ENVIRONMENTAL RADIOACTIVITY ASSESSMENT STUDIES
ON PLACEMENT AREA OF THE NEW EXTREME LIGHT
INFRASTRUCTURE NUCLEAR PHYSICS FACILITY

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The paper presents environment radioactivity data performed by the monitoring of the Extreme Light Infrastructure Nuclear Physics ELI-NP building placement area, nuclear physics facility which will be built within Horia Hulubei National Institute for R & D in Physics and Nuclear Engineering (IFIN-HH), Romania. The studies were necessary in order to achieve the reference values of radioactivity and quality for environment before starting the ELI-NP nuclear facility building process and the nuclear activities in this new objective. The ELI-NP building placement area was mapping into lots of about 1000 m\textsuperscript{2} and samples from twenty points were analyzed. Ten thermoluminescent dosimeters were also placed on ELI-NP area during forty-three days. The studies are based on measurements of radioactivity, especially the gross beta radioactivity in environmental samples, such as: soil, groundwater, spontaneous vegetation and aerosols samples, and ambient dose equivalent rates. The results show that the environment radioactivity values obtained by these studies are comparable with those previously obtained through environment radioactivity monitoring in IFIN-HH area and in different Romanian areas.

Key words: radioactivity environment assessment; gross beta; ambient dose equivalent rate.

1. INTRODUCTION

The radioactivity measurements are important for recording the radiation impact on environment, population and occupational personal exposed to radiation. Many papers report data about environment radioactivity measurements coming from manmade or natural radioactive sources. Some types of work activities...
determined by the economic world evolution contribute to the increase of environmental radioactivity: nuclear power plants, industry, building construction, nuclear activities of nuclear research, medicine etc.

Extreme Light Infrastructure Nuclear Physics (ELI-NP) a very important nuclear physics facility, European Community concept will be built in Romania, at Horia Hulubei National Institute for R & D in Physics and Nuclear Engineering IFIN-HH during the 2013–2018. ELI-NP is a new type of large-scale laser infrastructure designed to produce the highest peak power. The Steering Committee decided that ELI would be implemented in two phases as a distributed infrastructure. Three countries from Europe Union have been chosen to host objectives from the new nuclear project: the Czech Republic, Hungary and Romania, facilities specialized in three of the four scientific pillars of the project identified during the ELI – preparatory phase. The Attosecond Light Pulse Source facility (Szeged, Hungary) will be designed to make temporal investigation at the attosecond scale of electron dynamics in atoms, molecules, plasmas and solids; the Beam lines facility (Dolni Brzezany, Czech Republic) will mainly focus on the production of ultra intense and ultra short sources of electrons, and ions, coherent and energetic X rays; and the Nuclear Physics facility (Magurele, Romania) will be dedicated to laser-based photonuclear physics and will allow combined experiments with high-power lasers and a very brilliant gamma beam. The aim of these facilities is to construct ultra-high-power lasers with focussable intensities and average powers far beyond the levels reached by the laser systems currently under construction (APOLLON, Vulcan, PFS). http://www.eli-np.ro. Theoretical and practical research activities are planned to take place in ELI-NP nuclear physics facility: i) Establishing the ratio of $^{238}$U to $^{235}$U used in nuclear reactors, using gamma radiation beams; ii) The development of a measuring method of the fuel quantity from the bars of radioactive materials; iii) Processing radioactive waste with a long neutralization time in radioactive materials which have this characteristic greatly reduced; iv) Applications in medicine through the usage of laser devices (accelerators) for proton therapy. These send out a beam of accelerated protons in the tissue with the purpose of destroying with precision a sick cell, without affect the adjacent ones; v) Facilitating the manufacturing of radiopharmaceutical products used to diagnose and uninvasively treat sicknesses like cardiovascular ones or cancer.

Laboratory for Personnel and Environment Dosimetry (LDPM) from IFIN-HH performs monthly the radiation doses for occupational exposures and daily radioactivity environment measurements by different specifically methods. The radioactivity data, Hp(10) dose equivalent, radioactivity concentration are recorded, reported and achieved in accordance with Romanian radioprotection norms in force and consequently with European norms on the same area (Report 2011, IFIN-HH, Law no. 111/1996, Revision 2, 2000).
ELI-NP is a very complex facility which will host two machines of extreme performances: A very high intensity laser, where beams from two 10 PW lasers are coherently added to get intensities of the order of $10^{23} - 10^{24}$ W/cm² and electrical fields of $10^{15}$ V/m; A very intense ($10^{15}$ gamma/s), brilliant gamma beam, 0.1% bandwidth, with $E_{\text{max}} > 19$ MeV, which is obtained by incoherent Compton back scattering of a laser light off a very brilliant, intense, classical electron beam ($E_e \geq 720$ MeV) produced by a warm linac. So, before starting the ELI-NP building construction process and later the activities specifically for this nuclear physics facility it is necessary to perform radiological mapping of the ELI-NP placement area for to know the environmental radioactivity level. In this paper the data on ELI-NP area placement environment radioactivity are presented. In this order it has been performed: a) Environmental radioactivity measurements by analyzing of the soil, vegetation, underground water and aerosol samples from ELI-NP area of interest; b) Assessment of the equivalent ambiental dose rate using the environmental TL system; c) Analysis and interpretation of the results in order to perform the radiological map of the ELI-NP area.

The data recorded in this work are archived and will be used as reference values in later evaluation of the ELI-NP nuclear activity impact on the environment radioactivity.

Fig. 1 – Mapping of the ELI-NP facility placement area.
2. MATERIALS AND METHODS

2.1. SAMPLING AND SAMPLE CONDITIONING

The studies shown in the paper were made in the Laboratory for Personnel and Environment Dosimetry (LDPM) from IFIN-HH.

Out of personal monitoring, LDPM deals with measurements and reports of radioactivity in environmental samples and especially with those of environment radioactivity monitoring around the nuclear and radiologic installations from IFIN–HH (A. Stochioiu et al., 2012) in accordance with the IFIN-HH Radiation Monitoring Program. The Program is approved by the National Committee for the Control of Nuclear Activities (CNCAN), Romanian nuclear authority. Sampling, conditioning and measurement of samples are made in compliance with the LDPM specific procedures (A. Stochioiu et al., 2011).

The area surface destined for the construction placement of the ELI-NP facility is about 50,000 m² and presently is covered with rich vegetation. In order to establish the sampling points, the ELI-NP placement area has been split in 16 sides of approximately 1000 m², Fig.1. From each of these side soil and spontaneous vegetation samples were taken at random. To cover all area around the nuclear physics facility placement four more points for this study were considered.

Soil samples have been collected from flat sides unaffected by erosion and sedimentation. In an area of 1 m², from the first 5 cm, more individual samples are collected so that the final sample to have a weight of about 0.5 kg. The samples have been dried at (105 ± 5)° C for to obtain a constant mass; samples of about 0.5 g have been spread on a measuring tray and then alpha-beta global analyzed.

The spontaneous vegetation samples were collected from the same points as the soil samples. The vegetation for the samples was cut at a distance of (2–3) cm of ground surface. A known amount of fresh vegetation was dried till constant mass. The sample conditioning was followed by a gradual calcinations process: 6 hours at a temperature of (150–200)° C, 4 hours at (300 ± 10)° C and 8 hours at (350 ± 10)° C. To perform the alpha-beta global analysis 0.25g ash samples were put in a stainless steel tray with a diameter of 50 ± 2 mm and a height of 6 ± 2 mm and evenly sprayed on the tray surface and fixed with alcohol solution.

The samples of water were collected from 18 wells from studied area from the first layer of ground water. Each sample had a volume of 2L and was collected to the surface water (I. Chiosila, 1998). Before conditioning the samples have been shaken in order to homogenize the content and then 1L of water sample put into a porcelain capsule has been evaporated slowly on an electric heater taking care not to boils. The rest of the sample was kept in the dosimetry laboratory as control sample. After that the porcelain capsule was cooled down, the residue deposited on its walls was transferred and uniformly distributed on the tray to perform measurements. In order to measure the radioactive density the aerosol samples
were collected on a paper filter mounted to a suction pump from two points on the studied area; the aerosols suction process has lasted 5 hours (STAS 12457-86). The filters placed on the stainless steel tray were measured to determine the beta global level.

2.2. SAMPLE MEASUREMENT

The equipment used to measure the environment samples consists of:

i) installation for measurement of gross alpha-beta activity in ultra low background, Model 9300 PC-GFL, Soft VISTA 2000 of L. The background counting rates are: 0.050 ± 0.041 cpm alpha radiation with a minimum detectable activity (MDA) of 0.010 Bq and 0.600 ± 0.041 cpm beta radiation with 0.029 Bq MDA; ii) installation for measurement of gross, beta, gamma activities in low background with automatic sample changer, Model S5 XLB, Soft ECLIPSE. Minimum detectable activities are 0.01 Bq, 0.030 Bq and 1.12 Bq for alpha, beta and gamma radiation respectively, in water solution samples; iii) gamma-ray spectrometry installation used for the sample measurement in order to characterization the radionuclides.

The equipment was calibrated by the Laboratory for Radiation Metrology (LMR) from IFIN-HH; the standard sources used for calibration were $^{241}$Am, $^{90}$Sr-Y, $^{137}$Cs and $^{40}$K certified by the LMR.

The ambiental equivalent dose and its rate were determined using environment TL dosimeters. The Environment TL Dosimetric System, SDTM type, consist on: TL detectors reader called TL Reader, RA’94 type, calibrated for 2950 impulse of the test source and a heating cycle of (25–245) °C, characteristic of the type of detectors used. The laboratory for personnel and environment dosimetry uses detectors of Gr 200-A type which have advanced functional characteristics. The most important characteristics are: high sensibility, low errors of measurement, possibility of reusing up to 80 times, easy reading and interpreting of the results. The LDPM is accredited to measure the dose equivalent in the (0.1–100.00) mSv dose range with a measuring incertitude of about 12%.

3. RESULTS AND DISCUSSIONS

3.1. ACCURACY OF MEASUREMENT TO LOW AND HIGH ACTIVITY

The average values for gross activities are $812 ± 147$ Bq/kg in soil samples and $146 ± 44$ Bq/kg in the spontaneous vegetation fresh mass. These values are comparable with those measured in the samples collected from the influence area
of IFIN-HH. The $^{137}$Cs and $^{40}$K radionuclides were pointed out through the gamma-spectrometric analysis. In the vegetation samples, the $^{137}$Cs concentration is lower than MDA of the installation used for measurements. The radioactivity values given by $^{137}$Cs artificial radionuclide measured in soil samples are between $28.6 \pm 1.9$ Bq/kg and $74.8 \pm 3.9$ Bq/kg and its presence is caused by the Chernobyl incident. The presence of this radionuclide is higher especially in the samples of soil where the agricultural activities are not carried out. Nevertheless, the measured values regarding $^{137}$Cs artificial radionuclide are much lower than those allowed by the current standards approved by CNCAN. The radioactivity given by the $^{40}$K naturally radionuclide is between $501 \pm 25$ Bq/kg and $598 \pm 29$ Bq/kg in soil samples, and between $122.00 \pm 11.62$ Bq/kg and $202.72 \pm 14.49$ Bq/kg in vegetation samples. The results of the measurements for gross beta activity in soil and spontaneous vegetation samples are presented in Fig. 2.

![Fig. 2 – The values for gross beta activity in soil and spontaneous vegetation samples.](image)

The results for the gross beta analysis for the samples of subterranean water are presented in Fig. 3. For a relevant study the measured results in the 2012, March and November were taking into account.

The beta-global radiation concentration values distributed relatively homogenous in analyzed samples are between (0.15–0.30) Bq/L and are bellow 1.85 Bq/L maximum allowed value approved by the Romanian radioprotection norms (NSR-01, 2002).
These values of radioactivity are comparable with those recorded and reported in the previous years, (A. Stochioiu, 2012). The data recorded regarding the environment radioactivity around the IFIN-HH show that the activities developed in this nuclear research institute are made in safety in terms of radiation protection.

Through the gamma-spectrometric analysis on the subterranean water collected samples the radioactivity concentrations given by $^{137}$Cs and $^{40}$K radionuclides were bellow than the MDA of the equipment used in measurements.

### 3.2. ESTABLISHMENT OF THE AMBIENTAL EQUIVALENT DOSE FROM INTERS AREA BY TLD METHOD

Taking into consideration the features of the passive dosimeters, the TL detectors were used in the ambiental dose equivalent assessment for ELI-NP nuclear facility placement area.

The TL dosimeters were placed in ten representative points in order to cover all studied area. Each dosimeter has five thermoluminescent detectors in order to increase the number of measurements in each interest point and for to have a good accuracy on ambiental dose assessment. The results from Table 1 regarding the ambiental dose equivalent measured in studied area are given with the incertitude of 10% for $K=2$. The monitoring period was of 1032 h and some TL dosimeters
were kept in LDPM as witness for measurements. The values of the ambiental dose equivalent recorded in ELI-NP nuclear facility placement area were between 0.096 ± 0.004 mSv and 0.104 ± 0.006 mSv, while by reading of the TL dosimeter witnesses was obtained a mean dose value of 0.102 ± 0.007 mSv.

The mean values of the ambient dose equivalent rate were of 96.34 ± 4.25 nSv/h in the IFIN-HH influence area in 2012, and of 102.11 ± 2.05 nSv/h for the studied period in this work; all values are comparable with those given by http://meteo.nipne.ro.

Table 1
Values for the ambient equivalent dose- H*(10)- and the flow of ambient equivalent dose determined in representative points from the placement area of ELI-NP

<table>
<thead>
<tr>
<th>No. of dosimeter</th>
<th>Placement point</th>
<th>Ambient equivalent dose ± SD [mSv]</th>
<th>Ambient equivalent dose rate ± SD% [nSv/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1067</td>
<td>1</td>
<td>0.102±0.006</td>
<td>98.04±5.78</td>
</tr>
<tr>
<td>1066</td>
<td>2</td>
<td>0.099±0.005</td>
<td>107.41±5.09</td>
</tr>
<tr>
<td>1073</td>
<td>3</td>
<td>0.098±0.005</td>
<td>97.43±6.48</td>
</tr>
<tr>
<td>1056</td>
<td>4</td>
<td>0.104±0.006</td>
<td>92.14±2.77</td>
</tr>
<tr>
<td>3002</td>
<td>5</td>
<td>0.101±0.004</td>
<td>105.08±6.32</td>
</tr>
<tr>
<td>1065</td>
<td>6</td>
<td>0.103±0.005</td>
<td>108.12±6.63</td>
</tr>
<tr>
<td>1022</td>
<td>7</td>
<td>0.097±0.006</td>
<td>105.43±4.43</td>
</tr>
<tr>
<td>1071</td>
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<td>0.098±0.003</td>
<td>118.91±7.56</td>
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<tr>
<td>0193</td>
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<td>0.096±0.004</td>
<td>106.66±6.21</td>
</tr>
<tr>
<td>1046</td>
<td>10</td>
<td>0.098±0.003</td>
<td>111.08±7.22</td>
</tr>
</tbody>
</table>

4. CONCLUSIONS

The beta-global radioactivity values measured on environmental samples from ELI-NP placement area are comparable both with those measured around the nuclear and radiological installations from IFIN-HH and with those recorded nationally.

The mean value of the ambient equivalent dose rate assessed by TL system for environment is close to the annual average value from the perimeter and influence area of the IFIN-HH and also, is close to the values given by the weather tower from the institute and with the values obtained at national level.

The results of the beta-global and gamma-spectrometric analyses and the environment radioactivity from the studied area are the data base for the ELI-NP building placement area at the time zero. These will be used as reference data in order to evaluation the impact ELI-NP nuclear activities on the environment radioactivity safety.
REFERENCES