BGnS International Conference Nuclear Power for the People

10-13 September 2018, St.Vlas, Bulgaria

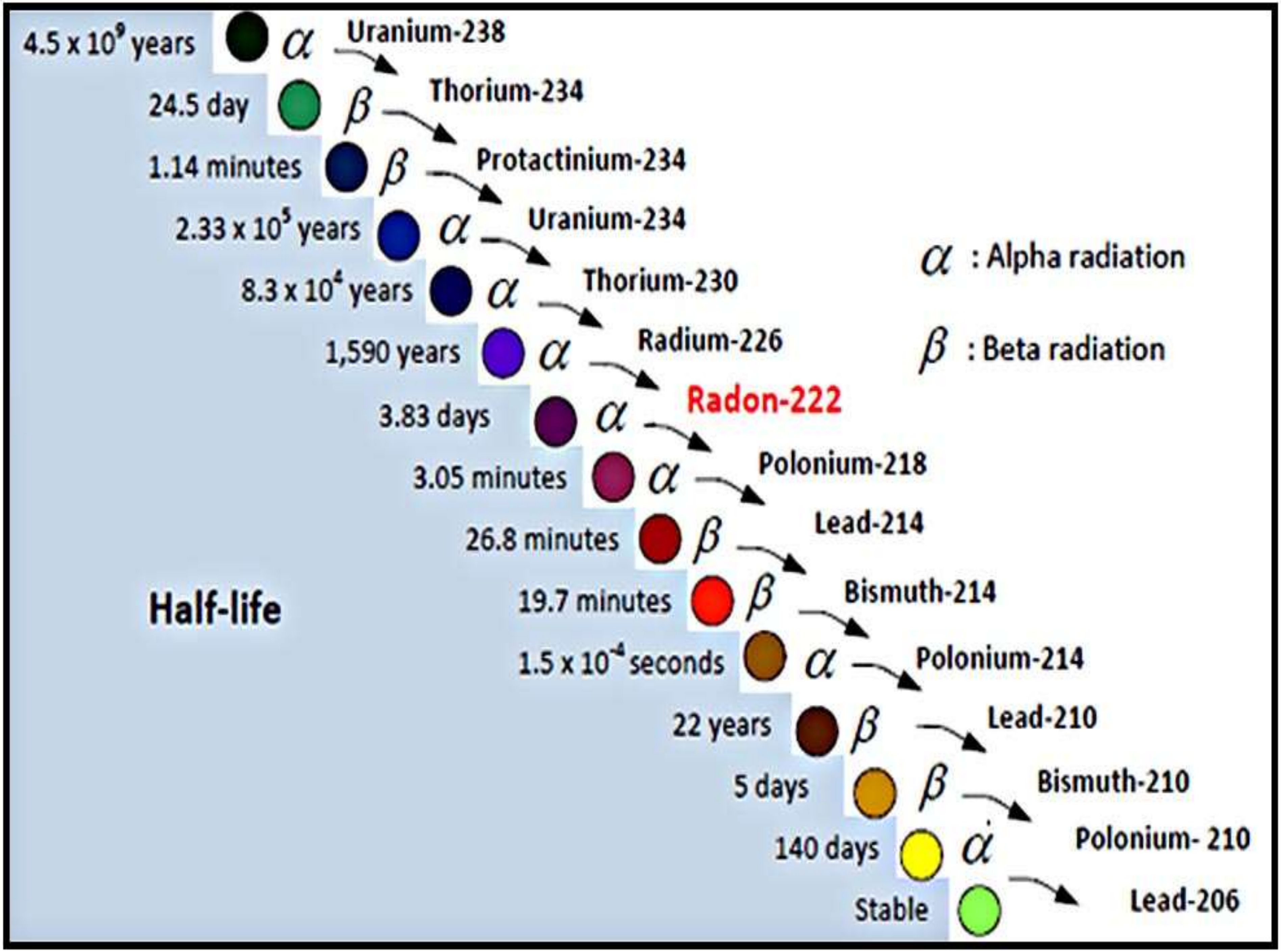
METHODOLOGY FOR RADON CONCENTRATION MEASUREMENTS AT THE IRT-Sofia RESEARCH REACTOR SITE

A. Mladenov, K.Krezhov

Bulgarian Academy of Sciences – Institute for Nuclear Research and Nuclear Energy
72 Tzarigradsko Chaussee, Blvd., 1784 Sofia – Bulgaria

RADON ISOTOPES

Radon isotopes 222, 220 and 219 are radioactive gases produced by the disintegration of radium isotopes 226, 224 and 223, which are decay products of uranium-238, thorium-232 and uranium-235 respectively, and are found in the Earth's crust. Radon is an odourless and colourless radioactive gas that occurs naturally in the environment as a result of the decay of radium in soils, rocks and building materials. It is a noble gas and does not form chemical compounds. The ^{222}Rn half-life of 3.8 days is long enough for it to migrate from the rock producing it, through the soil, to the air. The processes of radon exhalation depend on a multitude of factors, including among the others the content and distribution of radium in the soil, the soil's grain size, porosity, and permeability, soil moisture content, the radon diffusion coefficient through fractures and interstitial pores, and environmental parameters (air and soil temperature, barometric pressure, rainfall, snowfall). Once detached from a geological or anthropogenic matrix, radon mobility in the atmosphere is governed only by diffusion and transport. In principle, maps of radon-prone areas are to be used as planning aids for administration purposes to estimate the necessary further efforts and preventive measures.



4.5 x 10⁹ years
α
Uranium-238
24.5 day
β
Thorium-234
1.14 minutes
β
Protactinium-234
2.33 x 10⁵ years
α
Uranium-234
8.3 x 10⁴ years
α
Thorium-230
1,590 years
α
Radium-226
3.83 days
α
Radon-222
3.05 minutes
α
Polonium-218
26.8 minutes
β
Lead-214
19.7 minutes
β
Bismuth-214
1.5 x 10⁻⁴ seconds
α
Polonium-214
22 years
β
Lead-210
5 days
β
Bismuth-210
140 days
α
Polonium- 210
Stable
Lead-206
Half-life
α : Alpha radiation
β : Beta radiation

RADON ISOTOPES

The exposure of man to this alpha-particle-emitting gas is mainly to lung by inhalation. The indoor radon, thoron and their decay products from geogenic and/or anthropogenic origin are the main contributors of the total inhalation dose which has long been recognized as a potential radiological health hazard.

The potential effects of radon on human health lie in its decay products rather than the gas itself. The risk of radon exposure is associated with high levels of radon concentration in confined environments and the subsequent inhalation, increasing the risk of damaging the organ cells where radon short-life products are deposited. In houses, building characteristics and lifestyle, i.e. often or forced ventilation, have a significant impact on radon entry and dilution by fresh atmospheric air. Generally, health effects of exposure to radon in indoor environments (indoor air) depend mainly on the concentration of inhaled radon, the ventilation rate of the place, frequency and duration of the exposure.

IRT- Sofia monitoring

IRT-Sofia monitoring includes:

- Radon monitoring in selected points of the IRT-Sofia nuclear site, which is an important part of radiation surveillance activities during the operation and maintenance of the facilities at the Nuclear Scientific Experimental and Educational Centre (NSEEC) of the Institute for Nuclear Research and Nuclear Energy. Consideration is given to the evidence prior and during the dismantling activities related to the IRT research reactor refurbishment project and after their accomplishment.

- Evaluation the equivalent dose rates in different workplaces of buildings located within the NSEEC protected site on the basis of measured radon concentrations using active sampling of indoor air. The main conclusions consider outdoor data and indoor measurements carried out in the bottom floors of buildings, which are in direct contact with the ground.

IRT- Sofia nuclear site description

The nuclear site of the NSEEC comprises the research reactor IRT-Sofia, presently shut down because of undergoing reconstruction, two radiochemical workrooms, a ^{60}Co gamma irradiator, several radioactive waste (RAW) storages and a number of research laboratories that use radiation sources in their work. All the facilities and RAW storages convey issues that are imposing requirements for permanent dosimetric control and radiation monitoring of environment. The major buildings inspected in this survey were the nuclear research reactor IRT-Sofia, where in its basement the First Class Radiochemical Laboratory is located (radiochemical niches, glove boxes etc. for radiopharmaceuticals, as well as a technological conveyor line passing through four hot cells for treatment of high specific activity radioactive isotopes), the building of the central alarm system and the auxiliary building wherein the laundry facilities and the 60Co gamma irradiator GOU-1 are installed.

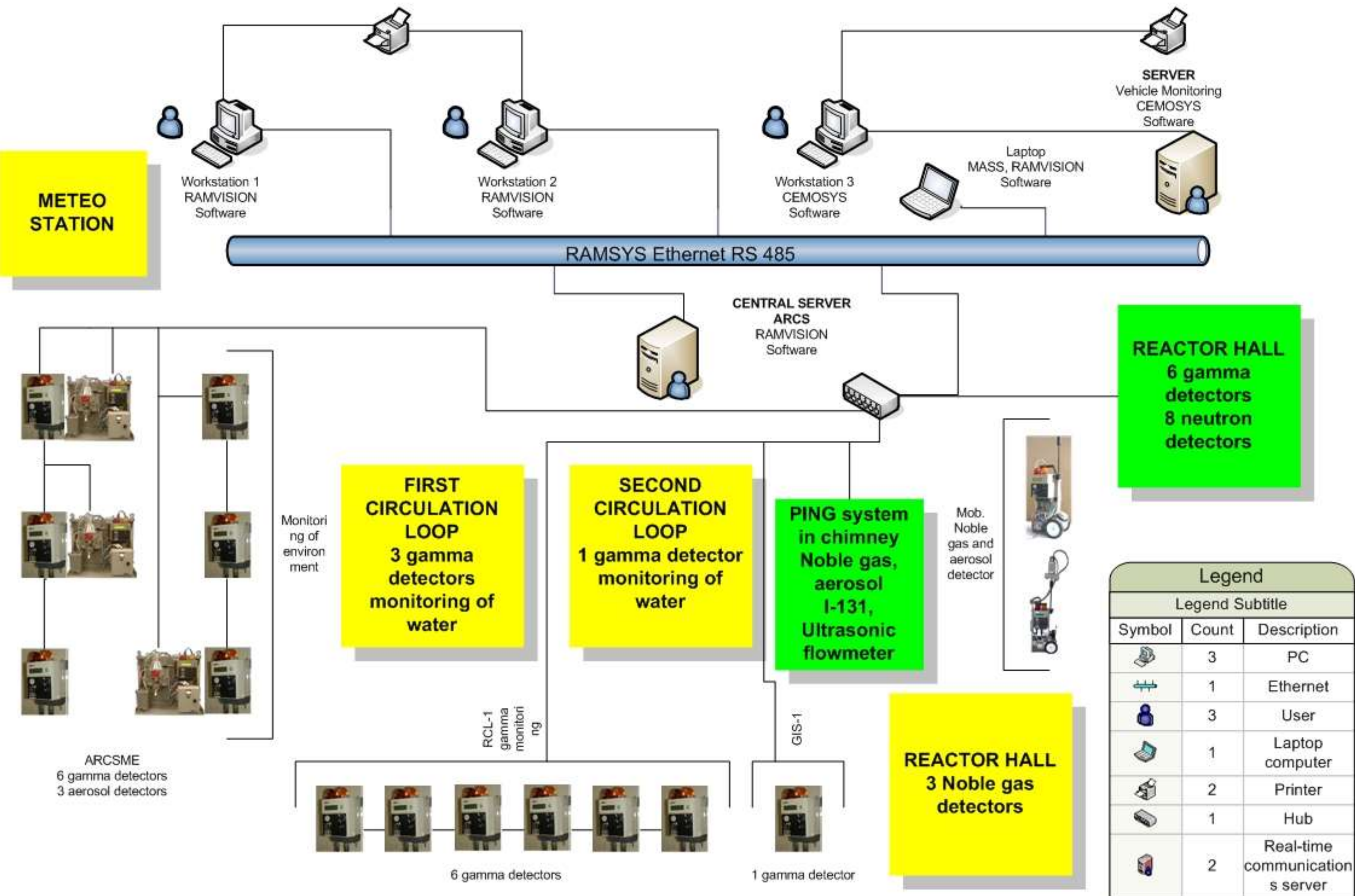
IRT- Sofia nuclear site

ARMS

The stationary technological (gamma and neutron detectors) and environmental (gamma and aerosol detectors) monitoring systems are online 24 hours. Environmental monitoring via the automated and integrated radiation monitoring system (ARMS) involves: monitoring of gamma dose rate, alpha and beta activity, radon activity, ^{218}Po, ^{214}Po and ^{212}Po activity, gamma control of vehicles. Technological control of gaseous effluents from the facilities includes alpha beta particulate monitor, iodine monitor, noble gases monitor and stack flow monitor.

The fully automated and integrated radiation monitoring system allows for the implementation of technological and environmental monitoring of all the facilities on the site and ensures the early detection of any abnormal radiological events.

AUTOMATIC RADIATION CONTROL SYSTEM of IRT-200



INSTRUMENTS AND METHODS

ABPM 201L
Dual large area silicon detectors:
(450mm^2 or 0.7 square inches)
Radiation detected:
α and β radiations
Energy range:
α: 4.2 MeV to 5.5 MeV (U, Pu, U+Pu)
β: 80 keV to 2 MeV
γ: 80 keV to 2 MeV
Measurement range:
β: 1 to 10^6 Bq/m^3 (2.7 10^{-11} to 2.7 10^{-4} Ci/ m^3)
α: 10^{-2} to 10^4 Bq/m^3(2.7 10^{-13} to 2.7 10^{-7} Ci/ m^3)
Filter type: FSLW
autonomy : > 2 months in normal conditions
efficiency (for 1m/s)
- > 99.59 % for particles Φ: 0.15μm
- > 99.63 % for particles Φ: 0.4μm
- > 99.99 % for particles Φ: 4μm
Standard Flow Rate: 35 l/min

INSTRUMENTS AND METHODS

<u>ABPM 203 M</u>

Detectors : large area silicon detectors

area 450mm^2 (0.7 in^2)

Energy range : alpha 2.0 MeV < E < 4.4 MeV

beta 80 keV < E < 420 keV

gamma 80 keV < E < 420 keV

Measurement range:

- ^{239}Pu or 233U : alpha: 10^{-2} to 10^{+4} Bq/m^3 (2.7 10^{-13} to 2.7 10^{-7} µCi/cc)
- ^{137}Cs : beta: 1 to 10^{+6} Bq/m^3 (2.7 10^{-11} to 2.7 10^{-5} µCi/cc)

Minimum Detectable Activity (MDA at 2 sigma) α detection

- With background compensation
- Radon activity of 10 Bq/m^3 Environmental conditions (0.1 µGy/h)

Minimum Detectable Activity (MDA at 2 sigma) β detection

- With background compensation
- Radon activity of 10 Bq/m^3
- Environmental conditions (0.1 µGy/h)

INSTRUMENTS AND METHODS

Both units are designed as computer software-aided alpha-beta-gamma dosimeters. The portable computer is an essential tool for the monitor. It is used to display measurement values stored by the monitor as well as local programming (measurement channel programming) to evaluate radon progeny using specialized dedicated software. The measurement could be compensated for naturally occurring radioactivity (radon) and for externally induced γ fields. The volumetric activity is measured in units Bq/m^3 or Ci/m^3.

Both units uses a filter (millipore FSLW) with efficiency (for 1m/s): > 99.59 % for particles with an effective size (Φ) of 0.15 μm, > 99.63 % for Φ of 0.4μm, > 99.99 % for Φ of 4μm. The standard flow rate is 35 l/min. This flow rate is higher than the human respiratory rate. This means that the response of the monitor to detect radiation is fast enough to alert the operator of the presence of a dangerous concentration of airborne radioactive particulate. The sampled air is discharged downstream of the pump. Radioactive particulates present in the air are trapped on a cellulose fibrous filter placed inside the CE200 detector.

INSTRUMENTS AND METHODS

A large-area silicon detector located in front of the filter detects α, β and γ radiation emitted by the deposited particulates. An identical second detector, placed immediately behind the first, detects only γ radiation. The gamma measurement enables dynamic background compensation to the net particulate activity measurements. The data can also be used to display the ambient dose rate referenced to ^{137}Cs. In the alpha and beta measurement channel, the detected pulse frequency is proportional to the activity deposited on the filter. The pulse frequency of the γ channel is associated with the ambient dose rate.

The CE 200 detector consists of 2 units: the upper unit contains 2 identical large area silicon detectors. The first detector, located in front of the filter, detects α, β and γ activity emitted by the particulates deposited on the filter. The second detector, placed immediately behind the first, detects only γ radiation. The gamma measurement enables background compensation to the actual particulate activity measurements. The data can also be used to display the ambient dose rate referenced to ^{137}Cs. The airborne radioactive particulates are deposited on the filter facing the Si detector which detects the charged particulates by generating pulses proportional to the energy lost by the particulates. Specific algorithms are used to estimate corresponding volumetric activity.

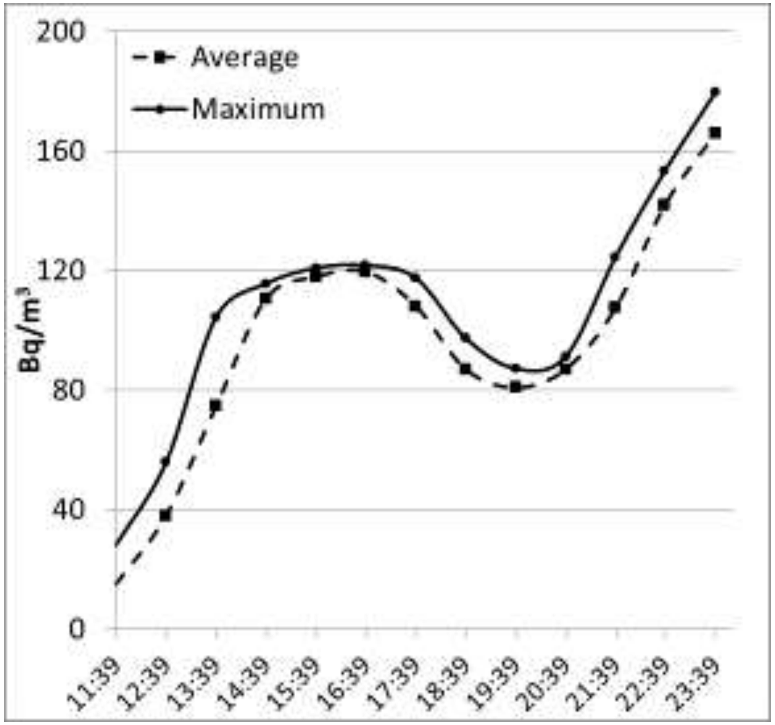
RESULTS

The results for the gamma background levels of the NSEEC site monitored continuously by the ARMS vary in the limits 0.08 μSv h^{-1} – 0.13 μSv h^{-1} for time span of more than 20 years. The average monthly values measured at all six control points included in the ARMS show minor seasonal variation. Gamma background data recorded for the protected area since 1961, although with other means for control, are in the same limits and indicate the quality of organization of the radiation safety control at the IRT-Sofia site throughout the time of active use of the research reactor and the long period of time afterwards.

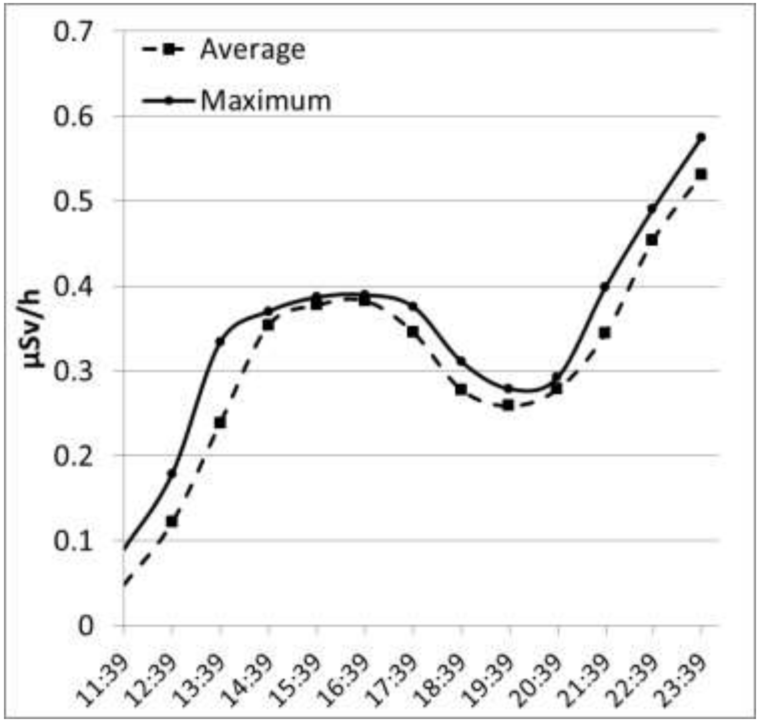
The large number of measurements conducted through many years with the ARMS system for environmental monitoring defined relatively constant levels of radon concentration in the supervised area of NSEEC. Slight variations in different seasons were observed in the vicinity of the research reactor but the radon concentration levels generally remain relatively constant. The measured radon concentration in the supervised area is 0.28±0.18 Bq m^{-3}. Somewhat higher levels of radon concentration were recorded mainly in summer. It is to note that the height of ambient air sampling nozzles of the 3 ABPM 201-L monitors in the site is fixed at 1.70 m above the ground to favor absorbed dose evaluation for public as well as to follow the gaseous discharge of IRT reactor when operational.

RESULTS

Laundry:



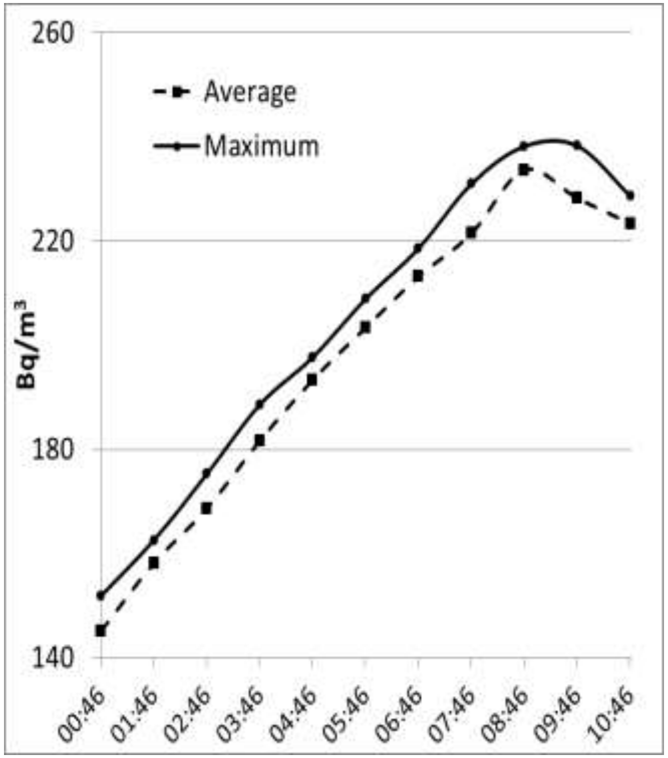
^{222}Rn Activity



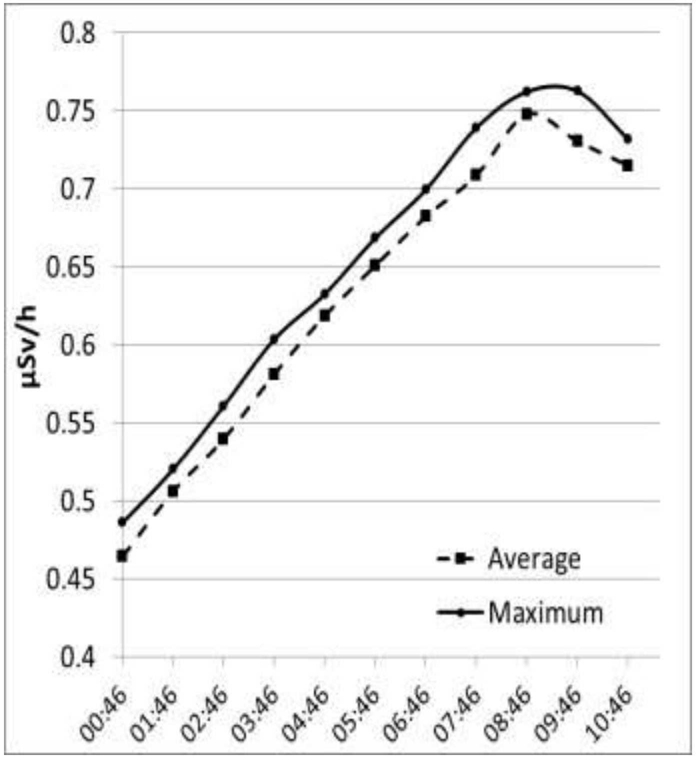
Effective Dose rate

RESULTS

Laundry before ventilation:



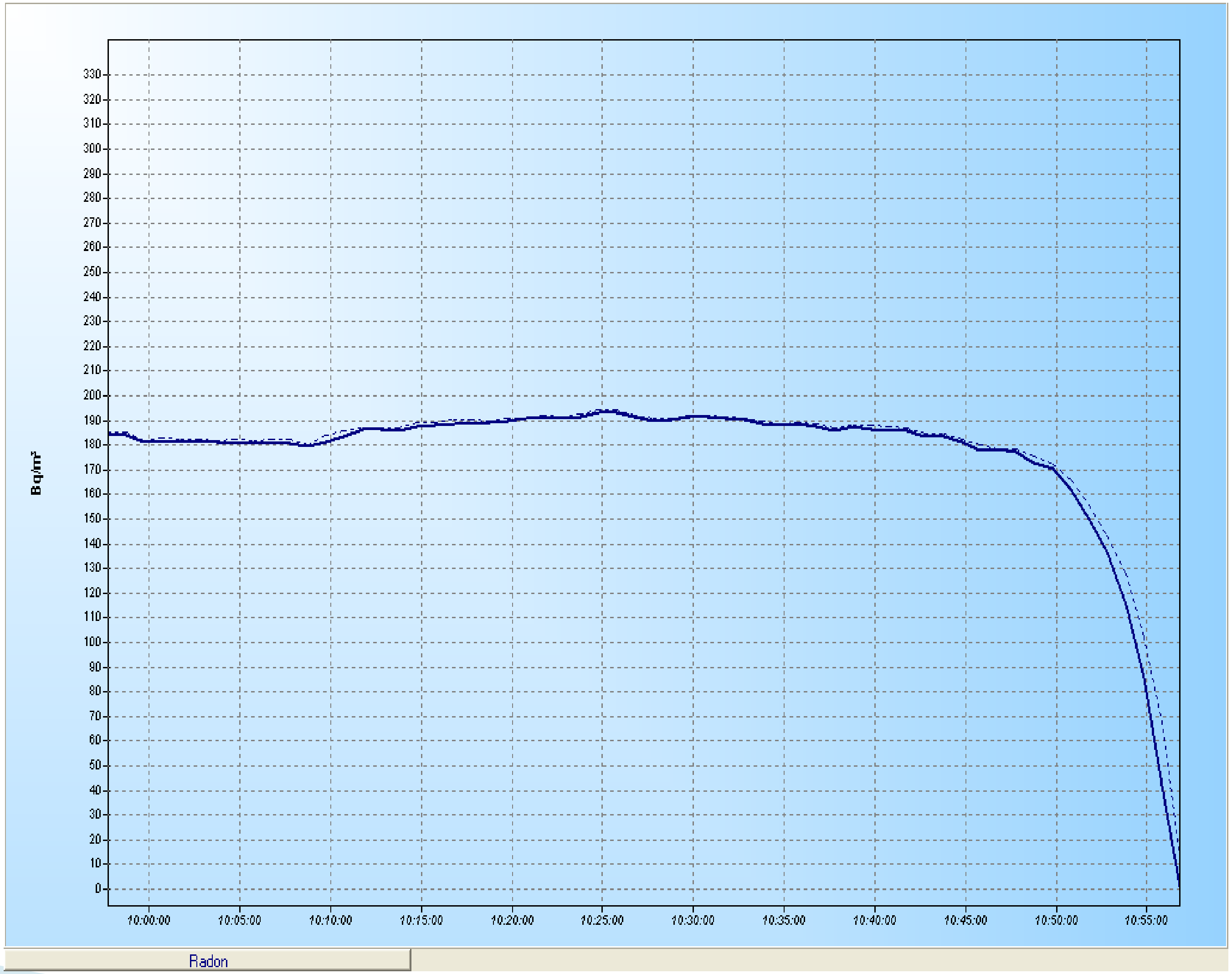
^{222}Rn Activity



Effective Dose rate

RESULTS

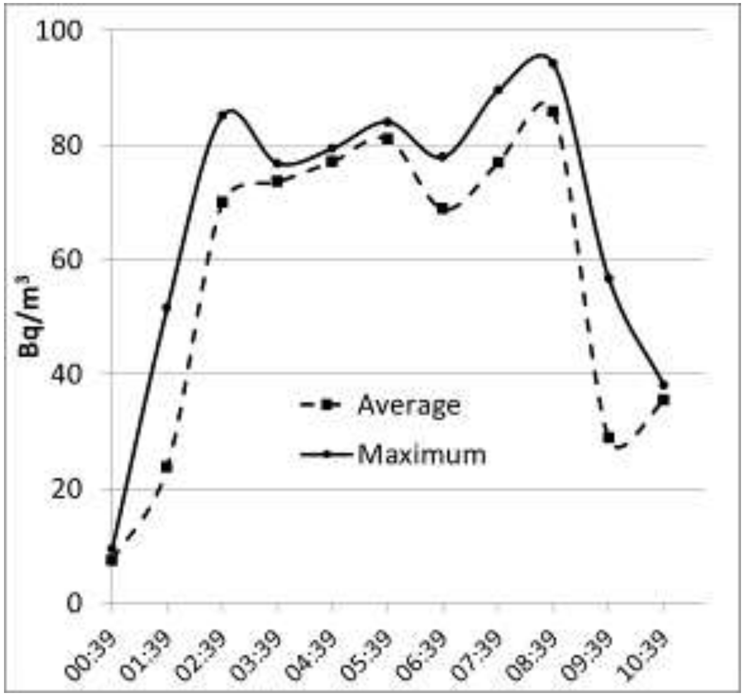
Laundry after ventilation:



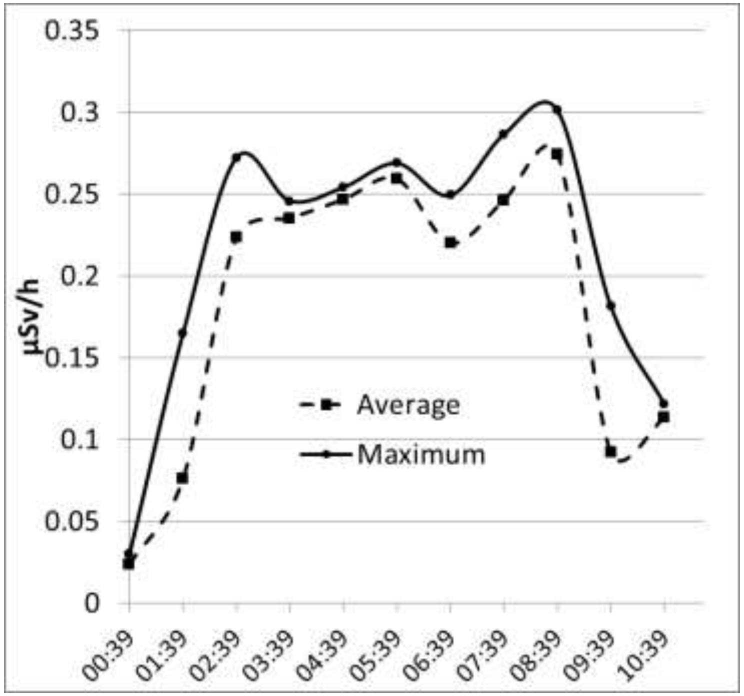
^{222}Rn Activity

RESULTS

Central Alarm Post:



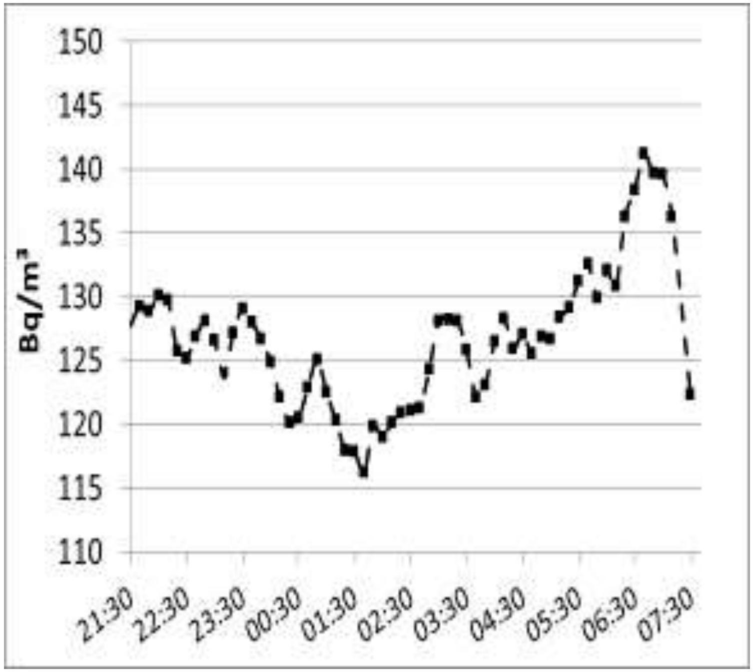
^{222}Rn Activity



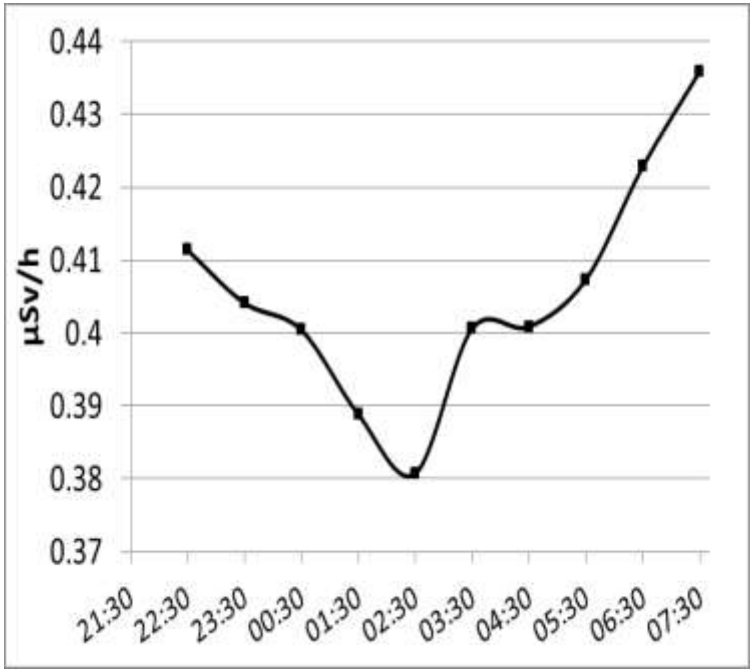
Effective Dose rate

RESULTS

Radiochemical Laboratory, room 065:



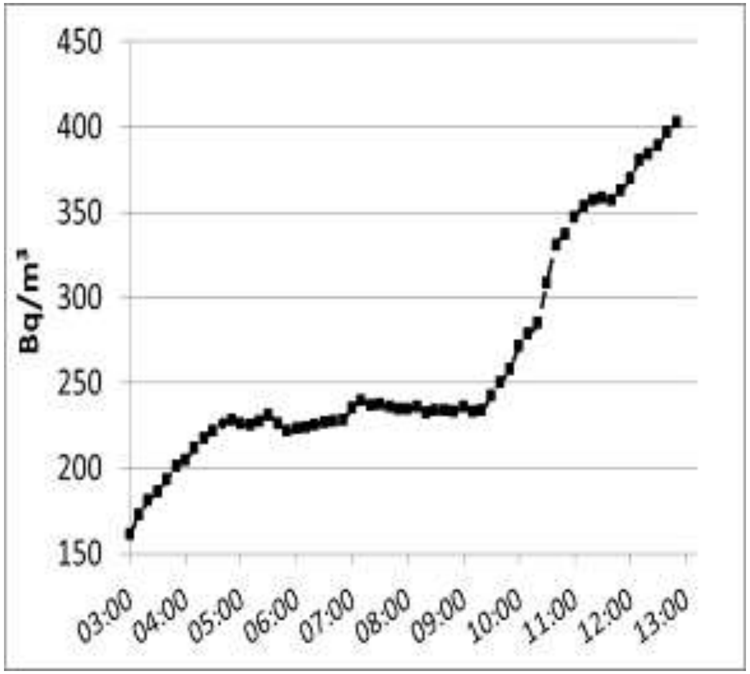
^{222}Rn Activity



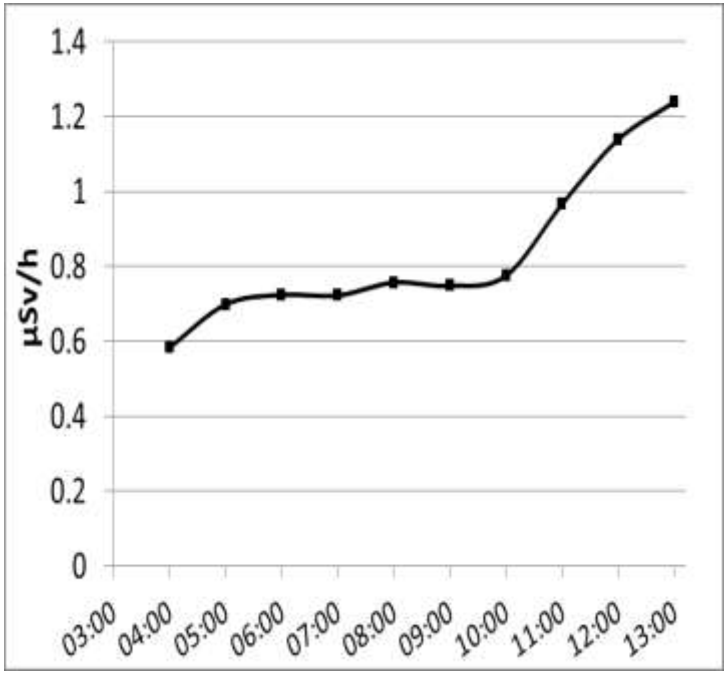
Effective Dose rate

RESULTS

Radiochemical Laboratory/no ventilation after 9:00 AM/, room 049:



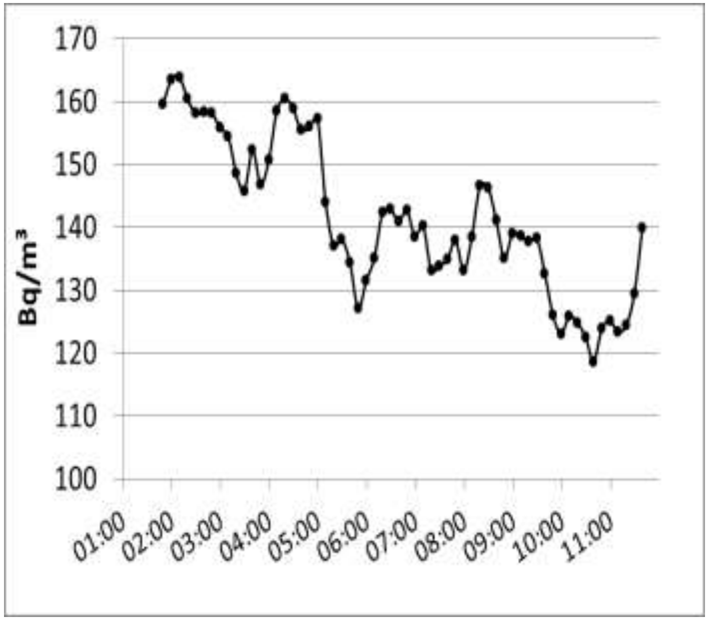
^{222}Rn Activity



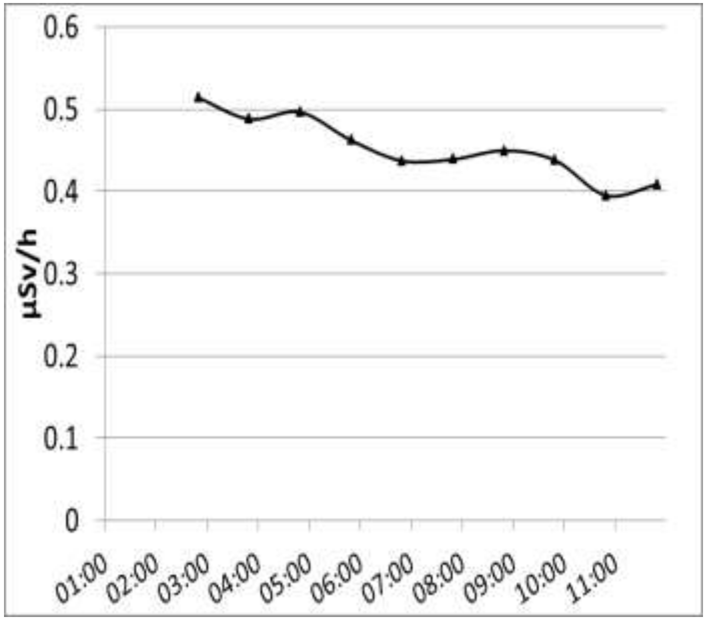
Effective Dose rate

RESULTS

Radiochemical Laboratory, room 043:



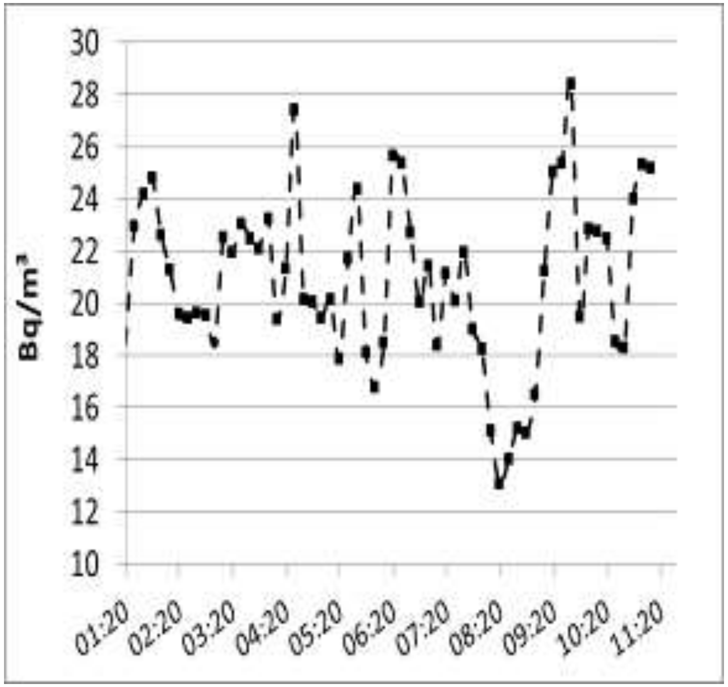
^{222}Rn Activity



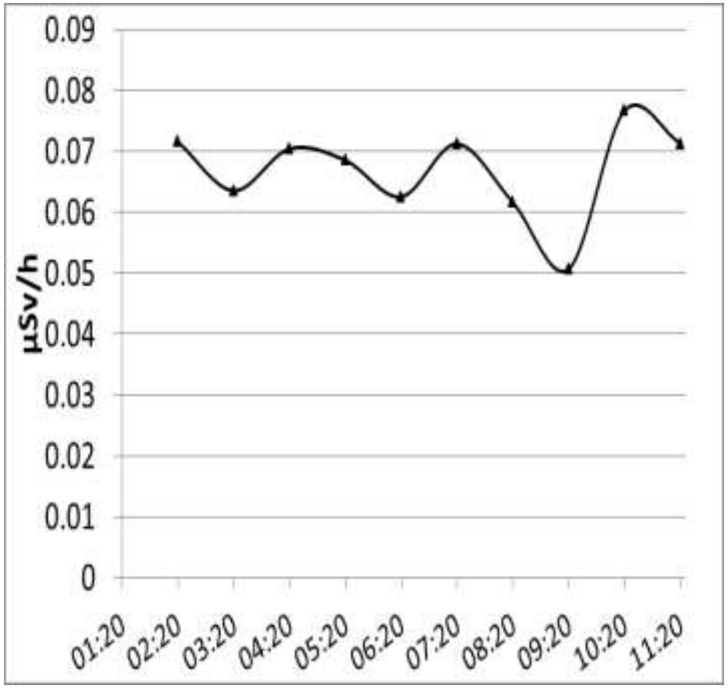
Effective Dose rate

RESULTS

Primary Circulation Loop:



^{222}Rn Activity



Effective Dose rate

CONCLUSION

The objectives of the monitoring program were to determine the distribution of radon levels in the buildings, to disclose areas where the risk of exposure to radon exceeds the established radiation protection safety threshold, to evaluate possible radon risk to the public and workers, and to evaluate the effectiveness of control measures on radon levels throughout individual rooms and hallways in the IRT-Sofia building. The proper work planning and implementation was considered central to achieving the goals.

The long-term radiation measurements and site monitoring at the NSEEC provide evidence that the radon management, as developed and adopted, meets all the requirements for radiation safety of personnel and prevents any radiation consequences to the public. The measures taken to keep the volumetric activity of air in working areas and corridors well below the reference level of 300 $Bq.m^{-3}$ for annual average activity concentration of ^{222}Rn in working places and 300 $Bq.m^{-3}$ in multipurpose public edifices have proved their efficiency.