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HUMAN HAIR INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS AND MEDICINE

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Periodically increasing and decreasing enthusiasm has accompanied the studies of medical significance of human hair elemental composition for at least two decades. In this field, nuclear analytical methods play an extremely important role, especially the instrumental neutron activation analysis (INAA). This paper tries to add some new knowledge to this problem. Two approaches are used - comparison of individual hair composition with certain diagnoses in clinic groups and comparison of population data with medical statistics. Rather large samples and multielement mathematical procedures helped reveal strong correlations valuable for diagnostic and health screening.

The human hair composition bibliography contains thousands of items. As a result of these studies, changes in hair elemental composition are believed to depend on alterations of the external and internal media of the human body. Specific changes (usually strong and significant) were found for people exposed to anomalously contaminated environments (in the work place, in polluted areas, etc.). On the other hand, the changes were also found for diseased patients. The informativeness of trace-elements of human tissues and fluids is still unclear (with only a few exceptions, e.g. iodine). Human hair, for a number of widely known reasons is very convenient subject for the study of human body elemental status. But even the medical significance of hair composition is also unclear. There is evidence that some diseases are accompanied by specific changes in hair composition[1], and some diseases can be diagnosed or, at least, suspected long before the clinical diagnosis is determined[2]. The data and conclusions of different authors differ very significantly, which makes it difficult to obtain strong diagnostic criteria. In our opinion, these differences are because hair composition is determined by superposition of normal physiological changes, local biogeochemical conditions, cure conditions, environmental and occupational conditions, etc. The prevalence of single element correlations studies instead of multiparameter methods is the main reason for ambiguity and inconsistency found in different studies.

The study of the medical significance of hair composition can be carried out in different ways. The most widespread method is clinical, where the composition of normal and diseased groups is compared. This method is simple but usually gives no possibility of expressing the degree of sickness mathematically. There is an additional way - the comparison of health statistics with data on hair composition for populations.

This paper tries to give some additional examples for the changes of hair composition for different groups of diseased people and to compare these data with data on the population level.

Experimental

Sampling: Hair samples from diseased patients were collected in collaboration with the medical institutions of Uzbekistan. The data for the Uzbekistan population (divided into 11 groups according to the number of districts with available health statistics) represented

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approximately 2000 samples collected within the framework of Uzbekistan hair composition mapping[3,4]. Hair samples were collected from five places on the head, and the surface washing, according to an established procedure[5], was performed. As an analytical method, INAA was used as the most convenient method for hair analysis.

The data on hair composition for different countries were taken from numerous studies listed by Zhuk and Kist[4], along with the world health statistics data[6].

Analytical Method: The measurements were carried out with Ge(Li)-detector system. Samples (20 - 100 mg) after washing and drying, were packed into bags of pure polyethylene foils and irradiated at a neutron flux of $5 \cdot 10^{11}$ n/cm^2·s for 1 min. and after 15 s the induced activities of ^{27}Mg and ^{28}Al were measured. Then the samples were irradiated again at a neutron flux of $5 \cdot 10^{13}$ n/cm^2·s for 15 s. Immediately after irradiation, the induced activities of ^{37}Cl and ^{128}I were measured. One hour after irradiation, the induced activities of ^{24}Na, ^{64}Cu, and ^{56}Mn were determined. One week later, the samples were repacked in pure aluminum foil and irradiated at the same flux for 15 h. A week later, gamma-ray spectrometry was used to determine concentrations of Ca, Br, As, Mo, Cd, La, W, Au, and U. One month later, Sc, Cr, Fe, Co, Zn, Se, Rb, Ag, Sb, Cs, Hg, and Th concentrations were determined.

Standard samples were made by placing a known amount of element solutions on strips of ashless paper. At the same time, a laboratory hair reference material was prepared. The quality of standards and that of the laboratory reference material were evaluated by analyzing IAEA HH-1 reference material. The agreement obtained was satisfactory.

Results and Discussion

Clinic Studies: The data obtained for various diseases are given in theTables 1 - 4.

In innate myocardosis (Table 1) changes for Mg, Ca, and Rb can be considered in accordance with their role in heart dysfunctions. Changes in essential trace elements (Cr, Mn, Fe, and Zn) can be connected with their biological role. Interesting, but unclear, are changes for La, Cs, U, and Th because of a lack of evidence for their biological roles.

The different studied malignant neoplasms localizations (Table 2) are characterized by a more or less significant increase in Na, Cr, Br, and Sb, and a decrease in Co. For other elements there are no general changes.

The changes in bromine in cerebral leptomeningitis (Table 3) can be explained by bromine-containing medicines (similar concentrations before and after cure). But for the other elements, concentrations also didn't change after treatment.

The similarity in changes for Cl, Ca, Sc, Cr, Fe, Co, Zn, Br, Hg and the elevation (from obesity to diabetes) in Na, Mn, I, Au seems to be an evidence, that from the point of view of elemental status, there is certain similarity between obesity and diabetes (Table 4).

The data are summarized in Table 5. This seems to be another of numerous examples for dependence of human hair composition on various diseases. In our opinion, sooner or later, the data obtained by various investigators will be compared and generalized to help solve the problem of medical significance of hair composition.

Uzbekistan Population: In previous work[3,4] the strong correlations between hair composition and disease for the Uzbekistan population were shown graphically. Some correlations are given in the Table 6.

Table 1
Hair composition of children with innate myocardosis, ppm (Arithm. mean ± St. error)

Element	Normal (n = 36)	Patients (n = 16)	P <
Na	550 ± 63	670 ± 150	N
Al	510 ± 5.3	150 ± 46	0.05
Mg	110 ± 25	5.5 ± 3.5	0.001
Cl	1200 ± 140	1900 ± 270	0.02
Ca	860 ± 72	170 ± 23	0.001
Sc	0.11 ± 0.016	0.15 ± 0.04	N
Cr	0.38 ± 0.06	0.13 ± 0.04	0.001
Mn	0.56 ± 0.05	0.44 ± 0.05	0.1
Fe	61 ± 16	20 ± 5.5	0.02
Co	0.08 ± 0.02	0.08 ± 0.02	N
Cu	20 ± 2	16 ± 2	N
Zn	170 ± 12	120 ± 12	0.01
Se	0.53 ± 0.05	0.44 ± 0.05	N
Br	3.3 ± 0.4	4.3 ± 0.9	N
Rb	0.31 ± 0.12	0.70 ± 0.08	0.01
Sb	0.26 ± 0.045	0.25 ± 0.027	N
I	0.60 ± 0.12	0.80 ± 0.20	N
Cs	0.085 ± 0.006	0.048 ± 0.008	0.001
La	0.11 ± 0.015	0.050 ± 0.01	0.001
Au	0.070 ± 0.006	0.070 ± 0.010	N
Hg	0.21 ± 0.02	0.50 ± 0.30	N
U	0.22 ± 0.04	0.11 ± 0.03	0.03
Th	0.62 ± 0.19	1.6 ± 0.48	0.05

Table 2
Hair composition of adults with malignant neoplasms, ppm (Arithm. mean ± Stand. error)

Elem.	Rectal (n = 35)	Stomach (n = 34)	Breast (n = 52)	Normal (n = 36)
Na	1300 ± 200	1050 ± 230	570 ± 75	290 ± 29
P	<0.001	<0.01	<0.001	
Cl	3800 ± 430	3300 ± 590	660 ± 97	1400 ± 210
P	<0.001	<0.02	<0.005	
Sc	0.013 ± 0.002	0.037 ± 0.007	0.018 ± 0.002	0.015 ± 0.002
P	N	<0.02	N	
Cr	1.0 ± 0.17	0.73 ± 0.12	0.88 ± 0.13	0.59 ± 0.07
P	<0.05	N	<0.1	
Mn	0.97 ± 0.17	0.73 ± 0.08	0.76 ± 0.15	0.61 ± 0.13
P	N	N	N	
Fe	100 ± 22	130 ± 24	38 ± 4	42 ± 5
P	<0.02	<0.001	N	
Zn	180 ± 11	230 ± 23	140 ± 10	200 ± 10
P	N	N	<0.001	
Se	0.63 ± 0.07	0.78 ± 0.11	0.52 ± 0.04	0.87 ± 0.08
P	<0.05	N	<0.001	
Br	23 ± 3.8	24 ± 4.6	6.1 ± 0.7	5.9 ± 0.7
P	<0.001	<0.001	N	
Sb	0.94 ± 0.17	0.54 ± 0.07	0.29 ± 0.07	0.28 ± 0.04
P	<0.001	<0.005	N	

Table 2 (Cont.)
Hair composition of adults with malignant neoplasms, ppm (Arithm. mean ± Stand. error)

Elem.	Rectal (n = 35)	Stomach (n = 34)	Breast (n = 52)	Normal (n = 36)
Au	0.076 ± 0.015	0.064 ± 0.009	0.087 ± 0.013	0.062 ± 0.015
P	N	N	N	
Hg	0.47 ± 0.06	0.85 ± 0.13	1.9 ± 0.19	1.1 ± 0.21
P	<0.01	N	<0.01	

Table 3
Hair composition of adults with cerebral leptomeningitis, ppm (Arithm. mean ± Stand. error)

Elem.	Normal (n = 10)	Before cure (n = 65)	P<	After cure (n = 45)	P<
Na	790 ± 220	717 ± 95	N	740 ± 90	N
Cl	2460 ± 430	2070 ± 230	N	2060 ± 150	N
Sc	0.010 ± 0.0017	0.020 ± 0.004	0.02	0.022 ± 0.005	0.02
Cr	0.70 ± 0.17	0.86 ± 0.07	N	0.91 ± 0.08	N
Mn	0.58 ± 0.09	0.62 ± 0.08	N	0.71 ± 0.10	N
Fe	59 ± 28	56 ± 7	N	46 ± 4.6	N
Co	0.065 ± 0.01	0.10 ± 0.01	0.01	0.082 ± 0.006	N
Zn	150 ± 19	160 ± 5	N	170 ± 6	N
Br	8 ± 1.5	28 ± 6	0.001	27 ± 4	0.001
Ag	0.18 ± 0.064	0.14 ± 0.027	0.05	0.13 ± 0.02	0.01
Sb	0.29 ± 0.14	0.38 ± 0.053	N	0.49 ± 0.08	N
I	1.5 ± 0.37	4.1 ± 1.1	0.03	3.3 ± 0.60	0.01
Au	0.03 ± 0.007	0.08 ± 0.02	0.02	0.067 ± 0.008	0.003
Hg	0.74 ± 0.11	0.60 ± 0.06	N	0.71 ± 0.07	N

Table 4
Hair composition of adults with diabetes mellitus and obesity, ppm (Arithm. mean ± Stand. error)

Elem.	Normal (n = 36)	Obesity (n=21)	P<	Diabetes (n=39)	P<
Na	290 ± 29	690 ± 160	0.01	840 ± 100	0.001
Cl	1370 ± 210	2560 ± 440	0.001	2350 ± 420	0.005
Ca	420 ± 90	720 ± 630	0.001	1730 ± 600	0.005
Sc	0.015 ± 0.002	0.031 ± 0.005	0.003	0.034 ± 0.006	0.003
Cr	0.59 ± 0.07	0.96 ± 0.18	0.05	1.00 ± 0.006	0.001
Mn	0.61 ± 0.13	0.76 ± 0.15	N	1.1 ± 0.50	N
Fe	42 ± 5	120 ± 27	0.01	120 ± 25	0.001
Co	0.12 ± 0.016	0.20 ± 0.04	0.05	0.19 ± 0.014	0.001
Cu	22 ± 2	90 ± 18	0.001	124 ± 26	0.001
Zn	200 ± 10	170 ± 6	0.02	170 ± 8.6	0.05
Se	0.87 ± 0.08	2.3 ± 1.6	N	0.66 ± 0.11	0.2
Br	5.9 ± 0.7	17 ± 5.0	0.01	17 ± 3.2	0.001
Sb	0.28 ± 0.04	0.26 ± 0.05	N	0.34 ± 0.075	N
I	2.8 ± 0.04	10 ± 6.2	N	47 ± 35	N
Au	0.062 ± 0.015	0.14 ± 0.045	N	0.17 ± 0.08	0.2
Hg	1.1 ± 0.21	2.8 ± 0.4	0.001	2.2 ± 0.4	0.02

Table 5
Charasteristic changes of hair composition of diseased people

Elem.	1	2	3	4	5	6	7	8
Na			+	+	+	+	+	+
Cl	+		+	+		+	+	-
Ca	-		+	+				
Sc		+	+	+	-		+	
Cr	-		+	+	+	+		+
Mn	-				+			
Fe	-		+	+		+	+	
Co			+	+	+	-		-
Cu			+	+	-	-	+	+
Zn	-		-	-	-			-
Se			+	-		-		-
Br		+	+	+		+	+	
Sb					+	+	+	
Cs	-							
Au		+		+				
Hg			+	+	-	-		+
U	-							

1 - Innate myocardosis 2 - Cerebral leptomeningitis 3 - Obesity
4 - Diabetes mellitus 5 - Vitiligo 6 - Rectal cancer
7 - Stomach cancer 8 - Breast cancer
+ - Significantly increased concentration - - Significantly decreased concentration

These data don't answer the question of what role certain elements play in certain pathologies but can stipulate such a study. At present, one can say that the analysis of the data of human hair composition for the general population can be a powerful tool for description (and possibly prediction) of the populations' health status and a method for screening of the risk groups.

World Population: Similar relationships can be obtained considering the different countries of the world. In many cases, the correlations are very significant:

Na - Negative: acute upper respiratory infection.

Mg - Positive: meningococ. infection, malign. neopl.of lung, diabetes mellitus, anaemias, atherosclerosis, acute upper respiratory infection, nephritis, nephrotic syndrome and nephrosis. Negative: malign. neopl. of oesophagus, bladder, multiple sclerosis, hyperten. disease, cerebrovascular diseases, congenital anomalies of heart and circulatory system.

Cl - Negative: malignant neoplasms of stomach.

K - Positive: tuberculosis of respiratory system, mental disorders, congenital anomalies of heart and circulatory system. Negative: cerebrovascular diseases, atherosclerosis, chronic liver disease, cirrhosis.

Ca - Positive: nephritis, nephrotic syndrom and nephrosis.

Sc - Positive: acute upper respiratory infection.

Mn - Negative: meningococ. infection, malign. neoplasm of stomach.

Co - Positive: anaemias, hypertens. disease, atherosclerosis, acute upper respiratory infection

As - Positive: malign. neopl. of female brest, mental disorders. Negative: tuberculosis of respiratory system.

Table 6
Relationship of health statistics and hair composition in Uzbekistan (correlation coefficient r, the + and - mean less significant positive or negative correlation, 0 - absence of correlation).

Elem.	Diabetes mellitus	Goiter	Hyper-tonia	Ishemia	Cerebro-vascular hypertonia	Anemia
Na	-0.71	0	-	-	-	-
Cl	-0.68	-	-	-0.70	-	+
Ca	-	-	+	+	-	+
Sc	-	-	0	-	-	+
Cr	0	-	+	+	+	-
Mn	-	+	-	-	-	0
Fe	-	-	0	-	+	+
Co	-	0	0	0	+	+
Cu	-	+	0	-	+	+
Zn	-	-	-	-	-	-
As	0	-	0	0	-	+
Se	+	-	0.64	+	+	0
Br	-	-	0	-	0	+
Mo	-	0.76	0	-	+	-
Ag	0	-	+	0	-	0
Cd	+	0	0	+	0	-
Sb	-0.75	-	-	-0.65	-	+
I	+	-	-	+	0	0
Cs	+	0	+	+	0.62	0
La	-	0	+	-	-	0
W	+	0	0.75	+	+	0
Au	-	-	-	-	0	+
Hg	0	0	-	0	0	+
U	-	+	-	-	-	-

Br - Positive: hypertens. disease, acute upper respiratory infection. Negative: malign. neopl. of stomach and bladder.

Mo - Positive: malign. neopl. of prostate, leukaemia, acute myocardial infarction. Negative: malign. neopl. of stomach, cerebrovasc. diseases, atherosclerosis, chronic liver disease, and cirrhosis.

Cd - Positive: tuberculosis of respir. system, nephritis, nephrotic syndr., nephrosis. Negative: malign. neopl. (general, lung, female breast, prostate, bladder), leukaemia, anaemias.

Sb - Positive: meningococ. infect., congenital anomalies of heart and circulatory system.

I - Positive: meningococ. infect., congenital anomalies of heart and circulatory system. Negative: malign. neopl. of prostate, leukaemia, diabetes mellitus, nephritis, nephrotic syndr., nephrosis

Cs - Positive: hypertens. disease, acute myocardial infarction, nephritis, nephrotic syndr., nephrosis.

La - Positive: Congenital anomalies of heart and circulatory system. Negative: meningococ. infection, diabetes mellitus, nephritis, nephrotic syndr., nephrosis.

Au - Negative: acute upper respiratory infection.

Hg - Positive: acute upper respiratory infection. Negative: meningococ. infection.

These data allow statements to be made about the possible role of some elements in the various pathologies. Unfortunately, they are hardly comparable to the data for the Uzbekistan population. There are some possible reasons, e.g. biogeochemical differences and different list of diseases, etc. For some elements there are some similarities (e.g. Sc, Zn, Sb, La in diabetes, Br and Sb in female breast cancer, etc.). This allows for the conclusion that it is possible to assume general regularities which can help find significant elements.

Considering more than single elemental concentrations leads to more significant correlations. Some examples for world health statistics are given in Table 7.

These data allow us to expect much stronger and more significant relationships using more sophisticated multiparameter procedure.Our preliminary data, for example, allowed us to find the significant elements which are probably indicative of diabetes[7] using Fisher discriminant analysis procedure.

The data given in this paper are is additional evidence that the study of medical significance of hair composition is not hopeless. Study of the possible relationships on the population level can be considered as a new and fruitful approach. The first steps in the

Table 7
Correlations for world health statistics

Elements	Disease	r
Cd x Hg	Malignant neoplasms	-0.69 ± 0.21
Cd x Hg	Malig. neopl. of stomach	0.65 ± 0.23
Cd x Hg	Malig. neopl. of breast	-0.72 ± 0.19
Cd x Hg	Malig. neopl. of prostate	-0.84 ± 0.12
Cd x Hg	Malig. neoplasm of bladder	-0.78 ± 0.16
Cd x Hg	Leukemia	-0.86 ± 0.11
Se x I x La	Diabetes mellitus	-0.77 ± 0.17
Co / Cd	Anemia	0.69 ± 0.23
As / Cd	Mental disorders	0.96 ± 0.026
Co / Mo	Atherosclerosis	0.98 ± 0.020
Cr x Sb x I x La	Congenital anomalies of heart and circulatory system	0.70 ± 0.18

multielemental relationships also indicate some success. The important role in these studies continues to belong to INAA for its sensitivity, simplicity, productivity and multielemental capabilities. The final goals - the early diagnosis, screening of populations, detection of the groups at risk, and possible prediction of population health status - is an important enough reason to continue efforts in this field.

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