Yttrium in the sample solution was extracted with 10% HDEHP
- The organic phases were washed with 0.08 M HCl
- Yttrium in the organic phases was back extracted by 3 M HNO_3
- Yttrium hydroxide was precipitated by adjusting pH solution to 9-10 with NH_4OH

Source preparation 10 min

- The yttrium hydroxide precipitates were dissolved with conc. HNO_3
- The purified yttrium solutions were transferred into 20 mL LSC vials and diluted to 15 ml

Measurement 30 min

- The prepared samples were taken for Cherenkov light measurement with LCS in Cherenkov mode for 30 min /sample

Method validation

Samples

- PT sample from IAEA 0.5 L : 0.1 Bq/L ^{90}Sr(PT 2015)
- Spiked samples 30 L : 0.01 Bq/L ^{90}Sr (SP 0.01)
- Spiked samples 30 L : 0.1 Bq/L ^{90}Sr (SP 0.1)
- Spiked samples 30 L : 1 Bq/L ^{90}Sr (SP 1)

Evaluation

Result evaluation

Sample*	PT 2015	SP 0.01	SP 0.1	SP 1
Target value	0.1009	0.0099	0.0993	0.9913
Target unc	0.0007	0.0003	0.0031	0.0306
MARB	25	25	25	25
Mea value	0.1133	0.0103	0.1086	1.0878
Mea unc	0.0084	0.0006	0.0051	0.0463
Rel bias	12.28	3.41	9.38	9.74
Accuracy	P	P	P	P
P	7.47	6.66	5.58	5.25
Precision	P	P	P	P
$\frac{Value_{measured} \times 2.58P}{Value_{target}}$	21.63	17.76	15.75	14.87
Trueness	P	P	P	P
Final score	P	P	P	P

*PT 2015 = PT 2015 sample and SP 0.01, SP 0.1 and SP 1 = Spiked samples having activity concentration of 0.01 Bq/L, 0.1 Bq/L and 1 Bq/L respectively

"All sample results passed the three criteria i.e. Accuracy, Precision, Trueness"

Data evaluation

Accuracy

$$RB = \frac{Value_{Measured} - Value_{target}}{Value_{target}} \times 100$$

If the absolute value of relative bias (RB) ≤ the Maximum Accepted Relative Bias (MARB) value, the result is considered "Accepted" for accuracy.

Precision

$$P = \sqrt{\left(\frac{unc_{target}}{Value_{target}}\right)^2 + \left(\frac{unc_{Measured}}{Value_{Measured}}\right)^2} \times 100$$

If P ≤ the Limit of Accepted Precision (LAP), the result is considered "Accepted" for precision.

Trueness

Value analysts results for trueness were scored as "Pass" when.

$$|Bias_{relative}| \leq \frac{Value_{measured}}{Value_{target}} 2.58\,P$$

Final Score

"Accepted" (P) when all three tests were passed.
"Not Accepted" (N) when the accuracy test was failed.
"Warning" (W) when accuracy test was passed but either precision or trueness test was failed.

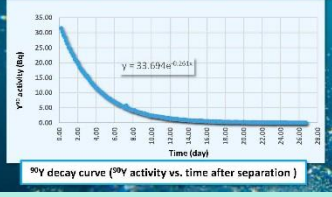
Results

Results of ^{90}Sr analysis

Sample	Volume (L)	Individual						Mean	
		Act (Bq/L)	%Y	Act (Bq/L)	%Y	Act (Bq/L)	%Y	Act (Bq/L)	%Y
PT 2015	0.5	0.1165 ± 0.0086	86.49	0.1209 ± 0.0089	86.49	0.1025 ± 0.0077	89.19	0.1133 ± 0.0084	87.39
SP 0.01	30	0.0085 ± 0.0005	64.91	0.0119 ± 0.0007	66.67	0.0104 ± 0.0006	66.67	0.0103 ± 0.0006	66.08
SP 0.1	30	0.1077 ± 0.0050	66.09	0.1126 ± 0.0052	59.13	0.1055 ± 0.0049	66.09	0.1086 ± 0.0051	63.77
SP 1	30	1.1030 ± 0.0469	64.10	1.0981 ± 0.0467	64.10	1.0623 ± 0.0452	69.23	1.0878 ± 0.0463	65.81

*PT 2015 = PT 2015 sample and SP 0.01, SP 0.1 and SP 1 = Spiked samples having activity concentration of 0.01 Bq/L, 0.1 Bq/L and 1 Bq/L respectively

- Each three repeated sample results had similar activity concentrations and chemical recovery yield values
- The PT results had higher chemical recovery yield than those of spiked samples due to less process loss when working with smaller sample volume



^{90}Y decay curve (^{90}Y activity vs. time after separation)

- The decay curve shown high purity of prepared ^{90}Y samples obtaining measured half live of 63.72 hr (theoretical half live is 64.1 hr)

Conclusion

- All results in a range of ^{90}Sr activity of 0.01 – 1 Bq/L passed criteria :

* Accuracy
* Precision
* Trueness

with relative bias in range from 3.41% to 12.28%, below accepted relative bias of ± 25% and therefore the method is validated.

- The developed method can be used to determine ^{90}Sr in seawater in :

* In case of routine monitoring : Very low level concentration in a range of 0.01 – 1 Bq/L from 30 L
* In case of any radiological incidents : Higher level concentration in a range of 0.1 – 1 Bq/L from 0.5 L

- The advantages of developed method was :

* Simple >> simple source preparation method
* Fast >> a short source preparation in a few hours
* Economical >> low cost for waste treatment as only producing acidic sample solutions

- Accuracy however can be improved by determining recovery yield from mass spectroscopy techniques such as AAS and ICP but the cost of the analysis would increase.