APPLICATION OF NUCLEAR METHODS

https://doi.org/10.46813/2022-141-092

IMBALANCE OF ESSENTIAL AND TOXIC ELEMENTS IN THE BIOSAMPLES OF PATIENTS WITH SURFACE GASTRITIS WITH DIFFERENT SECRETORY ACTIVITY

N.P. Dikiy[1], Yu.V. Layshko[1], E.P. Medvedeva[1], D.V. Medvedev[1], T.A. Parhomenko[1], K.Yu. Parhomenko[2]
[1]National Science Center "Kharkov Institute of Physics and Technology", Kharkiv, Ukraine;
[2]Regional Clinical Hospital, Kharkiv, Ukraine
E-mail: ndikiy@kipt.kharkov.ua

The results of the application of various nuclear physics methods (characteristic X-ray radiation, gamma-activation analysis, and X-ray fluorescence analysis) to the study of the imbalance of certain elements in various biological samples (blood, hair, gastric mucus) in patients with superficial gastritis with increased and decreased secretory activity. The detection limit ranged from 10^{-4}…10^{-7} mas.% of the mass. Particular attention was paid to sample preparation and the study of the analytical capabilities of the methods. It is shown that in this pathology there is an increased content of essential elements in the hair and a significant content of conditionally toxic and toxic elements in the blood and gastric mucus.

PACS: 87.64.-t

INTRODUCTION

The various elements that apprear part of enzymes, vitamins, and other highly active biomolecules in small quantities are the basis for the existence of living organisms. They play an important role in the regulation of metabolic processes at the level of the organism, an individual organ, and a molecule. Therefore, the determination of the mechanisms of disruption of the functioning of both an individual cell and the organism as a whole is impossible for studying the elemental content of biological objects. As a rule, the nature of the occurrence of various diseases is multifactorial: the possibility of an ecological origin, the individual metabolic nature of the disease, late diagnostic criteria, and much more.

Recently, for the analysis of biological objects, nuclear-physical methods have been increasingly used, since. They can provide simultaneous multi-element analysis with μg/g sensitivity. Nuclear physics methods of element analysis differ both in the type of radiation acting on the object and in the way the effects are registered. Each of these methods has its own advantages and disadvantages, and hence certain limitations in solving problems of elemental analysis.

In this work, an attempt was made to use the various nuclear physics methods to determine the content of elements in various biological samples during the development of such a pathology as gastritis.

It is known, that chronic gastritis is a general disease, which raise different metabolic processes. Gastric is characterized as multifactorial disease that results from individual genetic predisposition and exposure to environmental factors. This disease is rather wide-spread in the world and it can be relate to microelementozes [1]. The disturbance of absorption of biometals depends on the depth of inflamentory and destructive changes in gastric, accompanied by changes in metabolic processes and as resulted into imbalance of trace elements bioavailability. The early stages of gastric are usually asymptomatic or associated with nonspecific symptoms such as dyspepsia. Advanced stages may be accompanied by persistent abdominal pain, anorexia, and weight loss.

Much attention is currently paid to the role of microelements in the etiopathogenesis of the diseases of gastric [2]. The essential microelements have a significant influence on gastric secretion, production of protective factors, reverse diffusion of hydrogen ions, physiological activity of hormones and vitamins, tissue respiration.

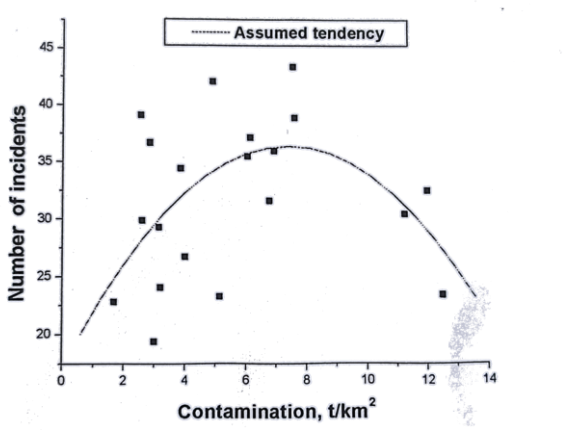

Fig. 1. The dependence of the incidence of stomach cancer on air pollution in various regions of Ukraine

Microelements and macroelements are naturally occurring elements that are found throughout the earth`s crust, most environmental contamination and human exposure result from anthropogenic activities such as mining and smelting operations, industrial production, and domestic and agricultural use of metals and metal-containing compounds [3]. Environmental contamination can also occur through metal corrosion, atmospheric deposition, soil erosion of metal ions and leaching of heavy metals, sediment resuspension, and metal evaporation from water resources to soil and

groundwater. Also, industrial sources include metal processing in refineries, coal burning in power plants, petroleum combustion, nuclear power stations, high tension lines, plastics, textiles, and others.

On Fig. 1 shows the dependence of the incidence of stomach cancer on air pollution in various regions of Ukraine.

1. MATERIALS AND METHODS

Methods of characteristic X-ray (PIXE), γ-activation, and X-ray fluorescence analysis were used to measure the content of elements in hair, blood, and parietal gastric mucus in patients diagnosed of superficial gastritis with increased and decreased secretory activity. Among the examined 47 patients with superficial gastritis (men 45…60 years) in 27 individuals with increased secretory activity and 20 with decreased. The diagnosis was verified at Regional Clinical Hospital.

For excitation PIXE in the examined samples (blood) was used to accelerate protons with energy from 1 of 3 MeV. The target was presented with a dried blood multilayer on pyrographic. The nuclear target was a thickness of 20 mg/cm^2. Trace elements in hair were determined by bremsstrahlung irradiated from linac accelerator electron with energy 23 MeV and current 500 μA. Activation of samples was carried out on air, the temperature of samples in the course of the activation did not exceed 40ºC.

X-ray fluorescence (two TXRF systems) on "Seifert" (Ahrensburg, Germany) was used to determine trace elements in parietal gastric mucus. In such a device, a drop of the test sample with a volume of 10…20 μl is applied to a quartz cuvette, quickly frozen and dried in a vacuum. Excitation of X-ray fluorescence is produced by a collimate scanning beam to the substrate surface at an angle of ~ 4. With such geometry of measurement, the substrate radiation practically does not contribute to the measured X-ray spectrum. The small volume of sample required for analysis and using internal standards for calibration are the main advantages of using this method in medical practice.

The emission spectra of the elements were recorded by Si(Li)-220 eV, in line 5.9 keV and Ge(Li)-detector volume of 50 cm^3 and resolution 3.2 at 1332 MeV line. To reduce the influence of the background, the detector is equipped with three-layer Pb-Cu-Al protection. Standard amplitude spectrum processing programs processed the spectra obtained from the samples. The detection limit of the elements was 10^{-4}…10^{-7} mas.% of the mass. Prior to analysis, the samples were prepared according to International Atomic Energy Agency (IAEA) Instruction [4].

2. RESULTS AND DISCUSSION

It is shown, that the blood and the hair of patients with superficial gastritis revealed significant variation of trace elements (Fig. 2). Severe imbalance of essential elements was typical for all types of superficial gastritis with increased and decreased secretory activity in comparison with the control group. A significant increase in the content of essential elements was marked for Cu, Mg, Ca, Rb, Si, Mn, Sr, conditionally toxic Cr, Ni, Al, Mo, Br, and for toxic elements – Pb, As. The level of increase was from 0.5 to 2.1 times. Zinc and selenium deficiency more often develop at inflammatory changes in the digestive tract.

The composition of trace elements in blood samples was studied by method of PIXE and γ-activation analysis. The results were identical.

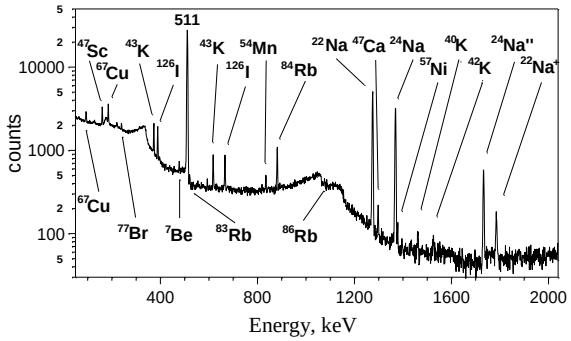

Fig. 2. Typical gamma spectrum of a blood sample activated for LAE

It is shown also that this pathology is accompanied by significant violations of the content of essential, potentially toxic trace elements and toxic elements not only in blood, and in other biosamples. These disorders in this pathology can be caused by both endogenous and exogenous factors. The character of gastritis depends on the general and specific environmental pollution, as well as the association with smoking, alcohol, and possibility coexistent diseases.

The results of elements content in hair of patients with superficial gastritis are presented in Fig. 3. These results demonstrate similarities for all types of superficial gastritis with increased and decreased secretory activity. It should be noted that hair is a good biological indicator and it can be used for the purposes of medicine. Hair analysis provides an opportunity to define disbalance in content essential and toxical elements between different all types of superficial gastritis with increased and decreased secretory activity. The content of essential elements, such as Zn, Cu, Mn, Fe, Rb, Sr, toxic elements, such as As, Pb and trace elements with an unknown role, such as Zr and Sc was defined. The content of essential elements, such as Zn, Cu, Mn, Fe in hair is strictly regulated by biological mechanisms. Several studies have confirmed this fact too [5-8].

One of the most important factors influencing Zn, Cu, Mn, and Fe content in hair is diet [9]. In this work, the patients had various types of diets, from mainly carbohydrate types of food to lipid/protein compounded diets. But the human body is an integrity organism, in which the components of tissue and cell, and bioactive substances including trace elements, enzymes, hormones, and messenger substances exit with a definite content and definite quantitative ratio. It is important to measure the content of each element, but it is more important to measure the quantitative ratio of bioactive elements. These ratios in normal keep in the state of dynamic balance within a definite range. If this balance is broken, pathological processes and functional disturbances will arise. In our case, the essential

elements contained in the hair of patients with chronic gastritis are higher than the normal value. At the same toxic elements Pb, As and conditional elements such as Ni, Al, Cr are concentrated in the blood and gastric mucus.

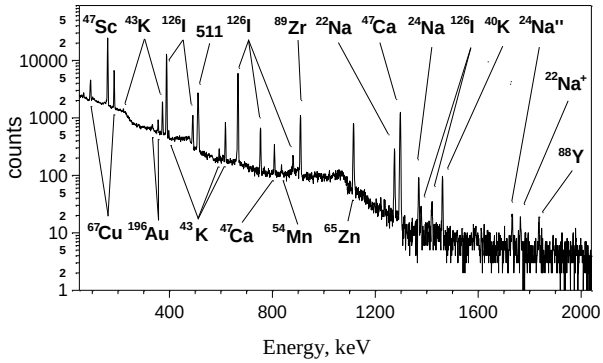

Fig. 3. Typical gamma spectrum of a hair

As for element content in gastric mucus that there are Ni, Ti, Pb, Al, and rare earth elements Y, La, and exotic elements Tl, Bi. Examined elements content in parietal gastric mucus characterized by a significant increase in the level of toxical elements Pb, As and conditionally toxic Cr, Ni, Al, Ti and systemic deficiency of essential elements. This fact, probably, can be connected with those, that essential elements as compensators were included in metabolism and in the inflammatory process, its reserve is exhausted rather rapidly.

The Table shows the lines of elements from nuclear reactions that were not represented in the spectra.

El.	Reaction	$T_{1/2}$	Lines of radio-nuclides, keV
C	$^{12}C(\gamma,n\alpha)^{7}Be$	53.3 D	477.6
Na	$^{23}Na(\gamma,n)^{22}Na$ $^{23}Na(n,\gamma)^{24}Na$	2.60 Y 15.0 H	1275 1369
Mg	$^{25}Mg(\gamma,p)^{24}Na$	15.0 H	1369.
Cl	$^{35}Cl(\gamma,n)^{34m}Cl$	32.0 M	146.4, 1177.
K	^{40}K->$^{41}K(n,\gamma)^{42}K$	1.3E9 Y 12.4 H	1461. 1525.
Ca	$^{43}Ca(\gamma,p)^{42}K$ $^{44}Ca(\gamma,p)^{43}K$ $^{48}Ca(\gamma,n)^{47}Ca$ ^{47}Ca->^{47}Sc	12.4 H 22.3 H 4.54 D 3.35 D	1525. 372.8, 617.5 489.2, 1297. 159.4
Ti	$^{47}Ti(\gamma,p)^{46}Sc$ $^{48}Ti(\gamma,p)^{47}Sc$ $^{49}Ti(\gamma,p)^{48}Sc$	83.8 D 3.35 D 43.7 H	889.3, 1121. 159.4 983.5, 1312.
Cr	$^{52}Cr(\gamma,n)^{51}Cr$	27.7 D	320.1
Mn	$^{55}Mn(\gamma,n)^{54}Mn$ $^{55}Mn(n,\gamma)^{56}Mn$	312.3 D 2.58 H	834.8 846.7, 1811.
Fe	$^{54}Fe(\gamma,2n)^{52}Fe$ $^{55}Fe(\gamma,p)^{54}Mn$ $^{57}Fe(\gamma,p)^{56}Mn$	8.28 H 312.3 D 2.58 H	168.7 834.8 846.7, 1811.
Ni	$^{58}Ni(\gamma,n)^{57}Ni$ $^{58}Ni(\gamma,p)^{57}Co$ ^{57}Ni->^{57}Co	35.6 H 271.8 D	127.2, 1378. 122.1, 136.5
Cu	$^{63}Cu(\gamma,2n)^{61}Cu$ $^{63}Cu(n,\gamma)^{64}Cu$	3.3 H 12.7 H	283.0, 656.0 1346.
Zn	$^{64}Zn(\gamma,2n)^{62}Zn$ $^{66}Zn(\gamma,n)^{65}Zn$ $^{68}Zn(\gamma,p)^{67}Cu$ $^{70}Zn(\gamma,n)^{69m}Zn$	9.2 H 244.3 D 61.8 H 13.8 H	548.3, 596.6 1116. 92.7, 184.6 438.6
Br	$^{79}Br(\gamma,2n)^{77}Br$	57.0 H	239.0, 520.7
Rb	$^{85}Rb(\gamma,2n)^{83}Rb$ $^{85}Rb(\gamma,n)^{84}Rb$ $^{87}Rb(\gamma,n)^{86}Rb$	86.2 D 32.8 D 18.6 D	520.4, 529.6 881.6 1077.
Sr	$^{84}Sr(\gamma,p)^{83}Rb$ $^{86}Sr(\gamma,n)^{85}Sr$ $^{87}Sr(\gamma,p)^{86}Rb$ $^{88}Sr(\gamma,n)^{87m}Sr$	86.2 D 64.8 D 18.6 D 2.8 H	520.4, 529.6 514.0 1077. 388.5
Y	$^{89}Y(\gamma,n)^{88}Y$	106.7 D	898.0, 1836
Zr	$^{90}Zr(\gamma,n)^{89}Zr$	78.4 H	909.2
I	$^{127}I(\gamma,n)^{126}I$	13.1 D	388.6, 666.3
Au	$^{197}Au(\gamma,n)^{196}Au$	6.2 D	333.0, 355.7
Tl	$^{203}Tl(\gamma,n)^{202}Tl$	12.2 D	439.6

CONCLUSIONS

The results of the application of the nuclear-physics methods of characteristic X-ray (PIXE), γ-activation, and X-ray fluorescence analysis to determination of element content in blood, hear and gastric mucus of patients with superficial gastritis are presented. The detection limit was from 10^{-4}…10^{-7} mas.% of the mass.

It has been shown that with the appropriate development of nuclear physics methods for determining trace elements in various biological samples in patients with superficial gastritis with different secretory activity, recommendations can be made to correct the imbalance of these elements.

REFERENCES

1. M. Anke. Trace elements intake and balance of adults in Central Europe // *Evian*. 1999, p. 3-7.
2. A. Agarwal, P. Khanna, D. Baiday, M. Arora. Trace elements in critical illness *// J. of endocrinology and metabolism.* 2011, 1(nexplained), p. 57-63.
3. Z.L. He, X.E. Yang, P.J. Stoffella. Trace elements in the agroecosystem and impacts on the environment // *J. Trace Elem. Med. Biol.* 2005, v. 19(2-3), p. 125-140.
4. *International coordinated program on activation analysis of trace elements.* Praeger Publisher, New York, 1980, p. 3-34.
5. E.J. Underwood. *Trace elements in human and animal nutrition*. Acad. Press, New York, 1971, p. 370.
6. W. Mertz. Trace elements nutrition in health and disease: contribution and problems of analysis // *Clin. Chem.* 2011, v. 21, p. 468-475.
7. K. Liebscher, H. Smith. Essential and non-essential trace elements // *Arch. Environ. Health*. 2001, p. 881-890.
8. D.I. Hammer, J.F. Finclear, R.H. Hendricks, C.M. Shy. Yair trace metal levels and environmental exposure // *Am. J. Epidemiol*. 2013, v. 93, p. 84-92.
9. M.H. Briggs, M. Briggs, A. Vakatama. Trace elements in human hair // *Experientia*. 1998, v. 28, p. 406-409.

Article received 30.08.2022

ДИСБАЛАНС ЕССЕНЦІАЛЬНИХ ТА ТОКСИЧНИХ ЕЛЕМЕНТІВ У БІОЗРАЗКАХ ХВОРИХ НА ПОВЕРХНЕВИЙ ГАСТРИТ З РІЗНОЮ СЕКРЕТОРНОЮ АКТИВНІСТЮ

М.П. Дикий, Ю.В. Ляшко, О.П. Медведєва, Д.В. Медведєв, Т.О. Пархоменко, К.Ю. Пархоменко

Показані результати застосування різних методів ядерної фізики (характеристичне рентгенівське випромінювання, гамма-активаційний і рентгенофлуоресцентний аналізи) для дослідження дисбалансу окремих елементів у різних біологічних зразках (кров, волосся, шлунковий слиз) у хворих на поверхневий гастрит з підвищеною та зниженою секреторною активністю. Межа виявлення елементів становила $10^{-4}…10^{-7}$ мас.%. Особливу увагу було приділено пробопідготовці та вивченню аналітичних можливостей методів. Показано, що при даній патології спостерігається підвищений вміст ессенціальних елементів у волоссі та підвищений вміст умовно-токсичних і токсичних елементів у крові та слизу шлунка.