

Artificial Intelligence for Radiation Monitoring of Large-Scale Projects

From thousands of environmental samples to maps and reports — putting AI to work across the workflow

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Radiation monitoring at scale

The activities of natural and artificial radionuclides are measured in **environmental samples** — for the large-scale projects that must pass a radiation safety assessment before they are built.

Where

- Nuclear power plant sites
- Mining, metallurgy, oil & gas
- Industrial & energy facilities

What

- ^{226}Ra , ^{232}Th , ^{40}K , ^{137}Cs , ^7Be
- Soil, water, sediments, plants, food, building materials

The recurring bottleneck

Each project produces **hundreds to thousands of gamma spectra** — every one must be analysed. Manual, one-by-one processing does not scale.

Large-scale projects demand many analyses

Radiological surveys cover huge areas; monitoring must be complete before construction can start.

Project	Location	Area	Samples & meas.
Nuclear Power Plant site	Jizzakh	30 km zone	~1 900+
Gas-to-liquids plant	Kashkadarya	150 ha	~2 500+
Uranium in-situ leaching	Navoi	38 km ²	~89
Metallurgical plant	Jizzakh	20 km ²	~61
Surgaly site	Navoi	18 km ²	~468
Coal-fired power plant	Samarkand	81 ha	~55

Thousands of spectra per campaign $\Rightarrow$ we need high-throughput, low-cost measurement.

The problem: scintillation vs. HPGe

Nal(Tl)

Room temperature

> 10× cheaper

Higher efficiency

Large crystals

Easy to operate

Poor resolution

HPGe

Liquid nitrogen (77 K)

Very expensive

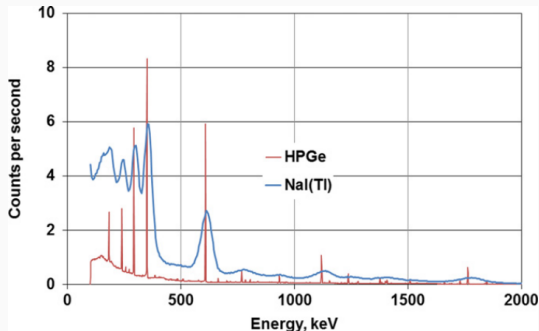
Lower efficiency

Limited volumes

Complex

Excellent resolution

Scintillation is the only affordable choice at scale — but its low energy resolution blurs the peaks.



^{226}Ra source measured with NaI(Tl) (broad) and HPGe (sharp).

Our solution: the decomposition technique

Approximate, then subtract.

The sample spectrum S is matched with standard-source spectra and stripped component by component ($S_0 \rightarrow S_4$).

Surface-soil example

$N_S = 2.63 \times 10^6$, $m = 1.3$ kg

^{226}Ra 32 (3)

^{232}Th 28 (3)

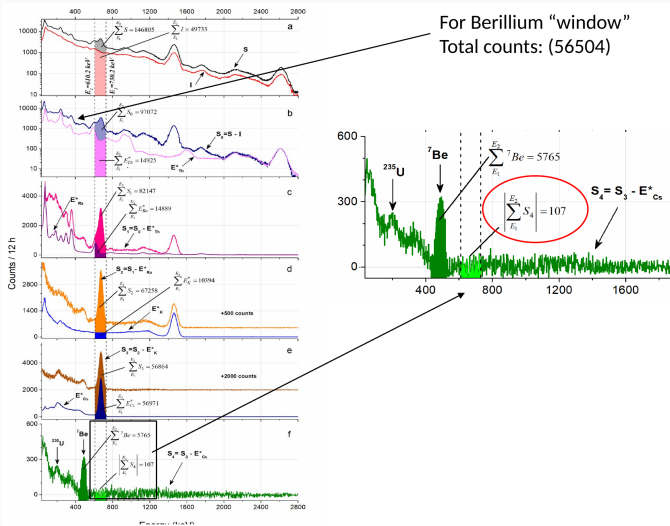
^{40}K 604 (50)

^{137}Cs 53 (4)

^7Be 32 (3)

^{235}U < 5.3 Bq/kg

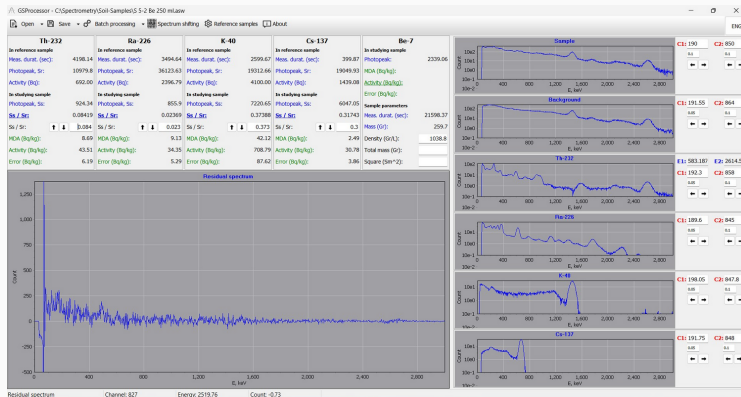
Even ^7Be — below background
— is recovered.



$S \rightarrow S_4$: components stripped one by one; even ^7Be (panel f) is recovered.

From technique to software: GSProcessor

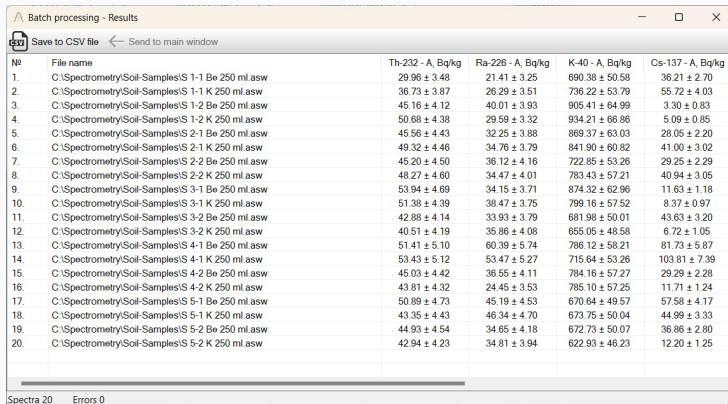
GSProcessor — developed by our team — turns the decomposition technique into a working tool (^{232}Th , ^{226}Ra , ^{40}K , ^{137}Cs and low-intensity ^7Be ; density and self-absorption automatic).



Manual mode — inspect and fine-tune one decomposition in detail.

GSProcessor: batch processing

The real gain at scale: point at a folder and process **hundreds of spectra at once** — no manual alignment needed.



Batch processing - Results

Save to CSV file Send to main window

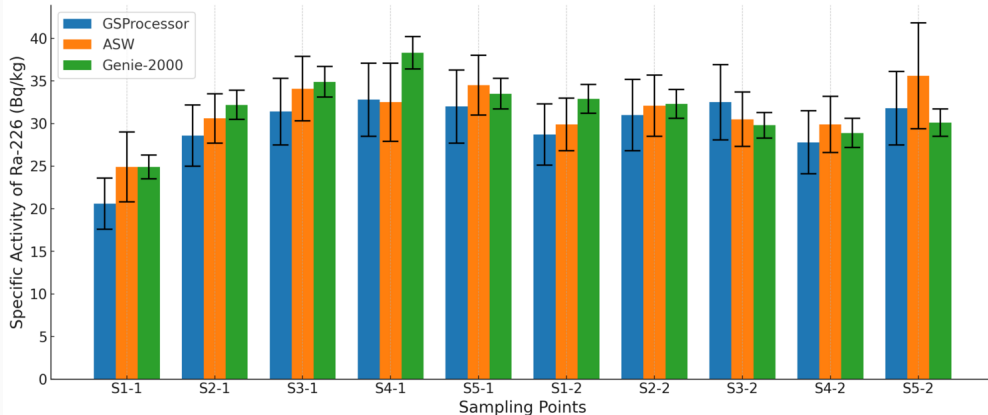
Nº	File name	Th-232 - A, Bq/kg	Ra-226 - A, Bq/kg	K-40 - A, Bq/kg	Cs-137 - A, Bq/kg
1.	C:\Spectrometry\Soil-Samples\S 1-1 Be 250 ml.asw	29.96 ± 3.48	21.41 ± 3.25	690.38 ± 50.58	36.21 ± 2.70
2.	C:\Spectrometry\Soil-Samples\S 1-1 K 250 ml.asw	36.73 ± 3.87	26.29 ± 3.51	736.22 ± 53.79	55.72 ± 4.03
3.	C:\Spectrometry\Soil-Samples\S 1-2 Be 250 ml.asw	45.16 ± 4.12	40.01 ± 3.93	905.41 ± 64.99	3.30 ± 0.83
4.	C:\Spectrometry\Soil-Samples\S 1-2 K 250 ml.asw	50.68 ± 4.38	29.59 ± 3.32	934.21 ± 66.86	5.09 ± 0.85
5.	C:\Spectrometry\Soil-Samples\S 2-1 Be 250 ml.asw	45.56 ± 4.43	32.25 ± 3.88	869.37 ± 63.03	28.05 ± 2.20
6.	C:\Spectrometry\Soil-Samples\S 2-1 K 250 ml.asw	49.32 ± 4.46	34.76 ± 3.79	841.90 ± 60.82	41.00 ± 3.02
7.	C:\Spectrometry\Soil-Samples\S 2-2 Be 250 ml.asw	45.20 ± 4.50	36.12 ± 4.16	722.85 ± 53.26	29.25 ± 2.29
8.	C:\Spectrometry\Soil-Samples\S 2-2 K 250 ml.asw	48.27 ± 4.60	34.47 ± 4.01	783.43 ± 57.21	40.94 ± 3.05
9.	C:\Spectrometry\Soil-Samples\S 3-1 Be 250 ml.asw	53.94 ± 4.69	34.15 ± 3.71	874.32 ± 62.96	11.63 ± 1.18
10.	C:\Spectrometry\Soil-Samples\S 3-1 K 250 ml.asw	51.38 ± 4.39	38.47 ± 3.75	799.16 ± 57.52	8.37 ± 0.97
11.	C:\Spectrometry\Soil-Samples\S 3-2 Be 250 ml.asw	42.88 ± 4.14	33.93 ± 3.79	681.98 ± 50.01	43.63 ± 3.20
12.	C:\Spectrometry\Soil-Samples\S 3-2 K 250 ml.asw	40.51 ± 4.19	35.86 ± 4.08	655.05 ± 48.58	6.72 ± 1.05
13.	C:\Spectrometry\Soil-Samples\S 4-1 Be 250 ml.asw	51.41 ± 5.10	60.39 ± 5.74	786.12 ± 58.21	81.73 ± 5.87
14.	C:\Spectrometry\Soil-Samples\S 4-1 K 250 ml.asw	53.43 ± 5.12	53.47 ± 5.27	715.64 ± 53.26	103.81 ± 7.39
15.	C:\Spectrometry\Soil-Samples\S 4-2 Be 250 ml.asw	45.03 ± 4.42	36.55 ± 4.11	784.16 ± 57.27	29.29 ± 2.28
16.	C:\Spectrometry\Soil-Samples\S 4-2 K 250 ml.asw	43.81 ± 4.32	24.45 ± 3.53	785.10 ± 57.25	11.71 ± 1.24
17.	C:\Spectrometry\Soil-Samples\S 5-1 Be 250 ml.asw	50.89 ± 4.73	45.19 ± 4.53	670.64 ± 49.57	57.58 ± 4.17
18.	C:\Spectrometry\Soil-Samples\S 5-1 K 250 ml.asw	43.35 ± 4.43	46.34 ± 4.70	673.75 ± 50.04	44.99 ± 3.33
19.	C:\Spectrometry\Soil-Samples\S 5-2 Be 250 ml.asw	44.93 ± 4.54	34.65 ± 4.18	672.73 ± 50.07	36.86 ± 2.80
20.	C:\Spectrometry\Soil-Samples\S 5-2 K 250 ml.asw	42.94 ± 4.23	34.81 ± 3.94	622.93 ± 46.23	12.20 ± 1.25

Spectra 20 Errors 0

Batch mode — a full sample set analysed in one run; problematic files can be sent to the main window.

Results: primordial radionuclides

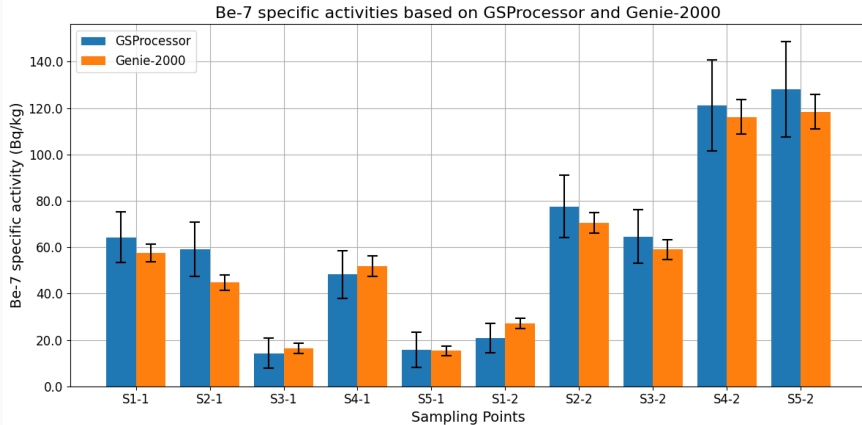
Cheap NaI(Tl) + GSProcessor reproduces expensive HPGe and commercial software.



^{226}Ra in deep soil layers: GSProcessor vs. ASW vs. Genie-2000. ^{232}Th , ^{40}K and ^{137}Cs agree just as closely.

Results: cosmogenic ^7Be

The hardest case — a peak that sits **below the background level** — and GSProcessor still recovers it.

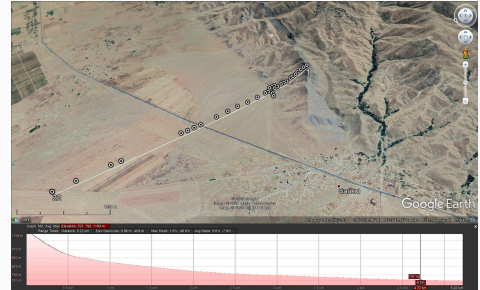


^7Be specific activities across sampling points: GSProcessor vs. Genie-2000 (HPGe).

Applications



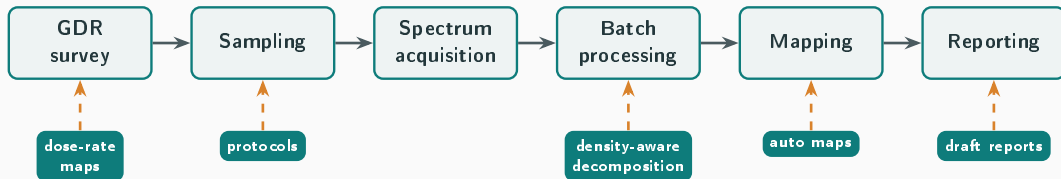
Baseline survey around the NPP construction site (Nuratau region).



Soil redistribution from ^{137}Cs / ^7Be along a slope transect.

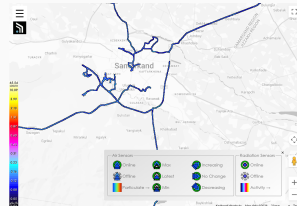
Used for: baseline radiation of NPP & industrial sites • soil erosion & sedimentation • safety of building materials.

Where AI fits: the whole field-to-report pipeline



GDR: Safecast bGeigie nano.

We start each survey with a **gamma dose-rate (GDR) walk** (bGeigie nano, GPS every 5 s), then sampling and lab spectrometry. AI can assist at **every** stage.



Gamma dose rate map.

Problem. Data quality is decided in the field. Depth, mass, geometry, density and labelling must be consistent across remote sites and many team members.

How I plan to use AI

- Generate **clear, step-by-step sampling instructions** for our team members — tailored to each object (soil layer, water, building material).
- Interactive checklists that flag missing metadata on the spot.
- Draft training material so everyone samples the same way.

Payoff

Consistent geometry and density — exactly the inputs the decomposition method relies on.

Compensating for low resolution is an **algorithmic** problem — and the tools are built **with AI, without hand-writing code**.

- **Software:** AI-assisted development, refactoring and testing of GSProcessor's batch pipeline.
- **Methods:** explore decomposition strategies for **density and self-absorption**; extend to new nuclides (^{131}I , ^{134}Cs , ^{60}Co , ^{54}Mn).
- **Quality control:** automatically flag “problematic” spectra for a closer look; learn from HPGe-validated results.

Built with AI, no coding: an interactive prototype



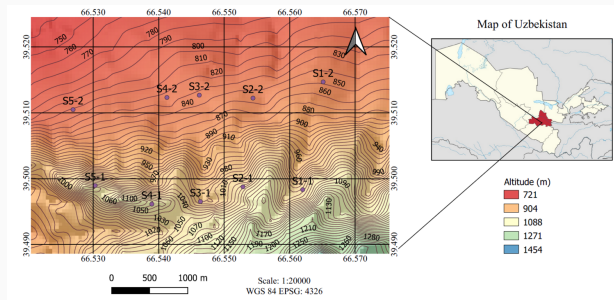
Interactive spectrum-processor prototype, built in Claude.

A working, browser-based γ -**spectrum processor** — acquisition, smoothing, background, calibration, peak fitting, ROI, isotope ID and activity — created **by describing it**, not coding it.

- Rapid prototyping of the analysis workflow
- A teaching & demonstration tool
- A sketchpad for the next GSProcessor features

Mapping

- Turn georeferenced results (KML, coordinates) into **activity and dose-rate maps** automatically.
- Interpolate, highlight hotspots, keep maps in sync as samples arrive.



From sample points to a finished activity map.

Reporting

- Draft **monitoring reports** from processed data — tables, figures and standards-compliant text.

What I already do: AI in teaching

Alongside research, I use AI **today** to enhance the teaching process.

- Prepare and adapt **lecture material** and problem sets in nuclear physics and radiation measurement.
- Build **worked examples** at the right level for each student.
- Generate quizzes and feedback; translate material for a multilingual class.
- Help students learn the tools the research pipeline needs: spectrum analysis and simple software.

Now

- AI in teaching
- AI-assisted development of GSProcessor
- Interactive prototypes

Near term

- AI-generated sampling protocols
- Automatic QC of batch results
- Extend to ^{131}I , ^{134}Cs , ^{60}Co , ^{54}Mn

Cheap scintillation detectors + smart AI processing = radiation monitoring that scales.

Simple wins to add

- Auto-generate maps from coordinates
- Draft reports & translate them
- Organise and archive datasets
- Summarise papers & standards
- Digitise old paper records
- A lab assistant for procedures

Thank you!



This presentation was created using AI.

The author has never coded.