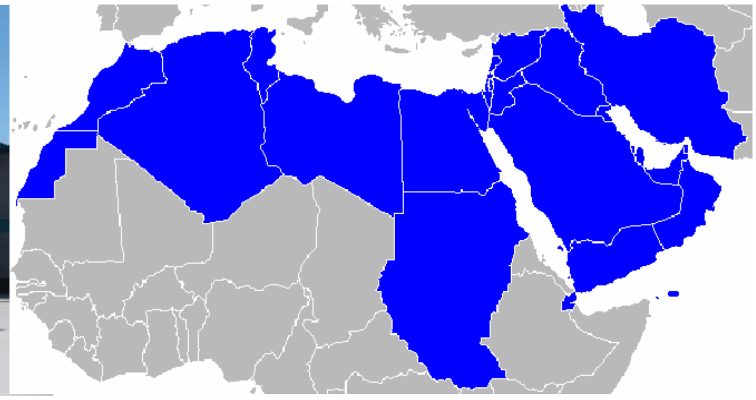
Report on

Collaborative Research and Development of Environmental Radiation Detection Stations (ERDS)



By:

Ilham Al-Qaradawi (Prof.), Qatar University, Doha, Qatar

ilhamq@gmail.com

Ektemal Al-Nemri (Dr.), JNRC, Amman, Jordan

ektimal_n@yahoo.com

Tahar El-Khoukhi (Dr.), CNESTEN, Rabat, Morocco

telkhoukhi@yahoo.com

April 2012

Abstract

In the present work, three Subject Matter Experts (SMEs) from three Middle East and North Africa (MENA) region countries (Qatar, Jordan and Morocco) present the results of their research study concerning establishing a concept of collaborative exchange of information for the real-time radiological monitoring of the environment to be able to detect the anomalous presence of anthropogenic radionuclides. This exchange is proposed to be supported by a regional network of detection systems and electronic data transmission following functional criteria proposed by the SMEs.

The main objective of this work study is to foster a system capability in the region that measures and analyzes radiation in the environment. The data provided by the system would be used to establish radiological background, baseline levels and to assess any radiological incident or nuclear accident; knowing that classical industrial accidents may also induce radiological situations such as happened at Acerinox in Algeciras, Spain in 1998.

This work was performed in the frame of a Visiting Research Scholar Study under the auspices of Sandia National Laboratories International Program Office.

The study consists of the definition of the objectives of an Environmental Radiation Detection Station (ERDS), the definition of technical criteria of the systems to achieve these objectives, and pointing out the necessity to share the information obtained.

The concepts in preparing this work were inspired by individual radiological detection stations already existing in the region and the experience of regional networks elsewhere in the world. In this effort the radionuclides of interest, the technologies needed for measurement, analysis, and communication are discussed. This report also discusses the types of information to exchange as well as the difficulties and challenges that might arise. Finally perspectives and recommendations are proposed.

The summary recommendations are:

- An ERDS should be installed in various places of MENA region countries. The data should be exchanged for reporting purpose and alerts.

- The ERDS should operate in real time to be effective.

- It is proposed that a prototype network consisting of at least three stations will be established across the region as a starting point.

- A network could use existing and/or new stations. A station should consist of at least one radiation detector.

- Standardization of data collection and analysis between the various stations is essential.

- The locations of stations need to be determined according to the requirements of each country and whether a new facility or an existing one will be used.
- Any first technical steps should be small and simple. A small, demonstration proof-of-concept test could form the nucleus of larger, future network design.
- There are numerous opportunities to gain from the experience and expertise regarding networks already in existence in other regions, such as the European, German, and CTBTO.
- The draft Visiting Research Scholar Report on the ERDS concept should be sent by the authors to the regional participants and workshop instructors for review, comment, and finalization.
- Regional subject matter experts at the ERDS Workshop expressed interest in joining a working group to refine the ERDS network concept. The refined concept could be distributed to their relevant institutes to identify which institutes in the region are interested.
- Internal and external regional project support could be solicited as a group. Arab Atomic Energy Agency (AAEA) concurrence of the ERDS network as a regional concept should also be sought. A regional approach could be explored under the technical umbrella of the International Atomic Energy Agency (IAEA).

Acknowledgment

This work is the result of close collaborative efforts between three Subject Matter Experts from the MENA region. The meeting of these three experts was made possible with the financial and logistical support of the Visiting Research Scholar Study Program under the auspices of Sandia National Laboratories International Program Office.

Not only the material support that was provided by this Program, but also the most important contribution were the kind discussions and exchange of ideas concerning the topic of this meeting with SNL Experts, namely: Dr. Faraj GHANBARI, Dr. David BETSILL, Mr. Mark MILLER, and Dr. Amir MOHAGHEGHI.

In addition to this SNL Expert team, our stay at the Laboratory was made comfortable in Albuquerque NM by the kind attentions of Mrs. Patricia DICKENS, Ms. Anita ROMERO, Mrs. Suzanne CORDOVA, and Mr. Scott STRUVE of the International Protocol Office at Sandia.

1. Introduction:

Nuclear accidents such as Chernobyl and Fukushima, as well as radioactive incidents or industrial accidents like the Algeciras Steel Mill Cs-137 release [7-13] (Figure 1 and Appendix 1), showed that even countries without any nuclear facilities can produce and/or being vulnerable to radiological contamination. This is due to travel of radiation across borders of countries and even continents. Society is faced with increasing threats from man-made disasters from radiological or nuclear sources which can be triggered by accidents or through intentional actions, such as terrorist attacks. Moreover several nuclear energy programs are starting in the region and in neighboring countries, which may raise concerns in the regional area if unplanned events were to occur in these facilities.

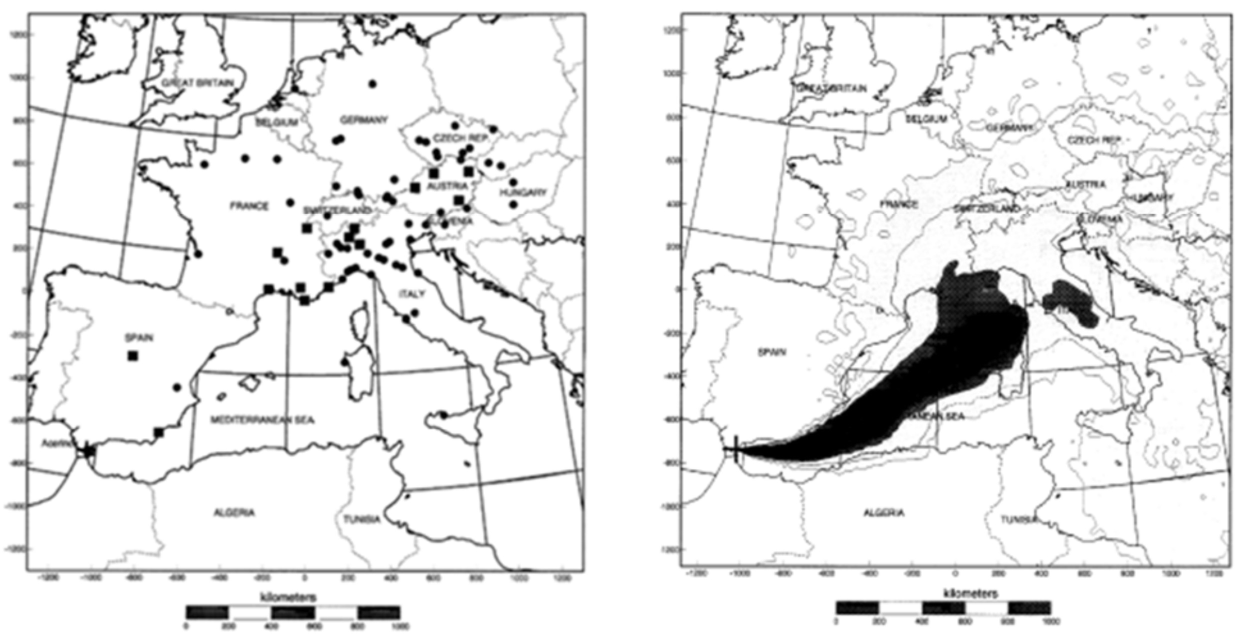


Figure 1: Algeciras Acerinox accident [11], (a) Measurement locations, (b) ^{137}Cs plume from release.

The controlled release of radionuclides from nuclear facilities to the atmospheric and aquatic environments is an important issue. An essential element in the control of the discharges is regular monitoring – both at the source of the discharge and in the receiving environment – to ensure the protection of the public and the environment [6].

The uncontrolled release of radionuclides from nuclear facilities to the atmospheric, aquatic, and terrestrial environments may occur as a result of a nuclear or radiological accident. Monitoring of the accidental release at its source, and especially the direct monitoring of the environmental contamination with radionuclides, is necessary for the assessment and execution of actions for public protection and longer term countermeasures as well as emergency occupational radiation protection. In such cases individual monitoring may also be justified.

In this report we will focus on environmental radiation detection and monitoring network that requires automatic air sampling, radionuclides detection, and identification. The transport media selected for the focus of the study is the air since airborne radiation in the environment spreads the fastest and most widespread via atmospheric movement.

An emerging activity in the security arena is developing methods to minimize the public health and economic impacts of a large-scale accident or terrorist attack. One approach for avoiding or mitigating the impacts is to perform monitoring in the context of Environmental Radiation Detection Stations (ERDS). Several regions of the world share real-time ERDS information through regional networks such as in North America, Europe, and Asia**.** Therefore, a regional ERDS network for the MENA region would also be advantageous for the public and environment.

In addition, there is a global network organized by the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO), which has monitoring stations all over the world (Figure. 2).

ERDS detect, characterize, and report anomalous releases to provide scientific-based information for mitigation responses, and when necessary, transmits information that can help scientists evaluate the risks to the population and the environment in order to inform decision makers.

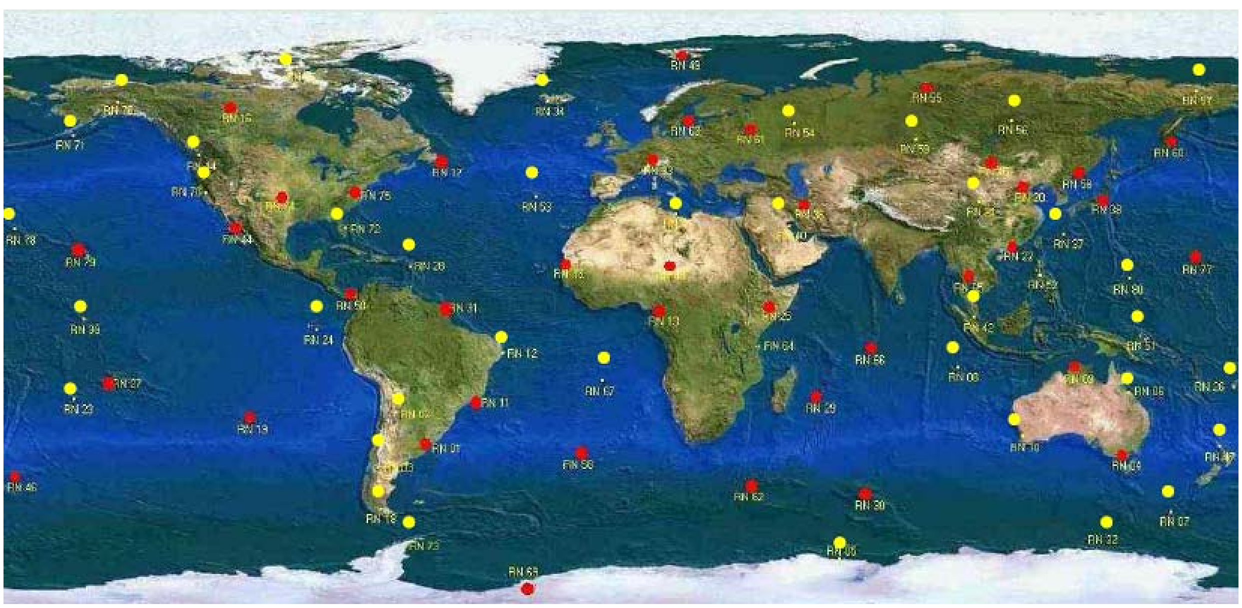


Figure 2: CTBTO Radionuclide Monitoring Network consist of 80 Radionuclide stations, 40 particulate monitoring stations (yellow), and 40 particulate and noble gas monitoring (red) [14].

2. Objectives of the Current Study:

Prepare a proposal concept for a regional ERDS network and radiological monitoring program for the MENA region.

The goal of this ERDS is to reliably identify radionuclides over a wide energy and concentration range over a wide geographic area. The identification should be in real time to permit an effective local response that mitigates or avoids entirely the adverse impacts that may result from a release or contamination event. The core of ERDS is a monitoring technology that, ideally, would detect or screen for a variety of radionuclides over a wide area and to share that information with others.

3. Scope of Work for the Study:

A team of three Subject Matter Experts (SMEs) were brought together for two weeks to define the problem and critical parameters for a monitoring system (to reflect and discuss early warning and radiation monitoring and detection) with support from Sandia National Laboratory. The team goals were to study and establish standards for data collection, analysis, sharing, and system management. The results will support future implementation of a possible regional monitoring system.

In this effort the radionuclides of interest and the technologies needed for measurement, analysis, and communication were discussed. The SMEs also discussed the type of information to exchange as well as the difficulties and challenges that might arise. Finally, perspectives and recommendations were proposed.

4. Advantages of a Regional ERDS:

Several regions of the world share ERDS through regional networks such as European and Asian networks. Therefore, a regional ERDS network for the MENA region would be advantageous for detection of radiation in the environment. This current study deals with monitoring and trending baseline background levels, and any radiological incident or nuclear accident, knowing that classical industrial accidents may also induce radiological events, such as happened at Acerinox in Algeciras, Spain in 1998. The main advantages of an ERDS can be summarized as the following:

- Continuously monitor and identify potential environmental problems and to provide information to evaluate the need for remedial actions or measures to mitigate the problems.

- Reliably identify radionuclides over a wide energy and concentration range over a wide geographic area. The identification should be in real time to permit an effective local response that mitigates or avoids entirely the adverse impacts that may result from a contamination event.
- Therefore, the core of ERDS is a monitoring technology that, ideally would detect or screen for a variety of radionuclides over a wide area.
- Providing monitoring for any anomalous radiation coming across borders.
- Proposing a regional network similar to the, EPA(1) Asian(2) and European(3) networks in order to share and verify the data between countries.
- Detecting, characterizing, and reporting any releases to the environment that can help scientists evaluate the risks to the population and the environment in order to inform decision makers and emergency response personnel to make recommend actions that minimize the impact to people and the environment.

5. Objectives of an ERDS:

The fixed monitor network is designed to accomplish the following objectives (26):

- Provide data to determine national impact of event in cities across the nation which may not monitor for contamination, especially if projections of contamination spread do not indicate large potential impact. (The system will provide data covering large cities as well as large areas of the nation.)
- Provide data quickly to decision makers and the public to provide assurance to citizens and decision makers in unaffected areas that the airborne radionuclide concentrations are normal under normal conditions.
- Provide data to decision makers to assist in prioritizing follow-up monitoring requirements and response resource allocation under abnormal conditions.
- Assist in identifying non-impacted areas by providing modelers and decision makers with “zeros” for areas where contamination is not present or is present below the detection levels, which are designed to be significantly below protective action guidance levels.
- Provide gamma radiation and airborne radioactive particulate data to modelers to assist in validation of model output or adjustment of input parameters.
- Assist decision makers in determining follow-up monitoring requirements and response resource allocation.

6. The Ideal Environmental Radiation Detection System:

Radiological monitoring systems have been considered previously by other agencies. For example, the International Life Science Institute recommends that an ideal ERDS should include the following [(4)]:

- “Exhibits warning in sufficient time for action.
- Affordable cost.
- Requires low skill and training.
- Cover all potential threats.
- Identifies the source.
- Gives minimal false positive or negative responses.
- Exhibits robustness.
- Allows remote operation.
- Functions all year round.
- Demonstrates sensitivity to quality changes at regulatory levels.
- Minimum maintenance actions.

7. The ERDS Core Criteria:

- Provide rapid response.
- Screen for a number of contaminants while maintaining sufficient sensitivity.
- Perform as automated systems that allow for remote monitoring.

8. Technical Characteristics for ERDS Network for the MENA region:

An ERDS is a system that measures and analyzes radiation in the environment. The data provided by the system is used to establish the background, and to assess the impacts of an anomaly or accident if it occurs. Therefore, the system should also transmit early warnings and give alarms if abnormal radiation is detected in order to trigger mitigation responses to lessen the accident’s impact on lives and property.

- An ERDS should be installed in various places of MENA region countries. The data should be exchanged for reporting purpose and alerts.

- The ERDS should operate in real time to be effective. This requires the availability of real-time data feeds to detect abnormalities as soon as they occurred and disseminate warnings. We have to stress the importance of a real-time Information Technology infrastructure to support early detection applications.

- It is proposed that a prototype network consisting of at least three stations will be established across the region as a starting point, providing geographic coverage. This builds on current expertise available in some countries of the region and makes use of experiences that exist in other regions. While the prototype network would start small, it could be used to better understand the issues and technical considerations applicable to a larger, region-wide network.

- An ERDS could use existing and/or new stations. A station should consist of at least one radiation detector. However, more capabilities can be added within the network to provide more detailed information. For example, adding detectors for radionuclide identification and gross alpha beta measurements as well as air sampling for delayed measurements. The information from the three ERDS can be used in concert with available plume-modeling software to determine plume data.

- A model is recommended to be available for analyzing plume data which will populate a database that can be used for simulating the migration path of the plume. The dispersion model can also provide quantitative data regarding the hazardous plume component, such as the identity and concentration of any radionuclides detected.

- Availability of collecting metrological parameters such as temperature, wind velocity and direction, atmospheric pressure, and precipitation is advantageous (and necessary for plume modeling), as can be shown in Figure 3.

- Standardization of data collection and analysis between the various stations is essential. The minimum requirement for the prototype should include a dosimeter for total dose rate, a gamma detector for identification of gamma emitters in the atmosphere by means of high volume air sampler, and a gross alpha/beta counter.

- The locations of stations need to be determined according to the requirements of each country and whether a new facility or an existing one will be used.

Figure 3: Example of radiation monitoring station developed by US EPA RadNet. The system includes meteorological data collection (24).

9. Alarm Levels and Response:

The alarm should be activated when the radiation level at the stations exceeds pre-set criteria. On one hand, concerning the dose rate the alarm can be triggered if the value is three times the background level or more. On the other hand, for anthropogenic radiation, the criteria can be 3σ above the background. In Figure 4 we can see the detected ^{137}Cs in Italy after Algeciras industrial accident which triggered the alarm.

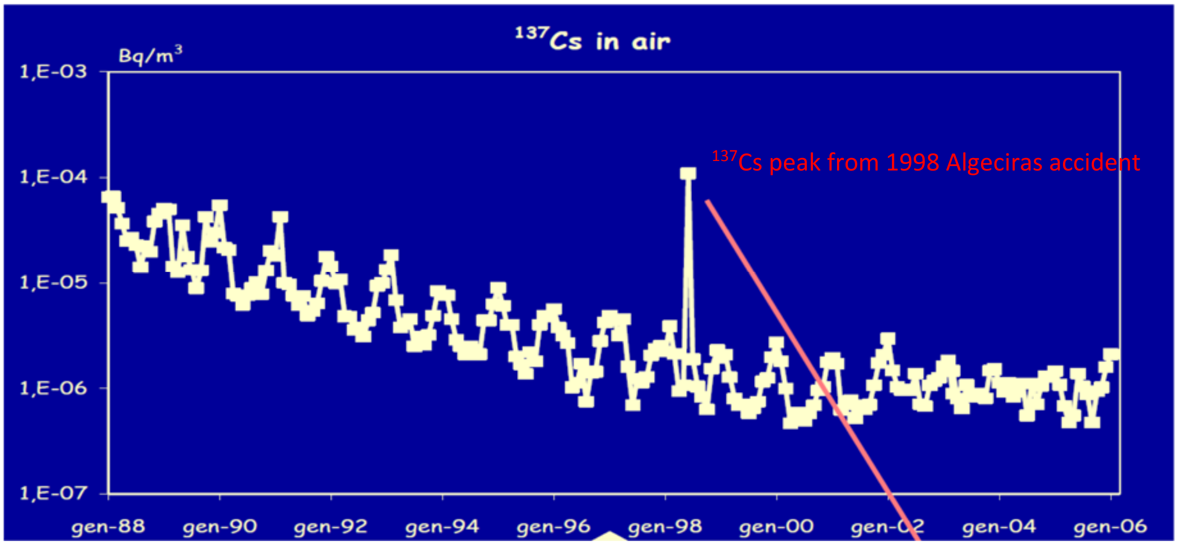


Figure 4: Detection of Algeciras ^{137}Cs accident in Italy is an example of an alarm identification[13]

- The basis for setting alarm levels will depend on the capability of the ERDS employed.
- It should also be noted that the alarm should be triggered by a combination of events, not a single detection, which may be a false positive.

10. ERDS System Quality System and Management:

The use of quality assurance should be an integral part of a monitoring program (for source, environment, and individual). Quality assurance should be used to provide for a disciplined approach to all activities affecting quality [6].

In order to ensure that data are accurate, reproducible, of known and desired quality, and suitable for their intended use, a formal, documented, and monitored system of quality assurance (QA) and quality control (QC) activities is required. The Quality System (QS) will provide the needed management and technical practices to assure that environmental data are of adequate quality and usability. This Quality System must function in both routine and emergency situations. It must include requirements and guidance for operational aspects starting from sample collection to reporting and data sharing. Such requirements can be summarized as following [6, 25]:

- Adequacy for the work to be performed.
- The systems are maintained and monitored to prevent adverse impact on data quality.
- The staff should be well qualified and trained.
- Personnel qualifications and training are fully documented.
- Availability of Quality Management Plan, Quality Assurance Manual (QAM), and applicable Standard Operating Procedures (SOPs).
- The organizational structure, functional responsibilities, levels of authority and interfaces for those managing, performing and assessing the adequacy of work are defined.
- All management measures, including planning, scheduling and resource considerations, are addressed.
- Uncertainty analysis.
- Record keeping requirements.
- The adequate qualification and training of personnel for the facilities in which they are required to work.
- Periodic audits and inspections should be conducted.

The Quality System must ensure continuous assessment of the capabilities of the analytical methods to meet the required data quality objectives (DQOs), monitor the routine operational performance of the instruments and equipment and perform corrective actions as necessary.

A program to assure the reliability of the data collected from ERDS needs to be in place by implementing quality control and quality assurance:

- Quality control requires regular checking of energy and efficiency calibration and resolution via control charts using standard reference materials.
- Inter-laboratory comparisons at the national or international level for methods and instruments are in place.
- For quality assurance the documentation of technical procedures, logbooks, and quality manuals will be required.

- **System Planning:**

Before initiating an early warning monitoring program, a comprehensive plan should be developed for the interpretation, use, and reporting of monitoring results. Ideally, the plan should be developed in coordination between scientists and evaluation of characteristics of similar already installed system that may exist elsewhere worldwide.

11. Data Communication:

One of the challenges of a continuous, real-time monitoring system is management of the large amounts of data generated. Use of data acquisition software and a central data management center is critical. This will require that individual sensors deployed in the system be equipped with transmitters, modems, internet, or some other means to communicate the data to the acquisition and management systems.

The data management system should also be capable of performing some level of data analysis and trending in order to assess whether or not an alarm level has been exceeded. The use of "smart" systems that evaluate trends and can distinguish between genuine excursions and noise could minimize the rate of false alarms.

The data collected from monitoring stations should be secured and undergo a process of authentication, to ensure the integrity of the data from the distributed monitoring stations has not been compromised, either accidentally or on purpose, either at the station or during the data transmission. See Appendix (F) for examples of technologies used for data authentication and security.

12. Open Questions Regarding an ERDS:

A number of issues arose during the ERDS study that remain as Open Questions. These open questions were discussed among MENA technical colleagues in order to develop an ERDS concept that is useful for all participants.

- Human resources: Capacity building programs need to be initiated to prepare the necessary human resources required for ERDS network. This includes physicists, computer programmers, engineers, radiation protection, communication experts, etc.
- Technologies: Rapidly changing technologies and high prices.
- Maintenance: Skilled technical personnel, spare parts, and infrastructure are essential.
- Transparency of process and data.

- Budget.
- Stake holders' commitment(s)/acceptance.
- How to share data? Immediately? With delay? Data storage? Archiving & retrieval?
- Use existing stations or build new ones?
- System data management details.
- System maintenance and management

13. Outputs of Second Annual Cooperative Workshop on ERDS in Morocco, June 7, 2012:

During a fruitful and positive discussion at the Workshop on the concept of a possible ERDS network in the MENA region, we conclude the following:

- There are numerous opportunities to gain from the experience and expertise regarding networks already in existence in other regions, such as the European, German, and CTBTO.
- The draft Visiting Research Scholar Report on the ERDS concept should be updated with comments offered during the discussion session at the Workshop from their subject matter colleagues. The Report should then be sent by the authors to the Workshop/ERDS participants and to the Workshop instructors for review and comment; and refining next steps.
- Several MENA country Subject Matter Experts at the Workshop expressed interest in joining an ERDS Working Group and to participate in refining the concept of a ERDS network. They are keen and willing to collaborate in order to make this network a regional success.
- The concept of an ERDS network developed by the MENA participants could be distributed to their relevant institutes in the MENA region countries. This will allow the participating countries and institutions who are interested in a regional ERDS network to be identified.
- After identifying which countries are interested in collaborating on an ERDS network, the parties can proceed to refine the concept and to apply for internal and external regional project support. In addition to their own countries, additional potential sponsors include the IAEA Technology Cooperation program. The participants may also want to seek AAEA concurrence of the ERDS network as a regional concept.

- Any first technical steps should be small and simple. A small, demonstration proof-of-concept test could form the nucleus of larger, future network design. A regional project could be implemented under the umbrella of IAEA.

14. Recommendations and Future Work:

- Generate this final report of the study with recommendations on the path forward for future implementation of a comprehensive regional monitoring system.
- Design an ERDS prototype that could be used in this project as a proof-of-concept technical demonstration. Developing the data sharing process and protocol would be a good first step of the demonstration design.
- Install and test the ERDS prototype at agreed suitable host location to be used in this project.
- Evaluate the progress of the prototype, report results to the ERDS members, and propose next steps plus lessons learned for use in a regional MENA approach to ERDS.
- It is essential for the implementation of the ERDS concept to be flexible and progressive. For example, we can start with small stations in a few countries containing one measurement unit; but with the possibility to expand and add more measurement instruments, locations, countries, etc.
- Expand ERDS concept and prototypes to more countries within the MENA region.

15. Conclusions of the MENA Collaborative ERDS Study:

It is generally recognized that it is fundamental to establish effective ERDS to better identify the risk and occurrence of radioactive hazards and to better monitor the level of the risk to a population and environment.

The resources necessary for the development, installation, operation, and maintenance of an ERDS will be substantial; therefore, virtually all of the decisions must be made in collaboration with local or regional level stakeholders.

The results of an ERDS can be used for the environmental and health risk studies, emergency response, and decision making, etc., by a regional program.

An ERDS collaboration can start small but it is open for all the countries in the region. Taking into account the importance of having more participants, which is necessary to have a powerful and effective environmental radiation detection capability.

A regional comprehensive ERDS can be built, based on the many existing systems and capacities. This will not be a single, centrally planned and commanded system, but a networked and coordinated assemblage of nationally owned and operated systems.

A regional approach to ERDS will also guarantee consistency of warning messages and mitigation approaches globally, improving, as a result, coordination at a multi-level scale.

Discuss the path forward for development of requirements for a prototype ERDS in the region and the purpose of such system; basic design requirements and basic performance are required.

References

1. http://www.epa.gov/radnet/.
2. http://www.cscap.nuctrans.org.
3. http://radiationnetwork.com/Europe.htm.
4. Early Warning Monitoring to Detect Hazardous Events in Water Supplies. International Life Science Institute Workshop Report, 1999. Thomas Bronson.
5. IAEA Safety Reports Series no. 64, Programmes and Systems for Source and Environmental Radiation Monitoring, 2010.
6. IAEA Safety Standards Series, Safety Guide no. RS G-1.8, Environmental and Source Monitoring for Purposes of Radiation Protection, 2005.
7. Europe Radiation Rise Linked to Accident, Published by The New York Times, June 14, 1998.
8. A. Baklanov et al., "Evaluation of Source–Receptor Relationship for Atmospheric Pollutants using Approaches of Trajectory Modelling, Cluster, Probability Fields Analyses and Adjoint Equations" in Atmospheric Pollution Research 2 (2011) 400-408.
9. http://www.iaea.org/Publications/Booklets/SealedRadioactiveSources/scrap_lessons.html, Reducing Risks in the Scrap Metal Industry.
10. http://www10.antenna.nl/wise/index.html?http://www10.antenna.nl/wise/495/4895.html, WISE NERDS Communique on August 7, 1998.
11. P. J. Vogt, B. M. Pobanz, F. J. Aluzzi, R. L. Baskett, and T. J. Sullivan "ARAC Simulation of the Algeciras, Spain Steel Mill CS-137 Release," American Nuclear Society, September 14-17, 1999.
12. http://sti.srs.gov, WSRC-MS-99-00660 Modeling Atmospheric Deposition from a Cesium Release in Spain Using a Stochastic Transport Model, Robert L. Buckley Westinghouse Savannah River Company Savannah River Site Aiken, SC 29808.
13. http://www.terviseamet.ee, ARPA Lombardia (Italy), "The Environmental Protection Agency of Lombardia."
14. http://www.arpa.fvg.it/fileadmin/Temi/Radiazioni/Radiazioni_ionizzanti/Chernobyl_25/presentazioni_convegno/NADALUT.pdf.
15. http://www.ctbto.org/verification-regime/the-global-communications-infrastructure/page-1-gci/.
16. http://rem.jrc.ec.europa.eu/RemWeb/activities/Ecurie.aspx.
17. http://tomcat.apache.org/tomcat-6.0-doc/ssl-howto.html.
18. http://www.cmc.sandia.gov/cmc-papers/jnc-paper.pdf.
19. http://www.microsoft.com/resources/documentation/windows/xp/all/proddocs/en-us/sec_vpn.mspx?mfr=true.
20. http://www.iaea.org/OurWork/SV/Safeguards/Symposium/2010/Documents/PapersRepository/1181371150124073732628.pdf.
21. Thermo Eberline user manuals.
22. CNESTEN, Internal Report, June 1998.
23. A. Noureddine, A. Hammadi, R. Boudjenoun, M. Menacer, A. Allalou, M. Benkrid and M. Maache, "Evaluation Of The Radiological Situation In Algeria after the Algeciras Incident," Mediterranean Marine Science Vol. 4/2, 2003, 59-63.
24. http://www.epa.gov/radnet.

25. Expansion and Upgrade of the RadNet Air Monitoring Network, V. 1 of 2, Radiation Advisory Committee RadNet Review Panel, Science Advisory Board, U.S. EPA, Office of Radiation and Indoor Air, 2005.
26. http://www.scribd.com/doc/29740499/Expansion-and-Upgrade-of-the-RadNet-Air-Monitoring-Network-Vol-1#outer_page_26.
27. http://environweb.lanl.gov/newnet/.
28. http://www.lanl.gov/environment/air/airnet/description.shtml?photo=2.
29. http://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-04-0195.
30. http://www.lanl.gov/environment/air/airnet/description.shtml?photo=3.
31. http://www.lanl.gov/environment/air/airnet/detail_description.shtml.

APPENDICES

Appendix (A): ^{137}Cs Accident Detection in Algeciras, Spain

In May of 1998, an unnoticed caesium-137 source was unintentionally melted in an electric furnace of Acerinox, a stainless steel factory located in Spain. As a consequence, the vapors resulted in contamination of the 270 tonnes of stack dust already collected in the process. The first warning of the event was in early June from a gate monitor that alarmed on an empty truck returning from delivering the dust. Several days later elevated levels of caesium-137 were also detected in Southern France and Northern Italy (9).

On June 11 it was made public that the escape of radioactive material came from the Acerinox metal company at Algeciras in the Cadiz region (south Spain) (10).

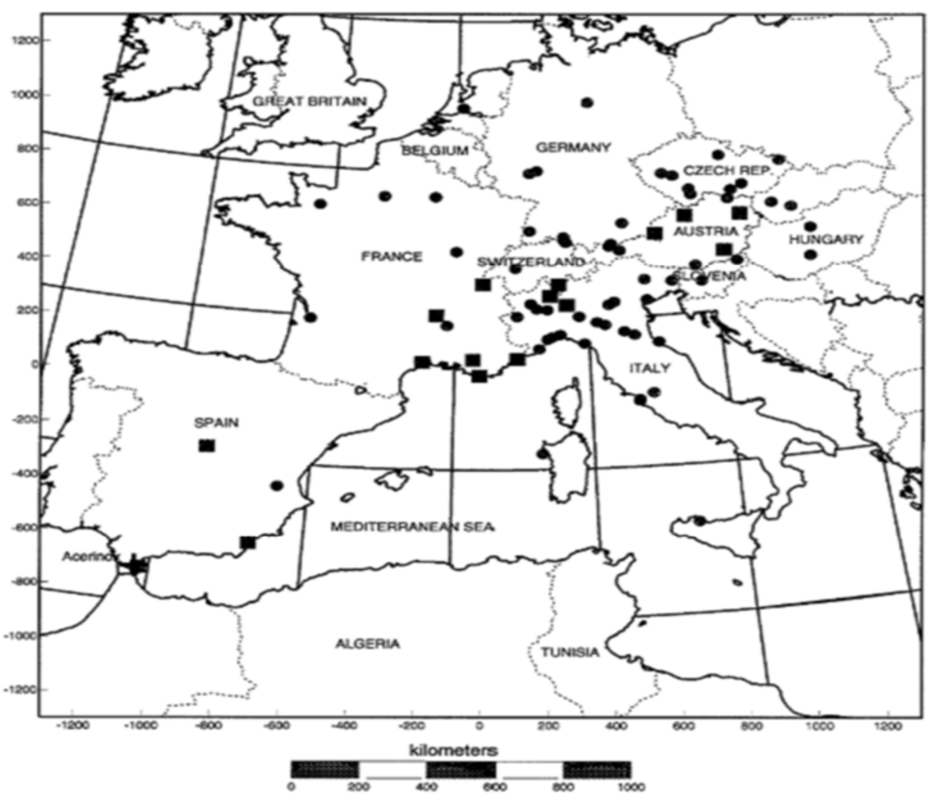


Figure A-1: Measurement locations (11): ■ Measurements used to assess the initial source term.

● All measurements used.

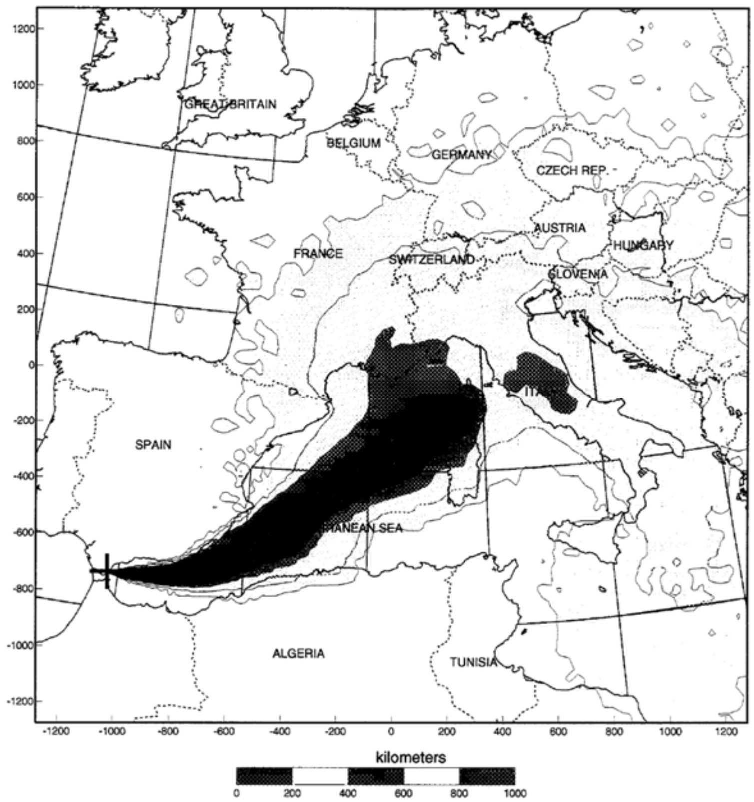


Figure A-2: Seven-day average air concentration of ^{137}Cs, Set 3 ending at 1200 UTC on 5 June 1998: Contours: >l0 (outermost or lightest), >l00, >500, and ~1000uBq/m3 (innermost or darkest) (11)

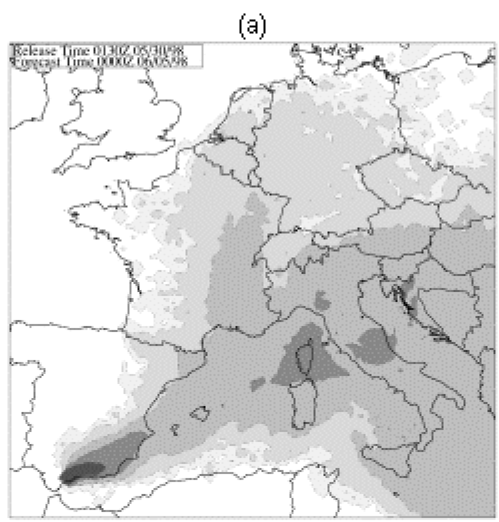


Figure A-3: Integrated airborne concentration near the surface after 6 days. Contour values decrease in orders of magnitude from $10^6 \mu Bq.m^{-3}$ (darkest shading) to $10^2 \mu Bq.m^{-3}$ (lightest shading) (12)

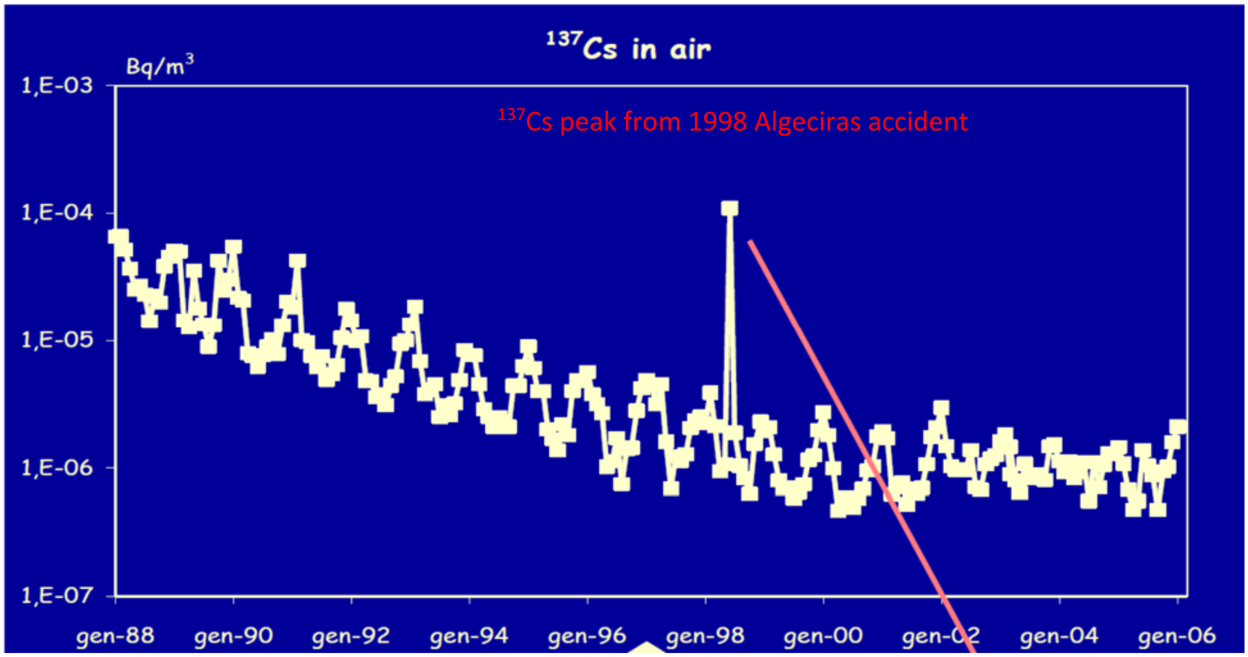


Figure A-4: Detection in Italy of ^{137}Cs from the accident in Algeciras, Spain. [(13)]

Table 1: Moroccan Monitoring of the Algeciras, Spain Accident and Release. [22] **(Original data, presented in French)**

Lieu de prélèvement	*Echantillon prélevé*	*Mesure réalisée*	*Activité en Cs-137*	*Débit de dose γ - ambiant* µSv/h
RABAT	Aérosols	Spectro. γ	< 25 µBq/m^3	/
	Sol	Spectro. γ	7.7 ± 0.4 Bq/kg	/
	/	Gamma ambiant	/	0.048
KENITRA	Eau de rivière	Spectro. γ	< 0.14 Bq/l	0.052
	Sédiments	Spectro. γ	<4.3 Bq/kg	/
LARACHE	Eau de mer	Spectro. γ	< 0.14 Bq/l	/
	Herbe	Spectro. γ	44 ± 12 Bq/kg	/
	Sol	Spectro. γ	5.1 ± 0.3 Bq/kg	/
	/	Gamma ambiant	/	0.045
TANGER	Aérosols	Spectro. γ	<61 µBq/m3	/
	Eau de mer	Spectro. γ	<0.35 Bq/l	/
	Sable	Spectro. γ	<4.3 Bq/kg	/
	/	Gamma ambiant	/	0.048
TETOUAN	Aérosols	Spectro. γ	< 20 µBq/m3	/
	Eau de mare	Spectro. γ	< 0.12 Bq/l	/
	Herbe	Spectro. γ	< 32 Bq/kg	/
	Sable	Spectro. γ	2.1 ± 0.3 Bq/kg	/
	/	Gamma ambiant	/	0.059
CHEF-CHAOUN	sol	Spectro. γ	2.5 ± 0.2 Bq/kg	/
	/	Gamma ambiant	/	0.077 µSv/h
AL HOCEIMA	Aérosols	Spectro. γ	< LD	/
	Eau	Spectro. γ	< LD	/
	Herbe	Spectro. γ	< LD	/
	Sol	Spectro. γ	15.8 ± 1.1 Bq/kg	/
NADOR	Herbe	Spectro. γ	< LD	/
	Sol	Spectro. γ	6.8 ± 0.4 Bq/kg	/
Fès	Eau	Spectro. γ	< LD	/
	Herbe	Spectro. γ	< LD	/
	Sol	Spectro. γ	9.1 ± 0.4 Bq/kg	/
KHEMISSAT	Sol	Spectro. γ	11.4 ± 0.8 Bq/kg	/

Table 2: Concentration in Bq/kg of Soil, Sediment, and Seawater in Algeria, Spain from the Acerinox Accident. [(23)]

Sampling Location	Nature	Concentration in Bq/kg	Concentration in Bq/kg	Range of Max and Min values in Bq/kg
		^{137}Cs	^{7}Be	
	Air	Not detected	___	___
Algiers	Fal. Precip.	Not detected	___	___
	Soil	4.4 ± 0.52	___	(1.0 ± 0.1 - 12 ± 1.0)
Les Andalouses (Oran)	Soil	___	16.83 ± 1.51	(9.0 ± 0.9 - 5.0 ± 0.6)
Ghazaouet	Soil	9.34 ± 1.09	16.72 ± 1.69	___
Mostaganem	Soil	10.22 ± 1.24	13.66 ± 1.2	(9.6 ± 1.0 - 4.0 ± 0.5)
Ain-Temouchent	Soil	6.46 ± 0.75	24.77 ± 2.3	(15.5 ± 1.5 - 3.6 ± 0.4)
Tlemcen	Soil	20.68 ± 2.08	18.81 ± 2.0	(24.3 ± 2.3- 11.0 ± 1.08)
Maghnia	Soil	7.52 ± 0.93	16.39 ± 1.71	___
Ghazaouet	Seawater	3.33 ± 0.3 (Bq/l)	___	___
Arzew	Seawater	3 ± 0.28 (Bq/l)	___	___
Chlef	Sediment	7.16 ± 0.99	___	___
Tlemcen	vegetation	not detected	___	___

Table 3: Ambient Gamma Measurement in Algiers and in the Western Part of Algeria from the Acerinox Accident. [(23)]

Locat.	Tlemcen[1]	Tlemcen[2]	Maghnia	Ghaza.	Ain Temouc.	Oran	Mostaganem	Chlef	Algiers
Min. val. µR/h	9.0 ± 0.49	5.3 ± 0.30	9.0± 0.49	8.5 ± 0.47	8.6 ± 0.47	5.3± 0.29	5.3 ± 0.29	9.3 ± 0.51	6.35± 0.35
Max. val. µR/h	11.6± 0.64	7.0 ± 0.39	10.1± 0.55	10.0± 0.55	9.6 ± 0.53	6.3± 0.35	6.8 ± 0.37	10.1± 0.55	6.65± 0.37

Tlemcen [1]: Station at the top of a mountain.
Tlemcen [2]: Station around the town.

Appendix (B): Example of a Simple, Community ERDS in the USA (NEWNET) [27]

NEWNET (Neighborhood Environmental Watch Network) is a system for involving the public community in the monitoring and understanding of nuclear radiation in the environment and provides access to radiation and meteorological data from a number of stations.

"NEWNET was started in 1993 with stations in Nevada, California, Utah, and New Mexico. It is based on concepts developed by the Department of Energy for the Community Monitoring Program at the Nevada Test Site Nuclear Testing Facility. These concepts date back to the Three Mile Island Nuclear Power Reactor accident in the late 1970's" [27].

NEWNET stations can vary in configuration. Most of the stations, have sensors to monitor ambient air temperature, barometric pressure, wind speed and direction, relative humidity and ionizing gamma radiation. Moreover, some stations contain a rain sampler in addition to air sampler as can be seen in Figure B-1.

Figure B-1: Example of NEWNET station (south of LANL near Bandelier National Monument) where we can find (a) rain sampler and (b) air sampler.

Appendix (C): Example of Jordan ERDS:

The network consists of three automatic remote stations located on borders. The remote monitoring stations are connected online to a central station at JNRC, the stations themselves are operated automatically and are capable of detecting alpha, beta, gamma radiation and iodine in the air. Air samples are continuously collected, and the aerosol particles deposited on filter tape are measured for activity.

To be able to perform this multitask function, each station is equipped with the following independent and integrated measuring units (Figure. 1):

a) FHT 59 N 1 (59 NE 1) Nuclide specific detection of gamma emitting radionuclides: The nuclide specific monitor FHT59N1 or FHT59NE1 (with E denoting the electric cooling version) is applied for continuous, automatic detection and early warning of aerosol-bound artificial and natural gamma emitters in air. Air samples are sucked through a special filter tape that is automatically moved every 4hrs. The high-purity germanium detector (HPGe) located under the filter continuously detects the gamma radiation emitted by the accumulated aerosols and the events are stored in the related energy channel of the multi-channel analyzer (MCA). The MCA data spectra are automatically analyzed (Figure. 2). After each spectrum analysis, the identified nuclides together with their respective limits of detection, activity concentration values, and statistical uncertainty are printed out and stored in the hard disk; example of the report can be seen in Figure. 3, where the results are displayed for the detected radionuclides. Determine the background count rate. The measurement is done during the accumulation. The results are displayed in units of Bq/m^3.

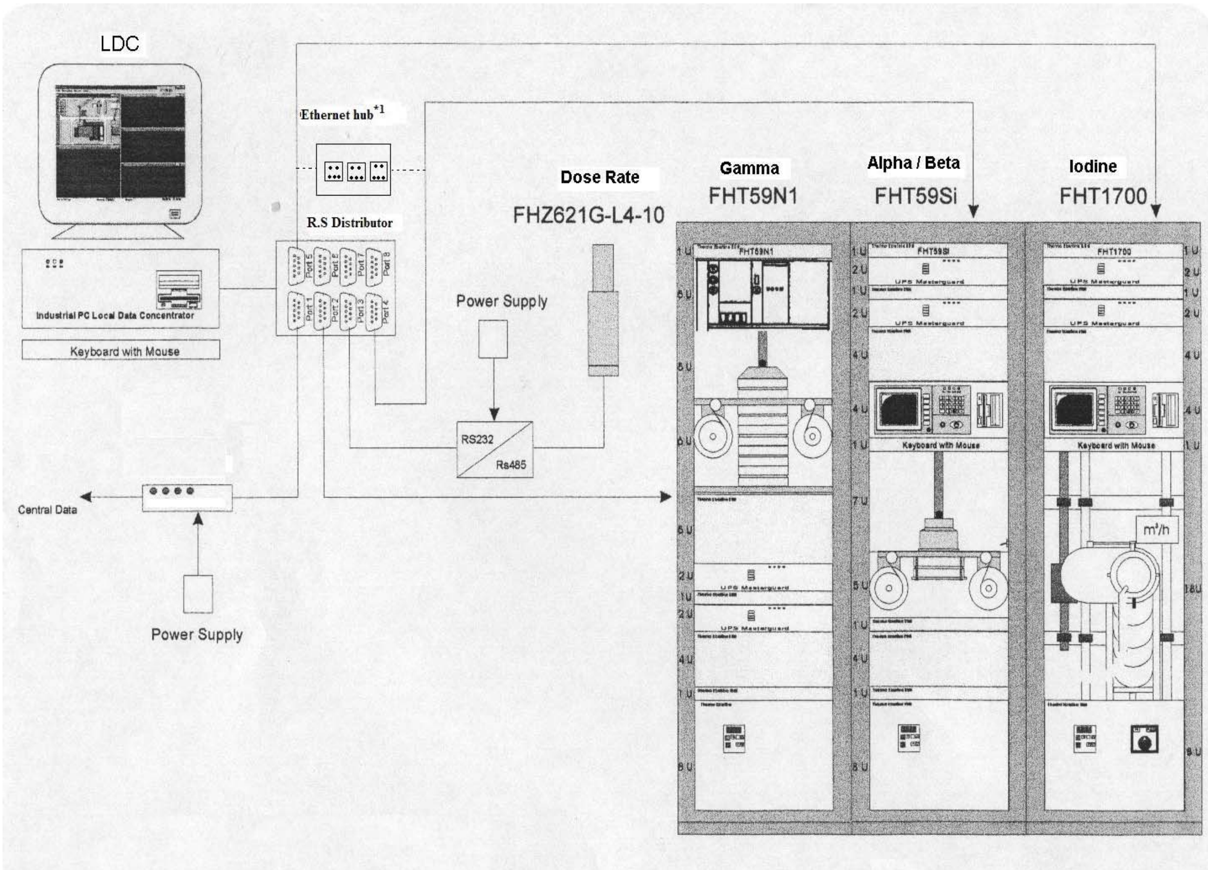


Figure C-1: Sampling and measuring units[20].

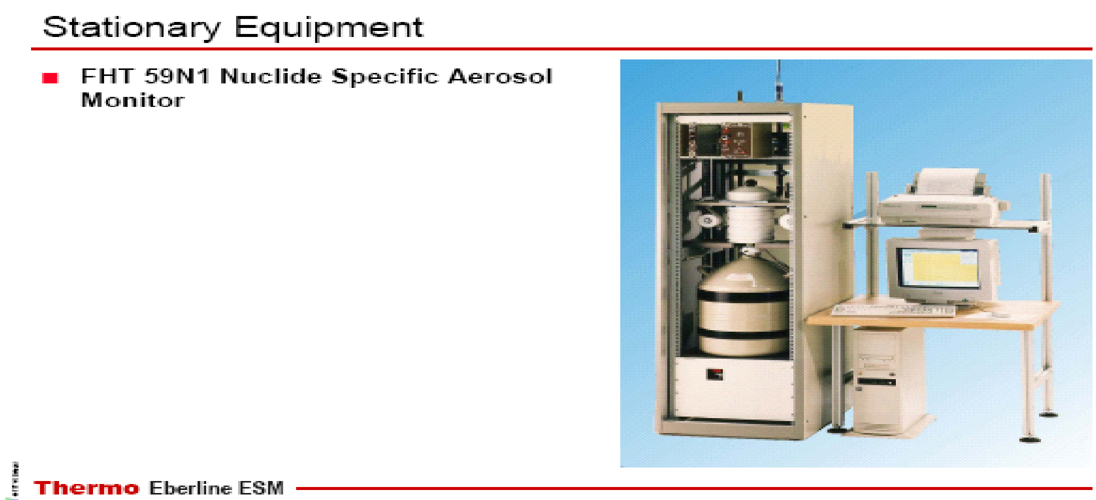


Figure C-2: The Nuclide specific detection of gamma emitting radionuclides Unit[20].

b) FHT 1700 Iodine (I-131) Monitor: NaI (Tl) detector with preamplifier contained in a Marinelli beaker filled with iodine adsorbent. The iodine monitor FHT1700 is used for the continuous monitoring and early warning of I-131 in ambient air. Air samples are sucked through filter cartridge in Marinelli beaker geometry filled with iodine adsorbent as well as organically bound iodine is precipitated. The filter cartridge is manually exchanged. A NaI-detector located in the center of the filter cartridge continuously measures the accumulated activity within the iodine window. Additionally, a second energy window with thresholds above and below the iodine window is measured.

c) FHT 59 Si Alpha/Beta Aerosol monitor, that is capable of discrimination of artificial from natural alpha activity: The aerosol monitor FHT59Si is used for continuous automatic detection and early warning of aerosol-bound alpha and beta radiation in air. Air samples are sucked through a special filter tape that is transported automatically every 10 min. The Positively Implanted Pure Silicon detector (PIPS) located above the filter continuously measures the accumulated activity. The results are displayed in units of Bq/m^3.

d) FHZ 621 G-L 4-10 Intelligent Probe for external dose rate measurement.

Data collected at each station is transferred via the internet to the JNRC central station at regular time intervals. Data and results files are displayed in numerical tables and graphic forms see Figure 3. Further formatting and analysis is performed at the JNRC central station. Control of the operating parameters of the remote stations is possible by suitable software package.

```
07/03/09/03:55:00  UTC 5;  58;
Sum-of-day-spectrum        Overall measuring period (h):    23.76
Averaged meas.time (h):    1.98 ;   Air flow (m3/h):    8.73*12
K40-FWHM:  2.1 keV  -ESH(FAR):  -0.1 keV  -CONT/h:   73.9 =  185%

Nuclide       Activ.conc.       Error          Detection limit
  name          (Bq/m3)          (%)           (Bq/m3)
   1 BE-7     ;  0             ;  0            ;  9.6902E-02    ;
   2 NA-22    ;  0             ;  0            ;  1.9300E-02    ;
   3 K-40     ;  2.1297E+02  ;Bq  4.6068       ;  3.4458E+01  ;Bq
   4 CR-51    ;  0             ;  0            ;  9.3643E-02    ;
   5 MN-54    ;  0             ;  0            ;  1.6766E-02    ;
   6 CO-57    ;  0             ;  0            ;  6.4804E-03    ;
   7 CO-58    ;  0             ;  0            ;  1.6135E-02    ;
   8 FE-59    ;  0             ;  0            ;  3.3707E-02    ;
   9 CO-60    ;  0             ;  0            ;  1.8936E-02    ;
  10 ZN-65    ;  0             ;  0            ;  3.7599E-02    ;
  11 SR-91    ;  0             ;  0            ;  5.9067E-02    ;
  12 SR-92    ;  0             ;  0            ;  2.6615E-02    ;
  13 Y-92     ;  0             ;  0            ;  1.8987E-01    ;
  14 Y-93     ;  0             ;  0            ;  1.0624E-01    ;
  15 NB-95    ;  0             ;  0            ;  1.5716E-02    ;
  16 ZR-95    ;  0             ;  0            ;  2.4422E-02    ;
  17 NB-97    ;  0             ;  0            ;  1.2073E-02    ;
  18 ZR-97    ;  0             ;  0            ;  1.6269E-02    ;
  19 MO-99    ;  0             ;  0            ;  1.0727E-01    ;
  20 TC-99M   ;  0             ;  0            ;  6.6910E-03    ;
  21 RU-103   ;  0             ;  0            ;  1.2238E-02    ;
  22 RU-106   ;  0             ;  0            ;  1.2249E-01    ;
  23 AG-110M  ;  0             ;  0            ;  1.2465E-02    ;
  24 TE-123M  ;  0             ;  0            ;  7.3600E-03    ;
  25 SB-124   ;  0             ;  0            ;  1.2016E-02    ;
  26 SB-125   ;  0             ;  0            ;  3.8690E-02    ;
  27 SB-129   ;  0             ;  0            ;  4.1468E-02    ;
  28 TE-129   ;  0             ;  0            ;  1.3583E-01    ;
  29 TE-129M  ;  0             ;  0            ;  4.4495E-01    ;
  30 I-131    ;  0             ;  0            ;  1.2400E-02    ;
  31 TE-131M  ;  0             ;  0            ;  3.7983E-02    ;
  32 I-132    ;  0             ;  0            ;  1.3569E-02    ;
  33 TE-132   ;  0             ;  0            ;  7.6198E-03    ;
  34 I-133    ;  0             ;  0            ;  1.2998E-02    ;
  35 CS-134   ;  0             ;  0            ;  1.2343E-02    ;
  36 I-135    ;  0             ;  0            ;  6.6404E-02    ;
  37 CS-136   ;  0             ;  0            ;  1.6415E-02    ;
  38 CS-137   ;  0             ;  0            ;  1.4994E-02    ;
  39 BA-140   ;  0             ;  0            ;  4.6141E-02    ;
  40 LA-140   ;  0             ;  0            ;  2.1367E-02    ;
  41 CE-141   ;  0             ;  0            ;  1.2424E-02    ;
  42 LA-141   ;  0             ;  0            ;  1.2700        ;
  43 CE-143   ;  0             ;  0            ;  2.0888E-02    ;
  44 CE-144   ;  0             ;  0            ;  5.1586E-02    ;
  45 ND-147   ;  0             ;  0            ;  3.0397E-02    ;
  46 PM-151   ;  0             ;  0            ;  4.2795E-02    ;
  47 HF-181   ;  0             ;  0            ;  1.2999E-02    ;
  48 TL-208   ;  2.8215E-02    ;  1.2425E+01   ;  2.1075E-02    ;
  49 BI-212   ;  0             ;  0            ;  2.2268E-01    ;
  50 PB-212   ;  1.4437E-01    ;  4.5173       ;  2.0916E-02    ;
  51 BI-214   ;  2.4278        ;  1.6632       ;  7.3548E-02    ;
  52 PB-214   ;  2.9702        ;  1.6471       ;  1.3259E-01    ;
  53 AC-228   ;  0             ;  0            ;  7.7537E-02    ;
  54 PA-233   ;  0             ;  0            ;  2.3615E-02    ;
  55 U-237    ;  0             ;  0            ;  2.3349E-02    ;
  56 NP-239   ;  0             ;  0            ;  2.5406E-02    ;
  57 AIR-m3/h;   104.7         ;  0            ;  0             ;
  58 mTIME-min;  118.8         ;  0            ;  0             ;
```

Figure C-3: Automatic report generated after performing the automatic analysis, where we can find which radionuclides have been detected together with their respective limits of detection, activity concentration values, and statistical uncertainty. [20]

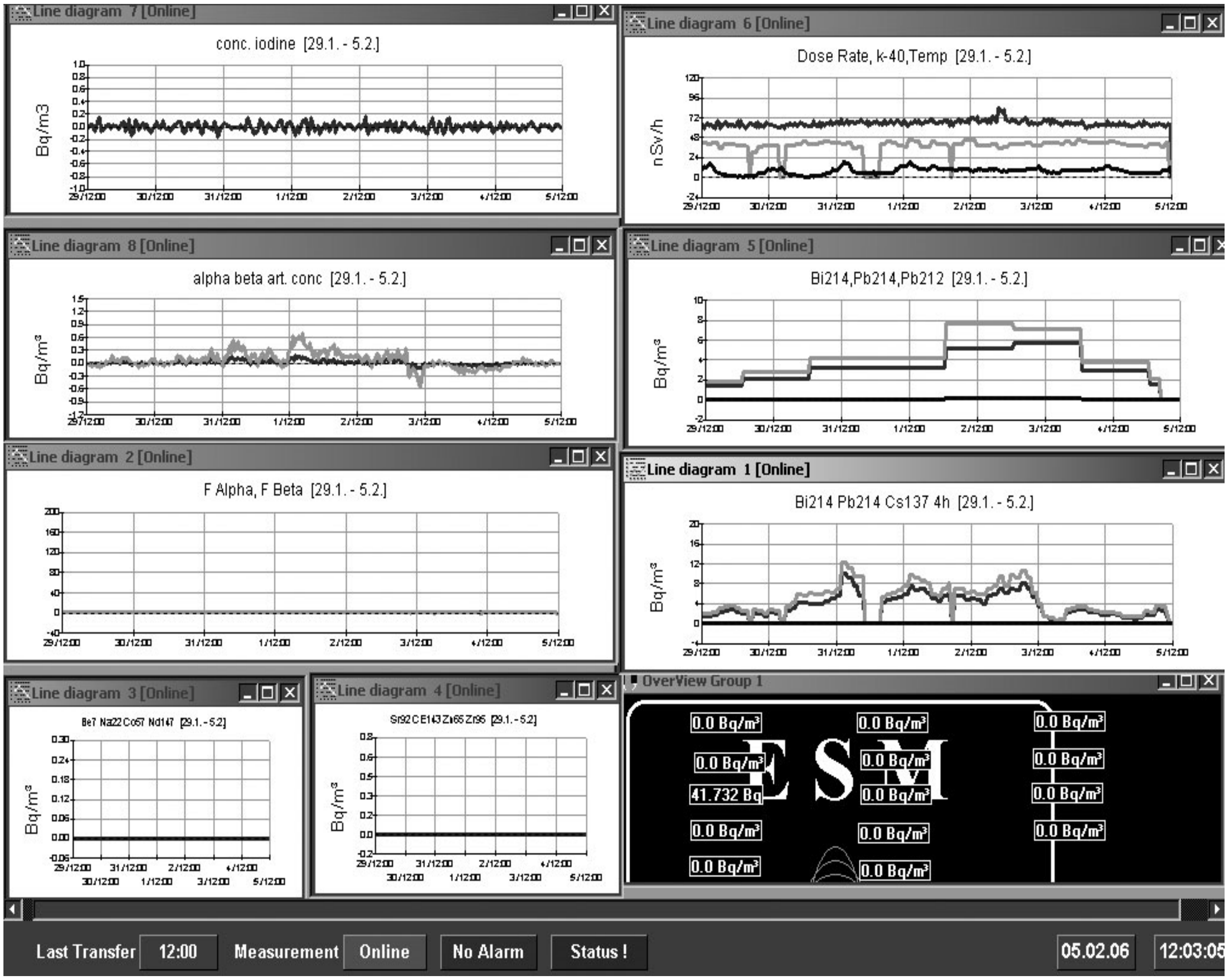


Figure C-4: The monitor in the central station at JNRC. All the results from the four units are displayed on graphical user interface accessible by authorized personnel [20].

Appendix (D): Example of Moroccan Real Time Monitoring System

CNESTEN, Moroccan National Nuclear Center accommodating TRIGA II Research Reactor has installed two stations for real-time monitoring purpose. Those stations consist of the probes for instant measurements and delayed measurements (Figure D-1).

Figure D-1: CENM's ERDS.

The instant probes allow the following readings:

- Alpha counting in cps
- Beta counting in cps
- Gamma counting in cps
- Air flow in l/m3
- Volumetric activity in Bq/m3
- Counts of Po-218 in cps
- Ambient temperature in °C

Appendix (E): AIRNET Network around Los Alamos National Laboratory (LANL) [29]

"AIRNET is a network of over 50 environmental air stations that continuously sample ambient air on and around Los Alamos National Laboratory property.[28]. AIRNET stations contain particulate filters and silica gel cartridges, in addition to a pump to draw air through the filter and cartridge. Where the airborne particulates are trapped by the filter, while tritium oxide is trapped by the silica gel. The filters and cartridges are replaced every two weeks. Therefore, samples are analyzed once every two weeks.

Figure E-1: AIRNET station photo from outside [29].

Figure E-2: A close-up view of the interior equipment of an AIRNET station, which show the filter and silica gel cartridge inside the station [30].

As particulate filters are sent to a commercial laboratory for analysis. "The filters are counted for a suite of gamma-emitting radionuclides. This suite includes the following nuclides: fission products (Cs-134, Cs-137, I-131), uranium daughters (Bi-214, Pa-234m, Pb-214, Th-234,), thorium daughters (Ac-228, Bi-212, Pb-212, Tl-208), naturally occurring K-40, an anthropogenic isotope (Co-60) and cosmogenic radioisotopes (Na-22, Be-7). Thereafter the filter is cut, one half being retained, the other combined with other half filters from the same station for the calendar quarter to form a composite. Chemical analyses consist of radiochemical separations followed by alpha spectroscopy for the radionuclides Am-241, Pu-238, Pu-239, U-234, U-235 and U-238; or inductively coupled plasma emission spectroscopy for the metals aluminum, beryllium and calcium. The moisture from the silica gel is distilled by the analytical laboratory and analyzed for tritium using liquid scintillation counting." [31]

"Minimum detectable amounts (MDAs) are functions of the standard deviation of background count rates for radioactive isotopes, or the standard deviation among multiple determinations of background signal for non-radioactive elements. The required 3 standard deviation MDA for tritium (500pCi/mL of distillate) demands a count time of 60 minutes. Similarly, the required MDA for the alpha emitters (0.04 pCi/filter) calls for a count time of 1000 minutes." [31]

Appendix (F): Examples of Several Technologies used for Data Authentication and Secure Communication.

1. The Comprehensive Nuclear-Test-Ban-treaty (CTBT) [15] in dealing with many stations all over the world needs a highly trustable technology to ensure a secure and authentic data communication system. In order to achieve these goals CTBT use "The Global Communications Infrastructure (GCI) which designed to ensure data transmission from the 337 facilities of the International Monitoring System (IMS) in near-real time to the International Data Centre (IDC) in Vienna where data are processed and analysed. The GCI is also used to distribute the raw data from IMS stations as well as IDC data bulletins to Member States. The GCI is a global satellite communications network based on Very Small Aperture Terminal (VSAT) technology. A VSAT is a set-up on the ground called earth station that allows for communication via a satellite. It employs a dish antenna to send and receive signals, and an interface to a PC.

2. The European Community Urgent Radiological Information Exchange (ECURIE):
"Which is a Community arrangements for the early notification and exchange of information in the event of a radiological or nuclear emergency. This requires from the ECURIE Member States a prompt notification of the European Commission (EC) and all the Member States potentially affected when they intend to take counter-measures in order to protect their population against the effects of a radiological or nuclear accident. The EC will immediately forward this notification to all Member States. Following this first notification, all Member States are required to inform the Commission at appropriate intervals about the measures they take and the radioactivity levels they have measured. All the 27 EU Member States as well as Switzerland and Croatia have signed the ECURIE agreement. The ECURIE system consists of three major parts:

- What type of information may be sent, as well as the format in which it has to be sent;
- Dedicated ECURIE software (called CoDecS) used to create, send and receive notifications in the CIS format using Internet.
- A network of Contact Points (CPs) and Competent Authorities (CAs) officially nominated by each Member State and by the EC to operate the ECURIE system." [16]

3. Virtual Private Networks (VPN): "Which provide secure data links over high-bandwidth Internet links, while improving inspector access and potentially reducing communication costs. Sandia National Laboratories and Finland's Radiation and Nuclear Safety Authority (STUK) have successfully tested the use of a VPN. A VPN allows secure data transmission over an untrusted public network, such as the Internet. VPN users can define encrypted and/or authenticated tunnels through the Internet as it converts data from a readable format to cipher text that only the intended recipient can decipher. Moreover, it ensures the data authentication by creating a unique signature based on the data. Consequently, a mismatch signature will be shown if the data were changed.” [17, 18]

4. The Apache Software which includes the Secure Socket Layer (SSL), [19] which allows web

browsers and web servers to communicate over a secured connection. This can be done by encrypting the data, transmit the data, and then decrypt the data on the receiving side before processing. Another feature of the SSL protocol is authentication. “This means that during your initial attempt to communicate with a web server over a secure connection, that server will present your web browser with a set of identifications, in the form of a "Certificate," as proof the site is who and what it claims.” (19)