EUROPEAN COMMISSION

DIRECTORATE-GENERAL ENVIRONMENT
Directorate C – Environment and Health
**ENV.C.4 – Radiation Protection**

# TECHNICAL REPORT

## VERIFICATIONS MADE UNDER THE TERMS OF ARTICLE 35 OF THE EURATOM TREATY

**ATHENS, GREECE**

**23 to 25 May 2000**

**Reference: GR-00/1**

# VERIFICATIONS MADE UNDER THE TERMS OF ARTICLE 35 OF THE EURATOM TREATY

FACILITIES: Installations for monitoring and controlling radioactive discharges and for surveillance of the environment in Greece during normal operations of the Democritos Research Reactor.

SITE: City of Athens, Greece.

DATE: 23 to 25 May 2000.

REFERENCE: GR-00/1.

INSPECTORS: C. Sauer (Head of team)

S. Van der Stricht

DATE OF REPORT: 15th of March 2001.

SIGNATURES:

C. Sauer S. Van der Stricht

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# TECHNICAL REPORT

## 1. ABBREVIATIONS AND DEFINITIONS

| | |
|---|---|
| GAEC | Greek Atomic Energy Commission |
| ERMD | Environmental Radioactivity Monitoring Department (GAEC) |
| ERLM | Environmental Radioactivity Monitoring Laboratory (GAEC) |
| NCSR | National Centre for Scientific Research |
| INT-RP | Institute of Nuclear Technology - Radiation Protection (NCSR) |
| DRR | Democritos Research Reactor (NCSR) |
| ERL | Environmental Radioactivity Laboratory (NCSR) |
| RPR | (Greek) Radiation Protection Regulations |
| EC | European Commission |
| LLD | Lower Limit of Detection |
| RRP | Institute of Radioisotopes and Radiodiagnostic Products (NCSR) |
| ERMP | Environmental Radioactivity Monitoring Programme |
| TRMN | (Greek) Telemetric Radioactivity Monitoring Network |
| GMS | Greek Meteorological Service |

## 2. INTRODUCTION

Article 35 of the Euratom Treaty requires that each Member State shall establish facilities necessary to carry out continuous monitoring of the levels of radioactivity in air, water and soil and to ensure compliance with the basic safety standards(1).

Article 35 also gives the European Commission the right of access to such facilities in order that it may review and verify their operation and efficiency.

The responsibility for undertaking these review and verification activities lies with the Radiation Protection Unit (Unit C.4) of the Directorate Environment and Health (Directorate C), part of the Directorate-General for Environment (DG ENV) of the European Commission (EC).

For the purpose of such a review a verification team from DG ENV C.4 visited the Greek Atomic Energy Commission (GAEC) and the National Centre for Scientific Research "Democritos" (NCSR), more in particular the latter's Institute of Nuclear Technology & Radiation Protection (INT-RP) that operates the Democritos Research Reactor (DRR). The verification activities took place between the 23rd and the 25th of May 2000. The verification team acted within the framework set by the 1990 Protocol agreed between the Greek authorities and the European Commission.

The scope of the review was to provide independent verification of the adequacy of:

- The monitoring facilities for gaseous and liquid discharges of radioactivity (effluents) from the Democritos Research Reactor into the environment.
- The analytical laboratories for effluent sample measurements.
- The monitoring facilities for levels of environmental radioactivity at the Democritos site perimeter, for all relevant exposure pathways.
- The analytical laboratories for environmental sample measurements.
- Within the time available, and to the extent possible, part of the environmental radioactivity monitoring programme for the marine, terrestrial and aquatic environment in Greece.

On request of the GAEC the verification mission also included a visit to the Department of Nuclear Medicine of the Alexandra hospital in Athens where the local implementation of radiation protection measures was demonstrated. The visit allowed the verification team to appreciate the implementation of the regulations applicable to the medical sector put in place by the Greek authorities.

The present report contains the results of the verification team's review of relevant aspects of the radiological surveillance of the environment around the Democritos Research Reactor site and the territory of Greece. The report is also based on information collected from various documents referred to under section 3.3 hereafter, and from discussions with representatives met during the visit as listed under section 3.4 below.

## 3. PREPARATION AND CONDUCT OF THE VERIFICATION

### 3.1 Preamble

The Commission's decision to require the conduct of a verification under the terms of Article 35 of the Euratom Treaty was forwarded to the Greek competent authorities in March 2000. Subsequently a preliminary meeting between an EC delegation and the GAEC took place in Athens on the 4th of May 2000 to prepare the verification visit.

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1 Directive 96/29/Euratom, which should be implemented in national legislation by 13 May 2000.

### 3.2 Programme of the visit

The Greek authorities proposed a verification programme covering all matters in which the Commission had expressed special interest. The verification activities were carried out in accordance with the proposed programme. A summary of the programme is provided in annex 1 to this report.

### 3.3 Documentation

In order to facilitate the work of the verification team, a package of information was supplied in advance by the GAEC. Additional documentation was provided during and after the verification visit. A list of this documentation is provided in annex 2 to this report.

### 3.4 Interlocutors

During the visit the verification team met the following representatives of the GAEC, staff of the INT-RP and the DRR, and staff of the Alexandra hospital:

The Greek Atomic Energy Commission

| | |
|---|---|
| Prof. L. Camarinopoulos | President |
| Dr K. Potiriadis | Head of Department of Environmental Radioactivity |
| Dr G. Drikos | Head of Department of Documentation |
| Dr A. Maltezos | Department of Environmental Radioactivity |
| Dr K. Kehagia | Department of Environmental Radioactivity |
| Dr A. Hadjiantoniou | Scientific Advisor |
| Dr V. Koukouliou | Department of Environmental Radioactivity |

The Institute of Nuclear Technology & Radiation Protection

| | |
|---|---|
| Dr G. Pantelias | Associate Director |
| Dr P. Kritidis | Director of Research – Environmental Radioactivity Laboratory |
| Dr H.G. Florou | Environmental Radioactivity Laboratory |
| K. Eleftheriadis | Environmental Radioactivity Laboratory |
| C. Chaloulou | Environmental Radioactivity Laboratory |
| C. Papastergiou | Democritos Research Reactor |
| A. Savidou | Democritos Research Reactor |
| A. Hanousis | Democritos Research Reactor |
| I. Tsourouyakis | Democritos Research Reactor |

The Alexandra Hospital

| | |
|---|---|
| Dr C. Servas | Head of the Nuclear Medicine Department |
| C. Palestidis | Health Physicist |

The verification team acknowledges the excellent co-operation it received from all the individuals mentioned above. The verification team also notes the quality and comprehensiveness of all presentations made during the visit and of the documentation provided.

## 4. THE GREEK ATOMIC ENERGY COMMISSION

### 4.1 Scope and history

The GAEC was established in 1954 as the authority responsible to plan, apply and supervise radiation protection measures. The GAEC was re-established in 1987 as an independent Civil Service, supervised by the General Secretariat of Research and Technology under the Ministry of Development, and became the competent authority responsible for matters concerning nuclear energy, nuclear technology and radiation protection from ionising radiation and from artificially produced non-ionising radiation.

Before 1987 specific departments of the then Nuclear Research Center "Democritos" acted as the implementation branch of the regulatory and licensing activities of the pre-1987 GAEC.

### 4.2 Statutory responsibilities

The statutory responsibilities of the GAEC to be mentioned in the context of this report are:

4.2.1 Protection of radiation workers, the general public and the environment against the dangers from ionising (and non-ionising) radiation through implementation of, between others:

-- Monitoring the environmental radioactivity by measuring air, water and soil samples.
-- Management of the personal dosimetry data of radiation workers in Greece.
-- Recurrent inspection of all installations handling radioactive materials in the medical, industrial, research, and educational sectors.
-- Licensing of non-medical applications of ionising radiation in the industrial, research and educational sectors.
-- Licensing of import, export, transport, storage, use and disposal of fissile and non-fissile radioactive materials.
-- Licensing of the import and use of radiation producing equipment.

4.2.2 Implementation, in compliance with EC Directives, of radiation protection regulations, safety standards and codes of practice for ionising radiation installations.

4.2.3 Education and training of radiation workers on radiation protection issues.

4.2.4 Implementation of emergency plans to cope with radiation accidents or increased radioactivity levels.

### 4.3 Legal framework and main regulations for radiation protection

Currently the legal basis for radiation protection in Greece consists of:

-- The Legislative Decree Nr 181/74: "Protection against the dangers arising from ionising radiation" (Gazette 3.47/A/20.11.1974).
-- The Ministerial Resolution Nr 14632 1416: "Radiation protection regulations – $2^{nd}$ revision" (Gazette 539/B/19.07.1991).
-- The Radiation protection regulations are currently under revision to comply with EC Directives 96/29/Euratom on Basic Safety Standards and 97/43/Euratom on Medical Exposure.

## 5. THE NATIONAL CENTER FOR SCIENTIFIC RESEARCH "DEMOCRITOS"

### 5.1 Introduction

The NCSR "Democritos" is a multidisciplinary research centre that started its operation in 1959 as an independent division of the public sector, under the then name of Nuclear Research Center "Democritos". Today the scientific activities of the NCSR are carried out in eight institutes. The relevant institute in the framework of this report is the Institute of Nuclear Technology and Radiation Protection (INT-RP).

### 5.2 The Institute of Nuclear Technology and Radiation Protection

The INT-RP was founded in 1987 following the gradual merging of the Divisions of Nuclear Technology and Radiation Protection and the Laboratory of Environmental Radioactivity Monitoring of the former Nuclear Research Center.

Today INT-RP comprises seven laboratories of which the Environmental Radioactivity Laboratory (ERL) and the Democritos Nuclear Research Reactor (DRR) are relevant in the context of this report.

## 6. DISCHARGES TO THE ENVIRONMENT AND THEIR MONITORING

Two entities on the NCSR site are at the origin of gaseous and liquid radioactive waste discharges into the environment: the Democritos Research Reactor (DRR) and, to a lesser extent, the Institute of Radioisotopes and Radio-diagnostic Products (RRP).

The DRR is a 5MW pool-type research facility, the only nuclear reactor in Greece. The DRR is mainly used for education purposes and to maintain nuclear engineering expertise, production of radioisotopes for pharmaceutical uses, sterilisation of bone implants, and neutron activation analysis.

The RRP is a research institution focusing on the development and evaluation of pharmaceutical compounds for scintigraphy, radiotherapy and immunodiagnosis.

The average yearly discharges and authorised yearly discharge limits for gaseous radioactive waste by the DRR and the RRP are:

| Atmospheric discharges via the stack | Yearly average discharge | Licensed, permitted discharge limits |
|---|---|---|
| Noble gases | 6 TBq | 40 TBq/a |
| Iodines | 15 MBq | 400 MBq/a |
| Particulates | 3 MBq | 40 MBq/a |

### 6.1 Atmospheric discharges

Both DRR and RRP are connected to a common stack of 33 metres height with a nominal stack flow rate of 5.0E+4 m³/h. The DRR contributes approximately 54% and the RRP 46% to the total volume rejected. Prior to release into the stack the air extracted from both DRR and RRP is passed through absolute filters. The stack is equipped with continuous monitoring devices for radioactive aerosols (particulates), iodine and noble gases. The former two monitors are located in a secured housing adjacent to the stack, the latter being positioned inside the chimney (technical details are given in annex 3 to this report).

The vacuum pump extracting air from the stack in order to feed the monitors and samplers is alarmed in case of failure. The vacuum pump is connected to a vacuum gauge and a flow-rate meter. Flow regulation is possible and can be set between 1 and 10 m³ per hour. Particulates and iodine are sampled in continuous mode. The iodine and particulate filters are exchanged every six weeks on average and measured at the analytical laboratory for effluent samples.

The three monitoring devices are connected to the DRR control room where real-time discharge values are displayed on a dedicated monitor. A similar and parallel connection with display is present in the DRR health physics room, acting as redundancy. The monitor displays, in near real time (integrated over one minute periods), the count rates registered by the gaseous effluent monitoring systems of the stack. The control room monitor simultaneously displays calculated emitted activity in Bq/m³ for iodine (per hour), calculated emitted activity in Bq/m³ for particulates (per minute and per hour), and calculated emitted activity in Bq (per minute) for noble gases. Date and time are also displayed, as are stack flow, sampling flow rate and functionality status of the vacuum pump feeding the samplers at the stack.

The displayed data are automatically registered on a dedicated PC and periodically archived on electronic supports. The on-line control systems are based on IBM PC/XT compatible hardware, type 8088 running under DOS 5 with 5 ¼ inch diskettes drivers and 12-inch monochrome monitors.

Alarm levels are pre-adjustable and are continuously displayed on the control monitor. For each detector two pre-alarm (warning) levels are set as well as the alarm level proper, expressed in counts per minute and as threshold levels of emitted activity. Stack and sampling flow rate variations beyond pre-set values will flash warnings. All types of alarms and warnings are of visual and audible nature.

### 6.2 Liquid discharges

There are three drainage systems for collecting and storing liquid wastes which are classified as 'hot' (typically 37 kBq/l of specific activity), 'low-level' (3.7 kBq/l) and 'inactive' (37 Bq/l).

The infrastructure for treatment of hot liquid waste has stopped operations since the Democritos site, in particular the RRP, does not generate such waste anymore. This dormant infrastructure (decay tanks, evaporator, cementation facility) can however be restarted whenever required to.

Eight steel tanks with a capacity of 10 $m^3$ each and located in a concrete bunker are available for the storage of low-level liquid wastes. Sampling of these decay tanks is performed twice. At first after filling of the tank has been completed, in order to assess the initial activity inventory. Secondly, after a variable period of time, in order to assess if the activity concentration complies with the regulatory limit of 37 Bq/l, above which the tank cannot be discharged. On average 2 to 4 tanks are discharged every year.

When decayed to safe limits, the contents of the decay tanks are transferred through inactive drains to two alternately used subterranean delay tanks (50 $m^3$ each). The delay tanks are sampled on a daily basis. One litre is pulled alternatively from each tank. From these samples a composite fortnightly sample is prepared and analysed for total beta activity. The delay tanks are discharged to the public sewage system.

Adjacent to the delay tanks and interconnected with them is a 600 $m^3$ buffer tank. The buffer tank has been built for emergency purposes to collect and temporarily store liquid effluents in case these would be contaminated above the 37 Bq/l activity level limit.

Inactive wastes are discharged directly into the inactive drains.

The daily volume discharged to the public sewage system amounts to approximately 30 $m^3$ per day.

## 7. VERIFICATION OF ENVIRONMENTAL DISCHARGES

### 7.1 Atmospheric discharges

#### 7.1.1 Verification activities

The verification team checked the adequacy and functionality of the monitoring and sampling provisions and control systems of the site's main stack that extracts air from DRR and RRP. However, the team decided not to inspect the noble gas detector because of its location inside the stack; gaining access to it would have required the shutdown of the extraction fan, such an intervention being deemed inappropriate.

The verification team visited the DRR control room where the operator demonstrated the functionality of the various control systems present. The team requested and received printouts of emission values as displayed on-line at the control room as well as printouts of archived historical data.

Finally the verification team visited the analytical laboratory measuring the discharge samples in order to assess its activities with respect to record management (see section 7.3).

7.1.2 Findings and recommendations

-- Monitoring and sampling provisions.

The operator demonstrated the functionality of the monitoring and sampling provisions. Upon enquiry the operator stated that all provisions had been taken to guarantee isokinetic sampling. In this context the team noted that the length of the sampling ducts is kept as short as feasible and that the sampling flow rate was set at 5.1 m³ per hour.

It was also noted that the particulate and iodine detectors are efficiently shielded from background noise and that the sample holders are motor driven (opening/closing) to allow easier periodical filter exchanges.

The operator informed the verification team about operational problems with the particulate monitoring system by stating that the electronics of the device are intermittently subject to temperature related malfunctions with loss of data acquisition.

> *The verification team recommends that the GAEC, in its role as regulator, investigate the temperature related operational shortcomings of the particulate monitoring system and implement remedial action within a reasonable delay.*

-- Control systems.

The operator demonstrated the functionality of the various control systems to satisfaction. However, the team observed that the hardware underlying the stack control systems is somewhat out of date

> *In view of the risk of a possible breakdown of the hardware underlying the stack control systems and the probable difficulties in obtaining spare parts should such a breakdown occur, the verification team recommends that the GAEC, in its role as regulator, pay particular attention to this issue and consider an upgrading of the systems.*

The team noted that the air extraction system feeding the stack is backed up and that guaranteed power supply is present (a generator powered by a diesel engine and equipped with a flywheel to stabilise voltage and overcome engine start-up delay).

## 7.2 Liquid discharges

7.2.1 Verification activities

The verification team visited the bunker containing the low-level decay tanks and the location of the delay tanks. Subsequently the analytical laboratory for effluent sample measurements was visited in order to assess its activities with respect to record management (see section 7.3).

7.2.2 Findings and recommendations

-- Decay tanks.

During the visit the verification team noted that the bunker was well maintained, that operational records were attached to every individual tank and that a sump is present to recuperate any leaks that may occur. Provisions have been made to allow the pumping of the contents of the sump into any tank, according to necessity.

The verification team notes that, for the purpose of activity release control, the sampling procedures of the decay tanks are satisfactory.

-- Delay tanks.

The team observed that the tanks discharge their contents via natural overflow and that an internal weir is present for sludge retention. The overflow is continuous in time and provisions for batch wise discharges are not foreseen.

*The team observes that delay tank sampling, as additional control, is subject to the following shortcomings. Because of the continuous discharge mode the analytical results of the samples taken are available after the liquids have already left site and escaped operational control. Furthermore, because of the non-continuous mode of sampling a transient contamination is likely to go unnoticed. The verification team therefore recommends the GAEC to consider fitting the liquid discharge delay tanks with a continuous monitoring device alarming the operator in case of activity concentration threshold transgression.*

### 7.3 The analytical laboratory for discharge sample measurements.

7.3.1 Verification activities

-- Atmospheric discharge samples.

The verification team requested the operator to submit sample and analysis records for audit.

-- Liquid discharge samples.

The verification team requested the operator to submit sample and analysis records for audit. For the decay tanks the records covering the period January 1996 up to December 1999 were made available; for the delay tanks records covering the period January 1997 up to verification date were provided.

7.3.2 Findings and recommendations

-- Atmospheric discharge samples.

The team noted that although stack monitoring results are recorded and archived, stack sampling records are not kept and that analytical results are not archived nor transmitted to the regulator. Furthermore the team noted that the regulator does not take independent samples for control measurements.

*Even though emissions are tending to zero for most radionuclides, it is considered essential to maintain a comprehensive control measurement programme with systematic recording of results. Therefore the verification team recommends the GAEC to consider the implementation of such a programme for the atmospheric discharges from the Democritos Research Reactor.*

-- Liquid discharge samples.

Decay tank records reflect tank identification, tank filling period, decay period and date of discharge, sequential sample number, measurement dates (initial sample and control sample) and measured activities expressed in µCi/10 $m^3$. Delay tank records reflect sampling period, sequential sample number, sample weight, measurement date and result expressed in µCi/ml.

The verification noted that analytical results are not transmitted to the regulator and that the regulator does not take independent samples for control measurements.

*The verification team recommends the GAEC to consider the implementation of a comprehensive control measurement programme for liquid radioactive discharges from the Democritos Research Reactor.*

### 7.4 Controls by the authorities

The verification team was not made aware of a regulatory control scheme exercised on the operator of the Democritos Research Reactor with respect to authorisation, control and assessment of radioactive effluent discharges to the environment. Also the team was not made aware of an independent control scheme exercised by the regulator to confirm the operator's statements with regard to releases of radioactivity into the environment. Although the NCSR and more in particular staff of the Democritos Research Reactor and the effluent laboratory can be presumed to work according to the highest standards, this can not dispense the GAEC from its regulatory responsibilities.

*The verification team recommends the GAEC to provide it with additional information on the role, powers and independent status of the regulatory authority with respect to the operator of the Democritos Research Reactor, more in particular where authorisation, prior authorisation of discharges, justification and inspection are concerned.*

*The Commission would appreciate being kept informed on any steps taken to modify the supervising role of the GAEC with respect to the operator of the Democritos Research Reactor.*

## 8. THE ENVIRONMENTAL RADIOACTIVITY MONITORING PROGRAMME

### 8.1 Introduction

The NCSR, through the Environmental Monitoring Laboratory (ERM) of the Institute for Nuclear Technology and Radiation Protection, implements the environmental radioactivity monitoring programme (ERMP) on behalf of the GAEC.

Currently the GAEC establishes its own laboratory infrastructure in order to perform the ERMP activities.

The GAEC is currently also commissioning and testing the future national Telemetric Radioactivity Monitoring Network (TRMN).

### 8.2 The Environmental Radioactivity Laboratory (NCSR – INT-RP)

#### 8.2.1 Description of the laboratory

ERL staff consists of 4 scientists (2 physicists, 1 biologist and 1 mathematician) and 5 technicians. The ERL comprises three basic units: the sample registry, the sample preparation and the radioactivity measurements units (an organisational flowchart is given under annex 4 to this report; annex 7 succinctly reviews the technical characteristics of the measurement instruments present).

#### 8.2.2 The environmental radioactivity monitoring programme

The ERMP is fully described in annexes 5 and 6 to this report. Annex 5 reviews sampling locations, frequencies of sampling and sampling procedures. Annex 6 deals with activities at the lab such as sample preparation and measurement methodology and characteristics.

#### 8.2.3 Quality assurance and control

The ERL frequently contributes to international research projects and routinely participates in intercomparison exercises organised by various international bodies.

## 8.3 The Environmental Radioactivity Monitoring Laboratory (GAEC)

The GAEC is currently developing and commissioning its own laboratory.

### 8.3.1 Description of the laboratory

The GAEC Environmental Radioactivity Monitoring Laboratory (ERML) is subdivided in three units, the ample preparation laboratory, the measurement laboratory and the chemical laboratory.

Currently two nuclear physicists, a medical physicist, a chemist, an electronic engineer and a technician staff the laboratory.

The ERML is equipped with two low-background gamma spectrometers, one alpha spectrometer, one alpha/beta gas-flow proportional counter and one X-ray fluorescence spectrometer. The gamma spectrometric systems are coaxial germanium detectors of 20% and 70% efficiency respectively, providing spectra in the energy range 50 keV to 3 MeV. The alpha spectrometer consists of a 600 $mm^2$ silicon-barrier detector under vacuum.

### 8.3.2 Quality assurance and control

The ERML is also developing the necessary quality assurance and control tools to obtain ISO 14001 accreditation.

## 8.4 The Telemetric Radioactivity Monitoring Network

### 8.4.1 Current status

The TRMN is currently under development and will consist of 25 gamma dose rate probes, of which 4 will be combined with as many river-water spectroscopy systems. At the time of the verification visit about half of the dose rate probes had been installed, two of which are part of the pilot project. The latter two gamma dose rate probes are operational and currently used in an evaluation and testing programme running in parallel with the installation phase of the network. The 4 river-water stations will be installed starting summer 2000. The network's installation programme is due to be completed by the end of 2000. The TRMN is expected to be fully commissioned and operational by end of June 2001.

### 8.4.2 General characteristics

All systems monitor in continuous mode, have backup power supplies and are linked to a local RSS-131 microprocessor. This microprocessor in turn is linked with data loggers and a modem. The data loggers ensure both data storage capacity and remote alarm raising, the latter function being controlled by pre-set alarm levels. The alarm levels can be remotely modified. The modem ensures communication with GAEC headquarters as well as interrogation capabilities from the headquarters control room.

The dose rate probe detectors are Reuters-Stokes ionisation chambers. Every detector is coupled to a rainwater gauge model YOUNG type 52203. The latter device is also connected to the local data logger and modem, allowing the registration and on-line consultation of pluviometric data.

The river-water stations contain, besides a dose rate probe, a NaI based spectrometer, its electronics (also linked to the local RSS-131 processor) and an automated sampling system. The sampling system has a capacity of 20 litres per month. The sampler operates in continuous mode by sampling 2 litres over 24 hours.

An anemometer and a wind direction indicator can be connected to the RSS-131 microprocessor via spare ports and thus be linked to the data recording and transmission system. The frame supporting the gamma probe is designed to allow quick mounting of a pole with those meteorological instruments, would conditions require so.

Additional information on locations and further technical details are given under annex 8 to this report.

# 9. VERIFICATION OF THE ENVIRONMENTAL RADIOACTIVITY MONITORING PROGRAMME

## 9.1 The Environmental Radioactivity Laboratory (NCSR – INT-RP)

### 9.1.1 Verification activities

The verification team visited the laboratory premises, audited record keeping, archiving and reporting where deemed useful.

### 9.1.2 Findings and recommendations

-- Record keeping.

Environmental radioactivity monitoring programme samples are registered and tagged with unique identifiers upon reception at the ERL. The registration information includes data on sample type, sampling period, date and time of sample arrival, sampling location, sample volume (or mass) etc.

After physical and/or chemical treatment in the sample preparation section the samples are directed to the radioactivity measurement section. Measurement results are added to the sample registration document. Additional calculations are performed in order to derive the final quantity (usually a specific activity value) and its error (the full error, including statistical and systematic (calibration) errors).

The final calculations are made through the use of spreadsheets. When results indicate that activity limits are exceeded, the analyst must submit these to the Head of Laboratory or his/her deputy for further evaluation. Depending on the type of sample and/or the magnitude of the excess value, the evaluating person may order additional measurement(s) and/or inform the GAEC if deemed a case of emergency.

*The verification team has no further remarks or recommendations with respect to record keeping.*

-- Archiving

The spreadsheet files are used for electronic storage of the results, in parallel to the archived physical records. In addition, the samples (or what was supplied for measurement after their pre-treatment) are stored at least for 5 years in order to ensure comparison and/or reference capabilities.

*The verification team has no further remarks or recommendations with respect to archiving.*

-- Reporting

The results of the routine environmental radioactivity control measurements are sent to the GAEC on a monthly basis, in the form of standard MS Excel spreadsheets, accompanied by a letter signed by the Head of ERL.

*The verification team has no further remarks or recommendations with respect to reporting*

## 9.2 The Environmental Radioactivity Monitoring Laboratory (GAEC)

### 9.2.1 Verification activities

The verification team visited the laboratory where it verified the status of infrastructure development as well as the status of the preparatory documents in view of ISO 14001 accreditation. The team received a copy of GAEC yearly environmental radioactivity reports covering the period 1994 – 1998.

Upon request by the GAEC, a short visit was paid to the National Calibration Laboratory and the Personnel Dosimetry Department. Also a presentation was given on the development status of an integrated database (named EEAEDB [2], on RDBMS Ingres) that contains relevant data from all fields of radiation protection in Greece.

### 9.2.2 Findings and recommendations

-- Environmental laboratory infrastructure.

The visit of the environmental laboratory demonstrated that the GAEC is developing state-of-the-art infrastructure for its future environmental monitoring activities.

-- Accreditation and quality control.

The verification team stresses the importance of achieving accreditation, as it will provide an internationally approved certificate of excellence. Accreditation may add to the public perception of the activities performed by the laboratory and the reports it issues and therefore be beneficial to the GAEC as a whole. The team also underlines the importance of regularly taking part in intercomparison exercises so as to maintain feedback on levels of performance.

-- Reporting of environmental data.

The verification team took the opportunity to audit the yearly environmental radioactivity reports covering the period 1994 – 1998, as issued by the GAEC. These review documents are based on the ERMP reports that are transmitted on a monthly basis by the ERL.

The team noted shortcomings in these reports such as transcription errors and, more in particular, incomplete data sets. Incompleteness of data sets is characterised by the intermittent or complete absence of data from various monitoring stations. Possible reasons for the blanks in the reports, such as for instance measurement results below detection limits or temporary failure of equipment, are not given. From the documents submitted for audit in transpires that the ERM may not have been fully implemented during these years.

> *The verification team recommends the GAEC to improve the quality and transparency of its official yearly reports on the results of the Greek ERMP.*

-- The visit of the National Calibration Laboratory[(3)] (NCL) and the Personnel Dosimetry Department allowed the verification team to collect background information on these infrastructures and activities. Because both topics are beyond the scope of the verification activities proper, the team can only comment that it was impressed with the efforts made by the GAEC to have state-of-the-art equipment installed.

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[2] Elliniki Epitropi Atomikis Energeias Data Base (Greek Atomic Energy Commission Data Base).

[3] The NCL is part of the Licensing and Inspection Division of the GAEC. Its main activity is to provide services to the medical sector by issuing certificates of dosimetric accuracy and reliability of various ionising equipment (including calibration and certification thereof) in the areas of radiotherapy, diagnostic radiology, nuclear medicine and radiation protection. Both activities are aiming at achieving harmonisation and uniformity of dosimetry in Greece. Additionally the NCL provides quality assurance audits and educational training on ionising radiation measurements.

-- The GAEC staff member in charge of the development of the EEAEDB database gave the verification team a comprehensive demonstration of the current status of the project. From the ensuing discussion the team understood that in the future the database would also contain all relevant data pertaining to the Greek ERMP.

*The verification team recommends that the Greek radiation protection database project receive particular attention from the GEAC management insofar that successful implementation of this project is likely to provide an excellent management tool, not in the least with respect to quality assurance and control.*

### 9.3 The N-Philadelphia environmental monitoring station

The station belongs to and is operated by the GMS. At least one GMS staff member is present on site at all times. The area upon which the meteorological instruments are installed is fenced-off[(4)]. The ERMP sampling devices (air sampler and deposition collector) are located within this secured zone, as is the TRMN gamma probe (see section 9.4 below).

#### 9.3.1 Verification activities

The verification team verified the adequacy and functionality of the various environmental monitoring devices situated on the premises of the monitoring station.

#### 9.3.2 Findings and recommendations

-- The air sampler.

The verification team noted that the device had been in a state of disrepair for some time. This observation is in contradiction with the requirements of the ERMP that air sampling be implemented at this location. The ERMP is therefore not fully implemented.

*The verification team recommends the GAEC to restore the air sampling capabilities at the N-Philadelphia station. The team also recommends the GAEC to consider replacing the existing air sampler with a device in line with modern standards.*

-- The deposition collector.

The verification team noted the rudimentary design of this sampling device, the collector being a simple dishwashing basin positioned on a table. The basin freely collects debris from the surrounding vegetation (absence of a filtering mesh) and is not protected from the sun (evaporation). Because of the basin being dry, the operational requirement of the ERMP that imposes a minimum 1cm layer of water in the basin at all times (to be controlled on a daily basis) could not be guaranteed.

*The verification team recommends the GAEC to ensure that deposition-sampling activities at the N-Philadelphia station are performed according to procedures. The team also recommends the GAEC to consider replacing the existing deposition collector with a device in line with modern standards.*

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4 It was noted that all sampling devices operated by third parties are located within areas controlled by those parties; and that the fences erected around these areas provide sufficient protection against any form of interference or vandalism by unauthorised individuals.

-- The location.

The verification team noted the abundant vegetation around and above the sampling devices, especially pine trees, literally covering the instruments. Also noted was the presence of a hearth (open fireplace, apparently frequently used) in the immediate vicinity of the samplers. In both cases a risk of interference may exist with regard to sample representativeness or functionality of a monitoring device (clogging of the filter of the air sampler).

*The verification team recommends the GAEC to ensure that various monitors and samplers belonging to the ERMP are located in areas free of possible sources of interference.*

## 9.4 The Telemetric Radioactivity Monitoring Network

### 9.4.1 Verification activities

The verification team visited one of these locations, the N-Philadelphia station. Subsequently, back at GAEC headquarters, the dedicated TRMN control room was presented by the operator and a demonstration of it capabilities given.

### 9.4.2 Findings and recommendations

-- The TRMN gamma probe.

*The verification team has no particular comments or recommendations with respect to the ambient gamma probe of the TRMN.*

-- The TRMN control room.

The verification team could check that the links to the N-Philadelphia station gamma probe and its rain gauge were functioning properly, this was demonstrated through online interrogation (real-time) of the gamma probe as well as on-line queries on historical data (database).

*The verification team, after having observed the current status of implementation of the TRMN and its high degree of technical performance, fully endorses the efforts made by the GAEC to develop and commission this state-of-the-art environmental monitoring tool.*

## 9.5 Controls by the authorities

### 9.5.1 With respect to the ERL as executor of the ERMP

The implementation of ERMP activities has historically always been the remit of the ERL. Since the GAEC became an independent regulatory body, the ERL continued this activity on behalf of the GAEC without the new situation having been formalised. The verification team was not made aware of regulatory requirements imposed on the ERL with respect to the execution of the ERMP. Also the team was not made aware of an independent control scheme exercised by the regulator to confirm the ERL statements with regard to the results of the ERMP. Although the ERL staff can be presumed to work according to the highest standards, the regulatory responsibilities as an independent regulator should be assured. Except for the voluntary transmission of ERMP results on a monthly basis, a well-defined relationship between regulator and 'contractor', with clearly defined responsibilities, was not apparent to the verification team.

*Taking into account the fact that the GAEC intends to take over the Greek ERMP from the NCSR Environmental Radioactivity Laboratory within the next two years, the verification team recommends that in the meantime a clear distribution of responsibilities between both parties be formalised.*

9.5.2 With respect to the future take-over of the ERMP by the GAEC

-- Delegation of responsibilities / outsourcing of activities.

The verification team noted that a considerable part of the in-field activities pertaining to the ERMP sampling operations are currently performed by third parties. The ERL staff only performs the dietary part of the sampling activities, the environmental sampling around the Democritos site and part of the sampling operations in the Athens locations. For all remaining sampling activities agreements have been reached to delegate this responsibility to the Greek Meteorological Service, the Thessaloniki University, the Greek Military Forces and the operators of lignite power plants (for details see annex 6, section 3, to this report). The verification team was not made aware of regulatory or contractual requirements imposed on third parties participating in the implementation of the ERMP.

> *The verification team recommends the GAEC, when the latter takes over full responsibility for carrying out the ERMP in Greece, to ensure that any part of the activities of the programme that it may intend to devolve to third parties be duly formalised.*

-- Continuity of knowledge.

Currently the ERL maintains an electronic archive containing historical data pertaining to the ERMP. Continuity of knowledge of these data and hence maintenance of follow-up and evaluation capabilities should be guaranteed.

> *The verification team recommends the GAEC to ensure that it inherits the ERL electronic archive containing the historical data pertaining to the ERMP, so as to preserve continuity of knowledge of environmental data and hence maintain follow-up and evaluation capabilities.*

## 10. CONCLUSIONS

All verifications that had been planned by the verification team were completed successfully. In this regard, the information supplied in advance of the visit, as well as the additional documentation received during and after the verification, was useful.

The information provided and the outcome of the verification activities led to the following observations:

Having regard to the radioactive effluents monitoring and control of the Democritos Research Reactor

1. The verification team recommends that the GAEC, in its role as regulator, investigate the operational shortcomings (intermittent temperature related on-line counter failures with loss of data acquisition) of the particulate monitoring system of the Democritos Research Reactor and implement remedial action within reasonable delay.

2. In view of the risk of a possible breakdown of the hardware underlying the stack control systems and the probable difficulties in obtaining spare parts should such a breakdown occur, the verification team recommends that the GAEC, in its role as regulator, pay particular attention to this issue and consider an upgrading of the systems.

3. The verification team notes that, for liquid activity release control purposes, the sampling procedures of the decay tanks are satisfactory. However, the team observes that delay tank sampling, as additional control, is subject to the following shortcomings. Because of the continuous discharge mode of the delay tanks, the analytical results of the samples taken are available after the liquids have already left site and escaped operational control. Furthermore, because of the non-continuous mode

of sampling a transient contamination is likely to go unnoticed. The verification team recommends the GAEC to consider fitting the liquid discharge delay tanks with a continuous monitoring device alarming the operator in case of an activity threshold transgression.

4. Even though atmospheric and liquid emissions are tending to zero for most radionuclides, it is considered essential to maintain a comprehensive control measurement programme with systematic recording and reporting of results. The verification team recommends the GAEC to consider the implementation of such a programme for the atmospheric and liquid radioactive discharges from the Democritos Research Reactor.

5 With respect to the monitoring and control of radioactive effluents, the verification team noted the absence of a well-defined statutory separation between the GAEC and the operator NCSR. The verification team recommends the GAEC to provide it with additional information on the role, powers and independent status of the regulatory authority with respect to the operator of the Democritos Research Reactor, more in particular where authorisation, prior authorisation of discharges, justification and inspection are concerned.

6. *The Commission would appreciate being kept informed about investigative results and envisaged remedial actions the GAEC may undertake in the framework of the above recommendations. Also the Commission would appreciate being kept informed on any steps taken by the GAEC to modify its supervising role.*

Having regard to the environmental radioactivity monitoring programme

7. The verification team recommends the GAEC to restore the air sampling capabilities at the N-Philadelphia station. The team also recommends the GAEC to consider replacing the existing air sampler with a device in line with modern standards.

8 The verification team recommends the GAEC to ensure that deposition-sampling activities at the N-Philadelphia station are performed according to procedures. The team also recommends the GAEC to consider replacing the existing deposition collector with a device in line with modern standards.

9. The verification team recommends the GAEC to improve the quality and transparency of its official yearly reports on the results of the environmental radioactivity monitoring programme.

10. The verification team notes that the GAEC intends to take over the Greek environmental radioactivity monitoring programme from the NCSR Environmental Radioactivity Laboratory within the next two years. Awaiting this take-over the verification team recommends the GAEC to formalise the distribution of responsibilities between both parties.

11. Furthermore the team invites the GAEC, in the context of the future take-over of the environmental radioactivity monitoring programme, to consider the following recommendations:

- To ensure that the GAEC inherit the ERL electronic archive containing the historical data pertaining to the current environmental radioactivity monitoring programme, so as to preserve continuity of knowledge of environmental data and hence maintain follow-up and evaluation capabilities.

- To replace, where appropriate the old air samplers and the old deposition collectors with devices in line with modern standards and to ensure that various monitors and samplers are located in areas free of possible sources of interference.

- To ensure that any part of the activities of the programme that it may intend to devolve to third parties be duly formalised.

12. The verification team recommends that the Greek radiation protection database project receive particular attention from GEAC management insofar that successful implementation of this project is likely to provide an excellent management tool, not in the least with respect to quality assurance and control capabilities it may provide.

13. The verification team, after having observed the current status of implementation of the Telemetric Radioactivity Monitoring Network and its high degree of technical sophistication, fully endorses the efforts made by the GAEC to develop and commission a state-of-the-art environmental monitoring tool.

14. *The Commission would appreciate being kept informed about investigative results and envisaged remedial actions the GAEC may undertake in the framework of the above recommendations. The Commission would also appreciate being kept informed on progress made with regards to the commissioning of the Telemetric Radioactivity Monitoring Network.*

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**ANNEX 1**

## DOCUMENTATION

| | | |
|---|---|---|
| 1. | The NCSR “Democritos” – 40 years of research and technology | (NCSR) |
| 2. | General description of the gaseous effluent monitoring systems | (NCSR-DRR) |
| 3. | General description of the control and management of liquid effluents | (NCSR-DRR) |
| 4. | Technical information on the routine environmental radioactivity control | (NCSR-ERL) |
| 5. | The Greek Atomic Energy Commission (various documents) | (GAEC) |
| 6. | The Environmental Radioactivity Monitoring Department | (GAEC) |
| 7. | The telemetric monitoring network in Greece | (GAEC) |
| 8. | Environmental radioactivity, monthly bulletins – 1994 | (GAEC) |
| 9. | Environmental radioactivity, monthly bulletins – 1995 | (GAEC) |
| 10. | Environmental radioactivity, monthly bulletins – 1996 | (GAEC) |
| 11. | Environmental radioactivity, monthly bulletins – 1997 | (GAEC) |
| 12. | Environmental radioactivity, monthly bulletins – 1998 | (GAEC) |
| 13. | A review of medical radiation protection in Greece | (GAEC) |
| 14. | Various source documents related to sampling activities and analytical results. | |

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**ANNEX 2**

## THE VERIFICATION PROGRAMME

| | | | |
|---|---|---|---|
| Tuesday 23 May | morning: | - | Introduction meeting at the GAEC premises. |
| | | - | Oral presentation of the relevant sites of the NCSR. |
| | | - | Visit of the Democritos Research Reactor and the atmospheric discharge monitoring and control systems. |
| | afternoon: | - | Visit of the liquid discharge facilities. |
| | | - | Wrap-up meeting. |
| Wednesday 24 May | morning: | - | Visit of the Alexandra hospital. |
| | | - | Visit of the N. Philadelphia environmental monitoring station. |
| | afternoon: | - | Wrap-up meeting. |
| Thursday 25 May | morning: | - | Visit of the INT-RP Environmental Radioactivity Laboratory. |
| | | - | Visit of the GAEC Environmental Radioactivity Monitoring Laboratory. |
| | afternoon: | - | Demonstration of the Telemetric Radioactivity Monitoring Network. |
| | | - | Wrap-up meeting. |
| | | - | Final meeting with the President of the GAEC. |

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**ANNEX 3**

## MONITORING DEVICES – atmospheric discharges

### 1. Particulates

- Filter: a fixed Millipore SM filter with a diameter of 50 mm.
- Detector: a beta scintillation detector (NE 107A), beryllium window of 1 mm thickness, Berthold Multiplier 9656, KSA EMI.
- Gap between filter and detector: 13.2 mm.
- Detection limit: 2.7 E+02 Bq/m³.

Note: the filters are collected periodically and then measured by gamma spectrometry.

### 2. Iodine

- Cartridge: a SAIC 2.27” diameter cartridge with 5% TEDA treated charcoal.
- Detector: a Bicron corporation model PA-14 with a 2”x2” NaI (TI).
- Gap between cartridge and detector: 5 mm.
- Detection limit: 0.13 Bq/m³.

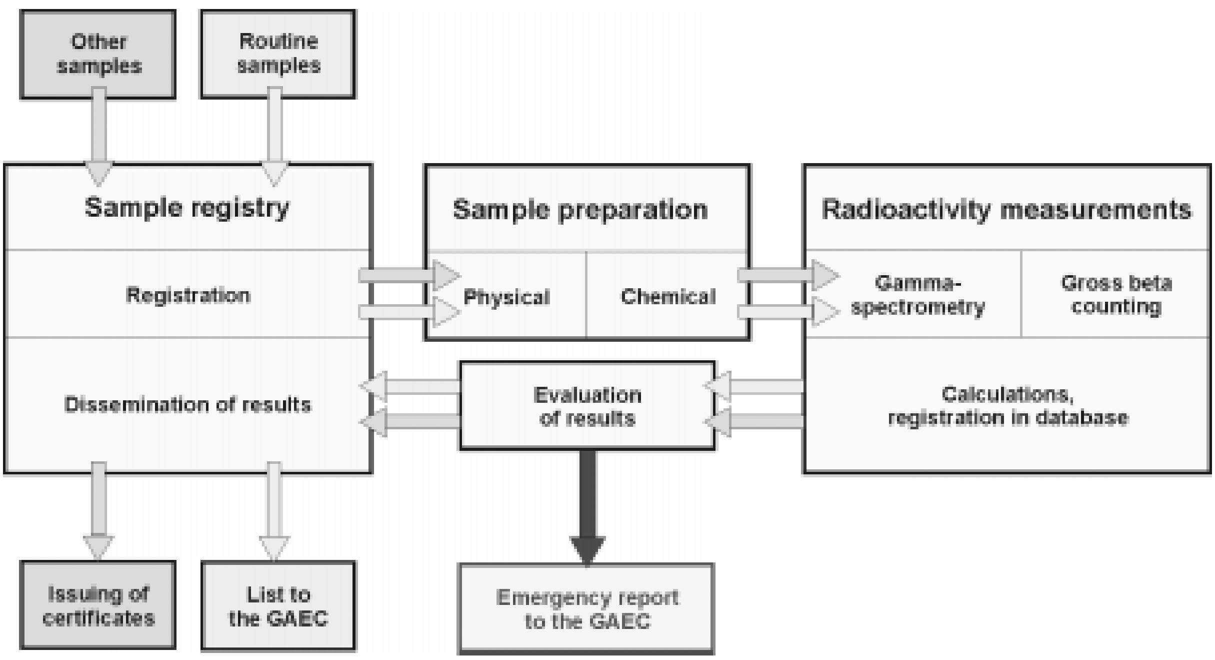
### 3. Noble gas

- Detector (inside the stack): a 5 inch plastic beta scintillation detector (NE-102A), aluminium window, photo-multiplier.
- Detection limit: 7.4 E+02 Bq/m³.

**********************

**ANNEX 4**

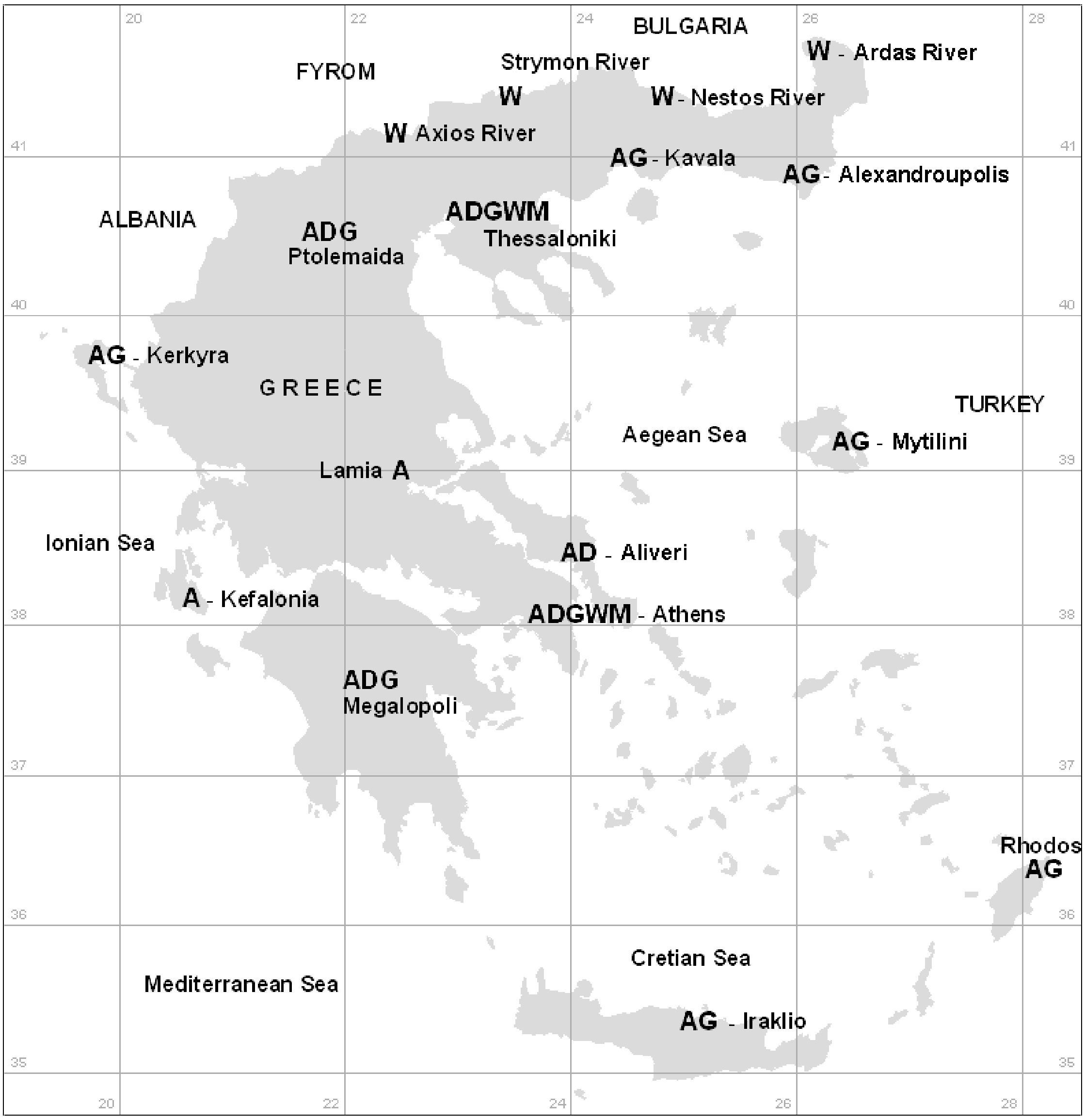
## ENVIRONMENTAL RADIOACTIVITY LABORATORY
## operational flowchart.



**ANNEX 5**

# ERL ENVIRONMENTAL SAMPLING – locations, frequencies and procedures

## 1. LOCATIONS OF THE SAMPLING AND MONITORING STATIONS OF THE ERL NETWORK




The code letter refer to the following type of sampling or measurement:

| | |
|---|---|
| A | air sampling |
| D | radioactive deposition sampling |
| G | gamma dose rate measurement |
| W | surface water and/or tap water sampling |
| M | milk and mixed diet sampling |

## 2. FREQUENCIES OF SAMPLING AND MEASUREMENTS

| Code | A | D | G | W | M |
|---|---|---|---|---|---|
| Explanation | air (sampling) | deposition (sampling) | γ dose rate (measurement) | water (sampling) | milk mixed diet |
| Frequency | weekly | monthly | 3 meas. per day | monthly | monthly |
| Nr of locations | 13 | 6 | 10 | 8 | 2 |
| Nr of samples per year | 676 | 72 | 3650 | 96 | 24 |
| Type | composite | integrated | grab | composite | grab |
| Details | 3 h/day | ------ | 9, 12 and 15 UTC | 30 l sample (one l per day) | Milk: major providers |

## 3. SAMPLING PROCEDURES

### 3.1 Air sampling (code A)

#### - Sampling devices

Two types of sampling devices are currently used: Zambelli 5000 air samplers with a sampling rate of 40 $m^3$ per day (10 devices), and piston oil pump samplers designed by the NCSR with a sampling rate of 50 $m^3$ per day (6 devices). Both systems use Watman 41 filter paper with an active area of 10.8 $cm^2$. The Demokritos environmental radioactivity monitoring station has recently been equipped with a high-volume sampler type Andersen ESM model GS2312-105BL (flow rate up to 2000 $m^3$ per day on a filter area of 500 $cm^2$). The sampling devices are supplied with air volume meters, the readings of which are reported with each sample.

#### - Sampling geometry

The air sampling devices are hosted in metal housings of approximately 1x1 metres in size, protecting them from rainfall while allowing air to enter freely through side grids. The sampling height is approximately 1.2 metres.

#### - Locations, operators

Most air samplers are located within the perimeter of meteorological monitoring stations belonging to the Greek Meteorological Service and are operated by its staff. Three samplers are located in lignite power plants and operated by the plant's staff. Staff from ERL operates the Demokritos station.

### 3.2 Radioactive deposition sampling (code D)

#### - Sampling devices

The sampling device is a cylindrical plastic vessel of 0.075 $m^2$ area, at one metre above ground level, directly exposed to atmospheric fallout. At the Demokritos station a 1 $m^2$ stainless steel sampling vessel is used too.

#### - Locations, operators

Three samplers are located in lignite power plants and operated by their staff. ERL staff operates the Athens stations. Thessaloniki University staff operates the Thessaloniki station.

### 3.3 Gamma-ray intensity measurements (code G)

**- Measuring devices**

The measurement devices are NaI-based Xetex 501A probes, protected from rainfall and exposure to sunlight by adapted housings placed at approximately 1 meter above ground level. Readings are recorded several times a day. These readings are transferred to the Greek National Meteorological Service on a daily basis.

**- Measurement parameters**

The detectors have a volume of 100 $cm^3$ and sensitivity of the order of 700 cpm per μR/h for the 661 keV $^{137}$Cs gamma ray. Reported count rates are integrated over one minute.

**- Locations, operators**

Most probes are located within the perimeter of meteorological monitoring stations belonging to the Greek Meteorological Service and are operated by its staff. Two probes are located in lignite power plants and operated by the plant's staff. ERL staff operates the Democritos station. Thessaloniki University staff operates the Thessaloniki station.

### 3.4 Water sampling (code W)

**- Sampling procedure**

The monthly river water samples are composed by daily samples of 1 litre taken from the river surface. The monthly composite samples are sent to ERL for further analysis. Composite tap water samples are taken on a weekly basis. The main water reservoirs in Athens are sampled on a monthly basis. The sample volume in the last two cases is 3 litres.

**- Locations, operators**

Four of the stations are situated within military bases on the borders with Bulgaria and the former Yugoslav republic of Macedonia (FYROM) and operated by Greek Army staff. ERL staff operates the Democritos and Athens stations. Thessaloniki University staff operates the Thessaloniki station.

### 3.5 Milk and mixed diet sampling (code M)

**- Sampling procedure**

For milk a monthly composite sample is made from samples taken at the 4 major milk producers of Greece. The composite samples take into account the market shares of the producers.
For mixed diet 14 basic components (meats, milk, vegetables, cereals etc.) are used and mixed according to their proportional contribution to the average Greek diet to obtain an overall sample of approximately 1.3 kg.

**- Locations, operators**

ERL staff performs the sampling.

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**ANNEX 6**

# ERL ENVIRONMENTAL SAMPLES – preparation and measurement

## 1. SAMPLE PREPARATION

### 1.1 Air samples (code A)

No preparatory treatment is applied to air samples.

### 1.2 Radioactive deposition samples (code D)

The volume of collected samples varies typically within a range of 1 to 3 litres. The samples are slowly evaporated in two stages at a temperature of 60 $^{o}$C. The solid residue is weighed. A total beta measurement is performed on an amount of residue not exceeding 500 mg. A gamma spectrometry to determine $^{137}$Cs deposition is performed on the whole of the residue obtained.

In case of emergency and/or when quick results are required, the deposition samples can be measured directly (without prior evaporation) in one-litre Marinelly beakers.

### 1.3 Gamma-ray intensity measurements (code G)

Not applicable.

### 1.4 Water samples (code W)

Water samples are treated exactly as radioactive deposition samples (see section 4.2 above).

In case of emergency and/or when quick results are required, the water samples can be measured directly (without prior evaporation) in one-litre Marinelly beakers.

### 1.5 Milk and mixed diet samples (code M)

For milk a one-litre sub-sample is taken from the monthly composite sample and ashed. The diet samples are mixed in accordance with their proportional contribution to the average Greek diet and subsequently homogenised and ashed. No further treatment is applied for the samples directed for determination of $^{137}$Cs by high-resolution gamma-spectrometry. In the case of determination of $^{90}$Sr, radiochemical analysis is applied to the ashed samples. The methodology used is described in the EML Procedures Manual [5].

In case of emergency and/or when quick results are required, the milk and mixed diet samples can be measured directly after homogenisation, in one of the two cylindrical geometries adopted by ERL (40 ml and 500 ml) or in one-litre Marinelly beakers.

[5] EML Procedures Manual, US DOE, 1983 (revised 1992), HASL 300, Editors N. A. Chiego et al, EML, New York, NY).

## 2. MEASUREMENT OF THE SAMPLES

### 2.1 <u>Air samples</u> (code A)

Air samples (filters) are routinely measured during 60 minutes in a low-beta counting device to determine gross beta activity. The lower limit of detection (2 sigma) equals 0.24 mBq/m$^3$ for 50 m$^3$ air samples.

The filters are also analysed for specific radionuclides using high-resolution gamma spectrometry with a measurement time of 20 hours.

Values of the lower limits of detection (2 sigma) are:

| Nuclide | $^{95}$Zr | $^{103}$Ru | $^{131}$I | $^{132}$I | $^{134}$Cs | $^{137}$Cs | $^{144}$Ce |
|---|---|---|---|---|---|---|---|
| LLD (15 min), in mBq/m$^3$ | 2.2 | 2.0 | 1.8 | 1.3 | 1.8 | 3.0 | 12 |
| LLD (20 h), in mBq/m$^3$ | 0.24 | 0.22 | 0.20 | 0.14 | 0.20 | 0.33 | 1.3 |

Notes:
1. The upper values refer to quick 15 minutes measurements typical for emergency conditions, the lower for routine measurements of 20 hours duration.
2. The values refer to air samples of 50 m$^3$.

### 2.2 <u>Radioactive deposition samples</u> (code B)

Routinely the residue obtained is transferred (maximally 500 mg) to a stainless steel pot of 2.3 cm diameter and measured during 60 minutes in a low-beta counting device to determine the gross beta activity per m². A self-absorption correction is applied according to the specific mass of the residue sample (mg/cm$^2$). The LLD (2 sigma) equals 0.2 Bq/m$^2$.

The residues are also analysed for $^{137}$Cs and other specific radionuclides by means of high-resolution gamma spectrometry using the whole amount of residue obtained. The geometry used is a 2.3 cm diameter stainless steel pot where the height of the sample does not exceed 3 mm. The duration of each measurement is 20 hours with a LLD value (2 sigma) of 0.16 Bq/m$^2$ for the standard sampling vessels (0.075 m$^2$) and 0.012 Bq/m$^2$ for the 1 m$^2$ sampling vessel of the Demokritos station.

Values of the LLDs (2 sigma) are:

| Nuclide | $^{95}$Zr | $^{103}$Ru | $^{131}$I | $^{132}$I | $^{134}$Cs | $^{137}$Cs | $^{144}$Ce |
|---|---|---|---|---|---|---|---|
| LLD (15 min), in Bq/m$^2$ | 1.5 | 1.3 | 1.2 | 0.9 | 1.2 | 2 | 8 |
| LLD (20 h), in Bq/m$^2$ | 0.17 | 0.14 | 0.13 | 0.10 | 0.13 | 0.22 | 0.88 |

Notes:
1. The upper values refer to quick 15 minutes measurements typical for emergency conditions, the lower for routine measurement of 20 hours duration.
2. The values refer to measurement of sample residues from the 0.075 m² collectors.

If quick and rough estimations are necessary, the deposition samples can be measured directly (prior to evaporation) by use of one-litre Marinelli beakers. Under these conditions the LLD values above are increased, depending on the volume of the deposition sample, by a factor ranging from 2 to 4.

### 2.3 <u>Gamma-ray intensity measurements</u> (code G)

The count rate data are converted to µR/h, using calibration coefficients derived from a 'Demokritos' calibration device using a $^{226}$Ra standard source. This is done for convenience and the results are used for comparative (indication) purposes only.
The observed exposure rate averages vary within a range of 4 to 12 µR/h. Temporary increases are observed after rainfalls. The estimated LLD value in the case of an accidental pollution is of the order of 2 to 3 µR/h, depending on the normal exposure rate of the station.

### 2.4 Water samples (code W)

Routinely the residue obtained is transferred (maximally 500 mg) to a stainless steel pot of 2.3 cm diameter and measured during 60 minutes in a low-beta counting device to determine the gross beta activity per m³. A self-absorption correction is applied according to the specific mass of the residue sample (mg/cm²). The LLD (2 sigma) equals 3.6 Bq/m³ (3.6 mBq/l).

The residues are also analysed for specific radionuclides using high-resolution gamma spectrometry with a measurement time of 20 hours.

Values of the LLDs (2 sigma) are:

| Nuclide | $^{95}$Zr | $^{103}$Ru | $^{131}$I | $^{132}$I | $^{134}$Cs | $^{137}$Cs | $^{144}$Ce |
|---|---|---|---|---|---|---|---|
| LLD (15 min), in mBq/l | 37 | 33 | 30 | 22 | 30 | 50 | 200 |
| LLD (20 h), in mBq/l | 4.1 | 3.7 | 3.3 | 2.4 | 3.3 | 5.5 | 22 |

Notes:
1. The upper values refer to quick 15 minutes measurements typical for emergency conditions, the lower for routine measurement of 20 hours duration.
2. The values refer to measurement of sample residues from a 3-litre sample.

If quick and rough estimations are necessary, the water samples can be measured directly (prior to evaporation) by use of one-litre Marinelli beakers. Under these conditions the LLD values above are increased by a factor of 3.5.

### 2.5 Milk and mixed diet samples (code M)

#### 2.5.1 Determination of $^{137}$Cs

The ashed milk and mixed diet samples are measured with high-resolution gamma-spectrometry in a 40 ml cylindrical geometry (70 mm diameter and 15 mm height) for 20 hours.

In the case of emergency and/or when quick results are required, the milk and food samples can be measured directly, after their homogenisation, in one of two cylindrical geometries adopted by ERL (40 ml and 500 ml) or in one-litre Marinelly beakers.

Values of the LLDs (2 sigma) are:

| Nuclide | $^{95}$Zr | $^{103}$Ru | $^{131}$I | $^{132}$I | $^{134}$Cs | $^{137}$Cs | $^{144}$Ce |
|---|---|---|---|---|---|---|---|
| LLD (15 min), in Bq/kg | 2.2 | 2.0 | 1.8 | 1.3 | 1.8 | 2.9 | 12 |
| LLD (20 h), in Bq/kg | 0.24 | 0.22 | 0.20 | 0.14 | 0.20 | 0.32 | 1.3 |

Notes:
1. The upper values refer to quick 15 minutes measurements typical for emergency conditions, the lower for routine measurement of 20 hours duration.
2. The values refer to direct measurement of homogenised milk or food samples of 40 ml volume. If ashing of the samples is applied, the LLD values are lower, typically by a factor of 2 to 3, depending on the water content of the sample.

#### 2.5.2 Determination of $^{90}$Sr

For the determination of $^{90}$Sr, radiochemical analysis is applied to the ashed samples in the following steps:

a. Chemical separation of Sr from Ca, other fission products and natural radionuclides (treatment by fuming $HNO_3$, $BaCrO_4$ and $Y(OH)_3$.
b. Delay for achieving radioactive equilibrium between $^{90}$Sr and $^{90}$Y.
c. Chemical separation of Y in the form of hydroxide, which is converted to oxalate for subsequent gross beta measurement.

The chemical yield is determined gravimetrically by adding stable Y as carrier.

The LLD (2 sigma) of the method equals 0.05 Bq/kg. The methodology used is described in the EML Procedures Manual.

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**Addendum to annex 6**

Other methods for radioactivity determination, applied on a non-routine basis.

- Determination of $^{137}Cs$ in seawater.
- Determination of mixed fission products in seawater.
- Determination of radon concentrations in air.
- Determination of specific activities and 'equilibrium equivalent concentration' of short-lived radon daughters in air.

**********************

**ANNEX 7**

# ERL MEASUREMENT SYSTEMS – technical data

## 1. HIGH-RESOLUTION GAMMA SPECTROMETRY SYSTEMS

| | |
|---|---|
| No of systems: | 3 stationary and 1 for in situ measurements. |
| Detector types: | HpGe |
| Relative efficiencies | 2 of 20%, 1 of 40% and 1 of 50%<br>(at 1.33 MeV, with respect to 3 x 3 inch NaI crystal). |
| Energy resolution: | < 2 keV at 1.33 MeV. |
| Background count rate: | About 1 cps within the 30 – 2000 keV region |
| Multi-channel analysers: | 4, computer-based, 4000-channel.<br>The field system is able of remote transfer of data. |
| Analysis software | Full analysis software in all cases.<br>Specialised natural and artificial radionuclide libraries. |
| Measuring geometries: | 1. Filters: D=3.7 cm, H=0.2 mm<br>2. Deposition and water residues: D=2.3 cm, H=1–2 mm<br>3. Food samples, ashed samples: D=70 mm, H=15 mm<br>4. Food samples: D=80 mm, H=100 mm<br>5. Food and water samples: Marinelli of 1 l volume |
| Calibration standards: | Point source standards,<br>Multi-nuclide standard solutions,<br>Multi-nuclide standards of different density (geometry 3). |
| Methodology: | As per “A Handbook of Radioactivity Measurements Procedures”,<br>NCRP Report Nr 58, Washington, USA (1978). |
| Quality assurance: | - Regular participation in international intercalibration exercises.<br>- Check measurements once per week for each system.<br>- Background measurements on a monthly basis. |

## 2. ALPHA SPECTROMETRY SYSTEMS

| | |
|---|---|
| No of systems: | 2 |
| Detector type: | Silicon surface-barrier detector. |
| Detector area: | 600 $mm^2$. |
| Energy resolution: | < 25 keV at 6 MeV |
| Background count rate: | About 1 E-04 cps within the 1 – 9 MeV region. |
| Multi-channel analysers: | 2, computer-based, 2000-channel. |
| Analysis software: | Specialised analysis software.<br>Specialised natural and artificial radionuclide libraries (table of istopes, C.M. Lederer et al). |
| Calibration standards: | Triple transuranium standard source. |
| Methodology: | As per “A Handbook of Radioactivity Measurements Procedures”,<br>NCRP Report Nr 58, Washington, USA (1978). |
| Quality assurance: | Calibration and background measurements are performed weekly. |

## 3. LOW-BETA COUNTING SYSTEM

| | |
|---|---|
| No of systems: | 1 |
| Detector type: | Gas flow proportional counter. |
| Counting efficiency: | Approximately 35% for both measuring geometries. |
| Background count rate: | < 1 cpm.<br>Physical shielding and anti-coincidence reduction of background. |
| Sample / data control: | Computer-based automatic operation, sample changing and recording / printing of data. |
| Data treatment and storage of results: | By specialised software developed in ERL. |
| Measuring geometries: | 1. Filters: D=3.7 cm, H=0.2 mm<br>2. Deposition and water residues: D=2.3 cm, H=1–2 mm |
| Calibration standards: | $^{40}K$ and $^{137}Cs$ standards. |
| Counting time: | Typically 60 min per sample. |
| LLD (2 sigma): | 12 mBq for 60 min counting time. |
| Quality assurance: | Calibration and background measurements on a daily basis. |

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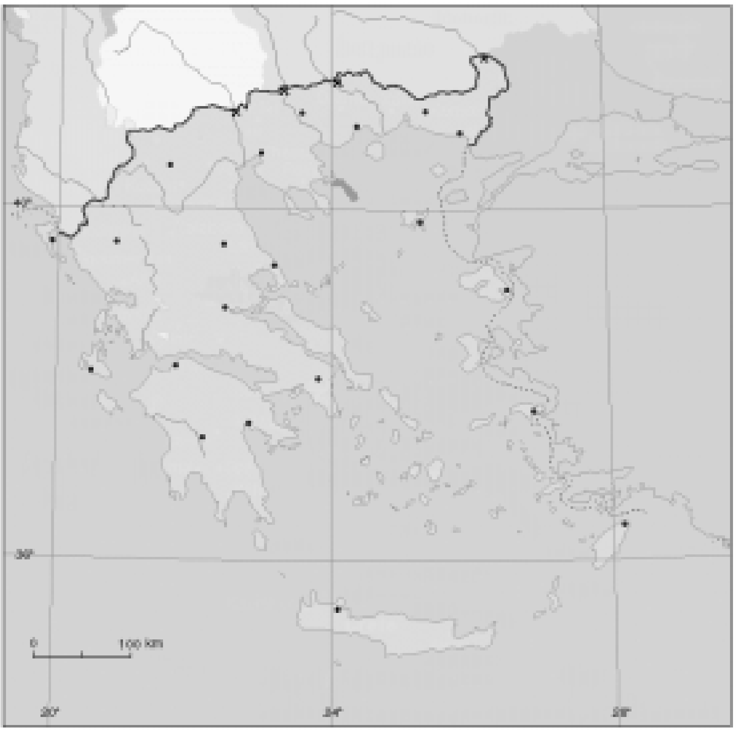
**ANNEX 8**

# TELEMETRIC RADIOACTIVITY MONITORING NETWORK

## 1. Locations



The stand-alone gamma probes are located at:

| | |
|---|---|
| Alexandroupolis | |
| Athens | Volos |
| Corfu | Ionnina |
| Kavala | Kefalinia |
| Komotini | Larissa |
| Lamia | Lesbos |
| Limnos | Megalopolis |
| Nafplion | Patra |
| Ptolemais | Rhodos |
| Salonica | Samos |
| Serres | Souda |

Note: crosses mark the location of river-water stations,
from left to right: rivers Axios, Strimonas, Nestos and Ebros.

## 2. The dose rate meters.

| | |
|---|---|
| Type | spherical high-pressure ion chamber |
| Gas / pressure | Argon at 25 atmosphere |
| Sensitivity | 50 keV to > 10 MeV |
| Range | 10E-08 to 0.1 Gy/h |
| Accuracy | ± 5% for the range between 10E-08 to 0.01 Gy/h, ± 7% above 0.01 Gy/h |
| Directional response | ± 2% over 4ð angle |

## 3. The river-water gamma spectrometers

| | |
|---|---|
| Detector | NaI (3 by 3 inch) |
| Geometry | Marinelli (stainless steel) |
| Shielding | lead with a thickness of 50 mm |
| Sensitivity | 10 keV to 1.25 MeV |
| Range | 100 Bq/m³ to 10E-06 Bq/m³ |
| LLD | < 500 Bq/m³ for Cs-137 and < 370 Bq/m³ for Co-60 (1800 seconds) |
| Pumping height | 10 m |
| Sampler | automated, 10 vessels of 2000 cm³ each (or one month sampling capacity) |
| Sampling rate | 2000 ml/day |