Laboratorio de Investigaciones Aplicadas con Tecnologías Atómicas y Nucleares

LIATAN

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XVI CONFERENCIA LATINOAMERICANA DE ANÁLISIS POR TÉCNICAS DE RAYOS X
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AVANCES EN INVESTIGACIÓN CON TECNOLOGÍAS ATÓMICAS Y NUCLEARES EN LA UNIVERSIDAD TECNOLÓGICA METROPOLITANA DE CHILE

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ABSTRACT

La reciente instalación de un acelerador electrostático tipo Van de Graaff KN3750 en el Campus Macul de la Universidad Tecnológica Metropolitana (UTEM) ha significado un avance fundamental en la conformación del Laboratorio de Investigaciones Aplicadas con Tecnologías Atómica y Nucleares (LIATAN). El acelerador junto con todas las líneas de irradiación que lo componen supondrán una mejora sustancial para la UTEM en investigación avanzada en campos tan diversos como el estudio de aerosoles atmosféricos, medición de secciones eficaces en física atómica y nuclear, y la caracterización de materiales mediante el uso de haces iónicos.

La aplicación de técnicas basadas en haces iónicos es una de las primeras tareas en las cuales está abocado actualmente el grupo de investigadores de nuestro Laboratorio. La línea PIXE (Proton Induced X-Ray Emission) está basada en una cámara de irradiación multipropósito que permite determinar la concentración elemental de muestras arqueológicas, antropológicas y de elementos traza en aerosoles. Dada su versatilidad, esta línea experimental podría también utilizarse para medir secciones eficaces de producción de rayos-X inducidas por protones de baja energía con el fin de completar su base de datos y en mejorar los modelos teóricos disponibles (por ej., ECPSSR). Por otra parte, la cámara de RBS (Rutherford Backscattering) permite, por ejemplo, medir el espesor de películas delgadas de oro depositadas sobre mica pudiéndose así determinar su resistividad. De igual manera, esta línea permite la medición de secciones eficaces de stopping power de muestras tales como Pd y Cu, para protones y partículas alfa a partir de lo cual se puede inferir, por ejemplo, la energía de excitación/ionización de dichos materiales.

La reciente adquisición de un equipo portátil de fluorescencia de Rayos-X (pXRF) permitirá el estudio de muestras que no pueden ser trasladadas hasta nuestro laboratorio para su análisis, dada su envergadura, fragilidad o por su valor histórico. De esta forma, la caracterización elemental de pinturas u otros objetos valiosos desde el punto de vista patrimonial podría ser estudiada mediante este método no-destructivo.

Acelerador Van de Graaff (técnicas IBA)

Equipo de XRF para análisis composicional

Detector Ge(Li) HP para estudio de radiación natural

Estación móvil de monitoreo ambiental

Laboratorio de Simulaciones

Acelerador Van de Graff

Rutherford Backscattering Spectrometry (RBS)

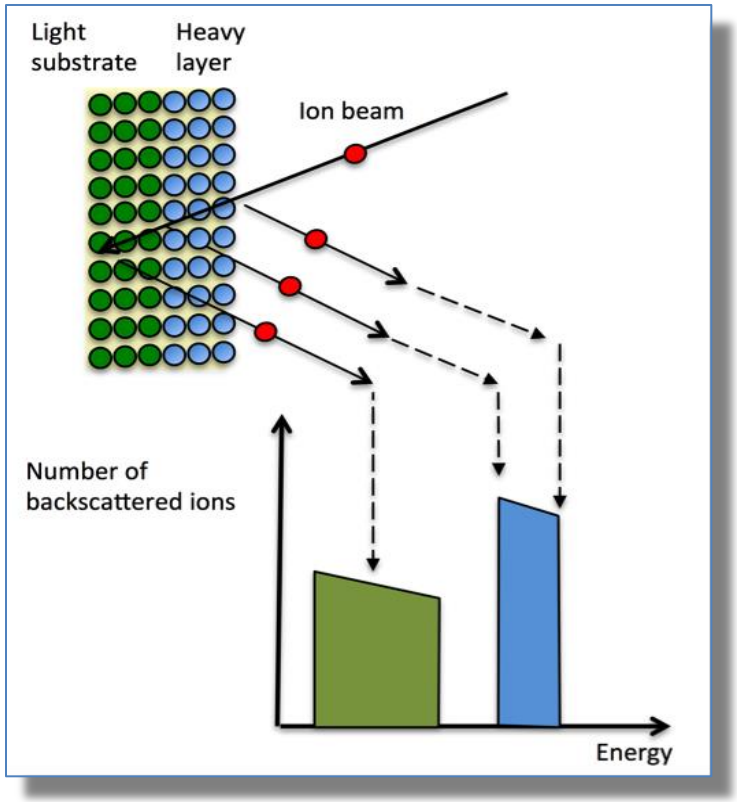
Elastic Recoil Detection Analysis (ERDA)

Nuclear Reactions Analysis (NRA) y
Particle Induced Gamma-ray Emission (PIGE)

Particle Induced X-ray Emission (PIXE)

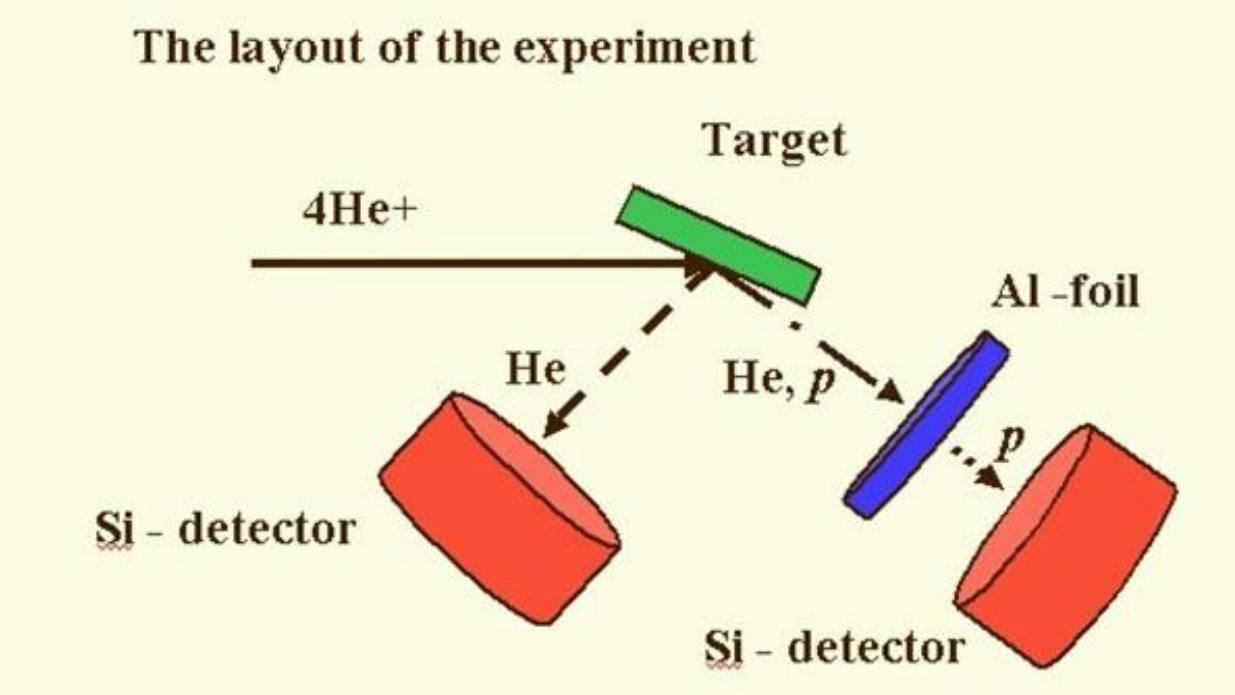
Proton Elastic Scattering (PESA)

Rutherford Backscattering Spectrometry (RBS)



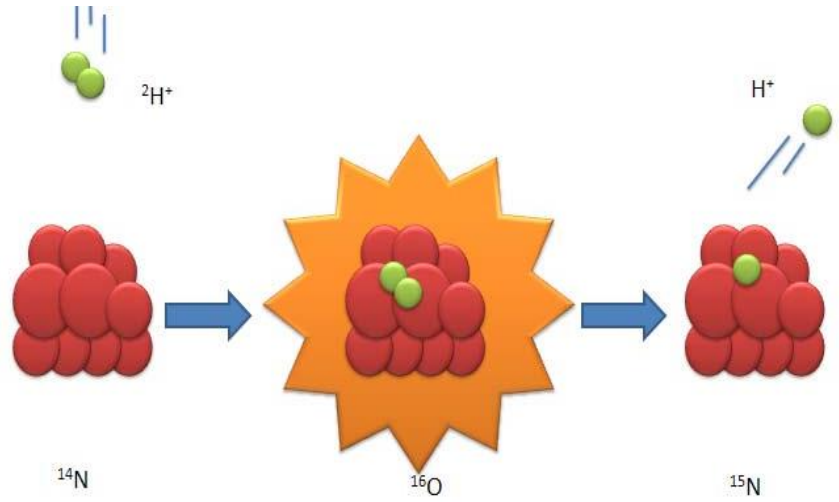
- El blanco es bombardeado con partículas ($^{1}H^{+}$ ó $^{4}He^{+}$) con energías entre 0,4 y 2 MeV.
- Colisionan elásticamente con los átomos del blanco.
- Pierden energía conforme atraviesan el material.
- Las partículas dispersadas son detectadas en direcciones mayores de 90°.

Elastic Recoil Detection Analysis (ERDA)



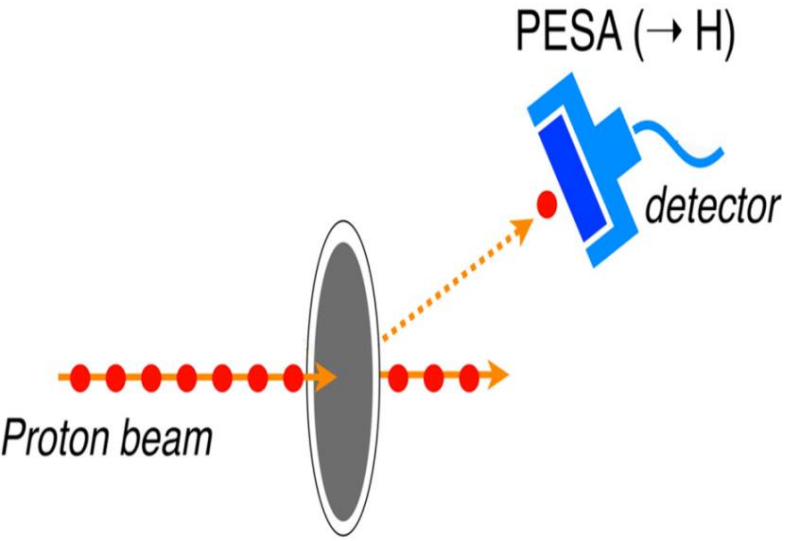
- Su principal aplicación es la detección de hidrógeno.
- Se bombardea con partículas α de 2 MeV.
- El haz incide en ángulo rasante sobre la muestra.
- Se detecta la energía de los protones arrancados.

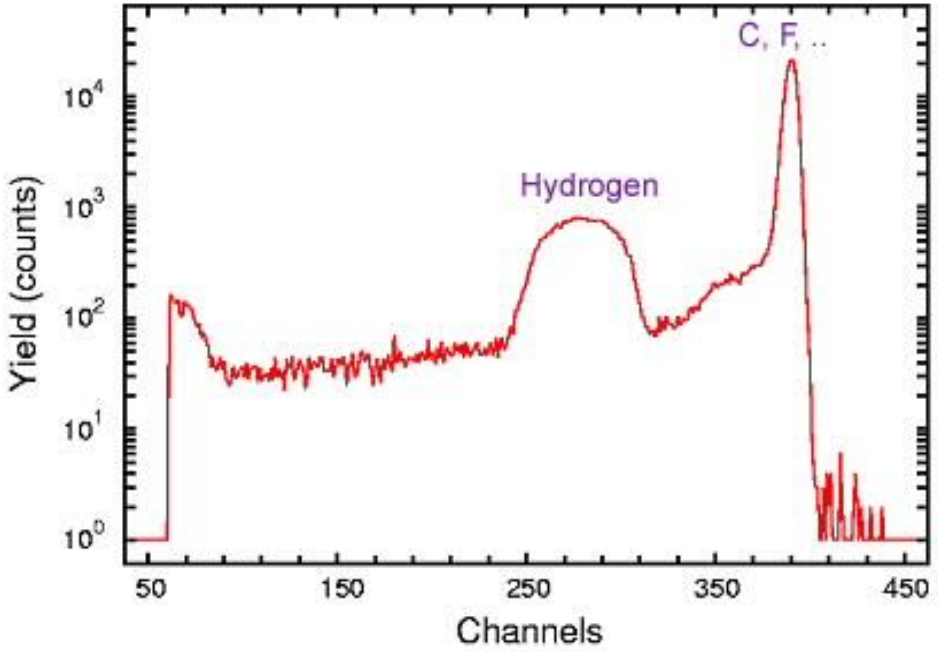
Nuclear Reactions Analysis (NRA) y Particle Induced Gamma-ray Emission (PIGE)



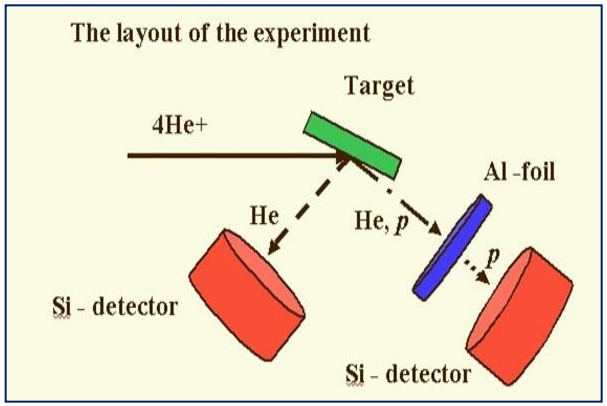
- Se obtienen los perfiles en profundidad de elementos ligeros (H, D, Li, B, C, O y F)
- Es una técnica complementaria al RBS.
- Entre los productos de una reacción nuclear puede aparecer radiación gamma, y entonces es posible realizar PIGE.

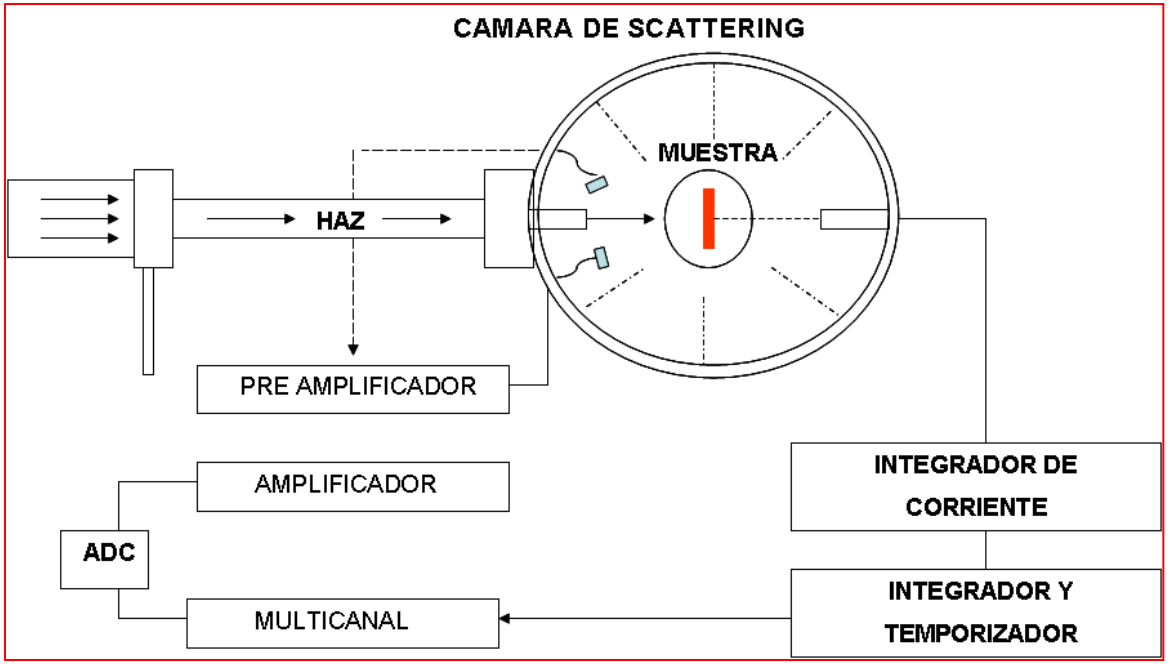
Proton Elastic Scattering (PESA)

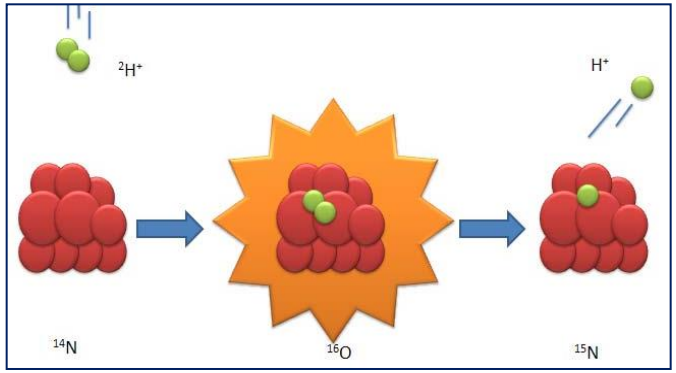


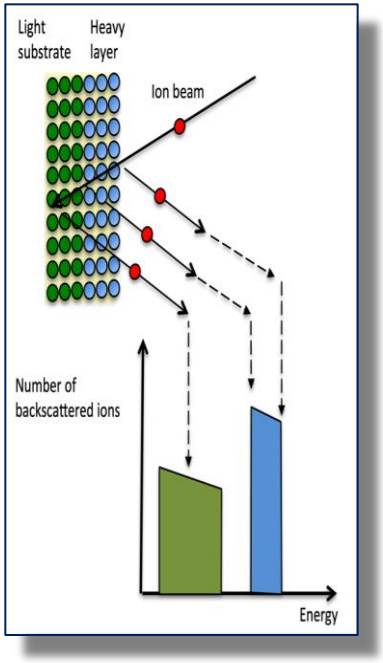


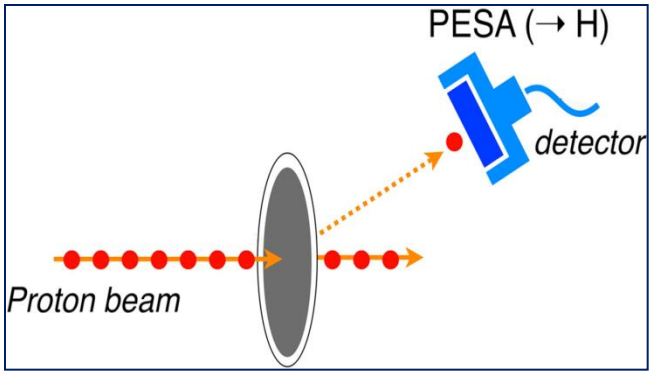
- La técnica es similar a RBS, pero se miden los iones incidentes dispersos en ángulos frontales. (30°)
- Solo se pueden medir elementos con Z bajos como el hidrógeno.
- Es ideal para medir la concentración de hidrógeno en muestras delgadas como, por ejemplo, aerosoles.

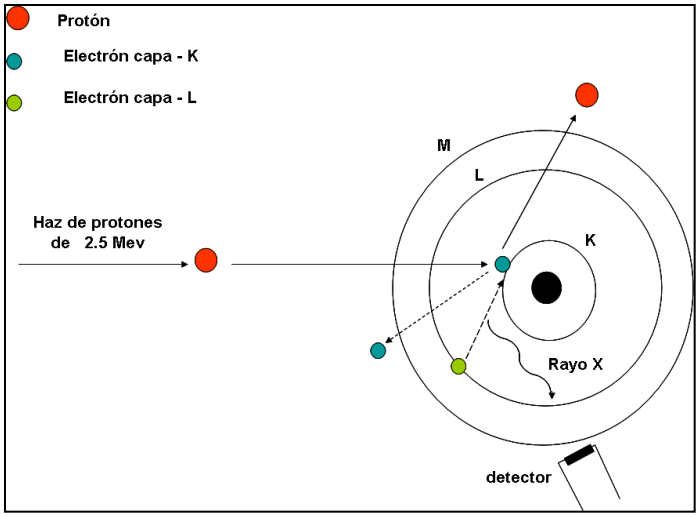

The layout of the experiment
Target
4He+
Al -foil
He
He, p
p
Si - detector
Si - detector


CAMARA DE SCATTERING
MUESTRA
HAZ
PRE AMPLIFICADOR
AMPLIFICADOR
ADC
MULTICANAL
INTEGRADOR DE CORRIENTE
INTEGRADOR Y TEMPORIZADOR


2H+
H+
14N
16O
15N


Light substrate
Heavy layer
Ion beam
Number of backscattered ions
Energy


PESA (→ H)
detector
Proton beam


Protón
Electrón capa - K
Electrón capa - L
M
L
K
Haz de protones de 2.5 Mev
Rayo X
detector

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Análisis PIXE

(Proton Induced X – ray Emission)

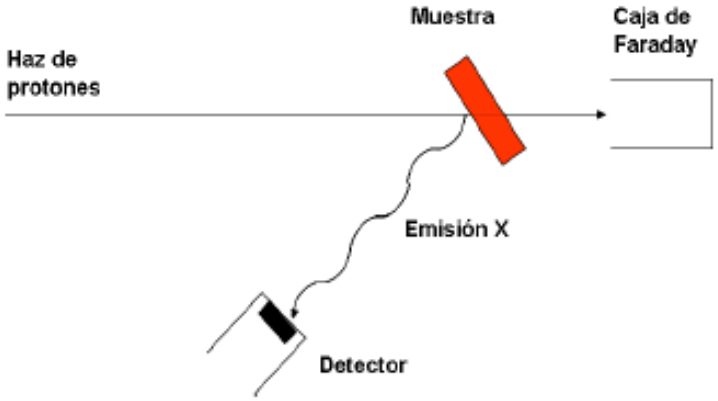
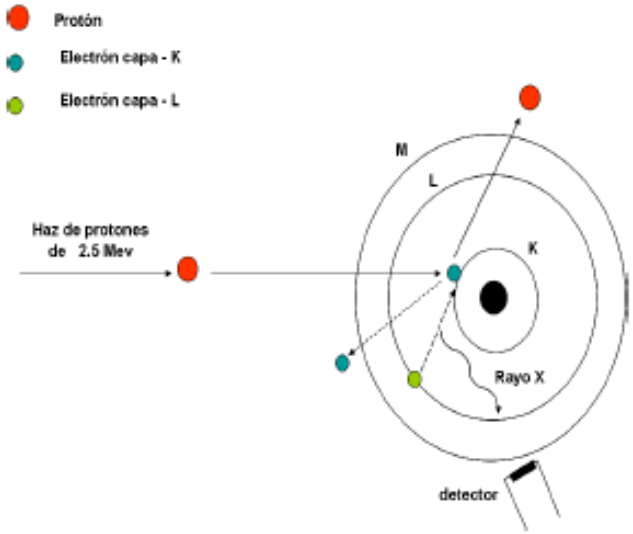
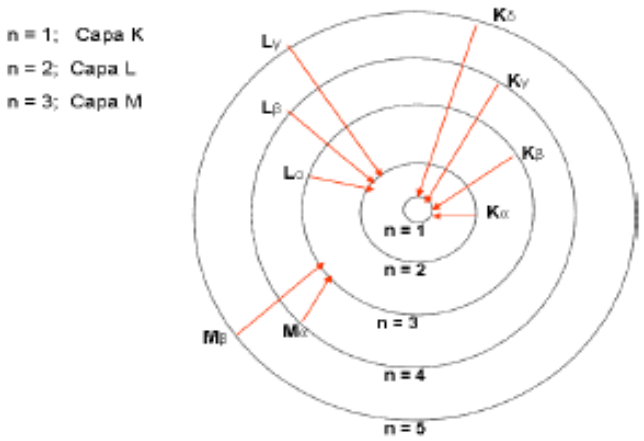


Diagrama del proceso de interacción del haz iónico con la muestra y disposición geométrica de los elementos.



Procesos que ocurren en la interacción de los protones con energía cercana a los 3 MeV con los átomos de la muestra.



Posibles transiciones de electrones en un átomo al generarse vacanci en los niveles más ligados: K, L y M. En experimentos PIXE las transiciones más probables son las K_α y K_β.

PIXE Analysis

- Proton beams of 2 MeV were provided by a Van der Graaff accelerator.
- Thirty seven aerosol samples were collected on Teflon filters in downtown in Santiago using stacked filter units (SFU).
- Spectra were obtained with a Canberra Si(Li) detector having a resolution of 200 eV approximately and standard pulse electronic units and MCA.
- Thirteen elements were detected in most of the aerosol filters (Al, Si, S, K, Fe, P, Cl, Ca, Ti, Cr, Mn, Cu, and Zn).
- These X-ray spectra were analysed using AXIL code provided by IAEA, which determines the number of counts in each peak.

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Beam Interactions with Materials & Atoms
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Artificial neural networks applied to quantitative elemental analysis of organic material using PIXE

R. Correa [a], M.A. Chesta [b,*], J.R. Morales [c], M.I. Dinator [c], I. Requena [d], I. Vila [e]

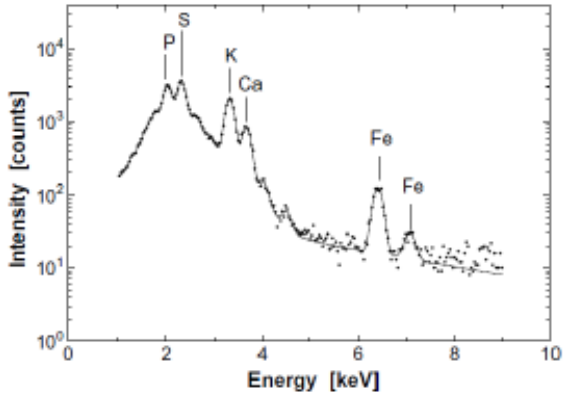

Fig. 2. Typical PIXE spectrum of a liver sample from fish *C. carpio*, using 2.0 MeV protons. The solid line is a fit given by AXIL.

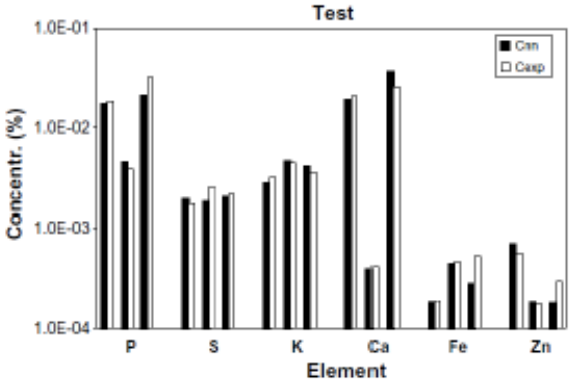

Fig. 5. Elemental concentration obtained from the three samples of the test set using ANN (C_{NN}) and PIXE (C_{exp}), are shown for gill, liver and muscle respectively for each element.

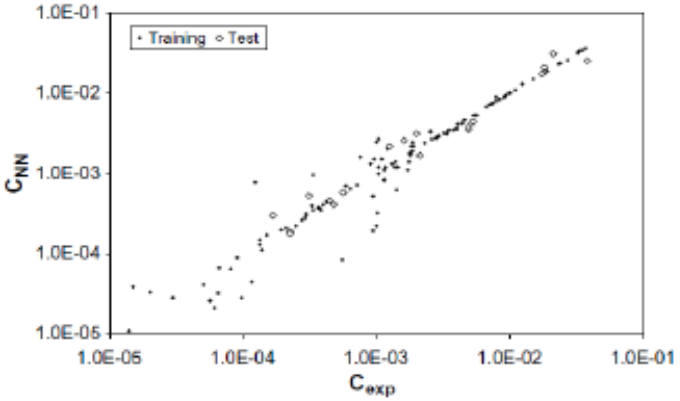

Fig. 6. The predicted concentrations from ANN (C_{NN}) as compared with PIXE (C_{exp}) concentrations.

Abstract

An artificial neural network (ANN) has been trained with real-sample PIXE (particle X-ray induced emission) spectra of organic substances. Following the training stage ANN was applied to a subset of similar samples thus obtaining the elemental concentrations in muscle, liver and gills of *Cyprinus carpio*. Concentrations obtained with the ANN method are in full agreement with results from one standard analytical procedure, showing the high potentiality of ANN in PIXE quantitative analyses.
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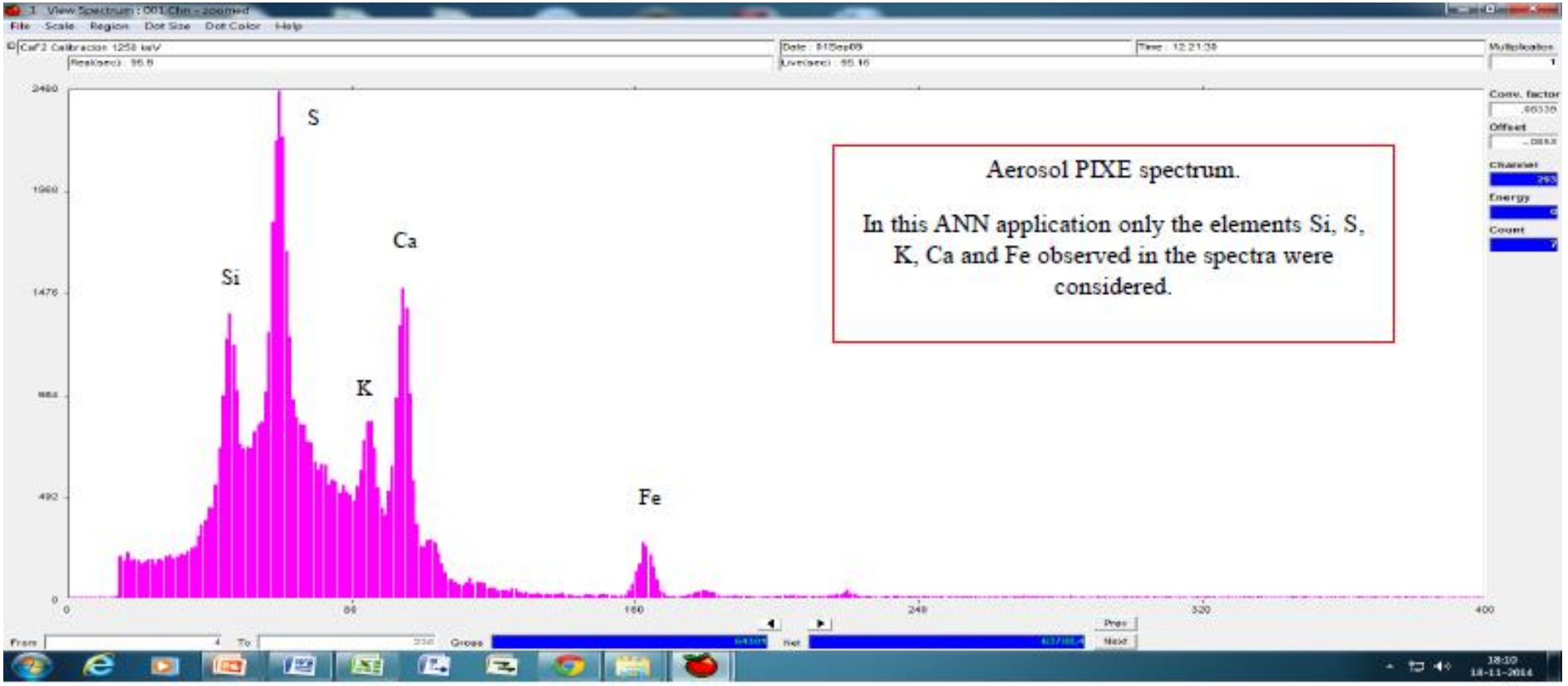
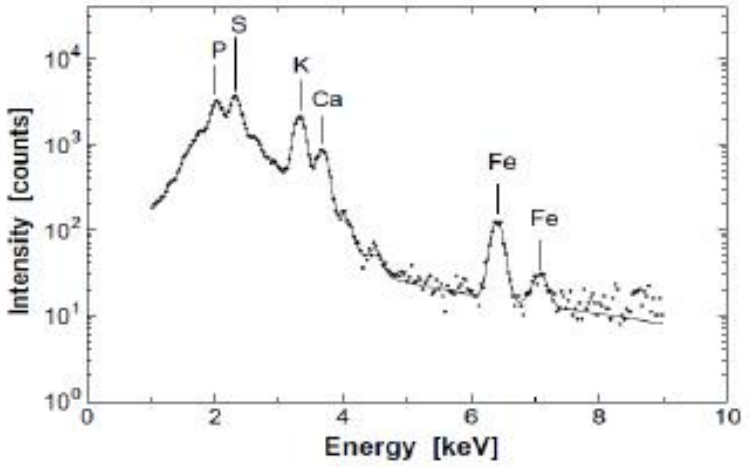
PACS: 29.85.+c; 87.64.Gb; 07.05.Tp

Keywords: Artificial neural networks; PIXE





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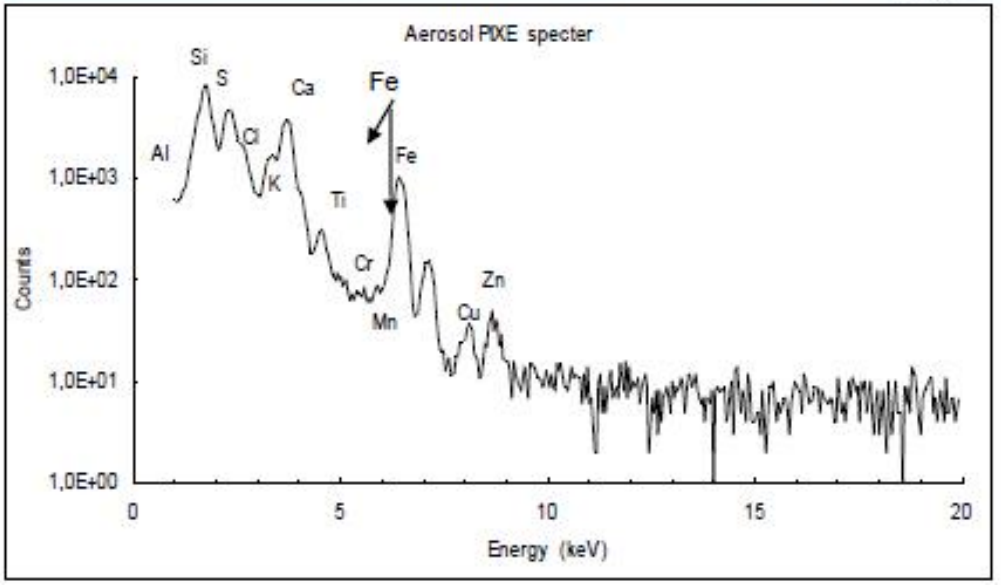

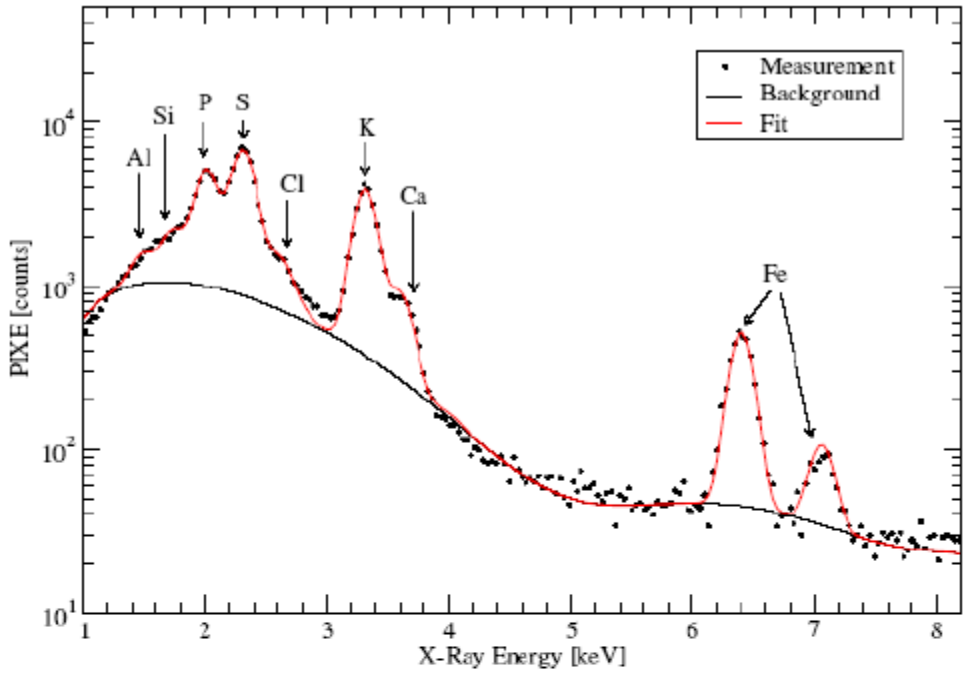

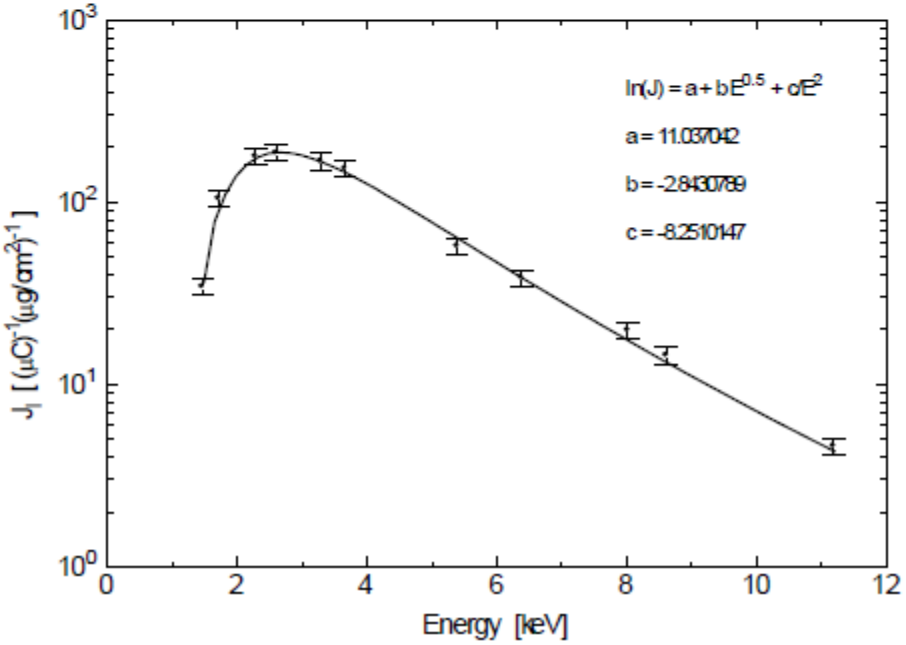

The relative elemental concentration C_Z, expressed by the ratio of th elemental surface mass density an the total mass per unit area of th sample, was obtained by th equation:

$$C_Z = \frac{I_Z(E_{K\alpha})}{M \cdot Q \cdot J(E_{K\alpha})}$$

Where

I_Z - is the number of counts in th Ka peak from the Z-element,

M [g/cm^2] - is the total mass surfac density of the target,

Q [C] - is the integrated charge i the Faraday cup, and

$J(E_{Ka})$ [g^{-1} cm^2 C^{-1}] - is the value o the sensitivity function at the pea energy obtained from experimenta data

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Application of PIXE in the determination of the production cross section of a radionuclide decaying by electron capture

J.R. Morales [a,*], M.A. Chesta [a], S.A. Cancino [a], P.A. Miranda [a], M.I. Dinator [a], M.J. Avila [b]

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Measurements of ^{67}Ga production cross section induced by protons on ^{nat}Zn in the low energy range from 1.678 to 2.444 MeV

J.A. Wachter [a,*], P.A. Miranda [a], J.R. Morales [b], S.A. Cancino [b], R. Correa [a]

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Stopping power of palladium for protons in the energy range 0.300–3.100 MeV

P.A. Miranda *, A. Sepúlveda, J.R. Morales, T. Rodríguez, E. Burgos, H. Fernández

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Recent IBA setup improvements in Chile

P.A. Miranda [a,*], M.A. Chesta [a], S.A. Cancino [a], J.R. Morales [a], M.I. Dinator [a], J.A. Wachter [a], C. Tenreiro [b]

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Sistemas Neuronales Artificiales (SNA) en Análisis de Espectros de Emisiones X

Redes Neuronales Artificiales (RNA).

➢ Una RNA es un conjunto de procesadores elementales interconectados, no lineal ni estacionario, que realiza al menos alguna de las siguientes funciones:

Aprendizaje,

Memorización,

Generalización

Abstracción

de características esenciales, a partir de un conjunto de ejemplos.

➢En la arquitectura de una RNA se pueden considerar tres aspectos esenciales:

Diseño Estructural

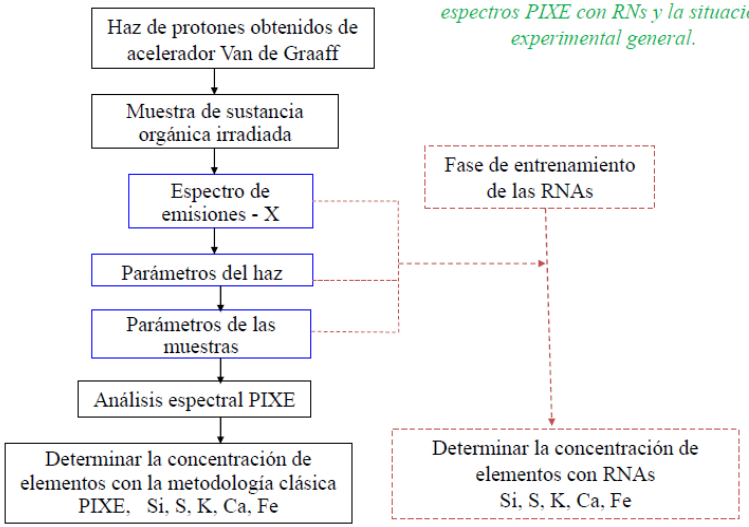
Aprendizaje

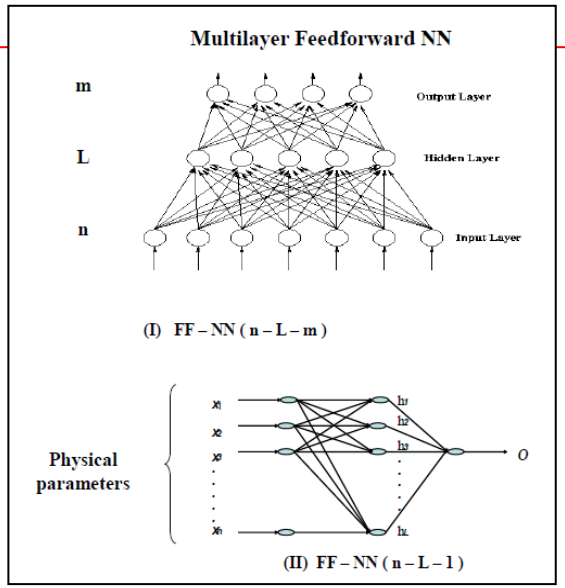
Supervisado

No supervisado

Recuperación de la información

Esquema de la relación del análisis de espectros PIXE con RNs y la situación experimental general.





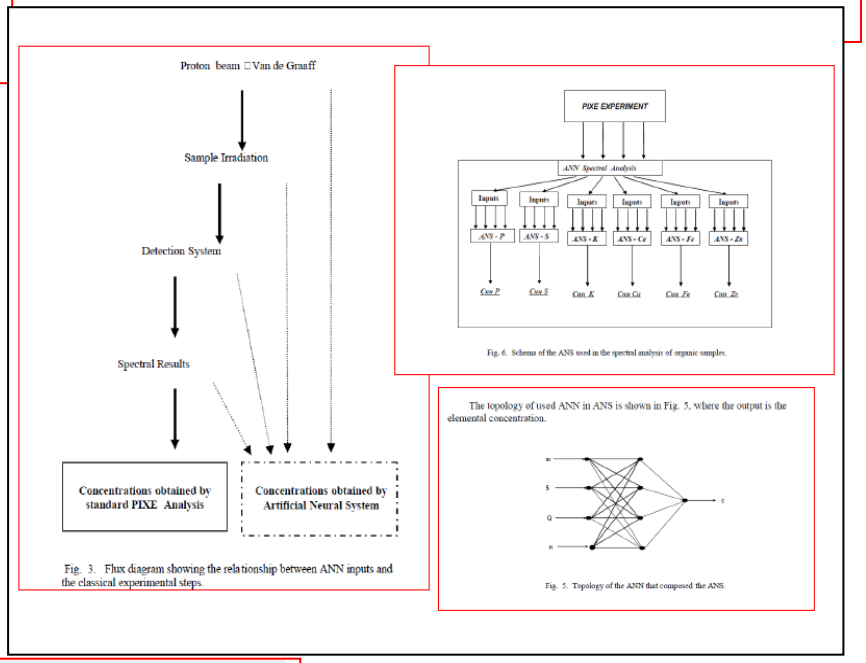


Fig. 3. Flux diagram showing the relationship between ANN inputs and the classical experimental steps.

Fig. 6. Schema of the ANS used in the spectral analysis of organic samples.

Fig. 5. Topology of the ANN that composed the ANS.

Source: International Journal of PIXE (IJPIXE) Online Volumes

Year: 2008 **Vol:** 18 **Issue:** 3/4 (2008) **Page:** 147 - 155 TOC

Algoritmo de Retropropagación del Error (BP)

$$E_K = \frac{1}{2}(y^K - O^K) \qquad (1)$$

Donde:

O^k es la salida calculada por la red

$y^k = (y_1^k, \ldots\ldots, y_n^k)$ es la salida esperada

$x^k = (x_1^k, \ldots\ldots, x_n^k)$ es el vector de entrada

La función de transferencia es de tipo sigmoidal.

$$O^K = (1 + \exp(-Wh^K))^{-1} \qquad (2)$$

Donde:

$h^k = (h_1^k, \ldots\ldots, h_L^k)$ es el vector de las salidas de la capa oculta y

$W = (W_1, W_2, \ldots\ldots\ldots\ldots, W_L)$ es el vector de pesos de la neurona de salida

$$h_l^K = (1 + \exp(-\sum w_l x^K))^{-1} \qquad (3)$$

$w_l = (w_{l1}, w_{l2}, \ldots\ldots, w_{ln})$ es el vector de pesos de la neurona oculta l, donde $l = 1, \ldots\ldots L$

La medida del error total es E:

$$E = \Sigma E_k \qquad (4)$$

Se utiliza el método del gradiente descendente para la minimización del error cuadrático medio E a través del siguiente proceso iterativo.

Al vector de peso W se le asigna el valor

$$W := W - \Delta W$$

Donde ΔW es la variación del peso, definido por la expresión

$$\Delta W = \eta \frac{\partial E_K(W, w)}{\partial W}$$

$\eta > 0$ es la tasa de aprendizaje

E_K se determina por la expresión (1) y considerando las expresiones (2) y (3), se obtienen los siguientes valores para W y w_l

$$W := W - \eta \frac{\partial E_K(W, w)}{\partial W} \qquad w_l := w_l - \eta \frac{\partial E_K(W, w)}{\partial W}$$

Realizando la adecuada derivación se obtiene

$$\frac{\partial E_K(W, w)}{\partial W} = \frac{1}{2}\frac{\partial}{\partial W}\left[y^K - \frac{1}{1+\exp(-W^T h^K)}\right]^2 = -(y^K - O^K)O^K(1 - O^K)h^K$$

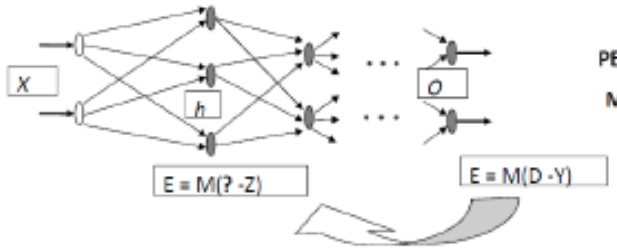
El vector de pesos en la salida $W = (W_1, \ldots\ldots, W_L)$ y los vectores de pesos w_l asociados a las neuronas ocultas ajustan su valor en cada ciclo de acuerdo a las siguientes expresiones.

$$W := W + \eta(y^K - O^K)O^K(1 - O^K)h^K = W + \eta\delta_K h^K \qquad W_l := W_l + \eta\delta_K h_l^K$$

Donde: $\delta_K = (y^K - O^K)O^K(1 - O^K)$ $\qquad \frac{\partial E_K(W, w)}{\partial w_l} = -O^K(1 - O^K)W_l h_l^K(1 - h_l^K)x^K$

$$w_l := w_l + \eta\delta_K W_l h_l^K(1 - h_l^K)x_j^K$$

Este proceso iterativo continúa hasta que se minimiza el error E en (4) hasta el valor deseado.



PERCEPTRON MULTICAPA

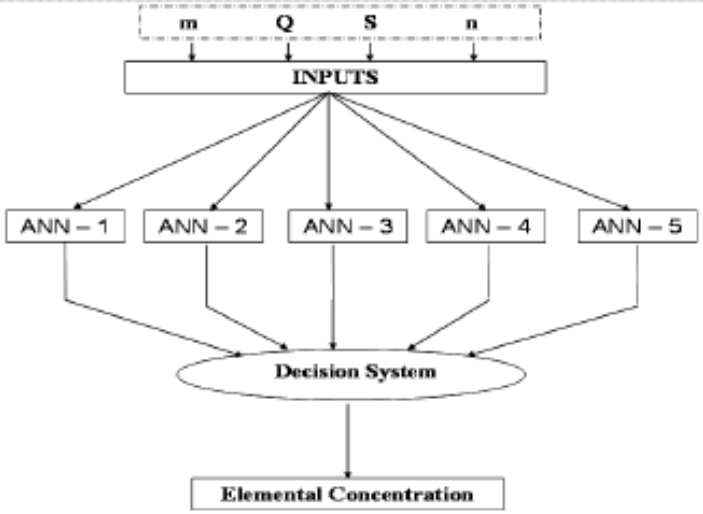
Error backpropagation algorithm:

Error: $\mathbf{E} = \sum_{pj} (t_{pj} - y_{pj})^2$

$\Delta_p w_{ji} = \eta\, \delta_{pj}\, x_{pi}$ $\quad \eta$ - learn rate

$\delta_{pj} = (t_{pj} - y_{pj}) y_{pj}(1 - y_{pj})$ $\quad$ si j de salida

$\delta_{pj} = y_{pj}(1 - y_{pj}) \sum_k \delta_{pk} w_{kj}$ $\quad$ *si j es oculta*



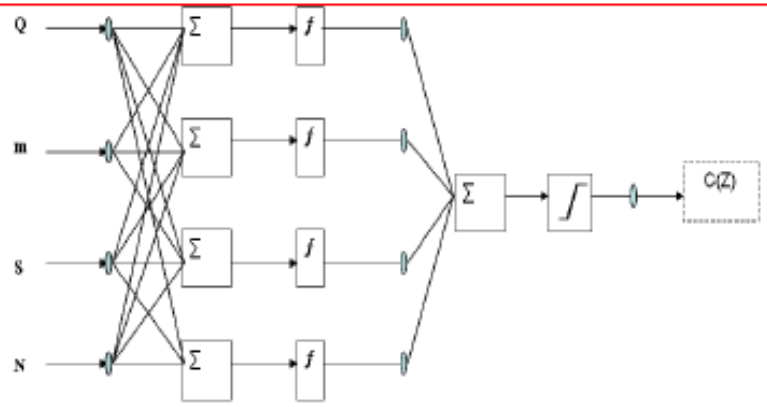
Schematic for ANS spectrum analysis for aerosol samples

- Several feed-forward ANN, of similar topology, operate in parallel inside each ANS trained with the well known back propagation algorithm in an independent process.
- The only difference is in the training process, so that the initial weights are different in each ANN, i.e., several ANN with the same topology and training set, are running at the same time.
- The ANS obtain the capacity to learn and apply this knowledge to unknown cases not included in the training phase.
- The input and output parameters in the training phase are the same for all ANN in the ANS.
- Each ANS output value is obtained by combining the ANN outputs in the decision system.
- The advantages in the use of a system of networks rather than single networks have been already shown

- For each one of the selected element a map with four input parameters was generated in an ANN, with three layers in the ANS, in order to provide a single output parameter, i.e. the elemental concentration *C(Z)*.
- The four input parameters were:

i. m, the deposited mass in the filter;
ii. Q, the total electric charge transported by the ions while crossing through the filter during irradiation;
iii. S, the size of the filter surface irradiated, and
iv. *N(Z)*, the total number of counts in peak.

Architecture of ANN used inside ANS



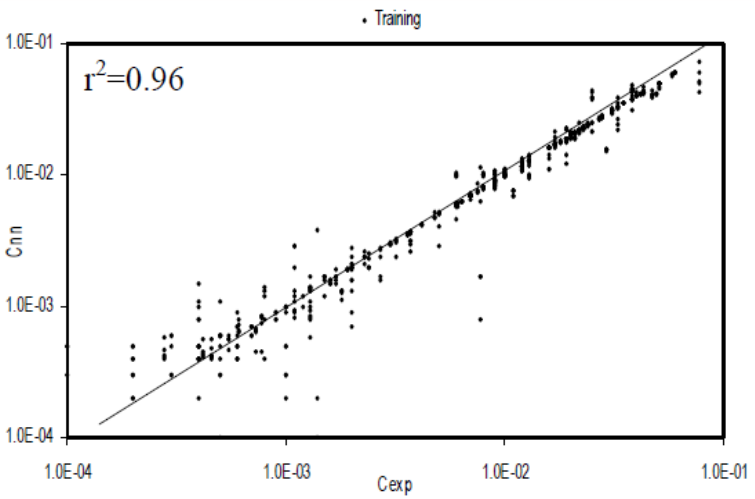


FIGURE 5. Predicted concentrations from ANS (C_{nn}) and expected concentration (C_{exp}) obtained from the training set

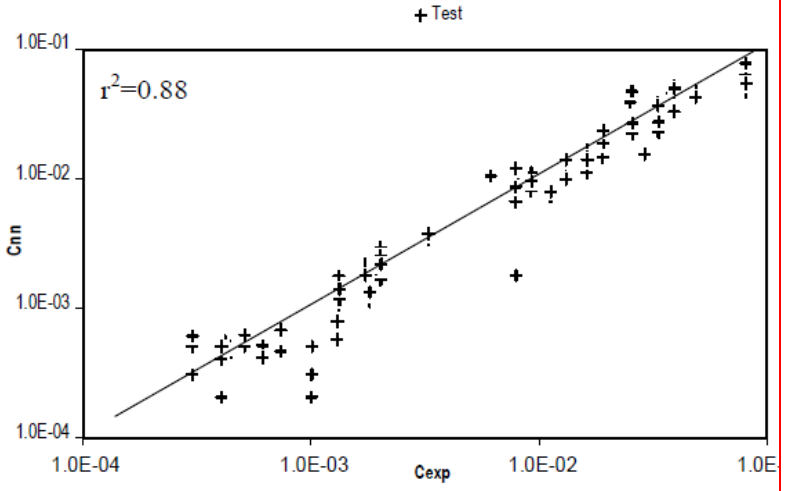


FIGURE 6. The predicted concentrations from ANS(C_{nn}) and expected concentrations (C_{exp}) in the test set.

TABLE I. Predicted concentrations (C_{nn}) from ANS analysis and expected concentrations(C_{exp}) in the test set

Aluminum - Al		Silicon - Si		Sulfur- S		Potassium- K		Iron - Fe	
Cnn %	*C exp* %	*Cnn* %	*C exp* %	*Cnn* %	*C exp* %	*Cnn* %	*C exp* %	*Cnn* %	*C exp* %
4.2E-02	4.9E-02	2.8E-01	2.5E-01	3.0E-02	3.3E-02	1.0E-02	8.0E-03	4.6E-02	3.8E-02
4.3E-02	3.8E-02	2.9E-01	1.7E-01	1.9E-02	1.9E-02	1.0E-02	6.0E-03	2.9E-02	2.5E-02
3.9E-02	2.5E-02	1.3E-01	1.4E-01	1.3E-02	1.6E-02	9.5E-03	9.0E-03	4.1E-02	4.7E-02
1.6E-02	2.9E-02	1.1E-01	1.7E-01	1.1E-02	1.3E-02	7.4E-03	1.1E-02	5.1E-02	7.8E-02
1.3E-03	1.8E-03	7.6E-02	6.9E-02	7.0E-04	1.0E-03	6.0E-04	5.0E-04	2.2E-03	1.7E-03
6.0E-04	7.0E-04	1.5E-03	1.3E-03	5.0E-04	3.0E-04	5.0E-04	6.0E-04	1.4E-03	1.3E-03
8.0E-04	1.2E-03	1.5E-03	1.2E-03	4.0E-04	4.0E-04	2.1E-03	2.0E-03	4.5E-03	7.7E-03

$$N_i(Z) = n_i(Z) + b_i(Z) \quad (1)$$

$$N_i'(Z) = N_i(Z) / N(Z)_{max} \quad (2)$$

and

$$n_i'(Z) = n_i(Z) / n(Z)_{max} \quad (3)$$

Since it has been observed that for each element, Bi(Z) fluctuates in a narrow range around the mean value $B(Z)_{mean}$, it can be expressed approximately as

$$B_i(Z) = B(Z)_{mean} +/- \sigma(Z) \quad (4)$$

From equations (4), $b_i(Z)$ can be expressed as

$$b_i(Z) \approx N_i(Z)(B(Z)_{mean} +/- \sigma(Z)) \quad (5)$$

and from equation (1)

$$n_i(Z) \approx N_i(Z)(1 - B(Z)_{mean} +/- \sigma(Z)) \quad (6)$$

where

$$k(Z) = 1 - B(Z)_{mean} \quad (9)$$

is a constant *and then*

$$n_i(Z) \approx N_i(Z)\,(k(Z) +/- \sigma(Z)) \quad (7)$$

So, the values n_{max} and N_{max} become related by a constant

$$n_{max}(Z) \approx N_{max}(Z)(k +/- \sigma(Z)) \quad (8)$$

Where

$$(k +/- \sigma(Z)) \approx n_{max}(Z)/N_{max}(Z) \quad (9)$$

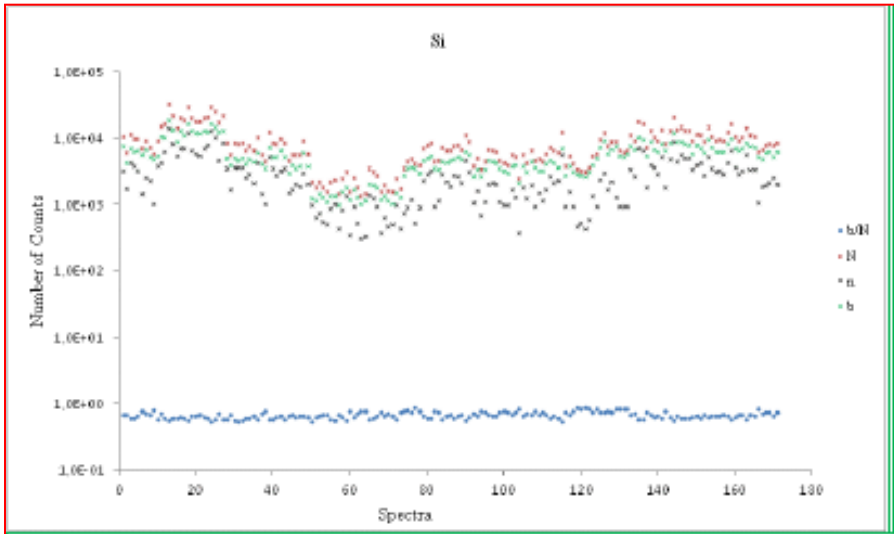
Combining with (7) it is found that the normalized values $n_i'(Z)$ and $N_i'(Z)$ are a like

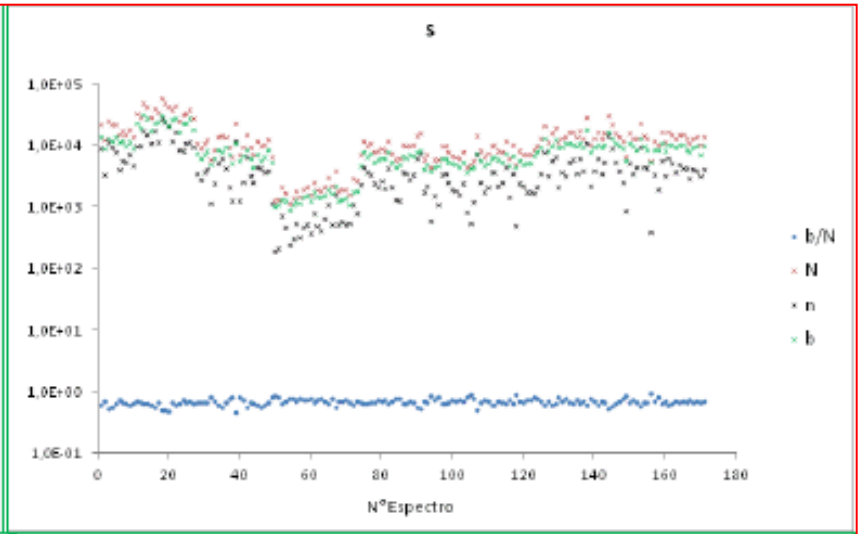
$$n_i'(Z) \approx n_i(Z) / n(Z)_{max} \approx N_i(Z) / N(Z)_{max} \approx N_i'(Z) \quad (10)$$

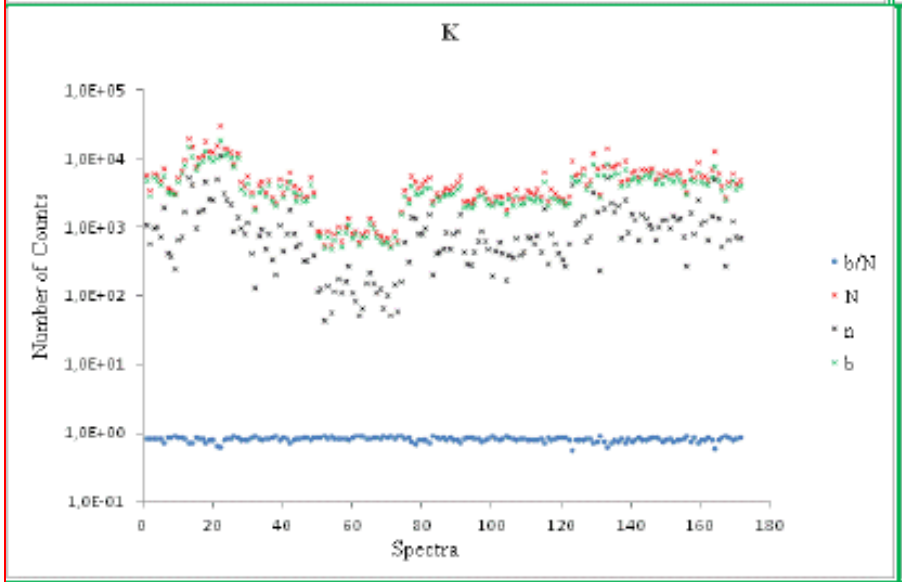
The similarity between $n_i'(Z)$ and $N_i'(Z)$ was verified for the most abundant elements (Si, S, K, Caa and Fe) in 172 spectra of aerosols collected in Mexico city.

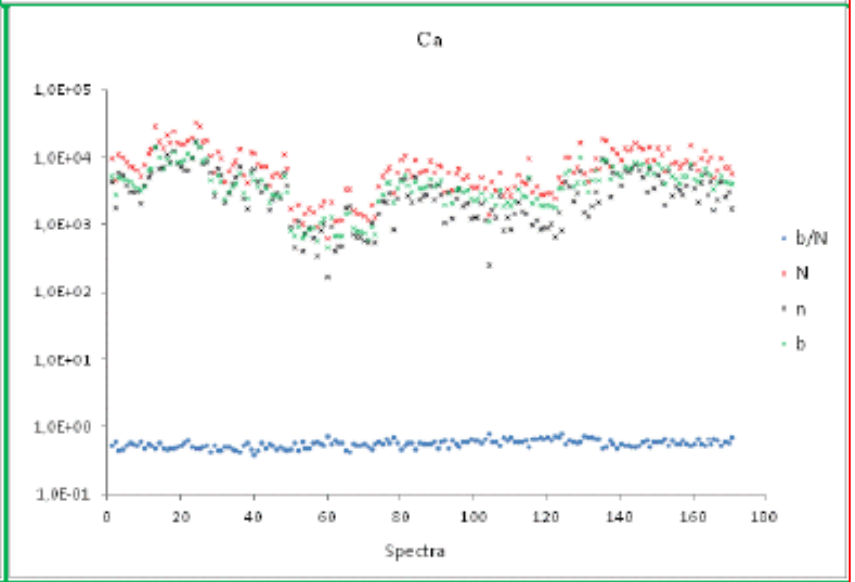
	$B(Z)_{mean}$	σ
Si	0.686	5.8×10^{-3}
S	0.692	6.0×10^{-3}
K	0.822	4.8×10^{-3}
Ca	0.574	6.0×10^{-3}
Fe	0.310	4.7×10^{-3}

The mean values $B(Z)_{mean}$ of the ratios $B(Z) = b(Z) / N(Z)$ for the major elements detected and their corresponding standard deviations.





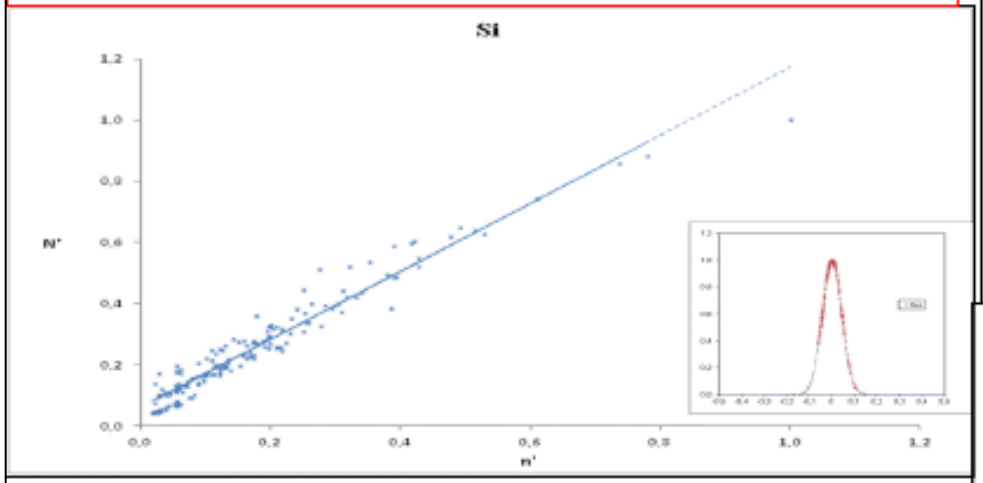


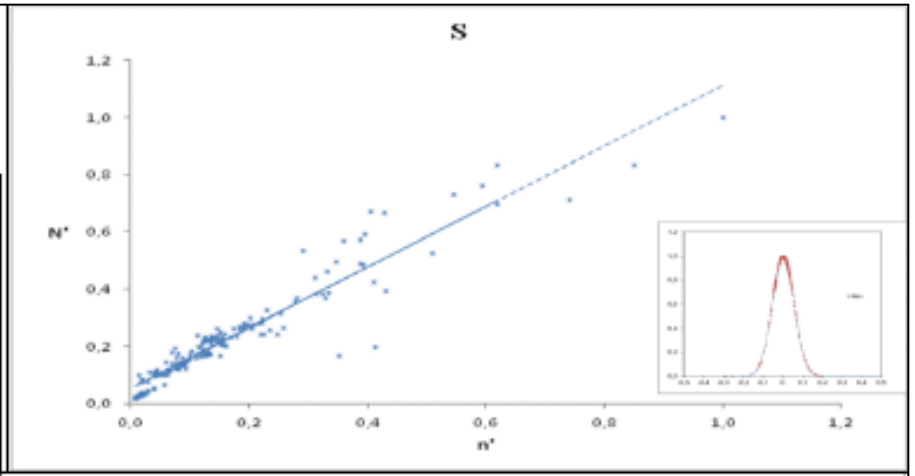


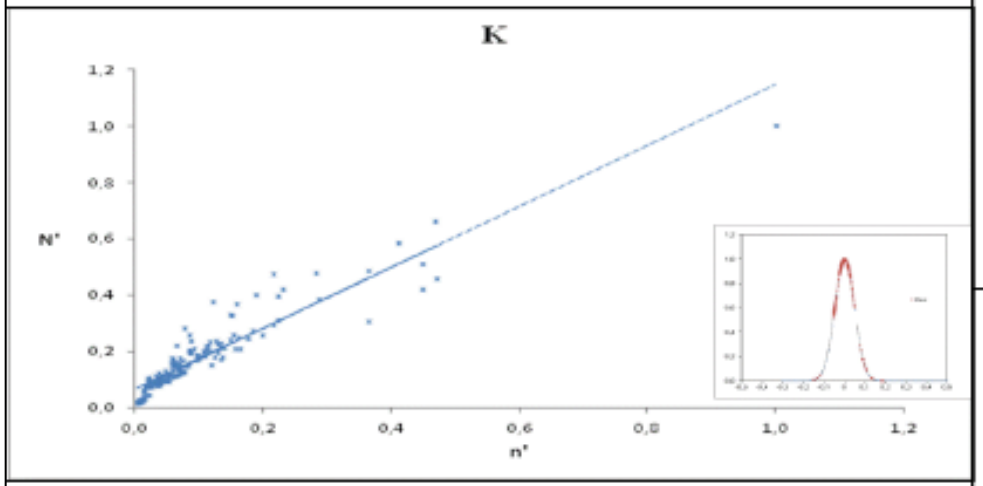
The figure illustrates the ratio between the number of counts in the background, *b*, to the total number of counts in the region of interest around the peak, *N*, for all 172 spectra analyzed

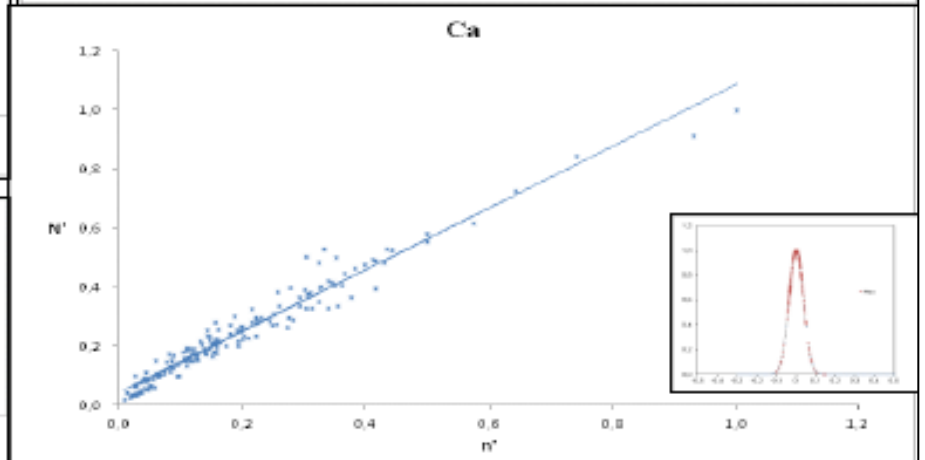
➢Correlation between the normalized total number of counts N´ and the normalized net number of counts n´.

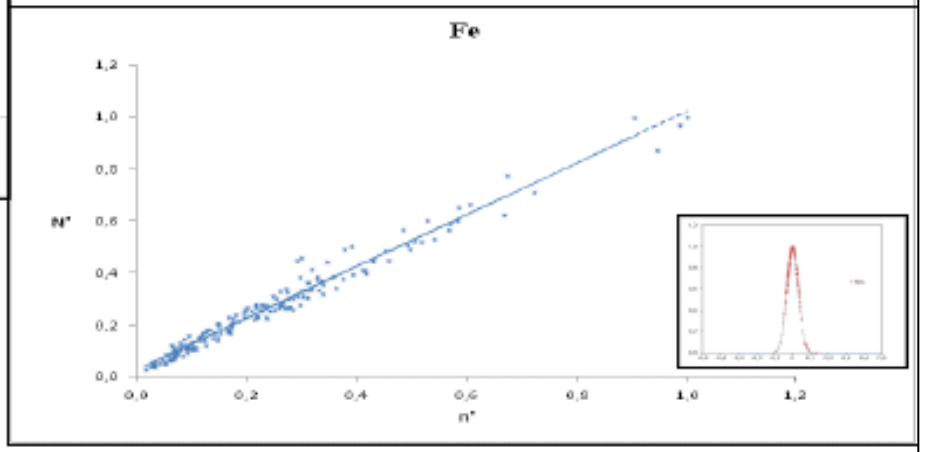
➢The residual distributions are shown in the inserted squares.











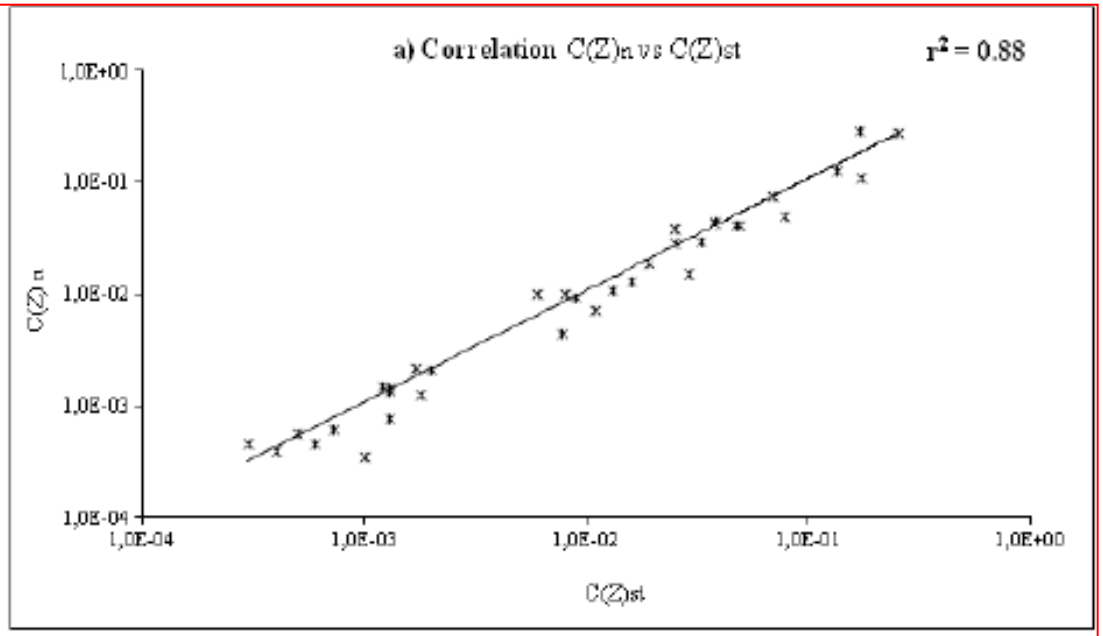
	r^2	σ
Si	0.95	4.07×10^{-2}
S	0.93	5.48×10^{-2}
K	0.87	4.84×10^{-2}
Ca	0.97	3.58×10^{-2}
Fe	0.99	3.19×10^{-2}

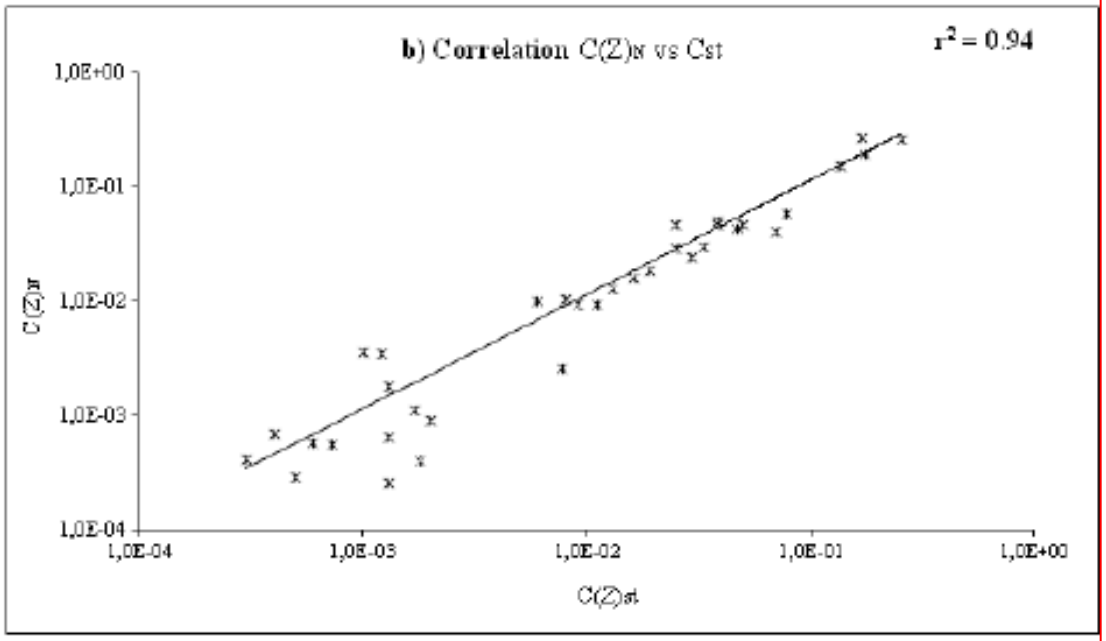
Concentrations, for the test set, of five elements, Si, S, K, Ca and Fe obtained by ANS using: a) the net number of counts in the peak, and b) the total number of counts in the peak, are compare with the expcted concentrations

$C\ (Z)_{st}$ expected concentrations determined by standard method (AXIL)

$C\ (Z)_{n}$ concentrations obtained by ANS using n(Z)

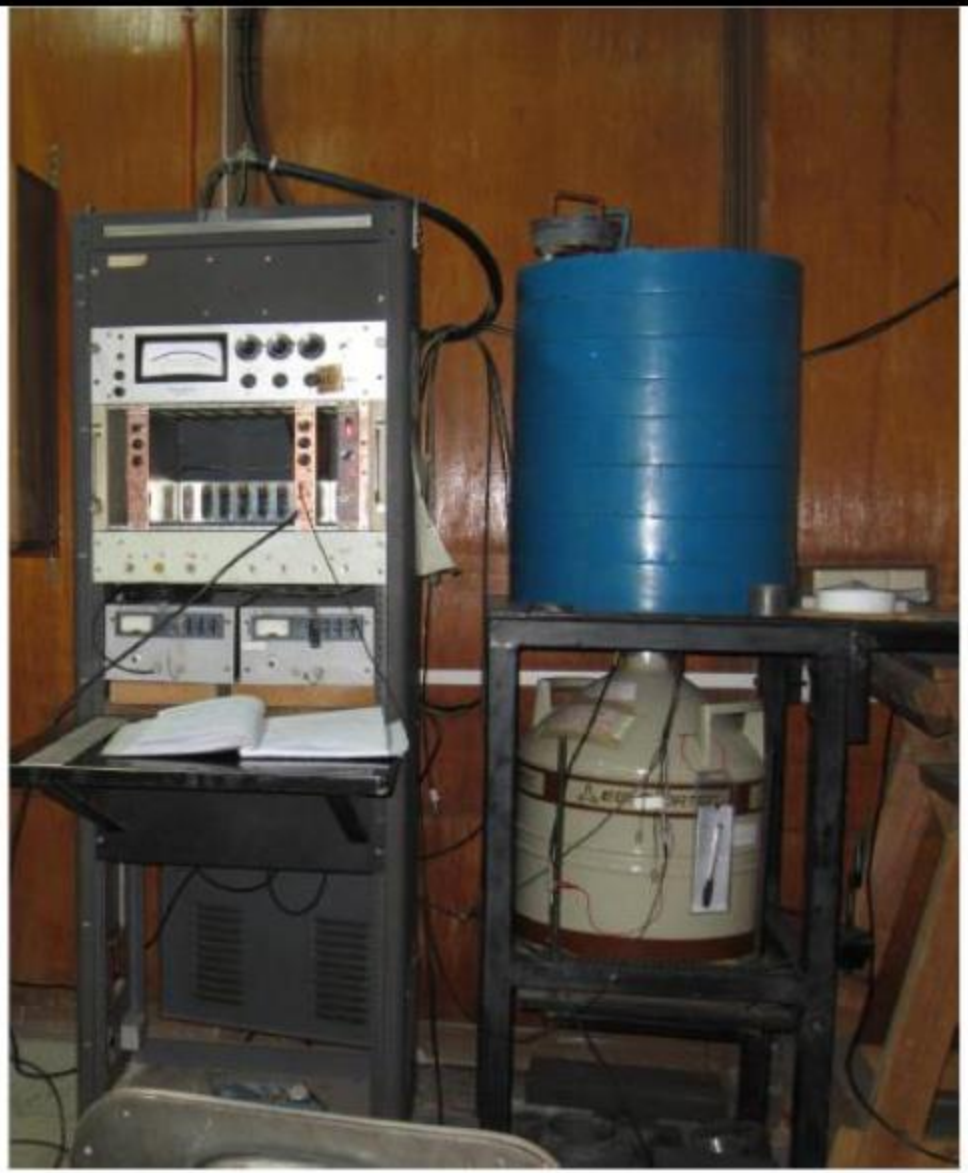
$C\ (Z)_{N}$ concentrations obtained by ANS using N(Z)

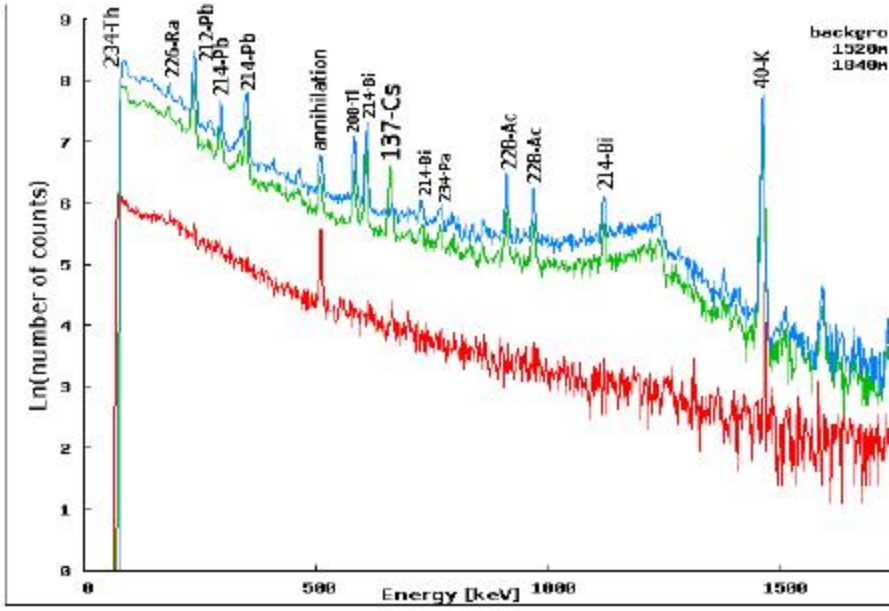




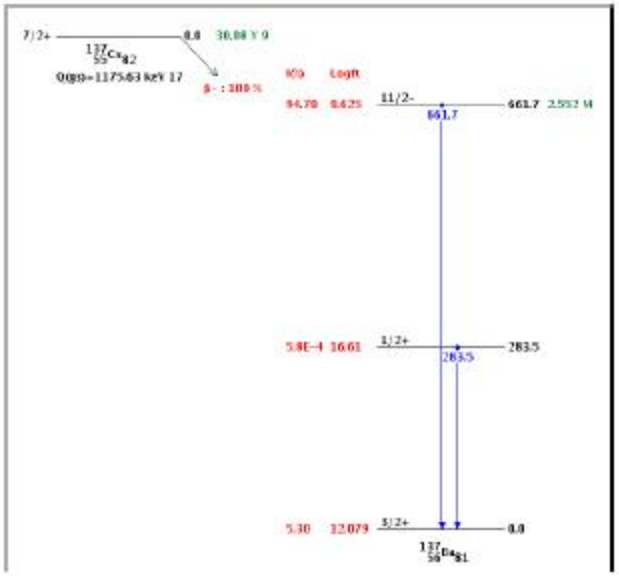
Análisis y Medición de Radiactividad Natural

Detector - HP Ge(Li)





Spectra from soil sample obtained at 1528 masl (green) 1840 masl (blue) showing the presence of ^{137}Cs background (red)



- Gamma-Ray HPGe Detector (ORTEC), Model GEM-10195.
- Detector is shielded by a cylinder of lead, 10 cm thickness with internal covers of cadmium

AIP | Conference Proceedings

Detection of 137Cs in the Andes Mountains near Santiago, Chile

R. Correa, J. R. Morales, L. Da Silva, S. Donoso, S. Godoy et al.

- The aim of the present work is to analyze soil samples from Andes mountains to detect the presence of radioactive elements and deduce its origin.
- The radioisotopes can be of natural or artificial origin. The first ones are related to those whose half-life are similar to the age of the Earth, while the second group have short half-life and are produced in nuclear experiments.
- Research on environmental radioactivity is important to estimate the impact caused by nuclear weapons and nuclear accidents.
- ^{137}Cs has a half-life of 30.1 year is an indicator of the existence of artificial radioactivity and is deposited in soils, lichens and moss trough radioactive fallout
- In this study we collected 14 samples at different altitudes above sea level in the range of (900m – 1800m) in the Andes mountain of Santiago, Chile (37.8 S – 62.7 W)
- Radionuclides originated in the decay series of ^{232}Th and ^{238}U , and ^{40}K, were detected in thirteen soil samples and in one from river sediment. All the soils samples contained the radioisotope ^{137}Cs.
- The detection of gamma radiation was carry out at the Nuclear Physics Laboratory of the Faculty of Sciences, University of Chile, using a high resolution spectroscopy system with a HPGe detector.

Soils samples were collected in mountainous region of Santiago

BAÑOS MORALE

LO VALDES

TABLE 1. Samples identification and their main characteristics.

Sample	Altitude (masl)	$^{137}Cs/^{40}K$	Soil type
1	1892	0.045	B
2	1840	0.015	B
3	1760	0.036	B
4	1677	0.228	A
5	1594	0.027	B
6	1520	0.313	A
7	1444	0.045	B
8	1348	0.025	B
9	1284	0.636	A
10	1203	0.052	B
11	1078	0.019	B
12	1008	0.184	A
13	918	0.029	B

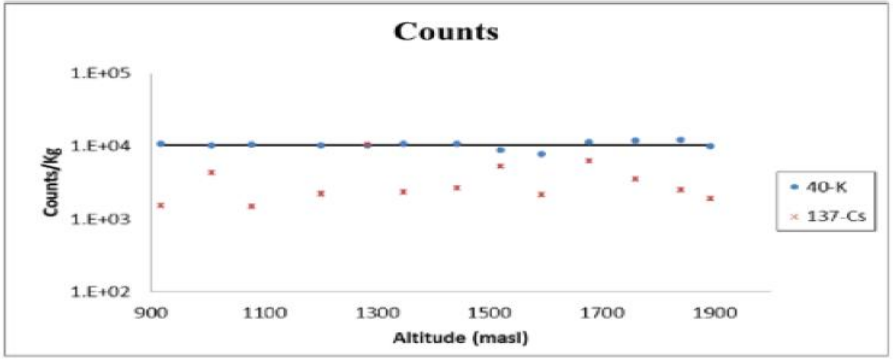
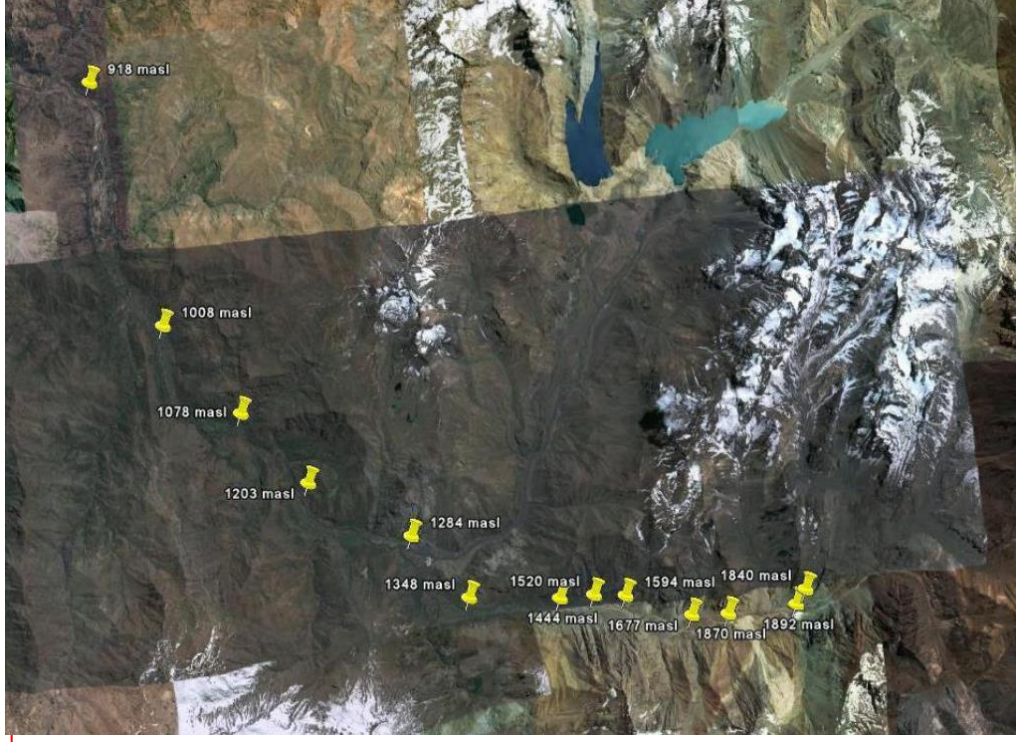


FIGURE 2. Relative activities of ^{137}Cs and ^{40}K.



Geographical Location

Measurement of Activity Concentration

- ^{238}U Activity Concentration was determined by using the next gamma lines

  ^{214}Pb → 295.2 and 351.9 keV

  ^{214}Bi → 609.3, 1120.3 and 1764.8 keV

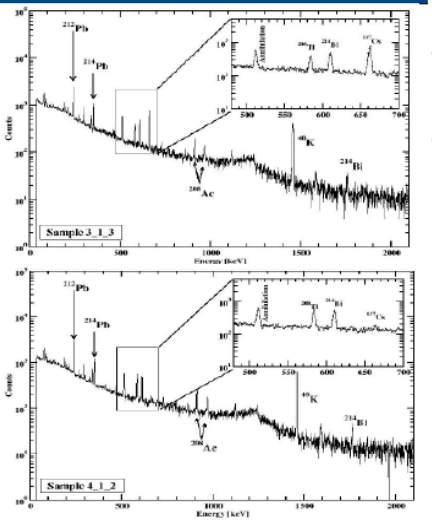
- The ^{232}Th activity was determined using:

  ^{212}Pb → 238.6 keV

  ^{208}Tl → 583.3 keV

  ^{228}Ac → 338.6, 911.1 and 968.9 keV

- The activities of ^{40}K and ^{137}Cs were determined directly from the 1460.8 and 661.6 keV, respectively.



- Spectra were collected during 48 hours. Background spectrum was measured in the same time interval.
- Radionuclide ^{137}Cs detected in 3 samples (M1, M2 and M3), but not present in Soil Sample M2 (altitude 2703 m).

AIP | Conference Proceedings
Detection of 137Cs in the Andes Mountains near Santiago, Chile
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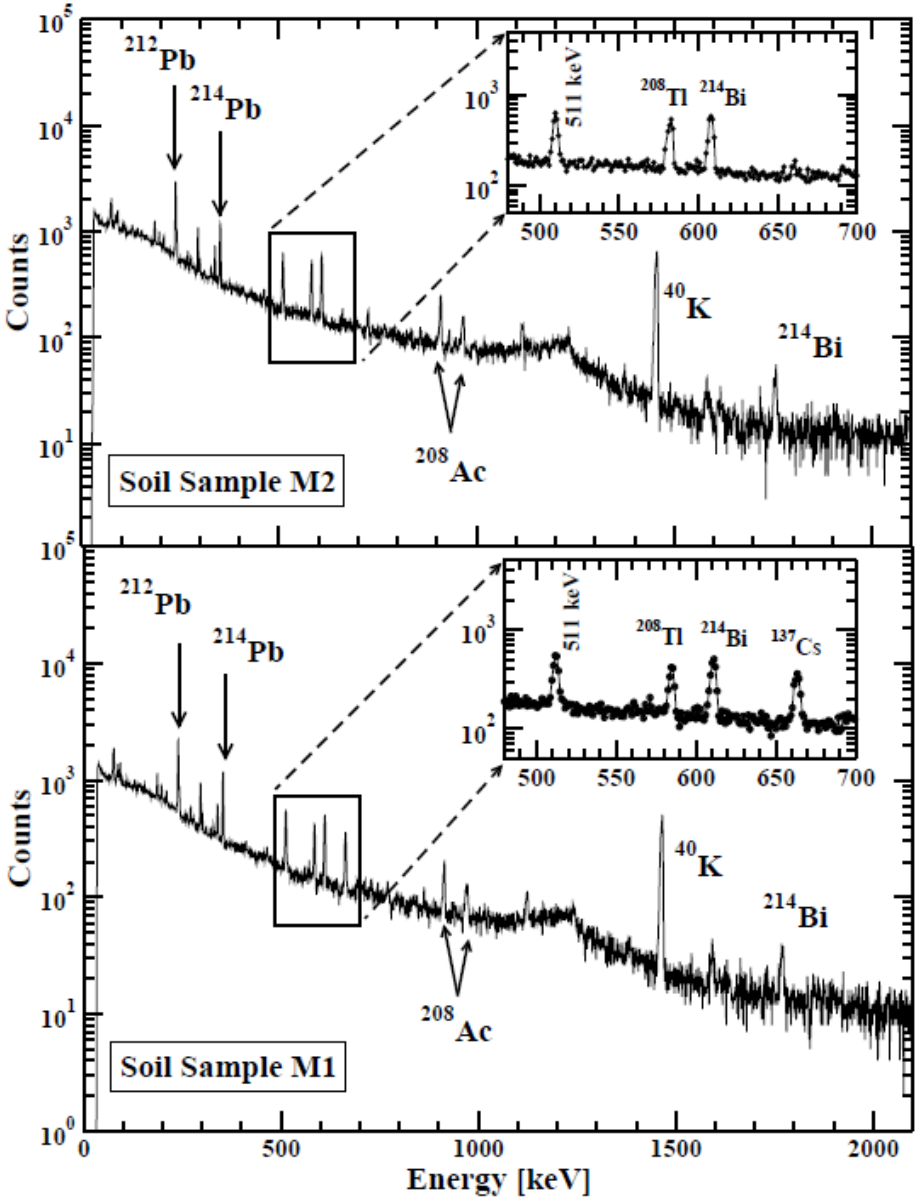


Figure 2. Gamma spectra corresponding to soil samples collected in two different locations at the Andes Cordillera. In the upper part, the gamma spectrum shows that anthropogenic radionuclide ^{137}Cs is not present in site M2 while in the lower part the gamma energy peak at 662 keV is easily detected in sample M1

Comparison of natural radioisotope concentrations in volcanic pyroclast samples from Chilean volcanoes.

VOLCANOES CONSIDERED IN THIS WORK

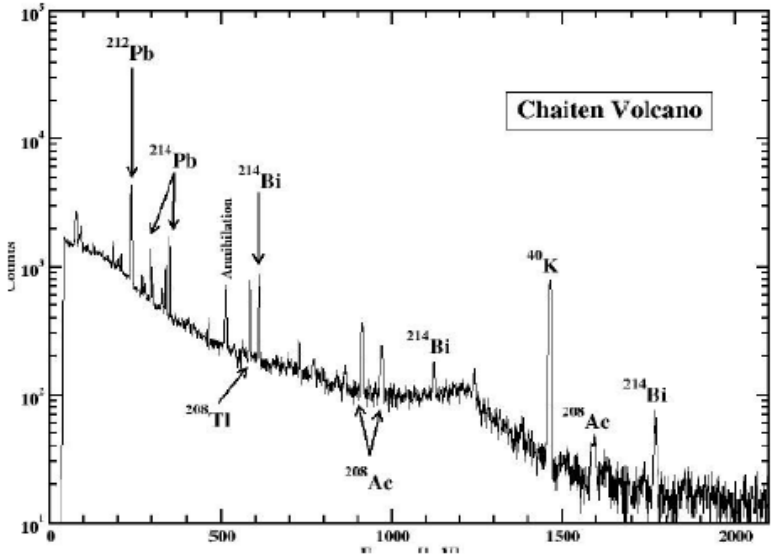
Lonquimay. 38°22′44″S 71°35′34″W
2865 masl
Last eruption 25 / 12 / 1988

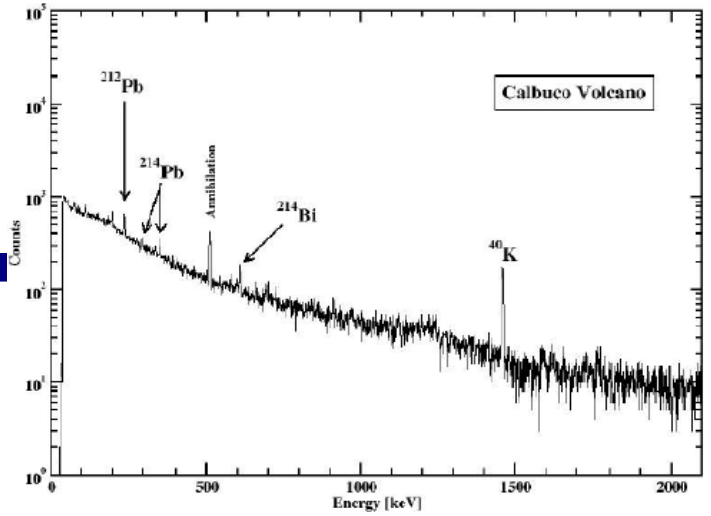
Puyehue (Caulle). 40°35′00″S 72°07′00″W
2240 masl
Last eruption 04 / 05 / 2011

Calbuco. 41°19′58″S 72°36′40″W
2003 masl
Last eruption 30/04/ 2015.

Chaitén. 42°49′58″S 72°38′45″W
1122 masl
Last eruption 02 / 05 / 2008

Hudson. 46°14′00″S 72°58′00″W
1905 masl
Last eruption 27 / 10 / 2011





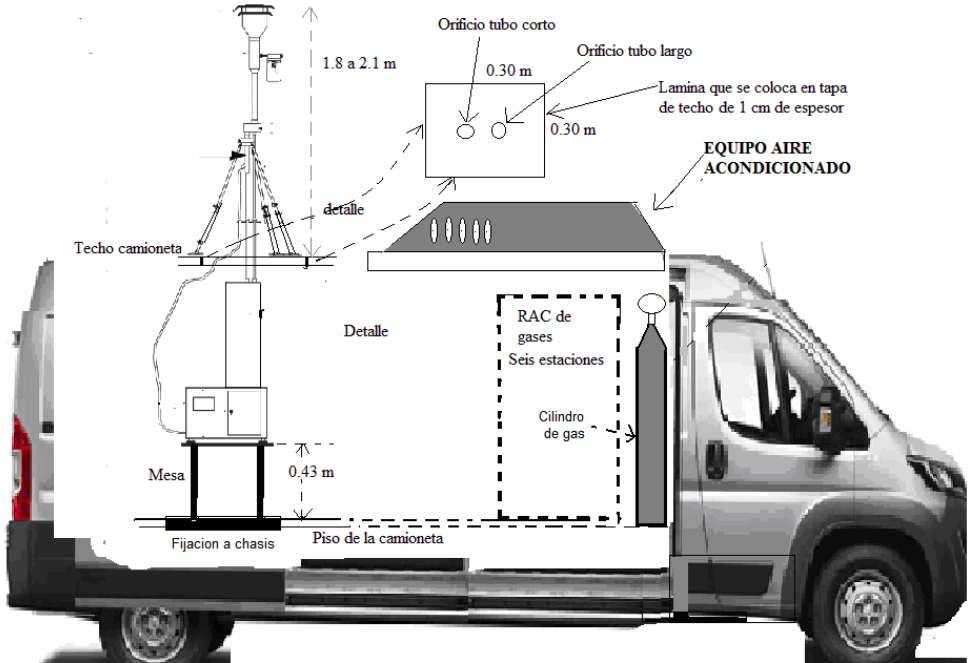
Main Results and Analysis

	Chaiten	Caulle	Calbuco	Hudson	Lonquimay	World Average	World Range
$A(^{238}U)$ [Bq/kg]	38,4 ± 2,5	20,8 ± 1,5	3,1 ± 0,5	19,2 ± 1,4	13,7 ± 1,1	35	17-60
$A(^{232}Th)$ [Bq/kg]	54,0 ± 2,3	25,7 ± 1,3	3,4 ± 0,4	20,8 ± 1,1	14,5 ± 0,9	30	11-64
$A(^{40}K)$ [Bq/kg]	885 ± 58	548 ± 40	85 ± 10	565 ± 39	305 ± 25	400	140-850
$Ra_{eq} < 370$ [Bq/kg]	183,8	99,7	14,5	92,4	58,0		
$H_{ex} < 1$	0,50	0,27	0,04	0,25	0,16	0,5	
D [nGy/h]	90,2	49,5	7,2	46,3	28,6	92	
AEDE [μSv/yr]	110,6	60,7	8,9	56,7	35,1	46,0	

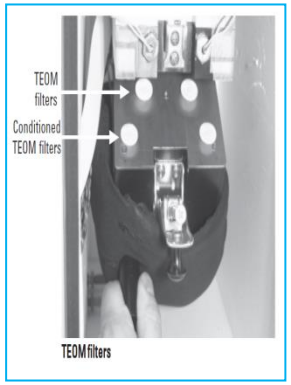
	Chaiten	Caulle	Calbuco	Hudson	Lonquimay	World Average	World Range
$A(^{238}U)$ [Bq/kg]	38,4 ± 2,5	20,8 ± 1,5	3,1 ± 0,5	19,2 ± 1,4	13,7 ± 1,1	35	17-60
$A(^{232}Th)$ [Bq/kg]	54,0 ± 2,3	25,7 ± 1,3	3,4 ± 0,4	20,8 ± 1,1	14,5 ± 0,9	30	11-64
$A(^{40}K)$ [Bq/kg]	885 ± 58	548 ± 40	85 ± 10	565 ± 39	305 ± 25	400	140-850
A_U/A_{Th}	0,71	0,81	0,93	0,92	0,95		
A_U/A_K	0,043	0,038	0,037	0,034	0,045		
A_{Th}/A_K	0,061	0,047	0,039	0,037	0,047		
$Ra_{eq} < 370$ [Bq/kg]	183,8	99,7	14,5	92,4	58,0		
$H_{ex} < 1$	0,50	0,27	0,04	0,25	0,16	0,5	
D [nGy/h]	90,2	49,5	7,2	46,3	28,6	92	
AEDE [μSv/yr]	110,6	60,7	8,9	56,7	35,1	46,0	

Unidad Móvil para el Estudio y Análisis de la Calidad del Aire

Estudio y monitoreo de la calidad del aire en zonas urbanas y rurales.
(Vinculación con el medio)



Thermo Scientific TEOM 1405-DF Ambient Particulate Monitor



TRILOGÍA. diciembre 2015

R. CORREA - C. RÍOS - J. WACHTER - P. PACHECO

Equipo de medición de gases

A continuación se presentan en sus características principales los medidores de contaminantes atmosféricos, la estación meteorológica y los modem.

a) Equipo de medición de material particulado PM10 y PM2.5

b) Analizador de Ozono, que utiliza fotometría ultravioleta, OZ2000 de la serie Seres 2000 con sistema modular (16 Bit, 220V/50Hz, 4-20mA).

b) Analizador de Óxidos de Nitrógeno en aire ambiente NO- NOX 2000 de la serie Seres 2000. El principio de medición está basado en una reacción química entre el ozono (O3) y el NO. Un fotomultiplicador mide la intensidad de la luz emitida, en una longitud de onda ubicada en el rojo (1000nm).

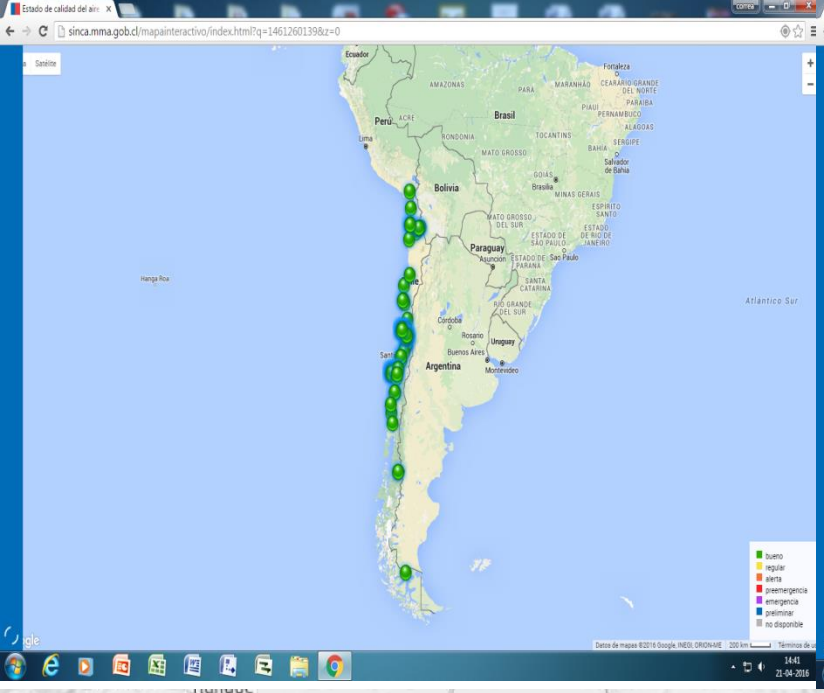
c) Analizador de amoniaco NH32000, de la serie Seres 2000 (220V/50Hz, 4-20mA).

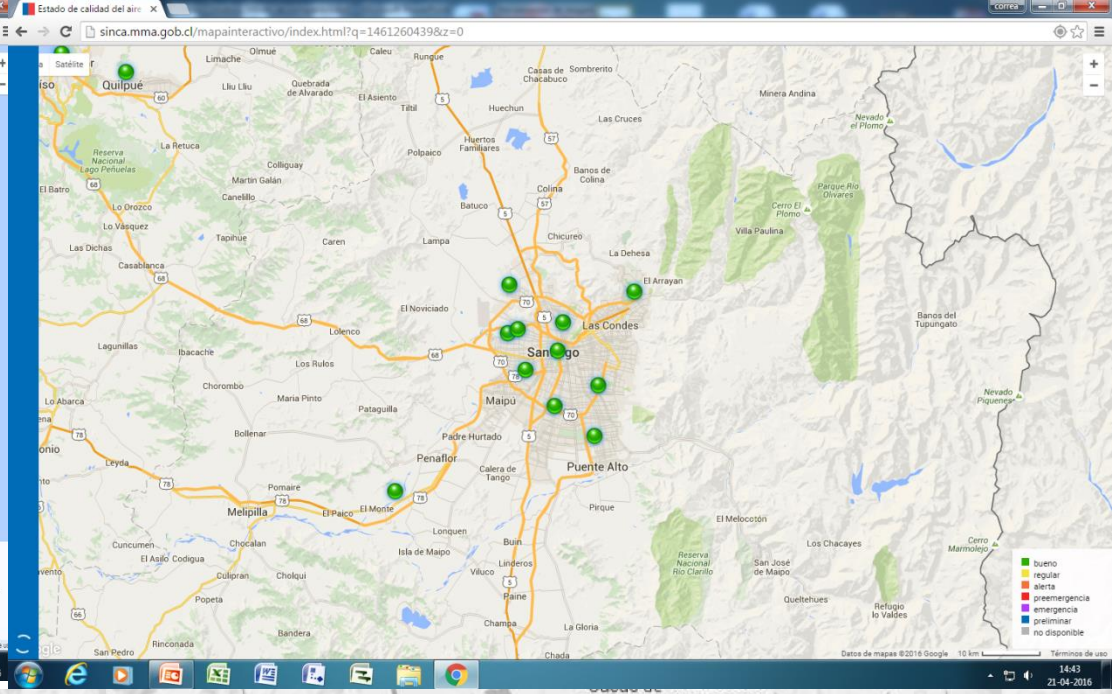
d) El rack de análisis de variables meteorológicas, consiste de:

1 taquio-anenómetro (DNA 501) ;
1 gonio anemómetro (DNA 510) ;
1 Termo higrómetro (DNA 533);
1 radiómetro (DPA 560) ;
1 barómetro (DQA 201)(24 V (AC), 4-20mA).

e) Un sistema de adquisición y transmisión de datos, DATA 2000, de la serie Seres 2000. La unidad de control y monitoreo es automática, esto asegura independencia de las unidades de análisis. Funciones:

- Scaneo de datos.
- Indicador de señales con problemas.
- Transmisión a un PC de los datos almacenados (1.200, 220V/50Hz, 4-20 mA).

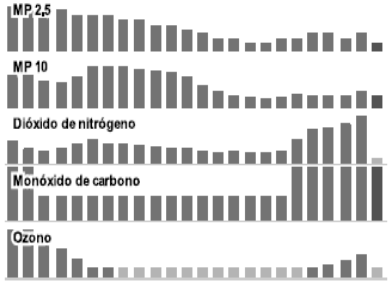




Parque O'Higgins

Comuna de Santiago

ver ficha | niveles | concentraciones horarias | descargar CSV



2016-04-21 13:52:55 UTC-4

Fecha y hora de consulta

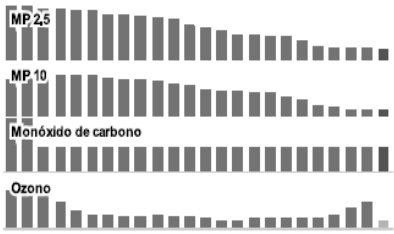
Últimos registros obtenidos

estado	parámetro	valor
bueno 2016-04-21 12:00	MP 2,5 media móvil 24 h	24,1 µg/m^3 48 ICAP
bueno 2016-04-21 12:00	MP 10 media móvil 24 h	56,9 µg/m^{3}N 38 ICAP
bueno 2016-04-21 12:00	Dióxido de nitrógeno concentración 1 h	62,8 ppbv
bueno 2016-04-21 12:00	Monóxido de carbono media móvil 8 h	1,4 ppmv
bueno 2016-04-21 12:00	Ozono concentración 1 h	13,9 ppbv

Cerrillos

Comuna de Cerrillos

ver ficha | niveles | concentraciones horarias | descargar CSV



2016-04-21 13:55:23 UTC-4

Fecha y hora de consulta

Últimos registros obtenidos

estado	parámetro	valor
bueno 2016-04-21 12:00	MP 2,5 media móvil 24 h	20,3 µg/m^3 41 ICAP
bueno 2016-04-21 12:00	MP 10 media móvil 24 h	41,8 µg/m^{3}N 28 ICAP
bueno 2016-04-21 12:00	Monóxido de carbono media móvil 8 h	1.0 ppmv
bueno 2016-04-21 12:00	Ozono concentración 1 h	22,6 ppbv

Acelerador Lineal de Electrones

Marca	VARIAN
Modelo	Clinac 21 ex
N° de serie	1606
Fecha de construcción	Agosto de 2000
Energías de tratamiento	Electrones de 6,9,12,15,18 MeV (de acuerdo a BJR 17 Fotones de 6 y 18 MV de acuerdo a BJR 17
Tasas de tratamiento	Fotones de 100, 200, 300, 400, 500 y 600 MU/min electrones de 100, 200, 300, 400, 500 y 600 MU/min.
Alta tasa de electrones de	1000 MU/min
Accesorios	Sistema de colimación multihoja. Sistema de imágenes de visión portal.
Estado del equipo	Operable para docencia
Valor mercado	US$ 2.500.000,00
Situación de entrega	Comodato a 100 años

VARIAN
medical systems

INSTITUTO NACIONAL DEL CÁNCER
CHILE

specifications

Clinac iX Accelerator

Innovative platform for today, solid foundation for the future

Convenios Nacionales

-Comisicón Chilena de Energía Nuclear - CCHEN

-Universidad de Chile

-Instituto Nacional del Cáncer. - INC

-Academia Politécnica militar del Ejército de Chile - ACAPOMIL

Convenios Internacionales

-Universidad de Granada, Decsai, España

-Centro Nacional de Aceleradores – CAN, Universidad de Sevilla

-Universidad Autónoma de Madrid, España - CMAM

-Universidad Politécnica de Madrid, ETS

1986 – Universidad de Chile, Fac. De Ciencias.

Ciclotrón

ÁREAS TEMÁTICAS

El simposio abarcará las siguientes áreas temáticas relacionadas con la tecnología nuclear

- Educación Superior (pre y postgrado)
- Capacitación docente
- Capacitación profesional (operadores, personal regulador)
- Educación permanente/continua
- Actividades de Extensión/Divulgación
- Actividades para favorecer la aceptación pública de las aplicaciones nucleares
- Gestión del conocimiento en educación, capacitación, extensión
- Metodologías docentes/procedimientos e instrumentos de evaluación para modalidades presenciales, semi-presenciales y no-presenciales de enseñanza/capacitación
- Recursos didácticos innovadores con integración de TIC