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Constraints from Transport Times and Minimum Detectable Activity on the Analysis of Low-Activity Samples at CTBT Radionuclide Laboratories

CTBTO PREPARATORY COMMISSION

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1. Introduction:

- Particulate samples collected at radionuclide stations of the International Monitoring System (IMS) are split in half and sent to two different IMS radionuclide laboratories for further analysis in case the sample is selected as relevant (Level 5). According to the most recent version of the draft IMS operational manual, one half of the sample is sent to the radionuclide laboratory closest in transport time and available to perform the analysis, the other half of the sample is sent to a different available radionuclide laboratory which is determined randomly using an algorithm residing at the Technical Secretariat.
- Depending on the half-life of the isotope, a certain number of nuclei will decay during the transport from the station to the laboratory. Furthermore, depending on the isotope and the specific particulate sample, each laboratory is able to detect a different Minimal Detectable Activity (MDA), which in general is significantly lower as compared to the IMS stations. Still, an isotope detected at a station might not be detectable at the laboratory.
- To estimate the detection probability of a low activity sample, the empirical MDAs of the laboratories and the transport times between the stations and the laboratories must be considered.
- In this work, we have estimated how many isotopes might not have been detected in the past years and for what isotopes it would be beneficial to optimize the sample transport and the laboratory selection process. The relevance of these considerations can be deduced from **table 1** which shows that in almost half of all samples, which were analysed between July 2007 and April 2015, a nuclide, which was originally detected at the station, was not detected by at least one laboratory. There are multiple reasons for this and one of them may be decay during transport to below MDA.

	Number of nuclides	Number of samples
Detected nuclides and Level 5 samples at the station	521	161
Nuclides not detected by at least one lab	125 (24%)	77 (49%)
Nuclides not detected by one lab	51 (9%)	34 (21%)
Nuclides not detected by two labs	74 (14%)	56 (35%)

Table 1: IDC-relevant nuclides in Level 5 samples detected at the station and sent to two different laboratories between July 11, 2007 and April 17, 2015

2. Method:

- For all findings, data stored in the International Data Centre (IDC) database have been used.
- To determine which isotopes shall be closer investigated in this work, occurrences of 61 CTBT-relevant isotopes in level 5 samples between July 2003 and May 2015 with a half-life below 45 days are presented in **figure 1**.
- I-133, La-140, Mo-99, Te-132, I-131, Ba-140 and Te-129m were chosen and plotted in **figure 2 – 8**. In these figures, the following data from 2015 is presented for each isotope:
  - The radioactive decay of the hypothetically detected isotope. For the activity at acquisition start (time = 0 days), the minimum and the median of the nuclide specific MDAs of all radionuclide stations was assumed. The plotted activity is half of the full sample activity to account for sample splitting assuming a homogenous activity distribution.
  - The median of the nuclide specific MDAs for each one of ten certified IMS radionuclide laboratories.
  - The points of intersection between the decay curve based on the median of station MDAs and the MDAs of each laboratory.
- To estimate whether an isotope can be detected in a laboratory, the duration of 233 sample shipments from stations to laboratories in 2015 were analysed. The distribution of transport times is visualized in **figure 9** as a box-and-whisker plot. To compare this diagram with **figures 2 – 8** the time = 0 days has been set to the acquisition start at the station. The transport is expected to begin after a pre-dispatch period of 2.5 days.

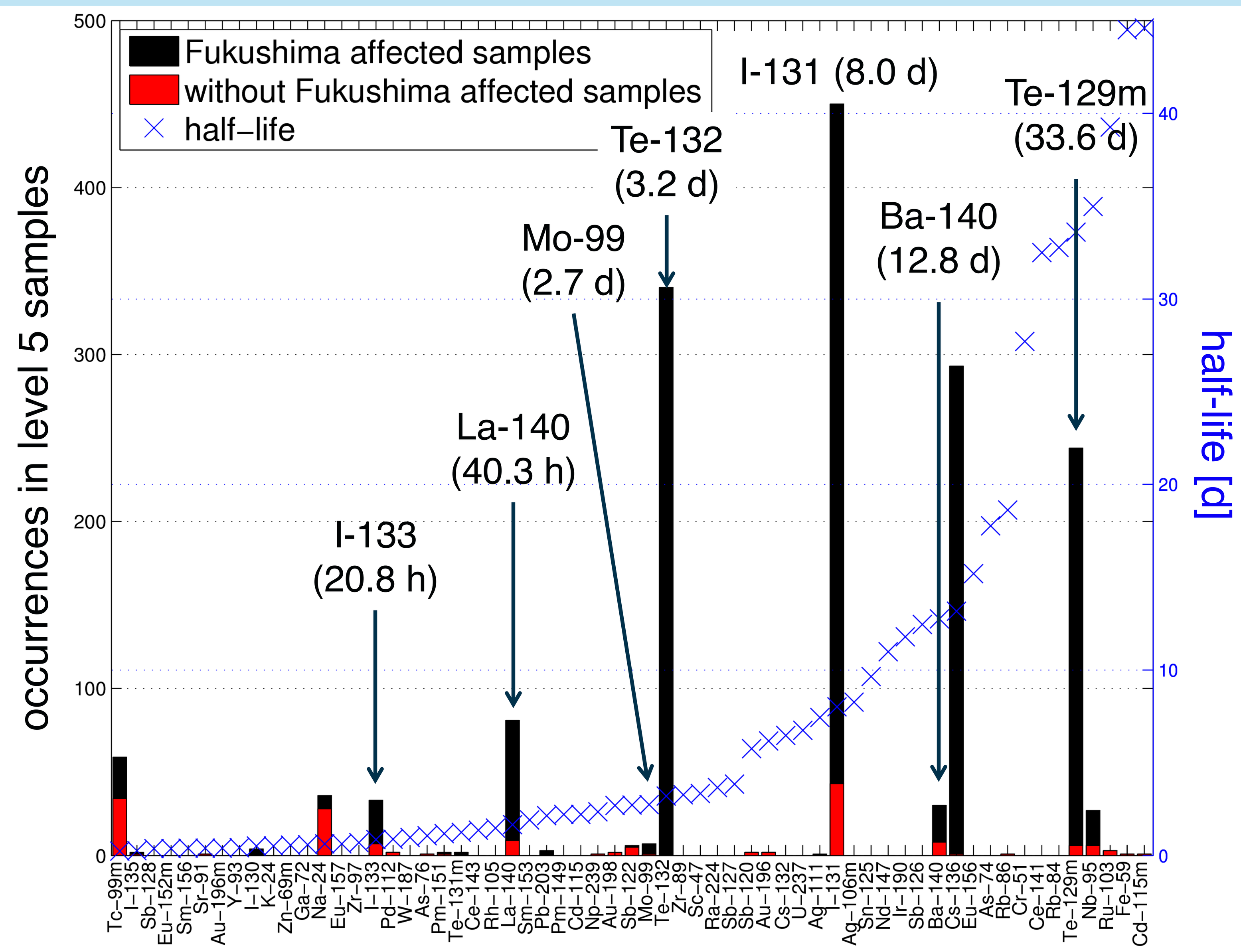
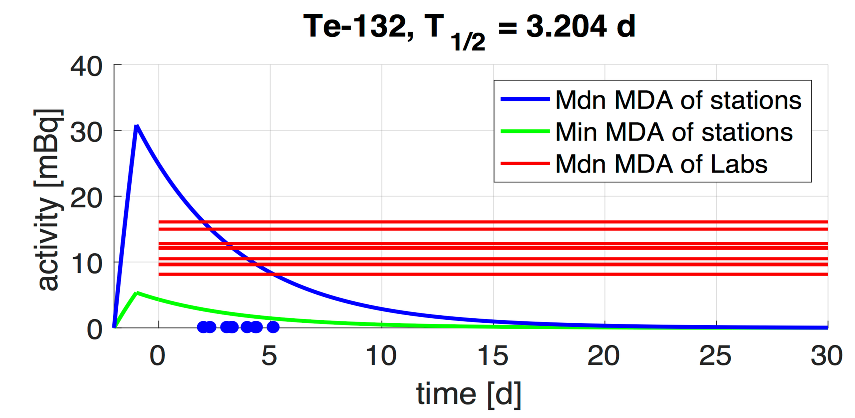
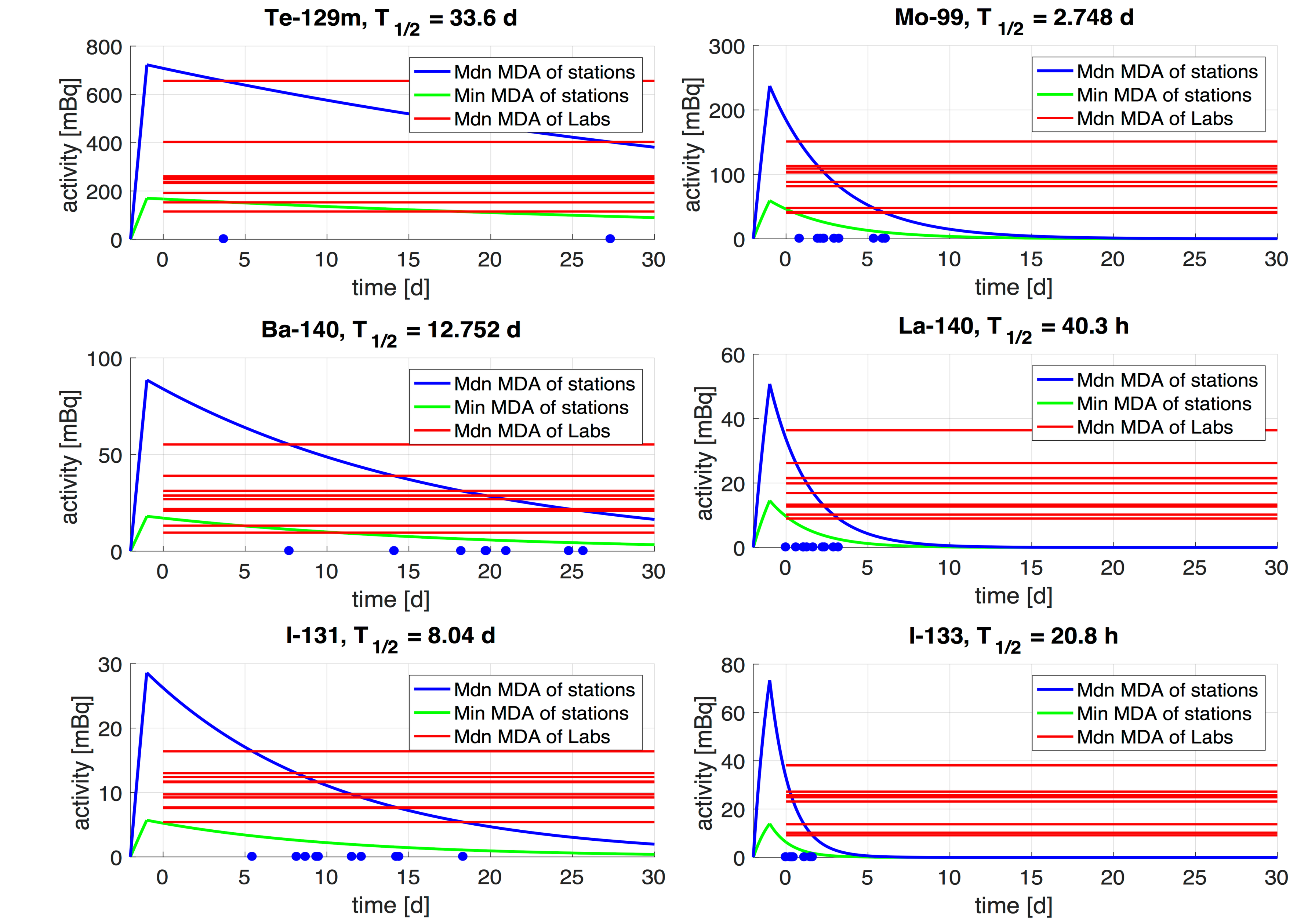


Figure 1: Occurrences of 61 CTBT-relevant isotopes in level 5-samples with $T_{1/2} < 45$ days between July 2003 and May 2015

Figure 2 – 8: Sampling and radioactive decay of Te-129m, Ba-140, I-131, Te-132, Mo-99, La-140 and I-133, and respective median of MDAs for each IMS laboratory





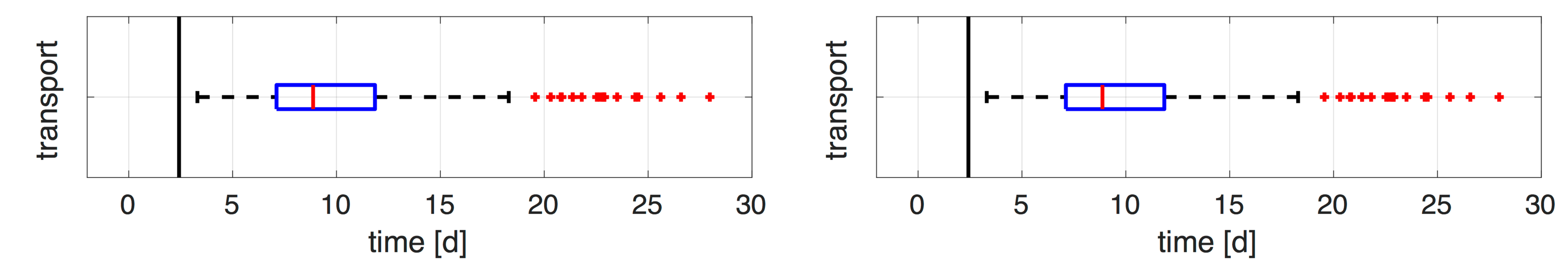


Figure 9: Transport time distribution of 233 sample shipments from stations to laboratories in 2015 as a box-and-whisker plot (presented twice for convenient comparison with figures 2 – 8)

3. Conclusion:

- From **figure 2 – 8**, it is noticeable that for all investigated isotopes the experienced MDA of the laboratories varies significantly up to an order of magnitude. This leads especially for longer-lived isotopes to a large spread of the points of intersection. By comparing **figure 2 – 8** with **figure 9**, it is apparent that in case of short-lived isotopes the points of intersection between the isotope decay and the laboratory MDA are below the median of the transport time distribution.
- From this comparison, it can be concluded that for very short-lived isotopes, such as La-140, and I-133, with low sample activity it is almost impossible to reach a laboratory in time before the activity has decayed below MDA. For short-lived isotopes, such as I-131, Te-132, and Mo-99, it would be beneficial to optimize the sample transport and the laboratory selection process. A selection process should be based on short transport times between stations and laboratories and the empirical MDAs of the laboratories to increase the possibility of detecting a certain isotope.
- For longer-lived isotopes, such as Te-129m and Ba-140, a random selection process is sufficient.