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Developing a Deployable, Flexible Radionuclide Analysis Pipeline

Matthew A. Goodwin[1], Rich Britton[1], Ashley V. Davies[1]
1. *AWE Plc, Aldermaston, Reading, RG7 4PR, UK*

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Abstract

The UK NDC Radionuclide (RN) analysis pipeline has been designed to be collapsed and rebuilt as required. Whilst the current pipeline is built across a number of high-performance computing systems at AWE Aldermaston, there was a requirement to produce a flexible system that can be deployed at short notice. Taking inspiration from the IDC's NDC-in-a-Box (NIAB), installation code and documentation has been compiled such that the system can be installed on a virtual machine, running a variety of operating systems. This opens up the radionuclide analysis pipeline capability for use externally, on a contained system. All of the radionuclide analysis and review tools (including BeGAX, GRINDER & GBL15 GUI) are accessible from within the virtual machine and the performance is similar to that of the UK NDC integrated solution.

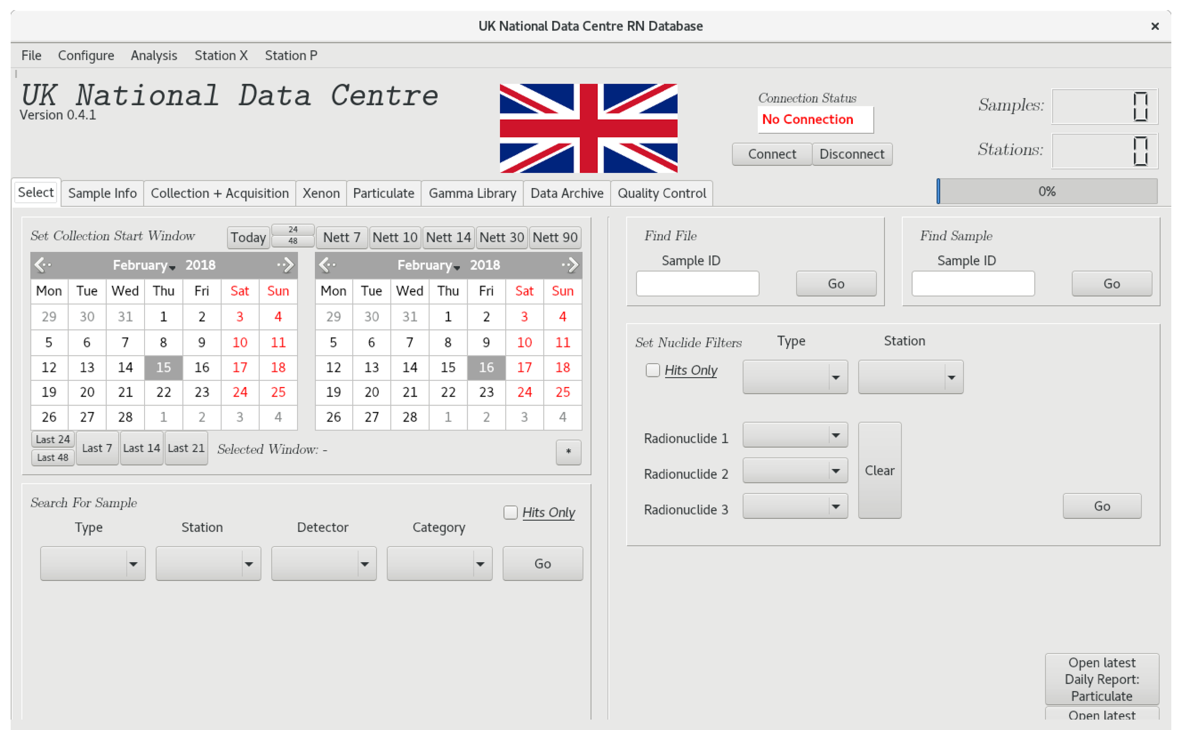


Figure 1. UK NDC Database Interface, used for displaying radionuclide data and RN-ATM fusion.

Motivation

Analysing radionuclide data from the International Monitoring System is not a straightforward task and is resource intensive. It takes a team of analysts at the IDC and a network of developers to maintain the IDC radionuclide analysis pipelines.

GBL15 scientists operating the UK NDC(RN) are unable to manually assess all spectra collected on the IMS, hence automated processing is required to be able to effectively monitor the network for Treaty relevant *events*. In order to do this, processing pipelines have been established, taking inspiration from IDC data processing.

By producing an in-house solution for IMS radionuclide analysis, and furthermore event analysis, any form of 'black box' code is avoided and can be fully understood, however it is a much more lengthy and involved undertaking.

With the development of the Mirion Genie U-SDK (Universal Software Development Kit), it has been possible to construct pure Python analysis codes for gamma spectrum analysis, applicable for both particulate and radioxenon (HPGe) measurements.

The results from the UK NDC analysis pipelines are used to actively search for radionuclide events and direct event analysis. Current efforts include fine-tuning and performance optimisation of the code.

A talk will be given at S&T 2019, discussing the analysis of *events* identified at JPX38, Takasaki (Japan):
UK NDC Analysis of Radionuclide Events near to North Korea (Friday 28th June)

Overview of RN Pipeline

The Radionuclide Pipeline is designed to run every day. It begins by downloading the last 3 days of SPHD, GASBK, QCPHD data from all stations (allowing for data that may have been backfilled) and validates each file. The raw data is then packaged and sent through one of three analysis codes:

- GGAP: Genie Gamma Analysis for Particulate
- GGAX: Genie Gamma Analysis for radioxenon (SPALAX)
- BeGAX: Beta-Gamma Analysis for radioxenon (SAUNA)

Each analysis takes the data that is yet to be analysed and performs an IMS specific method in order to calculate activity concentrations and other applicable radiometric values, before inserting the results into the NDC database. The radiometric analysis results are then passed through a series of algorithms in order to categorise the results such that any detections of interest to the NDC are flagged appropriately.

The database contains data from the PHD file (without duplicating what is already recorded), as well as any appropriate meta-analysis.

Table 1. UK NDC ATM Pipeline emitters table. Facilities compiled from [1]

Emitter ID	Emitter Name	Emitter Desc	Latitude	Longitude	Status
1	SA1	Pelindaba SA (NTP)	-25.480	27.560	1
2	BE1	IRE Belgium	50.270	4.320	1
3	PK1	PINSTEC Pakistan	33.390	73.150	1
4	AU1	ANSTO Australia	-34.050	150.980	1
5	CA1	Nordion Canada	45.340	-75.910	1
6	AR1	CNEA Argentina	-34.820	-58.580	1
7	CN1	HFETR China	29.750	103.670	1
8	RU1	Karpov Institute Russia	55.750	37.650	1
9	DPRK	DPRK Test Site	41.290	129.110	1
10	CARR	CARR China (RIAR)	39.440	116.030	1
11	IBAM	Marrinckrodt US	38.660	-90.190	1
12	NK1	DPRK reactor Yongbyon	39.790	125.750	1
13	SE1	Forsmark Sweden	60.403	18.167	1
14	JP1	Ikata Japan	33.490	132.310	1
15	JP2	Sendai Japan	31.820	130.190	1
16	JP3	Takahama Japan	35.520	135.500	1
17	JP4	Tomari Japan	43.040	140.510	1
18	JP5	Oma Japan	41.510	140.910	1
19	CH1	Hongyanhe China	39.790	121.480	0
20	CH2	Tianwan China	34.690	119.460	0
21	CH3	Qinshan China	30.430	120.950	0
22	SK1	Hanbit South Korea	35.410	126.420	0
23	SK2	Wolseong South Korea	35.710	129.480	0
24	SK3	Hanul South Korea	37.090	129.380	0
25	SK4	Kori South Korea	35.320	129.290	0

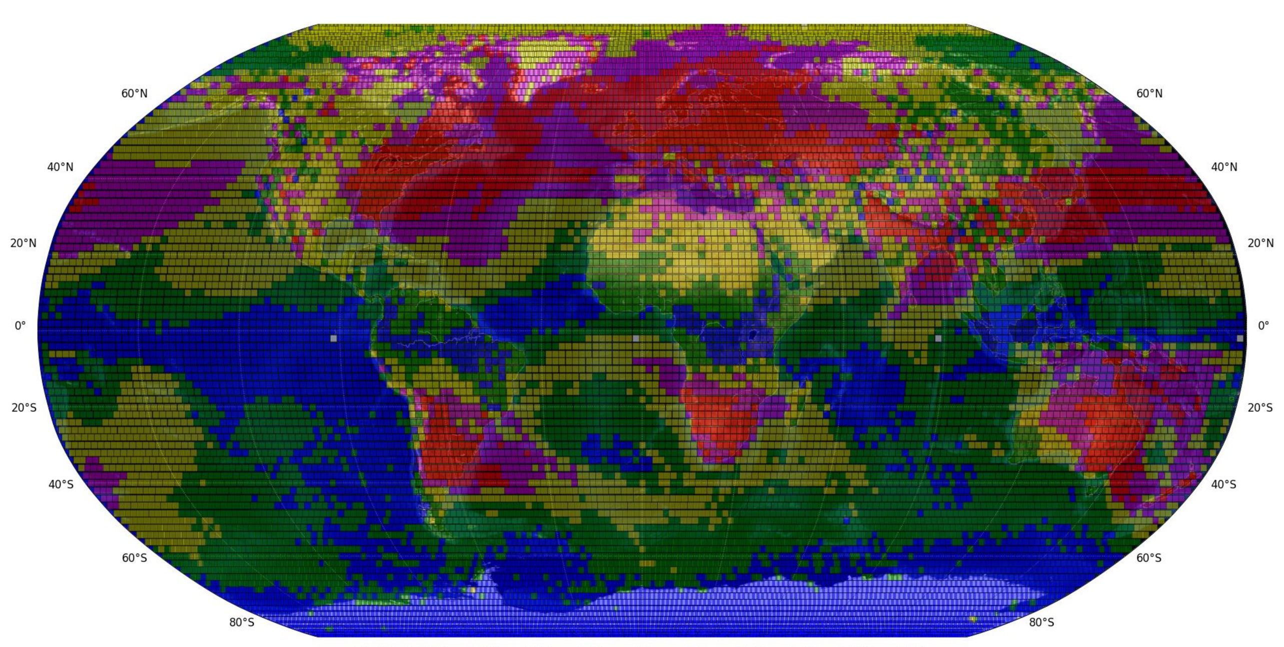


Figure 2. ATM Pipeline world sensitivity. Simulated raw contributions have been evaluated without stack data or estimates. Red areas show a higher sensitivity to possible radioxenon emissions

Overview of ATM Pipeline

The ATM Pipeline manages forward atmospheric modelling simulations for a number of facilities or sites of interest that may be contributing to the radioxenon background. Four emissions are simulated for each location every day and the contributions to each of the IMS RN stations are calculated.

All contributions are assessed and the results inserted into a MySQL database known as ATM_STATION. Detections identified in the RN Pipeline can be combined with simulated contributions to point to possible emitters. The ATM Pipeline is processor and storage intensive and can not be easily deployed, but a prototype portable database has been developed which could allow the sharing of identified contributions.

Associated tools

A number of tools have been developed to aid the interpretation of IMS data and results of the radionuclide and ATM pipelines.

- **GRINDER**: Gamma Review Interface for Detection of Radionuclides
  Graphical interface to analyse gamma spectral data from the data file and write results to the database.
- **BeGAX**: Beta-Gamma data can be reviewed using the BeGAX GUI.
- **RASCA**: Radioxenon Station Contribution Analysis – can be used to visualise the contributions to IMS stations from the simulated emissions.
- **NuDIC**: Nuclear Decay Iterative Calculator, designed to simulate decay and ingrowth of isotopes over time, based on fission yield data

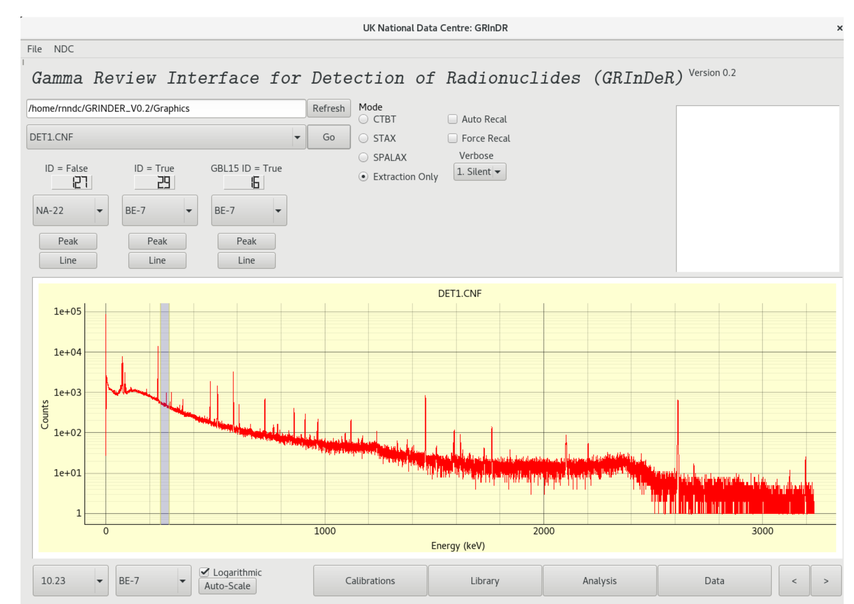


Figure 3. GRINDER main window, showing the interactive gamma spectrum view.

Deployment to NZL12

During December 2018, UK NDC scientists visited the New Zealand Radionuclide Laboratory to discuss developments to the New Zealand NDC capacity and to deliberate over lessons learnt at the UK NDC. NZL colleagues were provided with a prototype copy of the RN Pipeline and were able to operate it on a number of systems.

Since deployment, the UK NDC has provided an update to improve the speed of database queries on the virtual machine.

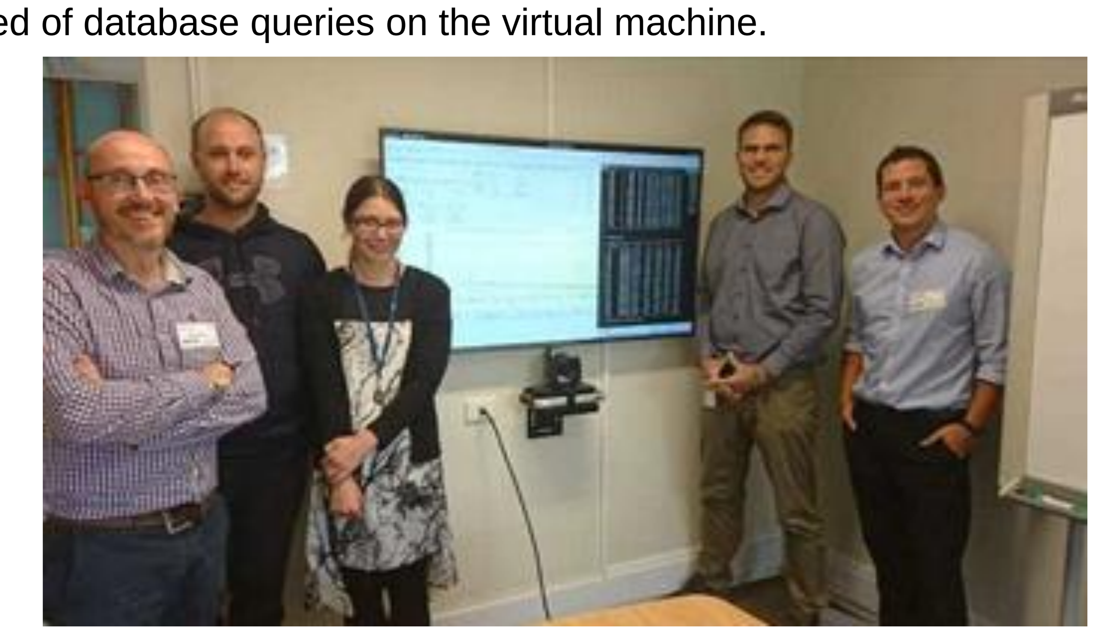
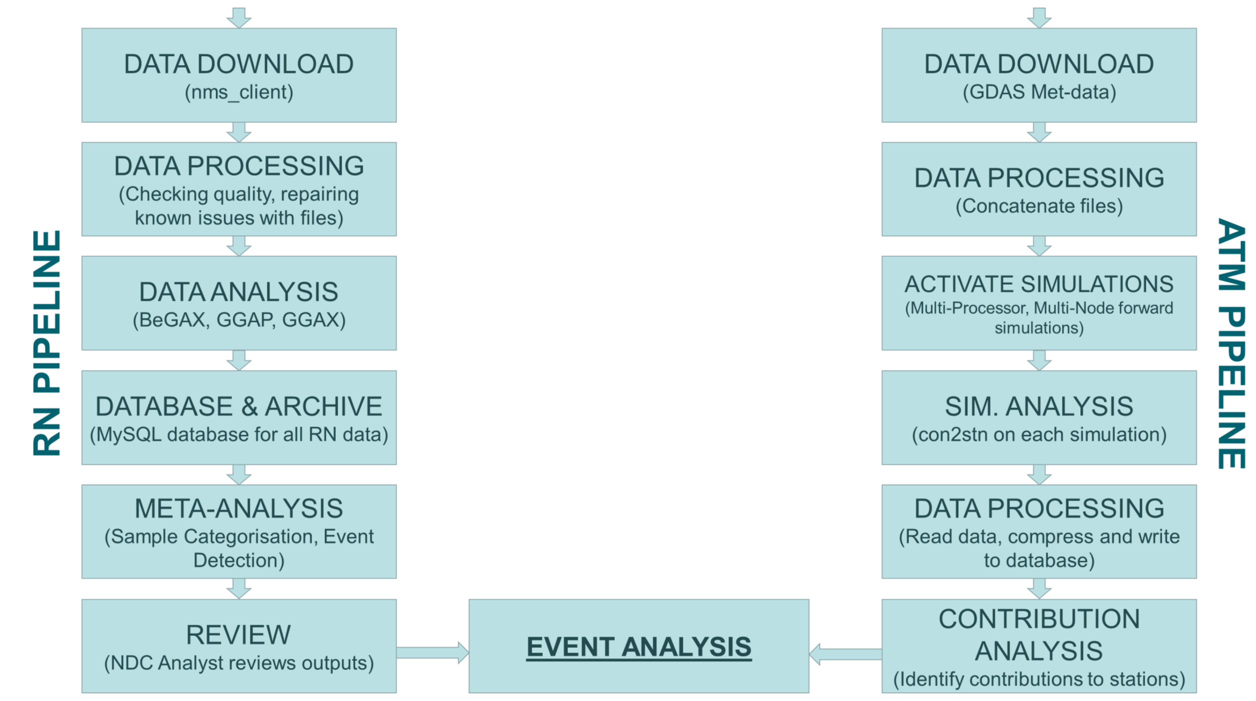


Figure 4. UK NDC scientists visit New Zealand NDC in December 2018

Data Fusion & Event Analysis



The objective of this work is to provide the data, results and tools required for interpretation of radionuclide detections, such that IMS *events* can be investigated and reported on. The RN and ATM Pipelines are combined / fused in order to associate detections with simulated emissions, or exclude sources where appropriate. Currently *events* are defined by detections that are of interest to the UK NDC.

Other UK NDC Pipelines

A number of other pipelines are in operation, including our own IDC Pipeline (NDC_IDC), a c++ code designed to parse data from RLR files and populate a database in parallel with the UK NDC database. This allows for continuous comparison between UK automatic RN results and IDC reviewed results. Other pipelines include NDC_EMAIL, used for processing data feeds arriving via email; NDC_SAUNA, used for processing data from the GBL15 SAUNA system when it is operating in IMS-mode; and NDC_NIMS, which is designed to process data from non-IMS systems.

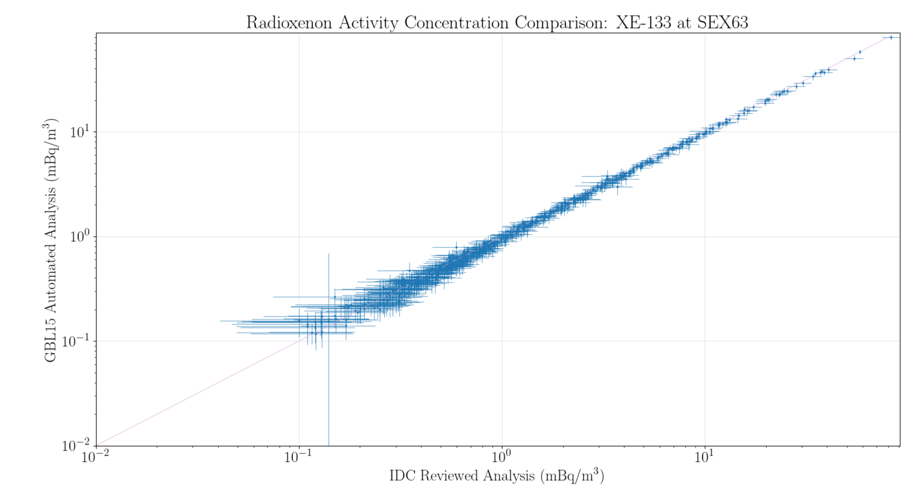


Figure 5. Comparison of UK NDC automated radioxenon analysis (using BeGAX), and IDC reviewed data, for SEX63

Ongoing Development

Pipeline 2.0 is currently being developed and the majority of current work is in refining the multi-processing code for particulate analysis. With the exception of data download, particulate analysis was the most time consuming part of the pipeline and is by far the most process-heavy. Significant effort has been put into the improved performance of this module.

Moving to a fully Python-based code has made it easier to build a single software package to analyse IMS data. The code is held in a git repository and can be installed with a `setup.py` script, making it increasingly easy to rebuild the system at other locations.

UK NDC developers continue to advance the analysis codes, with the aim of learning from RN event analysis experiences.

[1] IAEA Report NEA/SEN/HLGMR/(2017)