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ПОЛОНИЕВАЯ ВЕРСИЯ СМЕРТИ ЯСИРА АРАФАТА: РЕЗУЛЬТАТЫ РОССИЙСКИХ ИССЛЕДОВАНИЙ

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Polonium-210 Version of Arafat's Death: the Results of Russian Investigation

РЕФЕРАТ

Цель: Представить результаты исследований, выполненных российскими специалистами, для ответа на вопрос — явилось ли причиной смерти Я. Арафата радиационное поражение полонием.

Материал и методы: Исследование проводилось по двум направлениям — медицинскому и физическому. В рамках медицинского направления решалась задача детального анализа ксерокопий медицинских документов пациента и сопоставления их с материалами собственных клинических наблюдений случаев аварийного поражения полонием. В рамках проведения физических исследований использовались методы прямой регистрации содержания ^{210}Po и ^{210}Pb в изъятых при эксгумации останков покойного образцах (в общей сложности более 20 биологических и иных объектов), включая исследования проб с помощью радиохимического выделения ^{210}Po с последующим измерением на альфа-спектрометре и спектрометрические измерения содержания ^{210}Pb и ^{210}Po с помощью низкофоновых гамма-спектрометрических установок, а также косвенные методы, включая масс-спектрометрические и спектрометрические исследования по определению содержания ряда стабильных химических элементов и радионуклидов.

Результаты: Показано несоответствие симптоматики и течения заболевания Я. Арафата таковым при лучевой болезни, обусловленной поступлением в организм поражающих количеств ^{210}Po. Вместе с тем, в исследованных биологических пробах останков покойного обнаружено содержание радионуклидов ^{210}Po и ^{210}Pb, достоверно превышающее на один-два порядка их фоновые значения. В пределах погрешностей экспериментальных исследований значения активности радионуклидов ^{210}Po и ^{210}Pb в пробах совпадают, что свидетельствует о том, что они находятся в состоянии радиоактивного равновесия. Следовательно, повышенное содержание ^{210}Po в исследованных биологических пробах обусловлено его образованием в останках покойного в результате радиоактивного распада его предшественника ^{210}Pb. Выполненные на основании результатов исследований расчеты позволяют утверждать, что обнаруженному в останках в мае—июне 2013 г. количеству ^{210}Pb соответствует порядка 650 Бк в организме пациента в ноябре 2004 г. (это восстановленная активность с учетом периода полураспада ^{210}Pb, равного 22,3 года). Поступление подобного количества ^{210}Pb приводит к дозам облучения всего на уровне долей мЗв поглощенной дозы в отдельных органах за период до 30 сут после поступления. Очевидно, что такие дозы облучения не могли стать причиной каких-либо радиационно-обусловленных нарушений состояния здоровья пациента. Кроме того, содержание в организме подобного количества ^{210}Pb не могло бы вызвать и химического отравления изотопом свинца, поскольку обнаруженные весовые количества ^{210}Pb, соответствующие активности 650 Бк, находятся в пределах долей нанограмма.

Заключение: Следует исключить прямую причинную связь наличия повышенного содержания указанных радионуклидов в останках покойного с наступлением его смерти.

Ключевые слова: *Ясир Арафат, полоний-210, свинец-210, лучевая болезнь, эксгумация*

ABSTRACT

Purpose: The purpose of this article is to present the results of research carried out by the Russian specialists to answer the question as to the evidence of Yasser Arafat's death being caused by radiation exposure to polonium.

Material and methods: This research was conducted in two directions simultaneously: medical and physical. As part of medical research a task was set to have a detailed analysis of photocopies of the patient's medical records to compare with the materials of our own observations of accidental polonium injuries. As part of physical research it was essential to solve the problem of determining the content of ^{210}Po, ^{210}Pb and a number of other radionuclides in the samples recovered during the exhumation (a total of more than 20 biological and other objects). All possible methods of the direct determination of ^{210}Po and ^{210}Pb content in the remains of the deceased were used, including research of samples using radiochemical separation of ^{210}Po followed by alpha spectrometry measurements and spectrometric measurements of ^{210}Po and ^{210}Pb using low background gamma spectrometric systems. Indirect methods were also applied including mass spectrometry and spectrometric studies to determine the content of a number of stable chemical elements and of radionuclides.

Results: No objective evidence of the patient's symptoms of radiation damage as typical of that in the case of intake of ^{210}Po has been established. Meanwhile, an increased activity of ^{210}Po and ^{210}Pb in the range from 10 to 100 times higher than its background level was revealed on Arafat's tissue specimens exhumed. Within the error of experimental research the activities of ^{210}Po and ^{210}Pb in the analyzed biological samples of bones and internal organs detritus match, indicating the radioactive equilibrium state. Consequently, the source of high ^{210}Po content in the remains of the deceased is ^{210}Pb. The calculations made based on the results of the research suggest that the amount of ^{210}Pb found in the remains in May and June 2013 corresponds to about 650 Bq in the patient's body in November 2004 (this is a restored activity given the half-life of ^{210}Pb equals to 22.3 years). Intake of such a quantity of ^{210}Pb results in radiation doses only at the level of mGy fractions of the absorbed dose in individual organs over a period of 30 days after intake. Obviously, such doses could not have caused any radiation induced health problems of the patient. Moreover, the content of a similar ^{210}Pb amount in the body could not have caused the lead chemical poisoning because the detected ^{210}Pb weight amounts corresponding to 650 Bq activity are within the nanogram fraction.

Conclusion: Thus, on the basis of summarizing the complex research results, taking into account the absence of any objective evidence proving the presence of symptoms of acute radiation syndrome in the submitted medical records, and given the results of measurements of ^{210}Pb and ^{210}Po contents in the samples of biological materials taken during exhumation of the remains as well as evaluation of the radiation dose, a direct causal link between the presence of high content of these radionuclides in the remains of the deceased and his death should be excluded.

Key words: *Yasser Arafat, polonium-210, lead-210, radiation syndrome, exhumation*

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Introduction

Yasser Arafat was the founder and the first head of the Palestinian National Authority, a Nobel Peace Prize winner, who died on November 11, 2004 aged 75 in the Percy military hospital near Paris, where he had been taken in a severe condition from his residence on the West Bank of the Jordan River. French doctors reported the death of Arafat was caused by of a massive stroke brought on by cerebral hemorrhage due to an unidentified infection. Despite the vagueness of the wording of the cause of death, Arafat's widow did not give her permission for an autopsy.

However, in the summer of 2012 the world media published the results of the research done by experts from the Institute of Radiophysics (Lausanne), who had discovered in Arafat's personal belongings (his clothing, his hat and toothbrush) high concentrations of polonium-210, which, according to Swiss specialists [1], could have caused the sharp deterioration in the health of the 75-year politician, leading to his early death.

In light of the voiced version of a possible polonium-210 radiation injury, the widow filed a lawsuit in August 2012 accusing persons unknown in the murder of her husband. On the basis of this action, on November 13, 2012 the Prosecutor's Office of France announced an official investigation into the cause of death of the former Palestinian leader. The next day, Mahmoud Abbas, the President of the State of Palestine, gave his permission to exhume the remains of Yasser Arafat, which took place on November 27, 2012 in the town of Ramallah with the participation of international experts from three countries. Experts from Switzerland and Russia were brought to work on the request by the Palestinian Authority, while French experts took part in it in the framework of the criminal case brought in their country.

The purpose of this article is to present the results of research carried out by the Russian specialists to answer the question as to the evidence of Yasser Arafat's death being caused by exposure to polonium.

Material and Methods

It should be emphasized that the need for information about the contents of a particular radionuclide in the remains of a deceased person in connection with a suspected radiation exposure (as a possible cause of death) then became an issue for the first time in the world. In this regard, while choosing the research methods it was important to take into account all the possible circumstances that could directly or indirectly hamper the choice and/or interpretation of the results.

First of all, it was essential to take into account that due to the length of time elapsed between the burial (2004) and the exhumation of the remains of the deceased (2012), all the soft tissues of the body were subjected to total decay. This made it impossible to distinguish individual organs, including the organs of the preferable deposition of polonium, such as the spleen, liver, and kidneys. It also determined the priority of the study of the organs' detritus as well as bone samples as research objects, using the relevant methods of selection and preparing the material [2].

In addition, due to the remoteness of the alleged case of the lifetime entry of highly efficient amounts of ^{210}Po (in the autumn of 2004), the interpretation of the results of physical measurements largely proved difficult (spring–summer 2013), because after such a long period of time (~8.5 years, i.e. more than 22 half-lives of ^{210}Po, $T_{1/2}$ = 138.38 days) the decrease in activity of the researched radionuclide in accordance with the law of radioactive decay was about 7,000,000 times.

According to the actual data provided by the Russian clinicians [3] the entry of ^{210}Po in quantities equal to or in excess of 1.1×10^8 Bq results in the development of 'polonium' radiation sickness with a lethal outcome within two to three weeks. In view of the above, it is clear that if in October–November 2004 a similar amount of polonium had entered the body of Yasser Arafat, the initial activity would have been reduced to the values of the natural background (in the bones 0.6–4.3 mBq/g, in the soft tissues 0.04–1.7 mBq/g [4–6]) by the time of the residual measurement in May–June 2013 due to the radioactive decay of ^{210}Po. This would make it impossible to establish the fact of the ^{210}Po radiation injury (i.e. it would be a false negative result of the postmortem diagnosis) without a simultaneous study of the patient's medical records for compliance to the clinical and laboratory symptoms and the disease course that led to his death corresponding to those typical of lethal polonium intoxication.

At the same time, we should not forget that a false positive result of postmortem study is also possible: the detection of radionuclide activity of ^{210}Po in the remains, exceeding the natural background values, is not undisputed evidence of radiation exposure, because, in addition to the above mentioned circumstances, one more significant circumstance should be subject to mandatory consideration. The presence of a high content of polonium in the body and in the remains may be due to two alternative 'scenarios' [4]. The first is a direct entry of the radionuclide ^{210}Po with food, water or air inhaled. The second is an initial entry of its precursor — radioactive isotope of lead ^{210}Pb, from which the radionuclide ^{210}Po is accumulated through a chain of radioactive decay, given the relatively long $T_{1/2}$ = 22.3 of ^{210}Pb.

These circumstances required the use of diverse methods and approaches to address the unique scientific and practical task. It seemed the most appropriate to

conduct research in two directions simultaneously: medical and physical.

As part of medical research a task was set to have a detailed analysis of photocopies of the patient's medical records available online [7], provided by the Palestinian side, to compare with the materials of our own clinical observations of accidental polonium injuries and to answer the question of whether the cause of death of Yasser Arafat was radiation exposure to ^{210}Po.

As part of physical research it was essential to solve the problem of determining the content of ^{210}Po, ^{210}Pb and a number of other radionuclides in the samples recovered during the exhumation (a total of more than 20 biological and other objects), including:

- detritus of the internal organs in the projection of areas, anatomically corresponding to thoracic and abdominal cavities of the body;
- bone samples selected in accordance with the rule of anatomical standard (from the sites which were the most representative for the content of hematopoietic bone marrow accounting for the age of the deceased (75 years), and the ratio of compact and trabecular tissue);
- a sample of soft tissue of the occipital region of the head with hair;
- samples of the funeral attire (fragments of the shroud, positioned above and below the remains of the deceased);
- soil samples from above and below the remains and in the tomb outside the burial (not less than 500 g per sample).

In the physical research all possible methods of the direct detection of ^{210}Po and ^{210}Pb content in the remains of the deceased were used, including research of samples using radiochemical separation of ^{210}Po followed by alpha spectrometry measurements and spectrometric measurements of ^{210}Po and ^{210}Pb using low background gamma spectrometric systems. Indirect methods were also applied including mass spectrometry and spectrometric studies to determine the content of a number of stable chemical elements and radionuclides.

Results and Discussion

It is known that the polonium-210 is one of radionuclides that are relatively uniformly distributed in organs and tissues of the body. In this regard, large (~ 10^8Bq) amounts of ^{210}Po cause the development of injuries the clinical picture of which is similar to acute radiation syndrome (ARS) caused by an external uniform irradiation [3]. The main clinical feature in this case is the failure of hematopoietic system, which is manifested in the form of pancytopenia (i.e. three-lineage hemodepression), primarily lymphocytopenia and granulocytopenia, causing the development of infectious complications. Bone marrow examination in these patients shows a sharp decrease in the amount of hematopoietic tissue (myelosupression involving three hematopoietic lineages) up to its complete disappearance ('empty' bone marrow).

However, as evidenced by the Russian experience of observing cases of emergency entry of ^{210}Po [3, 8, 9], in contrast to the ARS caused by external exposure, the clinical picture of radiation injury caused by acute exposure to polonium is characterized by a number of features. These include, in particular, the lack of a clear periodization of the radiation disease course, and an earlier in time and degree-typical development of a hemorrhagic syndrome. There are multiple spontaneous hemorrhages and abundant repeated bleeding from the urinary tract, rectum, nose, etc., occurring even at a relatively high level of platelets ($80–150\times10^9$/l) due to affection of the vascular component of primary hemostasis [3]. In addition to hematopoietic failure and multiple hemorrhages, the signs of dysfunction of other "critical" organs (such as the liver and kidneys) are revealed in the clinical picture of the disease diagnosed in a timely manner even in cases of non-fatal intoxication.

Yasser Arafat, who died on the 30th day of the disease onset, showed no symptoms of hematopoietic depression. On the contrary, during the entire period of the disease in the absence of lymphocytopenia and granulocytopenia there was a tendency to neutrophilous leukocytosis with an adequate hyperleukocytosis reaction (39×10^9/l) to the glucocorticoid therapy. According to the myelogramms counting on the 14th and 16th day, and to the bone marrow trephine biopsy examination on the 23rd day of the disease, the bone marrow cellularity remained normal in expanding of myeloid cells and with up to 40 'budding' (i.e. functionally active) megakaryocytes available in the preparation. In addition, the patient did not have fever or any signs of focal infection. There were no clinical signs of bleeding as well, including the form of spontaneous hemorrhages in skin and mucous membranes, despite the declined (at least up to 26×10^9/l) platelet count. According to the experience as our own clinical observations, as mentioned above, it is known that the effects of ^{210}Po are characterized by a severe generalized hemorrhagic syndrome that occurs in a short time from the moment of its entry at a relatively shallow thrombocytopenia (addition of the microcirculatory level of bleeding).

Data on the hepatopathy syndrome development are recorded from 24.10.2004 (12th day). The first signs of liver dysfunction were revealed as the appearance of bilirubinemia with icteric sclera and a diagnostically insignificant elevation in hepatic transaminase tests (1.5–2 of the norm from the 6th day). It is also important to point out that the manifestations of the laboratory syndrome of hepatocellular deficiency (the prothrombin index decreased up to 36 % and the forming of expressed hypoprotein- and hypoalbuminemia) naturally coincided

in the time of appearance with the beginning of abstinence from food and liquids in the day time in relation to the patient following a religious fast from the 3rd day of the disease. Renal function remained intact until the 25th day of the disease. Its deterioration occurred only during the development of terminal multiple organ failure.

In respect of the acute gastrointestinal syndrome it should be noted that its clinical manifestations in the form of nausea, vomiting and watery diarrhea in the present case were intermittent (for example, in the history of the disease there are indications of the patient being prescribed laxative medications from time to time). In addition, it is well known that the development of this syndrome with the progressive deterioration of the general condition of patients is not pathognomonic for the intake of radionuclides, but is typical for a large number of acute and chronic infections, as well as digestive pathologies, especially at unsustainable course of concomitant diseases or changes in ordinary diet (see above).

Thus, on the basis of a detailed study of the medical documents available to the Russian specialists prepared as part of the medical research, no objective evidence of the patient's symptoms of radiation damage typical of that in the intake of ^{210}Po has been established.

As part of the physical research a special emphasis was given to the identification and quantitative determination of ^{210}Po in the samples of biological material selected at exhumation. The measurement results are shown in Table 1 (mean values of ^{210}Po content are given per sample[1]). As an example, Fig. 1 shows the energy spectrum of alpha radiation of sample #14 "Detritus in the projection of the abdominal cavity", showing the clearly defined peaks of ^{210}Po and ^{209}Po (the latter in the form of a standard solution was used as a reference mark during the radiochemical separation of polonium-210).

The results of the analysis of the content of ^{210}Po in the researched samples of the remains of Yasser Arafat were compared with the literature data [4–6] for the background content of this radionuclide. However, taking into consideration that we analyzed the materials, which were, unlike the objects of the research literature sources cited, presented by dehydrated tissue (posthumous dehydration), a preliminary analysis had been carried out of test bone samples, selected in a similar way from the body of a man of 71 who had suddenly died, to control the quality of research, as well as to independently determine the natural background values of ^{210}Po content in human bones.Methods for determining of ^{210}Po in both research and control biological samples were identical. It is important to emphasize that the values obtained for the content of ^{210}Po in control bone samples (1.4–3.2 mBq/g) are in the range of variability of these values in the bone tissue of people who live in different regions of the Earth (0.6–4.3 mBq/g) [4–6]. Background values of ^{210}Po content in the human soft tissues are somewhat lower and vary in the range of 0.06–1.4 mBq/g [5].

Table 1

The results of ^{210}Po determination in biological samples averaged over the measurements conducted in two laboratories

Sample #	Sample	Average content of ^{210}Po in the sample, mBq/g
1	Sternum (handle)	67
2	Left femur diaphysis (middle third)	28
3	Ilium (left)	69
4	Thoracic vertebra (Th_{IV})	25
6	Ilium right (wing)	22
7	Lumbar vertebra (L_{III})	12
9	III, IV, V right ribs (front ends)	140
11	Detritus in the projection of the abdominal cavity	82
14	Detritus in the projection of the abdominal cavity	220
14.1	The bone from sample 14	190
15	Detritus in the projection of the thoracic cavity	130
16	Detritus in the projection of the thoracic cavity	130

When comparing the results of the study presented in Table 1 with the reference data [4–6] and our own measurements of the ^{210}Po background values in the human body tissues, it is possible to draw an important conclusion: in the studied biological samples of Yasser Arafat's remains the activity of the radionuclide ^{210}Po was detected which significantly exceeded the natural background values by one — two orders of magnitude.

It is noteworthy that the above stated excesses were similar in the samples of the organs' detritus and bones of different skeletal structures which were independently investigated in two different laboratories. To do this, each individual sample was as a rule divided into several parts to be subsequently radiochemically processed and 'blind' measured using metrologically certified radiometers-spectrometers of alpha radiation *Alpha Analyst* (Canberra Inc., USA) and *Ortec Duo* by ORTEC US (Fig. 2). This approach allowed each laboratory to carry out an independent analysis of the material, providing an opportunity to obtain information about the reproducibility of the measurement results. The comparative analysis of the determination of ^{210}Po contents in the same biological samples, independently measured in two laboratories (Table 2), shows a good compliance

[1] Hereinafter: the relative error of determination of the content of ^{210}Po by the method used is an average of 30 %.

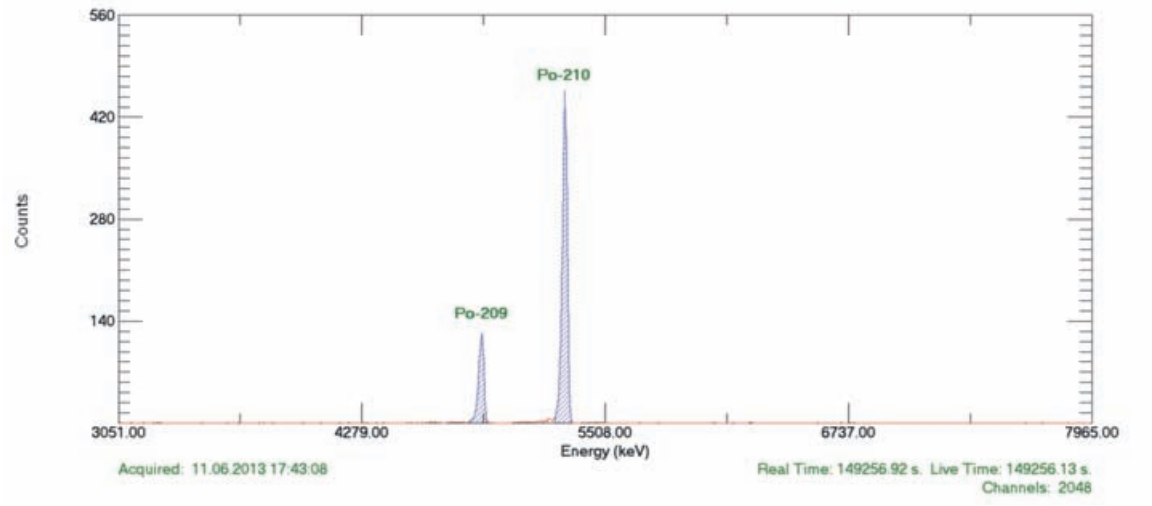

Fig. 1. The energy spectrum of the Sample #14 alpha radiation "Detritus in the projection of the abdominal cavity" received using the Ortec Duo alpha radiation radiometer-spectrometer. The presence of ^{209}Po is explained by it having been introduced on purpose as a reference mark while preparing the samples

Fig. 2. *Ortec Duo* Alpha Radiation Radiometer Spectrometer (ORTEC, USA)

within the measurement error, thus confirming the accuracy of the data.

We shall make a hypothetical assumption that the high content of ^{210}Po, discovered in the remains of Yasser Arafat in May–June 2013, was due to an acute entry of the radionuclide in the patient's body in October 2004, i.e. a month before his death. In this case, according to the calculations made taking into account the radioactive decay, the coefficient of polonium absorption in the gastrointestinal tract (the value is assumed to be 0.5) and its partial removal from the body over the 30-day period of the patient's stay in medical institutions, the content of ^{210}Po found in the remains in 2013, would have had to match its lifetime entry into Yasser Arafat's body in 2004 in absolutely superlethal quantities (about 10^{10} Bq). Obviously, the entry of such amounts of ^{210}Po would form in the patient's organs and tissues the absorbed dose of radiation of several hundred Gy. It is known that in such cases there is radiation damage of extreme severity (the most acute radiation sickness) with the victims dying in the near future from the moment of impact (within a few hours or days).

In addition, as it follows from the medical records of Yasser Arafat, two lifetime urine samples were measured in a French army laboratory of radiation toxicology control on 8 November 2004 (three days before his death) using a gamma-ray spectrometer within 15 hours. Subsequent analysis of gamma spectra did not reveal the presence of a peak in the vicinity of 803 keV (^{210}Po gamma-line with the intensity of 0.00107 %). The estimate of the minimal detectable activity (MDA) of the ^{210}Po gamma-line in the urine sample for the measurement setup in 2004 was about 25 Bq/g [10]. According to assessment using biokinetic models of ^{210}Po ingestion and urinary excretion [11], under the assumption of acute intake of polonium a month before the death, taking into account the value

Fig. 3. Gamma radiation spectrometer (CANBERRA, USA)

of the above MDA, its amount should not exceed about 3×10^7 Bq of ^{210}Po so that in the measured gamma-ray spectrum a peak of 803 keV would not be identified. Since such a peak was not detected, it can be concluded that the available results of physical measurements of the gamma spectra of Arafat's urine samples done in 2004 also exclude the hypothesis of a possible ^{210}Po activity entry into the body in an amount equal to or exceeding 10^8 Bq.

Given these facts, special attention was paid to the analysis of the significance of the above mentioned second possible scenario of ^{210}Po accumulation in the body due to radioactive decay of ^{210}Pb, the long-living precursor. A gamma-ray spectrometer (Fig. 3) was used to determine the content of that radioactive isotope of lead in the remains. Fig. 4 shows the energy spectrum of gamma radiation of the same sample, alpha-spectrum of which is presented in Fig. 1. Results of ^{210}Pb content determination also carried out in two independent laboratories are summarized in Table 3. It should be noted that the values of lead-210 content, identified in two independent laboratories, are well complied.

The comparative analysis of the obtained results was carried out based on the research findings [5], where the average values of natural background ^{210}Pb concentrations in individual organs and tissues (0.03–0.56 mBq/g) and bones (2.5–5.0 mBq/g) of people living in various regions of the Earth are provided. It was taken into account that in the samples obtained during exhumation over eight years of age, the ^{210}Pb concentration due to postmortem dewatering increases (to a greater extent, by several times, in soft tissue detritus; and to a lesser extent, up to 2 times, in bones), while the concentration of ^{210}Pb activity during the past period of time decreases by approximately 30 %. However, in consideration of the circumstances, the data presented in Table 3 may be used to make an important conclusion: the activity of radionuclide ^{210}Pb in samples is also higher than the natural background values by one–two orders of magnitude.

In order to explore the possible relationship between ^{210}Po and ^{210}Pb, the ratios of these radionuclides were estimated based on the results of independent measurements using several different methods applied to the same biological samples. As it could be seen from the data presented in Table 4, within the error of experimental research the activities of ^{210}Po and ^{210}Pb in the analyzed biological samples of bones and internal organs detritus match, indicating the radioactive equilibrium state (i.e., decay of the same number of atoms of these two radionuclides occurs per unit of time). A similar relation between ^{210}Po and ^{210}Pb was found in the study of the content of both radionuclides in the sample of the soft tissues of the occipital region of the head with hair, performed by liquid scintillation spectrometry. According to the analysis and processing of the spectrum the content of ^{210}Po was 550 ± 80 mBq/g, the content of ^{210}Pb was 750 ± 120 mBq/g, which is substantially higher than the natural background values of the content of both radionuclides in the skin of the head and human hair [4]. Given the error in the method of determining the content of both radionuclides, a conclusion could be drawn similar to the one regarding the detritus and bone samples: both radionuclides activities are equal, i.e. they are also found in the radioactive equilibrium state. Consequently, the source of high ^{210}Po content in the remains of the deceased is ^{210}Pb.

Table 2

The results of the determination of ^{210}Po in biological samples independently measured in two laboratories

Sample #	Sample	Average content of ^{210}Po in the sample, mBq/g		Ratio of the measurement results of the two laboratories
		Lab. A	Lab. B	
1	Sternum (handle)	73	61	1.2
2	Left femur diaphysis (middle third)	27	29	0.9
3	Ilium (left)	74	65	1.1
4	Thoracic vertebra (Th_{IV})	26	25	1.0
7	Lumbar vertebra (L_{III})	13	12	1.0
9	III, IV, V right ribs (front ends)	150	130	1.2
14	Detritus in the projection of the abdominal cavity	240	190	1.3

Table 3

The content of ^{210}Pb in biological samples, using a gamma radiation spectrometer

Sample #	Sample	Content of ^{210}Pb, mBq/g	
		Lab. B:	Lab. C:
2	Left femur diaphysis (middle third)	19	
3	Ilium (left)	47	57
7	Lumbar vertebra (L_{III})	28	< 30
11	Detritus in the projection of the abdominal cavity	75	
14	Detritus in the projection of the abdominal cavity	170	
15	Detritus in the projection of the thoracic cavity	170	
16	Detritus in the projection of the thoracic cavity	110	85

In analyzing the results, special attention was paid to the discussion of possible reasons for the high ^{210}Pb content in the studied samples of the remains. A hypothesis was examined that the high ^{210}Pb content was due to its entering the remains because of the radioactive decay of radon gas while the remains were being located in the tomb. However, migration of ^{210}Pb in significant quantities into a bone lattice in these conditions is not physically consistent. Consequently, this hypothesis can be rejected. Another hypothesis was presented: a significant ^{210}Pb activity was administered to the patient shortly before his death (within one month). However, considering his old age, when the rate of metabolic processes in the bone is reduced by two orders compared with the rate of these processes in early childhood [12], and the 30-day period of the disease, the assumption of accumulating significant ^{210}Pb amounts in the patient's bone tissue during the specified period seems unrealistic. Thus, this hypothesis should also be rejected. Unfortunately, it is not possible to state clearly the cause of the ^{210}Pb radionuclide presence in the samples only on the basis of the physical research results.

At the same time the calculations made based on the results of the research suggest that the amount of ^{210}Pb found in the remains in May and June 2013 corresponds to about 650 Bq in the patient's body in November 2004 (this is a restored activity given the half-life of ^{210}Pb equals to 22.3 years). Intake of such a quantity of ^{210}Pb results in radiation doses only at the level of mGy fractions of the absorbed dose in individual organs over a period of 30 days. Obviously, such doses could not have caused any radiation induced health problems of the patient [6, 13]. Moreover, the content of a similar ^{210}Pb amount in the body could not have caused the lead chemical poisoning

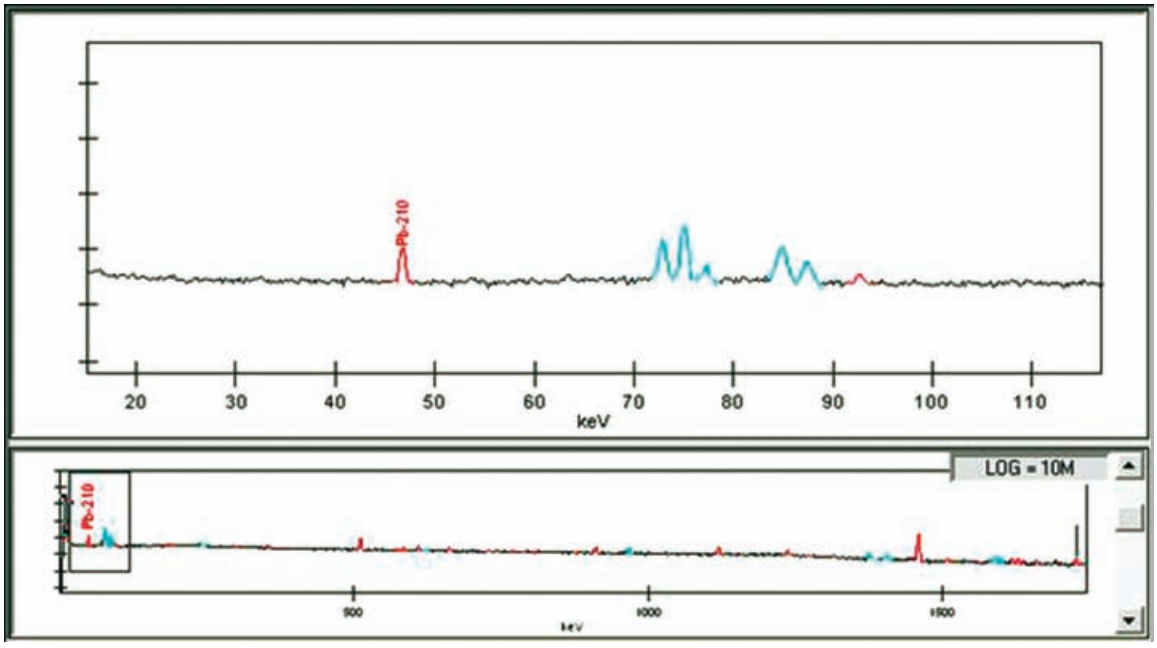

Fig. 4. The energy spectrum of the Sample #14 gamma radiation "Detritus in the projection of the abdominal cavity" received using the Canberra gamma radiation spectrometer. At the top there is an enlarged part of the initial portion of the total spectrum framed. The unmarked peaks of the spectrum are due to gamma radiation of natural radionuclides

Table 4

A comparison of the content of ^{210}Po and ^{210}Pb in the studied biological samples

Sample #	Sample	Average content of ^{210}Po, mBq/g	Content of ^{210}Pb (Lab. B), mBq/g	Ratio ^{210}Po/ ^{210}Pb
2	Left femur diaphysis (middle third)	28	19	1.5
3	Ilium (left)	69	47	1.5
7	Lumbar vertebra (L_{III})	12	28	0.4
11	Detritus in the projection of the abdominal cavity	82	75	1.1
14	Detritus in the projection of the abdominal cavity	220	170	1.3
15	Detritus in the projection of the thoracic cavity	130	170	0.8
16	Detritus in the projection of the thoracic cavity	130	110	1.2

(i.e. saturnism) because the detected ^{210}Pb weight amounts corresponding to 650 Bq activity are within the nanogram fraction (0.23 ng) which is 500 million times smaller than the content (120 mg) of this chemical element in the human body [14, 15].

Thus, on the basis of summarizing the complex physical and medical research results, taking into account the absence of any objective evidence proving the presence of symptoms of acute radiation syndrome in the submitted medical records, and given the results of measurements of ^{210}Pb and ^{210}Po contents in the samples of biological materials taken during exhumation of the remains, as well as evaluation of the radiation dose, a direct causal link between the presence of high content of these radionuclides in the remains of the deceased and his death should be excluded.

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