EUROPEAN COMMISSION
DIRECTORATE-GENERAL FOR ENERGY AND TRANSPORT

DIRECTORATE H - Nuclear Energy
**Radiation Protection**

# TECHNICAL REPORT

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

## GREECE

## 12 to 16 September 2005

**Reference: GR-05/5**

**VERIFICATIONS UNDER THE TERMS OF ARTICLE 35**
**OF THE EURATOM TREATY**

| | |
|---|---|
| FACILITIES: | Installations for monitoring and controlling radioactive discharges of the "Demokritos"Research Reactor into the environment and for surveillance of the environmental radioactivity on the territory of Greece. |
| SITE: | NCSR site in Athens; and the Greek nation-wide radiological environmental monitoring network. |
| DATE: | 12 to 16 September 2005 |
| REFERENCE: | GR-05/5 |
| INSPECTORS: | Mr C. Gitzinger (Head of team)<br>Mr S. Van der Stricht<br>Ms A. Godeanu-Metz |
| DATE OF REPORT: | 15/03/2006 (draft - in English), final report agreed upon with the Greek authorities on 12/04/2006. |

SIGNATURES:

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*[signed]*

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**TECHNICAL REPORT**

# 1 ABBREVIATIONS

| | |
|---|---|
| EC | European Commission |
| ERL | Environmental Radioactivity Laboratory (within INT-RP) |
| ERMD | Environmental Radioactivity Monitoring Department (within GAEC) |
| ERMP | Environmental Radioactivity Monitoring Programme |
| ESYD | Hellenic Acreditation Council |
| NRPR | National Radiation Protection Regulations |
| GAEC | Greek Atomic Energy Commission |
| GMS | Greek Meteorological Service |
| GRR-1 | Research Reactor (within INT-RP) |
| INT-RP | Institute of Nuclear Technology and Radiation Protection (within NCSR "D") |
| IRR | Institute of Radioisotopes and Radiopharmaceuticals (within NCSR "D") |
| LLD | Lower Limit of Detection |
| NCSR "D" | National Centre for Scientific Research "Demokritos" |
| TRMN | Telemetric Radioactivity Monitoring Network of GAEC |
| WML | Waste Management Laboratory (within INT-RP) |

# 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.

For the EC, the Directorate-General for Transport and Energy (DG TREN) and more in particular its Radiation Protection Unit (TREN H4) is responsible for conducting these verifications.

The main purpose of verifications performed under Article 35 of the Euratom Treaty is to provide an independent assessment of the adequacy of monitoring facilities for:

- Liquid and airborne discharges of radioactivity into the environment by a site (and control thereof).
- Levels of environmental radioactivity at the site perimeter and in the marine, terrestrial and aquatic environment around the site, for all relevant pathways.
- Levels of environmental radioactivity on the territory of the Member State.

A verification team from DG TREN visited (12 to 16 September 2005) the site of the Demokritos research reactor located in the North Eastern part of Athens and the Megalopolis environmental monitoring site in the Peloponés region. The team consisted of two sub-teams, one dealing with radioactive discharges (Team 1) and the other with environmental matters (Team 2).

The present report contains the results of the verification teams' review of relevant aspects of the environmental surveillance at and around the Demokritos site, as well as the national surveillance in general.

The present report is also based on information collected from documents received and from discussions with various persons met during the visit.

# 3 PREPARATION AND CONDUCT OF THE VERIFICATION

## 3.1 Preamble

The Commission's decision to require the conduct of verifications under the terms of Article 35 of the Euratom Treaty was forwarded to the Greek competent authorities on 17th June 2005. Subsequently, practical arrangements for the implementation of the verification were made with the Greek competent authorities.

## 3.2 Programme of the visit

A programme of verification activities under the term of Article 35 was discussed and agreed upon with the Greek competent authorities.

1 Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the health protection of the general public and workers against the dangers of ionizing radiation. (OJ L-159 of 29/06/1996 page 1).

The agreed programme comprised:

- Modifications to the environmental monitoring programme since the year 2000.
- The follow-up of the European Commission recommendations of the May 2000 Art.35 verification. To that effect the GAEC delivered, before the verification visit, an implementation review document on these recommendations.
- The verification of airborne and liquid radioactive discharges from the Demokritos research reactor (GRR-1): sampling and monitoring systems, analytical methods, quality assurance and control aspects, reporting.
- The verification of the environmental radiological monitoring programmes as implemented by:
    i. The Institute of Nuclear Technology and Radiation Protection (INT-RP), as operator of the GRR-1, through its Environmental Radioactivity Laboratory (ERL).
    ii. The GAEC, as regulatory authority, through its Environmental Radioactivity Monitoring Department (ERMD) and partly through tasks subcontracted to the network of collaborating laboratories, including the ERL.

A summary overview of the programme of verification activities is provided in Appendix 2 of this report. The verification activities were carried out in accordance with the proposed programme. At the locations listed in the programme the verification activities addressed technical aspects of monitoring and sampling, analytical methods used, quality assurance and control, archiving and reporting of data.

On 12 September, an opening meeting was held at the GAEC premises located on the National Centre for Scientific Research "Demokritos" (NCSR "D").

During the visit the verification team attended presentations on the following topics:

- The Greek Environmental Radioactivity Telemetric Network (GAEC).
- The National Environmental Radioactivity Monitoring Programme (GAEC).
- The National Environmental Radioactivity Monitoring Database (GAEC).
- The Environmental Radioactivity Monitoring Department (GAEC).
- Improvements achieved since the last EU Art.35 Inspection (GAEC).
- The Environmental Radioactivity Monitoring Programme (ERL).
- Environmental marine radioactivity in the Eastern Mediterranean: current and planned activities in Greece (ERL).
- The management of the liquid radioactive waste at NCSR "Democritos" (Waste Management Laboratory - WML).
- The Greek Research Reactor - releases to the environment (GRR-1).

Closing meetings were held on 16 September, with the operator as well as the GAEC. At these meeting the verification team presented and discussed its preliminary verification findings.

## 3.3 Documentation

In order to facilitate the work of the verification team, a package of information was supplied in advance by the Greek authorities. Additional documentation was provided during and after the verification visit. A list of this documentation is provided in the Appendix 1 of this report.

The verification team noted the quality and comprehensiveness of all presentations made and documentation provided. The information thus provided has been extensively used for drawing up the descriptive sections of the report.

## 3.4 Representatives of the competent authorities and the operator

During the verification visit, the following representatives of the national competent authority and the operator were met:

The Greek Atomic Energy Commission (GAEC)

| | |
|---|---|
| Prof. Leonidas Camarinopoulos | President |
| Dr. Vassiliki Kamenopoulou | Head of Licensing and Inspections Division |

Environmental Radioactivity Laboratory (ERL) of INT-RP

| | |
|---|---|
| Dr. Panayotis Kritidis | Head of the laboratory |
| Dr. Heleni Florou | Director of Research, biologist-radioecologist |
| Dr. Constantinos Eleftheriadis | Senior Researcher, Physicist, aerosol physics |
| Ms C. Chaloulou | Functional Scientist D' mathematician |

Greek research reactor (GRR-1) of INT-RP

| | |
|---|---|
| Dr. Ion Stamatelatos | Responsible for Radiation Protection Programme of GRR-1 |
| Dr. Faidra Tzika | Radiation Protection Officer |

The Waste Management Laboratory (WML) of INT-RP

| | |
|---|---|
| Dr. A. Savidou | Head of the laboratory |

The Environmental Radioactivity Monitoring Department (ERMD) of GAEC

| | |
|---|---|
| Dr Constantinos Potiriadis | Head of Environmental Radioactivity Monitoring Department |
| Dr. Antonis Maltezos | Nuclear Physicist |
| Dr. Virginia Koukouliou | Health Physicist |
| Dr. Konstantina Kehagia | Chemist |
| Mr. Eftathios Kyriakopoulos | Electronic Engineer |
| Mr. Sotiris Bratakos | Chemical Laboratory Assistant |

# 4 COMPETENT AUTHORITIES AND NUCLEAR LEGISLATION

## 4.1 The Greek Atomic Energy Commission (GAEC)

### *4.1.1 Scope and history*

The GAEC was established in 1954 as the authority responsible for promoting the peaceful applications of nuclear energy in Greece.

In 1987 the GAEC was separated from the Scientific Research Centre Demokritos, and was re-established as an independent Civil Service [(2)], supervised by the General Secretariat of Research and Technology (GSRT) under the Ministry of Development, responsible for matters concerning radiation protection of the public and radiation workers, nuclear energy and nuclear technology as well as for matters of emergency response in case of nuclear accidents and other radiological events.

In the framework of environmental radioactivity monitoring the GAEC is assisted by a network of cooperating laboratories of different universities and research centers in Greece.

[2] By Decree Law Nr 1733 (Article 28), Official Gazette of the Hellenic Republic Nr 171/A of 22 September 1987 "Establishing the Greek Atomic Energy Commission".

#### *4.1.2 Statutory responsibilities*

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

1. Protection of radiation workers, the general public and the environment from the use of 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.
2. Implementation, in compliance with EC Directives, of radiation protection regulations, safety standards and codes of practice for ionising radiation installations.
3. Education and training of radiation workers on radiation protection issues.
4. Implementation of emergency preparedness and response plans.

All GAEC laboratories participate in International and European networks and take part in inter-comparison exercises. The laboratories have been accredited by the Hellenic Accreditation Council (ESYD) according to the ELOT EN ISO/IEC 17025.

### 4.2 Legal framework

The legal basis for radiation protection in Greece consists of:

- Legislative Act Nr 181 "Protection against the dangers of ionizing radiation" (Official Gazette of the Hellenic Republic Nr 347 of 20.11.74). This Act establishes the framework for the protection of the public and goods against the dangers from ionizing radiations. The Act also stipulates that matters of radiation protection shall be regulated through Ministerial Orders.
- Ministerial Order No 1014 (FOR) 94 "Radiation Protection Regulations" (Official Journal of the Greek Government, Nr 16B of 06.03.01): this Order transposes EU Council Directive 96/29/EURATOM (Basic Safety Standards) and Council Directive 97/43/EURATOM (medical exposure) into national law. Hereafter called NRPR (national radiation protection regulation).
- The "Xenocratis" programme (Official Gazette of the Hellenic Republic, Nr 12 Vol.B of 19.01.98), defining actors and laying down responsibilities for emergency preparedness and response in the case of radiation accidents or increased radioactivity levels.

Although there is no nuclear powerplant (NPP) in Greece, the legislative framework establishing a system of licensing with regard to nuclear installations exists since 1971: Decree Law Nr 854 (Official Gazette Nr 54 of 18.03.1971) on the "Terms to establish and operate Nuclear Installations".

## 5 THE NATIONAL CENTRE FOR SCIENTIFIC RESEARCH "DEMOKRITOS"

### 5.1 Introduction

The NCSR "Demokritos" is a multidisciplinary research centre that started its operation in 1959 as an independent division of the public sector, under the name of Nuclear Research Centre "Demokritos". 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 Institute of Nuclear Technology and Radiation Protection (INT-RP)

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 Centre.

Today INT-RP comprises seven laboratories of which the Greek Research Reactor (GRR-1 - see section 6 below) and the Environmental Radioactivity Laboratory (ERL - see section 8 below) are the most relevant in the context of this report.

# 6 CONTROL OF RADIOACTIVE DISCHARGES

## 6.1 Introduction

Two entities on the site of the NCSR "D" are at the origin of liquid and airborne radioactive waste discharges into the environment. These are the Greek Research Reactor (GRR-1) and, to a much lesser extent, the IRR (Institute for Radioisotopes and Radiopharmaceuticals) and the Institute of Biology.

### *6.1.1 The Greek Research Reactor*

GRR-1 is the only nuclear reactor in Greece. It is an open pool type light water moderated and cooled reactor, operating at a thermal power of 5MW. It uses beryllium reflectors at the two sides of the core and is fueled by Material Test Reactor (MTR) type fuel elements. The reactor is now converted to LEU fuel. However, the reactor was operated with a mixed core containing LEU and HEU fuel, of enrichments of 19.75% and 93% respectively, for a transition period of five year (1999-2004). The GRR-1 is mainly used for research purposes and to maintain nuclear engineering expertise. Current research activities focus on neutron diffraction, neutron activation analysis, material irradiation studies and tissue sterilisation. In 2004 the GRR-1 has produced 1782 MWh, equivalent to approximately 15 days of continuous operation at 5 MW. The reactor was shut down at the end of June 2004 for security purposes related to the Athens Olympic Games. Since then the reactor remained shut down for maintenance purposes.

### *6.1.2 The Institute for Radioisotopes and Radiopharmaceuticals*

The IRR is a research institution focusing on the development and evaluation of pharmaceutical compounds for scintigraphy, radiotherapy and immunodiagnosis. It must however be noted that the production of radioisotopes within the IRR ceased in 2002.

The IRR's ventilation/extraction systems (equipped with absolute filters) link into the GRR-1 stack, downstream of the monitoring and sampling equipment installed for the surveillance of the reactor.

### *6.1.3 The Waste Management Laboratory*

The Waste Management Laboratory (WML) is a central laboratory that deals with all solid and liquid radioactive waste arisings from the whole NCSR "D" site.

## 6.2 Airborne discharges from the GRR-1

Airborne discharge limits are based on dose limits to the population (derived release limits - DRL) and are set as follows:

- noble gas (Ar-41) 8.50E+14 Bq/annum
- iodine 1.06E+13 Bq/annum
- particulate matter 1.26E+10 Bq/annum

The monitoring of the ventilation/extraction flow from the reactor hall into the environment is performed continuously, independently from the reactor operation cycles (discharges of activity occur only during reactor operations and are therefore discontinuous). The GRR-1 ventilation/extraction systems are equipped with absolute filters that are situated upstream of the monitoring devices. Under normal operation the reactor is only releasing noble gas, principally Ar-41 (> 99 %). However, airborne discharges are not only continuously monitored for noble gases, but also for possible iodine and radioactive particulate (aerosol) releases.

Noble gases are assessed by a 12.7 cm diameter, 0.3 cm thick NE-102A (BERTHOLD) plastic scintillation detector mounted in the off-gas tunnel leading from the reactor hall to the stack. The lower limit of detection (LLD) value for the noble gas (Ar-41) detector is 1 kBq/m³ (1 minute integration).

The monitoring and sampling systems for aerosol and iodine are fed from the off-gas tunnel via a by-pass sampling line, operated by a single stage rotary vane vacuum pump (BIGIESSE type S).

The off-gas tunnel and the by-pass sampling line are equipped with an air velocity transducer (Omega Technologies Inc. FMA-903) and a precision turbine flow meter (Omega Technologies Inc. FTB-900) respectively. Both flow measuring systems are interlocked and steer a flow control valve on the by-pass sampling line so as to ensure isokinetic sampling conditions.

The aerosol monitoring and sampling system consists of a 0.2 cm thick, 5.08 cm diameter plastic scintillation detector (BERTHOLD) and a glass fibre filter positioned at a distance of 0.15 cm from the detector. The iodine monitoring and sampling system consists of a 5.08 cm diameter, 5.08 cm height NaI(Tl) scintillation detector (BICRON) and a charcoal filter pack (SAIC CP-200). The LLD (1 minute integration) for the particulates and iodine monitors are estimated at 14 Bq/m³ and 108 Bq/m³ respectively. For a 1 hour integration the LLD are 0.03 Bq/m³ and 0.23 Bq/m³ respectively.

The aerosol and iodine monitoring and sampling systems, as well as the electronics belonging to the noble gas monitor, are located in an air-tight room adjacent to the reactor hall. This monitoring room is accessible from the reactor hall but has also an emergency access possibility from the outside.

The monitoring room also contains a stand-alone PC that processes the raw data from the detectors. The PC screen continously displays the various detector outputs in counts per minute (cpm). The average cpm over 10 minutes is stored on the hard disk. A dump file of these averages is created automatically every 24 hours.

Warning and alarm values for airborne releases have been specified in the GRR-1 Radiation Protection Regulation document (INT-RP/2004/1). These limits when breached, trigger visual alarms at the reactor's operation control room. In case the alarm threshold is reached the operator must manually shut down the GRR-1.

At the same time normal levels of activity (reference levels in cpm) have been defined for the three monitoring devices. These reference levels function as operational controls: in case these would be transgressed (especially where it concerns iodine and/or aerosol - such releases do not normally occur and may indicate a system or reactor malfunction) then the filters must be replaced and counted at once.

| activity level | Ar-41 | iodine | particulates |
|---|---|---|---|
| reference (cpm) | 12 E+04 | 1 E+03 | 0,75 E+03 |
| alert (cpm) | 14 E+04 | 1 E+04 | 1,50 E+03 |
| alarm (cpm) | 16 E+04 | 1 E+05 | 2 E+03 |
| alarm (% of DRL) | 20 | 0,04 | 0,1 |

Iodine and particulate filters are routinely exchanged and measured weekly (iodine) or monthly (particulates). The filters are measured at the Environmental Radioactivity Laboratory (ERL) of the INT-RP. The results, including the discharge values as calculated with the stack monitors, are transmitted to the regulator (GAEC) every four months (summary report) and yearly (full report).

In addition the results of the routine environmental radioactivity measurements (as check monitoring on the discharges) are communicated by the Environmental Radioactivity Laboratory to the GAEC on a monthly basis.

## 6.3 Liquid discharges from the NCSR "D"

Liquid discharge limits are based on dose limits to the population (derived release limits).

The National Radiation Protection Regulation stipulates that the daily limits for discharges of individual radionuclides (in any micture of radioisotopes) into the public sewage system are as follows:

| Radionuclide | Bq | Radionuclide | Bq | Radionuclide | Bq | Radionuclide | Bq |
|---|---|---|---|---|---|---|---|
| **H-3** | $3x10^9$ | **Co-57** | $2x10^7$ | **Sr-85** | $6x10^9$ | **Cs-137** | $4x10^6$ |
| **C-14** | $3x10^8$ | **Co-58** | $3x10^7$ | **Sr-87m** | $1x10^9$ | **Ba-131** | $1x10^8$ |
| **F-18** | $2x10^9$ | **Co-60** | $1x10^6$ | **Sr-89** | $5x10^6$ | **Ba-133m** | $9x10^7$ |
| **Na-22** | $2x10^7$ | **Ni-63** | $1x10^8$ | **Sr-90** | $1x10^5$ | **Ba-135m** | $1x10^8$ |
| **Na-24** | $1x10^8$ | **Cu-64** | $4x10^8$ | **Y-90** | $2x10^7$ | **La-140** | $2x10^7$ |
| **P-32** | $1x10^7$ | **Cu-67** | $2x10^8$ | **Tc-99m** | $3x10^9$ | **Sm-153** | $8x10^7$ |
| **P-33** | $1x10^8$ | **Zn-62** | $5x10^7$ | **Mo-99** | $2x10^8$ | **Yb-169** | $2x10^7$ |
| **S-35** | $8x10^7$ | **Zn-65** | $1x10^7$ | **In-111** | $2x10^8$ | **Re-183** | $3x10^7$ |
| **Cl-36** | $9x10^6$ | **Zn-69m** | $2x10^8$ | **Sn-113** | $2x10^7$ | **Ir-192** | $8x10^6$ |
| **Cl-38** | $6x10^8$ | **Ga-67** | $3x10^7$ | **Sb-124** | $1x10^8$ | **Au-198** | $4x10^7$ |
| **K-42** | $2x10^8$ | **Ga-68** | $6x10^8$ | **I-123** | $1x10^8$ | **Hg-197** | $2x10^8$ |
| **K-43** | $2x10^8$ | **As-73** | $8x10^8$ | **I-125** | $1x10^6$ | **Hg-203** | $2x10^7$ |
| **Ca-45** | $3x10^7$ | **As-74** | $8x10^7$ | **I-129** | $2x10^5$ | **Tl-201** | $6x10^8$ |
| **Ca-47** | $3x10^7$ | **Se-75** | $6x10^7$ | **I-130** | $1x10^7$ | **Tl-204** | $7x10^7$ |
| **Cr-51** | $7x10^8$ | **Br-76** | $1x10^8$ | **I-131** | $1x10^6$ | **Pb-210** | $9x10^3$ |
| **Mn-52** | $3x10^7$ | **Br-77** | $6x10^8$ | **I-132** | $1x10^8$ | **Pb-212** | $1x10^6$ |
| **Mn-52m** | $1x10^9$ | **Br-82** | $1x10^8$ | **Cd-109** | $1x10^6$ | **Po-210** | $2x10^4$ |
| **Mn-54** | $3x10^7$ | **Rb-81m** | $9x10^9$ | **Cd-115** | $3x10^7$ | **Ra-226** | $2x10^4$ |
| **Mn-56** | $2x10^8$ | **Rb-82** | $1x10^9$ | **Cs-129** | $9x10^8$ | **Th-232** | $4x10^1$ |
| **Fe-52** | $3x10^7$ | **Rb-86** | $2x10^7$ | **Cs-130** | $2x10^9$ | **U-238** | $2x10^3$ |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Fe-55** | $7x10^7$ | **Rb-88** | $7x10^8$ | **Cs-131** | $8x10^8$ | **Am-241** | $2x10^2$ |
| **Fe-59** | $1x10^7$ | **Rb-89** | $1x10^9$ | **Cs-134** | $3x10^6$ | **Cm-244** | $4x10^2$ |
| **Co-56** | $7x10^6$ | **Sr-85m** | $8x10^9$ | **Cs-134m** | $4x10^9$ | **Cf-252** | $1x10^3$ |

Further limitations apply during the discharge:

- The highest concentration of radioactive substances at any point of the draining system must not be higher than 1 GBq/m³. It should be noted here that the typical activity concentration of the liquids discharged is lower than 4 kBq/dm³, this is app. 250 times lower than the permitted highest concentration.
- In exceptional cases the released activities may be higher but never higher than 110 MBq.
- In case that a mixture of radioisotope is released, the daily limits are given by a formula mentioned in the NRPR:

$$\frac{A_1}{A'_1} + \frac{A_2}{A'_2} + \cdots < 1$$

Where: $A_1$, $A_2$, ... , is the activity of each radionuclide in the volume of liquid radioactive waste for release in a day, and $A'_1$, $A'_2$, ... , the maximum quantities for release in a day of the corresponding radionuclide which are given in the table above.

The operational control over liquid discharges is within the remit of the INT-RP waste management laboratory (WML), with exception of the discharge itself (see below).

Potentially radioactive liquid effluents (low-level waste, typically < 4 kBq/dm³) that are produced on the site are collected into decay tanks (7 tanks of 10 m³ + 1 tank of 6 m³ as spare capacity).

Such liquid wastes generated on the site are on average (per year):

| | | | |
|---|---|---|---|
| - | GRR-1 | 15 to 20 m³ | Co-60 and Cs-137 (mainly), Cs-134, Ag-110m, Eu-152, Mn-54, Zn-65 |
| - | IRR | < 1 m³ | I-129, I-131, Tc-99m, Re-186. |
| - | Biology | ~ 0.2 m³ | H-3, P-32, S-35 |

When the filling of a decay tank is complete it is sampled in order to establish its initial inventory. Then the contents are left untouched in order that the activity may decay.

At set intervals (based on decay calculations) all tanks are sampled in order to analytically establish their residual activity contents. To that effect, after a 30 minute homogenisation of the tanks (by stirring), samples are taken using mechanical pumps. The samples are measured for gross beta and submitted to gamma spectrometry.

The WML must formally (in writing) notify the GAEC about the analytical result obtained (gross beta activity) and request the authorisation to discharge the tank(s) for which the activity content does not exceed the regulatory limit of 1GBq/m³. The authorisation and thus the responsibility for the discharge therefore ultimately lies with the GAEC (the regulator).

The tank having the lowest activity concentration is then discharged over a number of days, taking into account that the daily release limit into the public sewers that is set at 1 MBq (Co-60 equivalent) cannot be exceeded.

Before the discharge reached the public sewer, the discharged effluent passes 2 alternatively used subterranean concrete pits of app. 50 m³ each. Every pit is equipped with an overflow weir for sludge retention. Surface spot samples are taken monthly (one from each pit). These reassurance samples are analysed for gross beta activity.

Finally, an additional 200 m³ containment pit is present that can be used to divert and retain a discharge from flowing into the public sewer.

# 7 VERIFICATION ACTIVITIES - RADIOACTIVE DISCHARGES

## 7.1 Verification activities

The verification team visited:

- The GRR-1 room where the monitoring/sampling devices for airborne discharges are located.
- The GRR-1 control room.
- The bunker in which the central storage (decay) tanks for liquid effluents are located.
- The Liquid Waste Management laboratory.

At the same time the team verified to what extent the recommendations that were listed in the Main Findings issued after the May 2000 verifcation had been implemented.

## 7.2 Verification findings

***7.2.1*** The verification team confirmed the existence and functionality of all the monitoring and sampling provisions as described in sections 6.2 and 6.3 above.

***7.2.2*** In May 2000 the verification team noted that the gaseous effluent particulate monitoring system of the Democritos Research Reactor suffered from operational shortcomings due to intermittent temperature related failures of the on-line counting device. These failures also entailed temporary loss of monitoring data.

This finding led to the following: "*The verification team recommends the GAEC to investigate the operational shortcomings of the particulate monitoring system of the Democritos Research Reactor and to consider remedial action".*

The 2005 verification findings were:

(1) The complete particulate and iodine monitoring and sampling systems were transferred to an air-tight room adjacent to the reactor hall and just above the off-gas tunnel leading to the stack. This room (that also houses the the noble gas monitor electronics) is temperature controlled.
(2) The noble gas monitor itself has been relocated from it earlier position inside the stack (at mid-height) into the off-gas tunnel.
(3) New sampling lines have been commissioned. The sampling nozzles are now located within the off-gas tunnel. The distance between sampling line nozzles and detectors (for particulates and for iodines) has been kept as short as possible. Isokinetic sampling has been ensured.
(4) Continuity of monitoring and sampling is guaranteed. Back-up power supply is available for the monitoring and sampling systems as well as for the extraction fan feeding the stack.
(5) Light indicators associated with normal operating conditions as well as alert and alarm level transgressions were installed in the reactor's operations control room.
(6) The operation of all systems was tested (and calibrations performed) at the end of the year 2003. The results were published as internal report P-INTR-P/2004/7 "GRR-1 tunnel monitor operational tests". The verification team received a copy of this report.

> *The verification team established that the recommendation that was made in May 2000 has been satisfactorily implemented.*

***7.2.3*** In May 2000 the verification team noted that the condition of the computer hardware upon which the stack control systems were based left them vulnerable to possible breakdown and that, should such a breakdown occur, the obtention of spare parts would be difficult.

This finding led to the following: "*The verification team recommends the GAEC to consider upgrading the computer hardware upon which the Democritos Research Reactor control and monitoring systems are based".*

The 2005 verification findings were:

(1) All hardware and software (data processing unit) have been replaced and are now in line with modern standards. The data processing PC is located within the room housing the particulates and iodine monitors/samplers.
(2) The new software provides on-line display of all detector ouputs (on the PC screen). Raw data (cpm) are integrated over one minute and the average value over ten cycles is stored on the hard disk. A daily file containing the recorded averages is automatically created and saved.
(3) Spare electronic components are available for the monitoring systems in case of malfunction.

> *The verification team established that the recommendation that was made in May 2000 has been satisfactorily implemented.*

It was furthermore noted that:

(4) Apart from the guaranteed power supply, the systems are not covered by functionality alarms relayed into the operations control room. Functionality control is however ensured through a procedure that requires the operator to visit the systems' room every three hours. A ledger to that effect is present: readings taken from the PC display are noted down systematically (cpm for noble gas, iodine and particulates).
(5) It is the operator's intention to incorporate the PC that houses the data processing unit into the LAN (local area network) of the GRR-1. This will provide the operator in the reactor control room with real time on-line information on discharged activity.

With respect to (4) and (5):

> *The verification team endorses the project that aims at integrating the data processing PC into the reactor's local area network. This will enhance the operator's efficiency in controlling the operational status of its monitoring devices.*

***7.2.4*** In May 2000 the verification team noted that that the sampling procedures of the decay tanks, aiming at controlling liquid activity releases, were satisfactory. However, the team observed that delay tank sampling, as additional control, was subject to 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, due to the non-continuous mode of sampling a transient contamination is likely to go unnoticed.

This finding led to the following: "*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".*

The 2005 verification findings were:

(1) Where in the past the operator was fully responsible for discharging liquid effluents into the environment (the public sewer), this responsibility has now been partly transferred to the regulator insofar that the latter has to formally authorise the discharge requests submitted by the operator.
(2) Taking into account point (1) above, the verification team now considers that the procedure of spot sampling the delay tanks is a reassurance sampling outside the domain of discharge control.

*The verification team believes that the modified discharge procedures for liquid effluent from the site into the public sewer are a satisfactory response to the recommendation that was made in May 2000.*

***7.2.5*** In May 2000 the verification team considered that, although airborne and liquid discharges of activity from from the Democritos site were very low, a comprehensive control measurement programme with systematic recording and reporting of results should be maintained.

This finding led to the following: "*The verification team recommends the GAEC to consider the implementation of a control measurement programme for the atmospheric and liquid radioactive discharges from the Democritos Research Reactor.*

The 2005 verification findings were, with respect to airborne discharges:

(1) The operator has a statutory duty to assess and report discharged quantities of activity (the source term) to the GAEC.

(2) On behalf of the operator, the Environmental Radioactivity Laboratory (ERL) implements a site-related environmental monitoring programme encompassing on-site airborne particulates and deposition sampling as well as dose rate assessment and in-situ gamma spectroscopy. This programme is in compliance with the GRR-1 Radiation Protection Regulation.

(3) The GAEC does not take samples (or shares samples with the operator) to independently assess the validity of the discharge data transmitted by the operator.

(4) The GAEC implements (since early 2005) an environmental check-monitoring programme with the aim to evaluate the environmental impact of the airborne discharges from the GRR-1.

This programme comprises:

- Continuous gamma dose rate assessment by a dose rate probe located on the NCSR "D" site (this probe is also part of the national telemetric network).
- Aerosol sampling (weekly with a low-volume pump, monthly with a high-volume pump) and subsequent analysis of the filter with gamma spectrometry, providing concentration (Bq/m³) of Cs-134, Cs-137, I-129, I-131 and Be-7. The samplers are located at app. 250 m from the GRR-1 stack. After 4 to 5 days a gross beta measurement is performed.
- Soil sampling from 18 locations around the GRR-1 but within the NCSR "D" perimeter and subsequent analysis of the samples with gamma spectrometry, providing concentrations (Bq/kg) for Cs-134, Cs-137, I-129, I-131, Co-60 and Am-241.

The 2005 verification findings were, with respect to liquid discharges:

(5) The decay tank samples taken by the Waste Management Laboratory, after having been prepared (evaporation) and measured, are forwarded on an ad-hoc basis to the GAEC for independent measurement and cross-checking of the results obtained (on average two times a year). The sampling itself and the preparation of the shared samples is however not witnessed (ad-hoc validation) by the regulator. The verification team believes that if a regulatory control is to be performed, it should include a verification/validation of all stages of the sampling and subsequent analytical procedures.

*The verification team established that the recommendation that was made in May 2000 has been partially implemented. Room for further improvement is available.*

Therefore, with respect to points (3) and (5):

*(a) It is suggested, in order to ensure full regulatory control, that whenever the GAEC decides to perform a check-measurement on a decay tank sample, this be accompanied by a validation - through witnessing - of the sampling procedure and sampling preparation as performed by the operator.*

*(b) It is suggested that the practice of cross-checking liquid effluent samples as described under (a) also be applied to airborne effluent samples in order to*

*complement the current regulatory control programme that mainly consists of intermittent site-related environmental monitoring activities.*

***7.2.6*** In May 2000 the verification team noted the absence, with respect to the monitoring and control of radioactive effluents, of a well-defined statutory separation between the GAEC and the NCSR, the latter being the operator of the Democritos Research Reactor.

This finding led to the following: *The verification team recommends the GAEC to clarify 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 2005 verification findings are:

(1) The GRR-1 Radiation Protection Regulation (first revision) that was enforced on 25 August 2005 addresses the issues listed in the above recommendation.

(2) It should be noted that the GRR-1 Radiation Protection Regulation (RPR) is an internal INT-RP document, approved by the INT-RP Director. The RPR is therefore an implementation document describing the internal rules that shall be abided by in order to be compliant with national legislation governing the protection against ionising radiation. The national legislative act that is transposed into the RPR is Ministerial Decision No 1014 (FOR) 94 "Radiation Protection Regulations", itself transposing EU Council Directive 96/29/EURATOM (Basic Safety Standards) and Council Directive 97/43/EURATOM (medical exposure) into national law.

*The verification team established that the recommendation that was made in May 2000 has been satisfactorily implemented.*

***7.2.7*** The verification team visited the decay tanks where it was noted that:

(1) The bunker containing the tanks was well maintained.

(2) Operational records were attached to every individual tank.

(3) 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.

(4) For the purpose of activity release control, the sampling procedures of the decay tanks are satisfactory.

*The verification activities performed do not give rise to particular remarks.*

***7.2.8*** The verification team visited the WML where it verified the adequacy of the analytical systems in place, including various aspects of quality assurance and control (working instructions, methodologies, calibration, maintenance, bookkeeping of results, reporting etc.).

The verification team noted that:

(1) The laboratory is adequately equipped for the assessment of liquid effluent samples.
- A total beta counter and two gamma spectrometers (NaI and HPGe) are available.
- For the calibration of the counters, standard sources, with the geometry of the samples, from the National Institute of Standards and Technology are used.
- The Lower Limit of Detection (LLD) for the gross beta determination (2 minutes measurement) is 1 Bq/dm³ of liquid effluent.
- The NaI LLD for Cs-137 and Co-60 (30 minute measurement) is 40 Bq/dm³ and 20 Bq/dm³ respectively.
- The HPGe LLD for CS-137 is 3 Bq/dm³ (15 minute measurement).

(2) The laboratory is not accredited. Accreditation is not required by the GAEC.

(3) A quality assurance and control system is not in place. Taking into account the small number of effluent samples that are analysed over a calendar year, and considering the minimal staffing of the lab, the team believes that the development of a comprehensive quality control system is not an absolute necessity.
(4) Sample receipt, preparation and analysis result ledgers were consulted and found to be meticulously kept.

*The verification activities performed do not give rise to particular remarks.*

***7.2.9*** General remark on the handling of analytical results below measurement systems' detection limit.

*It is reminded that the European Commission issued Recommendation 2004/2/Euratom [(3)] wherein substitution rules for values below the detection limit are presented. Such rules are proposed to avoid unnecessary over- or underestimation of discharged activities. These substitution rules are in line with ISO standard 11929-7:2005.*

*It is suggested that the competent regulatory authority consider the benefits of revising its regulatory requirements for substitutions of analytical results below detection limits by bringing these requirements in line with Commission Recommendation 2004/2/Euratom and ISO standard 11929-7.*

# 8 THE ENVIRONMENTAL RADIOACTIVITY MONITORING PROGRAMME

## 8.1 Introduction

The Environmental Radioactivity Laboratory (ERL) of the Institute for Nuclear Technology and Radiation Protection, implements the GRR-1 site-related environmental radioactivity monitoring programme.

GAEC, through its own laboratory infrastructure, the Environmental Radioactivity Monitoring Department (ERMD), is in charge of implementing the national Environmental Radioactivity Monitoring Programme (ERMP), more in particular the Telemetric Radioactivity Monitoring Network (TRMN). The TRMN is currently in its final commissioning and testing fase. A substantial part of the national ERMP is subcontracted to the ERL.

Those parts of the ERMP that the GAEC outsources to third parties are duly formalized. Such formal agreements exist, between others, with the ERL, with the National Meteorological service, with laboratories from various Greek universities or research centers and with customs.

The radiological and nuclear emergencies are covered and formalized by the General Plan of Civil Defence "Xenocratis".

## 8.2 The INT-RP Environmental Radioactivity Laboratory (ERL)

The staff of the ERL consists of 4 scientists and 5 technicians. Per year the ERL handles between 2000 and 3000 samples. The ERL comprises three basic units: the sample registry unit; the sample preparation unit, including separate divisions for physical and chemical treatment of the samples, and

[3] Official Journal L 002, 06/01/2004 P. 0036 - 0046

the radioactivity measurements unit, including separate divisions for gamma spectrometry, gross beta and other types of measurements.

The ERL network consists of 40 sampling/measuring points totalizing 12 air sampling, 6 radioactive deposition, 12 gamma-intensity measurement, 8 surface or tap water and 2 milk and mixed-diet sampling stations. A full description of the environmental monitoring/sampling programme and relevant technical details as implemented by the ERL are given in Appendices 3 and 4. Modifications in the environmental monitoring programme since the Art.35 verification of May 2000 were reported to the verification team: a summary overview of these modifications is given in Appendix 5.

ERL has no ISO certification. However, procedures have been externally approved by international expert groups (i.e. Integrated Safety Assessment of research reactors, IAEA, Technical Co-operation project RER/9/058).

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

## 8.3 The GAEC Environmental Radioactivity Monitoring Department (ERMD)

The GAEC has its own Environmental Radioactivity Monitoring Department laboratory. One of the main responsibilities of the ERMD is to keep the national record and to perform measurements of radiation and radioactivity levels all over Greece. Thus, it is responsible to inform the national authorities for any increases in the radioactivity levels. Participates in the National Emergency Response Plan "Xenocratis".

The ERMD is subdivided in four units, the sample preparation laboratory, the radiochemical laboratory, the measurement laboratory and the telemetric network department. Currently 8 scientific staff and 3 technicians are employed in the laboratory.

The environmental routine measurements and the laboratory equipment of the ERMD are given in appendices 6 and 7 respectively.

ERMD performs routine checks on the following environmental samples: air, surface and drinking water, soil, aerosol, milk, mixed diet and vegetables.

ERMD performs also radioactivity measurements in consumer products such as building materials, foodstuffs, etc.

Another ERMD's task is to assume responsibility for the Greek telemetric network for radioactivity monitoring (TRMN) by implementing a continuous and automatic on-line detection of external total gamma radiation within the whole Greek territory.

## 8.4 The GAEC Telemetric Radioactivity Monitoring Network (TRMN)

### *8.4.1 Current status*

The TRMN consists of three sub-networks: a network of 24 wide range detectors for gamma dose rate measurements, a network of four river-water gamma spectroscopy systems and a network of three aerosol measurement systems. Each gamma dose detector has a sensitivity < 10 nSv/h for a 10 minute measurement. Each station has the ability to add other probes like rain monitors. Online computers placed at GAEC give the possibility to evaluate any signal from the systems before eventually alarming the emergency planning offices. Gamma dose rate is calculated on 10 minute intervals, and data are stored in one hour intervals during normal periods and 10 minute intervals during emergencies. The river water gamma spectroscopic system provides spectra over 30 minute intervals. The aerosol measuring systems provides alpha/beta and gamma spectra over 30 minute intervals on

filters on-line, simultaneously with meteorological data. The TRMN provides continuous and automatic on-line detection of external total gamma radiation, river water and aerosols all over Greece.

#### *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 rising, 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 probes 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 Appendix 8 to this report.

# 9 VERIFICATIONS ACTIVITIES - ENVIRONMENTAL MONITORING

## 9.1 The INT-RP Environmental Radioactivity Laboratory

#### *9.1.1 Verification activities*

The verification team visited the effluent laboratory where it verified the adequacy of the analytical systems in place, including various aspects of quality assurance and control (working instructions, methodologies, calibration, maintenance, bookkeeping of results, reporting etc.). The team also visited the on-site environmental monitoring/sampling provisions operated by the laboratory.

#### *9.1.2 Verification findings*

- *Laboratory equipment.*

The verification team visited the ERL laboratories and verified the presence and operability of the laboratory instruments. The team verified the adequacy of the analytical systems in place, including various aspects of quality assurance and control (working instructions, methodologies, calibration, maintenance, bookkeeping of results, reporting etc.). The team visited the sampling preparation and the chemistry laboratory. The team noted that all the instructions and procedures are present and readily available at all workstations.

The calibration for gamma-spectrometry system is done weekly and the background measurements are checked on a monthly basis. The calibration of the alpha counter and the corresponding background measurements are done weekly and for the low-beta counting device the same parameters are checked on daily basis.

- *Environmental samples and 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. The sample is directed to the sample preparation unit and is treated physically and/or chemically. The parameters and results of the treatment are added to the sample registration document. After that, the sample goes to the radioactivity measurements department where the results are again added to the sample registration document. In most cases additional calculations are performed in order to derive the final activity value. The final calculations are made by use of Excel spreadsheets, where the whole sample data are recorded too. These files are used for electronic storage of the results, in parallel to their physical storage on paper records.

The Excel spreadsheets are used since 2003 for calculation and storage of the results of environmental radioactivity control. Sample printouts are provided separately, for the air monitoring stations of "Demokritos" (where additional measurements are made to estimate radon and thoron and total beta in water at the corresponding sampling point). Cs-137 and Sr-90 are measured in milk, Cs-137 and Sr-90 in mixed diet and total beta in deposition, and Marathon lake sampling point. Mixed diet and milk measurements are representative for the whole country.

In some cases copies of the initial hand-filled data sheets are provided as well.

The Greek meteorological service has a special contract by ERL for some specific sampling and installation maintenance activities all over the territory of Greece. They collect filters from air sampling and deposition samples etc. Samples such as air filters are directly sent by mail to ERL, which performs radionuclide analysis and sends the reports to GAEC. River water samples are collected partially by soldiers of the Greek army on a monthly basis. Mixed diet is collected by the ERL.

- *Archiving*

Exel spreadsheet files are used for electronic storage of the results, in parallel to the archived physical records on paper. In addition, the samples (or what was supplied for measurement after pre-treatment) are stored at least for 5 years in order to ensure comparison and/or reference capabilities. The team performed the tracing of an historical sample and its archiving. The sample was from Agostori on Kefalonia island. Sample code AP20 from 16$^{th}$ may to 23$^{rd}$ may 2004. The sample, from the measurement itself to the data reported as well as the archived sample could be perfectly traced by the team.

Data starting from 1990 and belonging to ERL have been recently introduced into GAEC database. All older data are archived in the ERL premises.

> *The verification activities with respect to laboratory equipment, sampling, record keeping and archiving do not give rise to particular remarks.*

- *Quality control*

The team noted that ERL regularly participates in international intercomparison exercises.

- *Reporting*

The results of the routine environmental radioactivity control measurements are sent by ERL in form of a report to GAEC on a monthly basis (weekly by electronic transmission of raw data). GAEC

manages and updates the national database with the new data every year and releases consequently the annual report. In most cases the final results are evaluated by GAEC for compliance with the properly defined limits. Should these limits have been exceeded, the operator informs the responsible scientist (the Head of Laboratory or his/her deputy). According to the type of the sample and/or the value of the abnormal result, the evaluating person may order additional measurement(s), formulate a special certification document and/or inform GAEC in the case when emergency requires special measures.

*The verification activities with respect to quality control and reporting do not give rise to particular remarks.*

- *Sampling points and air monitoring stations*

It is noted that the air sampler operated on the campus replaces the device that was formerly located at the N-Philadelphia station.

*The team considers that one air sampling system for the Attiki area suffices. The May 2000 verification finding to the effect that the air sampling capabilities [at N-Philadelphia] should be restored has therefore been satisfactorily implemented.*

*The verification activities with respect to the other locally installed monitoring (meteorological station) and sampling provisions (wet and dry deposition) do not give rise to particular remarks.*

- *Modifications since the May 2000 verification visit*

The verification team welcomes the modifications to the environmental monitoring programme of the ERL (listed in Appendix 5).

## 9.2 The GAEC Environmental Radioactivity Monitoring Department

### *9.2.1 Verification activities*

The team visited the GAEC laboratory ERMD (Environmental Radioactivity Monitoring Department) and received detailed explanations with respect to the follow-up given to the recommendations of the May 2000 verification. It also visited several sampling points and monitoring stations that are part of the environmental monitoring programme and the TRMN.

### *9.2.2 Verification findings*

In 2000 the verification team noted that the GAEC was intending to take over the environmental radioactivity monitoring programme from the ERL of the NCSR "D"within the next two years.

This finding led to the following: *The verification team recommends the GAEC, awaiting the future take-over of the environmental radioactivity monitoriong programme from the NCSR, to formalize the distribution of responsibilities between itself and the NCSR.*

At the same time the verification team invited GAEC to take into consideration the following:

- *To ensure that the GAEC inherits 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 is duly formalised.*

The above issues (distribution of responsibilities and formalisation of outsourced activities) have been thoroughly discussed with the GAEC during the 2005 visit. The team was told that according to its constitutional law the GAEC is responsible for organising the national environmental monitoring programme. In this framework the GAEC collaborates with 10 laboratories operated by Greek research institutes or universities (the ERL is the major participating laboratory). Collaboration is based on formal agreements between the GAEC and all participating bodies. Furthermore, the GAEC organises intercalibration exercises between the participants and may, where deemed necessary, provide material/financial support to the participants.

*The verification team believes that the above recommendation and related considerations have been followed-up in a satisfacty manner.*

The issue with the air samplers and deposition collectors: see section 9.1 above. The issue with the electronic archive: see section 9.6 below.

- *Environmental laboratory ERMD.*

The visit of the environmental laboratory demonstrated that GAEC has developed state-of-the-art infrastructures for its environmental monitoring activities.

The team verified the adequacy of the analytical systems in place, including various aspects of quality assurance and control (working instructions, methodologies, calibration, maintenance, bookkeeping of results, reporting etc.) and noted that all the instructions and procedures are present and readily available at all workstations.

Gamma-spectrometry systems are checked daily for calibration (energy and efficiency). The peak width (FWHM) in standard geometry is checked on a weekly basis by using the following sources: Co-60, Cs-137, Am-241. The background is checked on monthly basis. For the alpha counter, the calibration and background measurements are done weekly and for the low-beta counting device the same parameters are checked on a daily basis.

- *Telemetric network and air sampling station at ERMD premises*

At GAEC's premises a station of the telemetric network is installed on the roof of the ERMD laboratory. The measuring device is a high pressure ionization chamber, connected telemetrically with a central station placed in the laboratory premises. Measurements are performed every 10 min. During normal operation, measurement results are transferred once per day to the central station. In case of an alarm the signal is transferred immediately. Relevant records exist since 1999. LLDs are lower than 10 nSv/h for a measurement duration of 10 min. Archived data are stored in a data base (one hour intervals during normal operation and in 10 min. intervals during alarms).

Total gamma dose rate is measured by a Xetex 501A system with NaI detector on a daily basis. Air measurements are performed by collecting 1000 $m^3$ air through a 4'' diameter filter (~5 μm pore size), on a daily basis.

- *Accreditation and quality control.*

ERMD is accredited with the Accreditation certificate No. 117 ELOT EN ISO/IEC 17025 by the Hellenic Accreditation Council (ESYD), valid until 21 January 2007. The following services are accredited: non-ionising radiation, environmental radioactivity and ionizing radiation calibration laboratory. Recently the laboratory also achieved the ISO/IEC 17025 accreditation for gamma spectrometry using high purity Germanium detectors.

ERMD participates also in international intercomparisson exercises such as ALMERA proficiency test, PROCORAD, etc.

- *Reporting of environmental data.*

Review documents are based on the ERMP reports that are transmitted on a monthly basis by ERL.

*The verification activities with respect to the ERMD laboratory do not give rise to particular remarks.*

## 9.3 The N-Philadelphia environmental monitoring station

The station belongs to and is operated by the Greek Meteorological Service (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.

### *9.3.1 Verification activities*

In May 2000 the verification team noted that the local sampling devices at the N-Philadelphia station were not operated in an adequate fashion.

This finding led to the following: *The verification team recommends the GAEC to restore the air sampling capabilities at the N-Philadelphia station and to ensure that deposition-sampling activities are performed according to procedures. The team also recommends the GAEC to consider replacing the existing air sampler and deposition collector with devices in line with modern standards.*

### *9.3.2 Verification findings*

- *The air sampler.*

See section 9.1 above, under *Sampling points and air monitoring stations*.

- *The dose rate monitor.*

The verification team noted that the Reuters-Stokes ionisation chamber detector functions and that it is coupled to a rainwater gauge model YOUNG type 52203, also in a good state.

*The verification activities performed do not give rise to particular remarks.*

- *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 (same system as in May 2000). However, and contrary to the findings of 2000, the device is now filled with app. 5 cm of distilled water, this level being controlled on a daily basis, in accordance with the quality control procedure in force.

*The verification team established that the recommendation that was made in May 2000 has been partially implemented.*

Therefore:

*The verification team re-iterates its recommendation to the effect of replacing the current deposition sampler with a device in line with modern standards.*

[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.*

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

> *The verification team established that the recommendation "to ensure that various monitors and samplers are located in areas free of possible sources of interference" that was made in May 2000 has been satisfactorily implemented.*

## 9.4 The Megalopolis monitoring station

This station belongs to and is operated by ERMD. It is situated in the lignite power plant of Megalopolis city in Peloponés province. One designated staff member from the lignite central is present on site and is responsible for sampling and maintenance activities. The station where the meteorological instruments are installed is situated in an open area on the fenced-off company site.

### *9.4.1 Verification activities*

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

### *9.4.2 Verification findings*

- *The air sampler.*

The verification team noted that the device was continuously functioning.

- *The dose rate monitor.*

The verification team noted that the Reuters-Stokes ionisation chamber detector functions and it is coupled to a rainwater gauge model YOUNG type 52203, also in a good state.

> *The verification activities with respect to the air sampler and dose rate probe do not give rise to particular remarks.*

- *The deposition collector.*

The verification team noted the rudimentary design of this sampling device, the collector being a simple dishwashing basin positioned on a metallic frame.

> *The verification team suggests the GAEC to consider replacing the existing deposition collector with a device in line with modern standards.*

## 9.5 The Telemetric Radioactivity Monitoring Network

### *9.5.1 Verification activities*

At GAEC headquarters, the TRMN control room was presented by the operator and a demonstration of its capabilities given.

### *9.5.2 Verification findings*

The verification team could check that the links to various dose rate probe stations as well as to the corresponding rain gauges exist and are functioning correctly. Several on-line parameters have been verified and all were functioning properly. This has been demontrated by online interrogation (real-time) of several gamma probes. Historical data (database) have been verified on-line as well. The team noted that many improvements have been achieved towards the creation of a professional real-time database. The team noted that the control room has a new location, with independent power supply and air conditioning.

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

## 9.6 The National Environmental Radioactivity Monitoring Database

The database contains relevant data from all fields of radiation protection in Greece since 1990.

### *9.6.1 Verification activities*

At GAEC headquarters, the dedicated TRMN control room is actually the display room of the Greek national environmental radioactivity monitoring database. The database was presented by the GAEC responsible and a demonstration of its specific measurements format and analysis was given to the verification team.

### *9.6.2 Verification findings*

In 2000 the verification team noted that the database was intended to become the repository of all relevant data generated by GAEC regulatory activities in the area of radiation protection, including those data pertaining to the environmental radioactivity monitoring programme.

This finding led to the following: *The verification team recommends that the GAEC radiation protection database project receive particular attention; successful implementation will provide an excellent management tool, in particular with respect to quality assurance and control capabilities.*

The team noted that since May 2000 the scope of the database has been considerably expanded. It now contains information about:

- All Greek institutions and laboratories using ionising radiation equipment or radioactive sources.
- The National Dose Registry Information System for monitored workers.
- The National Inventory of Radioactive Sources.
- Use and distribution (inventory) of radionuclides in nuclear medicine or research laboratories.
- Environmental Monitoring data, including:
  - -- Gamma dose rate data (TRMN + data collected by the ERL network).
  - -- Gross beta results in air, deposition (wet/dry), surface and drinking water samples.
  - -- Cs-137 and Sr-90 results in mixed diet and milk samples.
  - -- Gaseous discharge monitoring data from the GRR-1 (noble gas, iodine and particulates).
  - -- Fission products in sea water samples taken at mooring locations of nuclear ships.

*The team fully endorses the efforts made by the GAEC to further develop and commission this data management tool.*

## 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 before the start and during the verification, was useful. The information provided and the outcome of the verification activities led to the following observations:

(1) The verification activities that were performed demonstrated that the facilities necessary to carry out continuous monitoring of levels of radioactivity in the air, water and soil around the NCSR "D" site are adequate. The Commission could verify the operation and efficiency of these facilities.

(2) The recommendations made after the May 2000 visit have been to a very large extent given due consideration by the GAEC.

(3) A number of topical recommendations are formulated. These recommendations aim at improving some aspects of discharge monitoring from the GRR-1 and environmental surveillance around the NCSR "D" site. The recommendations do not discredit the fact that environmental monitoring around the NCSR "D" site is in conformity with the provisions laid down under Article 35 of the Euratom Treaty.

(4) The facilities for monitoring environmental radioactivity on the territory of Greece are in general compliance with the provisions laid down under Article 35 of the Euratom Treaty.

(5) The verification findings and ensuing recommendations are compiled in the 'Main Findings' document that is addressed to the Greek competent authority through the Greek Permanent Representative to the European Union.

(6) The present Technical Report is to be enclosed with the Main Findings.

(7) Finally, the verification team acknowledges the excellent co-operation it received from all persons involved in the activities it performed.

**********

**APPENDIX 1**

## DOCUMENTATION

### 1. Legislation

1. Government Gazette of the Hellenic Republic, No.12/Vol B, 19 January 1998

### 2. GRR-1

2. Research Reactor Radiation Protection regulation (INTRP of NCSR), Revision R-1.0, July 2005
3. Research Reactor Radiation Protection regulation(INTRP of NCSR), Individual effective dose s and derivates release limits for the Greek Research Reactor Site, M. Varvayanni, P-INT-RP/2004/1
4. Research Reactor Radiation Protection regulation (INTRP of NCSR), GRR-1 Tunnel Monitor Operational tests, Tzika, F., Chanousis A., Kovastos C., Stamatelatos I.E., P-INT-RP/2004/7
5. Derived release limits for the Greek Research Reactor site based on a diagnostic atmospheric modelling system for irregular terrain, Varvayanni, M., Catsaros, N., Antonopoulos-Domis, M., published in Health Physics Revue, 88(4):340-349; 2005
6. GRR-1 Health Physiscs Report 2004
7. Opening meeting presentation “Releases into the Environment”
8. Opening meeting presentation “Monitoring of the liquid radiation waste at the NCSR – “Demokritos”

### 3. GAEC

9. Presentation brochure of GAEC, Ministry of Development

### 4. GAEC-ERMD

10. The Annual Report 2001 of the Radiation Protection Centre
11. Opening meeting presentation “Environmental Radiation Telemetric Network”
12. Opening meeting presentation “National Environmental Radiation Monitoring Database”
13. Opening meeting presentation **“**ERMD presentation”

### 5. ERL

14. Technical information on the routine environmental radioactivity control - 2005
15. Determination ofCs-137 in sea water samples using gamma spectrometry, Evaggeliou, N., Lycomitrou, C. & Zafiropoulou, A., , published in Book of Abstracts , 14th Hellenic Symposium on Nuclear Physics, p.28, Athens 21-22/05/2004
16. Field observations of the effects of protracted low levels of ionizing radiation on natural aquatic population by using a cytogenesis tool, Florou, H., Tsytsugina, V., Polikarpov, G., G., Trabidou, G., Gorbenko, V., Chaloulou, C.H., published in the Journal of Environmental Radioactivity, 75 (2004) 267- 283.
17. Modelling of the dispersion of depleted uranium aerosol, Mitsakou, C., Eleftheriadis K., Housiadas C., Lazaridis, M., published in Health Physics Revue, 84(4):538-544; 2003
18. Opening meeting presentation “Environmental Marine Radiation in Easter Mediterranean current and planned activities in Greece”

### 6. Local authorities’ websites

19. Greek Atomic Energy Commission www.gaec.gr

**APPENDIX 2**

## VERIFICATION PROGRAMME

**Monday 12/09**

1. Arrival at site at 09:030 and site access formalities (AM).
2. Opening meeting: introductions / presentations / discussion on the programme of the visit (AM).
3. Verification of the provision for monitoring/sampling of radioactive discharges of the Greek Research Reactor (airborne and liquid) and visit of the reactor's operations control room (PM).

**Tuesday 13/09**

4. Team-1 visits the analytical laboratory for discharge samples (AM).
5. Team-2 visits the analytical laboratory for site-related and national environmental samples (AM).
6. Verification of the site-related provisions for environmental monitoring/sampling (PM).
7. Visit of the control room of the telemetric environmental monitoring network (PM).

**Wednesday 14/09**

8. Verification of the monitoring/sampling provisions for the national environmental monitoring programme in the Attiki region (including sampling procedures for milk and mixed diet).

**Thursday 15/09**

9. Verification of the monitoring/sampling provisions for the national environmental monitoring programme on the Peloponnesus (Megalopolis site).

**Friday 16/09**

10. Closing meeting: presentation of preliminary verification findings.

**APPENDIX 3**

## ERL - ENVIRONMENTAL MONITORING PROGRAMME

### 1. SAMPLING NETWORK

The locations of the sampling and measuring stations of the ERL network are shown in Fig. 1.

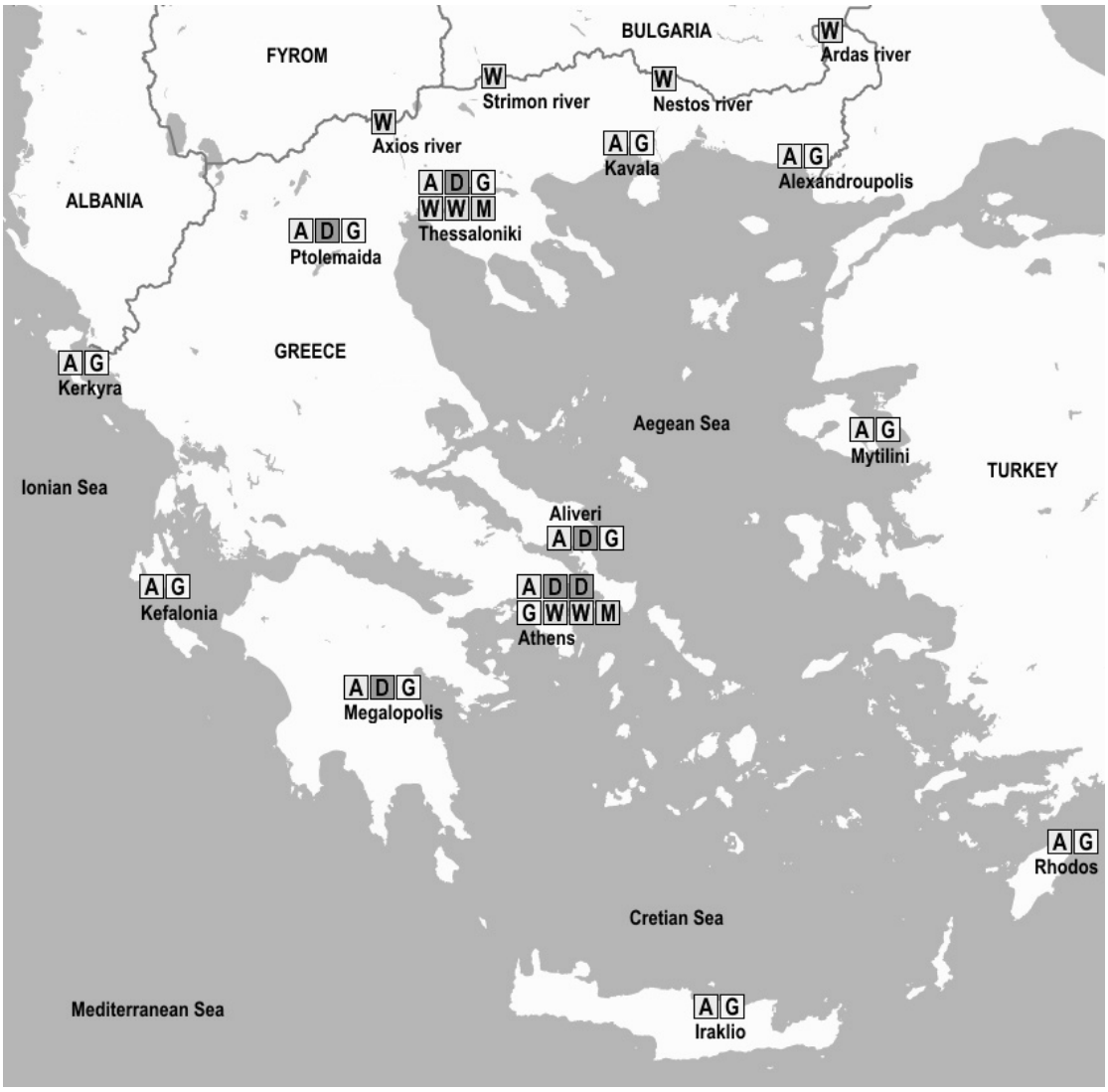


Fig. 1. Sampling and monitoring station locations belonging to the ERL network.

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

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

In the case of emergency, the sampling network can be expanded, depending on the existing information about the primary regional pollution and mainly with regard to agricultural product samples.

The names and the approximate geographic co-ordinates of the routine sampling / monitoring stations are given in Table 1:

| Station | Geographic co-ordinates | Type of sampling / monitoring | | | | |
|---|---|---|---|---|---|---|
| | | **A** | **D** | **G** | **W** | **M** |
| Alexandroupolis | 26.0 E , 40.9 N | x | | x | | |
| Aliveri | 23.9 E , 38.5 N | x | x | x | | |
| Ardas River | 26.1 E , 41.7 N | | | | x | |
| Athens (Athina) | 23.7 E , 38.1 N | x | x | x | x x | x |
| Axios River | 22.4 E , 41.1 N | | | | x | |
| Iraklio | 25.1 E , 35.5 N | x | | x | | |
| Kavala | 24.4 E , 41.0 N | x | | x | | |
| Kefalonia | 20.5 E , 38.2 N | x | | x | | |
| Kerkyra | 19.8 E, 39.8 N | x | | x | | |
| Megalopoli | 22.1 E , 37.6 N | x | x | x | | |
| Mytilini | 26.5 E , 39.2 N | x | | x | | |
| Nestos River | 24.1 E , 41.4 N | | | | x | |
| Philadelfia (Athens) | 23.6 E , 38.1 N | | x | | | |
| Ptolemaida | 21.6 E , 40.5 N | x | x | x | | |
| Rhodos | 28.2 E , 36.5 N | x | | x | | |
| Strymon River | 23.4 E , 41.3 N | | | | x | |
| Thessaloniki | 22.9 E , 40.7 N | x | x | x | x x | x |
| | **Total stations** | **12** | **6** | **12** | **8** | **2** |

Notes:

1. The code letters in Table 1 are the same used in Fig. 1
2. The names of the station follow the actual Greek spelling.
3. The total number of sampling / monitoring points of the ERL network equals 40.
4. Minor changes occurred since 2000.

## 2. SAMPLING / MEASUREMENT FREQUENCY

The sampling / measurement frequencies are given in Table 2:

| Code | A | D | G | W | M |
|---|---|---|---|---|---|
| Sampling frequency | weekly | monthly | 3 times/day | monthly | monthly |
| Sampling locations | 12 | 6 | 12 | 8 | 2 |
| Nr of samples per year | 624 | 72 | 13140 | 96 | 24 |
| Type | Composite | Integrated | Grab | Composite | Grab |
| Details | 3 times 1 hour per day | ----- | At 9, 12 and 15 UTC | 30 l sample, 1 liter per day | 10 major producers |

Note: In the case of emergency, the sampling frequencies can be intensified as follows:

- Air sampling: daily 24-hour samples.
- Deposition sampling: 1 sample per week or 1 sample per day in selected stations.
- Gamma dose rate measurement: no change.
- Water sampling: 1 sample per week, 1 sample per day in Athens and Thessaloniki.
- Milk and mixed diet: the sampling will be totally re-arranged and expanded, depending on the information about the regional radioactive pollution. In the case of the Chernobyl accident large

campaigns of food measurements were undertaken (cow and sheep milk, cereals, cheese etc.) and many thousands of samples were analyzed each month.

## 3. SAMPLING PROCEDURES

### 3.1 Air sampling (code A)

Sampling devices

Piston oil pumps samplers assembled in 'Demokritos', with sampling rate of 50 $m^3$ per day.
The sampling devices are supplied with air volume meters, the readings of which are reported with each sample.

Filters

The Watman 41 filter is used for air sampling. The active area of sampling equals 10.8 $cm^2$ (D = 3.7 cm).

Sampling geometry

The air-sampling devices are hosted in metal houses of approx. 1 x 1 m size, which protect them from the rainfall, while allowing the air to enter freely though the side grids. The sampling height is approx. 1.2 m.

Locations, operators

Most of the stations are located in the stations of the Greek Meteorological Service and are operated by its staff. In 3 cases the stations are located in lignite power plants and operated by their staff. The ERL staff operates the 'Demokritos' station.

### 3.2 Radioactive deposition sampling (code D)

Sampling devices and geometry

The sampling device is a cylindrical plastic vessel of 0.075 $m^2$ area, directly exposed to the atmospheric fallout at the height of 1 m. An additional 1 $m^2$ stainless steel sampling vessel is in use at the 'Demokritos' station.

The operators have been instructed:

a. To keep always a minimum of 1 cm of water layer in the vessel. This is controlled on a daily basis. Proper quantities of distilled water are sent to the measuring stations regularly.
b. To transfer the content of the vessels (after heavy rainfalls) in the transporting vessels regularly provided for this purpose.
c. To use additional distilled water in order to transfer efficiently the final part of the sample to the transporting vessels.

New stainless steel vessels will replace the plastic ones before the end of 2005.

Locations, operators

In 3 cases the stations are located in lignite power plants and operated by their staff. The Athens stations are operated by ERL staff and the Thessaloniki station by Thessaloniki University staff.

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

Measuring devices

The NaI-based Xetex 501A instruments are used for the routine gamma-ray intensity measurements. The instruments are protected from rainfall and exposure to sunlight in special housings. The

operators have been instructed to record readings three times each day. The readings are transferred to the Greek National Meteorological Service on a daily basis and the whole data are sent to ERL.

Measuring parameters:

The detectors are placed 1 m above the ground. The detector volume equals 100 $cm^3$ and the sensitivity is of the order of 700 cpm per μR/h (for the 661 keV Cs-137 gamma-rays). The count rate based on 1-minute readings is reported.

Locations, operators

Most of the stations are located in the stations of the Greek Meteorological Service and are operated by its staff. In 2 cases the stations are located in lignite power plants and operated by their staff. The 'Demokritos' and the Thessaloniki stations are respectively operated by the ERL and Thessaloniki University staff.

### 3.4 Water sampling (code W)

Sampling procedure

The monthly river water samples are composed by daily samples of 1 liter taken from the river surface. The composite 1-month sample is sent to ERL for further treatment. The tap water samples are composed in a weekly basis. The basic Athens water reservoirs are sampled also in a monthly basis. The sample volume in the last 2 cases is 3 liters.

Locations, operators

Four of the stations are located in military objects on the Greek borders with Bulgaria and FYROM and are operated by staff of the Greek Army. The Athens and 'Demokritos' stations are operated by the ERL staff and the Thessaloniki ones by Thessaloniki University staff.

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

Sampling procedures

Milk. Under routine conditions, a composite sample is formed once per month, by using samples from 9 major milk producers of Greece and mixing them with the proportions of their market coverage.

Mixed diet. 13 basic components (meats, milk, vegetables, cereals etc.) are mixed according to the official data on their percentage contribution to the average Greek diet.

Locations, operators

Milk samples are taken from 10 different Greek producers: Delta, Fage, Mevgal, Dodoni, Nounou, Sergal, Olympos, Kerkyraiki, Geoponiki Thessalonikis, Kriti.

The mixed diet samples are taken from a number of Athens supermarkets. The components of the homogenized sample are as follows:

| | | | | | |
|---|---|---|---|---|---|
| Beef meat: | 124 g | Milk: | 360 ml | Leafy vegetables: | 170 g |
| Pork meat: | 128 g | Cheese: | 82 g | Other vegetables: | 540 g |
| Chicken meat: | 64 g | Eggs: | 48 g | Fruits: | 516 g |
| Fish: | 68 g | Potatoes: | 336 g | Flour: | 550 g |
| Legumes: | 330 g | | | | |

The above quantities equal 2 times the daily consumption of the average Greek.

## 4. SAMPLE TREATMENT

### 4.1 Air samples (code A)

No treatment is applied to the air samples.

### 4.2 Radioactive deposition samples (code D)

The volume of the samples varies, depending on the rainfall in the sampling area, typically within 1 to 3 liters. The samples are mildly evaporated in two stages under temperature of 60 °C. The solid residue is weighed. In the case of following total-beta measurement a part of the residue, not exceeding 500 mg, is used. In the case of gamma-spectrometry for the determination of Cs-137 deposition the whole residue is used.

In the case of emergency and/or when quick results are required, the deposition samples can be measured directly in 1 dm³ Marinelli beakers.

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

Not applicable.

### 4.4 Water samples (code W)

The samples are treated exactly as those of the radioactive deposition (4.2 above). In the case of emergency and/or when quick results are required, the water samples can be measured directly in 1 dm³ Marinelli beakers.

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

The mixed diet samples are composed according to the average Greek diet weighting factors of different components and subsequently homogenized and ashed (3.3 kg material per sample). The 1 liter milk samples are ashed.

No further treatment is applied for the samples directed for determination of Cs-137 by high-resolution gamma-spectrometry.

In the case of emergency and/or when quick results are required, the milk and food samples can be measured directly after their homogenization, in some of the 2 cylindrical geometries adopted by ERL (40 ml and 500 ml) or in 1 dm³ Marinelli beakers.

In the case of determination of Sr-90, radiochemical analysis is applied to the ashed samples. The methodology used is based on the EML Procedures Manual (Ref. 1)*.

* References are listed at the end of this Appendix

## 5. MEASUREMENT OF THE SAMPLES

### 5.1 Air samples (code A)

Under routine conditions, the air samples are measured in a low-beta counting device and the 'gross beta' activity in air (the specific beta-particles emission rate) is determined. The duration of each measurement is 60 min. The low limit of detection (2 sigma) equals 0.24 mBq/$m^3$ for 50 $m^3$ air samples. Therefore, the typical total-beta activities in air, of the order of 1 mBq/$m^3$, are determined with sufficient precision and the EU reporting level of 2 mBq/$m^3$ (based on Sr-90, Ref. 2) is sufficiently covered too.

In the case of emergency, the determination of specific radionuclides in air will be performed by means of high-resolution gamma spectrometry.

Table 3. Lower limits of detection (2 sigma ) of selected radionuclides in air, by use of high-resolution gamma spectrometry system with detector of 90% relative efficiency (1.33 MeV).

| **Nuclide** | **Zr-95** | **Ru-103** | **I-131** | **I-132** | **Cs-134** | **Cs-137** | **Ce-144** |
|---|---|---|---|---|---|---|---|
| LLD (15 min), mBq/$m^3$ | 1.0 | 1 | 0.9 | 0.7 | 0.9 | 1.4 | 6 |
| LLD (20 h), mBq/$m^3$ | 0.12 | 0.11 | 0.10 | 0.08 | 0.10 | 0.16 | 0.7 |

Notes:

1. The upper values refer to measurement of 15 min duration (typical for emergency conditions) and the lower for measurement of 20 h duration.
2. The values refer to air sample of 50 $m^3$.

### 5.2 Radioactive deposition samples (code B)

Under routine conditions, the residue of the deposition samples or a part of it (not exceeding 0.5 g) is transferred to stainless steel pots of 2.3 cm diameter and measured in a low-beta counting device, where the 'gross beta' deposition (the specific beta-particles emission rate per $m^2$) is determined. The duration of each measurement is 60 min. Self-absorption correction is applied, according to the specific mass of the residue sample (mg/$cm^2$). The low limit of detection (2 sigma) equals 0.2 Bq/$m^2$. Therefore, the gross beta deposition values, typically within 10 to 20 Bq/$m^2$, are determined with sufficient precision.

The deposition samples are also analyzed for Cs-137 by means of high-resolution gamma spectrometry. In this case, the whole residue is used, in the geometry of the 2.3 cm diameter pot. The height of the sample does not exceed (typically) 3 mm. The duration of each measurement is 20 h and the LLD value (2 sigma ) is 0.16 Bq/$m^2$ for the usual 0.075 $m^2$ sampling vessels and 0.012 Bq/$m^2$ for the 1 $m^2$ sampling vessel of the 'Demokritos' station.

In the case of emergency, the determination of specific radionuclides in deposition will be performed by means of high-resolution gamma spectrometry of the solid residue.

Table 4. Lower limits of detection (2 sigma) of selected radionuclides in deposition, by use of high-resolution gamma spectrometry system with detector of 90% relative efficiency (1.33 MeV).

| **Nuclide** | **Zr-95** | **Ru-103** | **I-131** | **I-132** | **Cs-134** | **Cs-137** | **Ce-144** |
|---|---|---|---|---|---|---|---|
| LLD (15 min), Bq/$m^2$ | 0.7 | 0.6 | 0.6 | 0.45 | 0.6 | 0.9 | 0.8 |
| LLD (20 h), Bq/$m^2$ | 0.07 | 0.06 | 0.06 | 0.05 | 0.06 | 0.1 | 0.09 |

Notes:

1. The upper values refer to measurement of 15 min duration (typical for emergency conditions) and the lower for measurement of 20 h duration.
2. The values refer to measurement of the residue collected by deposition sampler with surface of 0.075 $m^2$.

If quick and rough estimations are necessary, the deposition samples can be measured directly (prior to evaporation) by use of 1 $dm^3$ Marinelli beakers. In this case the LLD values of Table 4 are higher by a factor within 2 - 4 (depending on the volume of the deposition sample).

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

The count rate data are converted to μR/h, according to calibration coefficients derived by use of a 'Demokritos' calibration device based on a Ra-226 standard source. This is done for convenience and the results are used for comparative (indicative) purposes only.

The observed exposure rate averages vary, from station to station, within 4 - 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 - 3 μR/h, depending on the normal exposure rate of the station.

### 5.4 Water samples (code W)

Under routine conditions, the residue of the water samples or a part of it (not exceeding 0.5 g) is transferred to stainless steel pots of 2.3 cm diameter and measured in a low-beta counting device, where the 'total-beta' activity (the specific beta-particles emission rate per $m^3$) is determined. The duration of each measurement is 60 min. Self-absorption correction is applied, according to the specific mass of the residue sample ($mg/cm^2$). The lower limit of detection (2 sigma) equals 3.6 $Bq/m^3$ (3.6 mBq/l). Therefore, the water gross beta values, typically of the order of 100 $Bq/m^3$, are determined with sufficient precision.

In the case of emergency, the determination of specific radionuclides in surface and drinking water will be performed by means of high-resolution gamma spectrometry of the solid residues.

Table 5. Lower limits of detection (2 sigma) of selected radionuclides in water, by use of high-resolution gamma spectrometry system with detector of 90% relative efficiency (1.33 MeV).

| **Nuclide** | **Z-95r** | **Ru-103** | **I-131** | **I-132** | **C-134s** | **Cs-137** | **Ce-144** |
|---|---|---|---|---|---|---|---|
| LLD (15 min), mBq/l | 18 | 16 | 14 | 11 | 14 | 24 | 95 |
| LLD (20 h), mBq/l | 2 | 1.7 | 1.5 | 1.2 | 1.5 | 2.7 | 11 |

Notes:

1. The upper values refer to measurement of 15 min duration (typical for emergency conditions) and the lower for measurement of 20 h duration.
2. The values refer to measurement of the residue of 3 liter water samples.
3. The Cs-137 LLD values are in good accordance with the related EU reporting levels, which are 1000 mBq/l for surface water and 100 mBq/l for drinking water (Ref. 2).

If quick estimations are necessary, the water samples can be measured directly (prior to evaporation) by use of 1 $dm^3$ Marinelli beakers. In this case the LLD values of Table 5 are higher by a factor of 3.5.

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

#### 5.5.1 Determination of Cs-137

The ashed milk and mixed diet samples are measured by means of high-resolution gamma-spectrometry in a 40 ml cylindrical geometry (D = 70 mm, H = 15 mm). The duration of measurement is 20 h.

In the case of emergency and/or when quick results are required, the milk and food samples can be measured directly, after their homogenization, in some of the 2 cylindrical geometries adopted by ERL (40 ml and 500 ml) or in 1 $dm^3$ Marinelli beakers.

Table 6. Lower limits of detection (2 sigma) of selected radionuclides in milk and food samples by use of high-resolution gamma spectrometry system with detector of 90% relative efficiency (1.33 MeV) - 40 ml cylindrical geometry.

| **Nuclide** | **Zr-95** | **Ru-103** | **I-131** | **I-132** | **Cs-134** | **Cs-137** | **Ce-144** |
|---|---|---|---|---|---|---|---|
| LLD (15 min), Bq/kg | 1.1 | 1.0 | 0.9 | 0.7 | 0.9 | 1.4 | 6 |
| LLD (20 h), Bq/kg | 0.12 | 0.11 | 0.1 | 0.08 | 0.1 | 0.15 | 0.65 |

Notes:

1. The upper values refer to measurement of 15 min duration (typical for emergency conditions) and the lower for measurement of 20 h duration.
2. The values refer to direct measurement of homogenized milk of food samples of 40 ml volume. If ashing of the samples is applied, the LLD values are lower, typically by a factor of 2 - 3 (depending on the water content of the sample).
3. The Cs-134 LLD values (within 0.1 - 0.15 Bq/kg for ashed samples and a 20 h measurement) are in good accordance with the related EU reporting levels, which are 0.5 Bq/l for milk, 0.2 Bq per day or approx. 0.15 Bq/kg for mixed diet (and 0.1 Bq/l for drinking water ) (Ref. 2).

### 5.5.2 Determination of Sr-90

In the case of determination of Sr-90, 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 Sr-90 and Y-90.
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 a carrier.

The LLD (2 sigma) of the method equals 0.05 Bq/kg. It is in good accordance with the related EU reporting levels, which are 0.1 Bq/l for milk, 0.08 Bq per day or approx. 0.06 Bq/kg for mixed diet (and 0.05 Bq/l for drinking water ) (Ref. 2).

The methodology used is based on the EML Procedures Manual (Ref. 1).

## 6. OTHER METHODS FOR RADIOACTIVITY DETERMINATION

These are applied on non-routine basis. Short descriptions are given.

### 6.1. Determination of Cs-137 in seawater

Radiochemical separation based in co-precipitation with AMP. Use of Cs-134 for yield determination. Measurement by gamma-spectrometry. (Methodology - Ref. 1 and 3)

### 6.2. Determination of mixed fission products in seawater

Radiochemical separation based in co-precipitation with $Y(OH)_3$. Measurement by low-beta counting system. (Methodology - Ref. 1 and 3)

### 6.3. Determination of radon concentrations in air

Total alpha-counting with a 0.17 liter ZnS Lucas cell system. Counting efficiency = 70%, LLD (2 sigma) = 20 Bq/m$^3$. The method is suitable for areas of enhanced radon concentrations, but the LLD conforms well with the EU suggested limits of 200 / 400 Bq/m$^3$ for indoor radon concentrations. (Methodology - Ref. 5).

### 6.4. Determination of specific activities and 'equilibrium equivalent concentration' of short-lived radon daughters in air

Three-interval total alpha-counting with a 3.5 cm ZnS scintillation window. Counting efficiency 35%, LLD (2 sigma) = 1 Bq/m$^3$ (for equilibrium-equivalent concentration).

## 7. TECHNICAL DATA OF ANALYTICAL SYSTEMS

### 7.1 High-resolution gamma spectrometry systems

| | |
|---|---|
| Nr of systems | 3 stationary and 1 for in-situ measurements |
| Detector types | HpGe |
| Relative efficiencies | 1 of 20%, 1 of 30% and 1 of 90%<br>(at 1.33 MeV, with respect to 3 x 3 NaI) |
| Energy resolution | about 2 keV at 1.33 MeV |
| Background count rate | about 1 cps within the 30 – 2000 keV region (20% eff). |
| Multi-channel analysers | 4, computer-based, 4000- and 8000-channels,<br>the field system is able of remote transfer of the data |
| Analysis software | full analysis software in all cases,<br>specialized 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 dm³ volume |
| Calibration standards | point source standards,<br>multi-nuclide standard solutions<br>multi-nuclide standards of different density (geometry 3) |
| Methodology | Ref. 4 |
| Quality assurance | - regular participation in international intercalibration exercises.<br>- check measurements once per week for each system<br>- background measurements on a monthly basis |

### 7.2 Alpha spectrometry systems

| | |
|---|---|
| Nr of systems | 2 |
| Detector types | silicon surface-barrier detectors |
| Detector areas | 300 mm$^2$, 1200 mm$^2$ |
| Energy resolution | < 25 keV at 6 MeV |
| Background count rate | below 1 cps within the 1 – 9 MeV region |
| Multi-channel analysers | 2, computer-based, 2000-channel |

| | |
|---|---|
| Analysis software | specialized analysis software,<br>specialized natural and artificial radionuclide libraries |
| Calibration standards | triple transuranium standard source |
| Methodology | Ref. 4 |
| Quality assurance | calibration and background measurements once per week |

### 7.3 Low-beta counting system

| | |
|---|---|
| Nr of systems | 1 |
| Detector type | gas flow proportional counter |
| Counting efficiency | approx. 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 specialized 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 | K-40 and Cs-137 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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4. A Handbook of Radioactivity Measurements Procedures, NCRP Report No 58, Washington, USA (1978).
5. 'Metrology and Monitoring of Radon, Thoron and their decay products', NEA / OECD Experts Report, OECD 1985, Paris.

**APPENDIX 4**

## ERL - STRUCTURE AND PROCEDURES

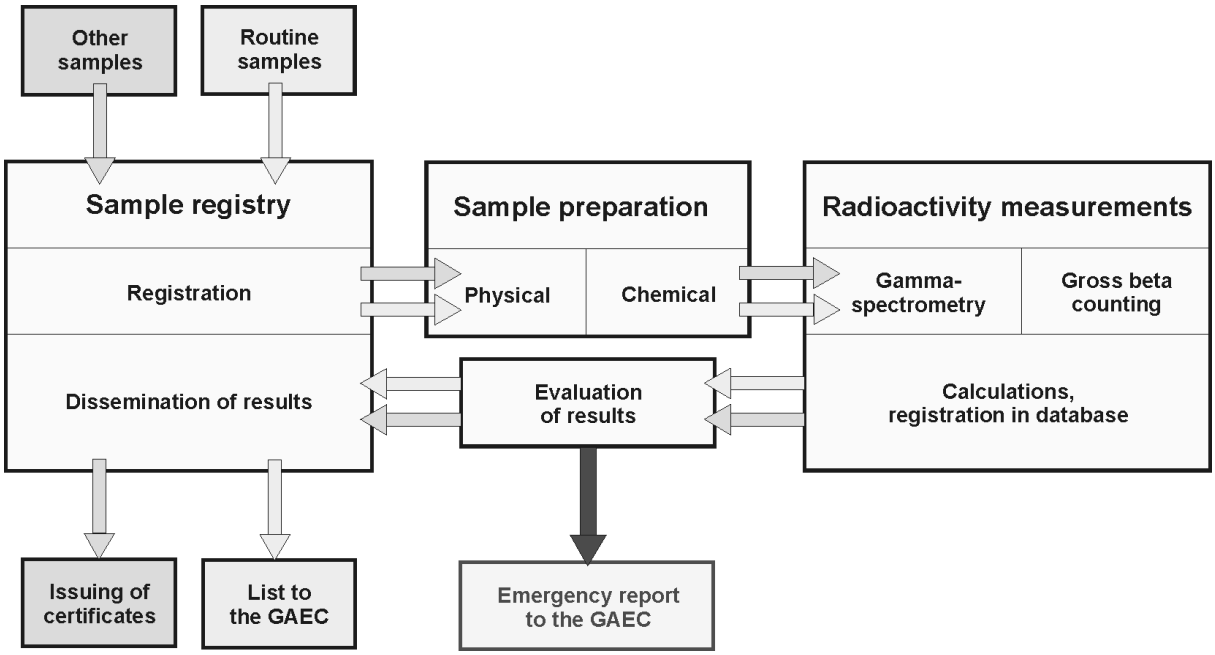
The ERL is staffed with 4 scientists (2 physicists, 1 biologist and 1 mathematician) and 5 technicians.

The ERL consists of 3 basic units:

a. The Sample Registry unit (where both registration of samples and issuing of output documents takes place.

b. The Sample Preparation unit (including separate divisions for physical and chemical treatment of the samples).

c. The Radioactivity Measurements unit (including separate divisions for gamma-spectrometry and gross-beat / other types of measurements.




### 1. Sample and measurement results flow

The routine control samples are registered under a unique sample name. The registration information includes all the necessary data (sample type, sampling period, date and time of sample arrival, sampling location, sample volume (or mass) etc.).

Where necessary, the sample is directed to the Sample preparation unit and is treated physically and/or chemically. The parameters and results of the treatment are added to the sample registration document.

After the physical and/or chemical treatment, the sample proceeds to the Radioactivity measurements section. The direct result(s) of measurement are also added to the sample registration document. In most of cases 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 by use of calculation MS Excel spreadsheets, where the whole sample data are recorded too. These files are used for electronic storage of the results, in parallel to their physical (paper) records storage. In addition, the routine control samples (or what was supplied for measurement after their pre-treatment) are stored at least for 5 years, for comparison / reference purposes.

## 2. Evaluation of results

In most cases the final results are evaluated by the measuring operator for compliance with defined activity concentration limits. When these limits are exceeded, the operator informs the responsible scientist (the Head of Laboratory or his/her deputy). According to the type of the sample and/or the value of the abnormal result, the evaluating person may order additional measurement(s), formulate a special certification document and/or inform the Greek Atomic Energy Commission (GAEC) for a case requiring a consideration of emergency.

## 3. Dissemination of results

Under normal conditions, 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 the ERL.

In the case of emergency, the frequency and the type of results provided to GAEC is determined by the related Nuclear Emergency Plan and may be a subject of modifications according to the specific needs.

**APPENDIX 5**

## ERL - SUMMARY OVERVIEW OF MAJOR CHANGES SINCE 2000

### 1. Air measurements

A common type of air sampler is used in the sampling network. The Lamia station is not used any more. A new telemetric meteorological device is operating in Demokritos station. Measured quantities include temperature, relative humidity, wind direction and speed, solar radiation intensity and precipitation.

### 2. Deposition measurements

New stainless steel vessels will replace the old plastic ones within 2005. The location of the main deposition sampler in Demokritos station has been change to ensure minimum interference from the surrounding environment.

### 3. Gamma measurements

Two new measuring stations have been added in Aliveri and Argostoli.

### 4. Milk measurements

The number of Greek milk producers providing samples has been increased to 10.

### 5. Mixed diet measurements

The quantity of the food mixture has been doubled in order to increase the sensitivity of the measurement. The sampling strategy has been changed to assure wider production coverage.

### 6. Calculations and data storage

New MS Excel spreadsheets are used since 2003 for calculation and storage of the results of environmental radioactivity control.

Sample printouts are provided separately for:

- air sampling at the Demokritos station (where additional measurements are made to estimate the radon and thoron progeny)
- air sampling at the Kerkyra station
- Cs-137 and Sr-90 in milk
- Cs-137 and Sr-90 in mixed diet
- total beta in deposition (Demokritos)
- total beta in water (Marathon lake)
- all gamma-spectrometry measurements

In some cases copies of the initial hand-filled data sheets are given as well.

**APPENDIX 6**

**ERMD - ENVIRONMENTAL SAMPLING PROVISIONS**

| Sampling | Sampling frequency | Sampling locations | Details |
|---|---|---|---|
| Reservoirs waters | monthly | 4 | 1 sample from the reservoir exit |
| Lake waters | 2 samples every 3 months | 3 | 1 sample from the center of the lake |
| River waters | monthly | 4 (rivers from the Greek Northern borders) | Fixed sampling points |
| Air | monthly | 200-300 m distance from the GRR-1 stack | Sampling duration is 8-10 days |
| Air | 3 times a month | 200-300 m distance from the GRR-1 stack | Sampling duration is 24h |
| Soil | 3 times a year | 3 different areas in NCSR | Each area has 6 sampling points |

**APPENDIX 7**

## ERMD - LABORATORY EQUIPMENT AND ROUTINE MEASUREMENTS

### 1 Analytical equipment

| Type of equipment |
|---|
| 3 low background gamma-spectroscopy systems (HPGe 70%, 50%, 20%) |
| 3 portable gamma-spectroscopy units (HPGe 35%, 20%, 35%) |
| Alpha/beta proportional counter (one gas-flow proportional counting system OXFORD-ECLIPSE and one proportional gas chamber Thermo Eberline FHT 1100) |
| Alpha-spectroscopy (12 chambers) Canberra Alpha Analyst |
| X-Ray Fluorescence Spectrometer |
| Greek Gamma Dose Telemetric Network with 4 gamma water monitors and 25 wide range detectors for gamma dose rate measurements. Each detector has a sensitivity less than 10 nSv/h for 10 minute measurement. |
| Several portable γ-radiation survey instruments |
| Portable radiation survey instruments for α, β, X rays |
| Portable air sampling system (3 units) |

### 2. Routine checks

| Samples | Radionuclide categories |
|---|---|
| Air | Ambient gamma dose |
| Airborne particulates | Gross-beta, Cs-137 |
| Surface water | Residual beta, Cs-137 |
| Drinking water | Cs-137, natural radionuclides |
| Milk | Cs-137, K-40 |
| Mixed diet | Cs-137 |

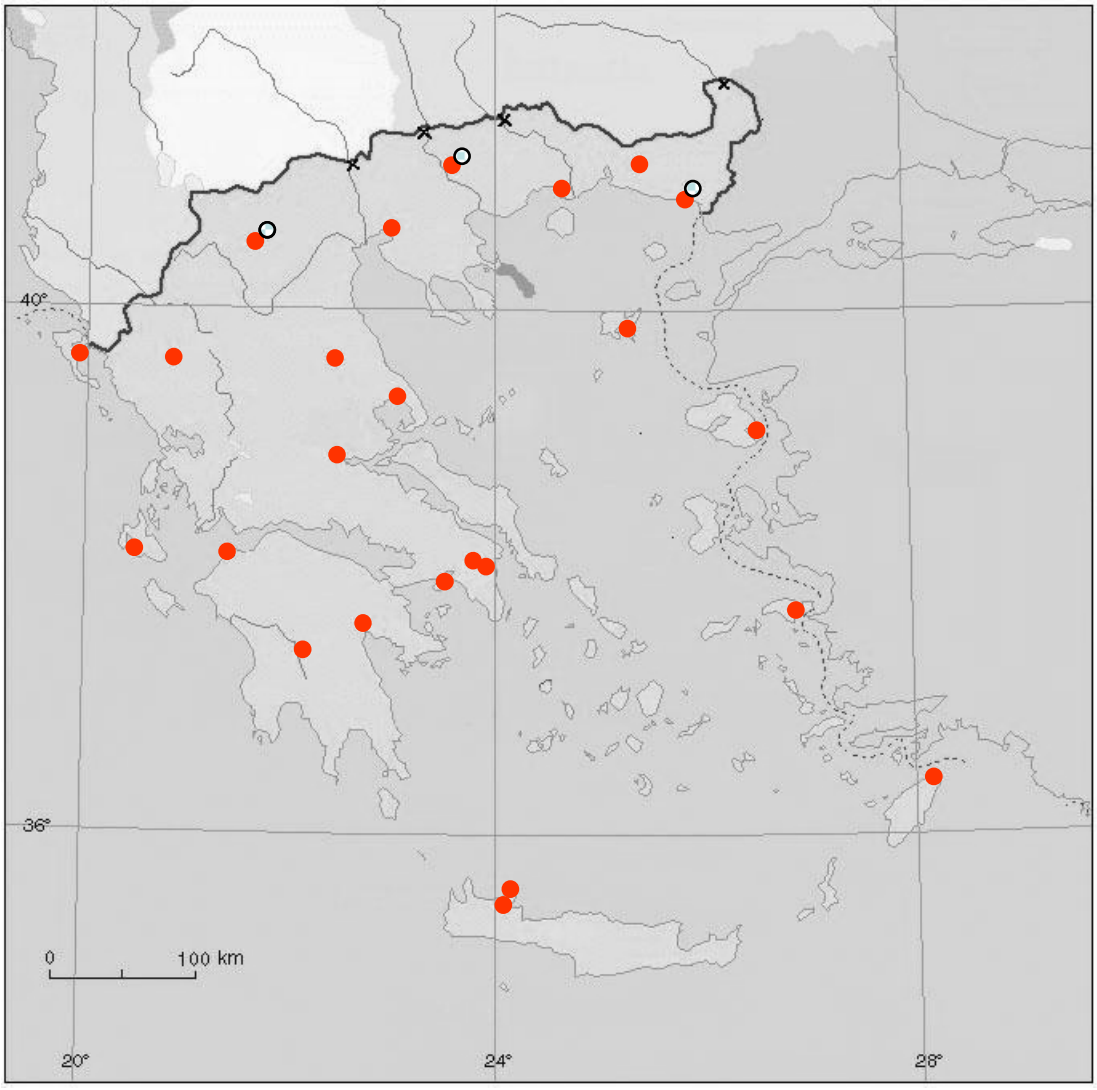
### 3. Analytical methods

- Alpha spectrometry. Isolation and precipitation of Uranium, Thorium, Plutonium and Americium in water, vegetation and soil.
- Isolation and determination of Cs-137 in water and milk.

**APPENDIX 8**

## ERMD - TELEMETRIC RADIOACTIVITY MONITORING NETWORK

### 1. Locations




1.1 The dose rate meters (dark spots) are located at:

| | | | | |
|---|---|---|---|---|
| Alexandroupolis | Ionnina | Larissa | Megalopolis | Patra |
| N. Philadelphia | Kavala | Lamia | Nafplion | Salonica |
| Volos | Kefalinia | Lesbos | Ptolemais | Samos |
| Corfu | Komotini | Limnos | Rhodos | Serres |
| Souda | Chania | A. Paraskevi | Salamis | |

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

1.3 Circled spots are the locations of the aerosol measuring devices: Alexandroupolis, Serres and Ptolemais.

### 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 4π 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 |

### 4. Aerosol Systems

| | |
|---|---|
| Aerosol filter | Glass fibre filters 0.5 μm (60 mm)<br>Active carbon filters (60 mm) |
| Pumping stystem | ~ $6m^3/h$ |
| PIPS detector | Aerea: 1700 $mm^2$<br>Resolution: ~55keV - α<br>~30 keV - β |
| NaI detector | 2" PM-tube<br>Resolution: 8.5% (662 keV Cs-137) |
| Gamma Dose rate | Proportional chamber |
| Meterological data | Temperature, wind velocity and direction, και rain-gauge |