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<https://doi.org/10.15407/jnpae2018.03.280>**Yu. A. Tomilin¹, L. I. Grygorieva^{1,*}, A. V. Grishan²**¹ *Petro Mohyla Black Sea National University, Mykolaiv, Ukraine*² *Laboratory of External Dosimetry, South-Ukraine NPP, Yuzhnoukrainsk, Mykolaiv region, Ukraine*

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RADIOACTIVE DUST WITH ¹⁰⁶Ru
OVER THE SOUTHERN REGION OF UKRAINE

According to research results of ¹⁰⁶Ru content in the air of certain settlements of Mykolaiv region, the radioecological situation in the southern region of Ukraine was analyzed due to the presence of the radioactive cloud in September - October 2017. A preliminary attempt was made to estimate the committed effective dose from the inhaled flow of ¹⁰⁶Ru to human during the stay of radionuclide in the air over Mykolaiv region.

Keywords: ¹⁰⁶Ru, radioactive dust, effective dose.

1. Introduction

During the end of September and October 2017, various institutions determined the radioactive ¹⁰⁶Ru in the air over Ukraine. As it is known from the media, the highest content of ¹⁰⁶Ru in the air was recorded above Zaporizhzhia - 40 mBq/m³, over Mykolaiv region, near Kyiv levels were about 30 mBq/m³. In Zaporizhzhia region, the average volumetric activity of ¹⁰⁶Ru in the air was 8 - 10 mBq /m³.

The presence of this radionuclide in the air in October 2017 was registered not only in Ukraine but also in Russia and the counties of EU. The presence of ¹⁰⁶Ru in the air was confirmed by the State Service for Hydrometeorology and Environmental Monitoring of Russia [1]. The highest data, which exceeded the background level in thousands times were registered at the period 26.09.2017 - 03.10.2017 in Arghayash (Chelyabinsk region), where Federal State Unitary Enterprise "Mayak Production Association" State Enterprise "Rosatom located, – is the leading enterprise of the Russian nuclear weapons complex and provides state security, fulfilling the state defense order for the production of components of modern nuclear weapons. Also, on 26 - 29.09.2017, ¹⁰⁶Ru in the air was registered in Tatarstan, Volgograd and Rostov-on-Don. Due to activity of the anticyclones that operated at the end of September over the territories of the Southern Urals and the Caspian Lowland, there were conditions for the transfer of ¹⁰⁶Ru to Ukraine and the Mediterranean and Northern Europe regions. The Czech Republic recorded the appearance of ¹⁰⁶Ru in 29.09.2017. The maximum activity of ¹⁰⁶Ru in the air in Czech reached several tens of mBq /m³. After 24.11.2017, the concentration of ¹⁰⁶Ru decreased to 0.001 mBq/m³ [1]. The presence of ¹⁰⁶Ru in the air was detected not only in Czech Republic, but also in other European countries

(Fig. 1): Switzerland, Poland, Italy, Germany, Austria, Slovakia and others. The highest level of ¹⁰⁶Ru in France was recorded in Nice in October 2 - 9; in some parts of Romania the concentration of ¹⁰⁶Ru in the air was 1.5 - 2 times higher than in Russia which is up to 10 mBq/m³. After 13.10.2017 the presence of this radionuclide in the air in these states was not observed.

The purpose of the research is to estimate the prevalence of the dust with ¹⁰⁶Ru in Mykolaiv region as at one of the southern regions, and rough estimate of dose load for the population from elevated levels of ¹⁰⁶Ru in the air.

2. Research methods

As the materials were taken the results of the radiometry of atmospheric air performed at the Laboratory of External Dosimetry of the South-Ukraine NPP (SUNPP). Sampling was carried out by precipitation method on a filter FNN-15-1.5 "Pitryanov's Fabric" with further measurement on the ORTEC GEM60-83-SMP gamma spectrometer. No. 54-P51294A (Certificate "11201212403416). The materials of our radioecological researches in the Mykolaiv region were also taken [2 - 5].

3. Results and discussion

Results. At the Laboratory of External Dosimetry of the SUNPP ¹⁰⁶Ru was registered in the air on the 30-km zone around the Nuclear Power Plant during the time from the end of September to the 1 October 2017 (Table). The appearance of ¹⁰⁶Ru in the air at that area occurred on 22 - 29.09.2017 at the level of 0.004 Bq/m³ (Yuzhnoukrainsk) by results of spectrometric studies. Lately (from 26.09.2017) the content of radionuclide in the air began to increase to 0.014 - 0.024 Bq/m³. The maximum value was

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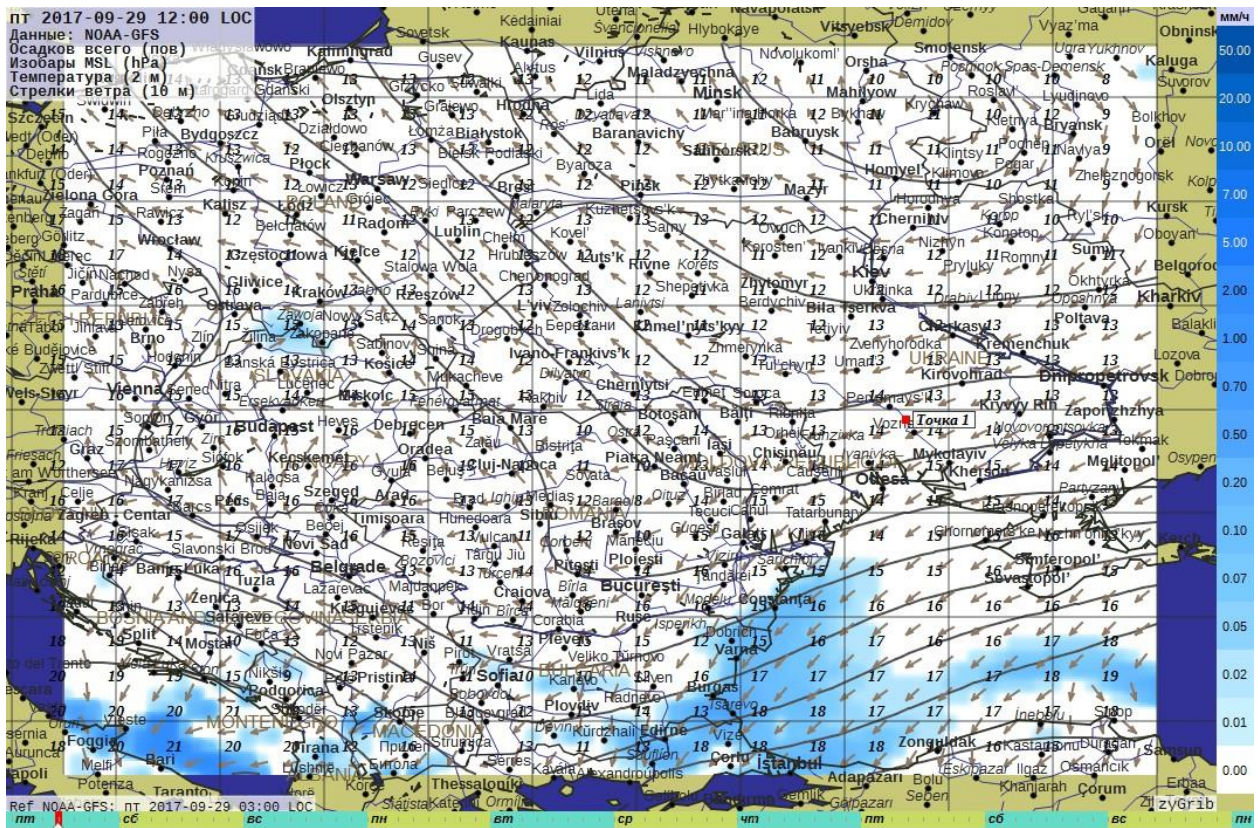


Fig. 1. Map of the movement of the cloud with ¹⁰⁶Ru over the territory of Ukraine and other states.

The content of ¹⁰⁶Ru in the air of the surveillance zone of the SUNPP

Place of selection	Distance from the SUNPP, km	Time of exposition	Date of measurement	Contents of ¹⁰⁶ Ru, Bq/m ³
LZD Yuzhnoukrainsk	3.0	22.09.2017 - 29.09.2017	04.10.2017	3.9 · 10 ⁻³
Arbuzinka	11.0	26.09.2017 - 03.10.2017	05.10.2017	2.9 · 10 ⁻²
Konstantinivka	6.0	26.09.2017 - 03.10.2017	05.10.2017	2.3 · 10 ⁻²
Ryabokonove	33.5	26.09.2017 - 03.10.2017	05.10.2017	1.4 · 10 ⁻²
Agronomy	5.0	27.09.2017 - 03.10.2017	05.10.2017	1.7 · 10 ⁻²
Buzke	7.5	27.09.2017 - 03.10.2017	05.10.2017	2.4 · 10 ⁻²
Volya	4.5	28.09.2017 - 03.10.2017	05.10.2017	2.4 · 10 ⁻²
ORU-150	0.5	28.09.2017 - 03.10.2017	05.10.2017	2.4 · 10 ⁻²
LZD Yuzhnoukrainsk	3.0	29.09.2017 - 06.10.2017	06.10.2017	1.6 · 10 ⁻²
LZD Yuzhnoukrainsk	3.0	06.10.2017 - 09.10.2017	09.10.2017	<MDA
Arbuzinka	11.0	03.10.2017 - 10.10.2017	10.10.2017	4.1 · 10 ⁻⁴
Konstantinivka	6.0	03.10.2017 - 10.10.2017	10.10.2017	4.8 · 10 ⁻⁴
Ryabokonove	33.5	26.07.2017 - 03.10.2017	05.10.2017	1.4 · 10 ⁻²
Ryabokonove	33.5	03.10.2017 - 10.10.2017	10.10.2017	2.2 · 10 ⁻⁴
Agronomy	5.0	04.10.2017 - 11.10.2017	11.10.2017	2.6 · 10 ⁻⁴
Buzke	7.5	04.10.2017 - 11.10.2017	11.10.2017	4.6 · 10 ⁻⁴
Volya	4.5	05.10.2017 - 12.10.2017	12.10.2017	<MDA
ORU-150	4.5	05.10.2017 - 12.10.2017	12.10.2017	<MDA

The previously recorded values of ¹⁰⁶Ru content were on the background levels and did not exceed the MDA (≈4.0 · 10⁻⁵ Bq/m³). Permissible levels 0.5 Bq/m³.

0.029 Bq/m³, which did not exceeded the maximum limits permitted according to the radiation safety standards of Ukraine [6] – 0.5 Bq/m³.

On 23.09.2017 - 05.10.2017 the content of ¹⁰⁶Ru in

the air began to decrease (0,0002 - 0,0005 Bq/m³) and already on 12.10.2017 was at the level of the background value. General picture of the change in the ¹⁰⁶Ru content in the air over Mykolaiv region in

September - October 2017 is shown on Fig. 2. In mid-October, the radioactive dust has already gone beyond Ukraine. In this case, of course, a certain amount of

¹⁰⁶Ru settled on the soil. The previously recorded values of ¹⁰⁶Ru content were on the background levels and not exceed the MDA ($4,0 \cdot 10^{-5}$ Bq/m³).

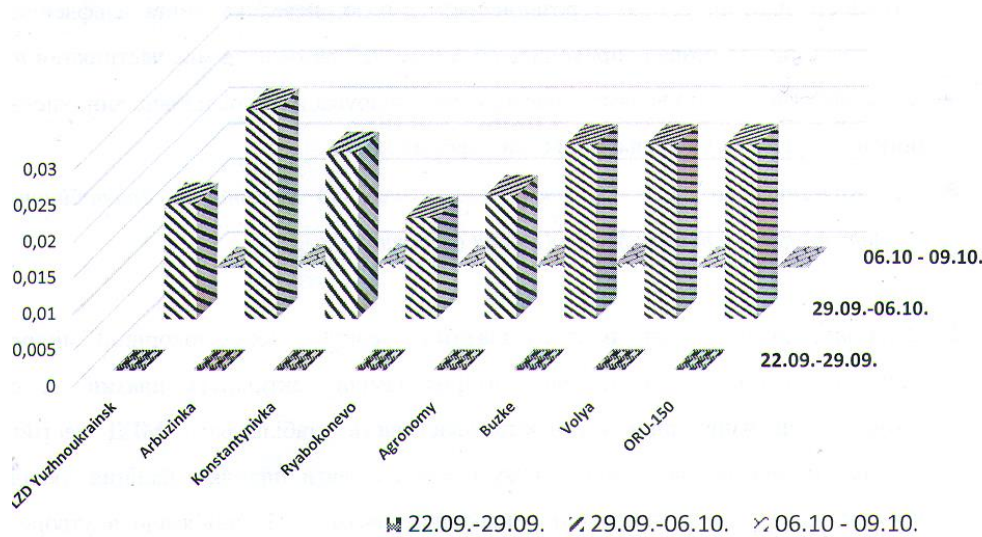
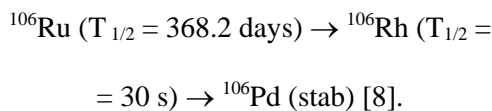


Fig. 2. Changing the content of ¹⁰⁶Ru in the air over the territory of Mykolaiv region in the area of SUNPP, in exponential units of concentration (in control points in accordance with WG 0.0026.0120 “Regulations of radiation monitoring of SUNPP”), Bq/m³. Designation: control points are given according to their distance from the SUNPP: LZD Yuzhnoukrainsk (Laboratory of External Dosimetry of the SUNPP) - 3 km; village Konstantynivka - 6 km; village Arbuzinka - 11 km; village Ryabokonevo - 33,5 km; village Buzke - 7.5 km; village Agronomy - 5 km; ORU-150 - 0.5 km; village Volya - 4.5 km.

Discussion. Ruthenium is an element of the eighth group of the V period of the periodic system of chemical elements. This is one of the platinum elements in living organisms. It accumulates mainly in the muscles. It is close to platinum metals (iridium, osmium, palladium, rhodium) by its chemical properties [7]. It is used in small atomic generators / nuclear-isotope battery of satellites. It is used as a radioactive indicator in medicine as part of applicators for radiation therapy.

¹⁰⁶Ru is beta-radioactive element. This isotope of ruthenium formed during the operation of NPP and nuclear explosions. It decomposes into the scheme:



¹⁰⁶Ru is in danger to humans because it is placed in the same level with ¹³⁷Ce of its toxicity. When it enters the atmosphere, water objects, it enters the human body with inhalation and oral paths, it accumulates in the lungs and organs of the gastrointestinal tract. This, in turn, contributes to the deterioration of the nervous, cardiovascular and digestive system, as well as to the increased risk of cancer. At the same time, the consequences of its harmful effects do not appear immediately, but in a few months.

Unlike other radionuclides, the distribution of

ruthenium in the body is determined by the physiological state of the organism and the physico-chemical properties of the compounds of the ¹⁰⁶Ru receptor, which complicates the assessment of the toxic hazard of ruthenium [9].

The dynamics of ¹⁰⁶Ru content in the atmospheric air in each of the settlements during the two-week period (from 22.09.2017 to 05-06.10.2017.) were analyzed. The total inflow of ¹⁰⁶Ru to human in each settlement – $A_i(\text{Bq})$ – can be defined as:

$$A_i = 22.2 \left(\frac{\text{m}^3}{\text{day}} \right) \cdot W_i \left(\frac{\text{Bq}}{\text{m}^3} \right) \cdot t_i (\text{day}),$$

where 22.2 is the reference daily volume of inhaling air by human, $\frac{\text{m}^3}{\text{day}}$ [6]; W_i is ¹⁰⁶Ru activity in the air during the period $\frac{\text{Bq}}{\text{m}^3}$; t_i is the duration of the period, day.

An effective dose from the inhaled flow of ¹⁰⁶Ru to human H_i (Sv) can be defined as:

$$H_i = A_i \cdot k,$$

where k is the dose rate of ¹⁰⁶Ru at inhalation intake (taken $1.8 \cdot 10^{-8}$ Sv/Bq [6]).

As a result, it was found the committed effective dose from the inhaled flow of ¹⁰⁶Ru for the population

– $0.077 \pm 0.001 \mu\text{Sv}$ when scattering values from 0,045 to 0,115 μSv . This is less than 0.01 % of the annual effective dose limit for the population (category B) – 1000 μSv [6].

It is clear that today the radiation background from ^{106}Ru in this territory has not changed significantly relative to the level to the ruthenium cloud.

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РАДИОАКТИВНА ХМАРА З ^{106}Ru НАД ПІВДЕННИМ РЕГІОНОМ УКРАЇНИ

За результатами досліджень вмісту ^{106}Ru у повітрі окремих населених пунктів Миколаївщини проаналізовано радіоекологічну ситуацію в південному регіоні України через проходження радіоактивної хмари у вересні - жовтні 2017 р. Зроблена спроба визначення очікуваної ефективної дози від інгаляційного надходження ^{106}Ru для місцевого населення за час перебування радіонукліда в повітрі над Миколаївщиною.

Ключові слова: ^{106}Ru , радіоактивна хмара, ефективна доза.

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РАДИОАКТИВНОЕ ОБЛАКО С ^{106}Ru НАД ЮЖНЫМ РЕГИОНОМ УКРАИНЫ

По результатам исследований содержания ^{106}Ru в воздухе отдельных населенных пунктов Николаевской области проанализирована радиоэкологическая ситуация в южном регионе Украины из-за прохождения радиоактивного облака в сентябре - октябре 2017 г. Сделана попытка оценки ожидаемой эффективной дозы от ингаляционного поступления ^{106}Ru для местного населения за время пребывания радіонукліда в воздухе над Николаевщиной.

Ключевые слова: ^{106}Ru , радиоактивное облако, эффективная доза.

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