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Pacific Northwest

Exploring the use of radioxenon to radioiodine isotopic ratios as additional screening method regarding possible CTBT-relevant events

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CTBTO PREPARATORY COMMISSION

INDRODUCTION

Xenon and iodine isotopes are major indicators for nuclear explosions and are monitored by the International Monitoring System to verify compliance with the CTBT. Xenon isotopes are intermediate decay products of radioiodine. If originating from the same source, the radioxenon to radioiodine ratio of isotopes from the same mass chain may be suitable for screening of events. This study investigates the radioxenon to radioiodine isotopic activity concentration ratios, as they occur in samples of co-located noble gas and particulate systems that significantly overlap in sampling time. These IMS observations are compared to ratios of the same isotopes for different sources that may be observed. Conclusions are drawn on the usefulness of radioxenon to radioiodine ratios for event screening in CTBT monitoring.

ISOTOPIC RATIOS OF COINCIDING OBSERVATIONS OF RADIOIODINE AND RADIOXENON AT IMS STATIONS

Observations at IMS stations are based on a subset of quality-controlled reviewed spectra data retrieved from the operational database, for the period Jan. 2010 – Dec. 2022, with the following additional criteria:

- Samples of co-located noble gas and particulate systems with significantly (i.e. more than 50%) overlap in sampling time,
- Concomitant detections of I-131 and Xe-133, I-131 and Xe-131m, I-133 and Xe-133,
- Focus is given on the ratio Xe-133/I-131, these two isotopes are the most frequently occurring,
- Further investigation is needed for other ratios, specifically those of the same mass chain.

These observations from IMS stations were compared graphically (cf. Comparison box) with several data sets:

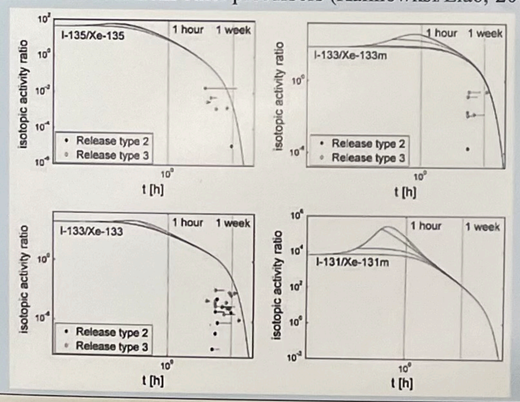
- Real emission values from an underground nuclear test explosions at Nevada (Kalinowski, 2011)
- Decay curves for initial yields of a nuclear explosion scenario, calculated with the Bateman equation (Kalinowski and Pistner, 2006)

Comparisons with further sources are facilitated on this poster:

- Box-and-Whisker plots using release reports of nuclear power plants and data for a spent fuel reprocessing plant (cf. Source Strength box).
- Development over time of the radioxenon to radioiodine ratios for pure radioiodine releases (cf. Pure Radioiodine Sources).

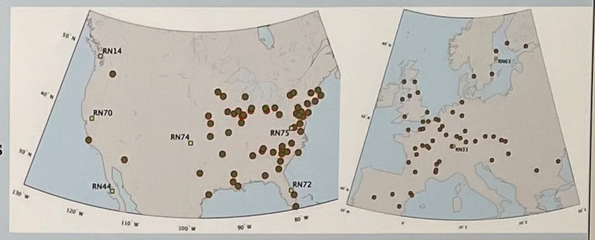
NUCLEAR EXPLOSION SCENARIOS

The plot shows radioiodine to radioxenon ratios for a nuclear explosion scenario with fractionation of both from other precursors (Kalinowksi/Liao, 2014).

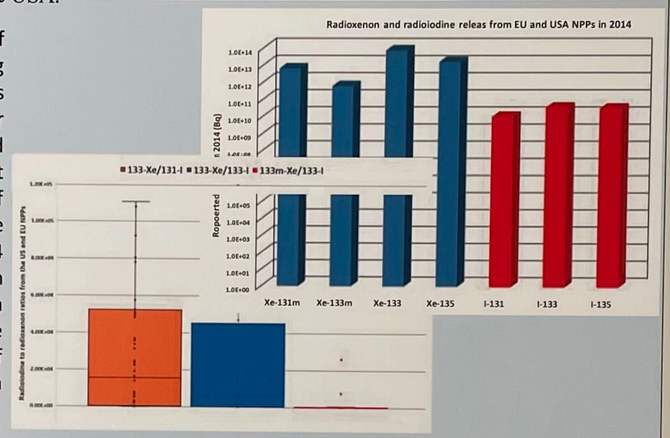


SOURCE STRENGTHS OF RADIOIODINE SOURCES

The radioxenon and radioiodine data in this work show both continuous and batch releases of gaseous effluent from the USA and EU NNPs. No quantitative data is available if effluent activity is within the lower limit of detection. Data from the NPPs shown in the maps below used. The maps show the locations of the IMS radionuclide stations and NPPs in the EU and the USA.

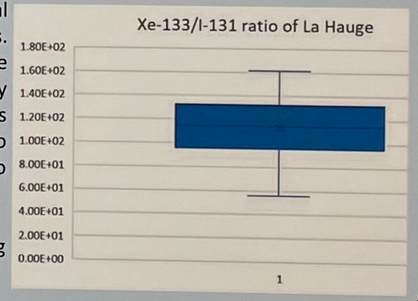


Iodine plays a crucial role as one of the primary fission products during the operation of NPPs and is released along with other radioisotopes in a controlled manner within authorization limit range during routine operation of the NPP. The bar chart shows the total emission inventory for 2014 covering all NPPs for which reported emission are available on RADD. The radioiodine isotopes are between one and four orders of magnitude lower than radioxenon from the same mass chain.



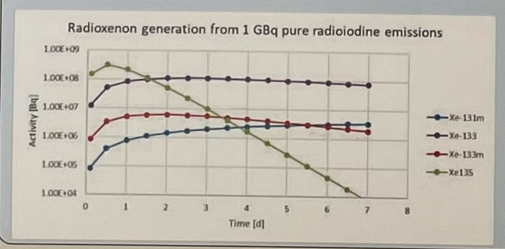
In general, the annual release of I-131 from pharmaceutical facilities is very low and cannot be detected by IMS systems. There is not much information available of radioiodine releases from medical isotope production facilities. The yearly authorization for I-131 releases from the Karpov Institute is 780 GBq. The Xe-133 release from that facility is estimated to be 300 TBq. Therefore, the Xe-133/I-131 activity ratio is two to three orders of magnitude high.

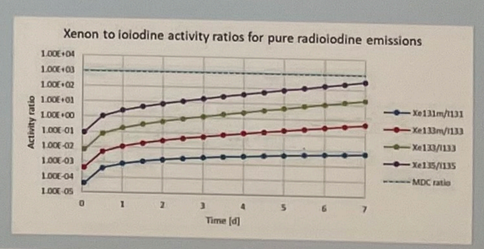
Spent nuclear fuel reprocessing facilities are not a strong source. The Xe-133/I-133 activity ratio is around 200.



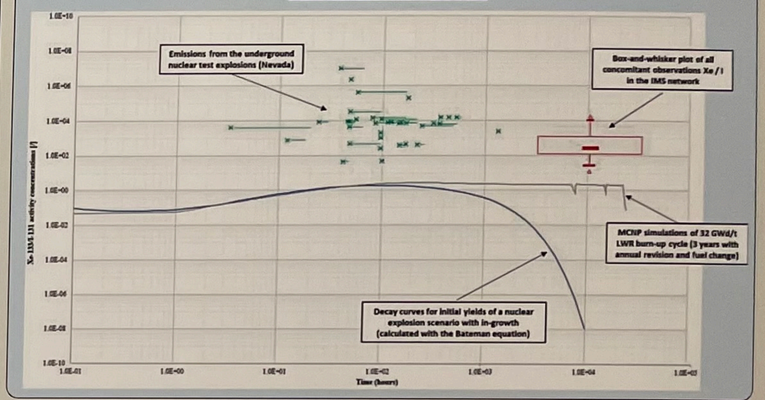
PURE RADIOIODINE SOURCES

Assuming there is a release of pure radioiodine, we calculated the activity ratio of Xe/I resulting from the decay product generation during the atmospheric transport. This is shown in the left plot.
The right plot shows the radioxenon to radioiodine ratios. For Xe-131m to be above MDC seven days after its release, the I-131 observation would have to be 5 orders of magnitude above MDC, i.e. in the range of 0.1 Bq/m3. For Xe-133, the situation is different. If I-133 is observed three days after the release and it is at least a factor of 1000 above MDC (i.e. around a few mBq/m3), it should be possible to observe Xe-133 at a co-located NG system just above MDC.





COMPARISON



CONCLUSIONS

On the ratio of concomitant detections of I-131 and Xe-133 at IMS stations:

- Xe-133/I-131 ratios are found in a relatively small band (2 orders of magnitude),
- The observed distribution is not reflecting atmospheric background because the MDCs of both isotopes are limiting the range of ratios observed,
- Comparison with ratios at known sources doesn't provide a hint of a typical single source type,
- It remains to be investigated whether concomitant detections are by chance or from the same source.

On IMS observations vs. nuclear explosion signals:

- The range of Xe-133/I-131 ratios in IMS observations happens to have large overlap with releases of underground nuclear tests. The overlap is even stronger when decay correction is considered.

On event screening :

- Xe-133/I-131 ratios from an underground nuclear test would appear like normal background,
- The upper part of the Xe-133/I-131 ratio distribution at Nevada is higher than ever observed at IMS stations. Whether this can be observed as anomaly at an IMS station depends on the source strength vs. MDC limits.
- Atmospheric nuclear test would cause an anomaly of very low ratios, if iodine wash-out remains limited.
- Better understanding the atmospheric background of I-131 and Xe-133 is vital for event characterization.

REFERENCES

Kalinowski, M.B.; Liao, Y-Y (2014): Isotopic characterization of radioiodine and radioxenon in releases from underground nuclear explosions with various degrees of fractionation. Pure and Applied Geophysics: Volume 171, Issue 3 (2014), Page 677-692.

Kalinowski, M.B. (2023): Global emission inventory of 131mXe, 133Xe, 133mXe, and 135Xe from all kinds of nuclear facilities for the reference year 2014. Journal of Environmental Radioactivity 261,107121.

IAEA-TECDOC-1240 (2001): Present and future environmental impact of the Chernobyl accident

Shigekazu Hirao et al., (2013), Estimation of release rate of iodine-131 and cesium-137 from the Fukushima Daiichi nuclear power plant, Journal of Nuclear Science and Technology, 50, 139-147

Eric R. Braverman et al., (2014), Managing Terrorism or Accidental Nuclear Errors, Preparing for Iodine-131 Emergencies: A Comprehensive Review, Int. J. Environ, Res. Public Health

DATA SHARING

These data were made available for participants to the 1st Nuclear Explosion Signal Screening Open Inter-Comparison Exercise via vDEC http://www.ctbto.org/specials/vdec.
Contact: vdec@ctbto.org