CTBT: SCIENCE AND TECHNOLOGY 2017 CONFERENCE

T2.4-P11

Setting the 2014 Baseline for Simulated Activity Concentrations of Four Radioxenon Isotopes at IMS Sites Based on Estimated Annual Releases of Known Sources

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Introduction

Worldwide monitoring of noble gases is an essential part of the verification system of the CTBT as it can provide a direct evidence of the nuclear nature of an underground or underwater explosion. The detection capability of the noble gas (NG) network is affected by the presence of a worldwide civilian radioxenon background. Improving the understanding of civilian radioxenon sources and their effects on the noble gas systems is crucial. In this study, a baseline radioxenon emission inventory is proposed for all four CTBT relevant radioxenon isotopes for the year 2014. The radioxenon emission inventory is used together with Atmospheric Transport Modelling (ATM) to estimate the radioxenon activity concentrations at IMS NG systems. The estimations are compared and discussed with regard to the observations of NG systems that were operational in 2014. This study is the first attempt to propose an emission inventory for all four CTBT relevant radioxenon isotopes and to compare the resulting estimated activity concentrations with all observations at IMS NG systems.

Baseline radioxenon emission inventory

The baseline radioxenon emission inventory defined in this study is based on a literature review for the Medical Isotopes Productions Facilities and Nuclear Power Plants. The locations of the identified radioxenon sources are shown in Figure 1. The selection of the best estimated yearly release rate for each source is based on 4 criteria. The dataset should (1) cover at least a full year, (2) be the most recent, (3) specify the isotope for which the release value is given and (4) originate from a peer-reviewed source. The resulting yearly source terms (in Bq/y) are presented in Table 1 together with the Xe-133 emission inventory developed by Achim *et al.* (2016). According to the radioxenon emission inventory, Xe-133 is the radioxenon isotope with the highest release rate. The Xe-133 release rates identified in this work are within one order of magnitude of the ones developed by Achim *et al.* (2016) except for CNEA. In addition, three other sources were not identified in the current work, as compared to Achim *et al.* (2016), as there is no peer-reviewed information on their location and xenon emission rates. Finally, the emissions were considered as constant and continuous in the current work.

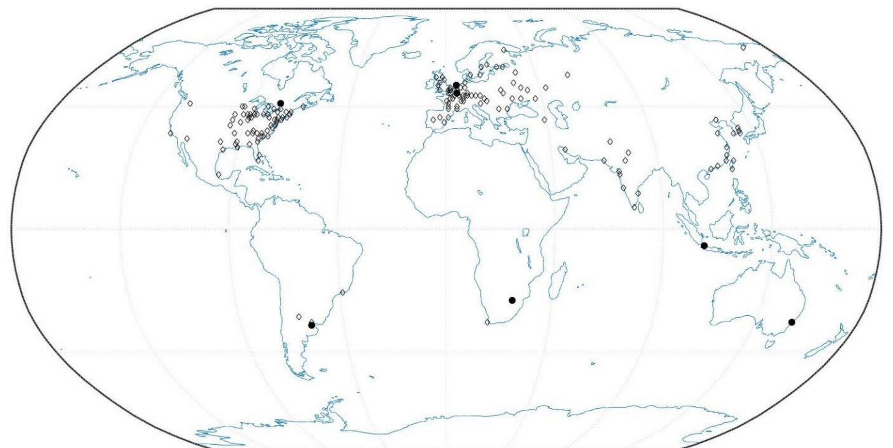


Figure 1 – Location of the NPPs (◊) and MIPFs (●) identified in this work.

	Annual emission (Bq/y)					
	Current work					[8]
Site	Xe-131m	Xe-133m	Xe-133	Xe-135	References	Xe-133
IRE	$3.2\ 10^{12}$	$5.0\ 10^{13}$	$2.0\ 10^{15}$	$1.9\ 10^{12}$	[1] & [2]	$9.9\ 10^{14}$
CRL	$3.0\ 10^{13}$	$3.5\ 10^{14}$	$1.5\ 10^{16}$	$1.1\ 10^{13}$	[1] & [2]	$6.0\ 10^{15}$
NTP	$1.9\ 10^{13}$	$1.0\ 10^{15}$	$2.3\ 10^{16}$	$2.2\ 10^{15}$	[3] & [2]	$4.7\ 10^{15}$
Mallinckrodt	$7.3\ 10^{8}$	$1.4\ 10^{10}$	$7.3\ 10^{11}$	$8.8\ 10^{6}$	[4] & [2]	-
ANSTO	$1.4\ 10^{12}$	$1.6\ 10^{13}$	$6.8\ 10^{14}$	$6.8\ 10^{11}$	[3] & [2]	$7.3\ 10^{14}$
BATEK	$4.0\ 10^{11}$	$4.8\ 10^{12}$	$2.0\ 10^{14}$	$4.6\ 10^{14}$	[3], [2] & [5]	$1.0\ 10^{15}$
CNEA	$1.7\ 10^{10}$	$1.5\ 10^{11}$	$7.4\ 10^{12}$	$7.4\ 10^{8}$	[3] & [2]	$3.7\ 10^{14}$
All NPPs	$3.9\ 10^{13}$	$1.5\ 10^{13}$	$6.7\ 10^{14}$	$4.8\ 10^{14}$	[6] & [7]	$1.2\ 10^{15}$
Total	$9.3\ 10^{13}$	$1.4\ 10^{15}$	$4.2\ 10^{16}$	$2.7\ 10^{15}$		-

Table 1 – Radioxenon emission inventory for the identified sources. The Xe-133 emission inventory developed in [8] is shown as well.

Estimation of the radioxenon background at IMS noble gas systems

The baseline radioxenon emission inventory was used together with 1 by 1 degree-sized Source Receptor Sensitivity fields as calculated with the atmospheric transport model FLEXPART to estimate the xenon activity concentration at the IMS NG systems (see **poster T2.4-P12** [10]). The estimated average radioxenon activity concentration at 39 IMS NG systems is shown in Figures 2, 3, 4 and 5 for Xe-131m, Xe-133m, Xe-133 and Xe-135 respectively. In addition, the contribution of each radioxenon source to the average value is shown as well in the figures. As expected, the Xe-133 average values are much higher than for the three other isotopes. The maximum average value is: **2 10^{-2} mBq/m³** for **Xe-131m** at USX75, **4 10^{-2} mBq/m³** for **Xe-133m** at USX75, **2.8 mBq/m³** for **Xe-133** at USX75 and **1 10^{-1} mBq/m³** for **Xe-135** at SEX63. The Xe-135 activity concentration at IMS NG systems is mainly coming from close sources due to its short half-life, *i.e.* 9 hours. For the three other radioxenon isotopes, sources at larger distances are contributing to the average activity concentration as a result of the longer half-lives.

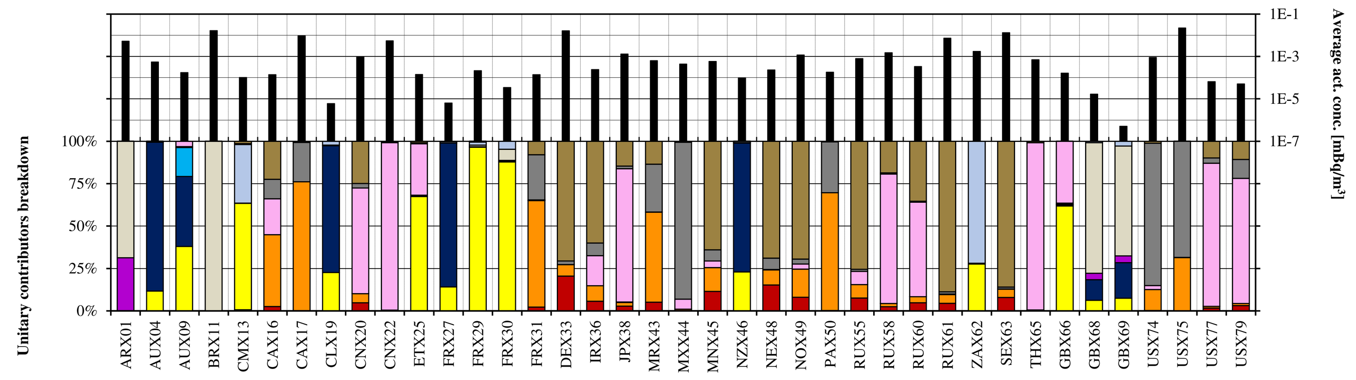


Figure 2 – Estimated Xe-131m average activity concentration at all 39 IMS noble gas systems.

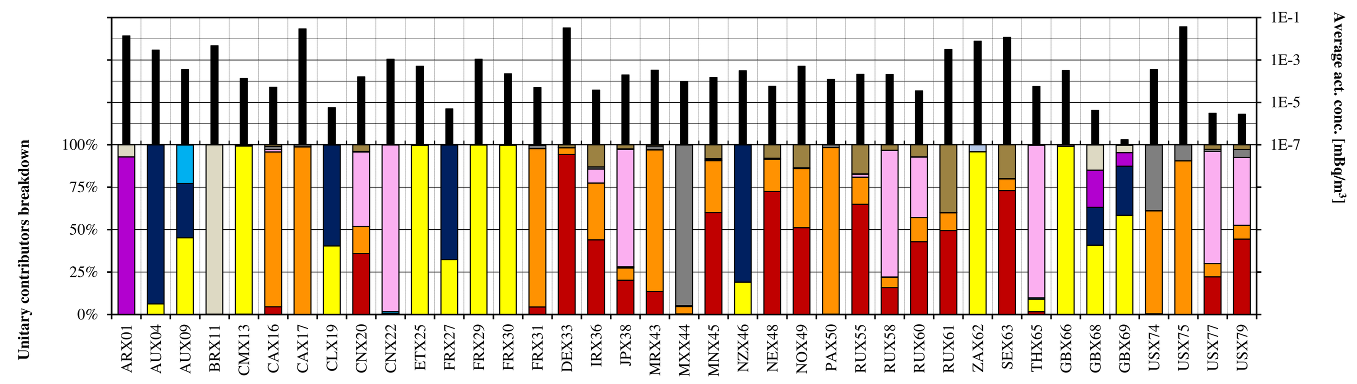
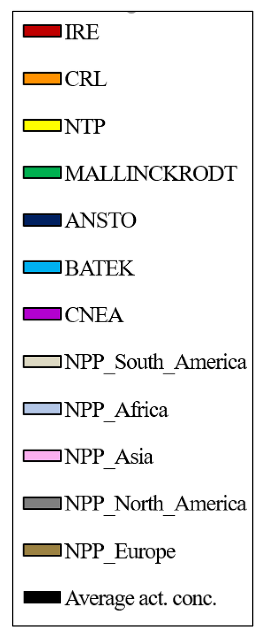


Figure 3 – Estimated Xe-133m average activity concentration at all 39 IMS noble gas systems.



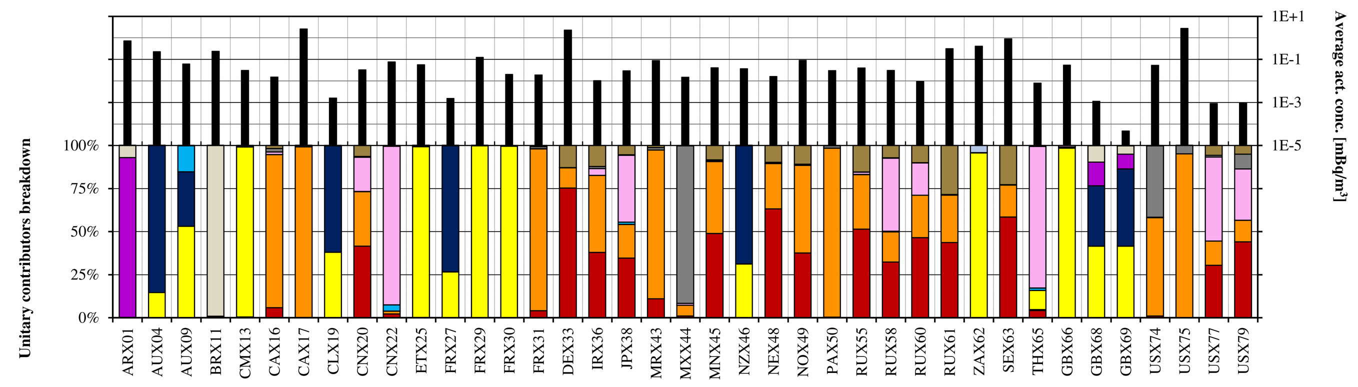


Figure 4 – Estimated Xe-133 average activity concentration at all 39 IMS noble gas systems.

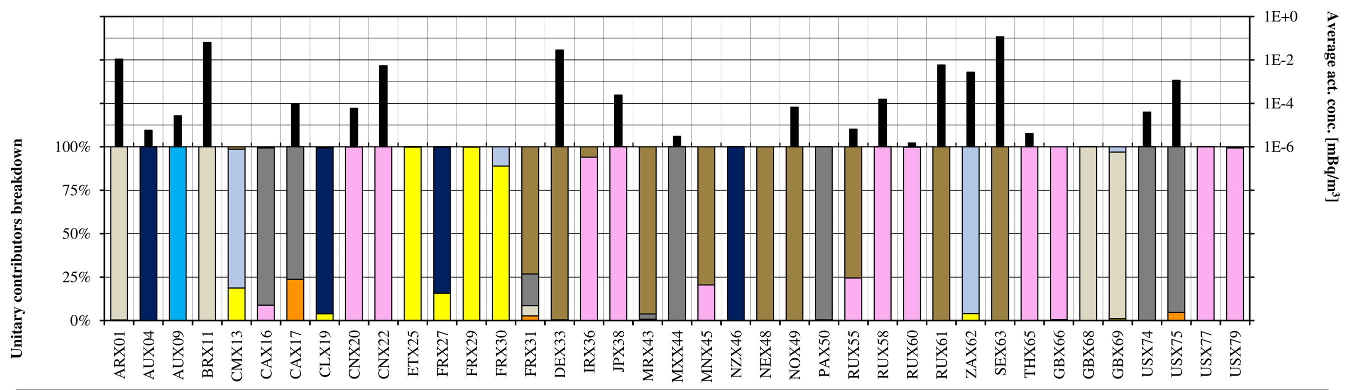


Figure 5 – Estimated Xe-135 average activity concentration at all 39 IMS noble gas systems.

Comparison of estimation and observation at operational IMS NG systems

During the calendar year 2014, 23 IMS NG systems were operational. Only samples interactively reviewed by the International Data Centre were considered. The number of valid samples that were taken in 2014 and the number of observations and estimations above the Minimum Detectable Concentration (MDC), called hereafter detections, for each xenon isotope is shown in Table 2. This study focuses on Xe-133 as its observed detection rate is the highest of the four relevant radioxenon isotopes. 18 IMS NG systems had at least one Xe-133 detection during the year 2014. Observed and estimated average activity concentrations (for samples with an observed detection) are compared in Figure 6. For about 80% of the IMS NG systems, the estimated average is within a factor 10. The IMS NG systems that had a Xe-133 detection rate higher than 25% were investigated in more detail. The distribution of Xe-133 observed activity concentration is compared to the estimated one (for samples with an observed detection) in Figure 7. For these NG systems, the medians of the estimations are always within a factor 2 of the observed ones.

	Observed	Estimated
Valid samples in 2014	10662	10662
Xe-131m detections	235	7
Xe-133m detections	137	6
Xe-133 detections	1907	1668
Xe-135 detections	36	7

Table 2 – Summary of radioxenon observations and estimations.

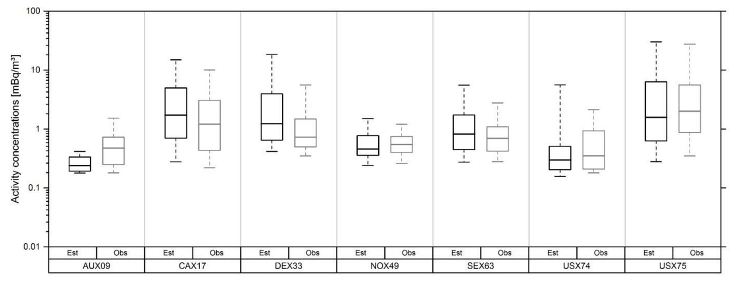


Figure 7 - Box-and-whiskers plots of estimations (black) and observations (grey).

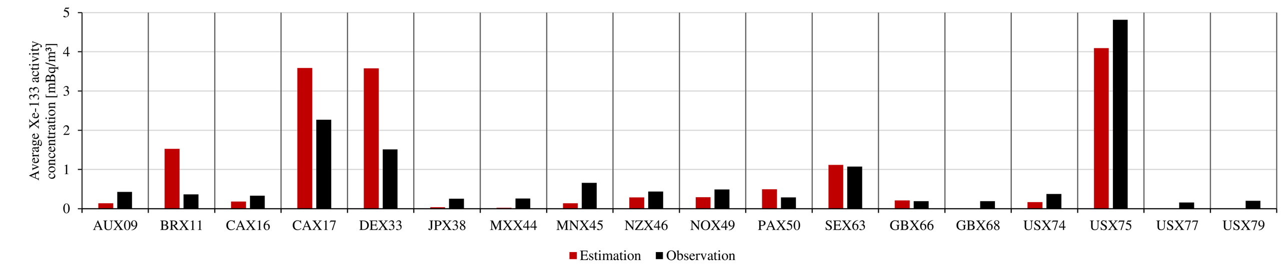


Figure 6 – Comparison of estimated and observed average Xe-133 activity concentration.

Conclusion

- A baseline radioxenon emission inventory for the calendar year 2014 has been defined to serve as a reference for future studies. The example of such an application is shown in **poster T2.4-P19** [11].
- First time comparison between estimated and observed activity concentrations of all 4 CTBT relevant radioxenon isotopes.
- The estimated radioxenon background at 39 IMS NG locations was characterized with regard to average activity concentration and civilian contributors.
- For about 80% of the IMS NG systems, the estimated Xe-133 average activity concentration is within one order of magnitude.
- For NG systems with an observed detection rate higher than 25%, the median estimated Xe-133 activity concentration is within a factor 2 of the observed one.

References

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