Development of Software to Provide Practical Guidance in the Managing of a Radiological Emergency

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Abstract. One of the most important aspects of managing a radiological emergency is the ability to promptly and adequately determine and take actions to protect members of public and emergency workers. This work brings up to date a computer software program in Delphi, with the tools, generic procedures and the data necessary to support the *Incident Commander*, the *Radiological Assessor* and other members of a generic response organization in case of radiological accident. The aim is also to provide practical guidance for the first responders who will respond during the first few hours to a radiological emergency and for the national officials who would support this early response. Software is now based on the *Manual for First Responders to a Radiological Emergency* (EPR-First Responders), published in 2006 as part of the IAEA Emergency Preparedness and Response Series, as well as in the IAEA technical document, *Generic Procedures for Assessment and Response during a Radiological Emergency*, the IAEA-TECDOC-1162, taking account of the lessons learned from using this last document in the area of early response and first responders' actions. The proposed procedures provide action criteria that are clear, concise and predetermined, based on the present knowledge and the accumulated experiences, allowing the immediate decision-making. The objective is to provide, through a portable computer, practical guidance, in the form of action guides, instructions, and supporting data for emergency response that, if implemented, will provide a basic assessment and the response capability needed to protect public and workers in case of different types of radiological emergencies. In addition to appropriate protective action recommendations, it will also provide, when it is necessary, general guidance on the recovery of radioactive sources and initial cleanup operations. The philosophy is to keep the process simple and fast, yet effective. Software is available in Spanish, English and Portuguese.

KEYWORDS: accident response; radiological accident assessment; radiological emergency managing; software for First Responder.

1 Introduction

As part of its Emergency Preparedness and Response Series, the IAEA published, in 2006, the *Manual for First Responders to a Radiological Emergency* – IAEA-EPR-First Responders [1-2]. The aim of this report is to provide practical guidance for those who will respond during the first few hours to a radiological emergency (referred as 'first responders'). The publication provides guidance in the form of action guides, instructions and data that can be easily applied by service personnel who would initially respond at the local level and the national officials who would support this early response.

In the area of early response and first responders' actions, this new publication replaces and builds on the IAEA technical document, *Generic Procedures for Assessment and Response during a Radiological Emergency,* IAEA-TECDOC-1162 [3], one out of a set of IAEA publications on emergency preparedness and response, published in August 2000 with the objective of provides the tools, generic procedures and data needed for response to a non-reactor radiological accident. The new *IAEA-EPR-First Responders* takes account of the lessons learned from using IAEA-TECDOC-1162, previous emergencies and research, while ensuring consistency with the IAEA Safety Standards Series N°. GS-R-2. But this publication does not address the response functions of the *radiological assessor*/team and does not provide guidance for the response initiator.

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One of the most important aspects of managing a radiological emergency is the ability to promptly and adequately determine and take actions to protect members of public and emergency workers. Radiological accident assessment must consider all critical and pertinent information available at any time and must be an iterative and dynamic process aimed at reviewing the response as more detailed and complete information becomes available. The IAEA General Conference, in resolution GC(49)/RES/9, encourages Member States "…to adopt the relevant Agency standards, procedures and practical tools…" and underlines "…the need for first responders to have appropriate training for dealing with ionizing radiation during nuclear and radiological emergencies…".

In this work, based on aforementioned TECDOC and on the new *Manual for First Responders to a Radiological Emergency*, one provides, of computerized form, generic response procedures to protect the public and emergency workers for different types of radiological emergencies; including the accidents involving sealed and unsealed radioactive materials, radiation generators, and transport accidents. This can also be applicable to radiological emergencies that could result from deliberate acts, such as terrorist activities. Only personnel who have been trained and drilled should use them.

The software program has been developed using Borland Delphi 6.0 (Object Pascal), a powerful programming tool for development of computer software that allows the creation of applications on the Microsoft Windows platform. The program indicates the procedures to be followed by the participants with different functions in a response organization structure during a radiological emergency. The procedures, in each case, are presented in sequential form. As a record keeping (data bank) is very important, the program also allows that the radiological response actions taken and implemented procedures should be adequately registered and stored. A field for fulfilling of the data is foreseen to each procedure, allowing that notations are taken step by step. Of this form one becomes easy that everything is adequately recorded for posterior recovery. This information may later be used for learning lessons or for legal arguments. The texts, tables and graphs are exhibited opportunely in the computer monitor screen to guide and to help the user for each step to be followed (see Fig. 1). The application presents options of choice of the wished information. The calculations of the dose estimate are done automatically. The program also allows the printing of the forms used in the response process.

It is hoped that this new tool, that computerizes the IAEA documents, also facilitates the process of training of the radiological emergency response staff, making it more attractive.

2 Generic Response Organization

The *Manual for First Responders* describes a generic response organization with the various functions and roles that would potentially be activated in the early response to a radiological emergency. The local response may include the following, as shown in Fig. 2:

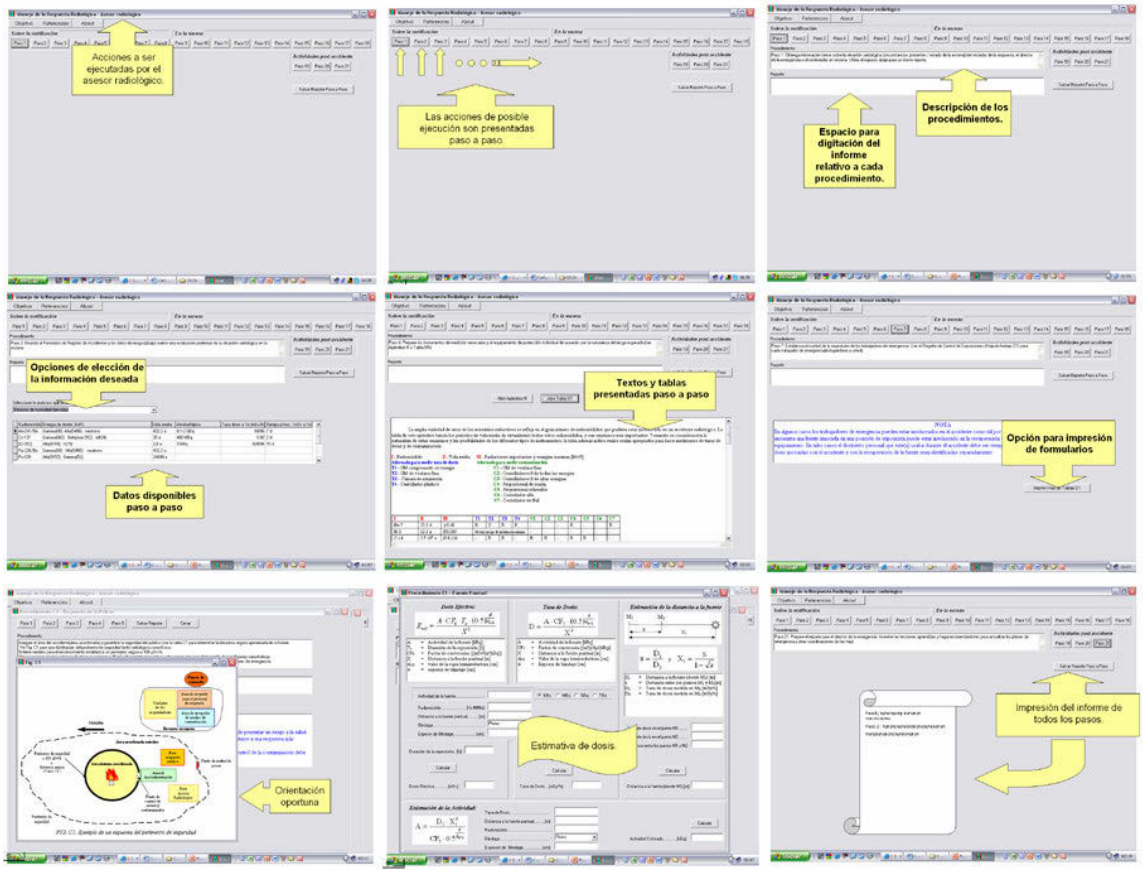
A **response initiator** is responsible for receiving the initial notification of a potential radiological emergency, getting basic information about the emergency, providing initial advice to the caller, notifying and dispatching the local emergency services to the scene and having the threat assessed. This function is operational 24 hours per day 7 days per week. The response initiator might be the "on-call" dispatcher/communicator of emergency services, such as law enforcement or fire brigade.

A **command function** is set up for directing the entire response. A unified command structure is used and may include a command group. The ***incident commander*** (IC) commands the entire response and directs the ***command group*** who may consist of local and national governmental representatives (or liaisons). The IC may delegate authority for performing certain activities to others as required: e.g. to ***on-scene controller***, to the ***public information officer (PIO)/team***, etc. The IC and *command group* normally operate at the *incident command post* (ICP).

A ***national emergency operations centre*** **(EOC)** is the national level centre that is ready to receive requests for assistance from the local level. This is the centre to be contacted to request the *radiological assessor*; to provide advice on the response from the *radiological assessor* and through which local and national media releases will be coordinated until, for a major emergency, a ***Public***

Information Centre (PIC) is established in the vicinity of the emergency scene. The EOC coordinates the national level support provided to the local response.

Figure 1: Characteristics of the diverse windows (Spanish version): a) Actions to be executed by the *Radiological Assessor*; b) The actions of possible execution are presented/displayed step by step; c) Space for typing the report relative to each procedure; Description of the procedure; d) Choice options of the wished information; Available data step-by-step; e) Texts and tables presented/displayed step-by-step; f) Option for print forms; g) Opportune orientation; h) Multiple windows for dose estimation; i) Option for print the report of all the stages.



A **planning function** is set up for planning, obtaining and coordinating the resources. The planning function may include *a **resource coordinator*** and a ***24-hour planning coordinator.***

An **operations function** is set up for implementing the incident action plans (response activities). For a small emergency the IC may direct operations; however, for a major emergency coordination of operations may require the assignment of an ***on-scene controller***.

The operations functions may include the ***fire brigade***, the ***emergency medical service*** (EMS), a ***law-enforcement/security team***, a ***forensic evidence management team*** (FEMT), a ***first responder monitor*** and a ***radiological assessor/team.***

In small-scale accidents some of these functions may be combined and carried out by one person. The functions of positions described, however, are essential to an appropriate response and the planning for an emergency should address each one of these functions.

On notification of an emergency, the *Response Initiator* obtains initial information regarding the emergency and decides if it is a radiological one. If it is, he/she provides to the caller the first advice

and initiates the response by alerting/activating the *incident commander*. In some cases the senior official at the scene automatically assumes the role of the *incident* until relieved or confirmed.

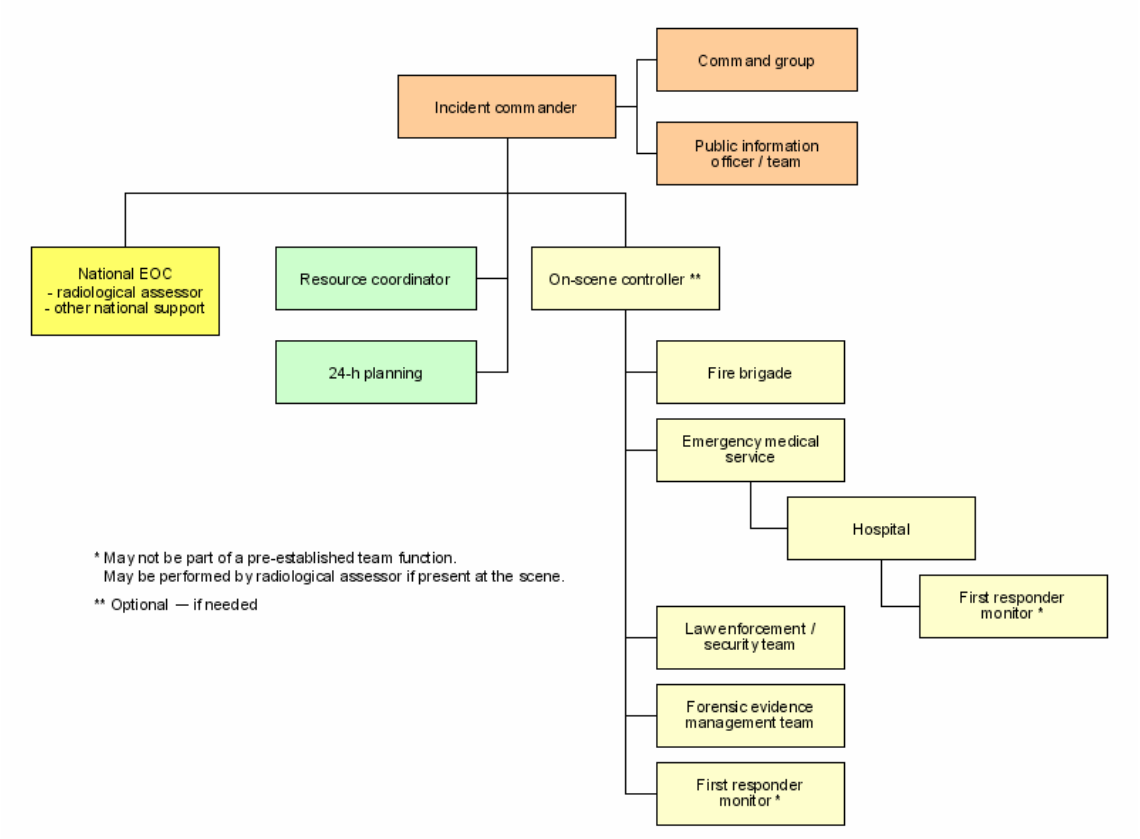
Based on available information the *incident commander* assesses the level of the present or suspected hazard. If medium or high, he/she activates local/national response organization(s) and a *Radiological Assessor* and any other needed services or authorities.

The first responders may or may not have available radiation detection equipment and dosimeters. Therefore, suitable generic precautions must be adopted to protect themselves and other people present at the scene from the radiological hazard and a qualified *Radiological Assessor* should in almost all cases be called to assist with the radiological aspects of the response.

The *Radiological Assessor* may be alone or part of a team. He/she is responsible at the scene for surveys, contamination control, radiation protection support to emergency workers and the formulation of protective action recommendations. The *Radiological Assessor* will also initiate and, in some cases, carry out source recovery, clean up and decontamination operations. The *Radiological Assessor* will also be responsible for setting turn back guidance for emergency workers, for estimating and recording the dose received by emergency workers and/or the public; for requesting additional radiological assessment resources, as required; and for health physics expertise to carry out specialized hazard and dose assessment tasks.

The computer software program is conceived, mainly, for its use by this team(s) of radiological professionals (qualified experts) sent to the scene of an accident to assess the radiological hazards, provide radiation protection for the First Responders and make recommendations to the *Incident Commander* and to the *On-Scene Controller* on protective actions. In addition the software offers orientation for the person responsible for the tactical management of response actions at the emergency scene, and for the others members of the response organization.

Figure 2. Generic response organization at the local level within a few hours.



3 Description of the Windows-Based Computer Software

3.1 Procedure D0: Managing Radiological Response

We can initiate the description of the software basically from Procedure D0 (*Managing of the radiological response at the scene of the accident*), described in IAEA-TECDOC-1162, that demands the following inputs: a) Notification of an accident or emergency situation (Worksheet A1 of the TECDOC); b) Briefing by the Response Initiator, the Emergency Manager, or the on-scene controller; c) Current circumstances/status of the scene; d) Identification of the actual or potential radiation hazard. With the attainment of this procedure, the outputs waited can so be described: a) Hazard/risk analysis; b) Protective action recommendations for public and emergency workers; c) Advice for on-scene management; d) Consideration of recovery and initial cleanup strategies.

Each procedure is organized in the order that assessment and response actions will most likely be performed. The Purpose of the procedure D0, to being performed by the *Radiological Assessor*, is to provide guidance on assessment of the radiological situation, on appropriate protective action recommendations and on recovering the source and initial cleanup operations. It contains 21 steps, divided in 3 different sections, which can be so summarized:

1- **On notification** (8 first steps)**: Step 1**- Obtaining briefing; **Step 2** - performing preliminary evaluation of radiological situation; **Step 3** - Recommending initial protective actions; **Step 4** - Selecting necessary instruments and equipment according to the nature of the expected hazard; **Step 5** - Estimating necessary personal protective actions; **Step 6** - Instructing response teams on personal protection. **Step 7** - Arranging exposure control for the emergency workers. **Step 8** - Briefing and dispatching radiological assessment team**.**

2- **At the scene** (step 9 to 18)**: Step 9** - Establishing contacts on arrival; **Step 10** - Confirming possible situation of exposure or contamination; **Step 10** - Surveying the perimeter to identify possible exposure or contamination; **Step 11** - Evaluating the need for immediate protective actions; **Step 12** - Establishing control points; **Step 13** - Establishing eventual area for decontamination; **Step 14** - Taking air samples; **Step 15** - Establishing protection in case of air contamination; **Step 16** - Supervising radiological monitoring and implementation of protective actions accordingly; **Step 17** - Attending the personnel who enters the safety perimeter; **Step 18** - Recovering the scene**.**

3- **Post accident activities** (the three last steps)**: Step 19** - Dose assessment; **Step 20** - Longer-term protective actions; **Step 21** - Report**.**

Already in the step 2, aforementioned, the program allows to select the practice or application with probability of being involved in the accident and presents/displays the corresponding risk related data (Radionuclide, Energy [keV], Half-life, Typical activity, Dose rate at 1 meter [mSv/h] and Time to exceed 1 mSv at 1 meter), in accordance with the table D5 of the TECDOC (RISK RELATED DATA FOR DIFFERENT PRACTICES). The options of the pop-up menu are these:

- **Sealed sources used in medicine:** Bone densitometry; Manual brachytherapy; Remote after loading brachytherapy; Teletherapy; Whole blood irradiation.
- **Sealed sources used in industry:** Industrial Radiography; Well logging; Smoke detectors; Lightning Rods; Moisture/density detector; Static electricity eliminator; Electron capture detector; X ray fluorescence analyzer; Sterilization and food preservation; Calibration facility; Level gauge; Thickness gauge; Density gauge; Conveyor gauge.
- **Sealed sources used in research:** Calibration sources; Electron capture detector; Irradiators; Calibration facilities; Tritium targets.

In the step 4, the program presents/displays a *GUIDE TO SUITABLE INSTRUMENTATION* (Appendix III of the TECDOC) with some guidance on the desirable level of instrumentation and equipment that

should be available to provide the services required. Suitable instrumentation can be selected for different purposes: Identifying and locating sources of radiation; Measuring gamma dose rate; Measuring beta dose rate; Measuring beta contamination; Measuring X ray dose rates and contamination; Measuring alpha contamination; Supplies. In addition there is a link for a *GUIDE TO SUITABLE DETECTORS* (table III-1 of the same appendix of the TECDOC) with radionuclide data and corresponding suitability for dose rate measurements and suitability for contamination measurements.

In step 5 of the same procedure, a table (Table D3 of the TECDOC) presents, for each type of task to be fulfilled, the values of effective dose that can be waited for. With another table (table D4), one can obtain guidance about *default emergency worker turn back dose*, when radioiodine inhalation hazard exist.

In step 7, the Worksheet D1 of the TECDOC can be printed, that allows the exposure control record for each emergency worker.

In step 8, the program displays the table D2 of the TECDOC, with guidance on monitoring and the objective to be reached, having in account the following accident types: Misplaced, lost or stolen source; Found source or contamination; Unshielded sealed source; Damaged sealed source; Unsealed source accident; Dispersion of alpha emitters; Nuclear powered satellite re-entry; Trans-boundary impact. The same guidance returns in step 16.

In step 9, already at the scene, it is possible that the *Radiological Assessor* must assume provisorily the duties of the *On-Scene Controller*, if he was the first one to arrive at the scene of the accident. In this case the program turns to Procedure C1.

3.1.1 Procedure C1: *On-Scene Controller* Response

The purpose of this procedure, to being fulfilled by the *On-Scene Controller*, is to provide guidance on mitigating the consequences of an accident and implementing response actions at the scene. It demands and results the following inputs and outputs. **Inputs**: a) Notification of an accident; b) Briefing by *Response Initiator***;** c) Situation at the scene. **Outputs**: a) Response actions at the scene; b) Liaison with the *Emergency Manager*. The subroutine relative to the procedure C1 contains 11 steps, divided too in 3 different sections, which can be so summarized:

1- **On notification: Step 1** - Establishing contact with the *Incident Commander*and the *Radiological Assessor*.

2- **At the scene** (step 2 to 10)**: Step 2** - Approaching cautiously to the scene; **Step 3** - Removing the people from the accident area and monitoring them if contamination is suspected; **Step 4** - Giving medical first aid; **Step 5** - Supervising response actions according to the priorities and the procedures C2, C3, C4 and C5; **Step 6** - Giving instructions to the emergency workers on personal protection (link to subroutine relative to the Procedure C6, of 6 steps) and guidance on safe distances (Table C1); **Step 7** - Controlling possible contamination with the support of the *Radiological Assessor*; **Step 8** - Getting regular briefings from the *Radiological Assessor*; **Step 9** - Implementing the approved or recommended protective actions; **Step 10** - Providing regular updates to the *Emergency Manager*.

3- **Post-emergency activities: Step 11** – Reporting and summing up lessons learned.

3.1.2 Procedure C2: Police Response

Considering that the Police will likely be first on the scene if an accident occurred in a public place, like a transport accident, scenario for which they have the role of first responder, the purpose of the procedure C2, of five steps, is to provide guidance for police response under radiological conditions. It demands the following inputs: a) Notification of an accident; b) Situation at the scene. The output waited is the response actions at the scene.

3.1.3 Procedure C3: Fire Service Response

The purpose of the procedure, of 5 steps, is to provide guidance for fire service response under adverse radiological conditions. The inputs are a) Notification of an accident; b) Situation at the scene. The output waited is the Response actions at the scene.

3.1.4 Procedure C4: On-Scene Emergency Medical Response

The purpose is to provide, in 7 steps, guidance on emergency medical response under radiological conditions or for the *First Responder* on the scene who must perform first medical aid to injured person(s). The procedure demands the following inputs: a) Notification of an accident; b) Situation at the scene. With the attainment of this procedure, the output is the determination of the response actions to be performed by the *Emergency Medical Responder* at the scene.

3.1.5 Procedure C5: Initial Response by Facility Responder

An accident will often be discovered by the user and managed by the on-site emergency organization. The facility staff, in some cases, will need to support and work in collaboration with off-site emergency responders. The purpose of the procedure C5 is to provide, in 10 steps, guidance on initial response in case of an accident at a facility and on coordinating response with off-site emergency responders. It demands the following input: Situation at the scene. The outputs waited are: a) Initial response actions; b) Request for assistance (if needed); c) Support to off-site emergency responders (if any).

3.1.6 Procedure C6: Personal Protection Guide

The purpose is to give emergency workers basic instructions on personal protection. Personal protection guidance is given in three areas: general instructions, thyroid protection and as emergency worker turn back guidance. It demands the following inputs: a) *On-Scene Controller* directives; b) Situation at the scene. The sought outputs are: a) Safely performed tasks; b) Report back to the On-Scene Controller.

3.2 Procedure D0 (continuation)

In step 11 of the Procedure D0, comparing measurements made with the *OPERATIONAL INTERVENTION LEVELS* (OILs), settled down in TABLE D1, the *Radiological Assessor* will be able to decide which immediate protective actions must be adopted.

In step 12, the program presents/displays an example of a layout of safety and security perimeter (figure C1 of the TECDOC) to establish and supervise an access and contamination control point.

In step 18, supposing the primary cause of the emergency under control, the source confined AND all the contamination contained, the program offers the possibility to deviate to following links**: procedure D1**: Recovery of the scene/removal of the radioactive material; **procedure D2**: Decontamination of people and equipment; **procedure D3**: Initial cleanup of the site and disposal of radioactive wastes.

3.2.1 Procedure D1: Source Recovery/Removal of Radioactive Material

The subroutine relative to the procedure D1 demands the following inputs: a) Characterization of the scene; b) Identification and quantification of the radioactive material(s) involved. The sought outputs are: a) Definition of safety precautions: b) Inventory of required resources; c) Prescribed recovery steps. The purpose is to provide general guidance on the basic steps necessary to initiate recovery of radioactive sources or removal of radioactive material when feasible. The 10 steps of this procedure can so be summarized:

Step 1 - Confirming that all necessary protective actions have been implemented and the location has been stabilized and secured; **Step 2** - Collecting and evaluating the available information (about the radioactive material and local resources for its removal); **Step 3** - Evaluating the effectiveness of the immediate removal; **Step 4** - Ensuring a location for secure storage; **Step 5** - Selecting the equipment and resources for the removal; **Step 6** – Assessing suitability for recovery activities; **Step 7** - Planning the suitable procedure for the cleanup operations; **Step 8** - Ensuring the radiological monitoring; **Step 9** – Reviewing all packages; **Step 10** - Conducting another survey to confirm the complete removal

3.2.2 Procedure D2: Decontamination of People and Equipment

The subroutine relative to the procedure D2 presupposes the following inputs: Information regarding the type and activity level of the radioactive material involved; Results of monitoring surveys of people, essential equipment and vehicles. The output is: Guidance on decontamination activities. The purpose is to provide guidance on simple decontamination of personnel, essential equipment and vehicles. The 18 steps of this procedure, of three sections, can so be summarized:

1- **General guidance** (5 first steps)**: Step 1** - Preparing appropriate equipment and resources to accomplish simple decontamination. **Step 2** - Designating the decontamination area; **Step 3** - Surveying before; **Step 4** - Verifying possible persistence of removable contamination; **Step 5** - Assuring the documentation regarding the decontamination process.

2- **Decontamination of people** (step 6 to 10)**: Step 6** - Accessing Table D7 for personal decontamination guide; **Step 7** - Clothes decontaminating, if feasible; **Step 8** - Impounding for further decontamination efforts; **Step 9** - Labeling contaminated items; **Step 10** - Recording contamination levels on the skin.

3- **Decontamination of vehicles and equipment** (step 11 to 18)**: Step 11** - Decontaminating the vehicle exterior; **Step 12** - Isolating vehicles not yet externally decontaminated; **Step 13** - Re-surveying the decontaminated vehicles; **Step 14** - Isolating vehicles not yet internally decontaminated; **Step 15** - Verifying possible persistence of removable contamination in the vehicle; **Step 16** - Monitoring and decontaminating tools and equipment; **Step 17** -Providing the owner with a receipt for contaminated items (Worksheet D3); **Step 18** - Bagging contaminated items for proper shipment or storage.

3.2.3 Procedure D3: Removal of Radioactive Wastes

The subroutine relative to the procedure D3 includes the following inputs and outputs: Inputs: a) Quantification and inventory of the wastes involved by category; b) Information on the availability of safe transport means, proper packaging, and storage options. Output: Recommendations for removal. The purpose is to provide guidance on preliminary considerations for the removal of radioactive wastes resulting from the consequences of a radiological emergency situation when possible. This procedure should be used during the emergency phase. If long-term cleanup measures are required these should be considered separately. The 6 steps of this procedure can so be summarized:

Step 1 - Categorizing wastes by type, level of activity, and volume. **Step 2** - Planning the disposal or storage; **Step 3** - Identifying the requirements for waste packaging **Step 4** - Identifying the appropriate means of transport and the need for in-transit security. **Step 5** - Preparing the transport documentations; **Step 6** - Resurveying the site after waste removing.

3.3 Procedure D0 (post accident activities)

Returning to the procedure D0 we will have the steps relative to the post accident activities. In Step 19, once the emergency situation is stabilized and recovery activities have been completed, the program puts available a subroutine to estimate the dose to victims, emergency workers and/or the

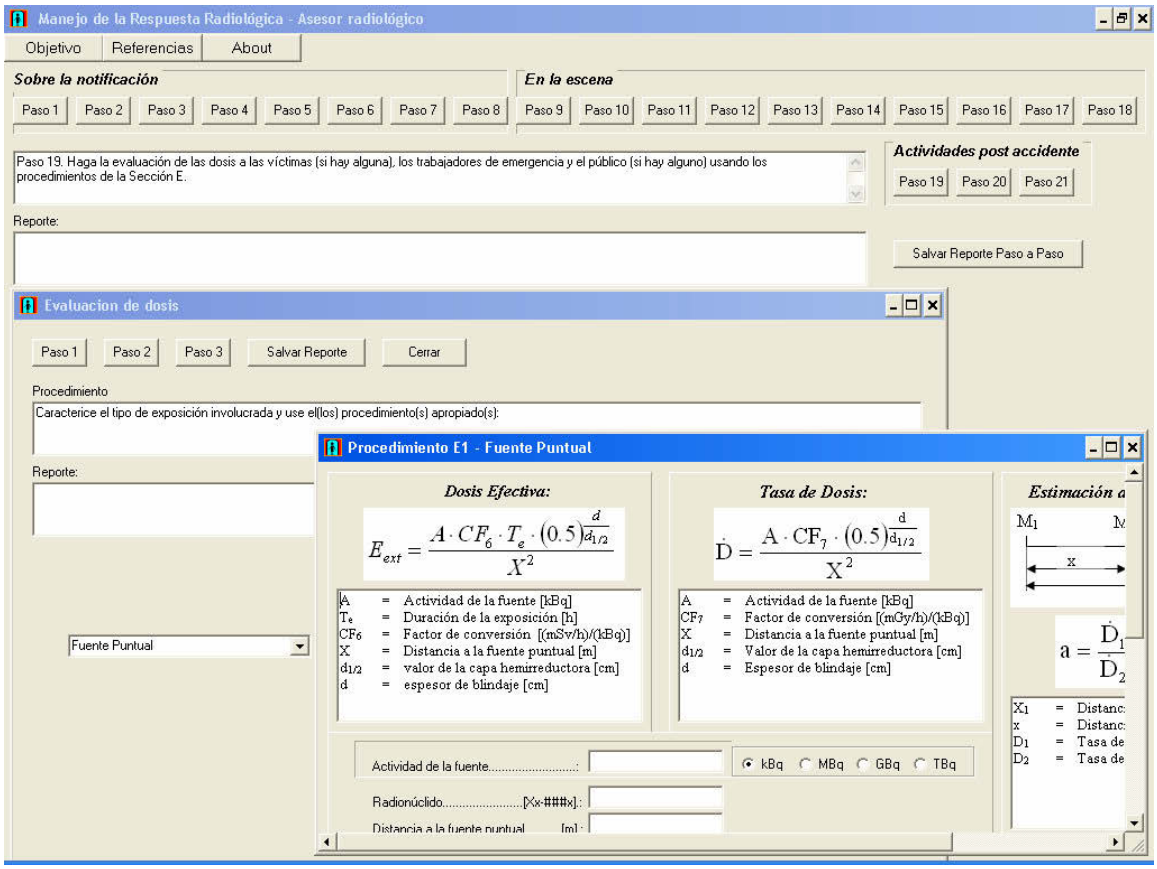
public, based on the type of sources or radioactive materials involved and the circumstances of the emergency situation.

3.3.1 Subroutine for Dose Assessment

This subroutine includes the following inputs and outputs: **Inputs:** a) Type of exposure involved; b) Radiation sources or material involved; c) Results of survey; d) Results from dosimeters; e) Chronology of events. **Output:** Accident-specific dose estimates. This sub-routine contains the three following steps:

> **Step 1** - It allows to assemble and assess the dosimetric information directly available; **Step 2** - It allows to select the type of exposure involved for the purpose of adopting the appropriate procedure(s) to calculate the dose rate, the effective dose or the source activity (see Fig. 3). The options are the following (procedures E1-E7): Point source (E1); Line source and spill in small area (E2); Ground contamination (E3); Skin contamination (E4); Inhalation (E5); Ingestion (E6); Air immersion (E7); **Step 3** - It allows to estimate total effective dose by summing up contributions from all relevant exposure pathways.

Figure 3: Screen (spanish version) of the dose calculation for point source



Total effective dose can be calculated by taking into account all dominant routes by which individuals were exposed in an accident.

$$E_T = E_{ext} + E_{inh} + E_{ing} \quad (1)$$

Where: E_T is the Total Effective Dose; E_{ext} is the Effective Dose from external radiation; E_{inh} is the Committed Effective Dose from inhalation and E_{ing} is the Committed Effective Dose from ingestion.

3.4 Procedure D0 (continuation)

In step 20 of the procedure D0, one assesses the need for longer-term protective actions. In step 21, the procedure ends with the report for the *Emergency Manager*, stressing lessons learned and making recommendations for updating the emergency plan. For so, the program allows access to all the information recorded step by step.

4 Conclusion

It is in the point dose assessment (presented in step 19 of the procedure D0, described in TECDOC 1162) that the program presents greater practical utility, for enclosing many calculations, associates to the data of countless tables. Another advantage is to make possible an entire view of the complex tasks to be made, especially by the *Radiological Assessor*, facilitating even its training. The program no longer limits the procedures to this team of qualified experts sent to the scene of an accident to assess the radiological hazards, provide radiation protection for the first responders and make recommendations to the *On-Scene Controller* on protective actions [4]. Beyond also including, as in the 2007 version [5], the basic response procedures for the police, the fire fighters and the members of the *emergency medical service*, in addition to the procedures for the other members of an assumed generic response organization, the program now is up-to-date, in accordance with the new *Manual for First Responders to a Radiological Emergency* (EPR-First Responders). This update becomes useful especially for the *Incident Commander*.

Acknowledgments

To Mrs. Elena Buglova of the IAEA's *Incident and Emergency Centre*, for encouraging the development of this software.

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