Distribution of Radioactive Elements in Environmental Objects

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Abstract: *The distribution of radionuclides in the soil, vegetation and drinking water sources of the country was studied. Drinking water supplied through the water consumption lines of regions of the country meet the requirements of the relevant standards. By systematic studies have established that the degree of assimilation of the K^{40} isotope by vegetation from soil and water is approximately 3,5-5,0 times higher than the degree of assimilation of radioactive isotopes of other elements.*

Keywords: *Vegetation, soil, drinking water, background, radionuclides.*

1. BRIEF LITERATURE REVIEW

By the staff of the Radiochemistry laboratory of the Institute of Radiation Problems of the Azerbaijan National Academy of Sciences has systematically taken numerous samples of water, soil and vegetation and carried out comprehensive physical-chemical and radiometric examination of these samples in stationary laboratory conditions. Studying the distribution of radionuclides in the soil is an urgent task to solve problems related to environmental safety.The accumulation of large amounts of harmful substances in the soil causes the risk of their entry into living organisms by translocation and migration paths along the soil-water-vegetation chain. Studying the various forms of the presence of chemical elements in soil samples allow us to estimate the ecological state of the soil [1].

The processing of minerals by outdated technological processes and the consequent pollution of environmental objects with small amounts of xenobiotics can cause the formation of ecological crisis zones. Therefore, there is a need for systematic measurements and studies to obtain results on the distribution of radionuclides, heavy metals and other xenobiotics in the soil, vegetation, water reservoirs of the country, trends in the direction of the emergence of zones of environmental crisis, information for predicting changes and the rate of change in the environment[1, 2].

2. METODICAL PART

The soil samples were treated with distilled water, weak solutions of acid and alkali with periodic mixing and filtration, isolation of sparingly soluble particles in a centrifuge with further evaporation to obtain minerals, heavy metals and radionuclides. After radiometric measurements, the obtained dry mineral was analyzed by methods of physical chemistry. Radiometric measurements were carried out using the İnSpector-1000 and Radiagem-2000 radiometers (manufactured by Canberra and equipped with alpha, beta and gamma detectors) and the İdentiFİNDER radiometer identifier (manufactured by Thermo Scientific).In the process of physical-chemical analysis of minerals were use the gamma spectrometer with HPGe detector manufactured by Canberra, Electronic Microscope "SEM"(manufactured by Carl-Ziess with an electron tube), atomic absorption AA-6800 spectrometer (manufactured by Shimadzu), Expert-3L and XRF X-ray fluorescence spectrometers [3, 4].

Pre-sterilized glassware was used to take water samples and samples were taken, stored and transported in accordance with the requirements of standards (GOST) 24481-80 and 18968-73[3].

3. DISCUSSION OF THE RESULTS

Samples of vegetation and soil were taken in summer and autumn from green grassy meadows, pastures or forest edges, at a distance of at least 10 kilometers from housing estates or industrial enterprises. Water samples were taken from nearest water reservoirs or from rivers flowing near these sites. Soil samples were also taken from these sites by digging the soil to a depth of 10-20 sm. A decrease in the mass of soil and vegetation samples by 1.4–1.5 and 4.5–6.0 times, respectively, after their two-week drying was determined. The activity of radionuclides in water, vegetation and soil samples taken from the same water sources are shown in table 1, 2 and 3.

Table1: Activity of radionuclides in water samples taken from the water sources of regions

Regions	Isotopes, *Bq/l*									
	$_{11}Na^{22}$	$_{19}K^{40}$	$_{26}Fe^{60}$	$_{27}Co^{57}$	$_{30}Zn^{65}$	$_{38}Sr^{91}$	$_{50}Sn^{113}, _{50}Sn^{126}$	$_{63}Eu^{152},_{63}Eu^{154}$	$_{88}Ra^{226}$	$_{90}Th^{228}$
Naftalan /artesian/	1,0	0,1	0,5	0,24	0,1	0,2	0,12; 0,15	0,12; 0,14	0,24	0,04
Ganja	0,50	0,13	0,28	0,24	0,05	0,16	0,004; 0	0,2; 0,16	0,16	0,01
Shamkir /Shamkir River/	0,60	0,1	0,16	0,45	0,03	0,1	0,004;0,1	0,1; 0,16	0,23	0,02

Table 2: The activities of radionuclides in vegetation samples taken from regions of country

Region	Isotopes, *Bq/kq*									
	$_{11}Na^{22}$	$_{19}K^{40}$	$_{26}Fe^{60}$	$_{27}Co^{57}, _{27}Co^{60}$	$_{30}Zn^{65}$	$_{38}Sr^{91}$	$_{50}Sn^{113} _{50}Sn^{126}$	$_{63}Eu^{152},_{63}Eu^{154}$	$_{88}Ra^{226}$	$_{90}Th^{228}$
Naftalan	1,6	1,4	0,72	0,48	0,20	0,38	0,20; 0,25	0,20; 0,24	0,46	0,06
Ganja	1,0	2,0	0,52	0,48	0,10	0,30	0,01; 0,04	0,38; 0,30	0,30	0,02
Shamkir	1,1	1,4	0,30	0,80	0,06	0,20	0,01; 0,20	0,20; 0,30	0,44	0,03

The results of radiometric measurements and the activity of radionuclides in soil samples taken from the same green lowland plots and pastures in the regions of the country are shown in table 3.

Table 3: The activities of radionuclides in soil samples taken in the country's regions

Regions (background - *μZv / h;* alpha ray *Bq_{eq} / sm²*)	Isotopes, Bq / kq									
	$_{11}Na^{22}$	$_{19}K^{40}$	$_{26}Fe^{60}$	$_{27}Co^{57}, _{27}Co^{60}$	$_{30}Zn^{65}$	$_{38}Sr^{91}$	$_{50}Sn^{113}, _{50}Sn^{126}$	$_{63}Eu^{152}, _{63}Eu^{154}$	$_{88}Ra^{226}$	$_{90}Th^{228}$
Naftalan (0,04; 0)	2,1	1,8	1,04	0,72	0,32	0,50	0,30; 0,35	0,30; 0,34	0,70	0,10
Ganja (0,03; 0)	1,5	2,0	0,88	0,72	0,16	0,45	0,02; 0,08	0,59; 0,56	0,45	0,03
Shamkir (0,03; 0-0,01)	1,6	1,8	0,51	1,10	0,10	0,30	0,02; 0,30	0,30; 0,42	0,66	0,05

The studies showed that the chemical and microbiological parameters of water samples taken from the central water supply lines of the population of the country's regionsmeet the requirements of GOST 2874-82 and AZS 282-2007 standards for drinking water.

The concentration (radiation activity) of the Na^{22} isotope in minerals of drinking water supplied through the water lines for the population and organizations of the regions is 0.5-1,0Bq/l, the isotope concentration of K^{40} is 0.10-0,13Bq/l (these values are characteristic low values for natural spring waters), the dose rate of gamma radiation from the background of these cities is 0.03-0.04 μZv/h, the intensity of alpha radiation ranges from 0-0.01 Bq_{eq}/sm^2.

According to the "Law of the Republic of Azerbaijan on Radiation Safety of the Population", the permissible value of the average annual dose for the population is 1 mZv, which is equivalent to the absorbed dose rate of 0.115 or approximately 0.12 mZv/h.

Table 3 shows the results of measuring the total radioactive radiation in the regions of the country, an assessment of the types of radiation and a study of the

distribution of radionuclides in the soil. The measurement results show that the values of the total radioactive radiation /absorbed dose rate/ in many areas of the country (0.03-0.04 mZv/h) do not exceed the maximum permissible value /PV = 0.12 mZv/h)/.

The comparison of the values of the components in 1 liter of water with the corresponding values of the components in 1 kg of soil and vegetation shows the higherassimilation of potassium by vegetation in comparison with other components.

The comparison of the indices of tables 1, 2 and 3, as well as the spectra obtained by gamma spectroscopy of minerals of water, vegetation and soil samples show identic values for the activity of the K^{40} isotope in 1 kg soil and in 1 kg vegetation samples, these values are 7-10 times exceed the corresponding activity value of the K^{40} isotope for 1 liter of water taken from the same site. This ratio for other elements is approximately 2. These values show that the assimilation process of K^{40} isotope by plants from water and soil is more (3,5-5,0 times) efficientthan the process of assimilation the other natural radioactive elements.

As is known, photosynthesis is a complex chemical process of converting light energy, infrared radiation into the energy of chemical bonds of organic substances with the participation of photosynthetic pigments (plant chlorophylls, bacteriochlorophyll bacteria, archaea bacteriorhodopsin).The binding energy of the hydrogen atom with the hydroxyl group of the water molecule is 5 eV / molecule. The established low values of the energy of light quanta allowed to conclude that the nature of the course of photosynthesis is complex and the complex mechanisms of the process of splitting water molecules in plants are proposed.In general, photosynthesis can be represented in the following equation:$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

Two types of pigments were found in living organisms (the retinal vitamin A derivative is less common, and chlorophylls are involved in photosynthesis in most organisms). In accordance with this, chlorine-free and chlorophyll photosynthesis are isolated. The efficiency of chlorophyll-free photosynthesis is relatively low (one H^+ is transferred to one absorbed quantum of light). This process is found in the mating membrane of halobacteria. As a result of the operation of the light-dependent proton pump (bacteriorhodopsin) of the membrane, the energy of sunlight transforms into the energy of the electrochemical gradient of protons on the membrane. Chlorophyll photosynthesis is more energy efficient. At least one H^+ is transferred to each absorbed light quantum against the gradient and energy is stored in the form of reduced compounds (ferrodoxin, etc.). Oxygen-free chlorophyll photosynthesis (purple, green bacteria and heliobacteria) proceeds without oxygen

evolution. Oxygenic chlorophyll photosynthesis (plants, algae, cyanobacteria, etc.) is accompanied by the release of oxygen. In the initial (photophysical) stage of photosynthesis, light quanta are absorbed by pigments, they transition to an excited state and energy is transferred to other molecules of the photosystem (plastoquinone).In the photochemical stage, charge separation occurs in the reaction center. A water molecule loses under the influence of a radical cation formed from a chlorophyll molecule after it loses its electron and transfers it to plastoquinone in the first stage ($H_2O - e- \rightarrow H^+ + \cdot OH$). Hydroxyl radicals formed under the influence of positively charged manganese ions are converted into oxygen and water ($4 \cdot OH \rightarrow O_2 + 2H_2O$).

In the chemical stage, light quantum is absorbed by another chlorophyll molecule and transfers its electron to ferrodoxin.Next, biochemical reactions of the synthesis of organic substances using energy accumulated at the already described light-dependent stages take place.

The energy of gamma rays (1.45 MeV) emitted by the K^{40} isotope is many times higher than the value of the binding energy of hydrogen with a hydroxyl group in water molecules (5 eV). In addition, K^{40} isotopes were found without exception in all the samples taken from the environment without exception, and the geometric dimensions of the studied vegetation specimens were directly proportional to the activity (concentration) of K^{40} detected in them.

Therefore, we concluded that along with the multi-stage processes of splitting water molecules in the proposed photosynthesis mechanisms, the cause of the splitting of hydrogen atoms from water molecules, in addition to the complex process of photolytic decomposition of water, is also the radiolytic decomposition of water under the influence of gamma rays of natural isotopes (in mostly K^{40}, having the greatest/ activity / concentration in vegetation).

A comparative analysis of the geometric, qualitative, organoleptic characteristics of the vegetation cover of different areas is in good agreement, proportional to the concentration of K^{40} in these plants, i.e. the high energy of gamma rays irradiated with K^{40} and the relatively high activity (relatively high concentration) are the reason for the increase in the current concentration of radicals in the mass of the plant, which is equivalent to the acceleration of high-barrier endothermic process of the splitting of hydrogen atoms from water molecules.

As is known, after completion of reactions in spurs, the values of the primary radiation-chemical yield of water gamma radiolysis products at pH = 4–9 are:

$G(H^+_{aq})$ = 3.4; $G(e^-_{aq})$ = 2.9; $G(H)$ = 0.6; $G(\cdot OH)$ = 2.9; $G(\cdot O)$ = 0.0067; $G(H_2)$ = 0.45; $G(H_2O_2)$ = 0.75; $G(OH^-_{aq})$ =

0.6 ion / 100 eV. In some sourcesthe value of $G(H^+_{aq}) = 4.25$ H^+ / 100 eV is indicated [4].

Taking into account the average value of K^{40} activity in 1 kg of plant mass (1.2-3.0 Bq / kg), exposure to this isotope during the year leads to the formation of (2,5 quanta / (s.kg)) * (4,25 H^+_{aq} / 100 eV) * (1.46 * 10^6 eV / quanta) = 15 * 10^4 H^+_{aq} / s.kg = 4.7 * $10^{12}H^+$ / (year. kg).The indicated value, although lower than the value of the resulting H^+ ions during photosynthesis.

In the 80s, the radiation-chemical chain process of hydrogen coversion into carbon monoxide was studied [5, 6].

Similar to the radiation-chemical process $H_2 + CO_2 \rightarrow CO + H_2O$, where after the radiation initiation of the process ($H_2 \rightarrow H \cdot + \cdot H$ or $H_2^* + CO_2 \rightarrow CO + \cdot OH + \cdot H$) in the energy region above the potential barrier of the limiting reaction stage the chain process begins ($H \cdot + CO_2 \rightarrow CO + \cdot OH; \cdot OH + H_2 \rightarrow H_2O + \cdot H$) and in the case of photosynthesis in the presence of K^{40} and Na^{22} after radiation initiation / formation of radicals, atoms and ions / closed cycles consisting of elementary reactions of the type ($H \cdot + CO_2 \rightarrow CO + \cdot OH; \cdot OH + RH \rightarrow H_2O + \cdot R$ / $ROH + \cdot H$ /) or ($H^+ + CO_2 \rightarrow CO^+ + \cdot OH, R^+ + CO_2 \rightarrow CO^+ + RO \cdot; H^+ + RR \rightarrow R^+ + RH, CO^+ + RR \rightarrow RCO + R^+$) with the following cliff type reactions ($R \cdot + R \cdot \rightarrow RR, R \cdot + CO \rightarrow RCO \cdot, R \cdot + \cdot OH \rightarrow ROH, R \cdot + \cdot OH \rightarrow ROH, CO^+ + e- \rightarrow CO$) serving the synthesis of organic molecules.

However, taking into account the multiplicity of intermediate products of water radiolysis, the radiation-chemical yields of which are given above, the insignificant exothermicity (2.8 kJ / mol) of the total reaction of the radiolytic conversion of a mixture of hydrogen and carbon dioxide into carbon monoxide and liquid water, a direct contribution ofwater's radiolysis radicals and ions in the course of many elementary reactions occurring in the plant massabsorbing light, the possibility of multiple participation of radiolysis products of water and the organic matrix ($H \cdot, \cdot OH, R \cdot, H^+, H^+_{aq}, e^-_{aq}, R^+, CO^+$) in the above repeated cycles of elementary reactions that occur with the resumption of the starting radicals and ions. Thus, in a comprehensive analysis of photosynthesis, the role of gamma radiation of the natural radioisotopes Na^{22} and K^{40} in this complex process, especially at its initial stage (initiating the formation of atoms, radicals and ions from water molecules and an organic matrix), should be taken into account.

This conclusion is consistent with the presence of Na^{22} and K^{40} radioisotopes in all analysed samples of water, soil, vegetation, livestock products without exception, with the revealed facts of increasing plant fertility in soils with relatively high concentrations of natural radioisotopes, observation of photosynthesis in the mating membrane of extreme halobacteria, in the purple and green bacteria, heliobacteria, cyanobacteria, green sulfur bacteria, plants, algae, in under thick layers of water, in the presence of only long-wave infrared rays or in the absence of chlorophyll and oxygen.

REFERENCES

[1] Samofalova I.A. The chemical composition of soils and soil forming components. Study guide. RF, Federal State-Funded Educational Institution of Higher Professional Education Perm State Agricultural Academy. - Perm: Publishing house of the Federal State-Funded Educational Institution of Higher Professional Education Perm State Agricultural Academy, 2009. - 132 p.

[2] Piskunov A.S. Methods of agrochemical research / Moscow, "Kolos", 2004, 312 p.

[3] Mamedov Kh.F. Radiolysis and Photolysis of Water Solutions of Phenol / European researcher.Series A. 2014. No. 7-1. pp. 1216-1236.

[4] Pikaev A.K. Modern radiation chemistry. Radiolysis of gases and liquids. M., Nauka, 1986, pp.136-137.

[5] Kurbanov M.A., Mamedov Kh.F.,Rustamov V.R. The chain formation of hydrogen during thermoradiolysis of gas mixtures of H_2S-CO. J. Chemistry of High Energies, 1988, V.22, № 3, pp.218-220.

[6] Kurbanov M.A., Rustamov V.R., Mamedov Kh.F., Iskenderova Z.I., Dzantiev B.G. Chain transformation during radiolysis of gas-phase mixtures CO_2-H_2. J. Khimicheskaya Fizika, 1986, V.5, № 1, pp.135-136.