Neutron activation analysis in life science

By

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The Sector of Neutron Activation Analysis and Applied Research

Outlines:

- introduction
- Neutron Activation Analysis (NAA)
- Fundamentals of NAA
- Types of NAA
- Applications
- Advantages and limitations
- REGATA

- Experimental work
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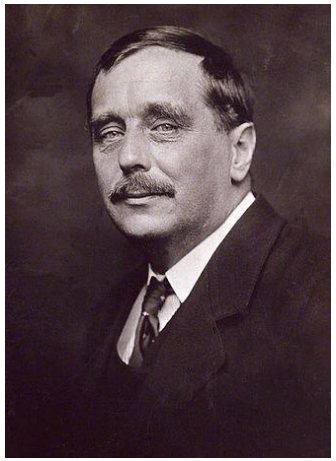
  - Sample preparation
  - Irradiation of samples
  - Measurements of samples
  - Spectra processing
  - Calculation of concentration
- Joint projects with Egypt
- Gained experience
- Social program

History and discovery of NAA

➢The discovery of artificial radioactivity was forecast by **Herbert George Wells** (1914) to take place in 1933. **Frederic and Irene Joliot- Curie** almost obliged Wells: two weeks into 1934 they produced radioactive ^{30}P by bombarding aluminum with alpha particles.



H. G. Wells (1866-1946)

➢In Rome, the theoretician **Enrico Fermi** recognized that artificial radionuclides could be produced more efficiently with neutrons than alphas since neutrons striking a nucleus have no coulombic barrier too vercome. He was awarded Nobel Prize.

Enrico Fermi (1901–1954)

Neutron Activation Analysis (NAA)

- NAA is a method for determination of elements based on conversion stable nuclei to other, mostly radioactive nuclei via nuclear reactions and measurements of reaction products [Bode, 1996]
- NAA was discovered in 1936 by G. Hevesy (Hungary) and H. Levi (Denmark)

Types of NAA

- Destructive:

(radiochemical) – the resulting radioactive sample is chemically decomposed, and the elements are chemically separated.

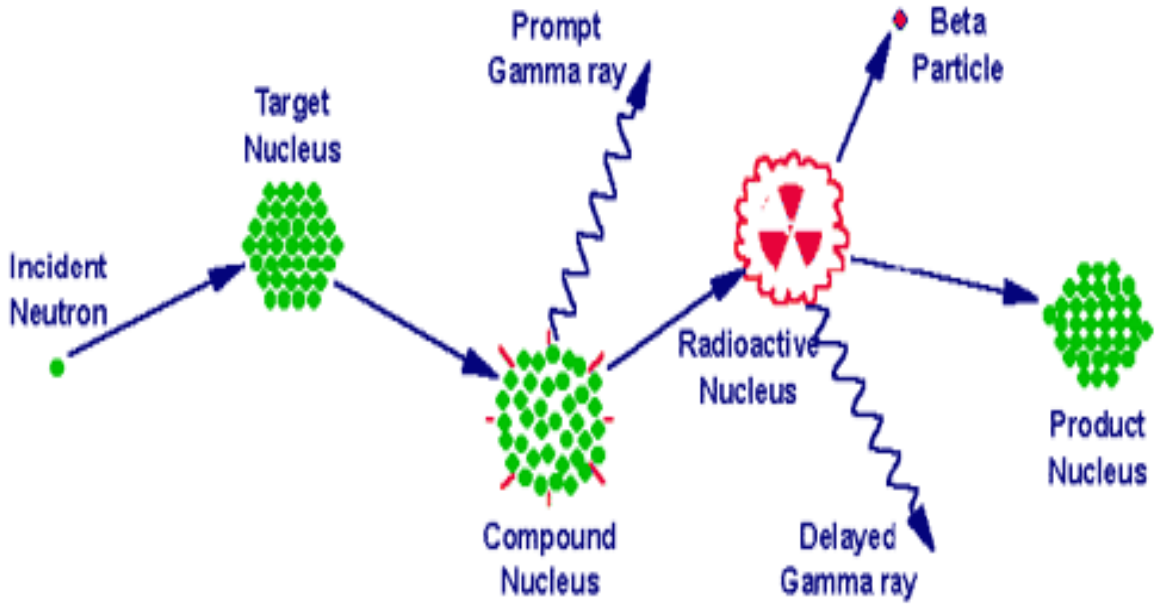
- Non-destructive:

(instrumental) – sample is kept intact and the radionuclides are determined, taking advantage of the differences in decay rates via measurements at different decay intervals.

INAA procedure is characterized by :

- **Activation via irradiation with neutron source (in our case, it is the reactor IBR-2)**
- **Measurement of gamma radiation after one or more decay times**
- **Interpretation of the resulting gamma ray spectra in terms of radionuclides, associated elements and their concentration**
- **Multi-element analytical technique**
- **The chemical form and physical state of the elements are not influenced by the activation and decay process**

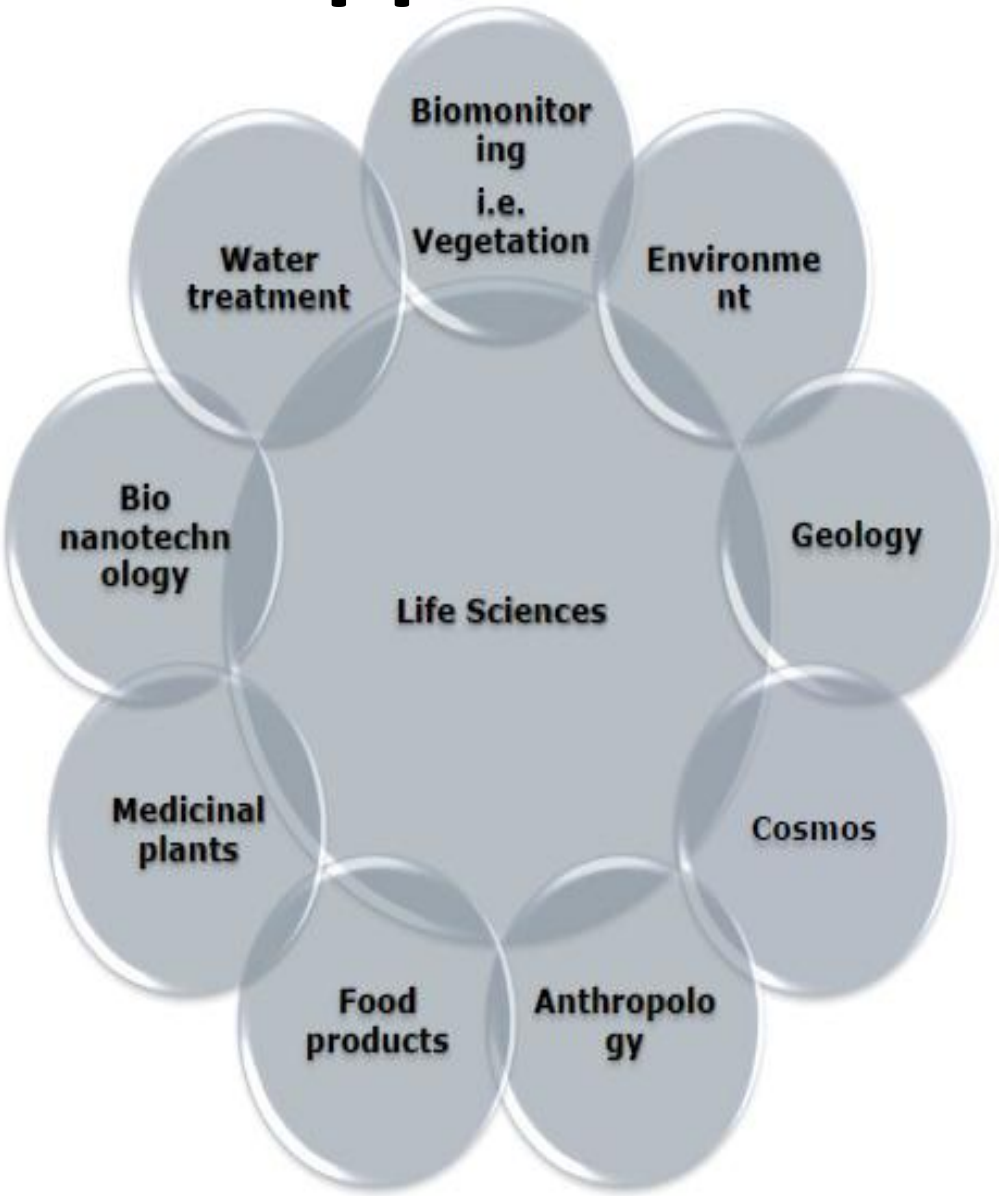
Fundamentals of NAA



When a neutron interacts with the target nucleus via a non-elastic collision, a compound nucleus forms in an excited state. The excitation energy of the compound nucleus is due to the binding energy of the neutron with the nucleus.
The compound nucleus will almost instantaneously de-excite into a more stable configuration through emission of one or more characteristic prompt gamma rays.
In many cases, this new configuration yields a radioactive nucleus which also de-excites (or decays) by emission of one or more characteristic delayed gamma rays, but at a much slower rate according to the unique half-life of the radioactive nucleus. Depending upon the particular radioactive species, half-lives can range from fractions of a second to several years.

The radioactive emission and radioactive decay paths for each element are well known and using this information, it is possible to study spectra of emissions of the radioactive sample, and determine the concentrations of the elements within it.

Applications



Advantages

- Wide possibilities of applications
- Non destructive analysis
- Multi-element analysis
- Sensitivity to parts-per-billion for specific elements
- Customizable analysis

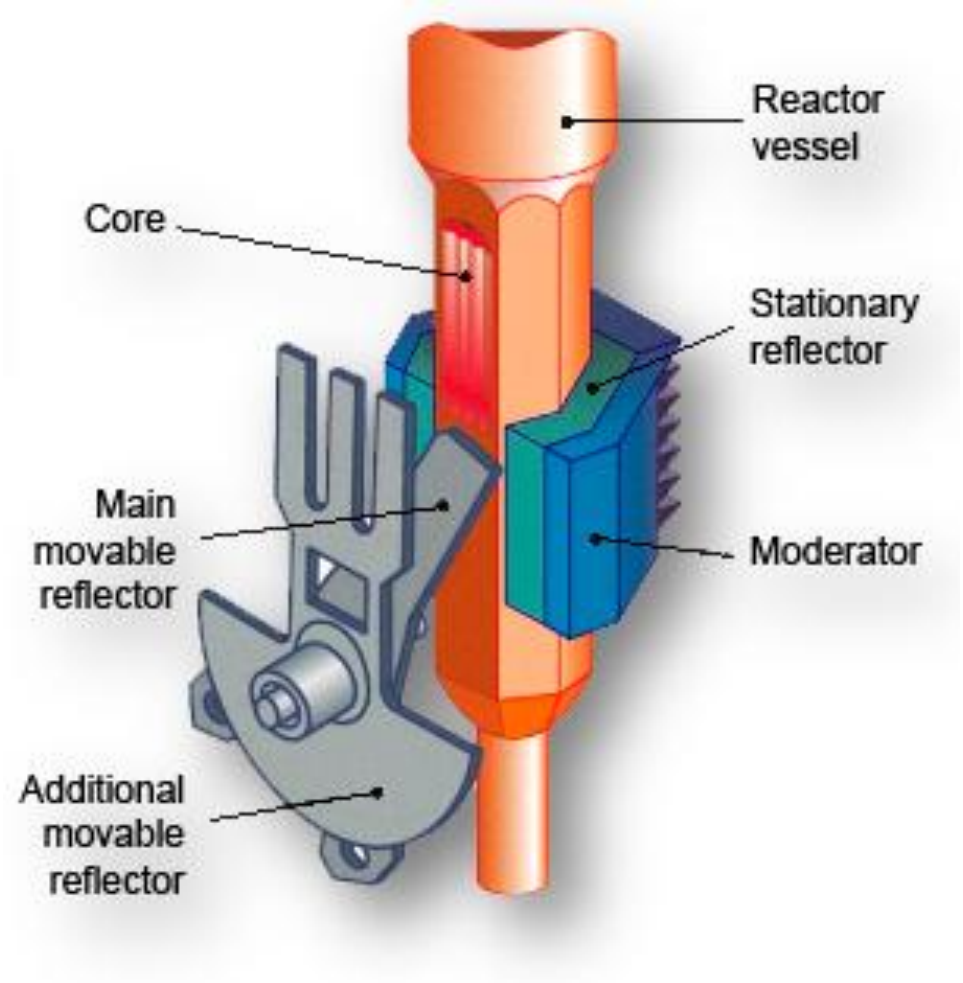
Limitations

- Need for nuclear reactor
- Work with radioactive materials
- Time of analysis
- Sample preference

IBR – 2 Reactor in JINR

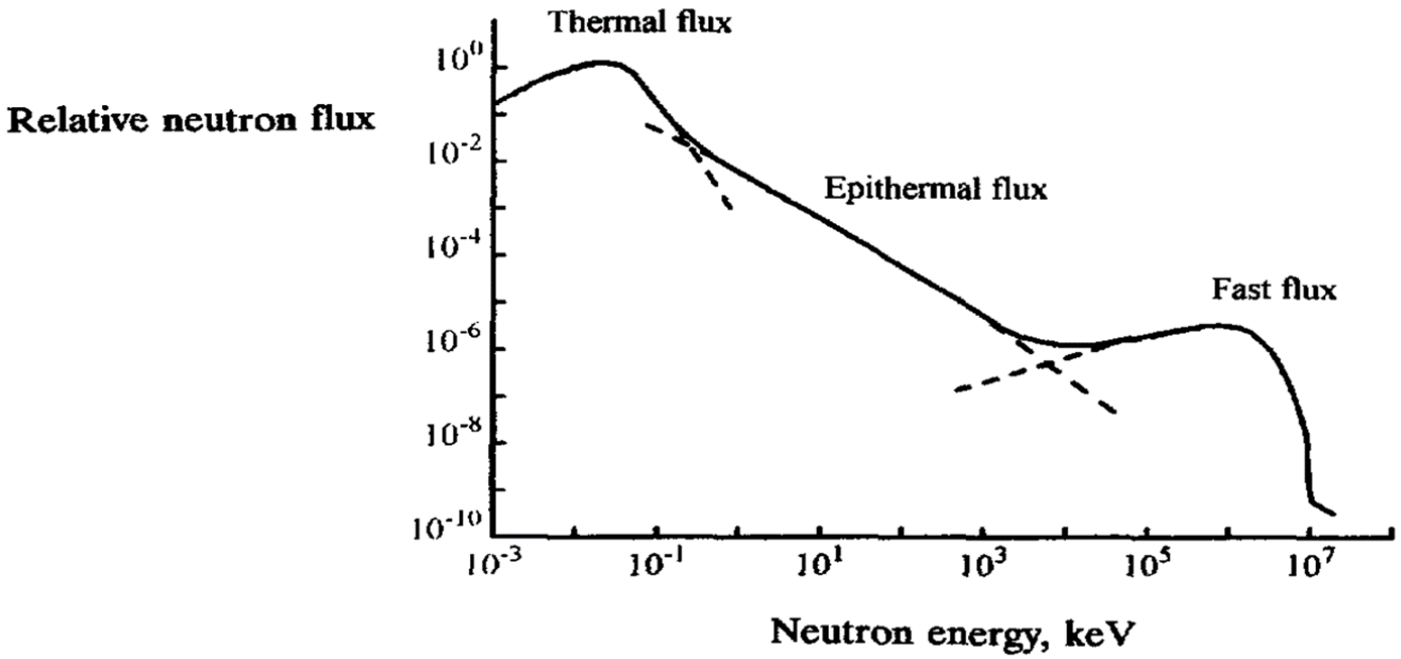
Parameters of IBR – 2:

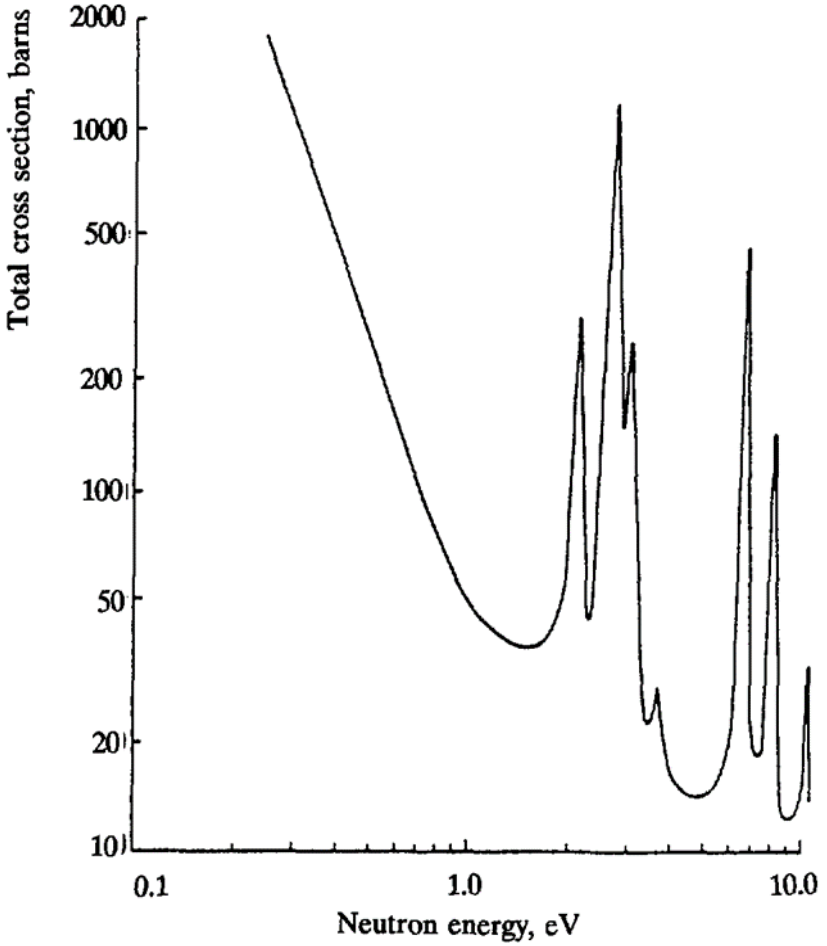
- Average power 2 MW
- PuO_2 fuel
- Rotation rate, rev/min:
  main reflector 600
  auxiliary reflector 300
- Neutron density flux 10^{16} $n \cdot m^{-2} \cdot s^{-1}$



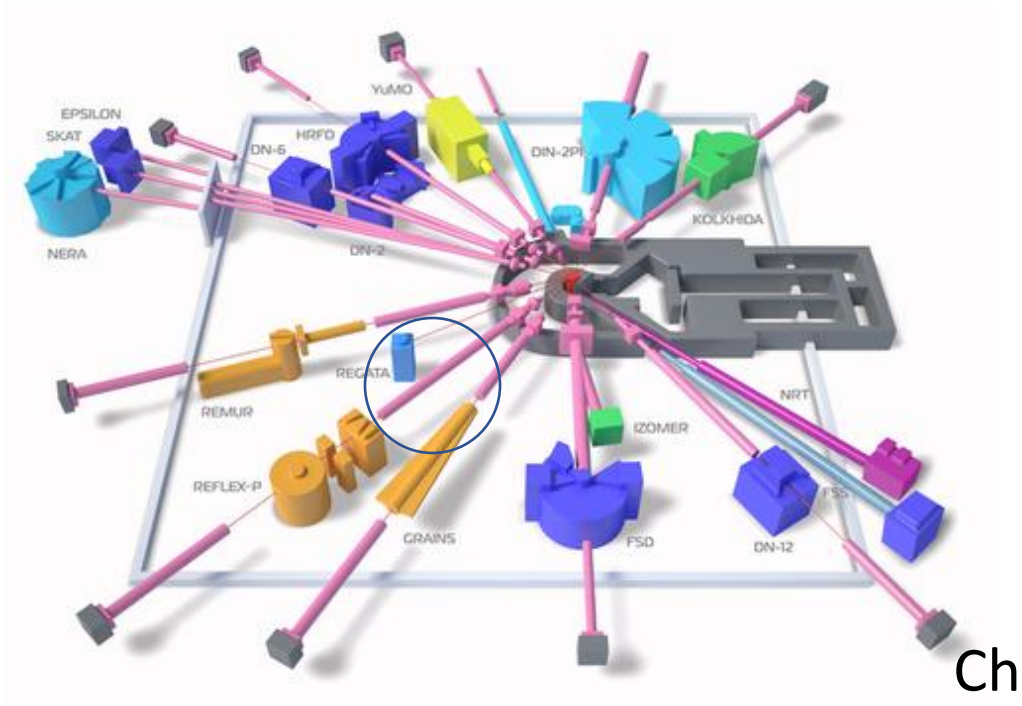
Neutron energy distribution

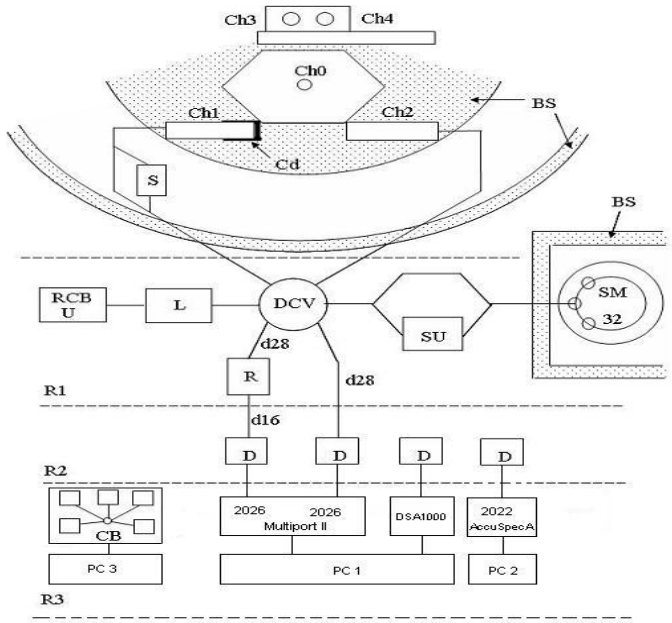
- Thermal 0.025 eV – 0.5 eV
- Epithermal 0.5 eV – 100 keV
- Fast 0.1 MeV – 25 MeV





Radioanalytical complex REGATA





Ch1-Ch4 –irradiation channels, S- intermediate storage, DCV- directional control valves, L- loading unit, RCB- radiochemical glove-cell, U- unloading unit, SU- separate unit, SM- storage magazine, R- repacking unit, D- detector, CB- control board, R1-R3- the rooms where the system is located.

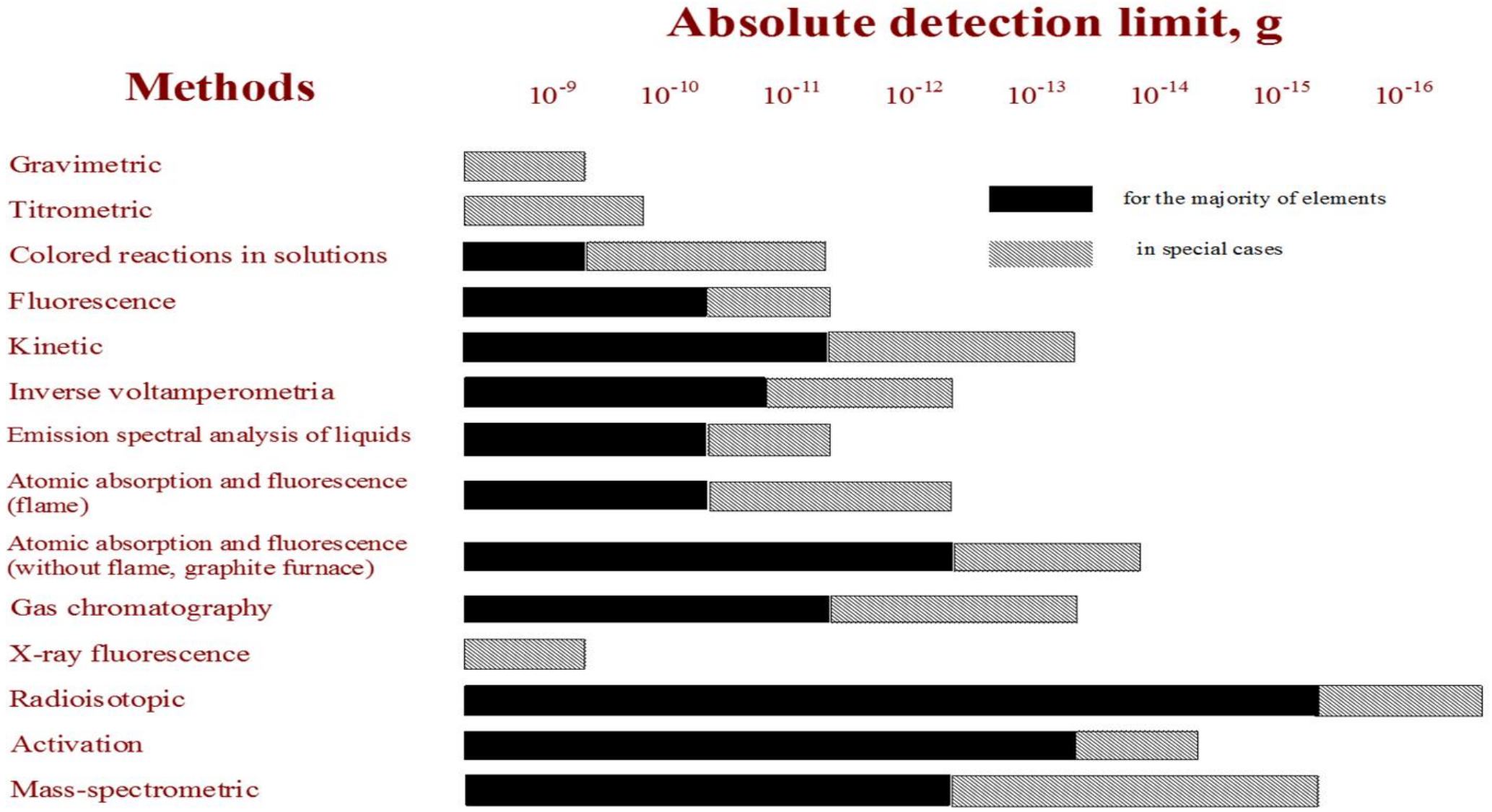
Instrumental neutron activation analysis

Instrumental neutron activation analysis (INAA) is used to determine the concentration of trace and major elements in a variety of matrices. A sample is subjected to a neutron flux and radioactive nuclides are produced. As these radioactive nuclides decay, they emit gamma rays whose energies are characteristic for each nuclide.

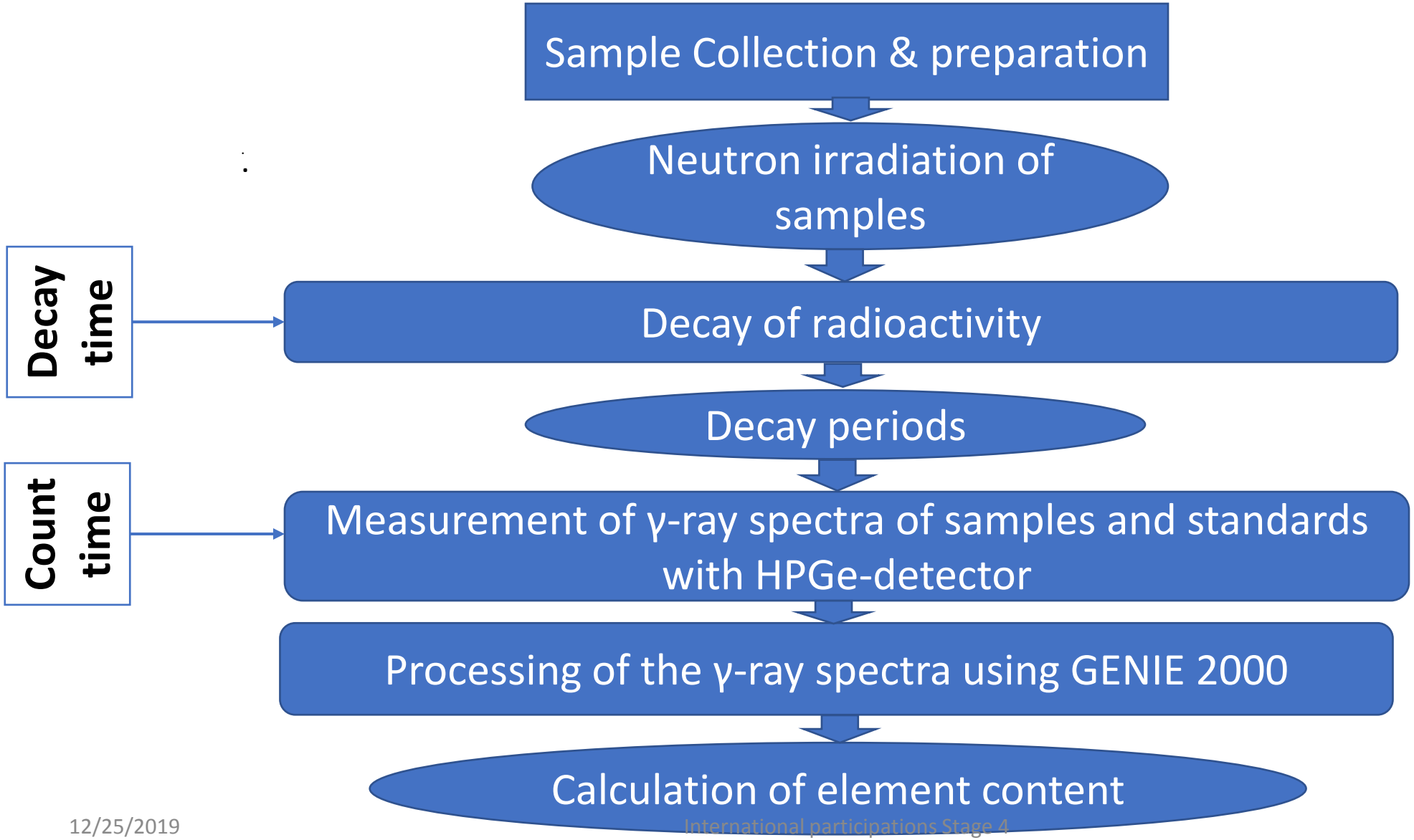
Elements Obtained By NAA

H																He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac**											Rf	Db	Sg	Bh	Hs
	*	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		
	**	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lw		

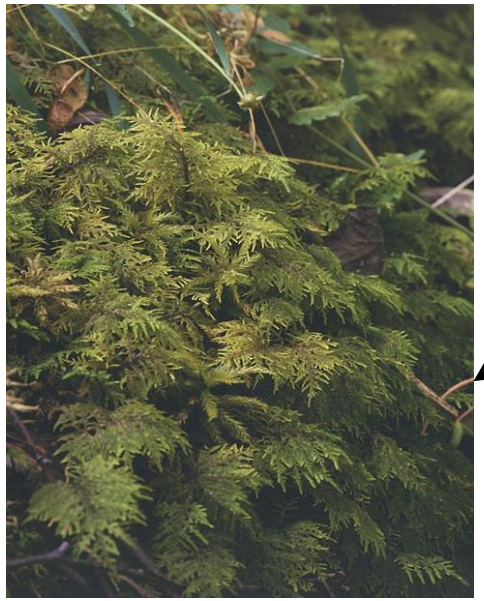
How Powerful is this Analytical Technique?



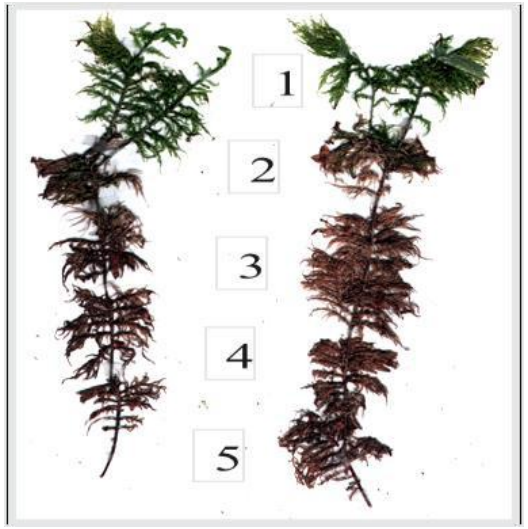
Measurement of content of samples



Sample Collection



Moss



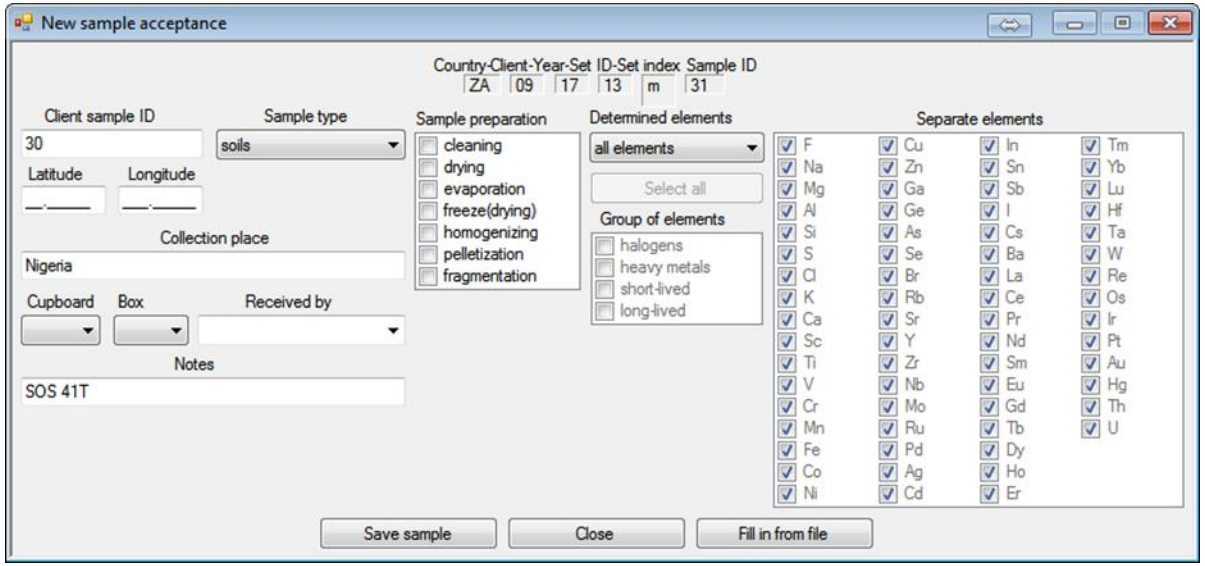
Annual Segments

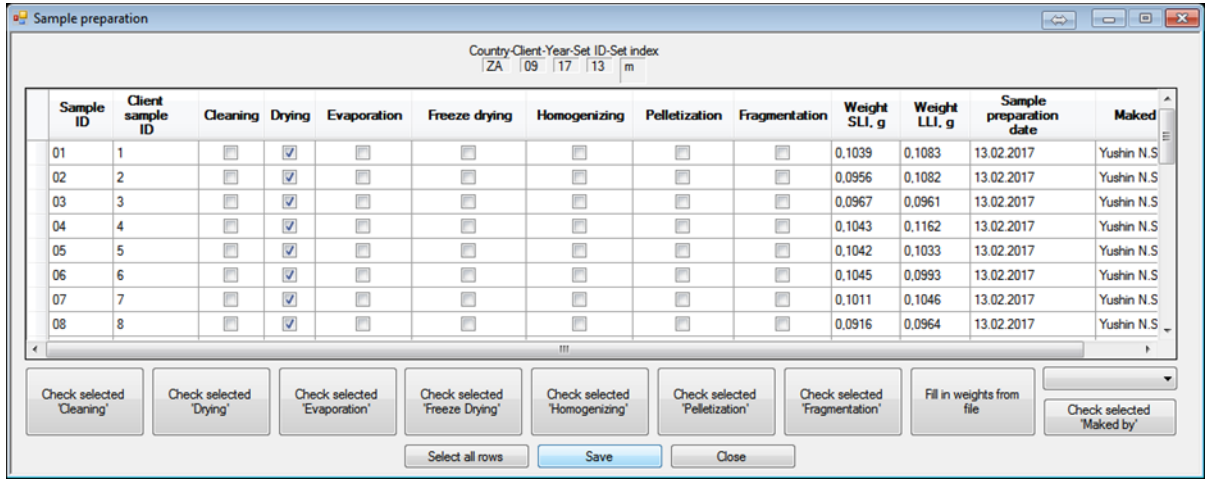
Moss collection

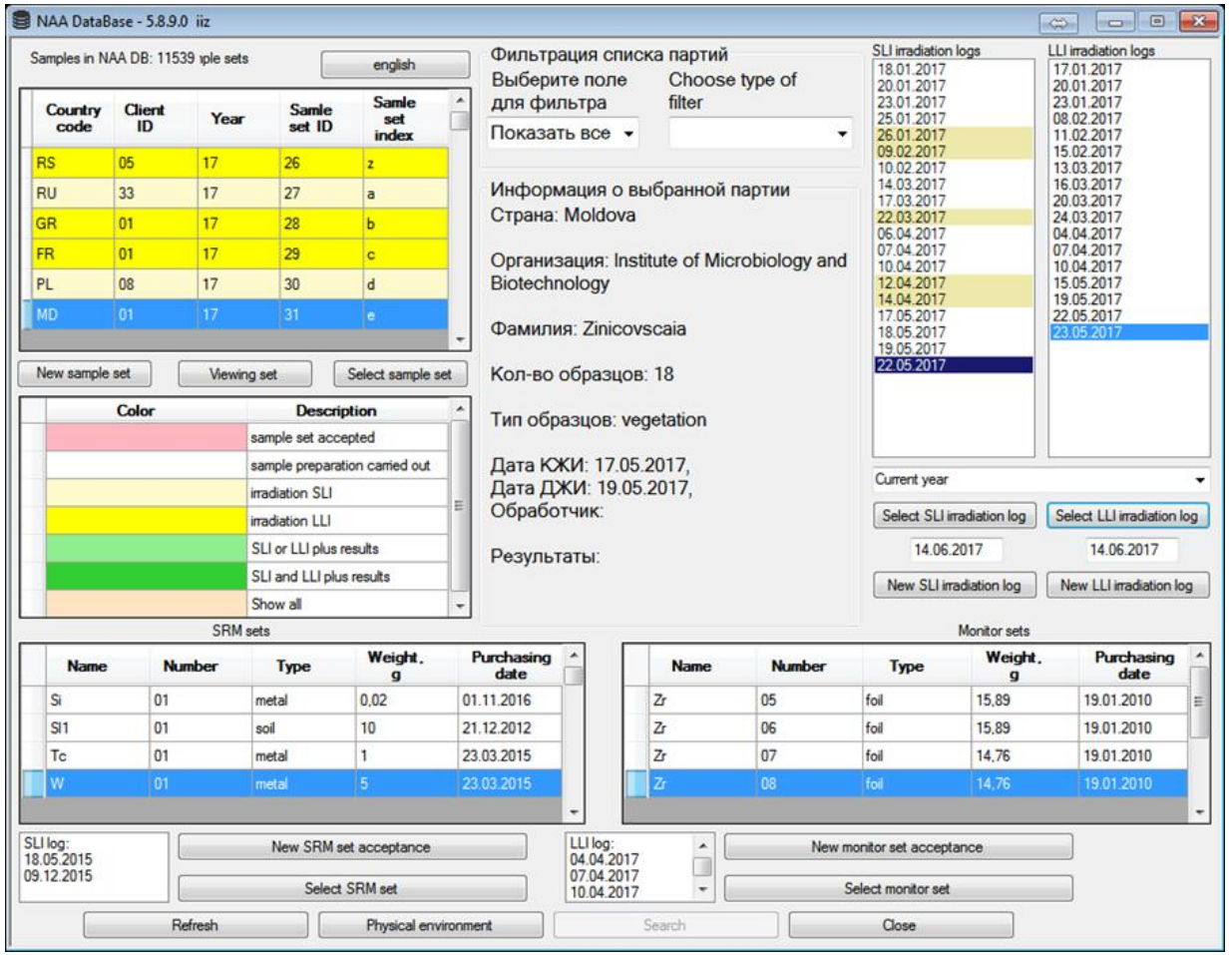
Sediments

Soil

Sample Information programs







Sample preparation:

- Samples air-dried and cleaned from roots of plants and wastes
- 3 g of the sample were weight and homogenized by an agate ball mill in pellets

Sample Packing:

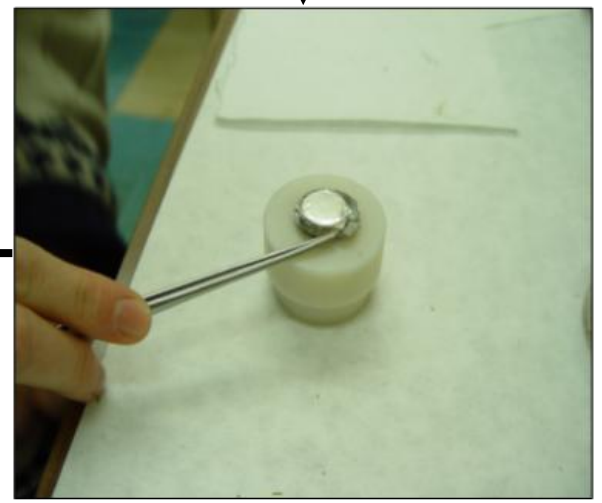
- The weight of the sample was then calculated and recorded by a weight software tool.

- Moss samples wrapped in polyethylene bag and aluminum pan for short- and long-lived irradiations respectively.

- Samples placed in transport capsules

- Short-lived isotopes - samples irradiated for 60

- Long-lived isotopes – samples irradiated for 3



Irradiation of Samples

- By using the pneumatic system the sample is sent to the reactor to be irradiated
- The short lived sample is irradiated for 60 s for soil and sediments. Whereas, moss for 180 s. the measurement is nearly 15 mins.
- The long-lived irradiation is 3 days and 3-4 days for decay and measured for 90 mins.

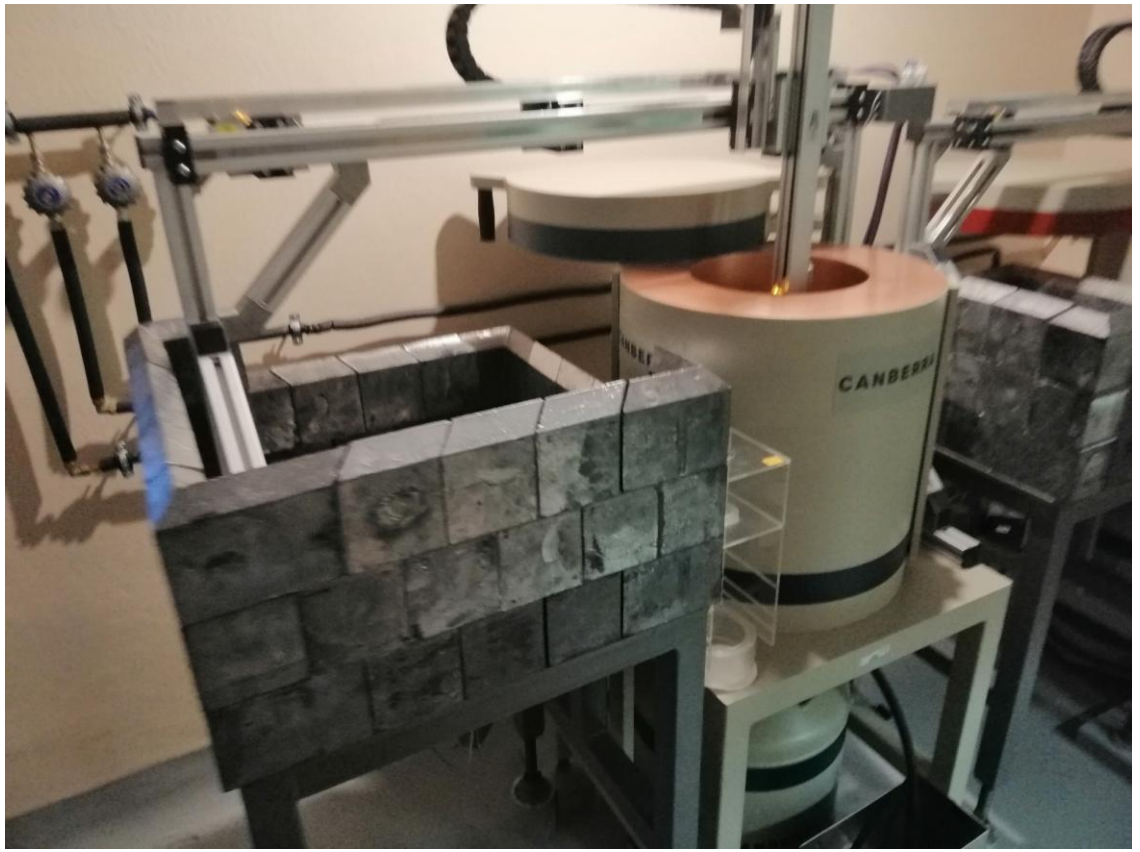
The practical stages of Irradiation in REGATA

Control panel

"Hot" cell

Detection of gamma ray

- By using the HPGe detector we can get the gamma spectrum of the sample

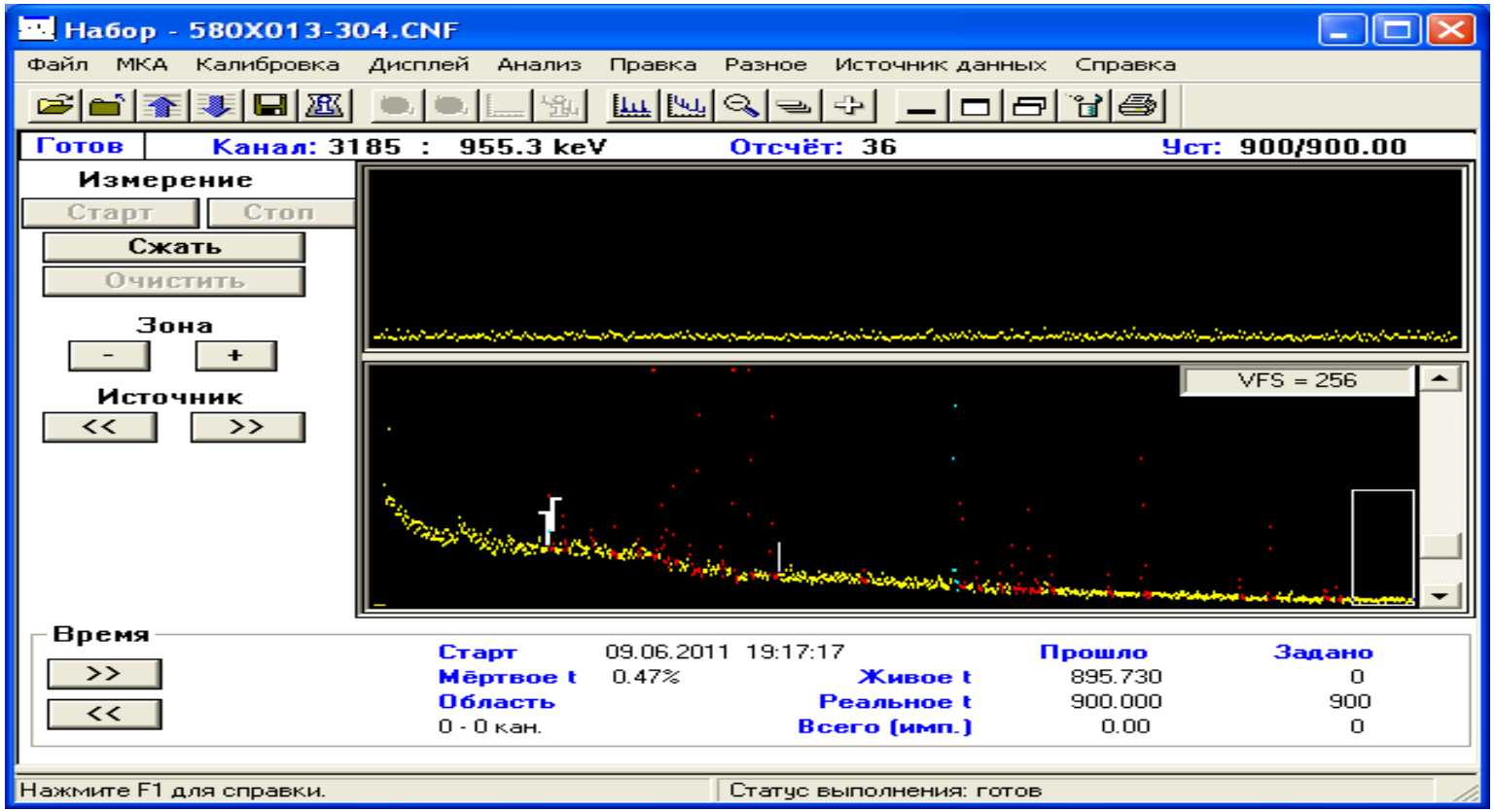


Analysis of gamma spectrum

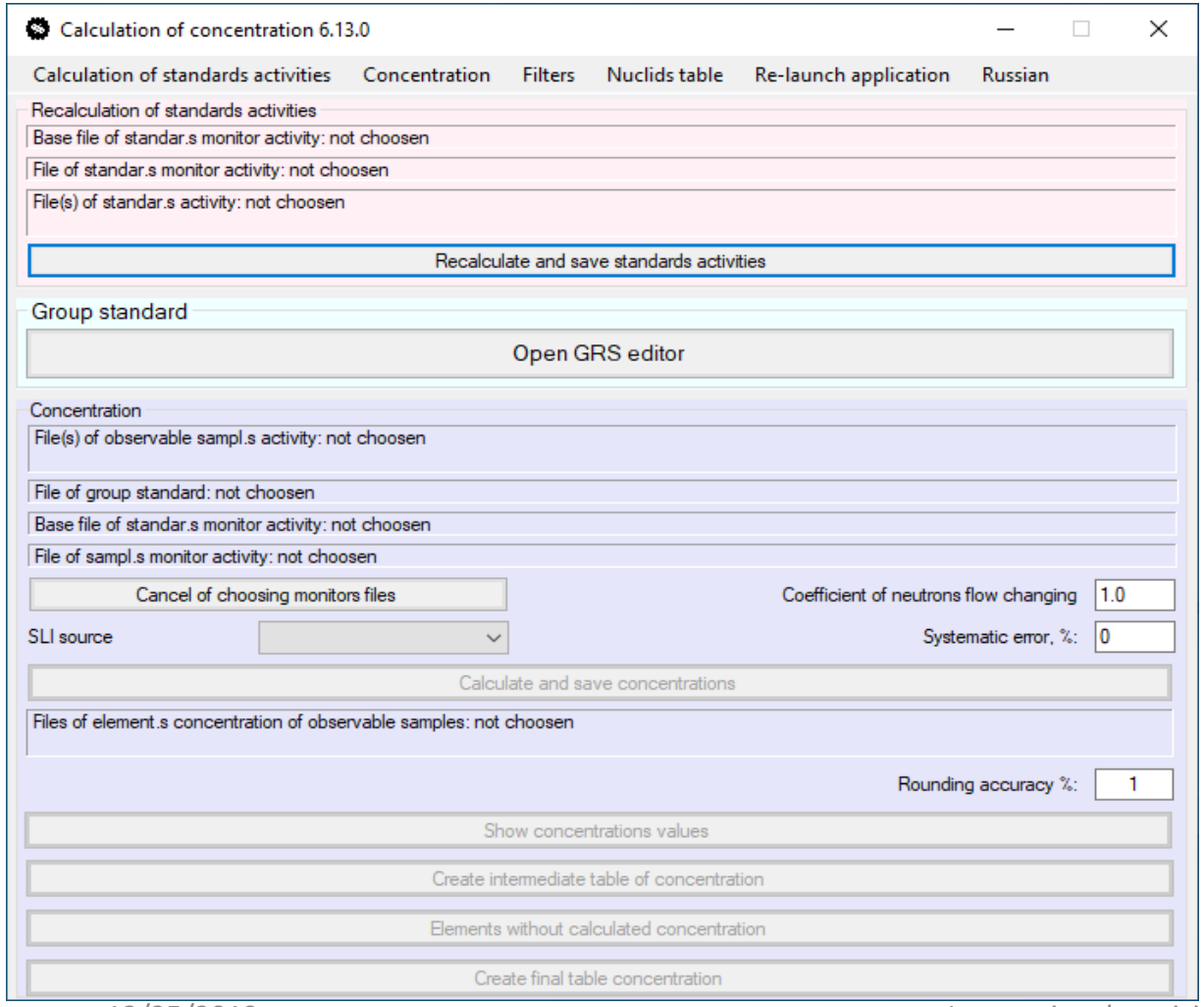
➢ GENIE 2000

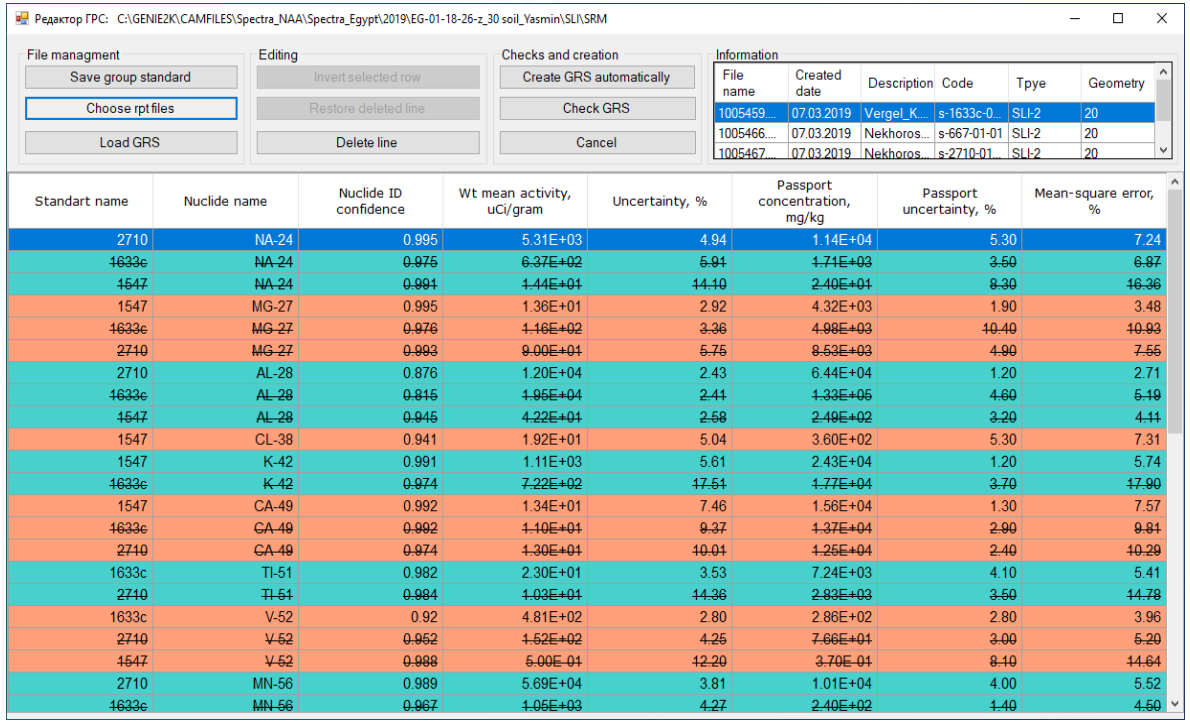
- the program allows minimizing human involvement in routine long-term measurements of the spectra of the induced activity
- simultaneous measurements are conducted

By using this program we can evaluate the activity of each element in the sample



Then we can determine the concentration of each element by using the con. Calculation program





Joint projects with Egypt

Projects:

1st Phase
•Assessment of the environmental situation in the basin of the River Nile using nuclear and related analytical techniques (2011-2014).

2nd Phase
•Environmental studies in Egypt using neutron activation analysis and other analytical techniques (2015-2018).

3rd Phase
•Assessment of the environmental situation in the marine ecosystems in Egypt using neutron activation analysis and other analytical techniques (2018-2020).

4th Phase
•An announcement of new proposals are ready posted on the site of ASRT- Egypt

Social program

Thank you for your attention