A KRYPTON-85 MONITORING REGIME TO DETECT CLANDESTINE PLUTONIUM SEPARATION IN THE MIDDLE EAST

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BACKGROUND AND MOTIVATION

DETECTING CLANDESTINE SEPARATION OF PLUTONIUM

- Precedents exist for attempts to make plutonium in undeclared facilities
- Concern of “Simple, Quick Processing Plant” (Oak Ridge, 1977)
- Challenge for NPT verification; also relevant for future FMCT verification
- Atmospheric (krypton) sampling appears most promising (“STR-321”)


- The cost of operating a WAES network “could be high and would be strongly dependent on: the type of facility ...; the target region to be covered; and the acceptable probability of detection and false alarm rate”
- Recommended additional work includes: “Refining evaluation of the variability in background levels of target signatures”

An air sample is taken somewhere on the globe (or in a region) is the measured Kr-85 concentration from a known or from an unknown plant?

How would a verification regime look like?
KRYPTON-85 CONTENT IN SPENT FUEL

(Authors’ estimates based on ORIGEN2/MCNP6 neutronics calculations)

CHARACTERIZING THE GLOBAL KRYPTON-85 BACKGROUND

PART 1: HISTORIC BASELINE

Background in 2010: \( \approx 1.5 \text{ Bq/m}^3 \) in the Northern Hemisphere and \( \approx 1.3 \text{ Bq/m}^3 \) in the Southern Hemisphere

Characterizing the Global Krypton-85 Background

Part 2: Ongoing Emissions

Fluctuations due to recent/nearby emissions
Increasing baseline due to cumulative emissions

GLOBAL KRYPTON-85 VARIABILITY

$\mu_1 + \sigma_1 \approx 84\%$ OF LOCAL SAMPLES ARE WITHIN INDICATED UPPER CONCENTRATION LIMIT ABOVE (QUASI-CONSTANT) BASELINE $\mu_0$
FICTIONAL PLANT IN SOUTH AMERICA
SEPARATING 8 KG OF PLUTONIUM PER MONTH

BOTTOM LINE: GLOBAL KRYPTON MONITORING WOULD BE VERY HARD (TODAY)

These concentrations above the baseline cannot be measured against a background of 1.3–1.5 Bq/m^3.
IS REGIONAL KRYPTON-85 MONITORING A MORE Viable OPTION?

(FOR EXAMPLE, IN THE MIDDLE EAST)
A NUCLEAR WEAPON FREE ZONE IN THE MIDDLE EAST

EFFORTS TO ESTABLISH A NUCLEAR WEAPON FREE ZONE IN THE MIDDLE EAST

• Underway since 1974 (UN General Assembly Resolution)
• 1995 and 2010 NPT Review Conferences calling for establishment of the zone

CHALLENGES TO ESTABLISHING THE ZONE

• History of covert proliferation efforts (and political turmoil) in the region
• Israel’s nuclear weapons program and Iran’s gas-centrifuge enrichment program

ROBUST VERIFICATION OF A ZONE IN THE MIDDLE EAST WOULD BE CRITICAL

• Deep mutual distrust among key countries
• Technical expertise is highly uneven; needs capacity-building in the area of verification

Source: www.bluesky-world.com (bottom)
RANDOMLY PLACING FICTIONAL REPROCESSING PLANTS

FOR EACH ONE OF SIXTEEN LOCATIONS:
HOW MANY SAMPLES ARE NEEDED TO REACH 90% DETECTION PROBABILITY?

(Shown are current fluctuations in the krypton-85 background)
MAKING ONE SIGNIFICANT QUANTITY (8 KILOGRAMS) OF PLUTONIUM

1 SQ PER WEEK
1143 grams per day during a one-week period

1 SQ PER MONTH
263 grams per day during a one-month period

1 SQ PER YEAR
22 grams per day during a one-year period

Aaron Dulley, 6iie.com
POSSIBLE KRYPTON-85 FUTURES

(Once emissions stop, fluctuations in the background decay quickly)
HOW HARD IS IT TO DETECT CLANDESTINE PLUTONIUM SEPARATION?

WHEN COVERING THE ENTIRE MIDDLE EAST

NUMBER OF (RANDOM) SAMPLES NEEDED FOR 90% DETECTION PROBABILITY

<table>
<thead>
<tr>
<th>Separation Rate</th>
<th>1 SQ per year</th>
<th>1 SQ per month</th>
<th>1 SQ per week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days of repeated sampling</td>
<td>365 days</td>
<td>30 days</td>
<td>7 days</td>
</tr>
<tr>
<td>Current emissions</td>
<td>310 samples/day</td>
<td>96 samples/day</td>
<td>95 samples/day</td>
</tr>
<tr>
<td>Soon after emission stop</td>
<td>190 samples/day</td>
<td>77 samples/day</td>
<td>79 samples/day</td>
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<tr>
<td>10 years after emission stop</td>
<td>45 samples/day</td>
<td>40 samples/day</td>
<td>38 samples/day</td>
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<tr>
<td>30 years after emission stop</td>
<td>9 samples/day</td>
<td>10 samples/day</td>
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</tr>
</tbody>
</table>

Based on Flexpart 8.2.3 simulations, 0.5° x 0.5° resolution (about 260,000 gridpoints)

Day-by-day emissions from all declared plants and one undeclared plant
HOW HARD IS IT TO DETECT CLANDESTINE PLUTONIUM SEPARATION?

WHEN COVERING ONLY THOSE COUNTRIES WITH NUCLEAR PROGRAMS/AMBITIONS
(Algeria, Egypt, Iran, Iraq, Israel, Jordan, Libya, Saudi Arabia, Syria, UAE; about 65% of region’s landmass)

NUMBER OF (RANDOM) SAMPLES NEEDED FOR 90% DETECTION PROBABILITY

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<td>365 days</td>
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<td>7 days</td>
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<tr>
<td>Current emissions</td>
<td>150 samples/day</td>
<td>55 samples/day</td>
<td>51 samples/day</td>
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<tr>
<td>Soon after emission stop</td>
<td>95 samples/day</td>
<td>43 samples/day</td>
<td>42 samples/day</td>
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<tr>
<td>10 years after emission stop</td>
<td>25 samples/day</td>
<td>22 samples/day</td>
<td>21 samples/day</td>
</tr>
<tr>
<td>30 years after emission stop</td>
<td>6 samples/day</td>
<td>6 samples/day</td>
<td>5 samples/day</td>
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Based on Flexpart 8.2.3 simulations, 0.5° x 0.5° resolution (about 260,000 gridpoints)
Day-by-day emissions from all declared plants and one undeclared plant.
Aircraft from Open Skies Treaty have a minimum range of 1,500 km
(but not a single country in the region is currently party to the treaty)

Few airports would be sufficient to support collection
Samples could be analyzed in regional labs and/or one central laboratory
SUMMARY

REGIONAL KRYPTON MONITORING: A Viable Option?

GLOBAL KRYPTON MONITORING IS CURRENTLY IMPractical

- Northern Hemisphere: Detectability of clandestine facilities inhibited by variability of background due to ongoing emissions from existing reprocessing plants (not only in Europe)
- On the order of 1000 samples/day required
  Note: this is lower than the numbers presented at INMM last year

REGIONAL KRYPTON MONITORING IN THE MIDDLE EAST

- 50–150 daily samples could be sufficient today (max. 300)
- Number could drop to 10–20 samples per day if krypton emissions (from large commercial reprocessing plants) stopped
- Verifying the absence of reprocessing activities could be an important building block for confidence-building in the region