THE ENVIRONMENTAL RADIATION MONITORING SYSTEM AND IN-SITU MEASUREMENTS FOR EARLY NOTIFICATION AND OIL CALCULATIONS.

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ABSTRACT

The National Environmental Radiation Monitoring System (NERMS) is composed by a network of 10 stations, located along the country. Each station consists of a gamma radiation detector and ambient dose rate meter that provides the early notification in case of a radiological or reactor accident. Low Level Radioactive particles detection is performed by air sampling with devices that collects suspended and settling particles. The network is connected to the control center through telephone lines providing 24 hour day the level of ambient radiation. The system has proved its efficiency early detecting an unregistered gamma radiography work in the area of two of the stations performed in June and December 96. Immediately after the radiography work started, an alarm sound and messages were sent by pager devices and a survey team approaches the station to check the situation.

Regular environmental sampling and In-situ HPGe detectors are used to establish the background level of environmental radiation in specific sites along the country.

The NERMS, air sampling measurements, sampling of ground, water and vegetables samples and In-situ measurements provides the operational quantities for OIL recalculations in case of emergency. By the above measurements and data a more precise and specific optimization analysis can be carried out on the basis of actual data efficiency of protective measures. This should result in a specific intervention level for each protective measure, to be used as criteria in the medium and long term. Choosing lower or higher levels of intervention would mean allocating more or less efforts and resources in radiation protection.

Key words: Environmental Radiation Monitoring, In-situ gamma-ray spectrometry, Operational Intervention Levels

INTRODUCTION

Environmental Radiation Monitoring is frequently used for early notification of the increase in the ambient level of local gamma radiation. The Radiation Safety Division manages an environmental radiation program that includes the continuous radiation monitoring system, environmental sampling methods as well as In-situ gamma-ray spectrometry system for field measurements.

The National Environmental Radiation Monitoring System (NERMS) provides the absorbed dose rate around the country, during normal situations and in case of nuclear accident in the country or over the borders.

In-Situ gamma-ray spectrometry has been used in several situations and environments and has proved to be a fast and accurate tool to determine soil activity concentration levels in the environment. The feasibility of applying a portable gamma-ray spectrometry system for In-situ measurements was experimentally investigated.

During nuclear and radiological emergencies the calculations of Operational Intervention Levels (OIL) are the basic parameters for decision on intervention. The intervention actions may include, after comparison with the GIL (General Intervention Levels) values, evacuation, relocation, foodstuffs countermeasures and decontamination of the affected area.

This work evaluates the efficiency of the environmental radiation monitoring, low level laboratory and In-Situ gamma-ray spectrometry as the systems for early notification and for determination of dose rate in air, surface contamination and activity.
concentration in food during emergencies for OIL recalculation.

**THEORY**

This section introduces the basic concepts of In-situ gamma-ray spectrometry calibration and OIL recalculation.

**In-situ gamma-ray spectrometry**

In-situ gamma-ray spectrometry provides a factor to convert the photopeak intensities to surface activity concentration. The factor depends on detector efficiency and angular response, calibration measurements as well as on calculation of unscattered flux $F_0$, assuming a certain distribution of the radionuclides in soil.

For naturally occurred radionuclides a good approximation of the source distribution is that an infinite half space with homogeneous source concentration in the horizontal plane and uniform concentration with depth in the soil. For fallout radionuclides, a decreasing exponential depth profile can be used for first few years after deposition or in undisturbed semi-arid regions [1].

The activity concentration of a particular radionuclide is related to absorption peak counting rate by [2]

$$\frac{N_f}{A_x} = \frac{N_0}{\Phi} \cdot \frac{N_f}{A_x} \cdot \Phi$$  \hspace{1cm} (1)

where $\frac{N_0}{\Phi}$ is the counting rate from a particular absorption peak per unit fluence rate for a plane parallel photon beam of energy $E$, $\frac{N_f}{A_x}$ is the angular correction factor of the detector at energy $E$, $\frac{\Phi}{A_x}$ is the fluence rate at energy $E$ due to a gamma transition for a particular radionuclide, not depending on detector. The detector angular correction can be calculated from

$$\frac{N_f}{N_0} = \frac{1}{\Phi} \int_{\cos \theta_1}^{\cos \theta_2} \Phi_{\cos \theta} \cdot \frac{N(\theta)}{N_0} d\cos \theta$$  \hspace{1cm} (2)

The radial contribution to the photon flux varies with the distance to the detector and it is assumed to be 85% of the total unscattered photon flux from the first 10 meters as detailed in figure 1.

**OIL recalculation**

The term *Operational Intervention Level* (OIL) defines the quantities that can be easily assessed at the time of decision intervention actions. This quantities includes air dose rate, surface contamination, activity concentration in food, etc. OIL are related to the avertable dose by a specific protective action as evacuation, relocation and banning of foodstuffs [3].

<table>
<thead>
<tr>
<th>Protective action</th>
<th>Operational quantity</th>
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<tbody>
<tr>
<td>Sheltering</td>
<td>Dose rate, air concentration</td>
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<tr>
<td>Evacuation</td>
<td>Dose rate, air concentration</td>
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<td>Thyroid prophylaxis</td>
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<td>restriction</td>
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<td>Temporary relocation</td>
<td>Dose rate, surface contamination density</td>
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<tr>
<td>Permanent resettlement</td>
<td>Dose rate, surface contamination density</td>
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<tr>
<td>Foodstuff restrictions</td>
<td>Surface contamination density, activity</td>
</tr>
<tr>
<td></td>
<td>concentration in food.</td>
</tr>
</tbody>
</table>

Generally, the avertable dose $\star E_{o,r,p}$ from exposure to a single radionuclide, $r$, and pathway, $p$, which could be averted by
implementing a countermeasure, \( c \), is given by:

\[
\Delta E_{c,r,p} = E_{c,p} - E_{c,r,p} \quad (3)
\]

In the case of external gamma dose over time related to evacuation or relocation

\[
\Delta E(t) = L \int_{t_i}^{t_2} D(t) \, dt = \frac{L}{\dot{\lambda}} \left(1 - e^{-\dot{\lambda}t}\right)
\]

\[
\equiv L \dot{\lambda} \hat{D}(t_i) \quad (4)
\]

where \( \hat{D}(t_i) \) is the absorbed dose rate in air from deposited activity on ground, therefore

\[
OIL_{rel} = \frac{IL_{rel}}{\Delta E(t) \hat{D}(t_i)} \quad (5)
\]

The collective effective dose rate from the consumption of contaminated foodstuffs is

\[
\hat{s}(t) = Q(t) e(50) V = s(t) V \quad (6)
\]

where \( V \) is the consumption rate, \( e(50) \) is the dose per unit activity ingested and \( Q \) the activity concentration. The avertable collective dose per unit mass of a given foodstuff over time related to foodstuff countermeasure is

\[
\Delta S(t) = \int_{t_i}^{t_2} \hat{s}(t) \, dt = S(t_i) - S(t_2) \quad (7)
\]

therefore

\[
OIL_{food} = \frac{IL_{food}}{\Delta S(t) Q(t_i)} \quad (8)
\]

**MATERIALS AND METHODS**

Environmental Radiation Monitoring

The National Environmental Radiation Monitoring System is composed by a network of 9 stationary stations and one mobile who measures the absorbed dose rate in the location of the station. Each station contains: wide range WD20 Geiger type detector, measurement instrument\(^1\), Front End Processor (FEP) to store data and modem to transfer the data to the PC in the control center through telephone lines [4]. The network is spread through the country in the main cities, close to nuclear facilities and in ports to monitor the ambient radiation level whenever nuclear vessels dock in the port.

The detector measures the absorbed dose rate once per hour in R/hr and once a day the FEP transfers the data to the control center. If a high absorbed dose rate threshold is overcome, the FEP transfers the data immediately to the control center and a message is broadcasted by a pager device simultaneously. The frequency sampling is increased to 5 to 1 minute depending on the case.

The mobile station is placed in the emergency patrol, powered by the car battery and can be mounted on a tripod at 1 meter height from ground. The transfer of data is done through cellular telephone.

Environmental Sampling Methods

The environmental sampling includes low level gamma-ray spectrometry analysis of a typical foodstuff basket, soil samples, well and run off water from different locations around the country including in the vicinity of nuclear centers. Airborne dust and settling particles are collected periodically in filters in each stationary station of the NERMS and analyzed by gamma-ray spectrometry. In this manner lower levels of environmental contamination can be detected and identified than through the radiation monitor detectors.

The low level gamma-ray spectrometry analysis is performed on a laboratory gamma-ray spectrometry system with a shielded intrinsic Ge detector of 20\% relative efficiency\(^*\). The soil samples for determination of \(^{137}\)Cs activity concentration were collected from a representative geographical distribution from the top 5 cm of the soil using a 12.3 cm diameter steel corer [5]. In the lab the samples were weighted and overnight dried at 105\(^\circ\)C and weighted again.

\(^1\) ENVIRAM B-10, Rotem Industries Ltd., Beer Sheva.

\(^*\) Canberra Industries, Inc. Nuclear Products Group, Meriden CT 06450.
and analyzed in 480 ml sealed plastic containers.

In-Situ gamma-ray spectrometry is performed with a portable system comprising p-type HPGe detector of 20% relative efficiency and spectrometry system\(^a\), 5-liters liquid nitrogen dewar, a lightweight multichannel analyzer operated by a notebook PC\(^b\).

Calibration of the detector was performed positioning it on a tripod, facing downward the floor, at a standard height of 1 meter. The calibration procedure included the determination of the detector angular response and efficiency. In-situ measurements of soil radioactivity were performed in a 300m x 300m, flat and homogeneous open phosphate ore mines. Soil samples were collected in the field at 5 cm depth for radius of 1, 3, 5, 10, 15 and 20 meter from the detector position. In the lab the samples were weighted and overnight dried at 105°C and weighted again and analyzed in 480 ml sealed plastic containers.

Those samples were analyzed in the lab in order to determine the \(^{238}\text{U}\) activity concentration in the open phosphate mine where the In-situ calibration was performed. Depth profile was investigated with samples at 5, 7.5, 10 and 15 cm depth at different radius as indicated above. The Uranium concentration in the soil was determined using the most intense gamma-ray spectra of the \(^{238}\text{U}\) progeny including 295, 352, 609 and 1765 keV spectral lines.

RESULTS AND DISCUSSION

Environmental Radiation Monitoring for early detection

In June 1996 an alarm signal indicating the overcome of the high dose rate threshold was received in the control center at 08:00 AM from the local station at Ashdod port. The frequency sampling was shortened to 5 minutes in order to confirm that the alarm is the response to a radioactive event and not electronic noise. Immediate information about the alarm was transferred to Ashdod’s port management and a survey team was sent to the location of the detector. This survey team could not found the source of the radiation.

No nuclear vessels were docking in the port at the time of the alarm was received.

The ambient gamma radiation increased more than 20 times more than background level as seen in figure 2.

\(^a\) NOMAD Plus with MCA, EG&G Ortec, Oak Ridge.
\(^b\) Versa V-50, NEC, Massachusetts.
The license of the companies involved in the unregistered radiography work was canceled for a period of two months. Since July 1996 the companies that would like to carry out radiography active measurements are obliged to inform the Radiation Division Management about the schedule and type of the work.

In-situ measurements

This measurement technique has been tested to calibrate the HPGe detector in the field and for the determination of the soil activity concentration of $^{137}$Cs fallout deposition due to Chernobyl accident.

The soil activity concentration of $^{137}$Cs due to Chernobyl accident was determined by laboratory measurements of over 260 soil samples distributed throughout the country [5]. The $^{137}$Cs/$^{134}$Cs ratio found extrapolated back to April 1986 yielded a ratio of approximately 0.5 confirming that the contamination was due to Chernobyl. The $^{137}$Cs concentrations in the surface soils were found to vary from 0.3 to 115 Bq/kg. Most of the samples fall within a much smaller range of approximately 3 to 20 Bq/kg. The large variability in the $^{137}$Cs concentration is a pattern that has been generally observed in the distribution of Chernobyl-derived contamination [6].

The calibration procedure comprised $^{238}$U determination in-situ in the open phosphate ore mines [7]. Good agreement with laboratory measurements has been achieved with a difference of 10% with laboratory measurements. This difference is being investigated nowadays by the authors.

The routine measurement of the ambient absorbed dose rate, soil activity density and activity concentration in foodstuffs with the above techniques, allow us to determine a known base level of radiation in the environment.

All the above techniques can be used also for the measurements of the operational quantities related to OIL recalculation. The quantities necessary for OIL recalculation includes: the absorbed dose rate $\dot{D}(t_i)$ for OIL1 and OIL2. The absorbed dose rate can be measured with the mobile station of the NERMS. The soil and surface contamination density $C_{g,r}$ measured for OIL4 through OIL7 recalculation. This quantities can be measured also with In-situ gamma-ray spectrometry. The activity concentration in food $Q(t)$ measured for OIL6 through OIL9 recalculation, measuring those quantities by laboratory gamma-ray spectrometry.

**CONCLUSION**

The suitability of different techniques for the measurement of operational parameters has been evaluated.

The National Environmental Radiation Monitoring System has proved its efficiency in the early detection of unregistered radiography work. The detection was immediately after the work commence allowing the authorities to take the correspondent preventive actions to avoid radioactive exposure of the general public and the environment. The mobile station of the network can be used for absorbed dose rate measurement during emergencies in contaminated areas.

The calibrated In-situ gamma-ray spectrometry system in the open phosphate ore mine has showed the efficiency of this technique for fast and accurate determination of soil activity concentration. The calibration for an uniform depth distribution can be easily mathematically converted to an exponential depth distribution in cases of radioactive material fallout.

Those measurements techniques provide the operational quantities for the determination of the base line and for OIL recalculation in case of nuclear and radiological emergencies.

By the above measurements and data a more precise and specific optimization analysis can be carried out on the basis of actual data efficiency of protective measures. This should result in a specific intervention level for each protective measure, to be used as criteria in the medium and long term. Choosing lower or higher levels of intervention...
would mean allocating more or less efforts and resources in radiation protection.

ACKNOWLEDGMENT

The authors would like to thank to Dr. Y. Nir-El from Soreq Nuclear Center for the joint work, knowledge and efforts in the calibration of the portable gamma-ray spectrometry system.

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