DETERMINATION OF TRACE ELEMENT CONCENTRATIONS IN HUMAN HAIR OF SOME GLASS FACTORY WORKERS BY THE K_0-METHOD

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الخلاصـــة :

عند تطبيق أسلوب التحليل التنشيطي بالنيوترونات أمكن تعيين التركيزات المختلفة للعناصر الشحيحة لشَعْر بعض عمال مصانع الزجاج في مصر . وقد استُخدمت طريقة (K_0) بأسلوب معياري جديد ، وأُخذ بعين الاعتبار معالجة الأخطاء الناتجة من انحراف توزيع فيض النيوترونات فوق الحرارية عن الحالة المثالية لقانون ($1/E$) وكذلك العوامل الأخرى المؤثرة على كفاءة العدّاد .

ولإثبات كلٍّ من دقة وصحة القياسات باستخدام هذه الطريقة فقد شُعِّعَتْ العيِّنات في مكانين مختلفين للتشعيع حيث الفارق الكبير بينهما في عدد النيوترونات الحرارية والفوق حرارية ، وقد أمكن تشعيع ثلاثمائة عيِّنة من شَعر الرأس للكشف عن ستة وعشرين عنصراً .

لقد أظهرت النتائج أن الاختلاف فى تركيز العناصر بين شَعر عمال مصانع الزجاج وغيرهم يرتبط بالتلوث الخارجي .

ABSTRACT

By applying instrumental neutron activation analysis techniques, a survey was carried out to determine the levels of a variety of trace element concentrations in human hair from some glass factory workers in Egypt, using a K_0-method as a new standardization technique, in which the deviation of the $1/E^{1+\alpha}$ epithermal neutron flux distribution from $1/E$-law, true coincidence effects of cascade γ-rays, and the efficiency of the Ge(Li) detector were taken into consideration. To prove its precision and accuracy, the method has been applied to the analysis of elements irradiated in two facilities of the Egyptian Research Reactor which have different spectral indices. Three hundred head-hair samples were analyzed and twenty-six elements instrumentally determined. The results obtained show that the variability of the hair content among the group is strongly linked to external contamination.

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1. INTRODUCTION

During the past few years, there has been an increasing realization of the importance of trace elements in biological systems. This awareness has been stimulated by the rising concern of the impact of man on his environment, and of its biological effect as reflected on him.

Human hair has attracted attention as one of the biological indicators of environmental pollution, because the trace element composition of hair can serve as a fairly reliable indicator of contamination of a human body by the corresponding pollutants, and also because tissue samples are easily accessible from a living person.

In order to expedite the study of trace elements in complex biological matrices, methods for multi-elemental analysis of high sensitivity for a large number of samples are required. This demand has enhanced the value of purely instrumental reactor neutron activation analysis, with its relative simplicity and its inherent selectivity.

A number of studies using this method have been reported on the trace element contents in hair of inhabitants of different regions of the world [1]. In general, however, the reported values can hardly be compared with each other because the concentrations of trace elements in hair vary significantly under different conditions, such as hair treatments. This fact makes intercomparison of data from different laboratories difficult, because the constituents of the population whose hair was analyzed are quite different from one laboratory to another.

In the present work, instrumental neutron activation analysis of trace elements in hair of some glass factory workers has been performed using the k_0 method.

2. K_0-NEUTRON ACTIVATION ANALYSIS

When applying the K_0-method [2–4] to reactor neutron activation analysis (RNAA), the concentration of an element i can be calculated from the following equation:

$$i,\ \text{ppm} = \frac{10^6}{W} \times \frac{1}{K_{0,\text{Au}}(i)} \times \frac{\left[\dfrac{N_p/tm}{(SDC)}\right]_i}{\left[\dfrac{N_p/tm}{SDC\,w}\right]_{\text{Au}}}$$

$$= \frac{F + Q_{0,\text{Au}}(\alpha)\,\epsilon_{p,\text{Au}}}{F + Q_{0,i}(\alpha)\,\epsilon_{p,i}}$$

where the weight of the sample (W) and the weight of the comparator (w) are expressed in the same units, and Au is the selected comparator.

In the above equation, the following parameters need to be considered [5].

$$K_{0,\text{Au}}(i) = \frac{M_{\text{Au}}\,\theta_i\,\sigma_{0,i}\,\gamma_i}{M_i\,\theta_{\text{Au}}\,\sigma_{0,\text{Au}}\,\gamma_{\text{Au}}},$$

K_0-factors, listed in Table 1.

N_P = peak area, to be corrected for real coincidence effect [6] and corrections for spectral interferences and ^{235}U-fission can be performed with increased accuracy by applying K_0-factors [7].

S, D, C = saturation, decay and counting factors; appropriate formula for specific count rate calculations.

F = thermal-to-epithermal flux ratio; can be determined by coirradiation with the sample of a Zr-foil (^{95}Zr–^{97}Zr) [5].

$Q_{0(\alpha)} = \dfrac{Q_0 - 0.429}{E_r^{\alpha}} + \dfrac{0.429}{(2\alpha+1)(0.55)^{\alpha}}$, ratio of the resonance integral to the 2200 m s^{-1} cross section (Q_0), corrected for non-ideality of the epithermal spectrum ($1/E^{1+\alpha}$);
Q_0: the principles applied for the experimental determination and the critical evaluation of Q_0-values were outlined and applied [8];
Q_0-values with related parameters are included in Table 1.

α = the experimental determination of the non-ideality of the epithermal spec-

trum has been elaborated in detail [7,9] a simple procedure using a Zr-foil together with a 0.5% Au–Al wire allows simultaneous α and F - determination.

E_r = effective resonance energy, recently introduced in activation analysis, E_r values were calculated for 96 isotopes [10].

ϵ_P = full energy peak efficiency; a procedure for the calculation of ϵ_P including γ-attenuation) for bulky samples at any source–detector distance was presented and proved to be accurate to within 2–3% [6].

Table 1. Nuclear Data Involved in the Present Study.

Element	Isotope Produced	Q_0 [8]	E_r (eV) [10]	$T_{1/2}$	E_γ (keV)	K_0 [4, 12, 13]
Na	^{24}Na	0.59	3130	14.96 h	1368.6 2753.8	4.68×10^{-2} 4.62×10^{-2}
Al	^{28}Al	0.73	8240	2.2405 m	1779.0	1.75×10^{-2}
Cl	^{38}Cl	0.69	306 000	37.3 m	1642.7 2167.5	1.97×10^{-3} 2.66×10^{-3}
Ca	^{49}Ca	0.45	—	8.72 m	3084.2	1.01×10^{-3}
Sc	^{46}Sc	0.44	4110	83.8 d	889.3 1120.5	1.21 1.21
Ti	^{51}Ti	0.67	49 900	5.76 m	320.1 928.6	3.74×10^{-4} 2.65×10^{-5}
V	^{52}V	0.55	5960	3.75 m	1434.0	1.96×10^{-1}
Cr	^{51}Cr	0.53	5940	27.70 d	320.1	2.65×10^{-3}
Mn	^{56}Mn	1.07	412	2.577 h	846.8 1810.7 2113.0	4.96×10^{-1} 1.35×10^{-1} 7.17×10^{-2}
Fe	^{59}Fe	0.96	325	44.50 d	1099.2 1291.6	7.52×10^{-5} 5.76×10^{-5}
Co	^{60}Co	2.03	133	5.272 y	1173.2 1332.5	1.31 1.32
Cu	^{64}Cu	1.14	742	12.701 h	511.0 (annih) 1345.8	3.44×10^{-2} 4.91×10^{-4}
Zn	^{65}Zn	1.96	853	243.8 d	1115.5	5.60×10^{-3}
Br	^{80}Br	11.4	51.4	17.6 m	616.9	6.67×10^{-3}
Sr	^{87m}Sr	4.11	672	2.806 h	388.5	1.49×10^{-3}
Zr	^{95}Zr	5.88	4520	64.03 d	724.2 756.7	9.14×10^{-5} 1.11×10^{-4}
Ag	^{110m}Ag	17.7	6.00	249.7 d	884.7	2.64×10^{-2}
In	^{116m}In	16.8	1.51	54.15 m	1293.5	2.39
Sb	^{124}Sb	28.8	24.9	60.20 d	1690.9	1.43×10^{-2}
Cs	^{134}Cs	18.4	8.68	2.062 y	604.7	4.33×10^{-1}
Ba	^{139}Ba	0.75	20 400	83.1 m	165.9	1.05×10^{-3}
Tb	^{160}Tb	17.9	11.4	72.3 d	298.6	8.20×10^{-2}
Lu	^{177}Lu	0.32 [11]	—	6.7 d	208.4	7.11×10^{-2}
Hf	^{181}Hf	2.52	—	42.4 d	133.6 (E_{eff})	2.38×10^{-2}
Ir	^{192}Ir	3.95 [11]	—	74.2 d	316.5	3.67
Au	^{198}Au	15.7	5.47	2.696 d	411.8	≡1

3. EXPERIMENTAL

During 1983 and 1984 a total of 300 human head-hair sample (100 males) were collected from some glass factory workers from various regions of Egypt so as to represent a cross-section of this group. The sample for each individual was taken from three spots on the head, then, it was cut as close as possible to the scalp, generally within a few millimeters.

The samples were washed with distilled water, acetone, and ether, and then dried in an oven at 40°C. About 15–40 mg samples, in polythene ampoules, were sealed and irradiated for 20s in a pneumatic tube facility of the Egyptian Research Reactor, where the thermal neutron flux and spectral index were $1.13 \times 10^{13} n cm^{-2} s^{-1}$ and 3.2×10^{-2}, respectively.

The radionuclides ^{28}Au, ^{38}Cl, ^{49}Ca, ^{51}Ti, ^{52}V, ^{56}Mn, ^{139}Ba, ^{80}Br, ^{116m}In, and ^{87m}Sr were measured for 200s within 6m after irradiation. The measurement system is composed of an ORTEC 40 cm^3 Ge(Li) detector and a 4096 channel pulse height analyzer. The radionuclides such as ^{46}Sc, ^{51}Cr, ^{59}Fe, ^{65}Zn, and ^{181}Hf, were measured for 1000s with ten days cooling after 48 hours irradiation, where the thermal neutron flux and spectral index were $1.32 \times 10^{12} n cm^{-2} s^{-1}$ and 3.5×10^{-4}, respectively.

The decays during the measurements and dead time losses in the multichannel analyzer were corrected. The peak areas in the γ-ray spectra were calculated as reported in reference [7]. From the individual results, the geometric means and the antilogarithm of the standard deviation of the logarithms were obtained from samples which showed detectable contents.

4. RESULTS AND DISCUSSION

As has already been mentioned, one of the main aims of this work was to develop a new standardization technique in RNAA. The analytical results obtained by considering 100 subjects (males) using the K_0-method are given in Table. By comparing the data for glass factory workers (cases) with the data on trace element concentrations in hair for normal populations living in the same parts (normal) the following conclusions can be drawn: it is clear that Sc, Cr, Mn, Fe, Co, Zn, Zr, Ba, Cs, Sb, Ag, Hf, Ir, and Au have higher concentrations in the cases, whereas the reverse occurs for Na, Cl, Ti, In, and Tb. The concentrations of other elements such as Al, Ca, V, Cu, Br, and Sr are less influenced.

Table 2. Concentrations of Elements in Human Head Hair (Normal and Cases) in ppm

Element	Geometric means Normal	Geometric means Cases
Na	2121.1 $\times/\div$ 1.38	1891.8 $\times/\div$ 1.41
Al	60.2 $\times/\div$ 1.88	63.2 $\times/\div$ 1.31
Cl	3421.5 $\times/\div$ 2.05	3083.7 $\times/\div$ 1.55
Ca	422.87 $\times/\div$ 2.44	409.6 $\times/\div$ 1.81
Sc	0.21 $\times/\div$ 1.54	1.10 $\times/\div$ 1.79
Ti	175.3 $\times/\div$ 1.94	131.9 $\times/\div$ 1.89
V	13.51 $\times/\div$ 1.47	13.51 $\times/\div$ 1.53
Cr	0.56 $\times/\div$ 1.73	1.03 $\times/\div$ 1.76
Mn	5.92 $\times/\div$ 1.41	8.69 $\times/\div$ 1.43
Fe	411.9 $\times/\div$ 1.89	448.7 $\times/\div$ 1.69
Co	1.49 $\times/\div$ 2.11	8.27 $\times/\div$ 1.83
Cu	384.75 $\times/\div$ 1.49	358.6 $\times/\div$ 1.90
Zn	89.70 $\times/\div$ 1.77	121.7 $\times/\div$ 1.36
Br	30.3 $\times/\div$ 1.52	29.6 $\times/\div$ 1.77
Zr	58.29 $\times/\div$ 1.99	125.1 $\times/\div$ 2.1
Ag	3.67 $\times/\div$ 1.67	4.42 $\times/\div$ 1.96
In	2.69 $\times/\div$ 1.38	2.24 $\times/\div$ 1.87
Sb	9.39 $\times/\div$ 1.87	13.44 $\times/\div$ 1.86
Cs	0.41 $\times/\div$ 1.74	0.77 $\times/\div$ 1.99
Ba	0.62 $\times/\div$ 1.45	1.55 $\times/\div$ 1.83
Tb	0.93 $\times/\div$ 1.28	0.84 $\times/\div$ 1.26
Lu	0.062 $\times/\div$ 2.10	—
Hf	0.75 $\times/\div$ 1.98	1.20 $\times/\div$ 1.93
Ir	0.035 $\times/\div$ 1.75	0.062 $\times/\div$ 1.97
Au	0.16 $\times/\div$ 1.85	0.22 $\times/\div$ 2.0
Sr	7.51 $\times/\div$ 1.14	7.11 $\times/\div$ 1.88

The result show, that many factors such as: hair treatment, dental treatment, age, sex, state of health, and the degree of impact of the environment, have some influence on the trace element.

We suggest that more work should be done on human hair elemental composition and its correlation in terms of age, sex, hair treatments, etc.

CONCLUSION

Neutron activation analysis has proved a useful and informative technique in the study of trace and toxic metals in hair, and to obtain more realistic estimates much more work needs to be done.

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