

RADIOISOTOPE CENTRE POLATOM

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Radioisotope Centre POLATOM, since January 1st 2007 in the structure of the Institute of Atomic Energy, is active in the research and development of application of radioactive isotopes in science, nuclear medicine, industry and environmental protection.

The main Research and Development domains of Radioisotope Centre are:

- new radiopharmaceuticals showing the affinity to cell receptors for diagnostic purposes and for radioimmunotherapy;
- radiopharmaceuticals containing peptides, proteins and monoclonal antibodies for imaging of inflammatory sites;
- methods of elements separation and their application for production of radionuclides of high specific activity, including radionuclides generators;
- new types of miniature sealed sources for brachytherapy;
- new types of sealed radiation sources for industrial applications;
- development of preparation methods for manufacturing radiopharmaceuticals, radiochemicals and medical materials;
- studies on the analytical techniques for quality assurance of medical products;
- development of methods for radiation activity measurement and determination of radionuclides in radioactive materials;
- new reference materials for ionizing radiation measurement.

Since 1999 RC POLATOM has been depositary of national standard unit of radionuclide activity to which the parameters of other reference materials are related through a chain of comparisons. The national standard is supervised by the President of The Central Office of Measures (GUM).

In 2007 several issues have been successfully accomplished:

- development of technology and implementation of isotope generator $^{188}\text{W}/^{188}\text{Re}$ production;
- manufacturing technologies for carrier free ^{90}Y and carrier-added ^{177}Lu suitable for labeling of radiopharmaceuticals for therapeutic use;
- manufacturing methods of ^{123}I - α -methyl-tyrosine and ^{131}I - α -methyltyrosine for diagnosis of brain tumour and its metastasis;
- method of internal electrolysis used for deposition of ^{106}Ru and ^{125}I layers on metallic surface for manufacture of active cores of sealed sources;
- manufacturing technology of ^{125}I sealed sources in the form of miniature ^{125}I seeds for brachytherapy of intrabrain, prostate and eyeball tumours;
- development of technologies for manufacture of peptide based kits for $^{99\text{m}}\text{Tc}$ -labelling for use in oncological diagnostics;
- development of absolute measurement methods of radionuclides' activity with liquid scintillation counters (LSC).

The Centre has developed very good communication links with the leading clinical centers and nuclear medicine departments and Institutes in Poland involved in radiopharmaceutical and radiobiological developments as well as with many international research institutions. This cooperation is supported by scientific and applied grants provided by Ministry of Education and Science. The Centre actively contributes to the research projects carried out by the international organizations and programs:

- International Atomic Energy Agency (IAEA);
- European cooperation program in the field of scientific and technical research COST;
- EUREKA Initiative.

Since 2005 RC POLATOM is a member of Consortium and takes part in the Network of Excellence Diagnostic Molecular Imaging (DiMI), in the framework of sixth program, FP6 of the European Community.

ELECTROCHEMICAL PROCESSES OF FIXING RADIONUCLIDES APPLIED IN SEALED SOURCES FOR BRACHYTHERAPY

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One of the methods frequently used in oncology is radiotherapy. In particular, dynamic development of brachytherapy is observed recently [1]. In this treatment sealed radiation sources of ^{106}Ru , ^{125}I and in some cases also ^{192}Ir , ^{90}Sr or ^{103}Pd are used. The most important task for manufacturing such sources is fixing of the radionuclides to the source cores [2-4].

Our results on application of electrochemical methods, in particular of the internal electrolysis [5], to the source fabrication are presented in [6]. These methods appeared to be effective for fixing both metallic (^{106}Ru , palladium) and non-metallic (^{125}I) deposits as well as simultaneous co-deposition of metal with non-metal e.g. ^{125}I with palladium on a silver substrate.

As a result of the investigations performed, optimum conditions for fixing ^{106}Ru on a silver base by means of an internal electrolysis were determined. This method was implemented in practice for manufacturing ophthalmic applicators used in eye cancers treatment.

These methods of manufacturing of the active cores of the ^{125}I seed-type sources are discussed comparatively. These were a fixing of ^{125}I on the silver surface, a fixing of ^{125}I on the silver plated with palladium and a codeposition of ^{125}I with palladium on silver.

After electrolysis, lasting 24 h, 80% of ^{106}Ru contained in an electrolyte solution was withdrawn and deposited on the silver cathode. The deposits thus obtained were 2 μm thick, metallic and lustrous, adhering well to the silver backing, showing no tendency to chipping or cracking.

The high quality of the deposit obtained with a carrier-free ^{125}I reduced contamination problems and made this choice more reasonable from a practical point of view. As a result of the process lasting 70-90 h, 97-98% of ^{125}I contained in the electrolyte solution was withdrawn.

For each technique applied, the yield and the uniformity of deposition as well as the leachability were determined. The leachability of ^{125}I fixed to the unprotected silver bars does not exceed 0.1% and is even lower for protected bars (Table 1).

Nevertheless, in the case of an unprotected source the leachability was still lower than others' results [7].

Table 1. The leachability of ^{125}I wire sources.

Description of source	Activity of source [MBq]	Activity leached out [kBq]/[%]
Protected Ag wire	35.43*	15.3*/0.04
Unprotected Ag wire	40.00*	43.1*/0.1

* Uncertainty of activity determination $\pm 5\%$

The distribution of ^{125}I along the wire is fairly good. However, a wide maximum is observed for the central part of the wire (Fig. 1).

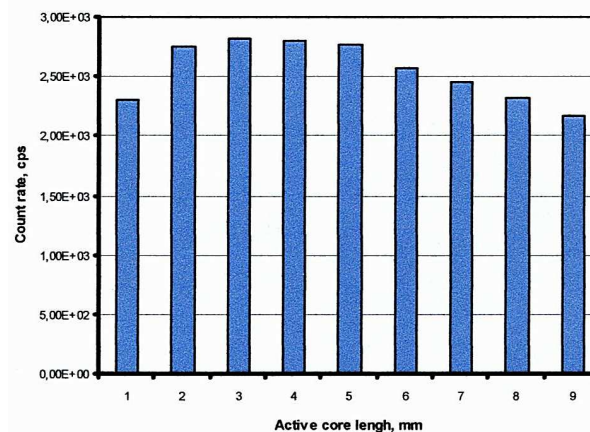


Fig. 1. Activity distribution along the unprotected silver wire.

The developed methods of fixing of ^{106}Ru and ^{125}I on a silver base enabled manufacturing of ophthalmic applicators with a monolithic active core of the activity required for therapeutic applications (13-27 MBq for ^{106}Ru and 1.85-9.25 GBq for ^{125}I).

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THE DEVELOPMENT OF A PREPARATION METHOD OF ALBUMIN MICROSPHERES AS POTENTIAL RADIONUCLIDE CARRIERS FOR DIAGNOSTIC AND THERAPEUTIC USE

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Human serum albumin microspheres (HAM) of various size have been widely used for clinical nuclear medicine as carriers for radioactive diagnostic and therapeutic molecules since 1969 [1, 2]. Their widest application was found in scanning of lungs in a diagnosis of pulmonary embolism, pulmonary infarction and other lung disorders.

The purpose of this study was to develop a preparation method of batches of albumin microspheres with reproducible statistics, reproducible physical and biological parameters which can be labeled with a variety of radionuclides and will comply with the requirements for API (Active Pharmaceuticals Ingredient). In general, the preparation of HAM consists in dispersion of a human serum albumin (HSA) solution in a suitable medium and heat stabilization of spherical particles.

In the present study HAM were prepared by the emulsification and heat stabilization technique described previously [3,4], with minor modifications. The processing parameters of homogenization (speed and time), oil phase (volume, emulsifier and denaturing factor concentration), water phase (volume and HSA concentration) and protein denaturation heat (temperature and time) were selected in an experimental way. The optimized method consisted of adding a HSA solution containing SDS to liquid paraffin containing SDS and Tween 80 and stirring the mixture with mechanical stirrer to obtain water/oil emulsion. This emulsion was then heated to allow the formation and solidification of microspheres. The supernatant oil was removed by decantation and microspheres were washed with diethyl ether. Then particles were dried in vacuum and later sieved.

Ten batches of microspheres ranging in a diameter from 10 to 32 μm were prepared by the described method. The particle size analysis was performed by an optical microscopy using a light microscope equipped with an ocular micrometer and a light camera (Fig. 1).

The microspheres were sized and photographed in a normal saline containing Tween 80 to prevent aggregation. The particles in each prepared batch were measured using a calibrated ocular micrometer and a special computer program.

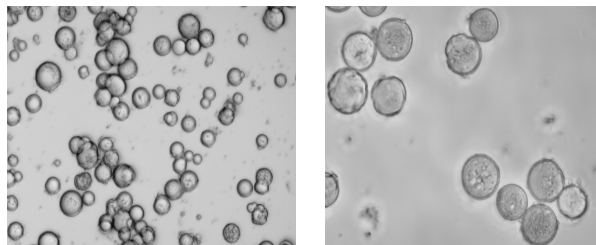


Fig.1. Optical micrographs of HAM in average size range of 10-32 μm taken at two different magnifications ($\times 200$ and $\times 400$).

The percentage frequency of microspheres particles in particular the size range was determined by weight analysis (Table 1).

Table 1. Particle size ranges of albumin microspheres.

Batch No.	Frequency of HAM[%]				
	<10	10-32	32-50	50-100	>100
1	0.9	86.9	7.2	2.3	2.7
2	0.4	84.1	11.8	2.2	1.5
3	0.3	81.8	13.9	2.1	1.9
Average	0.5	84.3	11.0	2.2	2.0

The average production yield of the desired HAM size range of 10-32 μm amounts to 84% and the mean size of particles was approximately 15 μm . Optical micrographs show microspheres as very regular spherical forms with quite smooth surfaces and slight scatter of size in the dominant range (Fig. 1).

In continuation of this project the albumin microspheres will be labeled with $^{99\text{m}}\text{Tc}$ and β -emitter radionuclides. For the HAM labeling with $^{99\text{m}}\text{Tc}$ the reduction of technetium valency is necessary. As reductor $\text{SnCl}_2 \times 2\text{H}_2\text{O}$ will be used and the development of a method of attaching technetium to microspheres will be required. The prepared radiopharmaceuticals will be then tested for their *in vivo* stability and biodistribution.

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NEW DIAGNOSTIC KIT HYNIC-IGG LABELLED WITH TECHNETIUM-99^m FOR INFLAMMATION IMAGING

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Scintigraphic detection of infection and inflammation enables the determination of both location and number of infectious and inflammatory foci throughout the body. Since scintigraphic images are based on functional tissue changes, infectious and inflammatory foci can be visualized in their early phases, when anatomical changes are not yet apparent. IgG accumulates in infectious foci by a non specific extravasation due the locally enhanced vascular permeability. The ^{99m}Tc – labelled preparations have known ideal radiation characteristics. Gammaglobulin can be labelled by a direct or indirect method of radiotracer incorporation in the protein molecule. The direct method of labelling is connected with changes in the secondary and tertiary structure of IgG molecule. The indirect labelling method using bifunctional chelate hydrazinonicotinamide (HYNIC) preserves the structure and biological activity of the protein [1-3].

The HYNIC-IgG conjugate with a HYNIC:IgG 2:1 molar ratio lyophilized in citrate buffer pH 5.5 stable in 4-8 °C for 6 month was obtained. The method of technetium-99m labeling of this conjugate was investigated in the presence of SnCl₂ as a reductor and tricine as a coligand. Finally, the formulation of the dry kit for the HYNIC-IgG labelling with technetium-99m was as follows: vial I – 2mg HYNIC-IgG in 200 µl, citrate buffer pH 5,5; vial II – 11.7 µg SnCl₂·2H₂O) + 200 µg tricine in 200 µl PBS.

The radiochemical purity of the tracer ^{99m}Tc-HYNIC-IgG was ≥95% (determined by instant thin-layer chromatography analysis - ITLC). The obtained tracer contained ≤16% of ^{99m}Tc-HYNIC-IgG aggregates (HPLC using BioSep-SEC-S-2000 PEEK column with isocratic elution analysis). ^{99m}Tc-HYNIC-IgG was stable in human serum in vitro during 4 h incubation at 37 °C.

In the animal biodistribution studies, 24 h post injection (p.i) of ^{99m}Tc-HYNIC-IgG a high specific radioactivity accumulation in the inflamed thigh muscle compared with a non treated muscle was observed (Fig. 1).

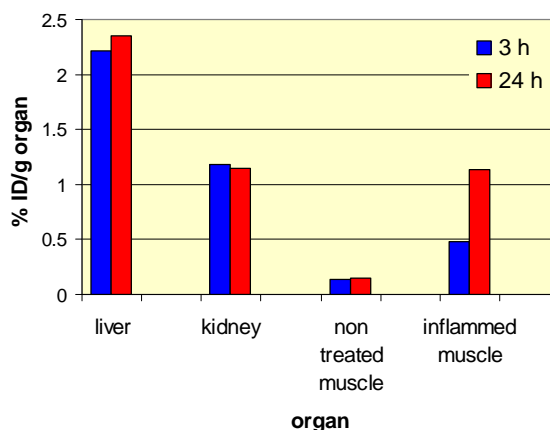


Fig. 1. The time-dependant organ biodistribution of ^{99m}Tc-HYNIC-IgG in rat with an inflamed thigh muscle after 3 and 24 h p.i. (% administration dose per gram of an organ).

Scintigraphy with ^{99m}Tc-HYNIC-IgG was performed in patients with clinically osteomyelitis or septic arthritis. The relative uptake of the radiopharmaceutical in inflammation spots comparing to the background was very high (Fig. 2).

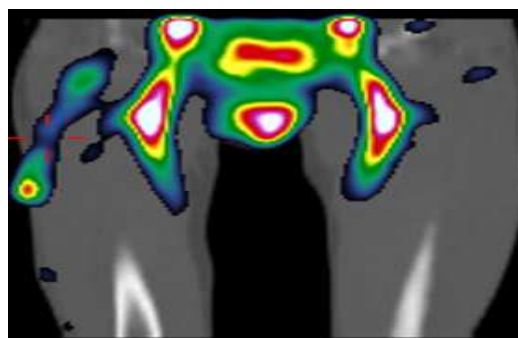


Fig. 2. SPECT/CT scintigraphy with ^{99m}Tc-HYNIC-IgG, acquisition 24 h after the tracer administration indicating an inflammatory process in the right hip.

The obtained new human immunoglobulin derivative IgG-HYNIC labelled with ^{99m}Tc by the indirect method with a high radiochemical purity can be very helpful in the assessment of localization and of the extension of the inflammatory process.

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THE DEVELOPMENT OF A $^{188}\text{W}/^{188}\text{Re}$ GENERATOR FOR THE THERAPEUTIC USE

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^{188}Re is a radioisotope of a high therapeutic potential for nuclear medicine, which belongs to the beta – gamma emitters group (maximal energy of beta radiation is 2.11 MeV, energy of gamma rays is 155 keV). With beta particles penetration in soft tissues of about 8 mm the cancer tissues can be destroyed, while the emission of gamma radiation permits imaging to locate accumulation. Studies include the clinical use of ^{188}Re complexes with HEDP as an effective pain palliation agent in painful bone metastases and with DMSA for cancer treatment. ^{188}Re complexes with peptides and monoclonal antibodies and their use in therapy against cancer are also in progress. Sterile and pyrogen-free solutions of ^{188}Re agents have been used in brachytherapy of coronary vessels to prevent restenosis [1-5].

Because of the short half-life of ^{188}Re , supplying the medicament to remote customers can create a logistic problem, which can be solved by delivering $^{188}\text{W}/^{188}\text{Re}$ generators as a source of ^{188}Re [6,7]. We have used a generator column and lead shielding used in our standard $^{99}\text{Mo}/^{99m}\text{Tc}$ generator (fission produced ^{99}Mo) to fabricate $^{188}\text{W}/^{188}\text{Re}$ generators. Aluminium oxide (Alumina A, ICN, MP Biomedicals) was used as a solid support. Before loading ^{188}W , the support was activated by subsequent washing with the following solutions: 5 ml 0,9% NaCl solution acidified to pH=3, 5 ml 32% HCl and 20 ml 0,9% NaCl solution, pH=3, all at a flow-rate 10 ml/min, to obtain an effluent of pH=3.

The ^{188}W (RIAR, Russia) with a specific activity between 27 GBq/g W and 133 GBq/g W, was dissolved, before loading on the column, in 0.5M NaOCl (0.5 ml NaOCl per 1 g of W), 80% CH_3COOH (1 ml CH_3COOH per 1 g of W) and 32% HCl, in order to lower the pH of the solution to 2.5, to obtain tungstic acid. The ^{188}W solution (as $\text{H}_2^{188}\text{WO}_4$) was then slowly loaded on the column using a peristaltic pump (flow rate 0.1 ml/min). The chemical quantity of W loaded on the column was between 40 to 80 mg/g of alumina. The ^{188}Re was eluted from the generator with 0.9% acidified saline.

The elution profile of the generator is presented in Fig. 1 where average values of generator yields obtained in 10 consecutive elutions (over the period of 4 weeks) are shown. More than 95% of ^{188}Re activity were accumulated at first and second fractions. The $^{188}\text{W}/^{188}\text{Re}$ equilibrium is reached in about 72 hrs, however, ^{188}Re can be milked from the generator more often with a satisfactory yield. According to the literature [6, 7] $^{188}\text{W}/^{188}\text{Re}$ generators can be used for above 6 months,

because the ^{188}W mother radionuclide has the half-life of 69 days.

In our testing procedure the performance of the generator has been evaluated for 6 months period. According to this procedure several generators were fabricated with a nominal activity of ^{188}Re in the range from 4 to 15 GBq at the calibration date. The activities of the ^{188}Re obtained from a generator were up to 500 mCi at the calibration date and over 90% of activity was eluted in first 4 ml of effluent (radioactive concentration of ^{188}Re from 15 to 120 mCi/ml), hence no post-elution concentrating was needed. The radiochemical purity was above 98.0% and radionuclidic purity >99.9% with respect to gamma impurities. ^{188}W leakage was <0.5%, whereas chemical purity testing showed Al < 10 ppm. The eluates were sterile and free of bacterial endotoxines. The quality of the ^{188}Re solution has been tested in labelling of bombesin analogue [8]. Described generators can be used in the clinics for routine applications as well as in research laboratories.

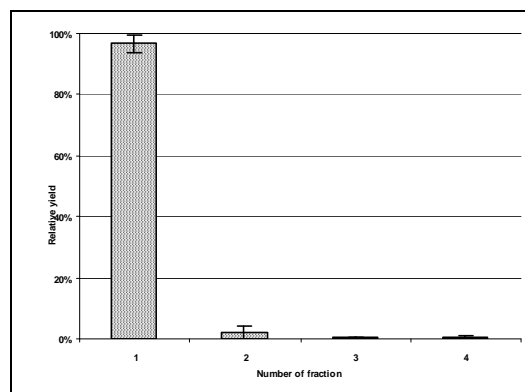


Fig. 1. The yields of ^{188}Re elution in collected 4 ml fractions over 10 consecutive elutions.

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THE INTERCOMPARISON OF ^{99m}Tc AND ^{131}I MEASUREMENTS BY RADIONUCLIDES CALIBRATORS IN POLISH HOSPITALS 2007

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Basing on the experience and publications of foreign metrological laboratories [1, 2], the Laboratory of Radioactivity Standards (LRS) has organized in Polish hospitals an intercomparison of activity measurements of ^{99m}Tc and ^{131}I . Both radionuclides are generally used for diagnostics and therapy. Organization of the intercomparison has been financed in 2007 by the National Atomic Energy Agency and supported by the Polish Society of Nuclear Medicine.

From among 58 Polish hospitals invited, 37 have participated in the intercomparison. Each hospital was identified by a confidential participant number.

The goal of the intercomparison was to obtain an information on the accuracy of activity measurements in Polish hospitals in relation to the National Standard Unit of Radionuclide Activity and to increase the efficacy of diagnostics, therapy and security of patients. All radioactive sources for measurements were manufactured in the RC POLATOM and delivered to participants successively during 4 months.

Each participant received about 4 ml of ^{99m}Tc eluate in a glass vacuum-vial used for elution, and two ^{131}I capsules, low- and high-active, in separate glass vials. Sources were standardized in relation to the National Standard using a measurement system with the 4π ionization chamber. The extended uncertainty of $\sigma_{\text{LRS}} = \pm 1.5\%$ for ^{131}I and of $\sigma_{\text{LRS}} = \pm 3.0\%$ for ^{99m}Tc with the extension parameter $k = 2$ has been evaluated. An exact measurement time has been noted. Participants performed measurements by their own radionuclide calibrators and sent results to the LRS. Data obtained from 37 hospitals participating in the intercomparison have shown a big variety of radionuclide calibrators used - 43 calibrators of 22 types from 12 various manufacturers.

The result given by each participant ($A_{\text{participant}}$) and the result obtained in the LRS (A_{LRS}) was recalculated for the same reference date and the ratio

$$S = A_{\text{participant}} / A_{\text{LRS}}$$

was determined. The half-life of (6.0067 \pm 0.0010) h of ^{99m}Tc and of (8.0233 \pm 0.0019) d of ^{131}I was adopted [3].

Not all of participants have delivered an estimated uncertainty of measurement, and then it was impossible to evaluate their measurement results using the E_n criterion [4]. The statistical criterion called normalized standard deviation, D

$$D = \frac{A_{\text{participant}} - A_{\text{LRS}}}{\sigma_{\text{LRS}} / \sqrt{3}}$$

has been used. The A_{LRS} was adopted as the reference value. The parameter D was used to classify the measurement results according to the specified limits [5]:

- $|D| \leq 2$ - good (within all limits),
- $2 < |D| < 3$ - acceptable (within the warning limits),
- $3 \leq |D|$ - non-acceptable (out of control).

The measurement result which differ no more than $\pm 5\%$ from the reference A_{LRS} value was assumed to be suitable for hospitals purposes [6]. Then $\sigma_{\text{LRS}} = 0.044 \cdot A_{\text{LRS}}$ was adopted instead of σ_{LRS} values given above and, as a consequence, the warning limits of $\pm 7.6\%$ for acceptable results were obtained.

Good and acceptable results composed jointly of 75%, 69.2% and 82% for all measurement results in the case of ^{99m}Tc eluate, ^{131}I capsules for diagnostics and ^{131}I capsules for therapy, respectively (Table. 1). From 118 results received from participants, 23 (19.5%) were non-acceptable.

Table. 1. Classification of the participant results of ^{99m}Tc and ^{131}I measurement as good, acceptable and non-acceptable, according to the limits specified by the D criterion. The limits of participant to LRS result ratio, S , are also given.

	Non-acceptable results $D \leq -3$ $S \leq 0.924$	Acceptable results $-3 < D < -2$ $0.924 < S < 0.95$	Good results $-2 \leq D \leq 2$ $0.95 \leq S \leq 1.05$	Acceptable results $2 < D < 3$ $1.05 < S < 1.076$	Non-acceptable results $3 \leq D$ $1.076 \leq S$
^{99m}Tc	17.5 %	7.5 %	62.5 %	5.0 %	7.5 %
^{131}I for diagnostics	12.8 %	0.0 %	64.1 %	5.1 %	17.9 %
^{131}I for therapy	7.7 %	2.6 %	64.1 %	15.4 %	10.2 %

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ON PHOTON STATISTICS IN THE LS-COUNTER

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The method of radionuclide standardization by the TDCR technique is based on the statistical Poisson model of the phenomena occurring when an ionizing particle interacts with the liquid scintillator (LS) [1]. The whole process can be described by binomial statistics as a result of a cascade of binomial processes. As the global probability of the whole process is low and the number of emitted photons in the case of high-energy emitters is large, the process can be approximated by a Poisson distribution for practical purposes. However, for the low-energy emitters ^3H or ^{55}Fe , the Poisson model failed [2, 3] yielding too high counting efficiency. Satisfactory results of standardizations have been obtained using the negative binomial (Polya) model. Evidently the model needs to include an effect that reduces the number of emitted photons. This could be result of an optical phenomena occurring when the scintillation light is emitted from a LS-vial. Cassette and Vatin [4] have pointed out that the probability of photon emission from the LS-vial depends on the emission location and that the global statistics of light emission has a larger variance than the Poisson law.

Probabilities of successive elementary processes leading to the fluorescence of a liquid scintillator (ionization along the particle track, quenching of primary excitation, energy transfer to the solvent, ionization or excitation of π -electrons, internal conversion to the S_1 state or quenching, recombination of ions to the S_3 or S_1 states, energy transfer to the solute, fluorescence, internal conversion or quenching in the solute) were described using existing data [5 - 12].

The low-energy emitters ^3H or ^{55}Fe of an average energy of interacting particles of 5.7 keV, transfer about 10% of the energy to the π -electrons and create about 20 photons per disintegration in fine. Using the evaluated number of photons and the light emission efficiency, ε , versus the radius, R , of the emission point in a vial [4], the global distribution of light collection by photomultipliers of a TDCR detector could be evaluated and compared with the Polya distribution. To simplify the calculations, only three binomial distributions for the number of photons, n , collected by photomultipliers were used. Distributions were calculated for three cylindrical layers of scintillator of radius a) $R \leq 0.6$, b) $0.6 < R \leq 0.8$ and c) $0.8 < R \leq 1.0$, and summed with the layer volume weighting factor $u = 0.36$, 0.28 and 0.36 , respectively. The sum-distribution, which approximated global distribution of light collection, the binomial, the Poisson and the Polya distribution were calculated for the expected number $n \approx 2.6$ of collected photons. The Polya distribution fits the global distribution of photons

quite well (Fig. 1), thus justifying its use for estimating the efficiency of low energy emitters..

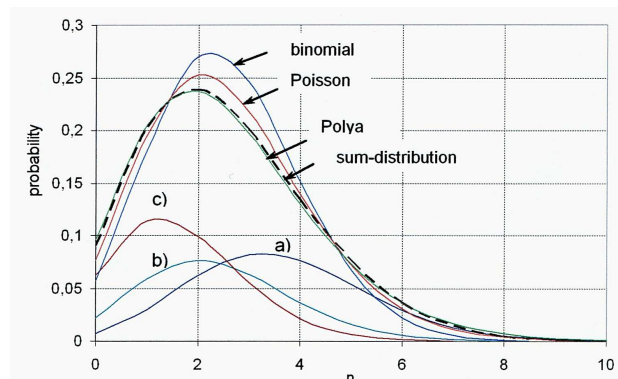


Fig. 1. Approximation of the global distribution for the number of photons, n , collected by photomultipliers from a LS-vial (dashed line) obtained by summing of the three binomial distribution a), b) and c) related to the different layers of scintillator.

The energy conversion factor for the liquid scintillator obtained when determining the ^{55}Fe activity using the Polya model [3], enabled an estimation of the scintillation efficiency for ^{14}C close to the experimental value. This gave further evidence of the correctness of the Polya model in the case of the ^{55}Fe measurement.

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SYNTHESIS AND TESTING OF GEL METAL-OXIDE COMPOSITES AS FILLING MATERIALS FOR W-188/Re-188 GENERATOR COLUMNS

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Rhenium has recently showed up as a useful radioisotope in variety of clinical trials.

At present the carrier-free Re-188 is obtained from W-188/Re-188 generators in which the tungsten-188 in form of a sodium tungstate W-188 solution is adsorbed on the alumina filling of a generator column. A new approach to preparation of chromatographic column packing of tungsten-188/rhenium generators is an application of nanocomposites obtained by means of the sol-gel technique [1-3]. A specific method for the synthesis of these materials was elaborated at INCT Warsaw Poland. The initial stage of the process is preparation of the ascorbate- NH_4^+ - tungsten, next the separately prepared zirconyl or/and silicon sols are added gradually to the reaction mixture. After a gelation step, gels are thermally treated at temperatures indicated by a thermal analysis (500, 650, 800°C). This way the synthesis of nanocomposites containing $\text{TiO}_2\text{-WO}_3$, $\text{ZrO}_2\text{-WO}_3$, $\text{ZrO}_2\text{-SiO}_2\text{-WO}_3$ at different ratios of oxides was carried out.

The several methods have been used for the determination of their structures and chemical purity.

The neutron activation analysis and spectrometry were applied for the determination of radionuclidic purity of components

The X-ray diffraction analysis and the neutron scattering analysis (wide and small angles) allowed for a determination of their crystal structure [4].

The samples were analyzed by XRD using a Rigaku Miniflex diffractometer with Cu-K α radiation (tube voltage 30kV and tube current 15mA) and scanning range from $2\theta=3^\circ$ to $2\theta=90^\circ$ (step 0.02° and rate $2^\circ/\text{min}$). The raw data were submitted to the smoothing process by the Savitzky method; the background elimination process by the Sonneveld method and a $K\alpha_2$ elimination process.

Next the elution profile of generator column packed on gels samples activated in a nuclear reactor have been studied using 0,9% NaCl solution as an eluent. The best results of elution (profile and eluent purity) appeared in the case of filling a chromatographic column with $\text{WO}_3\text{-ZrO}_2$ materials; in which the oxides molar ratio was 1:2 and a calcination temperature of 500°C and $\text{WO}_3\text{-TiO}_2$ with molecular ratio 1:2 and a calcination temperature of 650°C. The structural analysis of both composites allowed for their classification as amorphous materials.

Samples containing $\text{WO}_3\text{-ZrO}_2\text{-SiO}_2$ did not reveal satisfactory elution profiles.

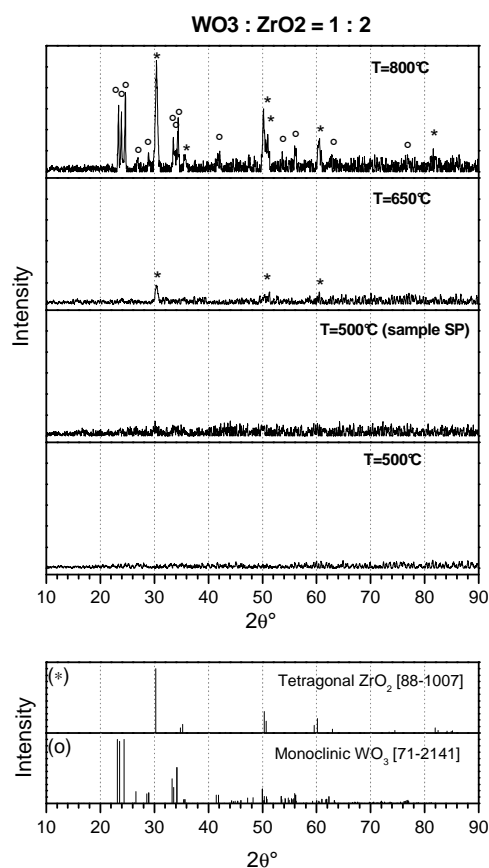


Fig. 1. The X-ray diffraction analysis of $\text{WO}_3\text{-ZrO}_2$ (1:2) nanocomposites after different temperature treatment.

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DEVELOPMENT OF RADIONUCLIDES STANDARDIZATION METHODS BY MEANS OF A LIQUID SCINTILLATORS TECHNIQUE USING MONTE CARLO CALCULATIONS

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The probabilities of interaction of photons in two different liquid scintillators (toluene and widely used commercial cocktail Ultima Gold) were calculated as a function of energy for two different geometries (standard 20 ml LS glass vial and LS cocktail volumes of 10 and 15 ml) using the Monte Carlo code PENELOPE [1].

The used geometries were described by coaxial cylinders (Fig. 1). The vial was surrounded by a simplified counting chamber structure.

In order to confirm a validity of our procedure, the results were compared to the results of the calculated absorbed spectra of the 835 keV photons of ^{54}Mn organized by the Liquid Scintillators working group of the International Committee for Radionuclide Metrology in 2004 [2]. The calculated interaction probability values and characteristics of the shape of the resulted spectra, namely, the ratios: the peak-to-valley, the peak-to-valley of the main Compton spectrum and the amplitude of the multiple Compton peak to the amplitude of the main Compton peak were similar in both simulations.

The main calculations were performed over the photon energy range 5 – 1000 keV. For each energy value and geometry at least $2 \cdot 10^6$ initial particles were simulated and the radiation source was assumed to be uniformly distributed throughout the LS cocktail. The calculated probabilities of photon interaction for different liquid scintillators are comparable (Fig. 2).

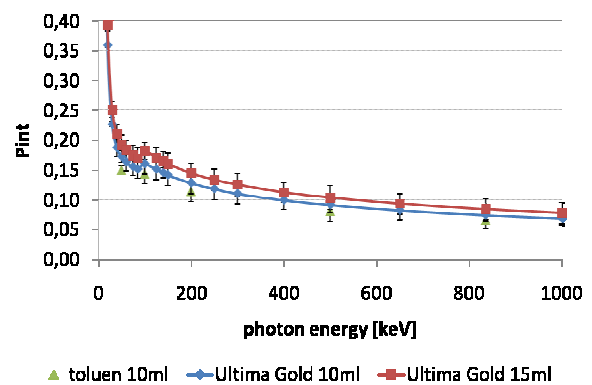


Fig. 2. Dependence of the photon interaction probability on the energy.

It was observed that in high energy range there was no significant difference between the used scintillators. For energies below 100 keV the difference did not exceed 12%. Lower interaction probabilities in the case of toluene result from the alternate composition of this cocktail having lower amounts of elements with high atomic number (S, P or Na). Difference between 10 and 15 ml of Ultima Gold can be neglected.

Table 1. Atomic composition of the scintillators.

	C	H	N	O	P	S	Na
UG	16,81	24,54	0,04	1,52	0,11	0,02	0,02
Tol	7	8	-	-	-	-	-

Results of this work, including calculated spectra of deposited energy in a liquid scintillator for a different energy, will be used in a primary standardization of radioactive solutions by the triple-to-double coincidence (TDCR) method in the Laboratory of Radioactivity Standards in RC POLATOM.

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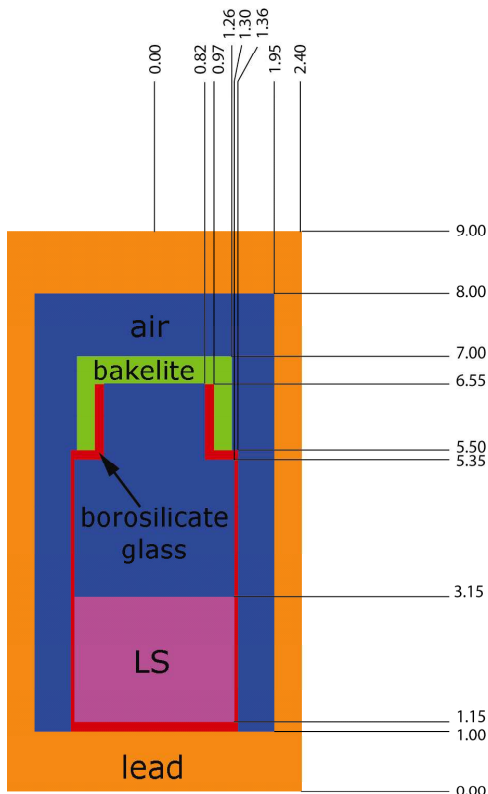


Fig. 1. Geometry of LS vial used in the Monte Carlo calculations. All dimensions are given in cm.