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CHALLENGES OF FRONT-LINE OFFICERS (FLO's) IN THE USE OF HANDHELD RADIATION DETECTION EQUIPMENT AND RADIOISOTOPE IDENTIFICATION

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Abstract. *Using portable handheld radiation detection instruments by front-line officers in all countries has challenges that impact detecting and combating the illicit trafficking of radioactive materials. The primary and secondary inspections at Border Crossing Points (BCP) or seaports where there is a high number of import and export commodities are made by front-line officers (FLOs) with non-technical backgrounds with expectations that high confidence and rapid alarm assessment must be done. Many alarms are simply the result of naturally occurring radioactive materials (NORM) moving through commerce, and separating alarms possibly caused by nuclear and other radioactive materials from the alarm pool of mostly NORM can be quite difficult. Response and inspection time become a challenge that requires responsibility and coordination. International Atomic Energy Agency (IAEA) has supported all Member States (MS) to improve the ability of responsible employees to control persons and vehicles for radioactive materials that are out of regulatory control, to prevent illegal movement and trafficking of these goods through different research coordinated projects as CRP J02012 "Advancing Radiation Detection Equipment for Detecting Nuclear and Other Radioactive Material out of Regulatory Control". In the frame of this project a survey was prepared with five sections and 28 questions in total and in this survey participated 42 different MS. This paper provides information about the personal information and experience of different FLOs, the equipment used during inspections, notifications of Personal Radiation Detectors (PRDs) and Radioisotope Identification Devices (RIDs), display and interfaces of RIDs, and features for radiation detection equipment in general. The purpose of this survey was to identify the problems related to the measurements and identification of different radionuclides using equipment like PRDs, RIDs, etc., especially for NORM alarms assessment which compose more than 99% of Alarms at BCP. The most preferred survey result on PRDs screen notification unit based on FLOs job function was in μSv/h.*

Keywords: *front-line officer, handheld equipment, NORM, radiation detection, radionuclides*

1. Introduction

Radioactive sources are an important part of various practices in industry, medicine, agriculture, and scientific research. Although simplified procedures are created for the movement of these goods, there is a constant need to improve the procedures, according to the latest standards and best practices recommended by the International Atomic Energy Agency (IAEA, 2007), and by other programs or institutions to ensure the protection of the public and the environment from the harmful effects of ionizing radiation. To operate efficiently, detection systems must distinguish illicit nuclear and radiological materials from common commodities shipped through different - supply chains which can also produce significant radioactive emissions IAEA (2002), IEEE (2003).

These include radioactive isotopes with legitimate medical and industrial uses, as well as naturally occurring radioactive materials (NORM), including granite, mineral sands, fertilizer, building industry, bananas, etc. Laws, procedures, and different systems are created for normal functioning at customs border points and seaports and for detection of illicit trafficking in the case that a wrongdoer may seek to mask the radioactive signature of undeclared nuclear or radioactive material by including it, for example, within a NORM shipment IAEA (2013), Albanian State Law no. 102, (2014).

These procedures also must handle a host of ever-changing local factors, including varying background radiation levels, different container speeds, etc. If it's not possible to adequately determine the cause of the alarm, a secondary inspection is conducted on the container (IAEA, 2013). Typically, a container is moved out of the traffic flow to a secure area, to conduct the secondary inspection using a handheld radioisotope identification device (RID).

The RIDs can distinguish between specific radioisotopes so that a comparison can be made with each commodity listed on the shipment manifest. The time taken to conduct a secondary inspection may vary, and studies estimate that manual container scanning takes one front-line officer (FLO) approximately half an hour or more to complete. Spectroscopic portal monitors can both detect radiation and identify radioactive sources (IAEA, 2007). In cases where secondary inspections are inconclusive, a further, tertiary inspection may be performed by certified

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radiation experts. It may involve the unpacking of the container contents to determine the source of the radiation readings which extends the process in time and makes it more complicated. PRDs are pocket-sized alarming instruments with user-readable displays. PRDs are worn on the body and used to detect radioactive materials for interdiction and prevention purposes and to indicate the gamma radiation exposure rate and neutron count rate. PRDs are the smallest, least expensive, and most commonly deployed instruments used to detect radioactive materials for homeland security-related applications (IAEA, 2006).

RIDs are used to detect, locate and identify radioactive material and simultaneously provide sufficiently accurate gamma dose rate measurements to ensure radiation safety during the localization and identification of radioactive material. These instruments provide greater sensitivity of detection compared with PRDs, but they are heavier and more expensive. Handheld RIDs are mostly used for detection in targeted search situations and for identification of the radionuclide causing an alarm (IAEA, 2006).

PRDs are used during primary inspection and RIDs during secondary and tertiary inspections. The PRDs and RIDs should be calibrated and tested periodically (IAEA, 2006).

They should be checked daily with small radioactive sources to verify that they can detect increases in radiation intensity and that corresponding alarms are triggered. Self-diagnostic tests should be included to cover as many functions as practicable. When these tests indicate the possibility of malfunction, an external alarm should be given. It is recommended that the equipment be inspected and its functions tested once a year by a qualified person or maintenance facility (IAEA, 2006). This process is a challenge in handheld radiation detection equipment's use and radioisotope identification from FLOs.

2. Materials and Methods

2.1. The purpose of the questionnaire

This questionnaire was initiated in the framework of the IAEA coordinated research project CRP J02012 "Advancing Radiation Detection Equipment for Detecting Nuclear and Other Radioactive Material out of Regulatory Control". The scientific scope of this CRP was to develop a set of physical design specifications for handheld radiation detection equipment (total weight, form factor, weight distribution, audible and tactile alarm levels, etc.) based on actual measurements of usage under field conditions by a representative sample set of users across age, gender, and job function under the various environmental conditions (season, noise, clothing). The coordination and support of all the countries involved in this CRP from the IAEA will help many member countries where import exports are very large. The gaps between the nuclear security detection needs and the current technical and functional capabilities of instruments (including, but not limited to, detection sensitivity, requirements for maintenance and calibration, lifecycle costs, information transfer, human interfaces with equipment, and training needs) are hindering the ability of Member States to develop, implement, and sustain nuclear security detection strategies IAEA (2002), IEEE (2003) effectively and efficiently. The use of handheld equipment at customs points is an important step in the implementation of standard operating procedures, which often takes time and requires patience and dedication. Reduction of time is a strong point of the project implementation.

2.2. Distribution of the questionnaire

The purpose of the questionnaire was to investigate and understand the challenges of FLOs with the use of PRDs and RIDs during their everyday work and inspections. FLOs will understand their important role in the security of nuclear and other radioactive material out of regulatory control and in countering threats by knowing better, the actual problems and requests of the different inspection systems IAEA (2002), IAEA (2013). "Front-line officers are potentially first alerted about nuclear and other radioactive material out of regulatory control, either through information alerts or detection equipment alarms," (IAEA).

In October 2019, a survey was conducted by using a questionnaire with different Front-Line Officers (FLOs) on PRDs and RIDs use. In this questionnaire participated 42 different Countries (Lebanon, Thailand, Algeria, Morocco, Colombia, Vietnam, Uganda, Armenia, Luxembourg, Argentina, Spain, Chile, Uruguay, Bosnia and Herzegovina, Russia, Croatia, India, Latvia, Finland, Ukraine, Rumania, Oman, Malaysia, Jordan, China, Bahaman Kingdom, Pakistan, Azerbaijan, U.K, Egypt, Paraguay, Cuba, Cyprus, Hungary, Ghana, Senegal, Cambodia, Malawi, Sudan, Nigeria, Georgia, Albania). The questionnaire was prepared in hard copy by CRP J02012 "Advancing Radiation Detection Equipment for Detecting Nuclear and Other Radioactive Material out of Regulatory Control" working group. Department of Nuclear Safety and Security, IAEA, enabled the distribution of this questionnaire to the target group of Front-Line Officers (FLOs). The questionnaire was divided into five sections with 28 questions in total. In this questionnaire, participated 39 males and 6 females.

3. Results and Discussion

In this questionnaire with five sections and 28 questions, some MS responded to two questionnaires such as China, Thailand, Albania, etc., so in total participated 47 different MS. This paper provides information about personal information, notifications of PRDs and RIDs, PRDs Display and interfaces, RIDs Display and interfaces, and features for radiation detection equipment in general (Kozeta et al., 2019, 2021). Equipment described in Fig. 1 below was used also to perform the research experiments in the frame of the coordinated research project CRP J02012 "Advancing Radiation Detection Equipment for Detecting Nuclear and Other Radioactive Material out of Regulatory Control".

Fig. 1 shows all the PRDs and RIDs types included in this questionnaire and their number used by different FLOs.

Figure 1. PRDs and RIDs types
(Others; 1. Ortec (2), 2.HDS minion (1), 3. Ludlu Model (1), 4. Radiation Server Meter (1), 5. High Purity Germanium and silicon detector (1), 6. Telefactors (1), 7. Individual detector (1), 8.ADS 6150 (1), 9. Rapiscan (1), 10. Atoms AD6 Aladox (1), 11. Atomex (1), 12. X-Rey detector (1), 13. Cambua (1), 14.ERA terra (1), 15.MKS-05 (1) 16. Radiation monitors (1) 17. Minitrace (1), 18. TSA (1), 19. Sam 940 (2)).

Table 1 shows personal information, job function, total work experience and working environment of all the FLOs involved in this questionnaire.

One of the main challenges often encountered is different FLOs educational backgrounds. The experience and continuous training should be an essential part of the sustainable capacity building of FLOs in all countries. Experienced FLOs number is low which shows that their working position is unstable due to high working position rotation in Customs Directories in all Member States that participated in this questionnaire. Also, most of FLOs that participated declared that are working in both environments Indoor and Outdoor.

Table 1. Personal Information of Front-Line Officers

Personal Information	No
Gender	
Female	6
Male	39
Age (years)	
< 30	1
30-35	11
35-40	7
>40	27
Job Function	
Commanding officer	2
Nuclear chemist	1
Leading the team to detect	2
Officer of civil protection	1
Specialist on CERN	4
Costumer	14
Security	3
First responder and regulatory	4
Police	4
Head of planning division	1
Shift manager at PCP	1
Researcher	7
NSDA	1
Head of nuclear security	2
Total work experience as FLO	
1-5 years	10
5-10 years	18
10-15 years	10
15-20 years	6
>20 years	3
Type of working environments	
Indoor	11
Outdoor	3
Both	33

Table 2 shows holding position and purposes of PRDs and RIDs use.

Table 2. Holding position and purposes of PRDs and RIDs use

Where do you wear the PRD? Check all that apply.	Answer
On the belt	35
In the pocket	9
Chest area	11
Others (please specify)	2
-RID-s sometimes use like backpack	
-Hands sometimes	
Based on your job functions, which of these are the purposes of using the equipment? Check all that apply.	
Safety dose rate	40
Search tool	37
Identification	33

Table 3 shows notifications of PRDs and RIDs which are mostly used by all FLOs in Border Custom Points.

Table 3. PRDs and RIDs notifications

What type(s) of notification do you use? Check all that apply.	
Audio/ sound	42
Tactile/ vibration	27
Visual/ light	24
Proposal -> with numbers	1
Do those notifications adequate for the job function and working environment?	
Yes	41
No	3
Others->-RID and PRD	

Most of FLOs have chosen the "On the belt", holding position as more suitable during the on-site inspections and for security reasons during passengers' inspections. The most preferable PRD notifications were audio/sound and vibration, especially in the countries where import-exports are very large, and the noise level is higher. Based on FLOs answers the purpose of using the equipment's safety function has more importance.

Table 4 shows PRDs display and interfaces issues in the daily use by FLOs in Border Custom Points.

Table 4. PRDs Display and Interfaces

Are there any issues with your PRDs?	**Answer**
Yes	9
Interface (please explain)	3
Display size (please explain)	1
Display brightness (please explain)	1
Text size (please explain)	1
PRD size (please explain)	1
Battery life (please explain)	4
Others (please specify)	4
No	34
Which of the following screen position of the PRDs is the most preferable?	
on top	23
on side	19
Based on the device you use, is the text size adequate?	
Yes	39
No	2

Regarding the PRDs display and interfaces most of the FLOs have answered No, which shows that PRDs are suitable for on-site inspections in the BCPs. Most preferable PRDs screen position is on top of the device, like the Polimaster PRD, as it is most suitable for holding it during inspections.

Table 5 shows RIDs interface issues and table 6 RIDs Display and holding time in the daily use by FLOs in Border Custom Points.

Table 5. RIDs Interfaces

Which interface/ buttons would simplify your uses of the RIDs?	**Answer**
Simple on/off	26
Search/Find	18
ID (for identification)	21
Menu driven interface	4
Are there any issues with your RIDs?	
Yes	4
No	39
Does the screen of the RIDs large enough to display the information you need for your job?	
Yes	39
No	3

Table 6. RIDs Display and holding time

What do they want the RIDs to immediately show on the screen? Check all that apply.	
Battery life	33
Count per second (cps)	28
Dose rate	37
Any others, please specify	1
Based on your SOP, how long do you have to hold the RID for ID?	
Yes, I can hold the RID to get the ID results without a break	32
No, I have to take a break to get the ID results	10

Based on the FLOs answers the display and interfaces of RIDs are appropriate for use in their daily work. The most preferable display unit is the Dose Rate which is more understandable from FLOs.

Table 7 shows general features for radiation detection equipment's issues in the daily use by FLOs in Border Custom Points.

Table 7. General Features for radiation detection equipment

What types of power or chargers do you prefer your equipment to have? Check all that apply.	**Answer options**
USB chargers	28
Rechargeable batteries	33
Magnet chargers	2
Wireless chargers	11
Others, please specify	1

What types of power or chargers do you prefer your equipment to have? Check all that apply.	**Answer options**
How long is the battery life of your PRD? How often do you have to change your PRD batteries?	
more than one hour	7
within 24 hours	4
once a week	4
more than once a week	2
once a month	5
more than once a month	3
once a year	1
more than once a year	2
Which of the following screen would you prefer? Check all that apply and explain.	
simple	19
green	26
yellow	3
red	13
Any of following features you think would be useful for your job?	
Display always visible during the measurement	33
Notify users when the ID is determined/ the timer reaches	26

The main challenges during the FLOs work in different Border Crossing Points are:

- General features for radiation detection equipment;
- Preventive maintenance;
- Different types of equipment;
- Battery lifetime and difficulties in finding original batteries;
- Charger issues (damages, connection issues) due to not proper use from different FLOs;
- Lack of trained personnel for the maintenance of the different equipment.

To find the detector with optimal characteristics, we performed multiple research experiments in the frame of the project CRP J02012 "Advancing Radiation Detection Equipment for Detecting Nuclear and Other Radioactive Material out of Regulatory Control", with many individuals with different physical parameters and this questionnaire gave us real personal information of Front-Line Officers and what devices they use most often.

The experiments were performed in four holding positions 0,15,30,45-degree angles. The strongest dependence was on the measuring angle. It was noted that the maximum time that men used the device was 150 seconds, while for women it was 110 seconds. To model the effect of detector shape in the measurement process, we used the elapsed time until discomfort became noticeable and the time elapsed until holding the device became unbearable. The main assumption was that the detector with a more appropriate form allows for extended working time and the user has less discomfort, or the discomfort appears later. We tried polynomials with higher order terms and the conclusions were practically the same.

4. Conclusions

This study shows some of the challenges faced by FLOs in handheld radiation detection equipment use and radioisotope identification. It also provides information about the personal data and experience of different FLOs, the equipment used during inspections, notifications of PRDs and RIDs, displays and interfaces of RIDs, and general features for radiation detection equipment. The purpose of the questionnaire was to address the gaps between operational/human needs and performance of actual PRDs and RIDs capabilities. The most preferable PRD notifications were audio/sound and vibration and the PRD screen position was on top of the device, like Polimaster PRD, as it is more suitable for holding it during inspections; The most preferable display unit is Dose Rate and PRDs "On the belt", holding position is most suitable during the on-site inspections. Display and interfaces of RIDs are appropriate for the use in their daily work;

From data and information collected [Kozeta et al., 2019, 2021] from this questionnaire and experiments performed in the frame of the project CRP J02012 "Advancing Radiation Detection Equipment for Detecting Nuclear and Other Radioactive Material out of Regulatory Control" was found that: The results do not depend on the age of the user, nor on height, nor on gender. The lightest available detectors were more comfortable to be used, with measurements at an angle of 0 degrees; The heaviest detectors available were also used, with more suitable measurements at a 45-degree angle.

The information obtained from this questionnaire and CRP J02012 will help to develop a set of physical design specifications for handheld radiation detection equipment (total weight, form factor, weight distribution, audible and tactile alarm levels) based on actual measurements of usage under field conditions.

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