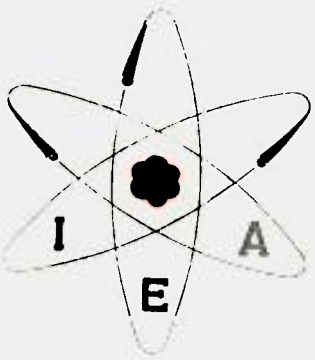

ACTIVATION ANALYSIS APPLIED TO FORENSIC INVESTIGATION

SOME OBSERVATIONS ON THE PROBLEM OF INDIVIDUALIZATION OF HUMAN HAIR

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ACTIVATION ANALYSIS APPLIED TO FORENSIC INVESTIGATION

Some Observations on the Problem of Individualization of Human Hair

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SUMÁRIO

Estuda-se a variação da concentração de elementos inorgânicos ao longo dos fios dos cabelos humanos, por meio da comparação dos espectros de raios gamas de duas amostras de cabelos irradiadas. Dá-se atenção especial à influência do ciclo de crescimento do cabelo na composição do mesmo, no que diz respeito à composição dos elementos inorgânicos. Fáz-se a comparação de cabelos de diferentes partes do corpo (cabeça e pubis). Apresenta-se uma discussão de como êstes fatos podem afetar um problema de individualização de dois cabelos humanos.

RESUMÉ

On étudie la variation de la concentration des éléments inorganiques au long du cheveux humaines par comparaison du espectro-gamma de deux échantillons irradiées.

On donne ici une attention spéciale a l'influence du cycle de croissance du cheveux sur sa composition, en ce qui concerne les éléments inorganiques.

Comparaison de la composition des cheveux des différentes parties du corps (tête et région pubienne) est faite, aussi bien que des cheveux à différentes périodes de leurs cycles de croissance.

On discute l'influence de ces facteurs sur le problème d'individualization.

SUMMARY

Variation of concentration of inorganic elements along human hair's lenght is studied through the comparison of the gamma spectra of two samples of irradiated hair. Special attention is given to the influence of the growing cycle of the hair on its composition, as far as the inorganic elements are concerned. Comparison of composition of hairs from different parts of the body (head and pubic hair) is also made as well as of hairs at different times of their growing cycles. A discussion of how these facts can affect the problem of individualization is made.

I. INTRODUCTION

In the study of the appendages of skin, on the view point of Forensic Sciences, hair takes a distinctive place due to the fact it has great importance in criminal investigation. Owing to its anatomic localization it is subjected to intensive vulnerability during the acts of criminal actions, specially by the instruments of agression, as well as by the mechanisms of defense. Frequently, criminal investigation is faced with problems where the fundamental trace is the presence of hair in the hands of the victim, or in the instrument of the crime, or in the surroundings where the criminal action took

place. In some cases, that trace is reduced to the presence of only a single hair.

Although the importance of hair has been stressed in criminalistic literature, the problem of individualization of hair by classical means still presents some weak points. Efforts on the way of individualization by lenght of hair, medullar index, etc., or other classical means have shown that they are not always reliable. Hairs from the same individual and from the some scalp are similar to each other but not identical, as far as size, shape, degree of pigmentation, lenght, etc. are concerned. Attention has been called by Gonzales "et al." /1/ that, for the purpose of individualization of hairs mere similarity is not sufficient and that another individual may have scalp hair similar to the specimen under consideration.

Jervis "et al." /2/, /3/, /4/, /5/ and Guinn /6/ have shown that the problem of individualization of hair can be definitely improved by means of the analysis of inorganic elements present in the hair, through the comparison of the gamma-spectra of two irradiated hair samples.

A complete chemical analysis of all elements present in the hair would be unpractical, specially if one takes into account that the amount of elements to be analysed is very small and that, frequently, only one single hair is available for examination. Consequently, very sensitive methods of analysis would have to be employed. Activation analysis would suit the requirements of analysing very small amounts of inorganic elements present in the hair and often, by application of instrumental methods, the analysis of various elements in one single test, can be made. Besides, in a way, it can be considered a non-destructive method, allowing use of the sample as

evidence to be presented in courts, if such is the case.

Perkons "et al." /3/ have shown that by considering, for instance, the elements copper, bromine, zinc and sodium, the possibility of encountering two persons with similar compositions of these elements in hair is about 1:15,000 and that if ten of possible thirty elements present in the hair are compared it is possible to individualize the hair of one person out of fifteen billion.

Although the method of investigation is of definite value there are still some points which must be ascertained in order that a systematization can be made in such a way that it can be applied, if not with the same simplicity as checking fingerprints, but with the same degree of certainty.

Of special importance to consider is the fact that hairs grow in cycles and composition of different hairs taken, for instance, from the scalp of the same person, may be different if the hairs are not in the same period of the cycle. That the composition of hair may alter along its lenght is a known fact, and a good example is the variation of arsenic concentration along Napoleon's hairs lenght, as examined by Smith "et al." /7/. Kerr /8/ has already called attention to the fact of the influence of the growing cycle of hair composition.

Hairs at the end of their life cycles are in a resting period and since they are not growing any more the shaft do not incorporates inorganic elements brought to the root by the blood supply. These hairs are the most easily ones to be plucked and removed. They remain inactively in the skin for some time while new hairs start growing and incorporating in-

organic elements brought by the blood supply. Depending on changing of feeding habits, for instance, environmental conditions of living, or even some intercurrent pathological state, the proportion of inorganic elements present in the blood may have changed and a new hair would have different composition from the inactive one.

If one considers the whole lenght of hairs, the shaft of an active hair and of an inactive one may not be very different, as far as the composition of inorganic elements is concerned, if comparison is made between an active hair and another one which has become inactive recently. Alteration of proportion of some inorganic elements that may have taken place at the root of the active hair may not still have appeared in the shaft of the active hair. The rate of growth of scalp hair is about 0.35mm per day /9/ and in a month the hair will have grown only about one centimeter. If two hairs are compared, one actively growing and one which has been in its quiescent period for only a month, the eventual difference between both hairs will be owed to the first centimeter in both samples. If the two hairs are long this difference may not be too noticeable. However the difference may be pronounced, even in the shaft, if comparison is made between an active growing hair and one which has been inactive for quite a long time.

One must have in mind that hairs more liable to be found in the crime scene, are the ones more easily to be plucked, i.e, the ones at the end of their life cycles. The composition of these hairs may show differences by the time of the criminal investigation, if suspect's hair used for comparison is not at the same period of the cycle of the hair he may had left at the crime scene. This fact is even more important when one considers that a variable time elapses between the

criminal action and the time of suspect's arrestment, and the longer this time is, more care must be exercized for making conclusions.

Also, it may happen that hair removed during the criminal action may be sectioned in some point perpendicular to its lenght and not at the skin level. Considerable differences in composition may be found along the lenght of sufficiently long hair. This is more true in the case of women in which scalp hairs with twenty or thirty centimeters lenght are not difficult to be found, representing periods of life of about two years.

In this paper observations made in connection with the mentioned facts, and which may influence the problem of individualization of hairs, if not taken into account, are presented. Special attention is given to the variation of concentration of some elements along the hair's lenght.

Some observations made in connection with the comparison of hairs from different parts of the body, such as pubic and scalp hair, as far as composition of inorganic elements is concerned, are also presented.

One of the lines of research which has been considered of outmost importance is to look for close-group influence in hair's composition, such as in workers at a same plant, for instance. Evidence up to now accumulated does not seem to be conclusive. It has been reported that workers in a selenium plant had increased amounts of selenium but the excess over the "normal" variations was not too high to allow conclusions concerning a person's occupation /3/, /5/.

However, hair's analysis of workers in an arsenic plant showed an extremely high concentration of that element, much above the maximum showed in frequency distribution curves. Trying to bring some contribution to the mentioned problem of close-group influence, the results of the arsenic's analysis will also be reported.

2. COMPARISON OF GAMMA-SPECTRA OF IRRADIATED HAIRS

If two samples of an homogeneous material are irradiated in the same conditions as far as neutron flux, geometry and irradiation time are concerned, and gamma-spectra of the activated samples are obtained also under the same experimental conditions and at the same cooling time, the two spectra will be equal, within counting and experimental errors. The radioisotopes formed in the sample could, at least in principle, be identified by means of the energy of the photopeaks in the spectra as well as by the rate which the corresponding activities decay. Having found that the two samples have the same radioisotopes and at the same proportion, inference would be made that the two samples would represent the same material.

The conclusion that two samples are taken from the same homogeneous material, however, can be made without the necessity of specific identification of the radioisotopes corresponding to each peak. It is sufficient that both spectra be equal and that the modifications of the spectra at different times of measurements, or decay, for both samples, be the same if they have been irradiated in the same conditions. It is not even necessary that the masses of both samples be equal since the spectra may be compared in logarithmic scale.

The problem of individualization of hairs is based

on these facts. In general, comparison is made of the spectra of the two hairs samples irradiated and counted at the same conditions. If the spectra are the same, whatever is the irradiation and cooling times, provided these times are equal for both samples, the corresponding radioisotopes are the same and the two hair samples were taken from one sole material, meaning from the scalp, for instance, of one individual, if every hair from the scalp have all the same composition, qualitative and quantitatively.

The criterion used to consider equal two spectra have already been discussed by Jervis /4/, /5/ who sows that the gross photopeak counting rate may be taken, including contributions from the Compton scattering, or a net portion of the peak estimated graphically to exclude Compton gammas. In fact, the analog recordings of the gamma-ray spectra show sufficient differences between dissimilar samples and sufficient similarity between samples from one individual. In this way visual identification can be made without having to resort to more elaborate comparison techniques.

2.1 Experimental

The techniques of preparing hair's samples for irradiation consists in washing the sample three times with distilled water (5 to 20ml each time, depending on the sample mass), followed by a three times washing with acetone-methanol mixture 1:1 and a final three times rinse with distilled water. The samples are dried in a current of warm air, weighed and place in polyethylene or filter paper envelopes for irradiation. After irradiation samples were usually removed from the polyethylene or filter paper envelopes, in order that no interference on counting, caused by external contamination on envelopes, would exist.

Times of irradiation may be chosen in order to activate, separately, short-lived radioisotopes (such as vanadium, iodine, chlorine, manganese), medium-lived radioisotopes (sodium, copper, arsenic, gold) and long-lived ones (such as bromine, zinc, mercury). However, if spectra comparison of two short irradiation periods of two samples shows that they are not equal, the samples are not equal themselves, being unnecessary to carry on with longer irradiation. Besides, in order that a conclusion may be reached that two hairs samples are equal the evolution of the spectra of two samples, with time, must be the same, indicating the same elements at both samples and at the same proportions.

For the study reported in this paper comparison were usually made through the examination of short-lived radioisotope's spectra. For these cases the irradiation period was in general, five, ten and thirty minutes at a thermal neutron flux of 5×10^{12} n/sec. cm^2. Using a pneumatic rabbit system, counting could be started 20 seconds after irradiation. The same irradiation and cooling times were always observed when comparing samples. Cooling was, usually, two minutes in order that samples could be removed from the polyethylene or filter paper envelopes in which they had been irradiated. Counting of samples were performed using a Model 404 TMC multichannel analyser coupled to a NaI (Tl) well scintillation crystal.

When no sufficient information could be get from the short irradiation period concerning difference or identity of samples, a longer one, in general from six to eight hours, was resorted to. Cooling times for the longer irradiation experiments were of the same order of the irradiation period, so that short-lived radioisotopes, whose information had been used when of the short irradiation, would have decayed and the

spectra would be compared through other radioisotopes.

In general, all counting data were normalized to one milligram samples.

3. COMPARISON OF HAIR'S COMPOSITION ALONG ITS LENGHT

Very recently Kerr /8/ stressed the importance of considering the hair's cycle when analysing single hair specimens, since one specimen may be actively growing and the other in its quiescent or resting phase and this fact would bring, as consequence, variability among hairs from the same individual. This variability should be much less in composite hair strands, in accordance with Jervis /4/.

During the investigation reported in this paper various cases were met in which important variability between different segments of the same strand of hairs, was observed. This variability, indicating cycle influence, was observed not only in single hairs, as mentioned by Kerr /8/, but even in hair strands. Variability may not be very pronounced between two subsequent segments, specially if these segments are of short lenght and hence, corresponding to about the same period in the hair cycle. However, large and larger variability may be observed if the various subsequents segments are compared with one of them taken as comparison standard (for instance, the one nearest to the scalp). Cases in which long strands of women's hair of about 30 centimeters were compared, showed marked differences between the first half of the strand (cut a 15 centimeters from the scalp end) and the other half. If one bears in mind situations as presented in the Introduction of this paper, when, eventualy, the hair strand is sectioned in some point of its lenght during the criminal action, it is seen the importance of considering and study this variability.

In Table I it is presented the data concerning the gamma-spectra of 4cm long fractions taken from a strand of scalp hair of total lenght of 28 cm (woman hair). Each fraction had a weight of aproximately 50 mg, with the exception of the last one which had 13 mg. Counting data were normalized to one milligram. Irradiation and cooling times, for this example, were 10 minutes and 2 minutes respectively, and thermal neutron flux $\times 10^{12}$ n/sec. cm^2. Comparison was made by taking the quotient of the activity of corresponding channels or energies, of two samples (net peak height), taking the first 4 cm fraction, nearest to the scalp, as reference.

TABLE I

Comparison of 4 cm fractions of strand of hair

Q \ C	46	51	60	70	84	104	160
1/1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2/1	2.2	0.9	0.6	0.6	1.0	1.2	0.3
3/1	1.5	0.9	0.6	0.7	1.1	1.2	0.3
4/1	1.4	1.1	0.8	0.7	1.3	1.5	0.4
5/1	3.7	1.3	0.8	1.3	1.9	1.6	0.5
6/1	17.4	1.3	0.9	1.1	1.5	1.5	0.5
7/1	60.0	1.7	1.1	1.0	2.1	0.8	0.5

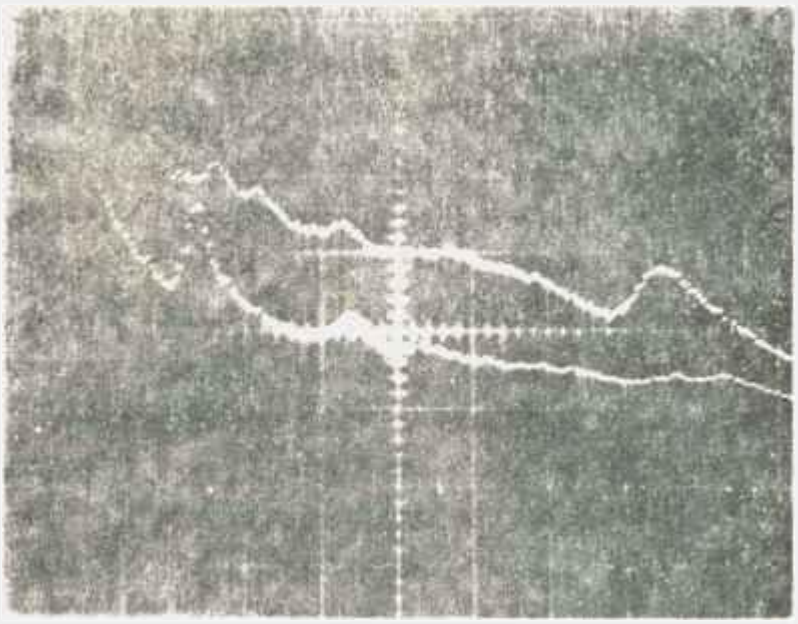
C = channel number

Q = quocient of each fraction value, to fraction 1 (at corresponding channels)

Case A: (O.M.) 24 years old. Hair: 28 cm long.

Noteworthy in this example is the extremely high concentration of I^{128} (channel 46) in the last 3 cm portion of the hair strand (fractions 6 and 7), as compared to the frac

tions nearest to the scalp (see figure 1). This experiment was repeated taking single hairs from different points of the scalp of the same individual and the results confirmed the observed in the strand. A large variation is also observed concerned the concentration of Cl^{38}(channel 160) in the first 4 cm and the rest of the strand; in each one of the consecutive 4 cm fractions the amount of chlorine, as compared to amount in fraction one is about half of the amount in fraction one.



2 Mev

Figure 1

Gamma spectra of two sections of same strand of hair.
Top: 4 cm fraction nearest to the skin.
Bottom: 4 cm fraction at the distal point.

It would be interesting to verify how the variations

registered in Table I would influence an individualization problem in which, for instance, a strand of 15 cm was available for comparison. For that, another strand of 29 cm was taken from the same subject and cut in two fractions of 14.5 cm each and having a mass equal to 63 mg each one. Comparison was made between both fractions. If they were equal all quotients for the corresponding peaks would be one. Results are shown in Table II.

TABLE II

Comparison of two strands of hair of 29 cm lenght cut in two halves of 14.5 cm each

C / Q	46	51	70	84	104	170
2/1	120	1.2	1.2	1.6	1.1	1.0

Same subject as in Case A. (Irradiation and cooling time as for Table I, see text.)

Table III, IV and V present the data for three others different cases. Although in these cases there are no striking differences as the one for iodine in Case A, some important alteration along the hair's lenght can be observed. In case B (Table III), (irradiation and cooling times 10 and 15 minutes, respectively; mass of each fraction about 50 mg; data normalized to one milligram) the peak-value corresponding to channel 84 (Mn) increases, at about 8 centimeters from the scalp end, to double of the value in the first fraction , to triple of that value, at the distal point (16 centimeters). Alterations are also observed for channel 137 (Na) for which a maximum value is reached at 8 centimeters, and for channel 46 with a maximum at about 16 centimeters. Taking the growing value of 0.35 mm per day /9/, Case B represents a period of life, for this subject, of about year and half.

Both subjects of Case A and B (personnel at the IEA) were chosen among girls who never used any dyeing or alike in the hairs.

TABLE III

Comparison of 2 cm fractions of strand of hair

C / Q	46	51	84	100	137	170
1/1	1.0	1.0	1.0	1.0	1.0	1.0
2/1	0.3	1.6	0.9	1.4	0.8	0.2
3/1	0.1	1.4	0.9	1.9	1.1	0.1
4/1	0.3	1.7	1.9	3.0	1.7	0.1
5/1	0.5	1.7	2.0	2.8	1.6	0.1
7/1	0.5	2.1	2.5	2.8	1.4	0.1
8/1	1.2	2.0	2.8	2.5	1.0	0.1

Case B: (M.J.N.) 26 years old. Hair: 16 cm long

In Case C, (Table IV) (irrradiation time 10 minutes; cooling time 2 minutes; mass of each sample about 10 mg; data normalized to one milligram) it is noticed a gradually increase of peak value at channel 84 (Mn) and a decrease at peak 160 (Cl). Some alteration of lesser importance is also observed in other peak values. The very long hair of this subject (40 cm) represents about four years of hair growth. Also this subject, a 12 years old girl when the sample was collected, never used dyeing in the hair.

TABLE IV

Comparison of 2 cm fractions of strand of hair

Q \ C	46	51	60	84	137	160
1/1	1.0	1.0	1.0	1.0	1.0	1.0
2/1	0.7	0.6	0.4	0.9	0.5	0.3
3/1	0.3	0.6	0.5	1.0	0.5	0.2
4/1	0.6	0.7	0.3	1.6	0.8	0.1
5/1	0.9	0.9	0.3	1.8	1.2	0.09
6/1	0.4	0.4	0.1	1.8	0.9	0.1
7/1	0.4	0.4	0.1	1.8	0.9	0.1
8/1	0.7	0.6	0.2	1.9	0.7	0.08
9/1	0.6	0.6	0.3	2.0	0.7	0.08
10/1	0.3	0.8	0.3	2.3	0.7	0.08
11/1	0.9	0.7	0.3	2.7	0.8	0.09
12/1	0.8	0.6	0.3	2.4	0.8	0.08
13/1	0.5	0.5	0.3	2.6	0.7	0.05
14/1	0.5	0.8	0.4	2.6	0.5	0.07
15/1	0.5	0.8	0.3	2.5	0.4	0.06
16/1	0.8	0.7	0.4	2.4	0.3	0.08
17/1	1.2	0.9	0.4	2.1	0.4	0.09
18/1	0.4	0.8	0.4	2.5	0.4	0.1
19/1	1.0	1.1	0.3	2.8	0.4	0.1
20/1	1.1	0.8	0.4	2.7	0.4	0.1

Case C: (F.M.) 12 years old. Hair: 40 cm long

In Case D (Table V) (irradiation time 6 hours; cooling time 20 hours; mass of each sample about 30 mg; data normalized to one milligram) a steady decrease, with slight oscilation, at the peak corresponding to channel 41 is observed from the root end to the distal point. At channel 51 (Cu^{64}) the concentration of copper in each of the last three centimeters of the strand of hair is less than half the concentration at the first two centimeters near to the root end; the copper concentration also decreases steadily from the root end to the distal point.

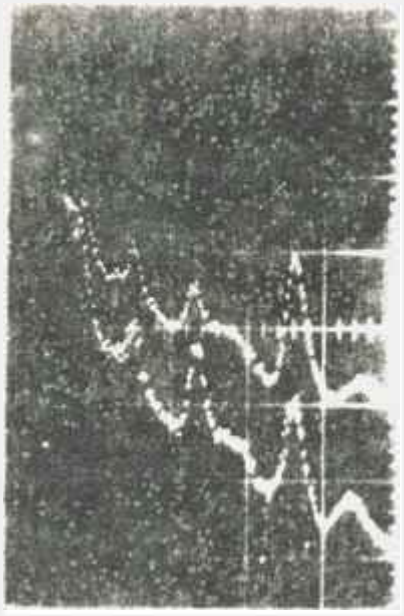
TABLE V

Comparison of 3 cm fractions of strand of hair

C / S*	41/137	51/137	102/137	137/1..
1**	0.1	1.7	0.5	1.0
2	0.1	1.9	0.6	1.0
3	0.1	0.9	0.4	1.0
4	0.02	0.7	0.4	1.0
5	0.05	0.5	0.4	1.0
6	0.05	0.4	0.4	1.0
7	0.06	0.4	0.5	1.0
8	0.05	0.5	0.4	1.0
9	0.02	0.3	0.4	1.0
10	0.02	0.4	0.4	1.0
11	0.01	0.4	0.4	1.0
12	0.01	0.4	0.4	1.0
13	0.01	0.5	0.4	1.0

* Fraction number
** First fraction: 2 cm
Case D: (M.C.P.) 15 years old. Hair: 38 cm long
In this table all samples were counted for a lenght of time sufficient to normalize for the sodium peak at channel 137. Comparison was then made by dividing each counting peak value to the value at channel 137.

In fact very good degree of similarity was found when comparing strand of pubic hair, with the last half of a double sized strand of head hair, Figure 2.



2 Mev

Figure 2

Gamma spectra of 2 cm segments of strands of head and pubic hair.
Bottom: pubic hair; 2 cm nearest to the skin.
Top: head hair; second half of a 4 cm long fraction taken starting from the skin.

This similarity, however, was not found in a subject for which the proportion of sodium in his scalp hair was such, as compared to other elements present, that the peak for Na^{24}

was not resolved after an irradiation time of thirty minutes, and a cooling time of four minutes. This peak was clearly resolved for pubic hair irradiated and counted for the same times. The hair used for this comparison was the second half of a double sized scalp hair as compared to the pubic hair of the same subject. Figure 3 shows the spectra.

2 Mev

Figure 3

Same as in Figure 2, for another subject.
Bottom: pubic hair; 4 cm nearest to the skin.
Top: head hair; second half of a 8 cm long fraction taken starting from the skin.

Variability along the lenght of pubic hair was also observed. Table VI presents the results for a strand of pubic hair cut in seven fractions of 0.5 cm and taking the first fraction as reference for comparison. (Irradiation and cooling times 30 minutes and 4 minutes, respectively; mass of each fraction about 3 mg; data normalized to one milligram).

TABLE VI

Comparison of 0.5 cm fractions of strand of pubic hair

Q \ C	51	58	82	105	137	170
1/1	1.0	1.0	1.0	1.0	1.0	1.0
2/1	1.1	0.7	0.9	1.1	0.8	0.7
3/1	0.9	0.7	1.3	1.4	0.8	0.6
4/1	1.2	0.9	2.4	1.7	1.0	0.6
5/1	1.4	0.9	1.4	1.8	1.2	0.6
6/1	1.4	1.2	1.7	1.9	1.1	0.5
7/1	1.1	1.5	3.7	2.9	0.7	0.6

Case E: (N.K.O) 26 years old. Seven fractions of pubic hair of 0.5 cm each.

6. CLOSE-GROUP INFLUENCE IN HAIR'S COMPOSITION

It seems that no definite influence of close-group (members of same family, workers in the same plant, etc.) has been found /5/. Examination by us of hairs from workers in an arsenic plant showed, however, and extremely high content of this element, much higher than the "normal maximum" of about 5 ppm found in frequency distribution studies and mentioned by Perkons and Jervis /5/. Gamma-spectra of 10 milligrams hair samples taken from miners, and whose hairs had been irradiated for six hours in a thermal neutron flux of 5×10^{12} n/sec. cm^2. followed by a cooling time of 15 hours, did show only a very

pronounced peak at 0.55 Mev which masked completely any other peak. To avoid any possibility of external contamination of those hairs, they were washed with sodium hidroxide solution at one per cent, besides the normal washing with water and acetone-alcohol mixture.

Decay curve of the peak value corresponding to 0.55 Mev indicated that antimony was also present in the hairs samples and also at a very high level. Instrumental analysis as well as radiochemical analysis of those samples gave arsenic results as high as 400 ppm. Antimony concentration was about 170 ppm. Table VII presents the results for those samples. Comments about these figures will be made in the Discussion.

TABLE VII

Amounts of arsenic and antimony in hairs of workers in arsenic plants

Case / ppm	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
As	258	219	248	40	50	371	116	241	195	57	137	47	372	120
Sb	39	36	39	21	12	166	12	56	40	11	33	16	159	8

Work is in progress in order to determine arsenic concentration of other parts of the body of those workers, such as nails, and for which it would be easier to remove any external contamination.

7. DISCUSSION

The results presented in this paper shows the impor

tance of studying more at lenght the fenomenon of hair cycle, specially for head hair. Sufficient information, concerning cycle, for hairs from various parts of the body has been accumulated. In accordance with Butcher /14/, hairs of the leg for instance, remain in a quiescent state for a period considerably longer than the growth period while, in the hairs of the axillary and pubic region, the reverse condition is found, i.e., in the pubic region the period of rest is shorter than the growth. The period of growth in terminal hairs of the ears and eyebrows is about eight weeks and the period of rest lasts three months.

It has been admitted that scalp hairs have an existence of from two to four years, but how long the scalp hairs generally grow and rest seems not to have been recorded, /14/. Trotter /12/ admits the possibility that for the head and beard hairs the rest period is much shorter than the growth period, each hair being replaced almost immediately after it had reached its ultimate lenght.

The variability between active and quiescent scalp hairs might be investigated by comparing strands made up of fallen hairs which come off easely, for instance, during the act of combing, and another strand made up plucked hairs taken one by one and choosing the ones that would not only offer reasonable resistency but even a painful reaction on the subject.

In any practical problem of individualization of hair, comparison of samples should be made as much as possible in fractions that would correspond most closely to the same period of the hair cycle.

Concerning the influence of close groups hair's composition, the example presented, although taken from a very drastic situation, the arsenic plant, indicates that continuous exposition of subject to dust, fumes, etc., may give a high concentration of the elements inhaled or ingested, in excretion routes of the body, of which hair is one of them.

The very high value for the arsenic concentration, and even for antimony, indicates example of mithridatism, in which the workers have acquired immunity by the administration of gradually increased doses of arsenic.

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