Гайдар В. О., Радченко С. П., Судаков О. О.
кафедра медичної радіофізики, факультет радіофізики, електроніки та комп'ютерних систем
Київський національний університет імені Тараса Шевченка

ВИДАЛЕННЯ АРТЕФАКТІВ ЕЛЕКТРООКУЛОГРАМИ ТА ЕЛЕКТРОМІОГРАМИ З ЕЕГ СИГНАЛУ

Однією з основних проблем при аналізі електроенцефалограм є артефакти: електроміограми (ЕМГ) і електроокулограми (ЕОГ). Були розглянуті методи видалення основані на методі сліпого розділення джерел (BSS) із використанням статистики другого порядку (SOBI). Ми застосували модифікований алгоритм SOBI з підбором асимптотично оптимальних вагових коефіцієнтів (WASOBI).

Ключові слова: *електроенцефалограма, електроміограма, електроокулограма, метод сліпого розділення компонент.*

Гайдар В. О., Радченко С. П., Судаков О. О.
кафедра медицинской радиофизики, факультет радиофизики, электроники и компьютерных систем,
Киевский национальный университет имени Тараса Шевченко

ВЫДЕЛЕНИЕ АРТЕФАКТОВ ЭЛЕКТРООКУЛОГРАММЫ И ЭЛЕКТРОМИОГРАММЫ С ЭЭГ СИГНАЛА

Главной проблемой при анализе электроэнцефалограмм есть артефакты, которые сильно искажают ЭЭГ сигнал. Наибольшое проявляються: артефакты электромиограммы (ЭМГ) и электроокулограммы (ЭКГ). Были рассмотрены методы выделения и дальнейшего изъятия этих сигналов с выходных электроэнцефалограмм. Нами был применен метод "слепого разделения компонент" (BSS) с использованием статистики второго порядка. Мы применили модифицированный метод SOBI с подбором асимптотических коэффициентов (WASOBI).

Ключевые слова: *электроэнцефалограмма, электромиограмма, электроокулограмма, метод слепого разделения.*

UDC 539.12.04:614.876

O. Gaidar, Ph.D, V. Tryshyn, Ph.D,
O. Svarichevska, Ph.D, I. Pavlenko, Ph.D,
Institute for Nuclear Research National Academy of Sciences of Ukraine
V. Gaidar, post grad. stud.,
Taras Shevchenko National University of Kyiv

ENVIROMENTAL IMPACT ASSESSMENT OF OPERATION OF POSITRON EMISSION TOMOGRAPHY CENTER

Impact assessment for centre of positron emission tomography has been carried out. It has been shown that risks, that arise due to the radiation impact factor, are acceptable. The adequacy of protective measures to ensure radiation safety of personnel, population and environment is analysed.

Keywords: *fluorodeoxyglucose, medical cyclotron, radionuclides, source term, radioactive waste.*

Introduction. The oncology illnesses are placed second in the mortality structure of the population after the heart-vessel system. The early diagnose is the very important moment in treatment of these illnesses what is explained the importance of creation of modern centre nets in the Ukraine for the positron-emission tomography (PET).

Today radiopharmaceuticals (RPhP), which include short-half-life radionuclides ^{11}C, ^{13}N, ^{15}O, ^{18}F, are generally recognized. The short period of life of these radionuclides demands location of cyclotron (for theirs production) and laboratories of radiopharmaceutical synthesis (RPhP) in close proximity to diagnostics centers, which often are located in dense population districts of the large towns. This requires the careful approaches to create reliable systems of engineering barriers to prevent unreasonable release of radioactive substances to the environment and to protect from irradiation personnel and population.

The modern center for early diagnostic of cancer by positron emission tomography (PET-center) will be built in Donetsk, where for manufacturing of fluorodeoxyglucose (FDH), based on short-lived radionuclides ^{18}F, the medical cyclotron MINITrace of GE Medical systems company is used.

Production is based on the irradiation of the target (with water, enriched by isotope ^{18}O) by protons, accelerated to the energy of 9.6 MeV. The produced radionuclide ^{18}F further is used for the synthesis of FDH radio-pharmaceutical, its dosage and transfer to the block of radio diagnostic department of PET-center.

PET center has several blocks, first is the cyclotron unit, block of radiopharmaceutical synthesis and block of radio diagnostic studies.

The block of cyclotron unit includes: cyclotron tank, utility room of cyclotron, the cyclotron control room, sanitary gateway in the output of the cyclotron block.

The block of radiopharmaceutical synthesis includes: laboratory of synthesis, clean changing rooms; laboratory of quality, passageway to transmit radiopharmaceutical to the diagnostic department of PET-center, sanitary gateway at the output of the block.

Also available support facilities, technical service corridor for the hot cells of laboratory of synthesis and interim storage of radioactive waste, emergency shower at the exit from the technical corridor to the corridor; space for calculations, documentation and personnel office room, and others.

Block of radio diagnostic studies is on the 2-nd floor and provides the facilities for receiving and preparation of radiopharmaceuticals based on ^{18}F, procedural for introduction of radiopharmaceuticals to patients; waiting rooms for patients after introduction of radiopharmaceuticals with a bathroom connected with the system of special sewage as well as procedural and console of PET/KT system.

During the operating the PET Center main factor of negative impact on the environment is the radiation one, namely:

- pollution of the surface layer of air in the surrounding PET-center territory by radioactive airborne emissions;
- formation and accumulation of solid radioactive waste (RW);
- formation of radioactive liquid radioactive waste (radioactive runoff).

In normal mode, the PET-center radioactive substances will be localized by system of protective barriers (containers, protective screens, elements of process equipment) that prevent their direct contact with the environment.

For this purpose we have developed the system of stationary biological barriers and appropriate calculations have been made. In this calculations as base was selected the request of non-exceeding of acceptable levels of design dose, which provide non-exceeding of the established limits of effective dose of irradiation for different categories of people: the staff category A and B, and

population [1]. Also in accordance with the requirements of paragraph 9.1.4 OSPU 2005 [2], biological shielding calculations were carried out with taking into account the safety factor equal to 2.

Emission of radioactive substances and the impact of PET-center on the environment and population on surrounding territory are possible due to emissions and discharges.

To reduce the environmental impacts during the operation of the PET center a number of special measures has been implemented.

Measures to protect air quality.

- Radioactive substances in gaseous state are collected in the vicinity of the cyclotron target node and time delay are proved to prevent their immediate release in to ventilation system in the case of possible leakage from the target;
- Cleaning from dust of air that is fed into the hopper of the cyclotron, with the aim to reduce the generation of radioactive aerosols in the room;
- Guarantee the maximum possible sealing of open radiation sources during operation, transport and storage operations;
- Carrying out work with radioactive substances of open type in the boxes, laboratory modules, and fume hoods with local ventilation and cleaning filters;
- The appropriate organization of special ventilation system and schemes of air overflows to prevent the direct flow of radioactive substances into the environment;
- Organization of special ventilation systems to adequate pressure distribution and air flow in the block of cyclotron, laboratories of syntheses, laboratory of quality control, technology corridor and buffer zone;
- Installation of automatic control and display pressure alarm and valve overlap for exhaust ventilation in case of accidental release of radioactive substances into the air of technological premises;
- Cleaning of ventilation air-out through the HEPA filters (with purification efficiency of at least 99.9%) and activated carbon at the outlet of exhaust systems and organization of continuously monitoring of the activity of airborne emissions from the manufacturing unit of PET-center.

Measures to protect the aquatic environment

To protect the water environment in the operation of the PET center will be used special sewerage system, consisting of four central decanter tanks, where radioactive wastewater will be accumulated.

The automatic control of filling of decanter tanks is used. After filling the tank drains automatically addressing to another tank, and filled tank is sludged overnight, after which, if the level of residual activity is less than control level, the content will be dumped to sanitary sewer.

To control of accumulated in tanks activity, they will be equipped with detectors of ionizing radiation dose rate and sampling devices.

Solutions, which will arise during routine operations with the parts of the cyclotron and decontamination of laboratory equipment, contaminated transport containers, etc., are considered as liquid radioactive waste (LRW) and be poured upon to special containers. These tanks will be located in a special shielded cabinet with ventilation in the premises of the temporary storage of radioactive waste.

Measures to minimize radioactive waste.

Radioactively contaminated materials of the PET/CT system, testing block in gamma camera, laboratories of synthesis and quality control, cyclotron block will be transferred to the appropriated premises of temporary storage for radioactive waste to store in special containers until the desired level of decay will be achieved. After that these they can be removed with the household waste.

Operating portable generators will be returned for recycling to the plant-manufacturer. Radioactive waste to be disposed will be transferred to a specialized company that has a license. To prevent uncontrolled radioactive waste, an alarm system and a blocking system will be used to lock the door to premises of temporary storage for radioactive waste.

The prediction of the formation of radioactive waste during decommissioning of PET-CT centre has been performed. So highest activity will be accumulated in the following structural elements:

- Accelerating chamber and the magnet yoke.
- Tantalum collimator.
- Foil made of titanium and HAVAR to remove the proton beam.
- Target holder with silver.
- Plastic protector of target.
- Concrete of integrated cyclotron radiation protection.
- Stainless steel designs of cyclotron and auxiliaries.

To reduce the amount of radioactive waste that will be disposed of, it is recommended to carry out decommission of the center in several stages, one of which is a conservation of facility for at least 1 year. As estimated, the largest by volume ($m \approx 35$ t, $V \approx 10$ m^3) of radioactive material at decommission of the cyclotron MINITrace will be the concrete, which is the part of integrated protection which activity after a relatively long exposure (within 1 year) is mainly determined by the content of long-lived gamma emitters ^{152}Eu and ^{60}Co and "pure" beta-emitting radionuclides ^{3}H, ^{39}Ar and ^{45}Sa.

To control the influence of the operation of PET Center, we have developed a system of radiological control, one element of which is the radiation monitoring of radionuclide activity in the emissions and discharges that flow into the environment.

Results.

We have evaluated the environmental impact of exploitation of PET-center during normal operation and emergency situations.

To evaluate environmental impact of operation of PET center on air and water the Ukrainian norms and methodology, the IAEA recommendations, and advanced specialized software (HotSpot, FRAMES, MCNP, MicroShield) were used.

According to forecasts, in normal operation the maximum daily discharge of ^{18}F from ventilation pipe of bloc for fluorodeoxyglucose manufacturing (BFM) does not exceed $1{,}85 \cdot 10^7$ Bq. Thus the annual effective radiation dose of the population will not exceed $8{,}2 \cdot 10^{-8}$ Sv, which is almost 500 times less than the quota of limit dose of 40 mSv per year, which is set [1] for reference nuclear radiation facility.

Maximum activity of the radionuclide ^{18}F in wastewater (end of second shift normal operation) in decanter of BFM will be ~ 10^8 Bq in the sump and in the block of radio diagnostic tests (BRT) - $1.87 \cdot 10^9$ Bq. After their retention interval (for at least 24 hours before being discharged to the sanitary sewer) concentration of ^{18}F radionuclide will be lower than the calculated value for allowable concentration in drinking water for category B (DK_B^{ingest}).

As a result of consideration of possible emergency situations during the operation of PET-center, which can lead to increasing of radiation impact on the environment, staff and population, the conservative and most likely scenarios were selected and evaluations of their impact were made, namely:

1. Design basis accidents in the block of cyclotron:

- Failure of the locking system startup accelerator, causing the cyclotron began working with open shielding door;

- Depressurization target or transport channel that leads to the release of all worked out activity of ^{18}F ($9{,}25 \cdot 10^{10}$ Bq per cycle).

2. Design basis accidents in the block of FDH production:

- Loss of external power supply;
- Emergency release of the produced ^{18}F activity to internal volume of synthesis/dosage modules or to the laboratory of FDH production due to violation of manufacturing process;
- Emergency release of the produced ^{18}F activity to the corridor due to a fire, caused by internal in-doings;
- Violation of the system of special ventilation (no filtering emissions through human error, violation of the integrity of the duct as a result of mechanical damage).

3. Design basis accidents in the block of radio diagnostic department:

- Spill a single dose of FDH in the room of reception and training FDH or procedural for intravenous introduction of FDH to patients;
- Loss of sources of ionizing radiation (closed or open);
- Curried out estimations shown that greatest possible impact on the environment is at design basis accident, associated with the release of ^{18}F to air environment due to failure of filtration in special ventilation system.

To exclude the possibility of such situation it is developed multiple levels of cleaning in particular HEPA filter (with an efficiency of more than 99.9%) and activated carbon filters, as well as continuous monitoring of release volume activity through the ventilation pipe and alarm in the case of excess of control levels of emissions. However, for the conservative estimation one more failure was considered – failure of monitoring system (within one month) and, as result, during this time contaminated air was released from the system of special ventilation without purification.

As magnitude of the total emissions from the block of FDH production (per cycle during normal operation of equipment) we conservative accept 1% of the worked out activity. Thus, the daily total emissions will be $\sim 2 \cdot 10^9$ Bq of ^{18}F.

It was also assumed that during the month the wind direction does not change, but the distribution of values of wind speed and categories of atmospheric stability were selected basing on regional conditions of the object disposition. To enhance the conservatism estimation it was assumed that during entire month the precipitation with intensity of 1 mm/h are observed.

Obtained results of estimations show that in the case of noted design basis accident maximum total effective dose to the persons from population is not exceeded $1{,}2 \cdot 10^{-5}$ Sv (at a distance of 10 m from the building), that does not exceed the level of acceptable risk.

Also the following beyond design basis accidents were considered:

1. Accidents caused by an earthquake or a sudden shift as:

Variant 1. Simultaneously, the destruction of the duct and release of contaminated air to the environment at a height of 3 m (ground-level release).

Variant 2. The integrity of the duct is remained, however, the filtration chamber is damaged and at a height of 16 m the unfiltered air is released.

2. Accidents caused by external anthropogenic impact (fire and destruction of the protective barriers due to the fall of the aircraft);

3. Car accident with a fire during a transportation of worked out production.

Obtained results indicate that even in the most challenging case of beyond design basis accidents (earthquake, variant 1) total effective dose to members of the population, which is located at a distance of 150 m from the emission source, not to exceed $5 \cdot 10^{-5}$ Sv. According to Table D.7.1 [1], this value is much less than the lowest limit for any countermeasures.

When analyzing the impact of failures on the PET-center in the aquatic environment the design base accidents, associated with flooding surface and groundwater, technical flooding and emergency discharges of radioactive substances or radioactive effluents have been considered.

Emergency discharges of radioactive substances into the environment directly are prevented by protective barriers and organizational measures, implemented in the PET-center.

In case of accidental discharge of all worked out activity of radionuclide ^{18}F ($9{,}25 \cdot 10^{10}$ Bq/per cycle) to the tank sump after 24-hour exposure its total activity decreased to about 10^7 Bq, and the specific activity - to ~ 5 MBq/m^3, that is well below DK_B^{ingest} for ^{18}F. Waste water with the noted concentration of ^{18}F can be discounted to the sanitary sewer.

To prevent accidents when operating PET center the emergency plans and instructions for radiation safety in emergency situations will be developed, conducted training with using the hardware (sensors with sound and light alarm, emergency alarm system, blocking the entrance to the premises, physical protection, etc.) and organizational measures will be carried out.

All locations with elevated levels of radiation hazard will be marked with appropriate warning signs.

There will be an organized system alerts staff in controlled areas on the first and second floors.

In case of power failure of cyclotron the security system, modules of synthesis and dosing provides automatic (without operator intervention) transfer of means in a safe condition which guarantees the preservation of the integrity of engineered barriers and prevent the release of radioactive substances in the environment, above.

The room and corridors will be equipped with autonomous emergency lighting and markings pointing toward exits (including emergency) in case of disconnection from the centralized energy supply system.

The diesel generator with an eight-hour supply of fuel is provided to prevent accidents due to disconnection of the object.

It is also provided the automatic monitoring and display of pressure (pressure difference) and backup ventilation system in block of FDH production. In the case of failure of prescribed limits of working pressure values, a alarm signal will be generated by which staff should activate the duplicate ventilation system or alarm system and stop operations at facility.

To prevent accidents involving emergency release of produced activity in the internal volume of the unit safety cameras of PD manufacturing, even in case of failure of standard filters and system of lock of chamber the project provides additional filters (HEPA-filters and activated carbon) of exhaust ventilation systems installed in the outlet exhaust system.

To prevent infiltration of groundwater into basements of PET Center it is provided that the floors and exterior walls are made of reinforced concrete with modern materials for extra waterproofing and back-filling clay around the perimeter of the exterior walls of the building. Moreover basement near decanter tanks will be equipped with alarm triggering, which operation will stop the operation of the facility till elimination of emergency.

To prevent the release of radioactive substances into the environment as a result of man-made flooding, after carelessness of staff, accident in water system in the public network sanitary sewer, the project envisages the following measures:

- The use of pedal taps or faucets automatic water supply in areas where we are working with radioactive substances;
- Drainage system drains to special sewerage from the rooms of premises and second zones;
- Alarm of overflow of decanter tanks of special sewerage;
- Floor and basement walls made of reinforced concrete.

To prevent accidents due to loss of ionizing radiation sources (IRS), the project envisages a system of lock and alarm facilities, which are stored the IRS, that will prevent the unauthorized access to IRS.

Also, PET-center is planned to organize security system, which should ensure the physical protection of the object (prevent accidental penetration of the public or third party personnel to the controlled area).

Conclusions Thus, basing on the results of environmental impact assessment of PET-center operation during normal mode and under emergency situations, it can be concluded that the risks arising from radiation influence on the environment and the population are within acceptable limit. At the same time the influence of construction of state-of-the-art medical center on the social environment will be positive.

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Submitted on 07.11.14

Гайдар О., канд. фіз.-мат. наук, Тришин В., канд. фіз.-мат. наук,
Сваричевська О., канд. біол. наук, Павленко І., канд. біол. наук, Інститут ядерних досліджень НАН України
Гайдар В., асп., Київський національний університет імені Тараса Шевченка

ОЦІНКА ВПЛИВУ НА ДОВКІЛЛЯ ЕКСПЛУАТАЦІЇ ЦЕНТРА ПОЗИТРОННО-ЕМІСІЙНОЇ ТОМОГРАФІЇ

Проведено аналіз впливу експлуатації центру позитронно-емісійної томографії на навколишнє природне середовище за рахунок радіаційних факторів. Показано, що в умовах нормального режиму експлуатації, а також при проектних і запроектних аваріях ризики, обумовлені цим впливом, знаходяться в межах прийнятних. Проаналізовано достатність захисних заходів для забезпечення радіаційної безпеки персоналу, населення і довкілля.

Ключові слова: *фтордеоксиглюкоза, медичний циклотрон, радіонукліди, радіоактивні газо-аерозольні викиди, радіоактивні відходи*

Гайдар А., канд. физ.-мат. наук,
Тришин В., канд. физ.-мат. наук, Сваричевская Е., канд. биол. наук,
Павленко И., канд. биол. наук, Институт ядерных исследований НАН Украины
Гайдар В., асп., Киевский национальный университет имени Тараса Шевченко

ОЦЕНКА ВОЗДЕЙСТВИЯ НА ОКРУЖАЮЩУЮ СРЕДУ ЭКСПЛУАТАЦИИ ЦЕНТРА ПОЗИТРОННО-ЭМИСИОННОЙ ТОМОГРАФИИ

Проведен анализ воздействия эксплуатации центра позитронно-эмисионной томографии на окружающую среду за счет радиационных факторов. Показано, что в условиях нормального режима эксплуатации, а также при проектних и запроектных авариях риски, обусловленные этим воздействием, находятся в пределах приемлемых. Проанализировано достаточность защитных мер для обеспечения радиационной безопасности персонала, населения и окружающей среды

Ключевые слова: *фтордеоксиглюкоза, медицинский циклотрон, радионуклиды, радиоактивные газо-аэрозольные выбросы, радиоактивные отходы.*

UDC 577.332

A. Glushenkov, post. grad. stud., D. Hovorun, Doc. Sci,
Department Molecular biotechnology and bioinformatics, Institue of High Technologies,
Taras Shevchenko National University of Kyiv

COMPLETE FAMILY OF H-BONDED 1-METHYLCYTOSINE HOMOASSOCIATES: QUANTUM-MECHANICAL INVESTIGATION

On the MP2/6-311++G(2df,pd)//B3LYP/6-311++G(d,p) theory level in vacuum for the first time was shown that stabilized by specific intermolecular contacts complete family of $m^1Cyt \cdot m^1Cyt$ homoassociates counts 37 structures in diapason of 0÷34,42 kcal/mol relative Gibbs energies. Centrally symmetric homoassociate corresponds to global minima which is stabilized by pair of antiparallel H-bonds N4H...N1 and has enthalpy of formation practically the same as in mass-spectrometry experiment (L.F. Sukhodub et al., 1976). Detail analysis of intermolecular H-bonds, especially weak CH...O/N, physico-chemical properties has been performed. Briefly discussed application of results in spontaneous point mutations of DNA theory.

Keywords: *nucleic base, nucleic bases pair, complete family, hydrogen bond, cytosine, methyl-, methyl group.*

Introduction. Nucleic bases (NB) play major role in coding genetic information, RNA spatial structure, engineering synthetic DNA. It's generally known that DNA strands hold complementary NB pairs of Gua·Cyt and Ade·Thy [23]. The complimentary principle is key factor supplying the transmission of genetic information in heredity line. Point changes of NB – mutations are possible through creation of incorrect pairs by rare NB tautomeric forms [24] which in turn leads to transformation of canonical NB pairs into non-canonical and errors during biosynthesis of DNA. RNA spatial structure in many respects is defined by intermolecular H-bonds between NB. Special emphasis in literature gives attention to non-canonical NB pairs in RNA [10–12, 20]. At the same time synthetic DNA can be designed to have non-canonical NB pairs. Every mentioned aspect demands knowledge about geometrical and physico-chemical properties of isolated NB as well as of their H-bonded associates.

Object and methods. The goal of this paper is to obtain geometrical and physico-chemical properties of all possible 1-methylcytosine (m^1Cyt) homoassociates which involve all of it's seven possible tautomeric forms. Input structures automatically generated by original algorithm. Geometrical and electronic structure of molecules and complexes as well as their wavefunctions were obtained using density functional theory on B3LYP/6-311++G(d,p) theory level in vacuum. All optimized structures has been checked on stability by absence of imaginary frequencies in their spectra. Electronic energies of NB interaction and NB Gibbs free energies were obtained on MP2/6-311++G(2df,pd)//B3LYP/6-311++G(d,p) theory level. Quantum-mechanical calculations were done in Gaussian 03 for Win32 application [9].