IMPACT OF WORLDWIDE Xe-133 ATMOSPHERIC BACKGROUND ON IMS NETWORK COVERAGE

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It is now well known that these facilities proceed to daily releases of radioxenons (Xe-133) into the atmosphere leading to a significant worldwide background.

The effective capacity of the IMS network to detect nuclear tests (NT) can be degraded compared to the expected one.

(I) Assessment of the global Xe-133 background (what are its characteristics?)
(II) Calculation of IMS noble gas network coverage depending on NT source term
(III) What is the loss of IMS network coverage due to the Xe-133 background?
(I) Identified types of industrial sources and simulation of Xe-133 global background

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**Identified civil sources**

<table>
<thead>
<tr>
<th>Identified civil sources</th>
<th>Release/day (Bq)</th>
</tr>
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<tbody>
<tr>
<td><strong>Medical Isotopes Plants (MIPs)</strong></td>
<td>$\sim 10^{12} - 10^{13}$</td>
</tr>
<tr>
<td><strong>Nuclear Power Plants (NPPs)</strong></td>
<td>$\sim 10^9$ / reactor</td>
</tr>
<tr>
<td><strong>Research Reactors</strong></td>
<td>$&lt; 10^9$</td>
</tr>
<tr>
<td><strong>Hospitals with nuclear medicine departments</strong></td>
<td>$&lt; 10^6$</td>
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</tbody>
</table>

- Potential total release per day $\sim 70$ TBq

- Worldwide Xe-133 background was simulated **over a period of 2 years**:
  - All identified (main) sources are supposed to be in operation:
    - 10 MIPs
    - 6 groups defined for the 195 NPPs (total: 440 reactors in Europe, America…)
  - Assuming daily releases:
    - 24-hour continuous releases for NPPs
    - 5-hour duration releases for MIPs
  - 12-hour sampling period

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Workshops WOSMIP I (2009) to V (2015)
Kalinowski et al.; J. Env. Radioactivity 100 (2009) 58-70
Strong daily variability of local activity concentration levels

Simulations show puffs of high activity concentration from MIPs, smaller contribution of NPPs

Daily Xe-133 background is not uniform and appears more dense in the Northern Hemisphere

Examples of time series of activity concentration simulated at IMS stations (JPX38-Takasaki, Japan and SEX63-Stockholm, Sweden)
(I) Annual average background (layer 0-100m AGL)

- Average levels > 0.1 mBq/m$^3$ in a large part of the Northern Hemisphere
- Higher than 0.5 mBq/m$^3$ in Europe, locally > 5 mBq/m$^3$
- Lower background in the Southern Hemisphere (there are fewer MIPs)

- The origin of local background can be complex (contribution of local and distant sources)

Comparison measurements/simulations

![Map showing the distribution of background levels worldwide](image)

![Graph showing the comparison between simulations and measurements](image)
Evolution of % of detection depending on the MDC (12hr collection periods)

Ex: an MDC = 0.2 mBq/m$^3$ would lead to ~25% of detections of the background per year for the whole IMS network

- 30% for Northern part of the network
- 15% in the Southern Hemisphere

- The industrial background is daily detected by several IMS stations

- Seasonal effect: maximum of detection of background > MDC in winter (for both Hemispheres)
Network coverage is evaluated by simulation of atmospheric transport (ATM)

- Over a period of one year (2013), backward calculations are daily made for each station (39 stations). Stations are supposed to operate with 12-hour collection periods (2 backward plumes per day for each station).

- Backtracking calculated over 14 days ($\Delta t_{ATM}$) considering the 4 isotopes Xe-131m (11.9d), Xe-133 (5.2d), Xe-133m (2.2d) and Xe-135 (9.1h).

- We assume a 6-hour noble gas release towards the atmosphere.

Objective: assess IMS global coverage without background interference (identify potential lack in coverage, characteristics depending on nuclear source term, potential seasonal variability)
(II) IMS network Xe-133 coverage depending on nuclear test source term (MDC=0.2 mBq/m$^3$)

Global coverage for $10^{13}$Bq = 52%

IMS network coverage calculated assuming different % leakage towards the atmosphere of maximum amount of Xe-133 (100%=10$^{16}$Bq for 1kt)

- Lack near Equator and Indian subcontinent
- Results for $10^{13}$Bq: lack in Antarctica (latitude < -70°) and significant differences between both Hemispheres (60% in Northern H., 44% in Southern H.)
Network Xe-133 Coverage depending on atmospheric test source term

- Differences between both Hemispheres (max. for $10^{13}$Bq)
- Coverage drops sharply with source term

Seasonal variability of coverage

- A weak seasonal variability is observed depending on test source term. Maximum effect for $10^{14}$Bq (mainly due to the Southern Hemisphere)
(III) Assessment of Xe-133 background interference on IMS network coverage (39 stations)

Calculation of coverage maps using:

\[ \text{ST}=10^{13} \text{ Bq} \]

1) \( \text{MDC}=0.2\text{mBq/m}^3 \) \( \text{without background} \) \( 52\% \)

2) \( \text{MDC}=\max(0.2\text{mBq/m}^3;\text{calculated background}) \) \( \text{with background} \) \( 45\% \)

\[ \text{Difference between the two maps to highlight most influenced areas} \]

In this example, global coverage loss due to industrial background is \(~7\%\)
(III) Loss of IMS network coverage due to Xe-133 background

- Calculations carried out for nuclear test source terms ranging from $10^9$ to $10^{16}$ Bq

- Considering the complete IMS NG network (39 stations), main interference is obtained with atmospheric nuclear test ST of $\sim 10^{13}$ Bq (DPRK 2006, 2013). In this case, the loss of coverage is about 7% for the globe (10% for the Northern Hemisphere, 4% for the Southern Hemisphere)

- Considering source terms > $10^{13}$ Bq, loss of coverage due to background is weak
Conclusion

(I) Comprehensive understanding of industrial radioxenon background has become a crucial part of discrimination of civilian/military events

- Xe-133 is measured daily by IMS Noble Gas station network
- Levels can be locally significant
- The origin of local background can be complex
- Strong daily variability of local activity concentration levels

(II) With the complete network (39 stations) and considering “reasonable” release (~10^{14} Bq Xe-133, 1kt), IMS global coverage is about 83% but it drops to 52% assuming “DPRK 2006, 2013” releases (~10^{13} Bq)

(III) Industrial Xe-133 background interference on IMS coverage could be locally significant. Our analysis suggests that the maximum coverage loss could be 7% for the globe and 10% for the Northern Hemisphere (4% for Southern Hemisphere) considering 10^{13} Bq atmospheric test release

- The detectability of the IMS noble gas network might be likely improved with more sensitive detection systems for other radioxenons (isotopic ratios, 131m, 133m, 135) and with network densification (by increasing number of NG stations)