D9.138- Concept/guidelines for apps and tools for dose measurement and health and well-being monitoring

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<th>Work package / Task</th>
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<th>ST9.8.4</th>
<th>SST9.8.4.1</th>
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<td>Deliverable nature:</td>
<td>Report</td>
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<tr>
<td>Dissemination level: (Confidentiality)</td>
<td>Public</td>
<td></td>
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<tr>
<td>Contractual delivery date:</td>
<td>Month 52</td>
<td></td>
<td></td>
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<tr>
<td>Actual delivery date:</td>
<td>Month54</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Version:</td>
<td>v.1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Total number of pages:</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Keywords:</td>
<td>Mobile apps; nuclear accident; citizen science; dose measurements; health/well-being; socio-economical impact assessment; SHAMISEN SINGS project</td>
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Approved by the coordinator: Month 54
Submitted to EC by the coordinator: Month 54

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Abstract

The current Deliverable presents the CONCEPTS and toolkits and recommendations for APPs for dose-measurements and health/well-being monitoring and communication after a nuclear accident based on the work and recommendations presented in D9.136 (WP2) and D9.137 (WP3).

An assessment of the potential costs and benefits of providing dose measurement APPs to populations affected by a nuclear accident is also presented under a particular scenario.

Information from the current Deliverable, together with that from D9.139 and D9.140 will be included in the final SHAMISEN SINGS Recommendations booklet for wide dissemination to potential stakeholders (to be published as a PDF freely available on-line).

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Overall aims of the SHAMISEN SINGS project and of WP4

The overall aim of SHAMISEN-SINGS is to enhance citizen engagement in preparedness for and recovery from a radiation accident, through the use of mobile apps for measuring radiation doses, monitoring relevant health and well-being indicators and providing a channel for practical information, professional support and dialogue (Liutsko, Sarukhan, Fattibene, Della Monaca, Charron, Barquinero, ... & Goto, 2018).

After a disaster, the need for information and the implication of this for different sectors of society is an important issue, since different people have different information needs and degrees of scientific literacy. Exposed populations need to know where and when they can receive assistance or answers to their questions, the most important being whether they will be safe living where they are. As far as decision makers are concerned, they require such information when evaluating the needs of affected populations and the relevance of potential strategies to manage the consequences of the accident.

In the early phase of response to an accident, there is an important but diverse need for information related to:

- Radiation: contamination levels, areas of exposure, behaviours to decrease exposure risk, and health consequences of radiation exposure;
- Social issues: such as where to meet families, access medical care and social facilities;
- Actions taken and planned: such as evacuation zones and routes,
- Providing personalised information.

In the long term, there will be a need to exchange information on local contamination levels, food contamination, health monitoring results, and local decisions, particularly in relation to lifting of evacuation orders and return of populations to their homes.

Building a strong relationship and timely information exchange with local stakeholders and affected populations is key for managing and mitigating the early and long-term consequences of a radiation accident. By obtaining real time and on-place information, citizens would benefit from a reduction in anxiety related to radiation exposure and acquire a basic radiation protection culture (Liutsko & Cardis, 2018).

The objective of WP4 of SHAMISEN SINGS was to develop the concept and guidelines for mobile apps for dose measurements and health/well-being indicators of populations affected by a nuclear accident that can be used (gathering of data) by the general public (including citizen scientists) both for their own information (with a possibility to be guided by professional stakeholders, where needed), as well to shared data for environmental and public health monitoring, public information and decision making processes. In addition, a general data management plan and tutorials have been prepared for users during the SHAMISEN SINGS project together with an economical evaluation of mobile use (D9.138 & D9.139).

Concept/guidelines for apps and tools for dose measurement

Concept

The review of existing apps and mobile devices for dose measurements was conducted in WP2 (task 2.1) and demonstrated that there are many mobiles devices and APPs that could be used by the general public and citizen scientists to measure radiation doses after a nuclear accident (Fig.1 and D9.133).
Enhancing Citizen Participation in preparedness and recovery in radiation accidents: review of existing APPS for citizen based dose measurements

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1. Background

Experiences after Fukushima accident did show that self-made radiation measurements create opportunities for:

- providing information to individuals
- empowering individuals to take an active role in their own decisions, thus regaining control on their lives
- increasing insight of individual exposure and official limits
- compare and integrate official data from off-site monitoring

On the contrary, Chernobyl experience demonstrated a deficiency of public involvement in data collection and dissemination, due to lack of training, education, methodological unity, etc. and evidenced the need for development of tools suitable to this scope.

Use of these technologies should be encouraged, but minimum quality standards should be fostered and misuse be avoided.

2. Project description and goals

The EU project SHAMISEN SINGS, funded under the CONCERT call 2017 and started on October 2017, aims at enhancing Citizen Participation in preparedness to, and recovery from, radiation accidents using novel tools and mobile apps for data collection of radiation measurements, health and well-being indicators.

Work Package 2 is focused on the usage of plug-in devices and apps for self-made radiation measurements. Here we report a list of gaps which deserve further studies that we identified from an analysis of the scientific literature and online information.

3. Types of citizen based radiation measurements

The types of citizen based tools can be classified in five groups:

1. Mobile apps able to convert to dose the signal coming from the CMOS sensor (used in the phone cameras) which is then used as ionizing radiation detector
2. Mobile apps calculating exposure based on data from network of environmental radiation measurements
3. Solid state or gaseous detectors that can be connected to the smartphone (via cable, BT or WI-FI) with display, storage and sharing of data through a dedicated mobile apps.
4. Autonomous solid state or gaseous detectors. Most detectors of type 3 and 4 for public are Geiger Muller tube and photodiode.

5. Website for sharing measured data: https://www.openradiation.org

Figure 1. Review of existing mobile apps and devices on dose measurements

4. Main results from the literature

- Information and communication technologies and uses have evolved rapidly since Fukushima (7 years ago). In parallel the number of mobiles is increasing and it is estimated that 70% of the world’s population will use smartphones by 2020.
- Devices and mobile apps were tested mainly by producers and in fewer cases by independent researchers.
- The tests were carried out in laboratory radiation fields (90Co or 137Cs) and mainly measured the response to dose and dose rate.
- Many mobile apps and devices studied are no more available.
- Mobile apps and detectors offer various possibilities: geolocation, data storage, data sharing, continuous monitoring.

5. Gaps which deserve further studies

- Tests in environmental radiation fields are missing.
- Response at low dose rate should be evaluated, because 95-99% of measurements performed by public fall in that range.
- Questions should address how cosmic radiation affects the response or how to evaluate the detector inherent background.
- Detector parameters other than its response to dose and dose rate should be evaluated, e.g. response stability through days, in different environmental and detector temperatures, the effect of using an incorrect calibration.
- How far improving characterization and calibration procedure would improve the measurement quality and reliability?
- Parameters such as reliability and quality of ergonomy, scientific content, connectivity, geolocation, data sharing were ignored in most of previous studies.
- In particular, accuracy of geolocation (if any) and quality of connection to internet or to mobile phone also play a relevant role in the good usage of these devices.
- The fast turn-over of technologies of detectors and mobile apps calls for a continuous going-on study of the tools on the market.
- Other questions related more to social aspects that should be addressed are: How will these data be used by institution, media, public in case of nuclear emergency? How will data be or can be trusted? Can it help in the management of a nuclear emergency? How can these tools be useful to educate public on radiation, radiation effect and risk? Finally, legal aspects should be explored (cf. responsibility for wrong or inaccurate geolocation or dose rate measurements).

Funding information, references and web sites

SHAMISEN SINGS is funded by CONCERT (Agreement N° 005/2017). EU Joint programme for the Integration of Radiation Protection Research.

Further work in WP2 of SHAMISEN SINGS led to the creation of a toolkit – in the form of recommendations and guidelines. This toolkit is structured into three sections containing recommendations for i) decision makers/authorities and other relevant stakeholders; ii) citizens/users, and iii) app developers (D9.136).

These Guidelines were discussed internally between SHAMISEN SINGS partners and experts as well as with external stakeholders during the RICOMET and ERPW SHAMISEN SINGS meetings in order to improve them and make them clearer.

Below we present the final draft of the section for users”. These guidelines, together with a tutorial (infographics elaborated for general public – see D9.139), will be included in the SHAMISEN SINGS project booklet, which will be published on-line (on the project website as well as Research Gate, and other free repositories) and will be downloadable as a PDF for free.

**Guidelines for users (general public, citizen scientists)**

Affected populations (general public and citizen scientists) can find a number of mobile apps for free or for a price that can be installed on their phones. We tested some of them, discussed widely their practical use, including ethical issues (D9.135) with different stakeholders including professionals, general public, authorities and apps developers within the work of the SHAMISEN SINGS project. To ensure that affected populations use informative APPs and that they use them appropriately, we have prepared a short version of the WP2 Recommendations for these users (general public and citizen scientists), which is presented below.

![Figure 2. Recommendations for the use of mobile apps for dose measurements (Source: D9.136)](image-url)
Recommendations in case you wish to measure radiation with your mobile phone

1: Choose an app
   - Prefer apps that have been recently updated and are recommended by recognized authorities

2: Prepare your mobile phone
   - Cover well the camera with a black, thick adhesive tape
   - Preferably, place the phone in a black container (box, bag, ...) when measuring

3: Set up the app
   - Follow manufacturer instructions
   - Download the conversion factor specific for your mobile phone model

4: Measure
   - Measure for at least 20 minutes
   - When possible, take several measurements with the mobile phone in the same position

5: Log the data
   - Register as many parameters as allowed by the app (dose rate, geolocation, time and duration of the measurement, temperature, etc.)

6: Share the data
   - You can choose to share these data with family and friends, public authorities, and crowdsourcing radiation maps

7: Remember
   - You are not using a professional tool.
   - These measurements can complement, but do not substitute, those made by authorities
   - In case of an accident, follow official radiation protection instructions

The detailed description of the toolkit – set of Recommendations/guidelines (including a visual tutorial – infographics for general public and citizen scientists) is included in the D9.139.

Ethical challenges (including issues of privacy and security of personal data) with reference to the ToS of mobile apps (for developers), data sharing, collection and further use by relevant stakeholders have been considered, widely discussed through a stakeholder workshop, and reported within SHAMISEN SINGS D9.135. Key ethical messages and Recommendations will also be included in the final SHAMISEN SINGS booklet to increase awareness of these challenges, and ensure a wide dissemination of the project results.
Concept of apps for health and well-being for affected populations by a nuclear accident

The concept of apps for measuring health and well-being indicators of affected populations in the case of a nuclear accident is quite complex since it can include:

- A variety of specific standardised and validated questionnaires (on health, well-being, anxiety, stress, quality of sleep, general screening for mental health state [see Annex for an example, the K-6 questionnaire], etc...)
- Links to existing apps for therapeutic advice and referral on treatment anxiety, PSTD, stress, depression, etc. already developed and successfully used in practice
- Measurement of some parameters (sometimes through the use of specific sensors or plugins): including level and routine of physical activity or sedentariness, pulse, etc...
- Feedback to the users based on information collected
- (if possible) Live chat interaction with professional stakeholders (doctors, public health officers, etc.).

The goal of using such apps is twofold:

- First to provide a quick feedback on the current health status and the relevant health indicators of individuals affected by an accident
- Second, if data are shared at the community level with public health professionals/researchers in a manner that preserves privacy and security of personal data, screening for changes in health and/or welfare of affected populations, monitoring trends in health indicators in affected communities that could also reveal specific health, social or psychological needs.

The work on the concept and apps development has started within WP3 (led by FMU, Fukushima Medical University) within SHAMISEN SINGS, based on that partner’s invaluable experience in working with evacuees and residents of areas contaminated by the major nuclear accident which took place at the Fukushima Dai-Ichi Nuclear Power Plant (FDNPP) in March, 2011.

In WP3, the activities carried out in Fukushima prefecture after the accident to check the health & well-being of the affected populations were reviewed and analysed (a summary was presented in a poster communication during the RICOMET conference in Barcelona, 2019 - see Fig. 3). Based on that work and the initial stakeholder consultation, it was decided that an ideal APP to monitor health & well-being indicators for populations affected by a nuclear accident should provide a health assessment tool package, including questions on health and well-being as well as a set of frequently asked radiation-related Q&As, based on lessons learned from the FDNPP accident. The general concept of such an app, with guidelines for developers and users is presented in SHAMISEN SINGS deliverable D9.140.

Since FMU is a no-cost partner in SHAMISEN SINGS, and given the relatively short duration and limited funding of the project, it was not possible to actually development an APP prototype, but rather develop the specifications. However, our Japanese colleagues obtained a 3-year grant from the Japanese government for the development of a mobile APP for monitoring health and welfare and providing a forum for sharing concerns and advice with affected citizens. Work on this APP will continue after the end of SHAMISEN SINGS and an agreement will be signed to allow translation and adaptation of the APP for use in other languages in Europe among the Partner Institutes.
Figure 3. List of activities on health and well-being surveys performed on affected populations after the accident in Fukushima region (Taka et al., 2019, poster, presented at RICOMET 2019).
Socio-economical impact assessment of mobile apps for health and dose measurements

General assessment of benefits and savings by using mobile apps for health/well-being after a nuclear accident

The attempts of successful application of a web-designed tools for mental health disorder prevention in a post-disaster period have been described as a potential health impact for the public and low cost (Ruggiero, Resnick, Paul, Gros, McCauley, Acierno, ... & Galea, 2012). Technological progress and mobile APPs developments now successfully allow diagnosis and treatment of common illnesses and problems via e-health to wide populations and save costs (time and money). Such programmes were used in particular in rural populations (Griffiths & Christensen, 2007), who have limited local access to health care and can therefore greatly benefit from them, especially vulnerable populations such as the elderly and people with travel difficulties or restrictions. The use of machine learning and artificial intelligence creates new opportunities for mental health care research by using already collected large datasets that enable the building of “predictive models for health monitoring, treatment selection, and treatment personalization” (Becker, D., van Breda, W., Funk, B., Hoogendoorn, M., Ruwaard, J., & Riper, H. (2018).

The effectiveness of e-health has been shown in applications related to mild depression in adults (Bolier, Haverman, Kramer, Westerhof, Riper, Walburg, ... & Bohlmeijer, 2013); social anxiety and panic disorder (Ivanova, Lindner, Ly, K. H., Dahlin, M., Vernmark, K., Andersson, G., & Carlbring, P. (2016); self-paced online intervention for depressed adults with type 2 diabetes (Cohn, Pietrucha, Saslow, Hult, & Moskowitz, 2014) and stress (Heber, Ebert, Lehr, Cuijpers, Berking, Nobis, & Riper, 2017), among others.

While the evidence of benefits of e-health applications are now clear, little is known to date about the cost-effectiveness of e-health for mental treatment vs. “usual face-to face” treatment. Beecham and colleagues have suggested a protocol to perform cost-benefit analysis (Beecham, Bonin, Görlich, Baños, Beintner, Buntrock, ... & Potterton, 2019) within a framework of ICare programme they developed:

“Following the analyses of service use and costs data, joint analysis of costs and outcomes will be undertaken to provide findings on the relative cost-effectiveness of the interventions, taking both a public sector and a societal perspective. These analyses use a well-established framework, the Production of Welfare approach, and standard methods and techniques underpinned by economic theory.” (Beecham, Bonin, Görlich, Baños, Beintner, Buntrock, ... & Potterton, 2019).
Deliverable <D9.138>

Cost-benefit analysis for citizen science use of mobile apps on dose measurements

The economic evaluation of using mobile apps on dose measurements by citizen (citizen science) was performed in terms of cost-benefit analysis. The estimate of the costs of the proposed strategy was quite straightforward, whereas the monetization of benefits was mainly based on the literature of citizen science in environmental monitoring projects. A sensibility analysis looking at different scenarios was carried out.

The following hypotheses were made in order to carry out the analyses.

1. The “case study” used figures from the Italian Piedmont region (29 radiation air monitoring stations).
2. The costs for the Agencies run program include:
   - monitoring stations
   - network implementation
   - personnel
3. The costs for the radiation measurements from Citizen Science (CS) include:
   - staff allocated to the CS project (researchers, administration, support)
   - advertising and recruitment (e.g. newsletters)
   - training (typically short for this kind of apps)
   - supplies and equipment (apps for radiation measurements are affordable – ca.5 euros)
   - data collection and validation (researcher).
4. The time frame is 1 year.
5. No benefit is considered at this point.

As far as costs are concerned, these include (but are not limited to): Staff salaries for project planning and development, coordinating and supporting volunteers, validation of collected data; storage of the collected information; citizen training for the use of the apps both for technical issues and for information interpretation; IT system development and maintenance; developing apps for monitoring citizen’s health and exposure to radiation (or buying existing ones); reimbursement to volunteers. Costs of citizen science vs. agencies run programs are simulated. The discussion of benefits is focused on: saving staff costs; reaching citizens more promptly; increasing education and skills; overcoming language barriers using pictures, videos, etc.; growing sense of community; increased interest in capabilities of citizen scientists; increased credibility of government given the transparency of procedures involved; increasing health and well-being.

Figure 4 shows the cost of the two strategies per number of volunteers employed. The two curves cross at N=500, i.e. number of volunteers above which citizen science is more expensive. Figure 5 shows the cost ratio by number of volunteers enrolled. The curve is not linear, above N=500 the increase is less steep than below 500.

In conclusion, to collect the same kind of information on health, citizen science is less costly up to 500 volunteers. At the same cost (N=500 volunteers), radiation measures are more widespread but may be less reliable in citizen science than in agencies run programs. As for benefits, specific surveys have to be conducted in order to monetize them.
Costs of Citizen Science vs Agencies run programs

![Graph showing costs comparison between Citizen Science and Agencies run programs. The y-axis represents costs in Euros, ranging from 0 to 200,000, and the x-axis represents the number of volunteers ranging from 100 to 2000. The graph shows two lines: one for Citizen Science and one for Agencies run program. The number of volunteers is approximately 500.]

**Figure 4.** Costs of Citizen Science vs. Agencies run programs

Citizen science vs agencies run program: costs ratio

![Graph showing the cost ratio between Citizen Science and Agencies run programs. The y-axis represents the ratio ranging from 0 to 1.4, and the x-axis represents the number of volunteers ranging from 100 to 2000. The graph shows an increasing trend in the ratio as the number of volunteers increases.]

**Figure 5.** Citizen Science vs. Agencies run program: cost ratio
References


D9.135_Consensus workshop report on ethical issues (submitted, available by the end of 2019)


D9.139_ Tutorials for apps and tools, including database management plan (in submission)

D9.140_ Prototype APP for health and welfare monitoring, diet, space-time distribution (general description & guidelines) (in submission)


Other related communications

Ohba, T. et al. (October, 2019). Adaptation of an EU-initiated mobile phone application interface for interactive support. European Radiation Protection Week, Sweden: Stockholm (oral)


Liutsko, L. et al. (October, 2019). Shamisen sings project – benefits and challenges by using apps for dose and health monitoring after a nuclear accident. European Radiation Protection Week, Sweden: Stockholm (oral)


Needs on Apps (mobile applications) for dose measurements & health/well-being related to radiation exposure (WP1 SHAMISEN SINGS project) (SHAMISEN SINGS project). RICOMET, Belgium: Antwerp (poster + oral).


Ohba, T. et al. (July, 2019). Development of a mobile phone application for interactive supports of returned residents in a nuclear accident. International conference RICOMET, Barcelona, Spain (poster)
Annex I. Example of a self-administrated pencil & paper-based questionnaire (K-6)

The self-administrated K-6 (pencil & paper version) test was used to test the affected population after the Fukushima accident. It could be programmed easily and used as an app also.

K-6 Self-administrated test (mental health):

The following questions ask about how you have been feeling during the past 30 days. For each question, please circle the number that best describes how often you had this feeling.

<table>
<thead>
<tr>
<th>Q1. During the past 30 days, about how often did you feel...</th>
<th>All of the time</th>
<th>Most of the time</th>
<th>Some of the time</th>
<th>A little of the time</th>
<th>None of the time</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ...nervous?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>b. ...hopeless?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>c. ...restless or fidgety?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>d. ...so depressed that nothing could cheer you up?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>e. ...that everything was an effort?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>f. ...worthless?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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Please turn over the page to continue
Q2. The last six questions asked about feelings that might have occurred during the past 30 days. Taking them altogether, did these feelings occur **More often** in the past 30 days than is usual for you, **about the same** as usual, or **less often** than usual? (If you never have any of these feelings, circle response option “4.”)

<table>
<thead>
<tr>
<th>More often than usual</th>
<th>About the same as usual</th>
<th>Less often than usual</th>
</tr>
</thead>
<tbody>
<tr>
<td>A lot</td>
<td>Some</td>
<td>A little</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>A little</td>
<td>Some</td>
</tr>
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<td>5</td>
<td>6</td>
<td>A lot</td>
</tr>
<tr>
<td>7</td>
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The next few questions are about how these feelings may have affected you in the past 30 days. You need not answer these questions if you answered “None of the time” to all of the six questions about your feelings.

Q3. During the past 30 days, how many days out of 30 were you **totally unable** to work or carry out your normal activities because of these feelings?

______ (Number of days)

Q4. **Not counting the days you reported in response to Q3**, how many days in the past 30 were you able to do only **half or less** of what you would normally have been able to do, because of these feelings?

______ (Number of days)

Q5. During the past 30 days, how many times did you see a doctor or other health professional about these feelings?

______ (Number of times)

Q6. During the past 30 days, how often have physical health problems been the main cause of these feelings?

<table>
<thead>
<tr>
<th>All of the time</th>
<th>Most of the time</th>
<th>Some of the time</th>
<th>A little of the time</th>
<th>None of the time</th>
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<tr>
<td>1</td>
<td>2</td>
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Thank you for completing this questionnaire.

Author of Tool: