# STAX-2 investigation into the impact of nuclear power plants on nuclear explosion monitoring

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## Introduction

Radioxenon from industrial sources, including nuclear power plants (NPPs), is detected routinely by the International Monitoring System (IMS) for the Comprehensive Nuclear Test-ban-Treaty (CTBT), which currently has 39 radioxenon monitoring stations globally and will expand to 80 stations following ratification of the CTBT. There are currently approximately 440 NPPs in 32 countries, along with additional NPPs being constructed, and more are planned. The combination of additional IMS noble gas stations, more sensitive noble gas monitoring equipment, additional NPPs makes understanding backgrounds from NPPs essential.

The Source Term Analysis of Xenon 2 (STAX-2) project is an investigation into how emissions (primarily radioxenon) released from NPPs affect nuclear explosion monitoring. The STAX-2 project builds on the original STAX project by investigating how radioxenon emissions released from NPPs affect measurements made by the IMS. This new project has been engaging with willing NPP facilities to improve our understanding of how xenon is released and measured at these facilities.

## The issue

Industrial radioxenon emissions can be difficult to distinguish from releases of xenon resulting from underground nuclear explosions. The IMS monitors for signatures, including radioxenon isotopes, that are indicative of nuclear explosion incidents. Knowledge of the amounts and isotopes of radioxenon released from industrial sources, such as NPPs and fission-based MIP facilities, helps give a better understanding of global radioxenon backgrounds that interfere with nuclear explosion monitoring.

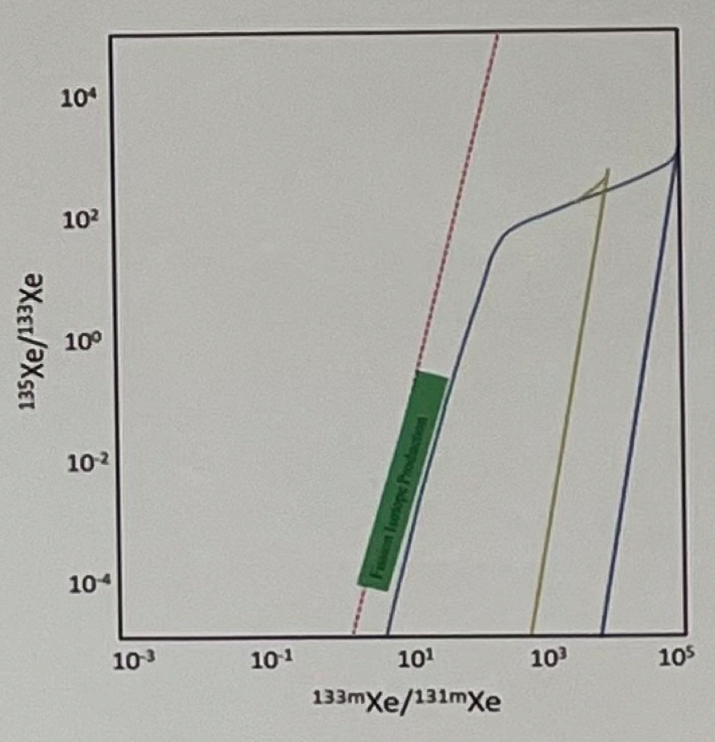


Figure 1: Overlap between signatures from MIP and nuclear explosions.

## ATM calculations to determine IMS impact

Atmospheric transport modeling (ATM) was used to examine the number of radioxenon isotopes detected by the IMS based on current and future power generation. These calculations are focused on current NPP designs. This analysis modeled daily releases of Xe-133, Xe-131m, Xe-133m, and Xe-135 from each NPP complex in 2021 along with several projections for 2030, 2040, and 2050. These models were used to examine the change in the number of detections by the IMS, Figure 2. An increase in detections was observed when considering both 40 and 80 stations. As seen in Table 1, the predicted increase in detections is not directly related to the number of IMS stations but is also dependent on the distribution of IMS stations relative to NPP locations. These additional detections would greatly increase the number of events that require investigation by national data centers and could cloak signals originating from nuclear explosions. This is especially true for IMS stations located in proximity to densely clustered NPP facilities.

ATM modeling was also used to determine the most influential NPPs on IMS radionuclide stations. Table 2 contains the results from this calculation. The analysis program that output these data allows us to adjust release rates, types of samplers, and how many samplers to consider. This spreadsheet is one example output to provoke discussion on what is useful.

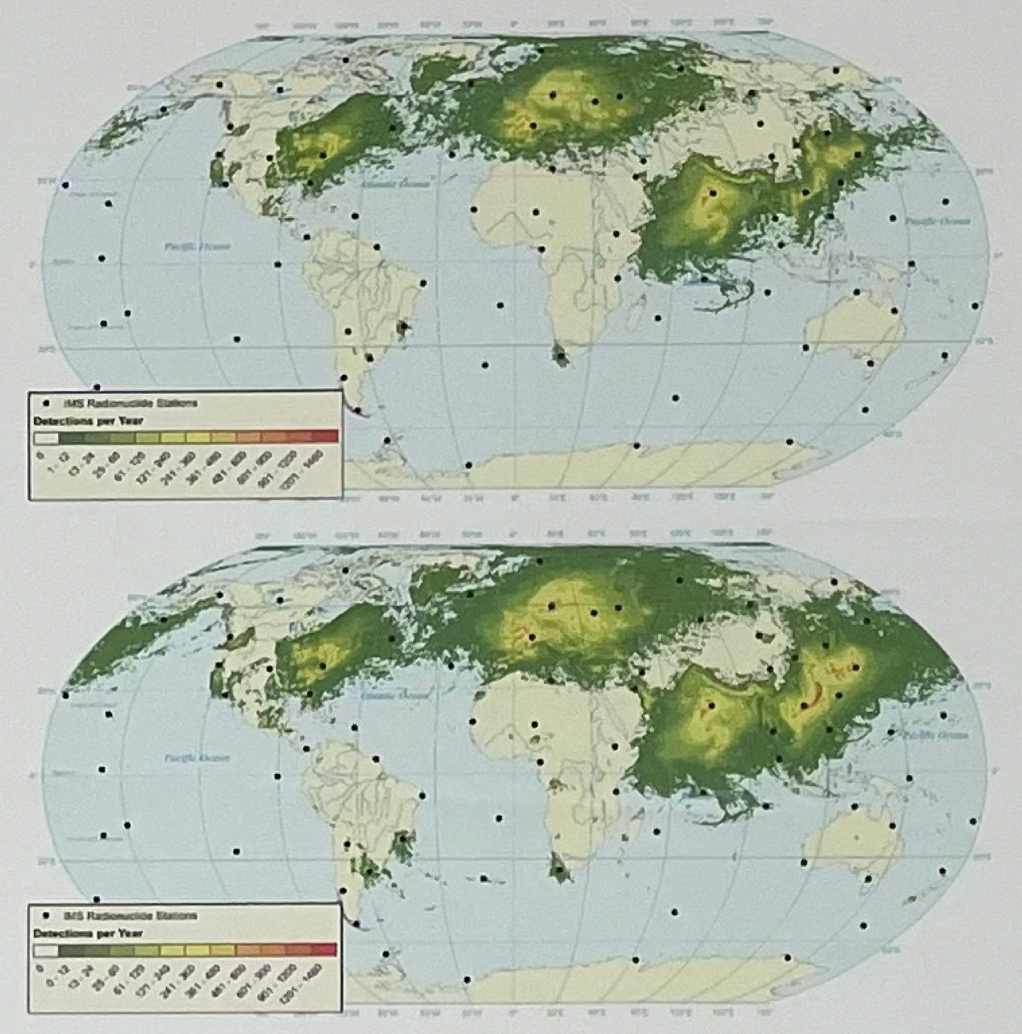

Figure 2: Number of Xe-133 detections per year based on 2021 (top) and 2050 (bottom) power scenarios. An increase in production in 2050 would likely lead to increased IMS detections in areas of NPP growth.

Table 1: Number of predicted annual IMS detections resulting from NPPs globally with 40 and 80 IMS stations

| Number of IMS Stations | Xe-133 | Xe-131m | Xe-133m | Xe-135 |
|---|---|---|---|---|
| 40 | 1451 | 1 | 0 | 160 |
| 80 | 1528 | 1 | 0 | 160 |

Table 2. Reactors with most impact based on 2021 data (abbreviated list)

| Reactor Complex | IMS Sampler | IMS Sampler Location | Reactor |
|---|---|---|---|
| AR001 | ARX01 | Buenos Aires, Argentina | Argentina (Atucha-1) |
| BE004 | DEX33 | Schauinsland/Freiburg, Germany | Belgium (TIHANGE-1) |
| BR001 | BRX11 | Rio de Janeiro, Brazil | Brazil (ANGRA-1) |
| BR001 | GBX68 | Tristan da Cunha, UK of Great Britain and N. Ireland | Brazil (ANGRA-1) |
| FI003 | SEX63 | Stockholm, Sweden | Finland (Olkiluoto-1) |
| FR011 | DEX33 | Schauinsland/Freiburg, Germany | France (Cattenom-1) |
| FR015 | DEX33 | Schauinsland/Freiburg, Germany | France (Chinon-B1) |
| FR052 | DEX33 | Schauinsland/Freiburg, Germany | France (St. Laurent-B1) |
| KR026 | JPX37 | Okinawa, Japan | Korea, South (Wolseong-2) |
| KR026 | JPX38 | Takasaki, Gunma, Japan | Korea, South (Wolseong-2) |
| KR026 | PHX52 | Tanay, Philippines | Korea, South (Wolseong-2) |
| KR026 | USX71 | Sand Point, AK, United States of America | Korea, South (Wolseong-2) |
| RU018 | NOX49 | Spitsbergen, Norway | Russian Federation (Kola-1) |
| ES003 | LYX41 | Misratah, Libyan Arab Jamahiriya | Spain (Asco-1) |
| **SE001** | **NOX49** | **Spitsbergen, Norway** | **Sweden (Forsmark-1)*** |
| **SE001** | **RUX54** | **Kirov, Russian Federation** | **Sweden (Forsmark-1)*** |
| **SE001** | **RUX61** | **Dubna, Russian Federation** | **Sweden (Forsmark-1)*** |
| **SE001** | **SEX63** | **Stockholm, Sweden** | **Sweden (Forsmark-1)*** |
| SE004 | SEX63 | Stockholm, Sweden | Sweden (Oskarshamn-3) |
| CH001 | DEX33 | Schauinsland/Freiburg, Germany | Switzerland (Beznau-1) |
| CH003 | DEX33 | Schauinsland/Freiburg, Germany | Switzerland (Goesgen) |
| CH004 | DEX33 | Schauinsland/Freiburg, Germany | Switzerland (Leibstadt) |
| UA005 | SEX63 | Stockholm, Sweden | Ukraine (Rovno-1) |
| GB003 | SEX63 | Stockholm, Sweden | United Kingdom (Heysham A1) |
| US007 | USX72 | Melbourne, FL, United States of America | United States (Browns Ferry-1) |
| US007 | USX75 | Charlottesville, VA, United States of America | United States (Browns Ferry-1) |
| US010 | USX72 | Melbourne, FL, United States of America | United States (Brunswick-1) |
| US036 | USX75 | Charlottesville, VA, United States of America | United States (Grand Gulf) |
| US040 | CAX17 | St. John's N.L., Canada | United States (Hope Creek ) |
| US040 | USX72 | Melbourne, FL, United States of America | United States (Hope Creek ) |
| US040 | USX75 | Charlottesville, VA, United States of America | United States (Hope Creek ) |
| **US041** | **CAX17** | **St. John's N.L., Canada** | **United States (Lasalle County-1)*** |
| **US041** | **ISX34** | **Reykjavik, Iceland** | **United States (Lasalle County-1)*** |
| **US041** | **PTX53** | **Ponta Delgada, Sao Miguel, Azores, Portugal** | **United States (Lasalle County-1)*** |
| **US041** | **USX72** | **Melbourne, FL, United States of America** | **United States (Lasalle County-1)*** |
| **US041** | **USX74** | **Ashland, KS, United States of America** | **United States (Lasalle County-1)*** |
| **US041** | **USX75** | **Charlottesville, VA, United States of America** | **United States (Lasalle County-1)*** |
| US043 | USX75 | Charlottesville, VA, United States of America | United States (Limerick-1) |
| US052 | USX75 | Charlottesville, VA, United States of America | United States (North Anna-1) |
| US054 | USX75 | Charlottesville, VA, United States of America | United States (Oconee-1) |
| US062 | USX75 | Charlottesville, VA, United States of America | United States (Perry) |
| US071 | USX72 | Melbourne, FL, United States of America | United States (Saint Lucie-1) |

*Stack release data is being shared from reactors in bold

## Discussions with reactors

To better understand radioxenon releases from different types of NPP facilities, PNNL has begun engaging with NPP technical staff from faculties to learn more about xenon release profiles and magnitudes for different types of NPP operations. The goal of these collaborative efforts is to gather information on the types of radioxenon monitoring equipment used to measure these facility emissions (continuous monitoring, grab samples, etc.), how often releases occur, what typical changes in emissions levels look like at different facilities, and causes of off normal release events. In addition, example data will be collected from willing collaborators on a voluntary basis to be shared on staxdata.net. Data received from these facilities will be evaluated to provide valuable insights into the production and emissions of radionuclides from NPPs.

### Current Progress

STAX has been receiving data transferred to staxdata.net from the Forsmark reactor in Sweden and the Hartlepool reactor in the UK previously. As part of STAX-2, PNNL has been leveraging contacts in the WOSMIP community and networking with NPP technical staff to build relationships within the NPP community. This has led technical discussions with several NPP facilities and has resulted in a collaboration with the Illinois Emergency Management Agency (IEMA) to share release data from NPP facilities in Illinois where they perform monitoring. Table 3 lists the current STAX and STAX-2 collaborators currently sharing data to staxdata.net.

Table 3. Current STAX collaborators who are sharing data to staxdata.net.

| Facility type | Country | Facility |
|---|---|---|
| MIP | Belgium | The National Institute for Radioelements (IRE) |
| MIP | Australia | Australia Nuclear Science and Technology Organisation (ANSTO) |
| MIP | Argentina | National Atomic Energy Commission (CNEA) |
| MIP | United States | Niowave |
| MIP | United States | SHINE |
| NPP | England | Hartlepool |
| NPP | Sweden | Forsmark |
| NPP | United States | Illinois Emergency Management Agency (IEMA) |

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