RADIOLOGICAL MAPPING USING SMARTPHONES EQUIPPED WITH PERSONAL RADIATION DETECTORS

A. NABIPOUR CHAKOLI
Nuclear Science and Technology Research Institute,
Tehran, Iran
Email: anabipour@aeoi.org.ir

C. MASSEY
International Atomic Energy Agency,
Vienna, Austria

H. Weibert
International Atomic Energy Agency,
Vienna, Austria

Abstract

Real-time radiological mapping is necessary for command and control of nuclear security at major public events, in searches for lost or stolen radioactive sources, and mitigation of radiological incidents[1]. The use of personal radiation detectors in conjunction with smartphones could play a key role in the aforementioned situations. Enhancements of technology in the field of radiation detection and national/global communication have made the use of personal radiation detectors connected to personal smartphones a viable and cost-effective option to address real time radiological mapping and security and safety coordination requirements. In this paper, elements of the necessary social and physical infrastructure for application of personal detectors and smartphones in the establishment of a real-time radiological monitoring and mapping center will be described. Additionally, the paper discusses the possibility of using data from general public smartphones connected to radiation detectors to supplement the data in control centers that comes from official nuclear security and safety detectors. The supplemental public member data could significantly and cost-effectively increase real-time awareness and command and control capabilities while enhancing public confidence.

1. INTRODUCTION

Nuclear safety and nuclear security are two subjects that must be considered in the field of nuclear science and nuclear technology. Radionuclides can be released to the environment from normal circumstances and incidents that include accidents and malicious acts. Because the release of radionuclides decreases the level of safety and security of countries, rapid and effective methods of preventing such release from occurring and quick response to mitigate effects is required to the extent possible to enhance public security and safety.

Experiences after the Chernobyl and Fukushima accidents have clearly shown that self-made measurement of radiation can create opportunities for providing information to individuals and empowering them to take an active role in their own radiation protection decisions. The data collected by the general public can also be used to compare and integrate with data from conventional off-site monitoring and modeling tools. The self-measurement process could thus become part of the necessary actions that are to be taken to build trust in radiation protection authorities and technical experts [References 1 and 2]. Additionally, the data from the general public could be used in combination with that of nuclear safety and security personnel to greatly enhance command and control of prevention, response, and mitigation efforts.

In this paper, improvement of national nuclear safety and nuclear security capabilities using a smartphone connected to a small personal radiation detector (PRD) is considered and discussed in the proposed context of

[1] 'Incidents' includes initiating events, accident precursors, near misses, accidents and unauthorized acts (including malicious and non-malicious acts).

smartphones connected to PRDs for (1) nuclear safety and security official personnel, and (2) members of the general public. In both cases (official personnel and general public), a small personal radiation detector can be connected wirelessly by blue-tooth or integrated/plugged into a smartphone according to the phone design. During nuclear security activities associated with a major public event or searches for lost or stolen sources, and radiological incidents in urban and suburban areas, nuclear security and safety control centers need complete and reliable real-time information about the level and location of radiation dose rates. New generations of personal radiation detectors that can be connected to smartphones have been developed by a number of companies. It is possible that national nuclear security command and emergency centers could greatly enhance their radiological mapping and analysis capabilities using personal smartphones and existing national communication systems.

2. SMARTPHONE AND RADIATION DETECTOR TECHNOLOGY AND INFRASTRUCTURE

A new generation of personal radiation detectors that can be attached to smartphone has been developed by many manufacturers and are already available for sale or patented with some examples shown in Figure 1. The plug-in devices include a variety of technologies such as diodes, Geiger counters, and scintillators that can detect external radiation as counts or dose rate. There are also software or application programs that can be installed in the smartphone to manage the attached radiation dosimeter. [3]

FIG. 1. Images of some commercial radiation dosimeter attachable to smartphones.

The quality, accuracy, reproducibility and limitation of these groups of smartphone technology and connected radiation detectors varies considerably, especially when used in real situations such as radiological incidents and daily life. These phone/detector systems would have to be carefully evaluated before use by a nation, but they offer intriguing possibilities in greatly enhancing coverage and public confidence. To improve quality of data and better accuracy of radiation readings, specifications and test results of these systems by appropriate national or international agencies could be provided to the public so that quality instruments and systems are used. Failure to do so may cause other issues with public confidence if false or incorrect indications of radiation levels are provided by these systems.

There are also a number of radiation detection manufacturers that have developed software and hardware that connects portable radiation detectors larger than the types shown in Figure 1. These detectors typically have greater detection and identification abilities than the much smaller detectors. The detectors (PRDs, handheld radioisotope identification devices, and detectors backpacks are typical instruments used by official nuclear security and safety officials) in these systems usually wirelessly connect to smartphones and display and analyze data at a command center. However, many of these systems have drawbacks when considered by nations interested in this mapping/tracking capability. The drawbacks include: (1) the systems only supports the vendor equipment and may require expensive or recurring fees for use of the data analysis and display, and (2) the system may require that data be transmitted to a cloud service where the vendor provides analytics and oversight. This second drawback is a major concern by many nations that do not want entities outside the nation's security/safety agencies having access to the data.

The International Atomic Energy Agency (IAEA) has recognized the importance of real-time mapping and control using systems with smartphones connected to detectors. In support of IAEA Member State (MS) requests, the IAEA has developed specifications for a software/hardware solution that can provide real-time command and control without the drawbacks mentioned in the previous paragraph. The IAEA system is called the Mobile-Integrated Nuclear Security Network (M-INSN). The M-INSN is intended to support a wide range of radiation detection operations in unconstrained environments such as major public events (MPEs) or wide area searches. The M-INSN is also intended to support IAEA MS awareness of the health and location of their handheld and portable radiation detection equipment.

The M-INSN will enable the secure distribution and analysis of nuclear security detection information between the relevant end-users designated by a MS for implementation of the MS's nuclear security detection activities. A State will completely control access and permissions of the network solution. The planned M-INSN will be developed, provided, and maintained by the IAEA for free use by its MS. All property rights of the developed software and associated products will belong to the IAEA, eliminating the need for license and user fees. The M-INSN is also planned as an open source software that will support innovations and additional features provided by users to enhance their nuclear security operations.

The M-INSN is designed to be compatible with any vendor equipment and thereby support existing radiation detection equipment already in use in Member States. The M-INSN will enable radiation detection and identification instruments from any vendor (supplying the appropriate data interface protocol), when paired with a smartphone via Bluetooth, to transmit relevant information including dose rates, identification results, time stamp, and Global Positioning System (GPS) location information to a command and control center via the phone's mobile network or cellular connection.

Regardless of the detector-smartphone solution, the basic infrastructure of the system is the same. For a national command center with radiological mapping capability using personal smartphones and national wireless communication network, Figure 2 presents a generic overview of the procedure of data transferring and processing for radiological mapping. Within this proposed network, citizens and officials can have a reliable connection to the radiation monitoring center and they can send and receive valuable data related to environmental radiation during daily life and in the event of a nuclear security or safety event.

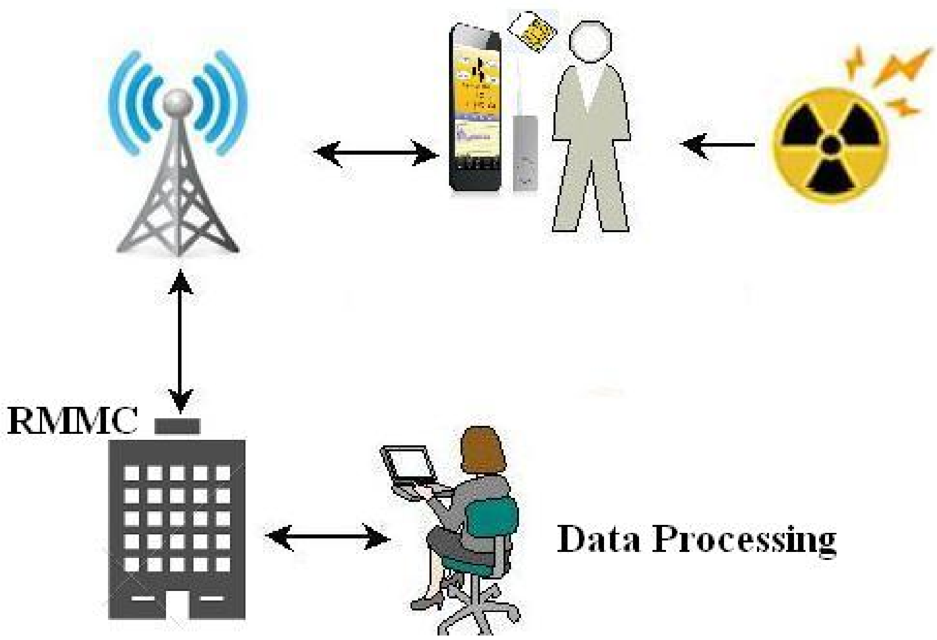

FIG. 2. Schematic representation for application of smartphone for radiation monitoring and mapping, RMMC (Radiation Monitoring and Mapping Center),

3. INTEGRATON AND ENHANCEMENT OF NUCLEAR SAFETY AND NUCLEAR SECURITY USING A NETWORK OF SMARTPHONES AND RADIATION DETECTIORS

The first step for protection of people against radiation hazards from an incident is the detection of the radiation. Once detected, the source of radiation and the associated levels of radiation must be determined. Radiation detection instruments are required for detection and measurement of radiation. Regulating nuclear and radiation safety is a national responsibility and many States have adopted IAEA safety standards and guidance for use in their national regulations and establishment of operational approaches. According to the IAEA Safety Principle 8: "Prevention of accidents," all practical efforts must be made to prevent and mitigate nuclear or radiation accidents, including accident management procedures that "must be developed in advance to provide the means for regaining control over a nuclear reactor core, nuclear chain reaction or other source of radiation in the event of a loss of control and for mitigating any harmful consequences."[4] Safety Principle 9: "Emergency preparedness and response" further elaborates that arrangements must be made for emergency preparedness and response for nuclear or radiation incidents. Under Principle 9, "the primary goals of preparedness and response for a nuclear or radiation emergency are: to ensure that arrangements are in place for an effective response at the scene and, as appropriate, at the local, regional, national and international levels, to a nuclear or radiation emergency…and for any incidents that do occur, to take practical measures to mitigate any consequences for human life and health and the environment." [ibid.] The use of a network of smartphones connected to radiation detectors could assist States in detecting and monitoring radiation using existing infrastructure in their country, thereby meeting obligations by enabling people to have their own personal radiation detector connected to a national system.

Due to rapid development of communication technology, a large percentage of people around the world have a smartphone. Additionally, it may be possible for radiation detector manufacturers to provide a cheap, reliable, and user-friendly personal radiation detector that could be integrated in the smartphone or attached as separate device [5]. Figure 3 presents the project global population density in 2020. About 40 percent of people around the world have a smartphone and this percentage is increasing fast. If about 10 percent of smartphones were equipped with a radiation detector, it would mean, on average, that 4 percent of the population of each country could detect and send real-time radiation data. This large amount of data could help the States monitor and control their nuclear safety and security activities with low cost by increasing awareness of real-time radiation levels and coordinating public radiation readings with those of official sources of data.

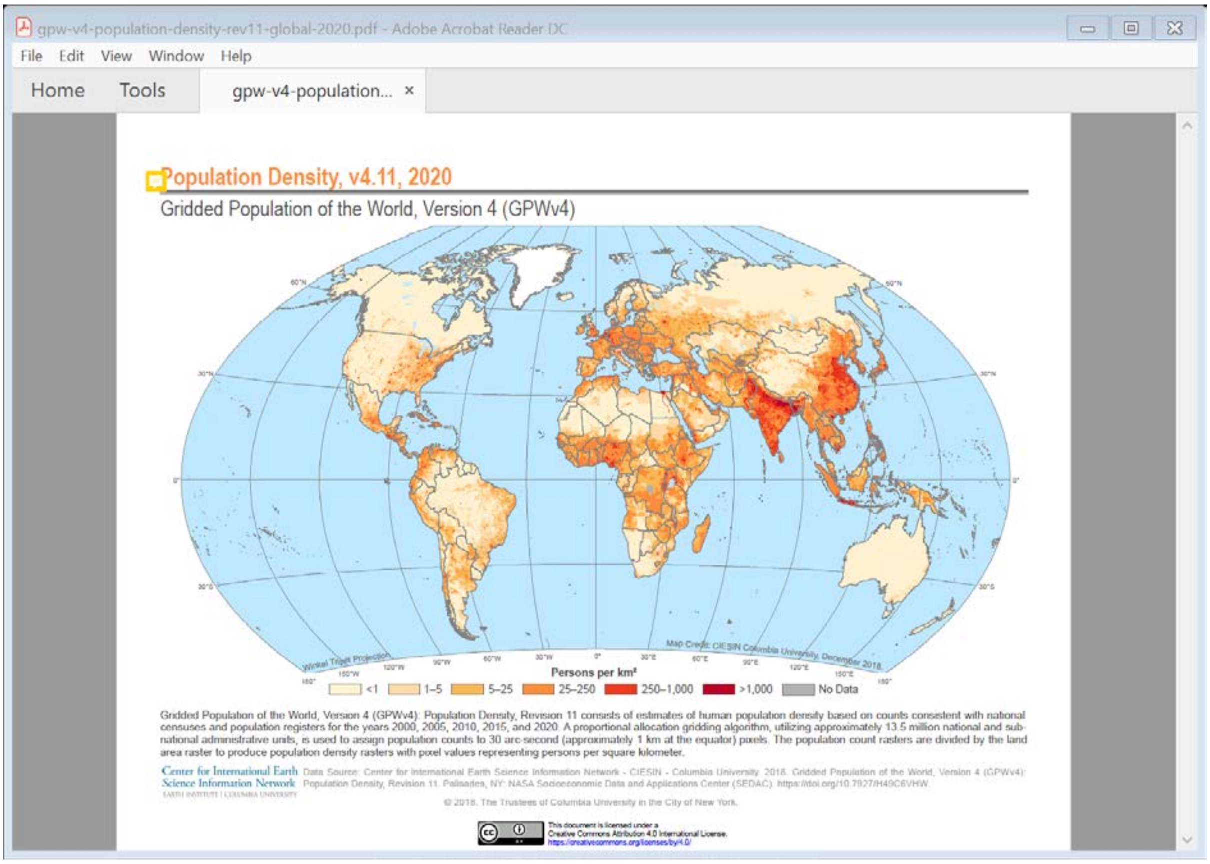

FIG. 3. Projected Global Population Density Map for 2020

However, there is an uneven level of experience and access to such techniques in the IAEA Members States. The IAEA has a vision that its Member States will eventually have in place a proper infrastructure and technologies for radiological characterization of the regions in a timely, safe and cost-effective manner. One of the many considerations in a radiation detection network for radiation mapping in a region is choosing the proper radiation detectors. Detectors are chosen based on their application and must be accurate and reliable in reporting results. Incorrect or false radiation readings of counts, dose rate, isotope identification, etc., all present potential safety, security, and public perception issues. Before selecting an instrument for radiation monitoring and connection to a network, Sates must have carefully developed specifications and means for testing and ensuring that those specification are met.

Figure 4 presents a real time radioactivity and environmental dose rate of European countries and some places around the world. European government agencies compile radiation readings as part of environmental monitoring mandates, making the readings available to the public in near-real-time. The European Radiological Data Exchange Platform (EURDEP) is a network for the exchange of radiological monitoring data between most European countries. It can be seen that the resolution of map is limited due to lack of enough detailed data from all regions of cities and also from rural areas.

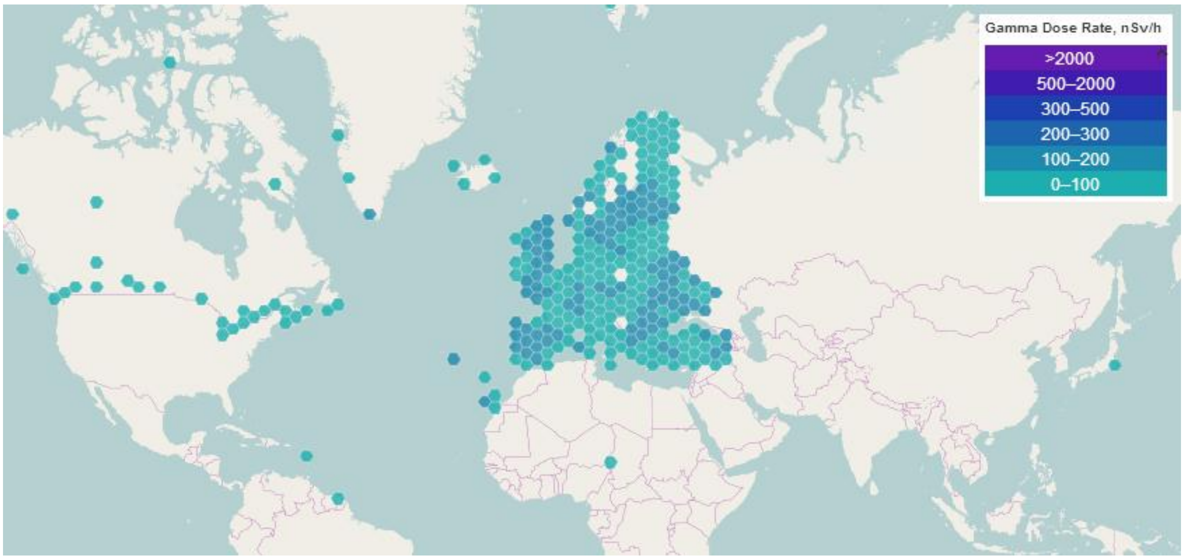

FIG. 4.Real time Radioactivity Environmental Monitoring, Join Research Center, European Commission, (2020.01.25)

The EURDEP is developed and maintained by the Joint Research Centre of the European Commission. The EURDEP network is used by participating countries for the continuous exchange of data from their national radiological monitoring networks in almost real-time. Continuously (routine and emergency) each organization makes data available on an hourly basis. Data is collected from the national data servers through dedicated channels. All incoming data-files are checked and aggregated into a common database. The accessible public maps allow viewing the monitoring data in a simple, intuitive way by citizens. The simple real-time monitoring map shows the latest measurements of environmental radiation in the form of gamma dose rate averages and maxima for the last 24 hours. It utilizes a modern responsive web design, which allows the map to be viewed on variety of desktop, tablet and smartphone browsers.

What if EURDEP or similar systems used smartphones of the general public equipped with detectors as part of the environmental monitoring network and incident management systems? The online smartphone could send two significant data points to the national nuclear emergency control center using wireless communication network:

— Geographical position, and
— Radiation dose rate of related geographical position.

Using the received date from each Smartphone, the data collection system can develop a more detailed radiation map of a region for use by decision makers. Not only could data gaps be addressed by providing a much wider network of detectors at a potentially cost-effective approach, but the public involvement in the system could enhance public confidence also give system operators contact points to reach out to in the event of an incident.

4. CONCLUSIONS

In the management of nuclear security and safety activities, access to real-time radiation data is crucial for making correct decisions. However, there are limitations in the number of sources of radiation data and this includes the lack wide-spread coverage of geographic areas by radiation detectors. In the event of a nuclear safety or security incident, it is necessary to characterize the radiation levels on as detailed a geographic basis as possible within as short a time frame as possible. However, the assessment of the incident requires large amount of accurate data with time stamps and longitude/latitude. The limitations resulting from States using only official sources of radiation readings (nuclear safety and security officials equipped with detectors) could be addressed by incorporating communication/detection devices used by the general public. Using general public devices could increase safety and security, as well as reducing national detection costs.

The Shamisen project, which analyzed experiences after the Chernobyl and Fukushima accidents, clearly showed that radiation measurements can help people to better apprehend and manage their situation, especially if they have the training and tools to make the measurements by themselves.[5] In particular, in Fukushima, self-made radiation measurements created opportunities for:

— providing information to individuals,
— empowering individuals to take an active role in their own decisions,
— increasing insight of individual exposure and official limits, and
— comparing and integrating official data from off-site monitoring.

On the contrary, the Chernobyl experience demonstrated a lack of public involvement in data collection and dissemination at the emergency and early phases, mainly due to lack of training, communication restrictions, education, methodological unity, etc. and showed the need for developing suitable communication and detection tools. The situation there has changed and people residing at the contaminated areas have better opportunities to measure and apprehend radiation doses in local food products, with corresponding increases in public confidence.

If the public had radiation detectors connected to their smartphones, individuals could be made aware of situations presenting increased levels of radiation. This ability could help people have less fear of radiation incidents and assist in increasing public confidence in States proposing or using peaceful applications of nuclear energy and nuclear technology. Additionally, the general public could also become a meaningful part of a State’s nuclear security and safety architecture. Smartphones connected to radiation detectors offer States enhanced capabilities for command and control of nuclear security and safety activities – a solution set that could be efficient, effective, affordable, and secure. Design and implementation of such a system is an intriguing option that requires careful consideration and specification. Important elements of systems are available or coming soon, such as the IAEA’s M-INSN. States should consider approaches to take advantage of evolving technology and keep the public involved. Experience has shown that access to radiation detectors and data has increased public confidence in the aftermath of a nuclear incident, and the public has also responded positively to involvement in many types of security programs such as reporting suspicious individuals and packages. The concept of using radiation data from smartphones to enhance nuclear safety and security is worth exploration.

REFERENCES

[1] FATTIBENE, P., ANGELIS, C., et al., D 9.136 - Guidelines/concept for dose, measurement apps and tools, EJP-CONCERT, European Joint Program for the Integration of Radiation Protection Research, H2020 – 662287.

[2] GOTO, A., OHBA, T., et al., D 9.137 - Preparation of core protocol for an APP to collect information on health and well-being, EJP-CONCERT, European Joint Program for the Integration of Radiation Protection Research, H2020 – 662287.

[3] FATTIBENE, P., MONACA, S. D., et al., D9.133- Review of applications and devices for citizen dose measurement, EJP-CONCERT, European Joint Program for the Integration of Radiation Protection Research, H2020 – 662287,

[4} INTERNATIONAL ATOMIC ENERGY AGENCY, Fundamental Safety Principles, Safety Fundamentals No. SF-1, STI/PUB/1273, Vienna, 2006.

[5] CARDIS, E., LUUTSKO, L., et al., SHAMISEN Nuclear Emergency Situations: Improvement of Medical and Health Surveillance (Project), Barcelona Institute for Global Health, Barcelona, Spain, 2017,