



History, development and main achievements in sixteen years of the Neutron Activation Analysis based method used for the establishment of the nuclear database at CNESTEN (Morocco).

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Abstract

Neutron Activation Analysis is a technique used to determine the chemical elemental composition of materials from various matrices.

Since the start-up of the Moroccan TRIGA Mark II research reactor in 2007, it has been used by the neutron activation laboratory at the National Centre for Nuclear Energy, Science and Technology (CNESTEN-Morocco).

Different approaches of this technique, such as the relative method utilizing the NADA programme and the k₀-standardisation method, were developed and enhanced at CNESTEN in 2009 and 2013, respectively, for determining multielemental concentrations.

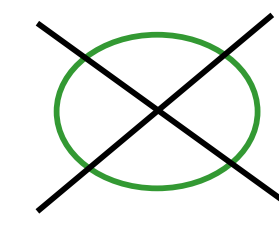
The outcomes of proficiency testing revealed which unacceptable data supplied by the NAA technique should be improved throughout time.

This study discusses the history of the NAA technique's development in our NAA laboratory as well as its major accomplishments.

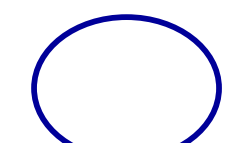
Keywords: Neutron activation analysis, Comparative method, k₀-standardization method, TRIGA reactor

Peak area, A → **k₀-method** → Element concentration, ρ

$$\rho_a (\mu\text{g/g}) = \frac{\left(\frac{N_p / t_c}{SDCW} \right)_a}{A_{sp,m}} \cdot \frac{1}{k_{0,m}(a)} \cdot \frac{G_{th,m} \cdot f + G_{e,m} \cdot Q_{0,m}(\alpha)}{G_{th,a} \cdot f + G_{e,a} \cdot Q_{0,a}(\alpha)} \cdot \frac{\varepsilon_{p,m}}{\varepsilon_{p,a}} \cdot 10^6$$



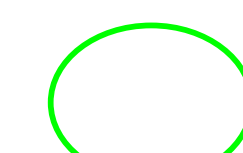
- k₀-Nuclear Data and Decay correction scheme's (all published in open literature)



- Reactor parameters: f and α (Høgdahl-convention, well described)

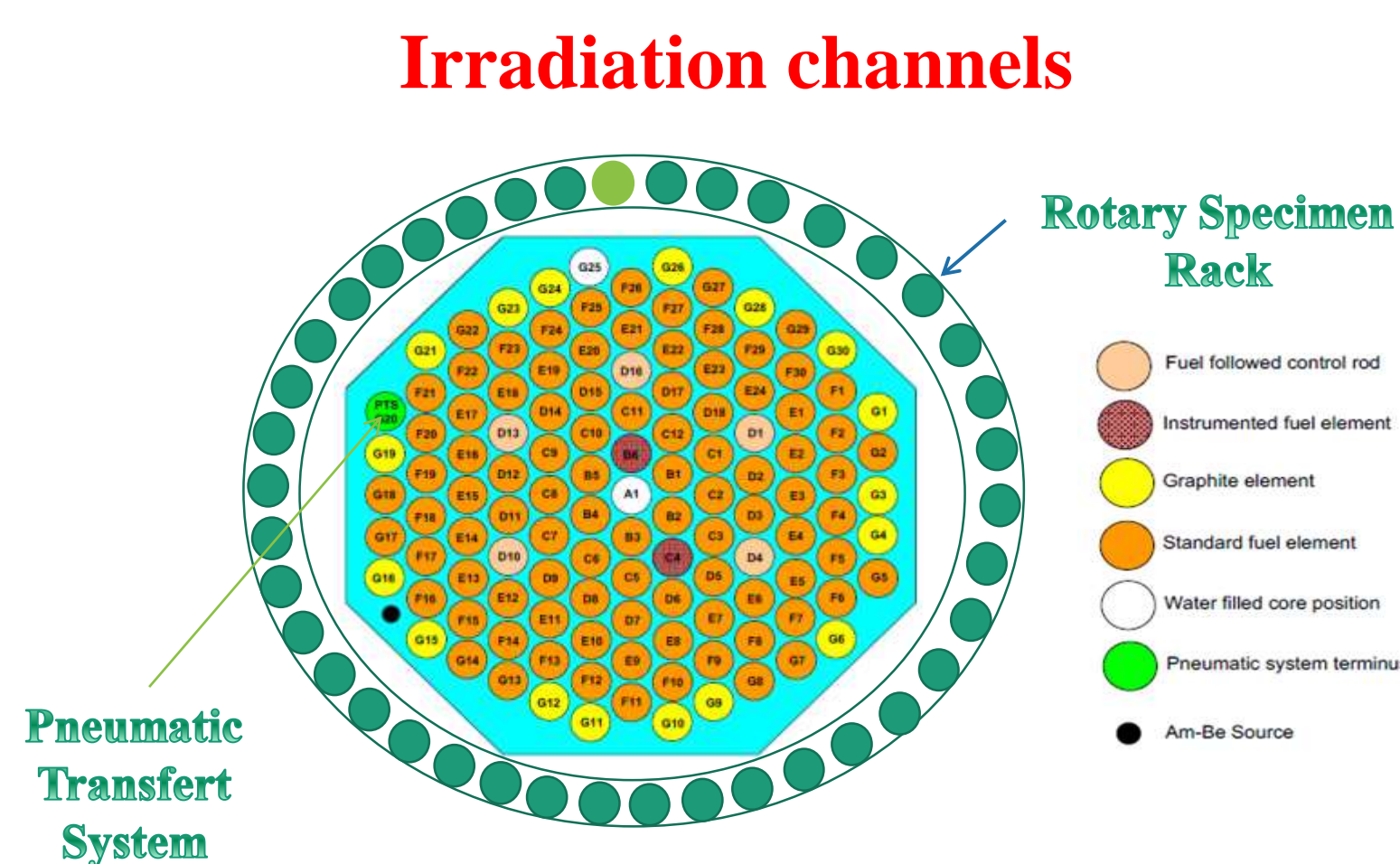


- Detection efficiency accounting for absorption in the sample (according to Moens)



-Irradiation and Measurement aspect: neutron self absorption in the sample dead-time, counting time, coincidence correction etc.

History of NAA at the Moroccan Triga Mark II Research Reactor



Nominal Power : 2 MW

(Start-up : Mai 2007)

- 4 beam ports :
- 3 radial and 01 tangential
- Thermal column
- PTS and RSR
- Central thimble

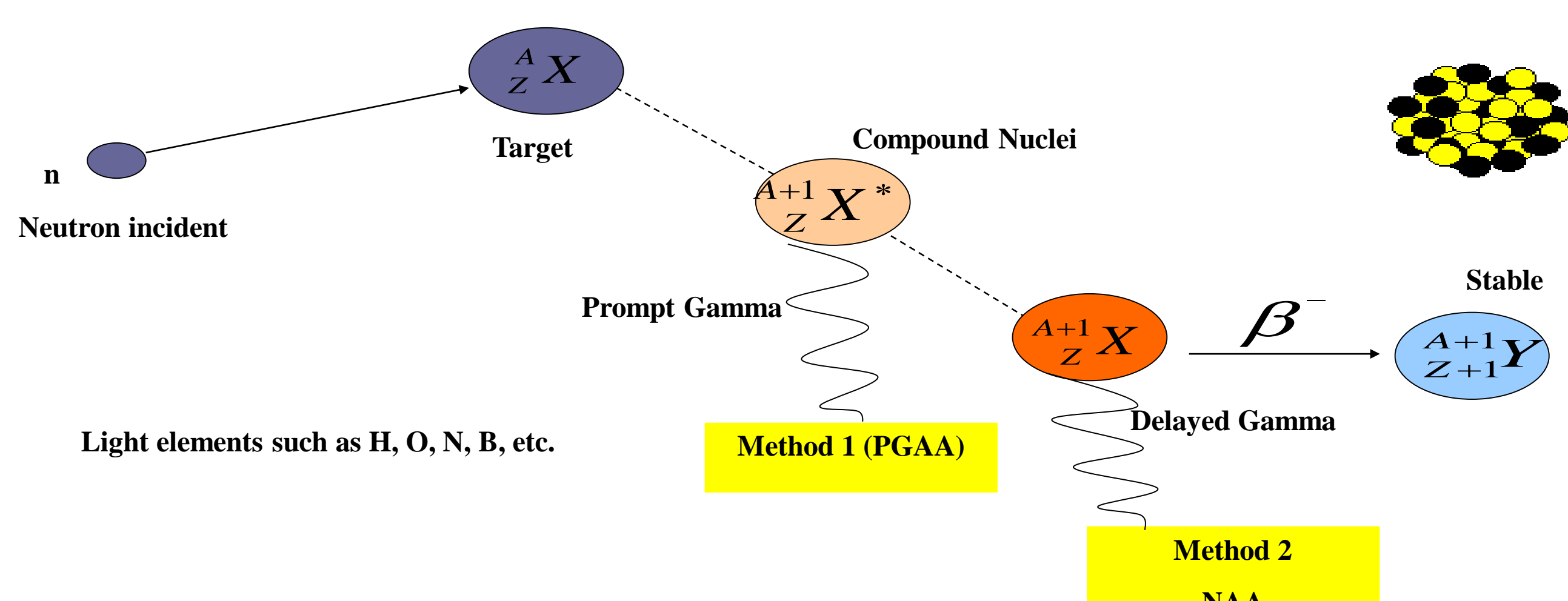
The Moroccan TRIGA Mark II Research at CNESTEN has been licensed to operate at 2 MW since January 2009.

Expert Missions	
Project Number:	MOR/4/018
Project Title:	Use of the Lateral Channels of the TRIGA MARK II Research Reactor, Phase II
Name of Expert:	Mr. Radojko Jačimović, Ph.D. Jožef Stefan Institute
Dates of Mission:	21 October 2007 – 3 November 2007
Name of Expert:	Dr. Menno Blaauw Reactor Institute Delft
Dates of Mission:	29 April 2013 – 10 Mai 2013
Training courses	
Project Number:	MOR/4/018
Project Title:	Use of the Lateral Channels of the TRIGA MARK II Research Reactor, Phase II
Training	University of Texas at Austin, Nuclear Engineering Teaching Laboratory
Supervisor	Dr Donna O'Kelly
Dates of Mission:	22 September 2008 – 21 December 2008
The main objective of this mission	Improve knowledge in the field of the Neutron Activation Analysis (NAA) particularly the relative method .
Training	Reactor Institute Delft, Faculty of Applied Sciences, Delft University of Technology
Supervisors	Dr Peter BODE & Dr Menno Blaauw
Dates of Mission:	17 th September 2012-16 th December 2012
The main objective of this mission	Improve knowledge in the field of the Neutron Activation Analysis (NAA) particularly the k₀-NAA method .

Duties performed of the Expert and training course missions :

- Establishment of sample irradiation and measurements protocols for instrumental NAA
- Measurement of the neutron spectral parameters: f (thermal-to-epithermal flux ratio) and α (deviation of epithermal neutron distribution from the ideal (1/E) dependence)
- Installation of the k₀-method of NAA on existing equipment's (KAYZERO/SOLCOI and k₀_IAEA software)
- Application of INAA to environmental sciences
- Mathematical model and computational tools to determine the measurement uncertainty
- Validation of the k₀-INAA for the purpose of QC/QA

How Does Neutron Activation Analysis Work?



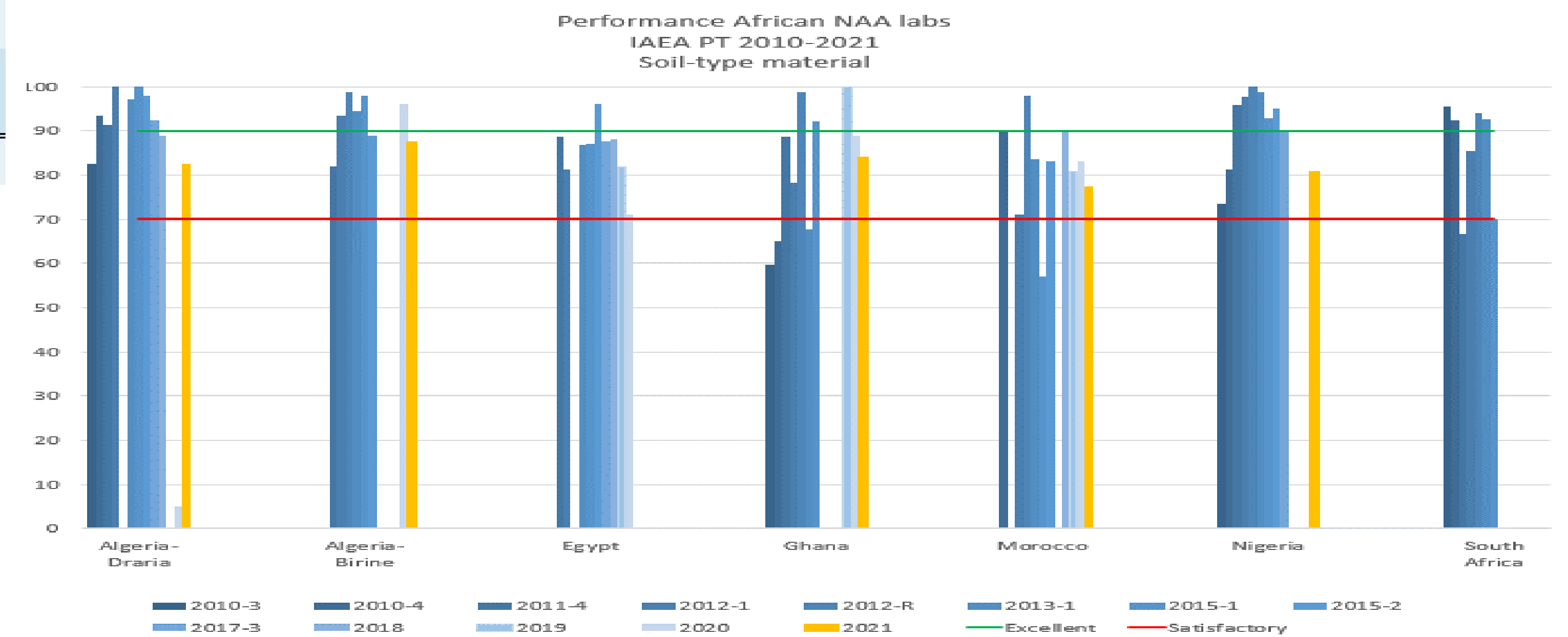
Applications of Neutron Activation Analysis at CNESTEN

- ❖ Determination of Rare Earth Elements in Soil Samples from gold mining area in Sudan using NAA method
- ❖ Assessment of radiological risks in the Djeno region, Congo Brazzaville
- ❖ Geochemical study of river basins (Oum Erbia, Elhachef, Raouz and Loukkous)
- ❖ Atmospheric pollution in several Moroccan cities (Kenitra, Meknes, Tetouan, Tanger)
- ❖ Contribution to nutritionnal statut study of the population of Kenitra.
- ❖ Environmental and socio-economical impact study of abandoned mines in Moulouya region
- ❖ Contribution to the valorisation of the Moroccan phosphates and their products by the characterization of radionuclides and trace elements.
- ❖ Participation to Intercomparison exercices for NAA and other Analytical Techniques

National and foreign partners

- AIEA, AFRA, CNRST, INRH, OCP, ONHYM, OCP, IAV.
- Moroccan Universities (Meknes, Fes, Rabat, Casablanca, Tanger, Tetouan and Kenitra),
- Foreign Universities and research Centers (African countries, France, Spain, Italy, Germany, Hungary, Slovenia, Netherland, USA and Portugal).

Achievements



We offer training and assistance for Nuclear Analytical Techniques:

- Hosting scientific visitors and providing research fellowship training
- Principle of Neutron Activation Analysis (NAA)
- Metrology of NAA (calibration, validation, uncertainty, primary method requirements)
- Quality Control/Quality Assurance in NAA
- Automation and facility design
- Principles and applications of compartmental studies
- Principles of carrier-free production of radionuclide

We offer training and assistance for QC/QA/QM:

- Principles and pragmatics of quality control, quality assurance and quality management
- Interpretation and implementation of the requirements of the ISO/IEC 17025:2005
- Training in Internal Auditing in nuclear science related laboratories

Conclusions

Neutron Activation Analysis Laboratory (NAAL) at CNESTEN related to k₀-standardized method concerns about keeping the method working well, looking for expanding the applications and looking for improving of the method. The objective is to offer to the customers (meeting the clients' analytical needs, researches, new developments) the best results that the method can produce using the current infrastructure.

Therefore, over the years, the NAAL has invested to improve the k₀-method. The results of the investment can be measured after 2013, when the method was re-established and improved by the number of papers published, dissertations and Ph.D theses concluded and the number of coordination of projects.

The participation in proficiency testings were very important on monitoring the performance of k₀-method, showing which reported elements could be improved along the years.

The good performance in the last PTs, points out that the method is working properly.