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Investigation of emission of ^{37}Ar from all nuclear research reactors worldwide

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Introduction

Air contains 0.933% argon. Natural argon consists of ^{36}Ar (0.3365%), ^{38}Ar (0.0632%), ^{40}Ar (99.6003%). ^{37}Ar is a radioactive isotope. Almost all ^{37}Ar is of natural origin and typically occurs at concentrations in the order of mBq/m^3. The possible anthropogenic sources are nuclear reactors and nuclear explosions. In the nuclear research reactor it is produced via 3 ways. The first and the main source is the neutron activation of air dissolved within the reactor pool water [1, 2]. The second way is the neutron activation of Ca impurities in the fuel elements, control rods, and moderator via the ^{40}Ca(n,α)^{37}Ar reaction. The third one is the ternary fission in the fuel. The ternary fission is 0.2 - 0.4% of fission events by which 2.2E-9 atoms of ^{37}Ar per binary fission are produced [1]. In case of a nuclear explosion, it is produced by capture of fission neutrons in calcium that is contained in the surrounding rocks with the nuclear reaction ^{40}Ca(n,α)^{37}Ar. The relatively long half-life of 35.04 days compared to short-lived Xe isotopes makes a stronger signal than the radioxenons approximately 50 days after a nuclear explosion [3]. Therefore, this radioisotope is an important indicator of an underground nuclear explosion during an OSI [4]. In order to enable the use of ^{37}Ar as a radiotracer for OSI, the sources of radioargon background must be characterized and quantified. As a side-product from a study on radioxenon emissions of nuclear research reactors [5], this poster estimates the emission of ^{37}Ar based on activation from the global fleet of these reactors.

Scaling Factor, SC

To estimate the ^{37}Ar release rate resulting from activation, we have empirical data available from the TRIGA MARK II reactor at University of Texas at Austin and from the high flux isotope reactor, HFIR, in Oak Ridge National Laboratory [2, 6].

TRIGA MARK II reactor at University of Texas at Austin

Johnson et al. [2], has measured the ^{133}Xe, ^{37}Ar and ^{41}Ar releases during different operational modes of the TRIGA reactor and various location around the reactor. The average release of ^{37}Ar has been reported 2.41E+4 Bq/h. By considering of capacity factor for this reactor (15.4%) and its power (950 kW) the emission rate per produced energy is 1.64E+02 Bq/kWh.

High Flux Isotope Reactor (HFIR)

Average of 10-year emission of ^{37}Ar from HFIR has been estimated by Fay [6] which is 1.86E+10 Bq/y. By considering of capacity factor for this reactor (46%) and its power (8.5E+04 kW) the emission rate per generated energy is 5.43E+01 Bq/kWh.

Scaling factor for ^{37}Ar

The average of the release rates of Texas and HFIR reactors is used as a scaling factor to estimate the emission rate of ^{37}Ar based on activation. This scaling factor SF equals:

SF = 1.08E+02 Bq/kWh

Capacity Factor, CF

Nuclear research reactors (NRRs) have not only a wide range of different thermal power P but also quite different capacity factors CF (fraction of time that the power is up during a year) according to the operational working schedules from a few hours to 7 days a week as can be found in the IAEA Research Reactor Database RRDB [7]. The combination of both P and CF makes the production and release patterns versatile. Figure 1 shows the product P×CF for all NRRs ordered with increasing value from bottom to top.

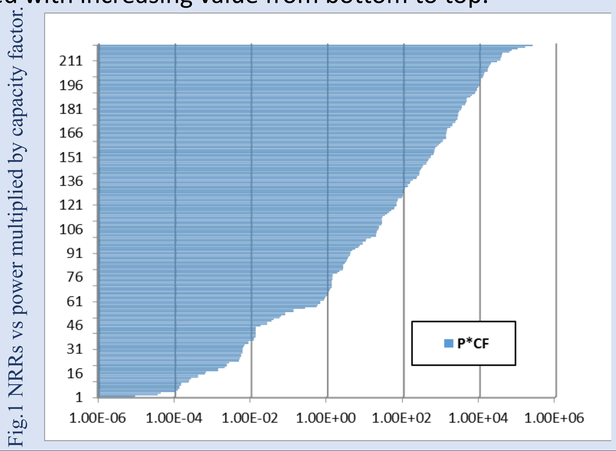

Fig.1 NRRs vs power multiplied by capacity factor.

Scaling the ^{37}Ar release rate originating from activation

The estimated annual emission from each nuclear research reactor is calculated with the following equation:

$$R = SC \times CF \times P \times 365 \times 24$$

Where
R (Bq/y): release rate
SC (Bq/kWh): Scaling factor
CF: capacity factor
P (kW): power
365×24: converting factor for h/y

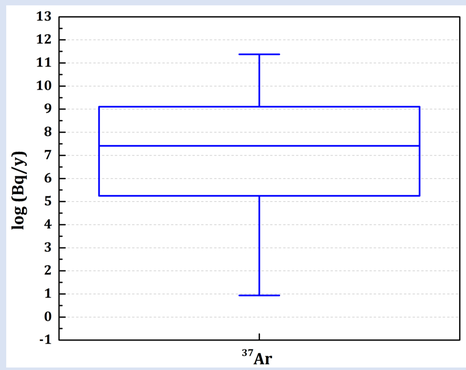

Figure 2. Box and Whisker Plot for ^{37}Ar.

Figure 2 shows the Box and Whisker plot for the annual emission of this isotope.

Results

Total annual release rate of ^{37}Ar from all 160 NRRs in 2014 is **1.13** TBq/y. The range of source strengths spans over more than 10 orders of magnitude. The median is **26** MBq/y. According to this estimate the research reactor with the largest estimated annual release is the ATR reactor in the USA with **0.24** TB/y.

Summary and Conclusions

In this poster, the emission of ^{37}Ar from research reactors is investigated based on two specific reactors for which published release estimates are available. These are the TRIGA MARK II reactor at University of Texas at Austin and from the high flux isotope reactor, HFIR, in Oak Ridge National Laboratory. The average of their release rates is used to get an extrapolated estimation for the release rate of all nuclear research reactors worldwide. The global emission data set can be used for studies to estimate the contribution of this anthropogenic source to the observed ambient concentrations of ^{37}Ar in support of OSI activities.

References

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