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Determination of ^{90}Sr by measuring ^{90}Y Cerenkov Counting

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Abstract. To determine ^{90}Sr activity in environmental samples advanced cerenkov counting using liquid scintillation counter has been widely investigated. Separated ^{90}Y in equilibrium with ^{90}Sr in a solution can be counted using a Cerenkov measurement without scintillation. In addition an equilibrium $^{90}Sr/^{90}Y$ in a solution can be directly measured using ^{90}Y Cerenkov counting. The ^{90}Sr Cerenkov counting is considered negligible due to its very low counting efficiency. In this work the Cerenkov technique to measure ^{90}Y counting from a series of $^{90}Sr/^{90}Y$ solution was studied in the two matrices, 16 mL of 1 M HNO_3 and 0.1 M HCl. A suitable counting window was found to be in the range of 0-50 keV. Cerenkov counting in the HNO_3 solution obtained a lower background count rate (2.2 CPM) than those of the HCl solution (3.32 CPM). ^{90}Y counting efficiencies of the HNO_3 solution (between 56.73 and 64.61%) were slightly lower than those of HCl solution (between 45.19 and 66.34%). However, FOMs of the HNO_3 (between 1418 and 1839) were much higher than those of HCl (between 615 and 1326). In this case the HNO_3 solution is a better matrix for the Cerenkov counting of ^{90}Y.

1 Introduction

A great number of radiochemical analysis have been developed and applied for determination of ^{90}Sr in environmental samples [1]. There are also various radioactivity measurement techniques depending upon physical prepared sources and analyte isotopes i.e. ^{90}Sr, ^{90}Y and both $^{90}Sr/^{90}Y$. For instance, ^{90}Sr radioactivity measurement can be done in precipitate form by classical gross beta counting using gas proportional counter and in liquid form with scintillator using liquid scintillation analyser. For measuring ^{90}Y activity in equilibrium to ^{90}Sr there are options such as the classical gross beta counting in solid form and advanced Cerenkov counting in a solution without a scintillator using liquid scintillation counter.

In the presence of contaminated beta emitters, results from the classical gross beta analysis using gas proportional counter would be overestimated. Cerenkov technique therefore has generated a lot of interest to determine ^{90}Sr in environmental samples [2]. For example, Suomela separated ^{90}Sr and ^{90}Y using liquid-liquid extraction technique, HDEHP [3] and measured ^{90}Y counting using Cerenkov measurement. ^{90}Y is a daughter isotope of ^{90}Sr. The maximum beta energy of ^{90}Sr is only 540 keV and its Cerenkov counting efficiency is approximately 1%. For ^{90}Y, its maximum beta energy is 2270 keV, having 60% efficiency in Cerenkov counting. In case of the absence of ^{89}Sr (40% counting efficiency), equilibrium $^{90}Sr/^{90}Y$ solution could be therefore measured in ^{90}Y Cerenkov counting directly. In addition only high energy beta particles (E_{max} > 800 keV) could produce Cerenkov light i.e. ^{32}P, ^{36}Cl, ^{90}Y and ^{89}Sr. Measuring Cerenkov light could have less interference from contaminated low energy beta emitters in samples [4].

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Although the Cerenkov technique clearly has advantages of simple sample preparation, less expensive measurement and convenient waste treatment, there are concerns about low counting efficiencies, volume dependence and media dependence [5]. And accurate results would only be obtained from suitable efficiency calibration. Therefore, this work was done to study Cerenkov technique to measure ^{90}Y radioactivity from an equilibrium of $^{90}Sr/^{90}Y$ solution. The two matrices, 1 M HNO_3 and 0.1 M HCl, were used to determine a suitable source preparation by comparing background count rate, counting efficiency and figure of merit (FOM = counting efficiency^2/background count rate) [2].

2 Experimental

2.1 Method to determine background count rates and ^{90}Y Cerenkov counting efficiency

There were two matrices for $^{90}Sr/^{90}Y$ standard solution i.e. 16 mL of 0.1 M HCl and 1 M HNO_3.

To determine background count rates, blanks of the 16 mL of 0.1 M HCl and 1 M HNO_3 in polyethylene vials were counted for 60 minutes in three energy windows i.e. 0-50 keV, 5-50 keV and 0-2000 keV. The blanks are shown in Figure 1.

For measuring ^{90}Y Cerenkov counting efficiency $^{90}Sr/^{90}Y$ in a series i.e. 0.08, 0.21, 0.41, 0.82, 1.65, 4.95 and 8.24 Bq was dissolved in the acid solutions

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contained in polyethylene vials [3]. The picture of $^{90}Sr/^{90}Y$ sources is shown in Figure 2. The samples were measured in counting efficiencies and FOMs to find out proper source preparation. The samples were counted for 60 minutes in the three energy windows i.e. 0-50 keV, 5-50 keV and 0-2000 keV.

Figure 1. Blank samples of the16 mL of 0.1 M HCl and 1 M HNO_3 in polyethylene vials.

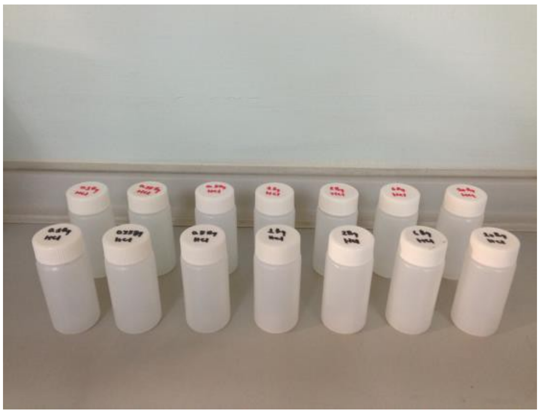


Figure 2. Series of $^{90}Sr/^{90}Y$ prepared solution sources of the16 mL of 0.1 M HCl and 1 M HNO_3 in polyethylene vials.

2.2 Reagent and radioactivity standards

All reagents were analytical grade. $^{90}Sr/^{90}Y$ standard solution was obtained from Eckert and Ziegler Isotope Product.

2.3 Counting vials

20 mL polyethylene vials were purchased from PerkinElmer.

2.4 Instrumentation and software

Liquid scintillation counter made from PerkinElmer, model Tri-Carb 3180 TR/SL with QuantaSmart evaluation software was used for the Cerenkov counting.

3 Results and discussion

3.1 Blanks for ^{90}Y Cerenkov counting

To determine background count rates the blanks of two matrices i.e. 16 mL of 0.1 M HCl and 1 M HNO_3 were measured in Cerenkov counting. The spectrum of two samples are shown in Figure 3.

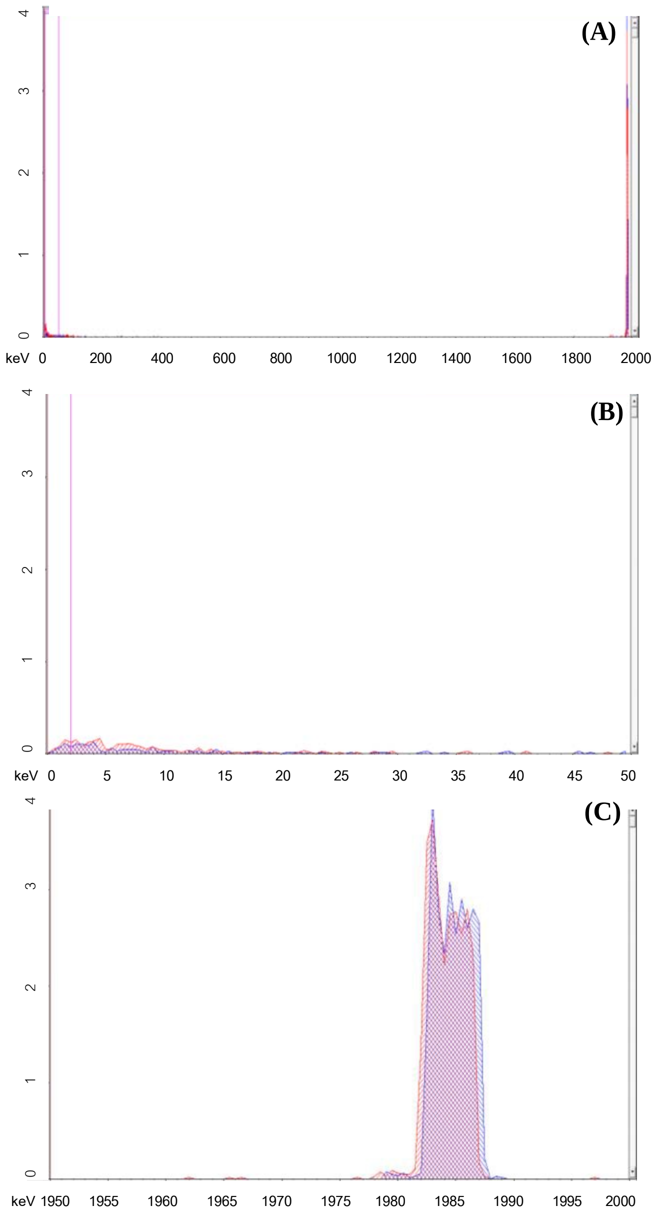


Figure 3. Spectrums of the two matrices: red; 16 mL of 0.1 M HCl and blue; 16 mL of 1 M HNO_3 : (A) full energy range of 0-2000 keV, (B) energy range of 0-50 keV and (C) energy range of 1950-2000 keV.

From Figure 3. Background of the two matrices shows the two peaks at energies between 0-30 keV and 1975-1990 keV. The peaks at high energy were interference. And the real background of ^{90}Y was at the low energy [2]. The peaks of two matrices looked similar, but HNO_3

had slightly lower count rate, a lower background as can be seen from Table 1.

Table 1. Background count rates of 0.1 M HCl and1 M HNO_3 in different energy windows.

Matrix	**0-50 keV**	**2-50 keV**	**0-2000 keV**
16 mL 0.1 M HCl	3.32	2.95	40.65
16 mL 1 M HNO₃	2.20	1.78	39.13

The background count rates in three windows are shown in table 1. Very high count rates of both matrices were found in the energy window of 0-2000 keV due to interference. The window between 2 and 50 keV of the two matrices had the lowest count rates because of excluding background count rates of ^{90}Y at 0-2 keV. Therefore, the window of 0-50 keV should be a proper range for ^{90}Y Cerenkov counting. To compare count rates between the two matrices the HNO_3 obtained a lower background than those of HCl.

3.2 ^{90}Y Cerenkov counting efficiency determination from ^{90}Sr/^{90}Y standard solution

3.2.1 The series matrix of ^{90}Sr/^{90}Y in 16 mL of 0.1 M HCl

The sources were measured in Cerenkov counting and the results can be seen from Figure 4. and Figure 5.

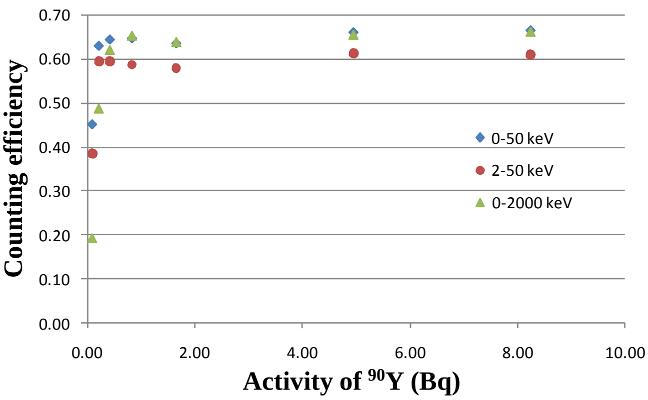


Figure 4. Relation between Activity of ^{90}Y and Counting efficiency in 0.1 M HCl matrix.

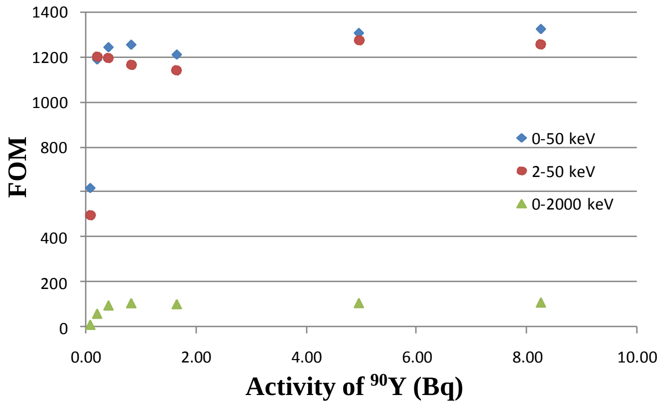


Figure 5. Relation between Activity of ^{90}Y and FOM in 0.1 M HCl matrix.

From Figure 4. The trend shows that the low activity was likely to give a low efficiency for the three energy windows. To compare between the three regions, the region of 2-50 keV seemed to give lowest counting efficiencies. Counting efficiencies of activity above 0.21 Bq were quite stable in all windows. For like counting efficiencies, low activity was prone to give smaller FOMs as can be seen from Figure 5. However, when compared between the three regions, the region of 0-2000 keV obtained very low FOMs due to the high background. And the region of 2-50 keV gave the lowest counting efficiencies. Therefore the best window for ^{90}Y Cerenkov counting in 0.1 M HCl was 0-50 keV.

3.2.2 The series matrix of ^{90}Sr/^{90}Y in 16 mL of 1 M HNO_3

The sources were measured in Cerenkov counting and the results can be seen from Figure 6. and Figure 7.

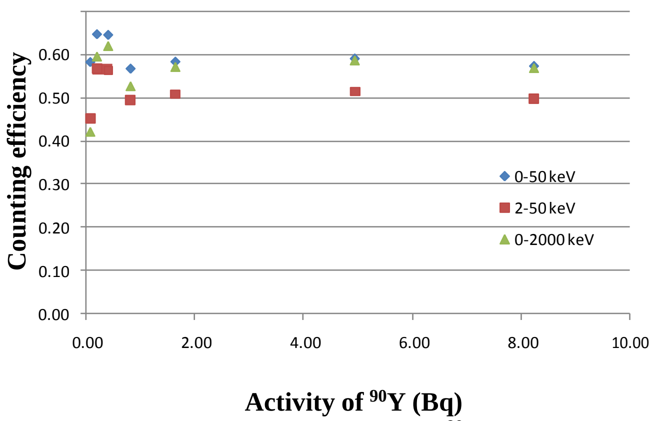


Figure 6. Relation between Activity of ^{90}Y and Counting efficiency in 1 M HNO_3 matrix.

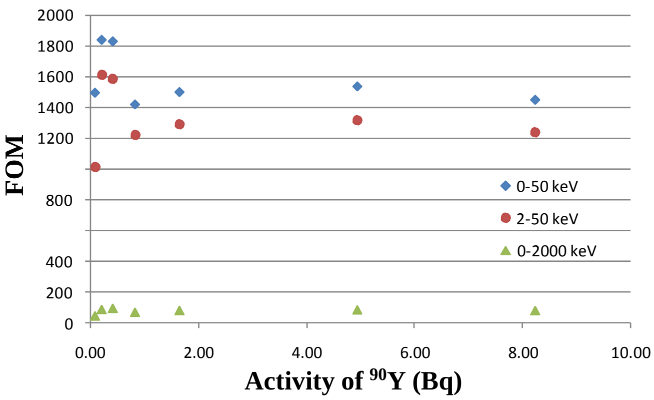
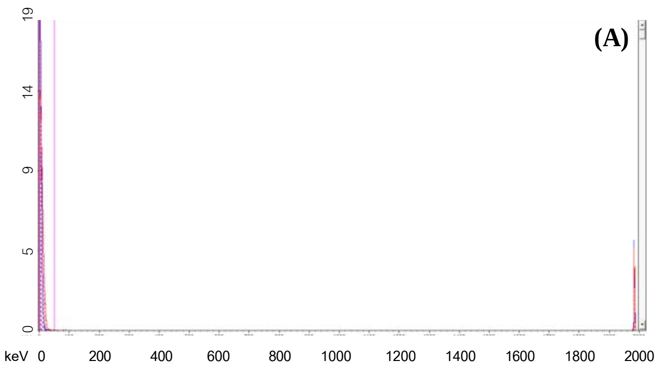


Figure 7. Relation between Activity of ^{90}Y and FOM in 1 M HNO_3 matrix.

As can be seen from Figure 6., efficiencies of the three energy regions were quite stable all over the activity range. Like for HCl matrix, the region of 2-50 keV seemed to give the lowest counting efficiencies. FOMs of three energy regions were quite stable all over the activity range as can be seen from Figure 7. Comparing between the different regions, the region of 0-2000 keV gave very low FOMs due to the high background. And the energy region of 2-50 keV obtained the lowest counting efficiencies. Therefore the best window for ^{90}Y Cerenkov counting in 1 M HNO_3 was 0-50 keV. This conclusion was the same as HCl matrix result.

To better understanding differences between ^{90}Sr/^{90}Y in the two matrices, the two spectrums are shown in Figure 8. And the plots between ^{90}Y activity and counting efficiency and FOM in window: 0-50 keV can be seen from Figure 9 and 10.



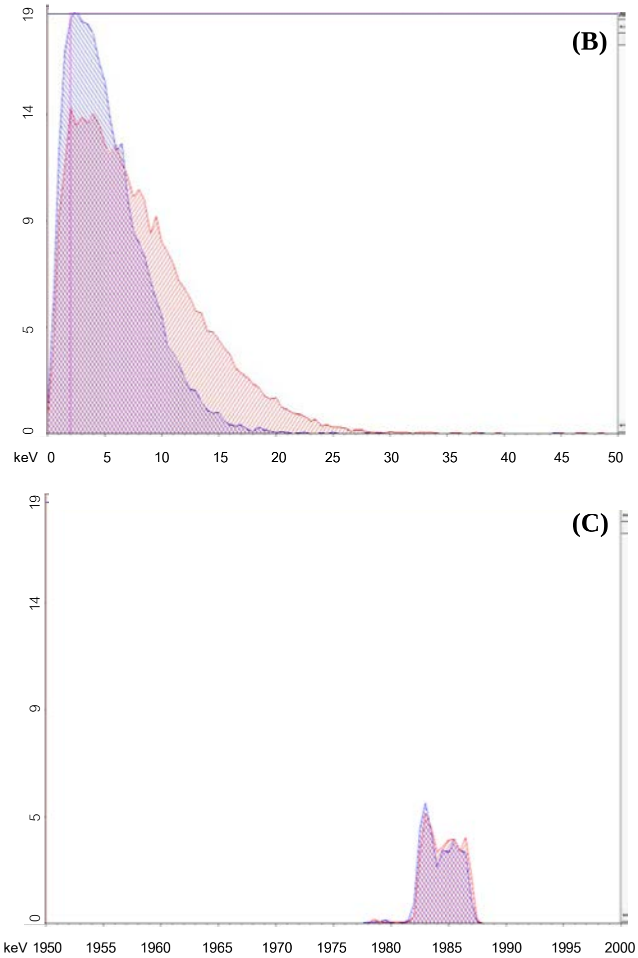


Figure 8. Spectrums of the two matrices of 8.24 Bq ^{90}Sr/^{90}Y: red; 16 mL of 0.1 M HCl and blue; 16 mL of 1 M HNO_3 : (A) full energy range of 0-2000 keV, (B) energy range of 0-50 keV and (C) energy range of 1950-2000 keV.

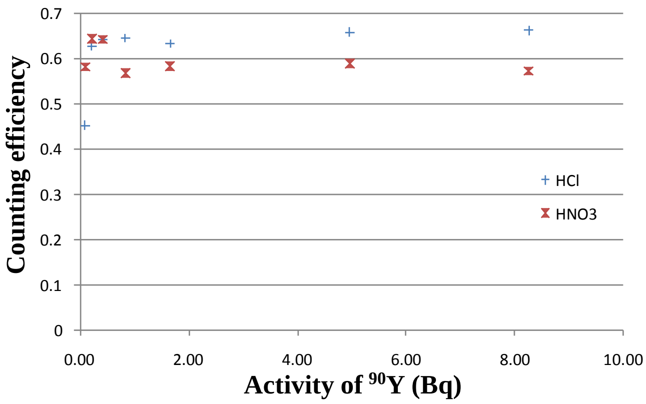


Figure 9. Relation between Activity of ^{90}Y in HCl and HNO_3 matrices vs Counting efficiency at energy window: 0-50 keV.

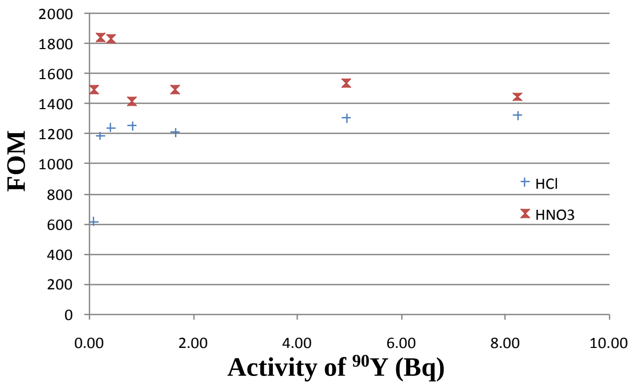


Figure 10. Relation between Activity of ^{90}Y in HCl and HNO_3 matrices vs FOM at energy window: 0-50 keV.

From Figure 9 and 10 the HCl matrix gave slightly better counting efficiencies but lower FOMs than those of the HNO_3. This was probably due to the higher background count rate in the HCl matrix. Therefore the HNO_3 matrix should be more suitable for ^{90}Y Cerenkov counting to determination ^{90}Sr.

3 Conclusion

^{90}Y Cerenkov counting was determined in the two matrices, 1 M HNO_3 and 0.1 M HCl solution. For both matrices a suitable energy window for ^{90}Y counting was found to be between 0 and 50 keV. This energy window gave low background count rates but high ^{90}Y counting efficiencies and FOMs. The matrix of HNO_3 resulted in a lower background than those of HCl one. For ^{90}Y counting efficiency determination the HNO_3 matrix obtained slightly lower efficiencies than those of HCl. This was possibly due to the lower background count rate of HNO_3 matrix. However FOMs of HNO_3 matrix were higher. It can be concluded that the HNO_3 solution should be a better matrix for the ^{90}Y Cerenkov counting for the analytical method.

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