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Considerations of xenon-133 to iodine-131 ratios for discriminating signatures of nuclear test explosions against normal operational releases from nuclear facilities

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1. Introduction

It has been considered whether the ratio between xenon-133 and iodine-131 can be applied to discriminate between a nuclear test explosion and reactor emissions. Ratios of xenon and iodine isotopes have been examined extensively in the past (Kalinowski & Pistner, 2006; Kalinowski et. al., 2012). Both elements can be detected by the International Monitoring System (IMS), set up by the Preparatory Commission of the Comprehensive Test Ban Treaty Organization (CTBTO). Ratios between xenon isotopes and between iodine isotopes can be used to discriminate between emissions from nuclear test and nuclear reactors. It is of further interest whether the ratio between certain xenon and iodine isotopes can be applied to differentiate the source of emissions, too. The ratios between Xe-133 and I-131 are considered since these isotopes have the highest production rate and are hence most likely detectable in comparison to other isotopes of the respective element.

2. Calculations

Emission ratios were calculated for nuclear tests using initial yields provided by England & Rider (1994) and applying the Bateman equation to determine the activities at every time step (Kalinowski & Pistner, 2006). The behavior of this ratio is plotted in **Figure 1**. The calculations were performed with different initial yields depending on the fissile material and the neutron energy. As can be seen in the figure, the curves start at different values and converge over time.
Reactor emissions were calculated by performing fuel-burn up simulations with the cell burn-up code-system MCMATH (Pistner, 2006). The ratios for Xe-133 to I-131 are presented in **Figure 2**.

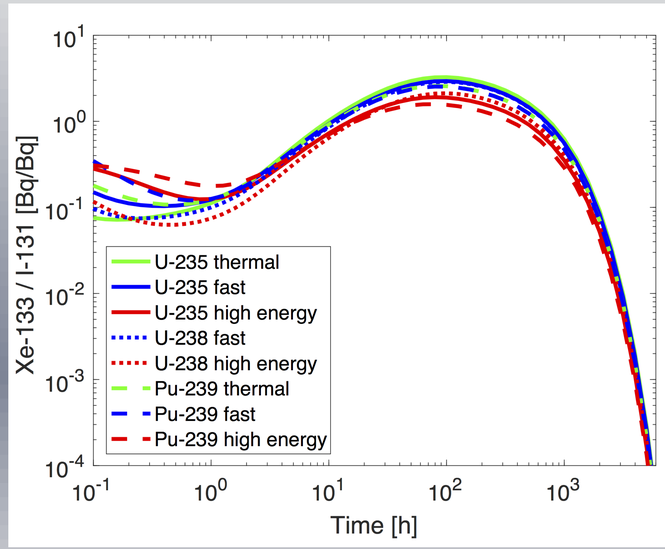

Figure 1: Calculations with Bateman equation starting with different initial yields (Kalinowski & Pistner, 2006)

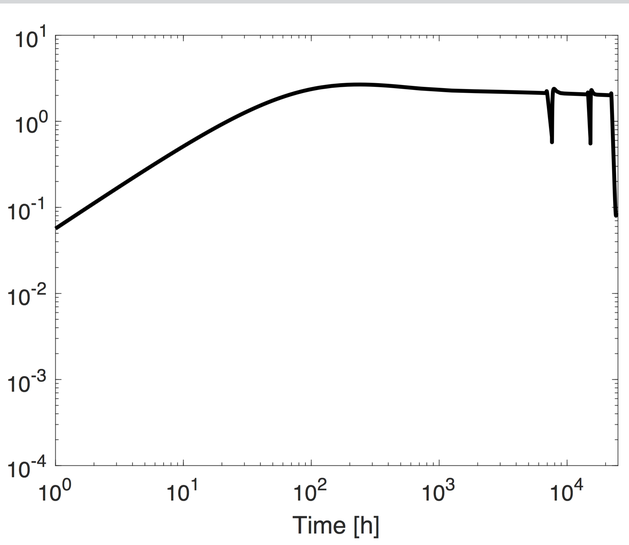

Figure 2: Simulation of a nuclear fuel burn-up with MCMATH (Pistner, 2006)

3. Measurements

The calculations are compared with measured emission data. In Schoengold et al. (1996) radionuclide emissions from nuclear underground tests at the Nevada National Security Site were reported. The available data is shown in **Figure 3**. Releases were measured between 3 and more than 1000 hours after the nuclear test explosion. The duration of the release is represented by an error bar. A trend in the spread of the data after some decay period is not observable.
Radionuclide emissions from nuclear reactors are frequently measured and publicized in the European Commission RAdioactive Discharges Database, RADD (http://europa.eu/radd/). The reported data in the reports for the years 1995-2003 are presented in **Figure 4**. Since most of the reported data are annual values a box-and-whisker plot was chosen to represent the distribution of results for ratios between the isotopes concerned.

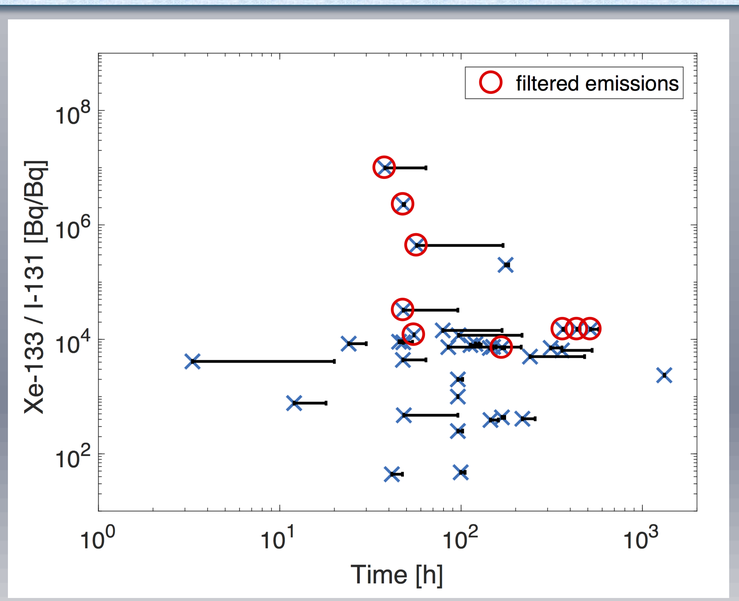

Figure 3: Emissions from underground test effluents (Schoengold et al, 1996)

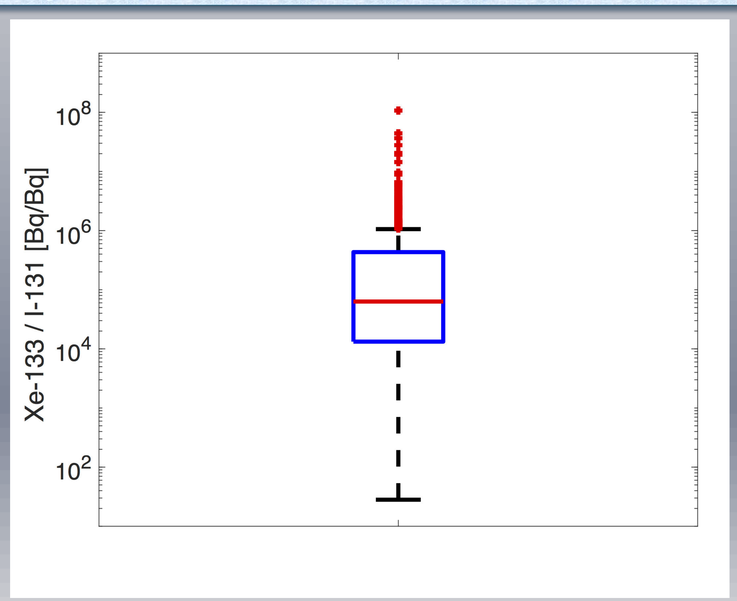

Figure 4: Distribution of nuclear reactor emissions (RADD, 1995-2003)

4. Conclusions

It can be observed that the ratios of the measured emissions are at least one to six magnitudes above the simulated ratios. This can be explained through filtration of iodine: Emissions from a nuclear underground test have to diffuse through soil to reach the atmosphere where they are detectable. A similar filtration process happens in a nuclear reactor. The simulated values represent the isotopic ratios in the reactor fuel elements. The measurements take place outside the power plant which give a lot of possibilities for filtration between the reactor core and the biological shielding. In general the filtration is stronger for iodine than for xenon since iodine can appear in particle form.
To discriminate a nuclear test explosion and a nuclear reactor based upon measurements of Xe-133 and I-131 an observable difference between their ratios would be necessary. Comparing **Figure 1** to **Figure 2** and **Figure 3** to **Figure 4** it is apparent that a significant difference in the ratios cannot be noticed – neither with the simulated data nor with the measured ones. Hence it is concluded that the simple approach presented here cannot be used to differentiate between nuclear test explosions and reactors. It might be possible to derive conclusions with a more comprehensive understanding of the diffusion mechanisms for different test setups and reactor types but based on presented considerations the approach to compare the ratio of xenon and iodine isotopes does not look promising.

References

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