

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± 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; Traceelements; 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, $M \pm SEM$, $n=34$) and group 2, 36-80 years

(52.9 ± 2.7 years, $M \pm SEM$, $n=28$). 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-cm^3 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 ${}^{60}\text{Co}$ 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,

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-arithmetic 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.

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.

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-arithmetic 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 M or M±SD, (n)**	This work M±SD
	Median of Means (n)*	Maximum 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	0.636c	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	0.453b	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≤0.05, bp ≤ 0.01, cp ≤ 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 selenoprotein 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 particularly 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 thyroidal trace

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.

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