

Age-Related Changes of Ag, Co, Cr, Fe, Hg, Rb, Sb, Sc, Se, and Zn Contents in Intact Thyroid of Males Investigated by Neutron Activation Analysis



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Abstract

A prevalence of thyroid dysfunction is higher in the elderly as compared to the younger population. An excess or deficiency of trace element contents in thyroid plays important role in goitro- and carcinogenesis of gland. The variation with age of the mass fraction of ten trace elements (Ag, Co, Cr, Fe, Hg, Rb, Sb, Sc, Se, and Zn) in intact (normal) thyroid of 62 males (mean age 35.9 years, range 2-80) was investigated by instrumental neutron activation analysis with high resolution spectrometry of long-lived radio nuclides. Mean values \pm standard error of mean for mass fractions (mg/kg, on dry-mass basis) of the trace elements studied were: Ag 0.0156 ± 0.0021 , Co 0.0352 ± 0.0031 , Cr 0.520 ± 0.041 , Fe 222 ± 12 , Hg 0.0461 ± 0.0053 , Rb 7.89 ± 0.58 , Sb 0.108 ± 0.010 , Sc 0.0051 ± 0.0012 , Se 2.36 ± 0.17 , and Zn 103 ± 5.5 . This work revealed that there is a significant tendency for an increase in Se mass fraction in normal male thyroid during a lifespan. Therefore, a goitrogenic and carcinogenic effect of inadequate Se level in the thyroid of old males and a harmful effect of disturbance in intra thyroidal trace element relationships with increasing age may be assumed.

Keywords: Thyroid; Trace elements; Age-related changes; Neutron activation analysis

Abbreviations: INAA-LLR: Instrumental Neutron Activation Analysis with High Resolution Spectrometry of long-Lived Radio Nuclides; CRM/ SRM: Certified/Standard Reference Materials; IAEA: International Atomic Energy Agency

Introduction

The endocrine organs, including the thyroid gland, undergo important functional changes during aging and a prevalence of thyroid dysfunction is higher in the elderly as compared to the younger population [1,2]. Advancing age is known to influence the formation of adenomatous goiter and thyroid cancer [3]. The prevalence of thyroid nodules is increased in the elderly, reaching a frequency of nearly 50% by the age of 65 [4]. Both prevalence and aggressiveness of thyroid cancer increase with age [2]. Women are affected by thyroid nodule and cancer two to five times more often than men, but in age over 65 years a prevalence of thyroid cancer may be higher in men [2-4,5].

Aging, considered as an impairment of body functions over time, caused by the accumulation of molecular damage in DNA, proteins and lipids, is also characterized by an increase in intracellular oxidative stress due to the progressive decrease of the intracellular reactive oxygen species (ROS) scavenging [6,7]. Oxidative damage to cellular macromolecules which

induce age-related diseases, including cancer, can also arise through overproduction of ROS and faulty antioxidant and/or DNA repair mechanisms [8]. Overproduction of ROS is associated with inflammation, radiation, and some other factors, including overload of some chemical elements, in both blood and certain tissues, or deficiency of other chemical elements with antioxidant properties [9-15]. The imbalance in the composition of chemical elements in cells, tissues and organs may cause different types of pathology. The importance of appropriate levels of many chemical elements is indisputable, due to their beneficial roles when in specific concentration ranges, while on the other hand they can cause toxic effects with excessively high or low concentrations [12].

In our previous studies [16-24] the high mass fraction of I and some other trace element were observed in intact human thyroid gland when compared with their levels in non-thyroid soft tissues of the human body. However, some questions about

the age-dependence of trace element mass fraction in thyroid of adult and, particularly, elderly males still remain unanswered. One valuable way to elucidate the situation is to compare the mass fractions of trace elements in young adult (the control group) with those in older adult and geriatric thyroid. The findings of the excess or deficiency of trace element contents in thyroid and the perturbations of their relative proportions in glands of adult and elderly males, may give an indication of their role in a higher prevalence of thyroid dysfunction in the elderly.

The reliable data on chemical element mass fractions in normal geriatric thyroid is apparently extremely limited. There are many studies regarding chemical element content in human thyroid, using chemical techniques and instrumental methods [25-36]. However, majority of the analytical methods currently used and validated for the determination of major and trace elements in thyroid and other human organs are based on techniques need in sample digestion. The most frequently used digestion procedures are the traditional dry ashing and high-pressure wet digestion that allow destruction of organic matter of the sample. Sample digestion is a critical step in elemental analysis and due to the risk of contamination and analytes loss contributes to the systematic uncontrolled analysis errors [37-39]. Moreover, only a few of these studies employed quality control using certified/standard reference materials (CRM/SRM) for determination of the chemical element mass fractions. Therefore, sample-nondestructive technique like instrumental neutron activation analysis combined with a quality assurance using CRM/SRM is good alternatives for multi elemental determination in the samples of thyroid parenchyma.

This work had three aims. The primary purpose of this study was to determine reliable values for the silver (Ag), cobalt (Co), chromium (Cr), iron (Fe), mercury (Hg), rubidium (Rb), antimony (Sb), scandium (Sc), selenium (Se), and zinc (Zn) mass fractions in the normal (intact) thyroid of subjects ranging from children to elderly males using non-destructive instrumental neutron activation analysis with high resolution spectrometry of long-lived radio nuclides (INAA-LLR). The second aim was to compare the Ag, Co, Cr, Fe, Hg, Rb, Sb, Sc, Se, and Zn mass fractions in thyroid gland of age group 2 (adults and elderly persons aged 36 to 80 years), with those of group 1 (from 2 to 35 years), and the final aim was to estimate the inter-correlations of trace elements in normal thyroid of males and their changes with age. All studies were approved by the Ethical Committee of the Medical Radiological Research Center.

Materials and Methods

Samples of the human thyroid were obtained from randomly selected autopsy specimens of 62 males (European-Caucasian) aged 2 to 80 years. All the deceased were citizens of Obninsk and had undergone routine autopsy at the Forensic Medicine Department of City Hospital, Obninsk. Age ranges for subjects were divided into two age groups, with group 1, 2-35 years (21.9±1.4 years, M±SEM, n=34) and group 2, 36-80 years

(52.9±2.7 years, M±SEM, n=28). These groups were selected to reflect the condition of thyroid tissue in the children, teenagers, young adults and first period of adult life (group 1) and in the second period of adult life as well as in old age (group 2). The available clinical data were reviewed for each subject. None of the subjects had a history of an intersex condition, endocrine disorder, or other chronic disease that could affect the normal development of the thyroid. None of the subjects were receiving medications or used any supplements known to affect thyroid trace element contents. The typical causes of sudden death of most of these subjects included trauma or suicide and also acute illness (cardiac insufficiency, stroke, embolism of pulmonary artery, alcohol poisoning). All right lobes of thyroid glands were divided into two portions using a titanium scalpel [40]. One tissue portion was reviewed by an anatomical pathologist while the other was used for the trace element content determination. A histological examination was used to control the age norm conformity as well as the unavailability of micro adenomatosis and latent cancer.

After the samples intended for trace element analysis were weighed, they were transferred to -20 °C and stored until the day of transportation in the Medical Radiological Research Center, Obninsk, where all samples were freeze-dried and homogenized [41]. The pounded sample weighing about 50 mg was used for trace element measurement by INAA-LLR. The samples for INAA-LLR were wrapped separately in a high-purity aluminum foil washed with rectified alcohol beforehand and placed in a nitric acid-washed quartz ampoule.

To determine contents of the elements by comparison with a known standard, biological synthetic standards (BSS) prepared from phenol-formaldehyde resins were used [42]. In addition to BSS, aliquots of commercial, chemically pure compounds were also used as standards. Ten certified reference material IAEA H-4 (animal muscle) and IAEA HH-1 (human hair) sub-samples weighing about 50mg were treated and analyzed in the same conditions that thyroid samples to estimate the precision and accuracy of results.

A vertical channel of nuclear reactor was applied to determine the content of Ag, Co, Cr, Fe, Hg, Rb, Sb, Sc, Se, and Zn by INAA-LLR. The quartz ampoule with thyroid samples, standards, and certified reference material was soldered, positioned in a transport aluminum container and exposed to a 24-hour neutron irradiation in a vertical channel with a neutron flux of $1.3 \cdot 10^{13} \text{ ncm}^{-2}\text{s}^{-1}$. Ten days after irradiation samples were reweighed and repacked.

The samples were measured for period from 10 to 30 days after irradiation. The duration of measurements was from 20 min to 10 hours subject to pulse counting rate. Spectrometric measurements were performed using a coaxial 98-cm³ Ge (Li) detector and a spectrometric unit (NUC 8100), including a PC-coupled multichannel analyzer. Resolution of the spectrometric unit was 2.9-keV at the ⁶⁰Co 1,332-keV line. Details of used

nuclear reactions, radio nuclides, and gamma-energies were presented in our earlier publications concerning the INAA chemical element contents in human scalp hair [43,44].

A dedicated computer program for INAA mode optimization was used [45]. All thyroid samples were prepared in duplicate, and mean values of trace element contents were used in final calculation. Using Microsoft Office Excel, a summary of the statistics, including, arithmetic mean, standard deviation, standard error of mean, minimum and maximum values,

median, percentiles with 0.025 and 0.975 levels was calculated for trace element contents. The reliability of difference in the results between two age groups was evaluated by the parametric Student's t-test and non-parametric Wilcoxon-Mann-Whitney U-test. For the construction of "age-trace element mass fraction" diagrams and the estimation of the Pearson correlation coefficient between age and trace element mass fraction as well as between different trace elements the Microsoft Office Excel programs were also used.

Results

Table 1: INAA-LLR data of trace element contents in certified reference material IAEA H-4 (animal muscle) and IAEA HH-1 (human hair) compared to certified values ((mg/kg, dry mass basis).

| Element | IAEA H-4 Animal Muscle | This Work Results | IAEA HH-1 Human Hair | This Work Results |
|---------|----------------------------|----------------------|----------------------------|----------------------|
| | 95% Confidence Interval | M±SD | 95% Confidence Interval | M±SD |
| Ag | - | 0.033±0.008 | 0.19b | 0.18±0.05 |
| Co | 0.0027b | 0.0034±0.0008 | 5.97±0.42a | 5.4±1.1 |
| Cr | 0.06b | 0.071±0.010 | 0.27b | ≤0.3 |
| Fe | 49.1±6.5a | 47.0±1.0 | 23.7±3.1a | 25.1±4.3 |
| Hg | 0.014b | 0.015±0.004 | 1.70±0.09a | 1.54±0.14 |
| Rb | 18.7±3.5a | 23.7±3.7 | 0.94b | 0.89±0.17 |
| Sb | 0.0056b | 0.0061±0.0021 | 0.031b | 0.033±0.009 |
| Sc | 0.0059b | 0.0015±0.0009 | - | - |
| Se | 0.28±0.08a | 0.281±0.014 | 0.35±0.02a | 0.37±0.08 |
| Zn | 86.3±11.5a | 91±2 | 174±9a | 173±17 |

M-arithmetical mean, SD-standard deviation, a-certified values, b-information values.

Table 1 depicts our data for Ag, Co, Cr, Fe, Hg, Rb, Sb, Sc, Se, and Zn mass fractions in ten sub-samples of IAEA H-4 (animal muscle) and IAEA HH-1 (human hair) certified reference material and the certified values of this material.

Table 2 represents certain statistical parameters (arithmetic mean, standard deviation, standard error of mean, minimal and maximal values, median, percentiles with 0.025 and 0.975 levels) of the Ag, Co, Cr, Fe, Hg, Rb, Sb, Sc, Se, and Zn mass fractions in intact (normal) thyroid of males.

Table 2: Some statistical parameters of Ag, Co, Cr, Fe,Hg, Rb, Sb, Sc,Se, and Zn mass fraction (mg/kg, dry mass basis) in intact thyroid of male.

| Gender | Element | M | SD | SEM | Min | Max | Median | P 0.025 | P 0.975 |
|---------------|---------|--------|--------|--------|--------|--------|--------|---------|---------|
| Males n=62 | Ag | 0.0156 | 0.0155 | 0.0021 | 0.0017 | 0.0800 | 0.0104 | 0.0018 | 0.0661 |
| | Co | 0.0352 | 0.0234 | 0.0031 | 0.0046 | 0.124 | 0.0302 | 0.0113 | 0.101 |
| | Cr | 0.520 | 0.286 | 0.041 | 0.130 | 1.30 | 0.414 | 0.152 | 0.980 |
| | Fe | 222 | 96 | 12 | 51.0 | 487 | 221 | 76.1 | 432 |
| | Hg | 0.0461 | 0.0391 | 0.0053 | 0.0091 | 0.180 | 0.0324 | 0.0102 | 0.150 |
| | Rb | 7.89 | 4.56 | 0.58 | 2.24 | 29.4 | 6.86 | 2.73 | 18.2 |
| | Sb | 0.108 | 0.076 | 0.010 | 0.0047 | 0.308 | 0.0965 | 0.0095 | 0.291 |
| | Sc | 0.0051 | 0.0036 | 0.0012 | 0.0005 | 0.0118 | 0.0044 | 0.0007 | 0.0112 |
| | Se | 2.36 | 1.34 | 0.17 | 0.530 | 5.80 | 1.96 | 0.804 | 5.70 |
| Zn | 103 | 43 | 5.5 | 34.0 | 221 | 94.6 | 40.5 | 200 | |

M-arithmetical mean, SD-standard deviation, SEM-standard error of mean, Min-minimum value, Max- maximum value, P 0.025-percentile with 0.025 level, P 0.975-percentile with 0.975 level.

Table 3: Median, minimum and maximum value of means Ag, Co, Cr, Fe, Hg, Rb, Sb, Sc, Se, and Zn contents in normal thyroid according to data from the literature in comparison with our results (mg/kg, dry mass basis).

| Element | Published Data [Reference] | | Maximum of Means of Means M or M±SD, (n)** | This work M±SD |
|---------|----------------------------|--|--|----------------|
| | Median of Means (n)* | Maximum of Means of Means M or M±SD, (n)** | | |
| Ag | 0.25 (12) | 0.000784 (16) [25] | 1.20±1.24(105) [26] | 0.0156±0.0155 |
| Co | 0.336 (17) | 0.026±0.031 (46) [27] | 70.4±40.8 (14) [28] | 0.0352±0.0234 |
| Cr | 0.69 (17) | 0.105 (18) [29] | 24.8±2.4 (4) [30] | 0.520±0.286 |
| Fe | 252 (21) | 56 (120) [31] | 2444±700 (14) [28] | 222±96 |
| Hg | 0.08(13) | 0.0008±0.0002(10) [32] | 396±40 (4) [30] | 0.0461±0.0391 |
| Rb | 12.3 (9) | ≤0.85 (29) [32] | 294±191 (14) [28] | 7.89±4.56 |
| Sb | 0.105 (10) | 0.040±0.003(-) [33] | 4.0 (-) [34] | 0.108±0.076 |
| Sc | 0.009 (4) | 0.0018±0.0003(17) [35] | 0.0135±0.0045 (10) [32] | 0.0051±0.0036 |
| Se | 2.61 (17) | 0.95±0.08(29) [32] | 756±680 (14) [28] | 2.36±1.34 |
| Zn | 118 (51) | 32(120) [31] | 820±204 (14) [28] | 103±43 |

M – arithmetic mean, SD – standard deviation, (n)* - number of all references, (n)** – number of samples.

The comparison of our results with published data for the Ag, Co, Cr, Fe, Hg, Rb, Sb, Sc, Se, and Zn contents in the human thyroid is shown in Table 3. To estimate the effect of age on the trace element contents we examined two age groups, described above (Table 4). In addition, the Pearson correlation coefficient

between age and trace element mass fraction was calculated (Table 5). Figure 1 shows the individual data sets for the Ag, Co, Cr, Fe, Hg, Rb, Sb, Sc, Se, and Zn mass fraction in all samples of thyroid, and also lines of trend with age.

Table 4: Differences between mean values (M±SEM) of Ag, Co, Cr, Fe, Hg, Rb, Sb, Sc, Se, and Zn mass fraction (mg/kg, dry mass basis) in normal male thyroid of two age groups (AG).

| Element | male Thyroid Tissue | | | | Ratio AG2 To AG1 |
|---------|---------------------|----------------------|-----------|----------|------------------|
| | AG1 2-35 Years N=34 | AG2 36-80 Years N=28 | T-Test P≤ | U-Test P | |
| Ag | 0.0159±0.0035 | 0.0152±0.0020 | 0.862 | >0.05 | 0.96 |
| Co | 0.0363±0.0049 | 0.0339±0.0034 | 0.692 | >0.05 | 0.93 |
| Cr | 0.518±0.057 | 0.523 tissue 0.061 | 0.947 | >0.05 | 1.01 |
| Fe | 215±18 | 230±16 | 0.530 | >0.05 | 1.07 |
| Hg | 0.0455±0.0080 | 0.0467±0.0071 | 0.917 | >0.05 | 1.03 |
| Rb | 7.92±0.63 | 7.84±1.07 | 0.947 | >0.05 | 0.99 |
| Sb | 0.113±0.013 | 0.103 tissue 0.016 | 0.641 | >0.05 | 0.91 |
| Sc | 0.0052±0.0012 | 0.0050±0.0024 | 0.949 | >0.05 | 0.96 |
| Se | 1.98±0.20 | 2.84±0.28 | 0.015 | ≤ 0.01 | 1.43 |
| Zn | 97.8±7.1 | 109.1±8.6 | 0.318 | >0.05 | 1.12 |

M-arithmetic mean, SEM – standard error of mean, t-test - Student's t-test, U-test - Wilcoxon-Mann-Whitney U-test, Statistically significant values are in bold.

Table 5: Correlations between age and trace element mass fractions in the intact thyroid of male (r – coefficient of correlation).

| Element | Ag | Co | Cr | Fe | Hg | Rb | Sb | Sc | Se | Zn |
|---------|--------|--------|--------|--------|-------|--------|-------|--------|--------|-------|
| Age | -0.116 | -0.121 | -0.067 | -0.054 | 0.201 | -0.059 | 0.018 | -0.065 | 0.432c | 0.058 |

Statistically significant values: c – $p < 0.001$.

The data of inter-correlation calculations (values of r – coefficient of correlation) including all trace elements identified by us are presented in Table 6.

Table 6: Intercorrelations of the chemical element mass fractions in normal male thyroid of three age groups (r – coefficient of correlation).

| Element | Co | Cr | Fe | Hg | Rb | Sb | Sc | Se | Zn |
|---------|---------------------|---------------------|--------------------|---------------------|---------------------|--------------------|---------------------|---------------------|---------------------|
| 2-35y | | | | | | | | | |
| Ag | 0.636 ^c | 0.472 ^a | 0.135 | -0.15 | 0.332 ^a | -0.105 | -0.284 | -0.113 | 0.008 |
| Co | 1 | 0.445 ^a | 0.089 | -0.477 ^a | 0.334 ^a | 0.218 | 0.521 | 0.13 | 0.209 |
| Cr | 0.445 ^a | 1 | 0.408 ^a | -0.495 ^b | 0.487 ^b | 0.231 | 0.939 ^a | 0.132 | 0.366 ^a |
| Fe | 0.089 | 0.408 ^a | 1 | 0.002 | -0.135 | 0.074 | 0.826 ^a | -0.006 | 0.390 ^a |
| Hg | -0.477 ^a | -0.495 ^b | 0.002 | 1 | -0.129 | -0.284 | -0.057 | -0.272 | 0.025 |
| Rb | 0.334 ^a | 0.487 ^b | -0.135 | -0.129 | 1 | -0.219 | 0.948 ^a | -0.257 | 0.310 ^a |
| Sb | 0.218 | 0.231 | 0.074 | -0.284 | -0.219 | 1 | -0.257 | 0.584 ^c | -0.023 |
| Sc | 0.521 | 0.939 ^a | 0.826 ^a | -0.057 | 0.948 ^a | -0.257 | 1 | 0.1 | 0.840 ^c |
| Se | 0.13 | 0.132 | -0.006 | -0.272 | -0.257 | 0.584 ^c | 0.1 | 1 | 0.208 |
| Zn | 0.209 | 0.366 ^a | 0.390 ^a | 0.025 | 0.310 ^a | -0.023 | 0.840 ^c | 0.208 | 1 |
| 36-80 y | | | | | | | | | |
| Ag | 0.26 | 0.211 | -0.121 | -0.085 | 0.286 | 0.424 | 0.864 | 0.037 | -0.063 |
| Co | 1 | 0.370 ^a | -0.005 | 0.028 | 0.197 | 0.206 | 0.993 ^b | 0.156 | 0.004 |
| Cr | 0.370 ^a | 1 | 0.003 | -0.137 | 0.461 ^a | 0.121 | 0.031 | -0.023 | -0.105 |
| Fe | -0.005 | 0.003 | 1 | 0.207 | -0.086 | 0.054 | -0.501 | -0.059 | -0.034 |
| Hg | 0.028 | -0.137 | 0.207 | 1 | 0.193 | 0.053 | -0.792 | 0.192 | 0.244 |
| Rb | 0.197 | 0.461 ^a | -0.086 | 0.193 | 1 | -0.031 | 0.845 | -0.248 | 0.381 ^a |
| Sb | 0.206 | 0.121 | 0.054 | 0.053 | -0.031 | 1 | 0.546 | 0.545 | -0.400 ^a |
| Sc | 0.993 ^b | 0.031 | -0.501 | -0.792 | 0.845 | 0.546 | 1 | 0.787 | -0.892 |
| Se | 0.156 | -0.023 | -0.059 | 0.192 | -0.248 | 0.545 | 0.787 | 1 | -0.023 |
| Zn | 0.004 | -0.105 | -0.034 | 0.244 | 0.381 ^a | 0.400 ^a | -0.892 | -0.023 | 1 |
| 2-80 y | | | | | | | | | |
| Ag | 0.537 ^c | 0.361 ^a | 0.069 | -0.128 | 0.264 ^a | 0.04 | 0.383 | -0.061 | -0.02 |
| Co | 1 | 0.391 ^a | 0.055 | -0.307 ^a | 0.258 ^a | 0.211 | 0.600 ^a | 0.108 | 0.112 |
| Cr | 0.391 ^a | 1 | 0.237 | -0.325 ^a | 0.453 ^b | 0.175 | 0.321 | 0.046 | 0.123 |
| Fe | 0.055 | 0.237 | 1 | 0.079 | -0.106 | 0.062 | 0.004 | -0.008 | 0.22 |
| Hg | -0.307 ^a | -0.325 ^a | 0.079 | 1 | 0.037 | -0.134 | -0.659 ^a | -0.03 | 0.13 |
| Rb | 0.258 ^a | 0.453 ^b | -0.106 | 0.037 | 1 | -0.114 | 0.800 ^b | -0.259 ^a | 0.342 ^a |
| Sb | 0.211 | 0.175 | 0.062 | -0.134 | -0.114 | 1 | 0.179 | 0.512 ^c | -0.204 |
| Sc | 0.600 ^a | 0.321 | 0.004 | -0.659 ^a | 0.800 ^b | 0.179 | 1 | 0.303 | -0.097 |
| Se | 0.108 | 0.046 | -0.008 | -0.03 | -0.259 ^a | 0.512 ^c | 0.303 | 1 | 0.116 |
| Zn | 0.112 | 0.123 | 0.22 | 0.13 | 0.342 ^a | -0.204 | -0.097 | 0.116 | 1 |

y - year; Statistically significant values: ap \leq 0.05, bp \leq 0.01, cp \leq 0.001.

Discussion

Good agreement of the Ag, Co, Cr, Fe, Hg, Rb, Sb, Sc, Se, and Zn contents analyzed by INAA-LLR with the certified data of CRM IAEA H-4 and IAEA HH-1 (Table 1) indicates an acceptable accuracy of the results obtained in the study of trace elements of the thyroid presented in Tables 2-5.

The obtained values for Cr, Fe, Hg, Rb, Sb, Sc, Se, and Zn contents, as shown in Table 3, agree well with median of means cited by other researches for the human thyroid, including samples received from persons who died from different diseases. However, the means for Ag and Co are an order of magnitude lower than the median of previously reported data. A number of values for trace element mass fractions were not expressed on a dry mass basis by the authors of the cited references. However, we calculated these values using published data for water (75%) [46] and ash (4.16% on dry mass basis) [47] contents in thyroid of adults.

A strongly pronounced tendency of age-related increase in Se mass fraction was observed in male thyroid (Table 4). In second group of males with mean age 52.9 years the mean mass fractions of this trace element in thyroids were 1.43 times higher than in thyroids of the first age group (mean age 21.9 years). There were no statistically significant differences between the Ag, Co, Cr, Fe, Hg, Rb, Sb, Sc, and Zn mass fractions within two different age-groups. The mass fractions of Se began to increase from the first decade (Figure 1). After age 20 years, content of Se was maintained at more or less steady level. It began again to increase from the sixth decade and reached the highest values in the thyroid of elderly persons. At the age of 80 years, content of Se was about 2 times higher than in thyroids of males aged 20-50 years (Figure 1). Age-dependence of Se mass fractions found using the comparison between results for two age groups was confirmed when the Pearson correlation coefficient between age and mass fractions of these elements was calculated (Table 5). No published data referring to age-related changes of Ag, Co, Cr, Fe, Hg, Rb, Sb, Sc, Se, and Zn mass fractions in thyroid of males were found.

A significant direct correlation, for example, between the Se and Sb, Co and Ag, Co and Cr, Co and Rb, Cr and Ag, Cr and Fe, Cr and Rb, Cr and Sc, Cr and Zn, Fe and Sc, Fe and Zn, Rb and Sc, Rb and Zn, Sc and Zn mass fractions as well as an inverse correlation between Hg and Co, and also Hg and Cr mass fractions was seen in male thyroid of the first age group (Table 5). In age group 2 many correlations between trace elements in thyroid found in the age group 1 are no longer evident (Table 5). For example, all correlations of Fe, Hg, Sb, Sc, Se, and Zn with other trace elements, existed in the age from 2 to 35 years, disappeared but new direct (Co and Sc, Sb and Zn) and inverse correlations (Zn-Sb) were arisen. Thus, if we accept the levels and relationships of trace element mass fraction in thyroid glands of males in the age range

2 to 35 years as a norm, we have to conclude that after age 35 years the relationships of trace elements in thyroid significantly changed. If some positive correlations between the elements in the group 1 were predictable (e.g., Fe-Cr), the interpretation of other observed relationships and their disturbance with age requires further study for a more complete understanding. No published data referring to inter-correlations of Ag, Co, Cr, Fe, Hg, Rb, Sb, Sc, Se, and Zn mass fractions in male thyroid and age-related changes of these inter-correlations was found.

The high level of Se content found just in the thyroid gland of old males cannot be regarded as pure chance. The seleno-protein characterized as Se-dependent glutathione peroxidase (Se-GSH-Px) is involved in protecting cells from peroxidative damage. This enzyme may reduce tissue concentration of free radicals and hydroperoxides. It is particular important for the thyroid gland, because thyroidal functions involve oxidation of iodide, which is incorporated into thyreoglobulin, the precursor of the thyroid hormones. For oxidation of iodide thyroidal cells produce a specific thyroid peroxidase using of physiologically generated hydrogen-peroxide (H_2O_2) as a cofactor [48]. It follows that the thyroid parenchyma must be continuously exposed to a physiological generation of H_2O_2 and in normal conditions must be a balance between levels of Se (as Se-GSH-Px) and H_2O_2 . Thus, it might be assumed that the elevated level of Se in thyroid of old males reflects an increase in concentration of free radicals and hydroperoxides in male gland at age above 60 years.

An age-related disturbance in inter-correlations of trace element mass fractions in thyroid parenchyma may contribute to harmful effects on the gland. There are good reasons for such speculations since many reviews and numerous papers raise the concern about toxicity and tumorigenesis of the trace elements and their different combinations [49-83].

All the deceased were citizens of Obninsk. Obninsk is the small nonindustrial city not far from Moscow in unpolluted area. None of those who died a sudden death had suffered from any systematic or chronic disorders before. The normal state of thyroid was confirmed by morphological study. Thus, our data for Ag, Co, Cr, Fe, Hg, Rb, Sb, Sc, Se, and Zn mass fractions in intact thyroid may serve as indicative normal values for males of urban population of the Russian Central European region.

Conclusion

The instrumental neutron activation analysis with high resolution spectrometry of long-lived radionuclides is a useful analytical tool for the non-destructive determination of trace element content in the thyroid tissue samples. This method allows determine means for Ag, Co, Cr, Fe, Hg, Rb, Sb, Sc, Se, and Zn (10 chemical elements).

Our data reveal that there is strongly pronounced tendency of increase in Se mass fraction in the normal thyroid of male during a lifespan. Moreover, a great disturbance of intra thyroid altrace

element relationships with increasing age was found. Therefore, a goitrogenic and carcinogenic effect of inadequate Se level in the thyroid of old males and a harmful impact of disturbance in intra thyroid altrace element relationships with increasing age may be assumed.

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Conflict of Interest Statement

The authors declare there is no conflict of interest.

References

- Gesing A (2015) The thyroid gland and the process of aging. *Thyroid Research* 8(Suppl 1): A8.
- Mitrou P, Raptis SA, Dimitriadis G (2011) Thyroid disease in older people. *Maturitas* 70(1): 5-9.
- Kwong N, Medici M, Angell TE, Liu X, Marqusee E, et al. (2015) The influence of patient age on thyroid nodule formation, multinodularity, and thyroid cancer risk. *J ClinEndocrinolMetab* 100(12): 434-440.
- Mazzaferri E (1993) Management of a solitary thyroid nodule. *NEJM* 328(8): 553-559.
- Smailyte G, Miseikyte-Kaubriene E, Kurtinaitis J (2006) Increasing thyroid cancer incidence in Lithuania in 1978-2003. *BMC Cancer* 11(6): 284.
- Olinski R, Siomek A, Rozalski R, Gackowski D, Foksinski M, et al. (2007) Oxidative damage to DNA and antioxidant status in aging and age-related diseases. *ActaBiochim Pol* 54(1): 11-26.
- Minelli A, Bellezza I, Conte C, Culig Z (2009) Oxidative stress-related aging: A role for prostate cancer? *BiochimBiophysActa* 1795: 83-91.
- Klaunig JE, Kamendulis LM, Hocoavar BA (2010) Oxidative stress and oxidative damage in carcinogenesis. *ToxicolPathol* 38: 96-109.
- Järup L (2003) Hazards of heavy metal contamination. *Br Med Bull* 68: 167-182.
- Zaichick V, Zaichick S (1999) Role of zinc in prostatecancerogenesis. In: *Mengen und Spurenelemente*, 19 Arbeitstagung. Anke M, et al (eds). Friedrich-Schiller-Universität, Jena, p.104-115.
- Zaichick V (2004) INAA and EDXRF applications in the age dynamics assessment of Zn content and distribution in the normal human prostate. *J RadioanalNuclChem* 262: 229-234.
- Zaichick V (2006) Medical elementology as a new scientific discipline. *J RadioanalNuclChem* 269: 303-309.
- Toyokuni S (2008) Molecular mechanisms of oxidative stress-induced carcinogenesis: from epidemiology to oxygenomics. *IUBMB Life* 60: 441-447.
- Gupte A, Mumper RJ (2009) Elevated copper and oxidative stress in cancer cells as a target for cancer treatment. *Cancer Treat Rev* 35: 32-46.
- Lee JD, Wu SM, Lu LY, Yang YT, Jeng SY (2009) Cadmium concentration and metallothionein expression in prostate cancer and benign prostatic hyperplasia of humans. *Taiwan yizhi* 108: 554-559.
- Zaichick V, Tsyb A, Vtyurin BM (1995) Trace elements and thyroid cancer. *Analyst* 120: 817-821.
- Zaichick V, Choporov Yu (1996) Determination of the natural level of human intra-thyroid iodine by instrumental neutron activation analysis. *J RadioanalNuclChem* 207(1): 153-161.
- Zaichick V, Zaichick S (1997) Normal human intrathyroidal iodine. *Sci Total Environ* 206(1): 39-56.
- Zaichick V (1998) Iodine excess and thyroid cancer. *J Trace Elements in Experimental Medicin* 11(4): 508-509.
- Zaichick V (1998) In vivo and in vitro application of energy-dispersive XRF in clinical investigations: experience and the future. *J Trace Elements in Experimental Medicin* 11(4): 509-510.
- Zaichick V, Iljina T (1998) Dietary iodine supplementation effect on the rat thyroid 131I blastomogenic action. In: *Die Bedeutung der Mengen- und Spurenelemente*. 18. Arbeitstagung. Anke M, et al (eds). Friedrich-Schiller-Universität, Jena, p.294-306.
- Zaichick V, Zaichick S (1999) Energy-dispersive X-ray fluorescence of iodine in thyroid puncture biopsy specimens. *J Trace and Microprobe Techniques* 17(2): 219-232.
- Zaichick V (1999) Human intrathyroidal iodine in health and non-thyroidal disease. In: *New aspects of trace element research*. Abdulla M, et al (eds). Smith-Gordon and Nishimura London and Tokyo, p.114-119.
- Zaichick V (2000) Relevance of, and potentiality for in vivo intrathyroidal iodine determination. In: *In Vivo Body Composition Studies*. Yasumura S, et al (eds). *Annals of the New York Academy of Sciences* 904: 630-632.
- Zhu H, Wang N, Zhang Y, Wu Q, Chen R, et al. (2010) Element contents in organs and tissues of Chinese adult men. *Health Phys* 98(1): 61-73.
- Vlasova ZA (1969) Dynamics of trace element contents in thyroid gland in connection with age and atherosclerosis. *Proceedings of the Leningrad Institute of Doctor Advanced Training* 80: 135-144.
- Katoh Y, Sato T, Yamamoto Y (2002) Determination of multielement concentrations in normal human organs from the Japanese. *Biol Trace Elem Res* 90(1-3): 57-70.
- Salimi J, Moosavi K, Vatankhah S, Yaghoobi A (2004) Investigation of heavy trace elements in neoplastic and non-neoplastic human thyroid tissue: A study by proton-induced X-ray emissions. *Iran J Radiat Res* 1(4): 211-216.
- Tipton IH, Cook MJ (1963) Trace elements in human tissue. Part II. Adult subjects from the United States. *Health Phys* 9(2): 103-145.
- Reddy SB, Charles MJ, Kumar MR, Reddy BS, AnjaneyuluCh, et al. (2002) Trace elemental analysis of adenoma and carcinoma thyroid by PIXE method. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms* 196(3-4): 333-339.
- Ataulchanov IA (1969) Age-related changes of manganese, cobalt, copper, zinc, and iron contents in the endocrine glands of females. *ProblemyEndocrinologii* 15(2): 98-102.
- Boulyga SF, Zhuk IV, Lomonosova EM, Kanash NV, Bazhanova NN (1997) Determination of microelements in thyroids of the inhabitants of Belarus by neutron activation analysis using the k0-method. *J RadioanalNuclChem* 222(1-2): 11-14.
- Boulyga SF, Becker JS, Malenchenko AF, Dietze H-J (2000) Application of ICP-MS for multielement analysis in small sample amounts of pathological thyroid tissue. *MicrochimicaActa* 134(3-4): 215-222.
- Fuzailov YuM (1981) Reaction of human and animal thyroids in the conditions of antimony sub-region of the Fergana valley. In: *IX All-Union Conference on Trace Elements in Biology*. Kishinev. pp. 58-62.
- Kvicala J, Havelka J, Zeman J, Nemeč J (1991) Determination of some trace elements in the thyroid gland by INAA. *J RadioanalNuclChem* 149(2): 267-274.

36. Zabala J, Carrion N, Murillo M, Quintana M, Chirinos J, et al. (2009) Determination of normal human intrathyroidal iodine in Caracas population. *J Trace Elem Med Bio* 23(1): 9-14.
37. Zaichick V (1997) Sampling, sample storage and preparation of biomaterials for INAA in clinical medicine, occupational and environmental health. In: *Harmonization of Health-Related Environmental Measurements Using Nuclear and Isotopic Techniques*. IAEA, Vienna. pp.123-133.
38. Zaichick V (2004) Losses of chemical elements in biological samples under the dry ashing process. *Trace Elements in Medicine* 5: 17-22.
39. Zaichick V, Zaichick S (2000) INAA applied to halogen (Br and I) stability in long-term storage of lyophilized biological materials. *J RadioanalNuclChem* 244(2): 279-281.
40. Zaichick V, Zaichick S (1996) Instrumental effect on the contamination of biomedical samples in the course of sampling. *The Journal of Analytical Chemistry* 51(12): 1200-1205.
41. Zaichick V, Zaichick S (1997) A search for losses of chemical elements during freeze-drying of biological materials. *J RadioanalNuclChem* 218(2): 249-253.
42. Zaichick V (1995) Applications of synthetic reference materials in the medical Radiological Research Centre. *Fresenius J Anal Chem* 352: 219-223.
43. Zaichick S, Zaichick V (2011) The effect of age on Ag, Co, Cr, Fe, Hg, Sb, Sc, Se, and Zn contents in intact human prostate investigated by neutron activation analysis. *J ApplRadiatIsot* 69: 827-833.
44. Zaichick S, Zaichick V (2010) The effect of age and gender on 37 chemical element contents in scalp hair of healthy humans. *Biol Trace Elem Res* 134(1): 41-54.
45. Korelo AM, Zaichick V (1993) Software to optimize the multielement INAA of medical and environmental samples. In: *Activation Analysis in Environment Protection*. Joint Institute for Nuclear Research, Dubna, Russia, p.326-332.
46. Katoh Y, Sato T, Yamamoto Y (2002) Determination of multielement concentrations in normal human organs from the Japanese. *Biol Trace Elem Res* 90(1-3): 57-70.
47. Schroeder HA, Tipton IH, Nason AP (1972) Trace metals in man: strontium and barium. *J Chron Dis* 25(9): 491-517.
48. Aaseth J, Frey H, Glatte E, Norheim G, Ringstad J, et al. (1990) Selenium concentrations in the human thyroid gland. *Biol Trace Elem Res* 24(2-3): 147-152.
49. Sunderman FW (1979) Mechanism of metal carcinogenesis. *Biol Trace Elem Res* 1: 63-86.
50. Snow ET (1992) Metal carcinogenesis: mechanistic implications. *PharmacolTher* 53: 31-65.
51. Toyokuni S (2009) Role of iron in carcinogenesis: cancer as a ferrotoxic disease. *Cancer Sci* 100: 9-16.
52. Martinez-Zamudio R, Ha HC (2011) Environmental epigenetics in metal exposure. *Epigenetics* 6: 820-827.
53. Tokar EJ, Benbrahim-Tallaa L, Waalkes MP (2011) Metal ions in human cancer development. *Met Ions Life Sci* 8: 375-401.
54. Tchounwou PB, Yedjou CG, Patlolla AK, Sutton DJ (2012) Heavy metal toxicity and the environment. *EXS* 101: 133-164.
55. Koedrich P, Kim H, Weon JI, Seo YR (2013) Toxicogenomic approaches for understanding molecular mechanisms of heavy metal mutagenicity and carcinogenicity. *Int J Hyg Environ Health* 216: 587-598.
56. Tabrez S, Priyadarshini M, Priyamvada S, Khan MS, Na A, et al. (2014) Gene-environment interactions in heavy metal and pesticide carcinogenesis. *Mutat Res* 760: 1-9.
57. Zaichick V, Zaichick S (1999) Role of zinc in prostate cancerogenesis. In: *Mengen und Spurenelemente*. 19. Arbeitstagung. Anke M, et al (eds). Friedrich-Schiller-Universität, Jena, p.104-115.
58. Zaichick V (2004) INAA and EDXRF applications in the age dynamics assessment of Zn content and distribution in the normal human prostate. *J RadioanalNuclChem* 262(1): 229-234.
59. Zaichick S, Zaichick V (2011) INAA application in the age dynamics assessment of Br, Ca, Cl, K, Mg, Mn, and Na content in the normal human prostate. *J RadioanalNuclChem* 288(1): 197-202.
60. Zaichick S, Zaichick V (2011) The effect of age on Ag, Co, Cr, Fe, Hg, Sb, Sc, Se, and Zn contents in intact human prostate investigated by neutron activation analysis. *J ApplRadiatIsot* 69(6): 827-833.
61. Zaichick V, Nosenko S, Moskvina I (2012) The effect of age on 12 chemical element contents in intact prostate of adult men investigated by inductively coupled plasma atomic emission spectrometry. *Biol Trace Elem Res* 147(1): 49-58.
62. Zaichick S, Zaichick V, Nosenko S, Moskvina I (2012) Mass Fractions of 52 Trace Elements and Zinc Trace Element Content Ratios in Intact Human Prostates Investigated by Inductively Coupled Plasma Mass Spectrometry. *Biol Trace Elem Res* 149(2): 171-183.
63. Zaichick V, Zaichick S (2014) INAA application in the assessment of chemical element mass fractions in adult and geriatric prostate glands. *J ApplRadiatIsot* 90: 62-73.
64. Zaichick V, Zaichick S (2014) Determination of trace elements in adults and geriatric prostate combining neutron activation with inductively coupled plasma atomic emission spectrometry. *Open Journal of Biochemistry* 1(2): 16-33.
65. Zaichick V, Zaichick S (2014) Use of INAA and ICP-MS for the assessment of trace element mass fractions in adult and geriatric prostate. *J RadioanalNuclChem* 301(2): 383-397.
66. Zaichick V, Zaichick S (2014) Age-related histological and zinc content changes in adult nonhyperplastic prostate glands. *Age* 36(1): 167-181.
67. Zaichick V, Zaichick S (2015) Differences and relationships between morphometric parameters and zinc content in nonhyperplastic and hyperplastic prostate glands. *BJMRR* 8(8): 692-706.
68. Zaichick V, Zaichick S, Davydov G (2015) Differences between chemical element contents in hyperplastic and nonhyperplastic prostate glands investigated by neutron activation analysis. *Biol Trace Elem Res* 164: 25-35.
69. Zaichick S, Zaichick V (2015) Prostatic Tissue Level of some Androgen Dependent and Independent Trace Elements in Patients with Benign Prostatic Hyperplasia. *Androl Gynecol: Curr Res* 3: 3.
70. Zaichick V, Zaichick S (2016) The Bromine, Calcium, Potassium, Magnesium, Manganese, and Sodium Contents in Adenocarcinoma of Human Prostate Gland. *J Hematology and Oncology Research* 2(2): 1-12.
71. Zaichick V, Zaichick S (2016) Trace element contents in adenocarcinoma of human prostate investigated by energy dispersive X-ray fluorescent analysis. *Journal of Adenocarcinoma* 1(1): 1-7.
72. Zaichick V, Zaichick S (2016) Trace element contents in adenocarcinoma of the human prostate gland investigated by neutron activation analysis. *Cancer Research and Oncology* 1(1): 1-10.
73. Zaichick V, Zaichick S (2016) Variations in concentration and distribution of several androgen-dependent and -independent

- trace elements in nonhyperplastic prostate gland tissue throughout adulthood. *J AndrolGynaecol* 4(1): 1-10.
74. Zaichick V, Zaichick S (2016) Prostatic tissue levels of 43 trace elements in patients with prostate adenocarcinoma. *Cancer and Clinical Oncology* 5(1): 79-94.
75. Zaichick V, Zaichick S (2016) Levels of 43 trace elements in hyperplastic prostate tissues. *British Journal of Medicine and Medical Research* 15(2): 1-12.
76. Zaichick V, Zaichick S (2016) Prostatic tissue level of some major and trace elements in patients with BPH. *JJ NephroUrol* 3(1): 025.
77. Zaichick V, Zaichick S (2016) Age-related changes in concentration and histological distribution of Br, Ca, Cl, K, Mg, Mn, and Na in nonhyperplastic prostate of adults. *European Journal of Biology and Medical Science Research* 4(2): 31-48.
78. Zaichick V, Zaichick S (2016) Variations in concentration and histological distribution of Ag, Co, Cr, Fe, Hg, Rb, Sb, Sc, Se, and Zn in nonhyperplastic prostate gland throughout adulthood. *Jacobs Journal of Cell and Molecular Biology* 2(1): 011.
79. Zaichick V, Zaichick S (2016) Age-related Changes in Concentration and Histological Distribution of 18 Chemical Elements in Nonhyperplastic Prostate of Adults. *World Journal of Pharmaceutical and Medical Research* 2(4): 5-18.
80. Zaichick V, Zaichick S (2016) Age-related changes in concentration and histological distribution of 54 trace elements in nonhyperplastic prostate of adults. *Int Arch UrolComplic* 2(2): 019.
81. Zaichick V, Zaichick S (2016) The Comparison between the contents and interrelationships of 17 chemical elements in normal and cancerous prostate gland. *Journal of Prostate Cancer* 1(1): 105.
82. Zaichick V, Zaichick S, Wynchank S (2016) Intracellular zinc excess as one of the main factors in the etiology of prostate cancer. *Journal of Analytical Oncology* 5(3): 124-131.
83. Zaichick V, Zaichick S, Rossmann M (2016) Intracellular calcium excess as one of the main factors in the etiology of prostate cancer. *AIMS Molecular Science* 3(4): 635-647.



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