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Identical mother and daughter radionuclides related to CTBT for improving the detection of nuclear event

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INTRODUCTION

Some fission products decay to radionuclides which are among the CTBT relevant radionuclides. Considering the different decay reactions of these radionuclides in mother or daughter states, estimating zero time of nuclear event can be improved.

METHODS/DATA

The nuclei ratio has been calculated using Bateman equation for two scenarios:

1. Fission radionuclide in daughter state
2. Fission radionuclide in both mother and daughter states

Zero time of a nuclear event has been estimated for two given scenarios.

START

RESULTS

The nuclei ratio of ^{140}La to ^{140}Ba, ^{99m}Tc to ^{99}Mo, ^{156}Eu to ^{156}Sm, ^{125}Sb to ^{125}Sn, ^{91}Y to ^{91}Sr, ^{131}I to ^{131m}Te, and ^{95}Nb to ^{95}Zr versus decay time has been investigated.

CONCLUSION

By discrimination of radionuclides in daughter state or combination of mother and daughter states, the occurrence probability of nuclear event and the zero time can be determined.

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Introduction

One of the most important issues in radionuclide monitoring technology is analysis of radionuclide data of the International Monitoring System (IMS). The number and concentration rate of the CTBT relevant detected radionuclides determine the possibility of nuclear event occurrence in radionuclide monitoring. Fission and activation products being on the standard list of CTBT relevant radionuclides, decay to nuclides which are stable or unstable. Some of these radionuclides decay to radionuclides which are also among the 83 CTBT relevant radionuclides. Therefore, the activity concentration of these radionuclides increases when both the daughter and mother radionuclides are present. Considering the different decay reactions of these radionuclides in mother or daughter states, estimating zero time of nuclear event can be improved by discriminating these two decays.

Objectives

In this study, CTBT relevant fission radionuclides that decay to unstable radionuclides which are among the 83 CTBT relevant radionuclides are focused and their decays over time are investigated using Bateman equations in mother and daughter, and the combination of these states. Then, the ratio of concentration of intended radionuclides to fission radionuclides are obtained for two scenarios including radionuclides detection in daughter state or combination of mother and daughter. Finally, the occurrence probability of nuclear event and its time are evaluated in these two scenarios.

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Methods

The ratio of nuclei remaining undecayed using Bateman equation:

Scenario 1: CTBT relevant radionuclide (N) is in daughter state ($N_1 \xrightarrow{\lambda_1} N \xrightarrow{\lambda} ....$)

$$\frac{N}{N_1} = \frac{\lambda_1}{\lambda - \lambda_1}\left(1 - e^{(\lambda_1 - \lambda)t}\right)$$

Scenario 2: CTBT relevant radionuclide (N) is both daughter state ($N_1 \xrightarrow{\lambda_1} N \xrightarrow{\lambda} ....$) and mother state ($N \xrightarrow{\lambda} ....$)

$$\frac{N}{N_1} = \frac{\lambda_1}{\lambda - \lambda_1}\left(1 - e^{(\lambda_1 - \lambda)t}\right) + \frac{\alpha}{\alpha_1} e^{(\lambda_1 - \lambda)t}$$

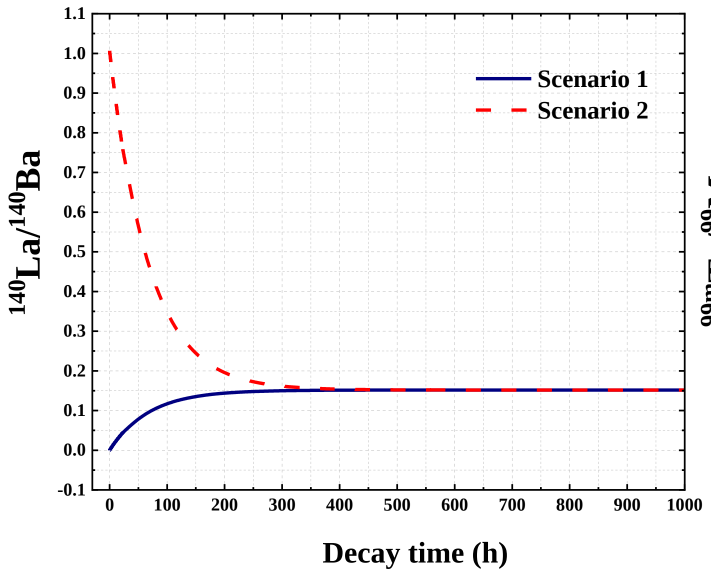
λ : Decay constant
α: Fission yield for a fission scenario where high-energy neutrons are involved ($^{235}U_{HE}$)

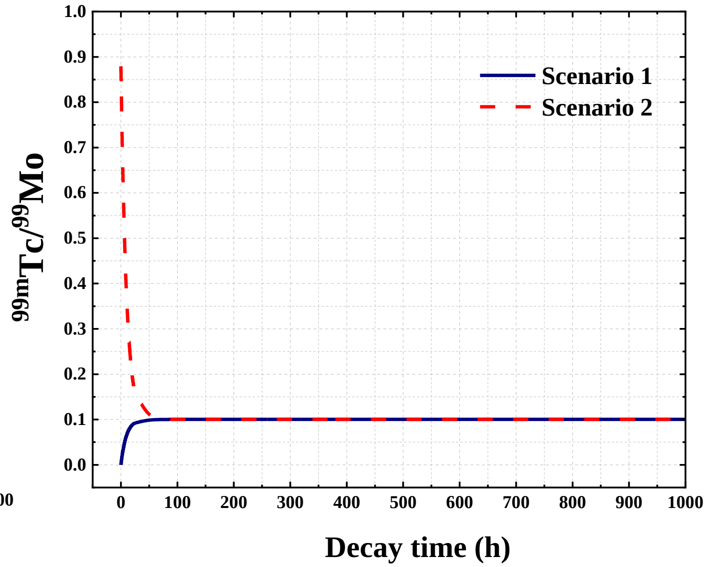
Methods

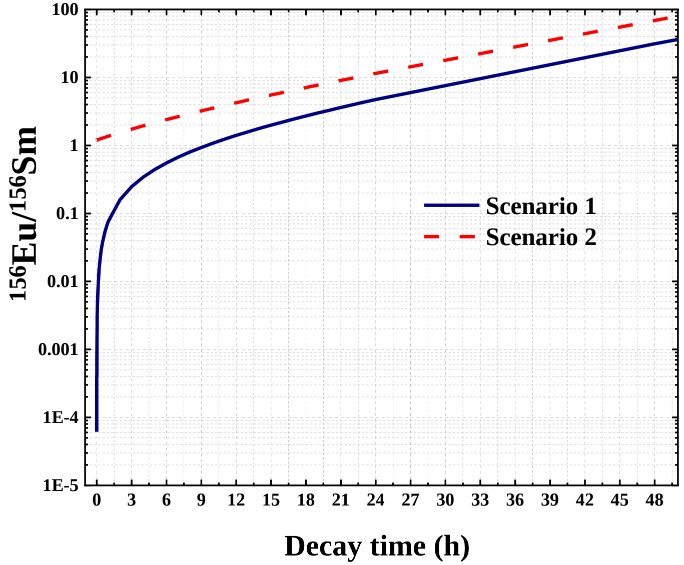
Table 1. Decay chain of investigated radionuclides related to CTBT

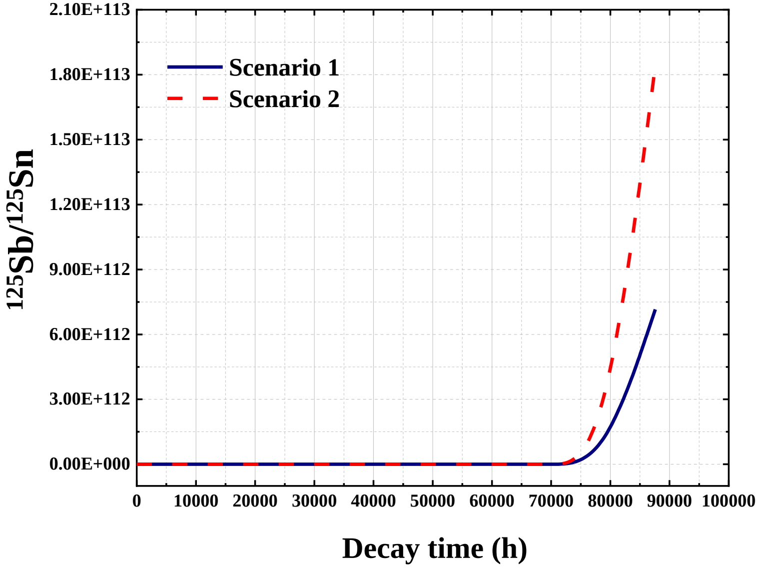
Radionuclides relevant to CTBT	Daughter radionuclides relevant to CTBT	Decay chain
^{140}Ba	^{140}La	$^{140}Ba \xrightarrow{00.002265} {}^{140}\mathbf{La} \xrightarrow{0.017202} {}^{140}Ce$
^{99}Mo	^{99m}Tc	$^{99}Mo \xrightarrow{0.010508} {}^{99m}\mathbf{Tc} \xrightarrow{0.115362} {}^{99}Tc,\ {}^{99}Ru$
^{156}Sm	^{156}Eu	$^{156}Sm \xrightarrow{0.073723} {}^{156}\mathbf{Eu} \xrightarrow{0.001901} {}^{156}Gd$
^{125}Sn	^{125}Sb	$^{125}Sn \xrightarrow{0.002995} {}^{125}\mathbf{Sb} \xrightarrow{2.87E-05} {}^{125}Te$
^{91}Sr	^{91}Y	$^{91}Sr \xrightarrow{0.071813} {}^{91}\mathbf{Y} \xrightarrow{0.710648} {}^{91}Zr$
^{95}Zr	^{95}Nb	$^{95}Zr \xrightarrow{0.000451} {}^{95}\mathbf{Nb} \xrightarrow{0.000825} {}^{95}Mo$
^{131m}Te	^{131}I	$^{131m}Te \xrightarrow{0.020842} {}^{131}\mathbf{I} \xrightarrow{0.003598} {}^{131}Xe$

Results



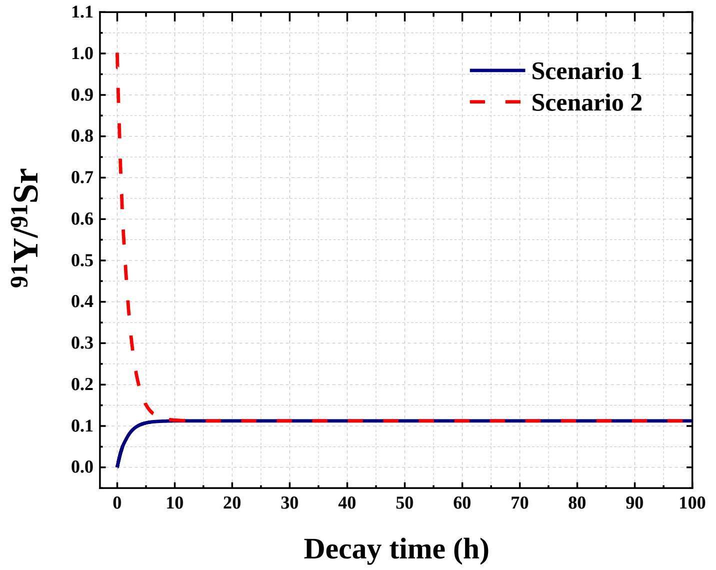


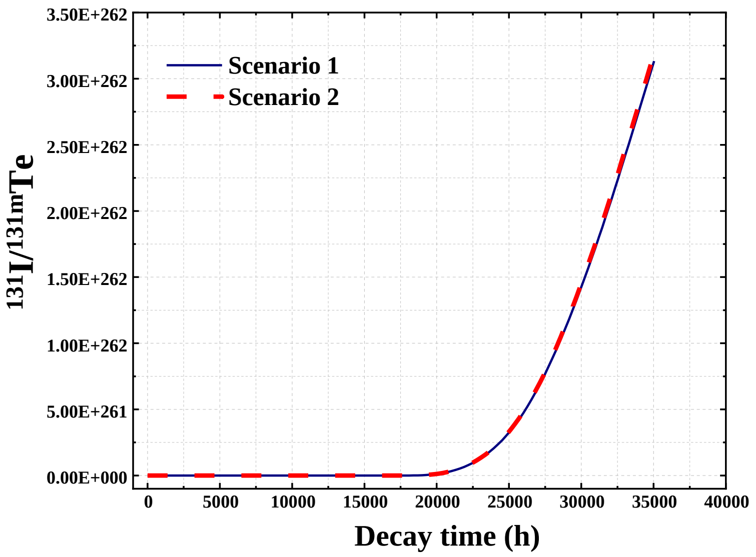


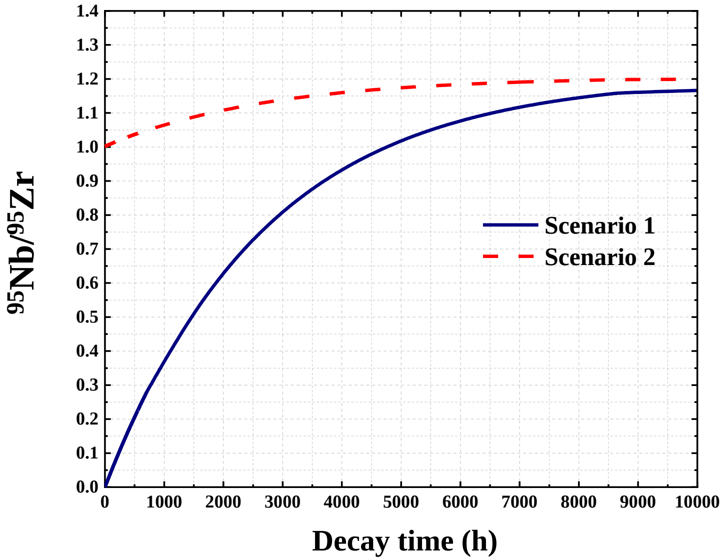


Figs 1-4. the ratio of nuclei remaining undecayed versus decay time. Scenario 1 (navy color curve) is related to detection of radionuclide in daughter state and scenario 2 (dashed red color curve) is related to detection of radionuclide in both mother and daughter states.

Results







Figs 5-7. the ratio of nuclei remaining undecayed versus decay time. Scenario 1 (navy color curve) is related to detection of radionuclide in daughter state and scenario 2 (dashed red color curve) is related to detection of radionuclide in both mother and daughter states.

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Results

Table 2. The event detection time according to nuclei ratio

Daughter / Mother	Ratio	time (h) First scenario	time (h) Second scenario
Lanthanum-140 / Barium-140	0.151627	648 h	1440 h
Technetium-99m/Molybdenum-99	0.100210	96 h	120 h
Europium-156 / Samarium-156	4.727283	24 h	13 h
Antimony-125 / Tin-125	2.205201	384 h	72 h
Yttrium-91 / Strontium-91	0.112412	19 h	48 h
Iodine-131 / Tellurium-131m	0.254071	11 h	10 h
Niobium-95 / Zirconium-95	0.022760	5040 h	288 h

Conclusion

By regarding the ratio of daughter nuclei to mother nuclei in two scenarios including detection of radionuclide in daughter state or combination of mother and daughter, and discrimination of these two scenarios, the zero time and the possibility of occurrence nuclear event can be determined.

References

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