EPR-HARMONIZED ASSISTANCE CAPABILITIES
2017

EMERGENCY PREPAREDNESS AND RESPONSE

Guidelines on the Harmonization of Response and Assistance Capabilities for a Nuclear or Radiological Emergency

IAEA
International Atomic Energy Agency

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GUIDELINES ON THE HARMONIZATION OF RESPONSE AND ASSISTANCE CAPABILITIES FOR A NUCLEAR OR RADIOLOGICAL EMERGENCY

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EPR-HARMONIZED ASSISTANCE CAPABILITIES [2017]

GUIDELINES ON THE HARMONIZATION OF RESPONSE AND ASSISTANCE CAPABILITIES FOR A NUCLEAR OR RADIOLOGICAL EMERGENCY

INTERNATIONAL ATOMIC ENERGY AGENCY
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FOREWORD

Under Article 5.a(ii) of the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, a function assigned to the IAEA is to collect and disseminate to States Parties and Member States information concerning methodologies, techniques and results of research relating to response to a nuclear or radiological emergency. This publication is intended to help fulfil this specific function.

In 2015, the IAEA General Conference, in Resolution GC(59)/RES/9, Para. 114, requested the Secretariat "to work with Member States to strengthen the IAEA Response and Assistance Network (RANET) to ensure that, if and when requested, timely assistance can be provided, and further requests the Secretariat to work with Member States to facilitate, as appropriate, bilateral and multilateral arrangements, and to enhance efforts to establish technical compatibility for international assistance, and encourages Member States to register national capabilities in RANET".

The aim of this publication is to provide guidelines to Member States and relevant international organizations on processes and arrangements that may be implemented as part of emergency preparedness and response (EPR) arrangements to assist in harmonizing national EPR capabilities and international assistance, when requested so that the products of their response operations are comparable and compatible. This publication provides details on the types, contents and formats of data and mapping products that may be generated during a response to nuclear or radiological emergencies.

The publication applies the safety principles stated in IAEA Safety Standards Series No. SF 1, Fundamental Safety Principles, primarily Principle 9 on EPR, and it will be of assistance to Member States in meeting the requirements established in IAEA Safety Standards Series No. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency. Requirement 17 of this publication establishes that the "government shall ensure that adequate arrangements are in place to benefit from, and to contribute to the provision of, international assistance for preparedness and response for a nuclear or radiological emergency." As part of these arrangements, it is required that due account is taken of the "compatibility requirements for the capabilities to be obtained from and to be rendered to different States so as to ensure the usefulness of these capabilities." These guidelines are intended to help Member States to ensure that compatible response and assistance capabilities are in place.

This publication is intended to be used by national authorities involved in emergency preparedness and response, and national response teams in all States. The guidelines provided need to be adapted to fit a State's particular organizational arrangements, language, terminology, concept of operation, and capabilities. However, the products generated need to be compatible with the types and formats of the products described in this publication.

IAEA Member States that have registered their National Assistance Capabilities in RANET are strongly encouraged to review and adapt their arrangements to ensure that the assistance they provide is compatible with the guidelines described in this publication.

The IAEA officer responsible for this publication was P. Kenny of the Incident and Emergency Centre, Department of Nuclear Safety and Security.

EDITORIAL NOTE

This publication (including the figures, tables and references) has undergone only the minimum copy editing considered necessary for the reader's assistance.

The views expressed remain the responsibility of the contributors and do not necessarily reflect those of the IAEA or the governments of its Member States.

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CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

Nuclear and radiological emergencies can and do occur in a number of different forms. Some emergencies, such as an accident at a nuclear power plant, may result in a release and dispersal of radioactive material that can have serious consequences over wide geographical areas, well beyond the immediate location of the emergency. Radiological emergencies predominately include the loss of control of radioactive sources that, regardless of whether the sources are dispersed or not, may lead to the potential or actual exposure of individuals.

Regardless of its type and potential consequences, an emergency may exceed the national response capabilities of the Accident State and/or affected State(s). When an emergency does occur, appropriate response actions are required to regain control of the situation in order to mitigate the impact of the emergency and to ensure that the public and the environment are protected from the harmful effects of ionizing radiation.

The IAEA has published safety standards [1] to help Member States in establishing and maintaining adequate arrangements for preparedness and response to a nuclear or radiological emergency of any type and origin. The authorities within States are responsible for ensuring an effective and efficient response and for ensuring resources are available for achieving this. IAEA Safety Standards Series No. GSR Part 7 (hereinafter referred to as 'GSR Part 7') [1] requires that: "**The government…ensure that an integrated and coordinated emergency management system for preparedness and response for a nuclear or radiological emergency is established and maintained**" and that "The emergency management system…be designed to be commensurate with the results of the hazard assessment…and shall enable an effective emergency response to reasonably foreseeable events (including very low probability events)."

An effective response to a nuclear or radiological emergency may require resources that exceed the capabilities of individual States, potentially necessitating the need to request and obtain international assistance. Governments are also required to "**ensure that adequate arrangements are in place to benefit from, and to contribute to the provision of, international assistance for preparedness and response for a nuclear or radiological emergency**" [1].

The Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (hereinafter referred to as the Assistance Convention) [4] provides the legal framework for States to request and provide international assistance. The IAEA has established the Response and Assistance Network (RANET) [5] as an operational tool to assist in the effective implementation of the Assistance Convention. Through these legal and operational mechanisms, States affected or potentially affected by an emergency may request, and be provided with, international assistance, regardless of whether or not the emergency occurs within their territories.

In response to a request for assistance, the IAEA may prepare and deploy an Assistance Mission, which may be implemented in various ways and may include but may not be limited to:

— A Field Assistance Team (FAT) consisting of a group of technically qualified, experienced and equipped personnel deployed to provide in situ assistance in a requesting State.

— External Based Support (EBS) providing technical advice and analytical expertise to address nuclear or radiological incidents provided from home offices or other offsite locations. This support is not deployed to the event scene.

— A Joint Assistance Team (JAT) comprising a combination of one or more FAT and/or EBS.

Regardless of whether the response is provided only by national capabilities or supported through international assistance, all parties responding and assisting need to work together in an effective and harmonized manner and will need to generate compatible and comparable products containing the necessary information that will contribute to the decision making process.

To ensure that the requested assistance can be effectively rendered, it is important that the FAT and/or EBS participating in the Assistance Mission can work effectively and harmoniously with each other, and with the national response teams, to generate the required response products.

The International Action Plan for Strengthening the International Preparedness and Response System for Nuclear and Radiological Emergencies [6], as well as IAEA General Conference Resolution GC(59)/RES/9 [7], recognize that there is a need to maximize the compatibility between the National Assistance Capabilities of assisting States and the response capabilities of States requesting international assistance in order to ensure that such assistance can be effectively rendered.

1.2. OBJECTIVES

The objective of this publication is to provide guidelines to Member States and relevant international organizations on processes and arrangements that may be implemented as part of emergency preparedness and response (EPR) arrangements to assist in harmonizing national EPR capabilities, and international assistance when this is requested, so that the products of their response operations are comparable and compatible.

The publication provides guidelines on the format and content of the types of products that may be generated in the response to a nuclear or radiological emergency, including those generated through the provision of international assistance. The products described are intended to contribute to effective decision making in an emergency.

Application of these guidelines will support Member States in the implementation of paragraph 5.94 of GSR Part 7 [1], which states:

> "Arrangements shall be put in place and maintained for requesting and obtaining international assistance from States or international organizations and for providing assistance to States (either directly or through the IAEA) in preparedness and response for a nuclear or radiological emergency, on the basis of international instruments (e.g. the Assistance Convention), bilateral agreements or other mechanisms. These arrangements shall take due account of compatibility requirements for the capabilities to be obtained from and to be rendered to different States so as to ensure the usefulness of these capabilities."

1.3. SCOPE

This publication provides guidelines on processes and arrangements to be implemented during the preparation and conduct of response and assistance actions with the goal to achieve compatibility of products during the response to a nuclear or radiological emergency.

The processes presented within this publication need to be considered and implemented, as applicable, on a national level to ensure compatibility between different national response capabilities.

This publication describes types of products that could be generated by national and international emergency response capabilities in the following areas:

— Radiation monitoring;
— Environmental sampling and analysis;
— Source search and characterization;
— Dose assessment and reconstruction.

This publication does not provide guidelines on the products generated in response areas not defined above, such as nuclear installation assessment and advice; source recovery; medical support; atmospheric dispersion, hydrospheric dispersion and radioecological modelling; decontamination; or remediation.

The guidelines contained herein are complementary to and are presented within the framework of RANET in accordance with the concept of operations and are applicable to IAEA Assistance Missions. The guidelines are also applicable to assistance provided through bilateral and multilateral international assistance agreements and arrangements.

1.4. STRUCTURE

This publication consists of six sections, two appendices and an annex.

Section 2 provides guidelines related to common issues that need to be considered by both receivers and providers of international assistance. Some of these issues may be considered and implemented, as appropriate, in advance, while others may need to be agreed upon before or at the start of an Assistance Mission.

Sections 3 to 5 are structured in correspondence with the functional areas of RANET that fall within the scope of this publication. Section 3 provides guidelines for radiation monitoring products; Section 4 provides guidelines for environmental sampling and analysis products, which include a number of steps from the collection of a sample to the final product(s); and Section 5 provides guidelines for dose assessment products. Finally, Section 6 provides guidelines on the generation of compatible map products to aid decision making and communication.

The appendices present supporting and exemplifying information regarding the generation of response and assistance products in the International Radiological Information Exchange (IRIX) format and the types of information to be reported to describe the systems used to generate products.

The annex to this publication describes the technical considerations for the utilization of aerial measuring systems during nuclear or radiological emergencies for the purpose of detailing

some of the technical and operational considerations required to ensure that the results of such measurements are comparable thus leading to the generation of compatible products.

Note: Sections 1–2 can be considered general sections that are not directly related to a certain response activity, while Sections 3–6 describe the content and format of the products generated in that particular functional area and can thus be read independently.

1.5. UTILIZATION OF THE PUBLICATION

The publication needs to be considered by all Member States in the perspective of being both potential requestors and/or potential providers of international assistance. The guidelines need to be incorporated, as appropriate, into national emergency arrangements for responding to a nuclear or radiological emergency and for receiving or for providing international assistance, when requested.

For those States that are capable of and willing to provide international assistance, the guidelines need to be implemented to ensure that requested assistance is rendered in an effective manner and that the products generated through the provision of assistance are compatible with those of other States providing assistance and also with those of the State(s) receiving assistance.

States implementing the guidelines contained within the publication need to do so in a coordinated manner at the national level so that national response capabilities are compatible.

1.6. TERMS USED IN THIS PUBLICATION

To the extent practicable and possible, this publication is using the terms as defined in the IAEA Safety Glossary [8] and GSR Part 7 [1]. The following list explains, in alphabetical order, some of the terms specific to this publication:

- **Assisting party:** A State, an individual, or a team of experts from a State or international organization providing international assistance, requested under the Assistance Convention, in response to a nuclear or radiological emergency.
- **Product:** Results, such as raw radiation monitoring data, refined radiation monitoring data or an assessment, delivered either as an *intermediate* or *final product*.
    - **Final product**: The *final product* is an agreed *product* delivered either by a local responder or by an *assisting party* to the Requesting State through the provision of international assistance. A *final product* supports the decision making process and contains all the necessary information to present the results of the response and assistance action and is defined for a given point in time.
    - **Intermediate product**: A *product* created to be used as a step towards the *final product*. An *intermediate product (or products)* may be produced and used internally or by other *assisting parties*.
- **Reference time:** A time or date in the past or future to which decay or ingrowth correction calculations of nuclide specific or dose rate values are performed.
- **Reporting level:** A level above which the result of a radiological measurement is reported. The reporting level needs to be established by the Requesting State and coordinated with assisting parties.

2. GENERAL INFORMATION FOR ASSISTANCE MISSIONS

2.1. RESPONSE AND ASSISTANCE PRODUCTS

IAEA GSR Part 7 [1], Para. 5.40, states: "Within emergency planning zones and emergency planning distances, arrangements shall be made for the timely monitoring and assessment of contamination, radioactive releases and exposures for the purpose of deciding on or adjusting the protective actions and other response actions that have to be taken or that are being taken. These arrangements shall include the use of pre-established operational criteria in accordance with the protection strategy".

Throughout the response to a nuclear or radiological emergency, either through the national response or during the conduct of an Assistance Mission, one or several teams will perform a range of tasks specific to the emergency. Common tasks include but are not limited to radiological monitoring, environmental sampling and analysis and dose reconstruction. The outputs from these tasks performed by assisting parties are generally referred to as response and assistance products (hereinafter referred to as products).

During the initial phases of a nuclear or radiological emergency, the availability of products, in particular radiation monitoring and environmental samples, may be limited due to time and resource constraints. Where applicable, a monitoring strategy may need to be formulated and implemented, taking into account the nature of the event, the availability of resources and the monitoring priorities designed to gather the necessary information to support the decision making process to mitigate the consequences and to protect people and the environment.[1]

The availability of products will increase as the emergency moves from the urgent to the early phase, as well as during the transition to long term recovery operations. This will be due to the increased number of resources helping to generate the products, and because some products, such as the results of environmental sampling, take more time to be generated. In addition, the applicability and utilization of some products may become more or less relevant for supporting decision making as the emergency evolves.

In the process of generating the final products, there may be a need to generate intermediate products that require further processing before the final product can be prepared. An example of this would be a situation in which processed radiation monitoring data (i.e. not raw data) from several radiation monitoring teams may need to be compiled into one collective dataset, which could then be used to generate a visual map to display the data. In some cases, the data may be prepared by one team and handed over to another team that performs the processing.

There is a need to ensure that the intermediate and final products generated are both compatible and comparable to the extent that the data generated can be used effectively by different assisting parties and by the Requesting State.

[1] Further guidelines on monitoring strategies for emergency situations can be found in the relevant IAEA Safety Guide [9] and IAEA-TECDOC-1092 [10].

2.2. COMMON ISSUES TO BE AGREED ON AT THE START OF AN ASSISTANCE MISSION

An IAEA Assistance Mission is formally agreed on through the Assistance Action Plan (AAP), which is developed and signed by the Requesting State, the assisting parties and the IAEA. The AAP contains higher level mission objectives and tasks, as well as administrative and logistical information. However, the AAP does not include comprehensive technical details on some fundamental issues that will need to be determined and agreed on between the local authorities and the assisting parties.

Some of the common issues to be agreed on before or at the start of an Assistance Mission include details regarding the tasks to be performed (e.g. types of measurements, areas to be monitored) and general issues such as units, date formats and naming conventions. Technical details need to be specified, such as the height above ground at which dose rate measurements are conducted. Agreement on these issues will assist in maximizing the compatibility of the assistance products generated so that they may be effectively received and utilized by the Requesting State.

The remainder of this section describes considerations that may be cross-cutting for a range of tasks performed as part of the response to a nuclear or radiological emergency. The application of these, as appropriate, is designed to help ensure a compatible response.

2.3. FUNDAMENTAL ITEMS

There are fundamental items that may need to be considered and, as appropriate, agreed upon prior to the start of an Assistance Mission, and periodically reviewed, if necessary, as the mission continues. Below is a list with short descriptions of some of the items that may need to be clarified prior to the commencement of response and assistance activities. The relevant authorities of the Requesting State, the assisting parties and the IAEA need to ensure that these items are addressed as appropriate, as well as any others that may be identified. In most cases, it is anticipated that they will be derived from national systems, in which such issues need to be determined in advance. However, some of the items presented may be specific to the receipt of international assistance and may need to be determined between the assisting parties.

The items are listed in alphabetical order:

Aerial monitoring: All aerial monitoring measurements are performed based on the objective of the survey. Unless otherwise agreed, the nominal height to which dose rates are calculated is at 1 m above ground, in order to be comparable with other types of dose rate measurements. Other elements, such as background correction, flying patterns and time-lag correction and the application of reference areas, need to be agreed on to ensure comparability of results. Additional information on aerial monitoring systems is provided in the Annex.

Assumptions: All responding parties (either assisting or national responders) need to agree on and communicate assumptions used to produce results. These assumptions will be specific to the response actions being performed and need to be specified in the products. Some assumptions are likely to need to be reviewed and, if deemed necessary, updated throughout the conduct of an Assistance Mission.

Data formats: The formats for data files to be exchanged before, during and after the Assistance Mission need to be agreed. Descriptions on data formats are given in Section 2.10.

Date and time formats: The time zone and formats for reporting date and time need to be clearly defined with a reference to Coordinated Universal Time (UTC). Special consideration needs to be given to potential changes in time zones due to daylight savings or if assistance is being provided in locations that are divided by time zone boundaries. The Requesting State may request that the final products are reported in the local time zone to assist the decision making process. Further guidelines on date and time formats are given in Section 2.4.

Deposition: When performing in situ gamma spectrometry, mobile radiation surveys or other types of measurement where the output is a value for activity per unit area, an agreement of assumed radionuclide distribution as a function of soil depth needs to be reached. Unless otherwise agreed, the default assumption needs to be surface deposition. Guidelines on default assumptions used in radiation monitoring are given in Section 3.3.

Dose assessment: The standards and relevant dose models, i.e. the system of radiological protection to be used during the Assistance Mission, needs to be agreed on, referenced and communicated.

Dose rate: Dose rate readings need to be reported in ambient dose equivalent rate, $H^*(10)$, at 1 m above ground, unless otherwise agreed.

Operational criteria: The operational criteria to be applied for initiating/triggering protective actions and other response actions need to be defined and communicated to all assisting parties by the Requesting State. IAEA default operational intervention levels (OILs) [2] could be applied if Requesting State specific default OILs have not yet been determined. If operational criteria are revised during the response to the emergency, those need to be clearly communicated to the various response teams by the Requesting State.

Language: The language to be used in reports, products and for the exchange of information during the Assistance Mission needs to be agreed upon in the AAP before the start of the Assistance Mission. English is considered the default language used during an Assistance Mission. The Requesting State may need to provide translation services that, preferably, are familiar with the technical terms that may be part of the assistance products and reports.

Location coordinates: Each radiological measurement or sample shall be associated with a specific location where the measurement was taken or the sample was collected. The location is ultimately defined by the latitude, longitude and altitude or depth. If applicable, the direction of the measurement needs to also be recorded. The positioning system, for example the global positioning system (GPS), and format must be agreed. Further guidelines are given in Section 2.7.

Map colour coding and scales: The colours, symbols and scales used to visualize radiation monitoring data on maps need to be agreed. Preferably, each colour needs to correspond to a fixed and agreed category of values and remain consistent throughout the duration of the Assistance Mission. The operational criteria applicable to the type of event need to be considered and, where appropriate, used when agreeing on the categories and ranges of values. Further guidelines on map products are given in Section 6.

Quality management: Field teams and laboratories performing sample measurements are responsible for maintaining their own equipment. Maintenance includes quality control to ensure that instruments are working properly. However, certain procedures may need to be considered and coordinated at the planning stage of the Assistance Mission, including

the establishment of a reference area and inter-comparison points as described in Section 3.2.

Reference time: The Requesting State needs to clarify whether there needs to be any decay correction from the measurement time back to the collection time of the sample or a single time corrected for a series of measurements (e.g. mobile monitoring results). Clarifications or agreements on decay or ingrowth correction need to be made on a case-by-case basis depending on the situation. Where possible, consideration needs to be given to the main radionuclides contributing to the dose.

Reporting levels: Reporting levels need to be declared by the Requesting State and coordinated with assisting parties, notwithstanding confidentiality issues. System-specific detection limits as well as other considerations for the protection of the public, such as operational criteria, need to be considered when determining the reporting level. Agreement is needed on how samples or measurements with concentrations or values lower than the reporting level, e.g. 'zeroes', are to be reported. Simply stating 'less than reporting level' may be enough, for example, when screening a large number of potentially contaminated individuals or conducting an orphan source search.

Special considerations: Depending on the nature of the initiating event that resulted in a State requesting assistance, there may be special considerations that need to be applied. This may include the need for chain of custody of samples and the preservation of forensics. The Requesting State needs to define any such requirements and/or consider proposals made by the assisting parties.

Time stamp: Each individual radiological measurement, sample or product needs to be associated with a specific time — for example, when the measurement was taken, the sample was collected or the time when a product is valid (note: this is relevant to an evolving situation). The date and time format need to be clearly defined and agreed. Further guidelines are given in Section 2.4.

Uncertainties: Assisting parties and the Requesting State need to agree upon what type of uncertainties are to be reported, for which type of measurements the uncertainties need to be reported and to what level of confidence. Further guidelines on uncertainties can be found in Section 2.9.

Units and physical quantities (including prefixes): The units and prefixes to be reported need to be consistent with the units used by the Requesting State, unless otherwise agreed. A list of default units is provided in Table 1.

Wet or dry weight: When analysing environmental samples, the reporting of activity per unit mass of dried or wet samples need to be agreed on. The agreement needs to consider the different types of samples that are expected to be collected during the Assistance Mission. Section 4.2.1 gives further guidelines on sample collection.

2.4. DATE AND TIME NOTATION

The correct use of an agreed representation of date and time appropriate to different products is essential to ensure that all products are easily understood by their receiving parties. The representation including the time zone may change depending on the intended recipient(s) and the products' use. These details need to be agreed by all parties at the start of an Assistance Mission. This section presents some of the different formats that may be used in different products.

For most purposes, the default time zone will be UTC. If local authorities in the Requesting State prefer to work in local time, the final products need to be presented with both local time zone and UTC indicated.

In contexts such as the text of a document or the header of a map it is preferred to spell out the month (e.g. **29 May 2016),** thereby avoiding confusion about the order of the day, month and year fields if given as numerals.

The date and time format of relevant systems where the intermediate and final products may need to be considered when collating and preparing data. For example, the preparation of emergency radiation monitoring data for reporting to the International Radiation Monitoring Information System (IRMIS) needs be in the UTC time zone using the format YYYY-MM-DD HH:MM:SS.

2.4.1. Date and time notation for electronic information exchange

Alternatively, to facilitate the import and export of date and time data into spreadsheets, and to be compliant with the IRIX format (see Section 2.10.1.2), dates and times need to be converted into the same time zone, preferably UTC. According to the ISO standard 8601 [11], UTC time is marked by a 'Z' at the end of the time string, to indicate 'Zulu time'. For data exchange, date and time strings can be presented in the format YYYY-MM-DDThh:mm:ssZ, which would, for example, represent 13:00:00 UTC May 29 2016 as **2016-05-29T13:00:00Z**.

It needs to be noted that common spreadsheet software generally does not recognize strings in this format. Examples of import functions that may be used to parse ISO date and time strings in this format by common spreadsheet software are given in APPENDIX I, which also provides examples of radiation monitoring reporting in the IRIX format.

2.5. DEFAULT UNITS OF MEASUREMENT

The Requesting State and assisting parties need to agree on the notation, prefixes and units of measurement used for products reported. The notations, prefixes and units need to be clearly coordinated with all teams, which need to ensure that they report in the agreed manner.

Where practicable, the International System of Units (SI) needs to be applied. However, in some cases, such as the use of units of time as hours when reporting ambient dose equivalent rate, the SI unit (e.g. seconds) may not be appropriate.

Initial measurements may be performed in units that the assisting parties are comfortable using, however the results may need to be converted prior to submission to another party (from another State) or the Requesting State.

Table 1presents a list of default units for different types of measurements. Where practicable, these units need to be used by both the Requesting State and the assisting parties; the remainder of this publication assumes that the default units and notations are used.

It needs to be noted that Table 1includes curie (Ci) as an alternative unit of activity. While not an SI Unit, it has been included as a suitable alternative only for the purpose of reporting the activity of radioactive sources. It is preferable that it not be used when reporting the concentration of activity in different media and geometries.

The default unit for distance may either be metres (m) or kilometres (km), depending on the nature of the nuclear or radiological emergency. For example, for radiation dose rate measurements close to a radioactive source the appropriate unit would be m. Alternatively, in situations where radiation dose rate surveys are conducted in public locations as part of a response to an accident at a nuclear installation, the appropriate unit for distance from the event location would be km.

Table 1. DEFAULT UNITS AND NOTATIONS

Measured or calculated quantity and/or notation	Default unit or format	Possible alternatives / comments
Radiation types	alpha, beta, gamma, neutron	'α', 'β', 'γ', 'n'
Activity	Bq	Ci
Activity concentration in air	Bq/m^3	Bq/L
Activity concentration food, water or milk	Bq/kg	Bq/L, Bq/m^3
Deposition on the ground	Bq/m^2	Bq/cm^2, s^{-1} (counts per second (cps), surface area of probe to be included)
Deposition rate	$Bq \cdot m^{-2} \cdot h^{-1}$	
Surface activity concentration (activity per unit area)	Bq/m^2	cps, counts per minute (cpm)*
Excretion rate	Bq/day	
Absorbed dose	Gy	
Equivalent dose	Sv	
Effective dose	Sv	
Committed effective dose	Sv	
Personal dose equivalent, Hp(10)	Sv	
Ambient dose equivalent rate, $H^*(10)$	Sv/h	
Date (For written text)	DD-MMM-YYYY	When presented in written text, write month with three letters, e.g. 'Jun'
Date and time (For data exchange)	YYYY-MM-DDThh:mm:ssZ (where Z denotes UTC***)	For data exchange, pad with leading zeroes (ISO 8601) [11]
Decimal mark	00.00	Do not use ','
Numerical separator	10000	Do not separate by ',' or space
Location (latitude and longitude)	Decimal degrees	Reference WGS84**
Air sampling rate	m^3/h	L/h, L/min
Distance	m or km	Units used should be agreed based on the situation
Height	m	
Temperature	°C	°F

* cps or cpm may be used to compare direct readings from contamination meters to operational criteria. The instrument specific OIL 4 value in cps or cpm may be calculated based on instrument coefficient and calibration factors [12].

** The World Geodetic System, a standard for use in cartography, geodesy and navigation. WGS84 is the latest revision, established in 1984 and last revised in 2004.

*** Coordinated Universal Time (UTC).

2.6. NAMING CONVENTIONS

The utilization of predefined and agreed naming conventions can help different national and international teams work together effectively during an Assistance Mission to develop

compatible products that contain unique identifiers for team, locations, samples, file names, reports and system specifications.

These identifiers, in the form of codes of a predefined nomenclature, need to be used by teams in communications and when reporting the results of monitoring activities (e.g. environmental sampling or dose rate measurements).

The implementation of a naming convention regime is intended to help ensure that the coordinated response is effective and efficient. Without implementing such a regime there is the potential that different national and/or international parties responding or assisting may apply their own naming conventions that could potentially cause confusion when the products of their activities are compiled.

Default naming conventions are provided below.

2.6.1. Team identification (TID)

Each team, either a FAT or EBS, needs to have a unique identification that must be applied during communications and reporting of mission activities and products. The default team identification (TID) nomenclature is as follows:

XX–ABC–#

Where:

XX	is a two letter country code[2] defined in ISO 3166-1 [13];
ABC	is a three letter code indicating whether a team is a FAT or EBS;
#	is a numeral to differentiate between teams from the same country.

2.6.2. Location identification code (LIC)

Radiation monitoring and environmental sampling may be frequently performed at static locations, referred to here as monitoring points (MPs), so as to assess radiological changes over time. The location characteristics for a fixed location are described in Section 2.7. The accuracy of GPS equipment means that latitude and longitude coordinates are unlikely to be reproduced each time a measurement is made. Hence, it is advisable to define the coordinates for a location once and repeat using the same coordinates for any subsequent measurements from that location. Alternatively, a location identification code (LIC) may be defined once for each static location and reused each time measurements are made in that location.

Note: The use of LIC is not applicable for mobile measurements that automatically record radiation measurements along with time and GPS location, e.g. backpack, vehicle or aerial monitoring systems.

[2] Whenever a team is provided by an international organization, the acronym of the organization's name in English needs to be used (e.g. IAEA).

The default LIC nomenclature is as follows:

MP–XX–ABC–####

Where:

MP	Used as a preface to ensure no confusion between codes for TID and LIC;
XX	is the two letter country code defined in ISO 3166-1 [13] for the country where the MP is located;
ABC	is the name of the town or municipality where the MP is located (in some situations the text may need to be more specific);
####	is a numeral to differentiate between different locations within the same town.

2.6.3. Sample identification (SID)

A large number of samples may be collected during an Assistance Mission, possibly with several teams collecting samples at different locations at the same time. All samples need to be uniquely identified. That is, the analysis and results provided by the laboratory need to be independent of the sample location. The default sample identification (SID) to be used is as follows:

TID–####–n

Where:

TID	is the team identification;
####	is an incremental 4-digit number;
n	is the subsample number (optional).

It should be noted that, in order to preserve traceability, the original sample need not be renamed, even though a subsample has been taken. Splitting a sample can be considered a special case of subsampling, and the same notation may be used.

2.6.4. Report identification (RID)

During the response to a nuclear or radiological event, a large number of products may be produced, each referenced by using a unique RID as follows:

TID–(I/D/F)R–####

Where:

TID	is the team identification;
(I/D/F)R	represents intermediate, draft or final report (Note: parentheses should not be used);
####	is an incremental 4-digit number.

2.6.5. System specification (SS)

During preparedness activities, it is advisable that system specifications be produced for all systems used during response and assistance activities and reported once. Once reported, a system specification ID may then be used to reference the system when generating the products obtained from the use of the system. The following convention may be used:

TID–SS–####	
Where:	
TID	is the team identification;
SS	is the text “SS” to indicate system specification;
####	is an incremental 4-digit number.

2.6.6. File naming convention

Files produced during an Assistance Mission need to be named in a transparent and consistent way. Ensuring consistency in naming conventions for data files will facilitate data exchange and will also be helpful when archiving data. Depending on the scenario of the Assistance Mission, many different types of data files may be produced, but for compatibility and traceability purposes, the following fields may be used to constitute the file name:

TID–D–T–ABC.EXT	
Where:	
TID	is the team identification;
D	is the date as YYYY–MM–DD;
T	is the time in UTC as hhmm;
ABC	is a short text field describing the file contents, e.g. ‘picture’, ‘in situ spectrum’, ‘site report no. 1’, etc.;
EXT	is the file extension (as set by software; determines file type).

Date and time fields need to correspond to the creation time of the file content (measurement date for direct measurements and sample date, for example, for environmental samples) rather than file creation time. The use of the date format YYYY-MM-DD is preferable to allow for easier chronological sorting of what may be a large number of files, based on the file contents rather than the creation or save dates of files. Options for the text field describing the file content needs to be agreed on for each mission in consultation with the Assistance Mission Leader or other official, as appropriate. The file extension, normally set by the software, will identify the type of data file. Generally, there is no need to have incremental numbers in the file name, as the TID, date and time fields will differ among files. If additional numbering is required to tell files apart, the text field described above can be used.

2.7. LOCATION CHARACTERISTICS

Each fixed location where radiation monitoring or environmental sampling is performed needs to be defined once, at the first time a measurement or sample is collected. In doing so, a unique LIC needs to be generated and relevant information, described in

Table 2 below, needs to be recorded to help properly define the location. A picture of the location, as well as some markings or references on the ground, can also be useful if the location needs to be found again later. Once an LIC has been defined, it needs to be used for the recording and reporting of all samples and measurements (i.e. multiple reporting of GPS locations is not necessary). Subsequent measurements or samples collected at the same location need not record the details, but rather ensure that the location is consistent with the previously defined LIC.

Note: This does not apply to mobile radiation monitoring systems (e.g. backpack, vehicle and aerial) that automatically record radiation measurements along with time and GPS location.

Table 2. FIXED LOCATION IDENTIFICATION CODE FORMAT AND REQUIREMENTS

Descriptor	Default format / description	Requirement
LIC	MPXX–ABC–# format	Mandatory
Location description	Name of location, town, street name to help ensure repeatable identification	Mandatory
Latitude	WGS84 datum in decimal degree format	Mandatory
Longitude	WGS84 datum in decimal degree format	Mandatory
Height above sea level	m (depth as a negative value)	Optional
Uncertainty of location reading	m	Optional
Location	Land, sea or air	Optional
Surface type	Soil, grass, asphalt, concrete, etc.	Optional
Direction from source / release point	Direction in degrees or approximate direction, e.g. NE, NNE, SW.	Optional
Distance from source / release point	Distance in m or km, depending on situation	Optional
Picture or sketch	Overview, to identify location	Optional
Markings or reference to a recognizable point	To ensure repeatability	Optional

Where appropriate, the remainder of this publication assumes that this information is recorded, and that the LIC is used as the main reference whenever a location needs to be recorded.

2.8. DECIMAL MARK AND NUMERICAL SEPARATOR

A decimal mark and numerical separators are defined by using symbols or spaces. These symbols can differ depending on the system that has been implemented. In English, decimals are indicated by a decimal point (dot) and not, as in certain other languages, by a comma. To prevent formatting issues and aid compatibility, the following needs to be applied:

— To separate the integral part of a number from the fractional part, the decimal mark symbol needs to be consistent with '.' — the decimal point;
— For numbers with many digits, a numerical separation or digit grouping is not to be used as a delimiter.

2.9. UNCERTAINTIES

The ISO standard, Guide to the Expression of Uncertainty in Measurements (GUM) [14], prescribes the evaluation of the uncertainty of a measurement by considering two types of classifications: Type A and B. Uncertainty of Type A is obtained from a statistical analysis of a series of observations (repeated measurements) yielding an observed frequency distribution, which for radioactive measurements typically follows a Poisson probability density function. Type B uncertainties are instead evaluated by means other than statistical analysis of observations, and are often based on expert judgement of the teams performing the measurements. Examples of possible input to Type B evaluations can be: previous measurement data; manufacturer's specifications; or experience with an instrument's behaviour or properties. The different uncertainties are summed to a combined standard uncertainty (expressed as a standard deviation), typically multiplied with a coverage factor to obtain an expanded uncertainty.

For measurements in controlled environments such as those performed in a laboratory, it is preferred to follow GUM [14] in its entirety. However, in uncontrolled environments, such as in the field, or where results are reliant on assumptions, it can be difficult to properly evaluate Type B uncertainties. In these cases, it needs to be clearly stated which type of uncertainties is being reported.

Reported uncertainties must be indicated either by stating exactly what they represent or by describing how they were calculated, because a simple X±Y statement may be interpreted in any number of ways. The statement of uncertainty needs to include estimates of all significant sources of error involved [10].

2.10. DATA FORMATS

The formats for intermediate and final products need to be agreed upon in advance among all parties, especially the formats for products being provided to the Requesting State. A list of common data file formats that may be used is presented in Table 4.

For multimedia content, it is preferred to use compressed open source formats (codec and container), with compression rates that do not compromise the understanding of the multimedia content, and where available and appropriate.

2.10.1. Exchanging monitoring data

For data exchange in general, possible proprietary formats need to be avoided, unless otherwise agreed, since they may not be accessible, viewable or editable by all parties owing to accessibility and licensing issues. Furthermore, non-open formats may not be accessible in the future, as documentation and description of such formats is also often restricted compared with standards and open source formats. Taking these considerations into account, the exchange and archiving of Assistance Mission data in proprietary formats is not advisable without a prior agreement from the parties involved.

Guidelines regarding the use of character separated values and the IRIX Format is presented below.

2.10.1.1. Comma separated values

An easy and transparent way of organizing tens to thousands of data points is using.csv (comma separated value) files that can be read by common spreadsheet software. Where possible, the generation of.csv files needs to be automated, e.g. by implementing or utilizing an export function from the database or software used for radiation monitoring. Analogously, the import of.csv files also needs to be automated. However, to facilitate both import and export, a standard structure needs to be devised and agreed.

Table 3 presents a csv template with some example data following the guidelines for mobile dose rate measurements presented in Section 3.3.1. As the value and unit columns can hold any type of point values, e.g. dose rates, activity concentrations or counts, the template could be used for exchange of most types of radiation monitoring data.

Table 3 - CSV TEMPLATE FOR LARGE DATA SETS WITH SOME EXAMPLE (FICTIONAL) DATA POINTS

HEADER INFORMATION (as defined by individual products)							
Time	**Latitude**	**Longitude**	**Height (m)**	**Value**	**Unit**	**Uncertainty (optional)**	**Other fields (optional)**
2016-05-29T13:00:00Z;	50.862585;	−1.168622;	1;	1.1E-7;	Sv/h;	20%;	…
2016-05-29T13:00:02Z;	50.862561;	−1.168263;	1;	1.3E-7;	Sv/h;	20%;	…
…	…	…	…		…	…	…
2016-05-29T14:11:42Z;	50.857604;	−1.148114;	1;	9E-8;	Sv/h;	20%;	…

Due to compatibility issues with the use of a comma, it is preferred to use a semicolon ';' as field separator in the.csv file as shown in the template above. The first row of the.csv file needs to contain the header information as described in this publication for the specific type of product, unless it is already given elsewhere, e.g. in an IRIX report.

The .csv files need to be named according to the file naming convention described in Section 2.6.6.

2.10.1.2. International Radiological Information Exchange format

The IRIX Format is an open format developed by the IAEA based on the Extensible Markup Language (XML), which makes it both machine readable and human readable. IRIX can be used to exchange radiological information during nuclear or radiological emergencies between IAEA and RANET teams, but also between two or more assisting parties. One of the advantages of the XML based format is that the information can be validated using a schema, which could reduce the number of errors in stressful situations. More information on the IRIX format including a format description and XML schemas can be found at the IRIX collaboration area on the dedicated website [15].

Where available and appropriate, it is preferred to use the IRIX format when delivering products. The use of IRIX will also save time for personnel in the Requesting State, considering that they will mostly work with final products, some of which will be communicated to the international community through the appropriate channels. However, certain types of measurements and data were outside of the scope of IRIX version 1.0, such as the reporting of spectrometry data or large data sets from mobile radiation surveys. In these cases, the use of ANSI/IEEE N42.42 and.csv files, respectively, may be more appropriate, as listed in Table 4.

APPENDIX I gives examples of IRIX formatted XML files validated against the IRIX XML schema for some of the monitoring products that may be produced during an Assistance Mission.

Table 4. DEFAULT FILE FORMATS[3]

Type of data or document	Default format(s)	Comments
General		
Audio	.mp3	
Images	.jpg, .png, .tif, .gif	
Videos	.mp4, .avi	
Read-only text	.pdf	ISO 32000 May apply to any final product, as agreed between parties
Editable text	.odt, .txt, .rtf, .doc/docx	ISO/IEC 26300:2006
Spreadsheet	.ods, .csv, .xls/xlsx	ISO/IEC 26300:2006
Presentation	.odp, .ppt/pptx	ISO/IEC 26300:2006
Map (GIS) information	shape files (.shp, .shx, .dbf), .kml, .kmz	
Technical		
Spectrum	.xml, .csv, .txt	ANSI/IEEE N42.42
Dose rate measurement	.xml, .csv, .odt, .xlsx	IRIX, spreadsheet
Set of dose rate measurements	.xml, .csv, .odt, .xlsx	IRIX, spreadsheet
Environmental samples	.xml, .csv, .odt, .xlsx	IRIX, spreadsheet
Counts or time series of values/results	.xml, .csv, .odt, .xlsx	IRIX, spreadsheet

2.11. SYSTEM SPECIFICATION

A system specification is a sub-product that describes the functionality, limitations, calibration and quality assurance and control procedures, as well as other relevant information concerning the radiation monitoring systems used, as appropriate and notwithstanding any confidentiality issues. The system specification may also describe the methods by which measurements are conducted and data is processed.

The purpose of the system specification is so that an intended reader, e.g. a radiation protection expert or scientist in a Requesting State, or another assisting party, can understand and utilize product(s) delivered by the system.

The development and delivery of system specifications applies equally to systems used in the field as well as those used by EBSs.

The content within the system specification only needs to be delivered once per emergency (unless changes are made to the system during an emergency) and may then be referenced as part of the product(s) generated by the system, ideally using the system specification naming convention.

The generation of system specifications is considered a preparedness activity so that they are ready to be delivered as soon as products are delivered by the system during an emergency.

[3] Note that the data formats presented are those commonly used and are not an endorsement of any commercial products or formats by the IAEA.

Examples of the type of information to be provided in system specifications for some commonly used radiation monitoring systems are given in APPENDIX II.

3. RADIATION SURVEY, SOURCE SEARCH AND CHARACTERIZATION

3.1. RADIATION SURVEY

Radiation surveys are direct measurements of radiation and can take different forms, depending upon the nature of the event and what is being measured. Radiation surveys may be performed in a number of ways, which are utilized depending on the nature of the event and the available resources. Irrespective of the purpose, radiation survey measurements are specific to the time and location of the measurement. The types of surveys may include, but are not limited to:

— Aerial based surveys;
— Vehicle based surveys;
— Ground based surveys (e.g. backpack);
— Portal monitors;
— Deployable or permanent probes;
— Manual radiation surveys using hand-held instruments that do not have spectral capabilities (e.g. dose ratemeters or contamination monitors);
— In situ gamma spectrometry or hand-held portable gamma spectrometers.

3.1.1. Mobile radiation survey systems

A typical mobile system will comprise a gamma ray detector and other systems that report the geographical location and time of the collected radiological information. The system will record the information so that it is available for further detailed processing and analysis. A number of actions will need to be performed by teams to ensure that results are both comparable and compatible.

3.1.1.1.Aerial based systems

Aerial based surveys can be conducted with fixed-wing aircrafts, rotary-wing or others, such as unmanned aerial vehicles. Availability of aircrafts, potential extent of the dispersal or search area, speed and spatial resolution needed may determine the appropriate platform to be employed in an aerial based survey.

The analysis will require the application of multiple corrections to the data to produce a dose rate at a nominal height above ground, the deposition or aerial concentration of radionuclides on the ground, background correction and time-lag adjustments. The corrections need to be described in the system specification. Some of the prerequisites of the analysis (e.g. the altitude at which monitoring is conducted) need to be determined and agreed between the Requesting State's authorities and those parties rendering the assistance.

3.1.1.2.Vehicle based systems

Vehicle based systems can be used as an alternative or a complement to an aerial system. Since the spatial resolution of a survey is increased at the ground level and at lower speeds compared with aerial monitoring, vehicle based systems can be feasible alternatives when surveying specific locations of interest, such as roads, railways, ports or other well-defined areas. However, variations and geometrical effects will increase when monitoring is performed closer to the ground level, as a result, for example, of influences from the roads.

Teams performing vehicle based monitoring need to document these variations in the report, as appropriate.

If the detector system is mounted inside the vehicle, the analysis will require the application of corrections to the data to correspond to the dose rate or deposition outside the vehicle. These corrections need to be described in the system specification. Where practicable, reference measurements need to be regularly performed to ensure that any accumulation of contamination on the vehicle itself is taken into account when correcting the data.

3.1.1.3.Ground based systems

Continuously measuring equipment, such as a spectrometer connected to a multichannel analyser and coupled with a GPS, can be used in a portable format such as a backpack. In this publication, such systems are categorized as ground based survey systems; they have the highest spatial resolution of mobile survey systems but have less coverage time than vehicle or aerial systems.

The analysis will require the application of corrections to the data to produce a dose rate at a nominal height above ground or a surface deposition. The corrections need to be described in the system specification.

3.1.2. Other radiation monitoring systems

3.1.2.1.Hand-held monitoring

Portable radiation monitoring equipment designed for standalone use is classified here as hand-held monitoring equipment. A reading using a hand-held instrument (for example, of the dose rate) is taken at a predetermined reference height, with the default height being 1 m above ground. On the occurrence of hot spots or point sources, a reading closer to the radiation source might be warranted, taking into consideration geometrical effects and turn-back guidelines. The attachment of a photograph, possibly showing the source and the hand-held monitor in the same picture, can be valuable for the readers' understanding of the report at a later stage.

3.1.2.2.In situ gamma spectrometry

In situ gamma spectrometry is important for the characterization of radionuclides. It is usually the fastest and most accurate method by which to determine radionuclide deposition on a surface (e.g. the ground) or activity concentration in soil or in air. It can be a powerful way to obtain representative measurements (ground truth) to be used for inter-calibration with mobile monitoring systems. Although its deployment and basic use can be performed by novice users, assessment of results will usually need expert follow-up for confirmation and detailed analysis.

Care needs to be taken to find locations suitable for in situ measurements; ideally a homogeneously contaminated flat surface, at least 20 m × 20 m and with an undisturbed soil cover that is representative for the location, needs to be found. The detector needs to be placed 1 m above the ground at the centre, far away from walls, drainages, trees or other objects that may be contaminated and hence affect the deposition pattern. Objects that may have significant influence on the reading need to be mentioned in the report.

3.1.2.3.Monitoring posts

Continuously measuring radiation monitoring systems placed at fixed locations are here referred to as monitoring posts. Such systems need not be different, for example, from a backpack system used in ground based surveys; both of these systems typically collect time referenced spectra or dose rates. But a monitoring post does not require a GPS unit, as its position is fixed and can be recorded manually.

Many countries already have networks of fixed monitoring posts in place around nuclear installations, for instance, which continuously measure the dose rate, spectra or activity deposited on air filters. These networks are often put in place in order to give authorities or other organizations involved in the emergency response confirmation or disconfirmation of a release of radioactive materials.

Assisting parties that use deployable monitoring posts transmitting data over radio channels or mobile networks need to ensure that the communication technology is compatible (in terms of availability, operability and permission) with regulations in the country requesting assistance. This needs to be considered and agreed upon by the Requesting State and assisting party/parties prior to the start of the Assistance Mission.

3.1.2.4.Contamination monitoring

Measurements inferring the unintended presence of radioactive substance inside or on an object, reported in dose rate, cps or activity per unit area is defined as contamination monitoring [8]. Radioisotopes emitting gamma radiation can often be detected — for example, by portal monitors or hand-held instruments, even if the contamination is inside an object — owing to the penetrating nature of gamma photons. Pure alpha or beta emitting radionuclides are normally identified using laboratory measurements, but indications of the presence of such radionuclides on a surface, e.g. by the use of hand-held instruments with alpha or beta probes, could also be reported, where appropriate.

Portable devices measuring such items as smear samples or air filters could also be used to assess the presence of contamination. Portable systems may also have alpha spectrometric capabilities, which can potentially be used to identify radionuclides present in a sample in the field.

Contamination monitoring can also include the monitoring of individuals, items and vehicles, as discussed in Section 3.5.

3.2. REFERENCE AREA AND INTER-COMPARISON POINTS

The results obtained from radiation surveys need to be both comparable and compatible. Experience from the responses to the accidents at the Chernobyl and Fukushima Daiichi nuclear power plants have shown that a reference area needs to be established as part of the response [16] to enable in-field inter-comparison between different radiation monitoring systems.

For emergency situations involving the dispersion of radionuclides over large areas, aerial and mobile monitoring systems may be calibrated using a well-known reference area with a radionuclide composition that is representative of the emergency scenario [16]. The reference area needs to be characterized at the start of the response, using, for instance, dose rate measurements, in situ gamma spectrometry and the collection and measurement of soil

samples. Spectrometry systems used in the characterization have to be performance verified, accounting for the angular and energy dependence of the system as well as the attenuation of the photons. Once the reference area has been characterized, conversion factors to dose rate at 1 m above ground can be derived from signature spectra measured at the reference area. It is possible that the reference area will need to be characterized several times during the response owing to the decay or migration of radionuclides or in the event of an ongoing release of radioactive materials during an event.

For quality assurance purposes, it is good practice to conduct quick checks of all monitoring instruments, including hand-held instruments, at selected reference points and at regular intervals. Furthermore, the reference points may be used for inter-comparisons, ensuring a consistent response between the different instruments deployed. Calibration or reference sources could be positioned at the reference points to ensure proper responses from the instruments used, if the reference radionuclide composition at the selected location, does not give sufficient instrument responses. A report on the establishment of the reference area and the use of reference points needs to be composed and kept up to date by the Assistance Mission leader or other official, as appropriate. The report needs to be reviewed by mission teams, with special attention to be given to possible systematic discrepancies in the inter-comparisons exceeding the uncertainties of the measurements.

3.3. RADIATION SURVEY PRODUCTS

Radiation monitoring systems with spectral capabilities may generate raw spectral data that is subsequently used to calculate dose rates, activity concentrations or a list of the present gamma emitting isotopes. The raw spectral data collected by one or more teams may be used as an intermediate product to be analysed or collated by another team. Where raw spectral data is provided, it needs to be accompanied by a relevant description of the spectrometry system, including calibration and resolution data (system specification).

If decay corrections are performed, they must be clearly described and reported. In the lists presented in 3.3.1 and 3.3.2, it is assumed that no decay correction has been applied, and thus the reference time equals the measurement time. Guidelines on the formats for the products listed below are given in Section 2.10 and in APPENDIX I.

3.3.1. Dose rate monitoring data products

The height above ground at which the dose rate is valid, or the distance from the source, as applicable, needs to be recorded and delivered as part of the product. Some systems, for example, aerial based systems, use a nominal height to which the dose rate is calculated, referred to as calculated height; it needs to be recorded together with the actual height above ground of the measurement system. In addition, each fixed location, or LIC, need to be associated with a height above ground level, as described in Section 2.6.2.

The following information is preferred to be provided for dose rate measurements:

Dose Rate Measurement Products
Header information:
— Team identification (TID); — Product and purpose of product; — Survey description; — Method of measurement; — Detection system identification with reference to (or reference to SS): • Energy and efficiency calibration details; • Reference area, if applicable. — Environmental conditions (e.g. temperature, humidity) (optional); — Radiation type(s) reported (e.g. β, γ, n or combination); — Uncertainties: • Uncertainty type(s) reported (e.g. 'Type A'); • Coverage factor (e.g. '$k = 2$'); • Statement of Type B uncertainties (optional); — Assumptions about source geometry (if applicable).
Each reading needs to include:
— Date and time; — Latitude and longitude (or LIC, if applicable); — Actual height above ground (m); — Corrected height, if applicable (m); — Distance from source (m or km depending on nature of event and measurement), if applicable; — Dose rate; — Unit; — Preferably Uncertainty.

3.3.2. Deposition monitoring products

In order to make ground deposition data meaningful and compatible, assumptions about radionuclide distribution as a function of soil depth and lateral extension have to be made. Even though they underestimate the true deposition, it is preferred that products are calculated with the assumption of surface distribution (i.e. no vertical distribution below the surface) as the default option. Subsequent analysis (e.g. from soil samples), or an agreement among assisting parties and the Requesting State, may result in a change in the assumptions to use other depth profiles to better reflect the true deposition, as appropriate. This, in turn, may require recalculation of the results based on the new assumptions.

The following information is to be reported for deposition measurements:

Deposition Measurement Products
Header information:
— Team identification (TID); — Measurement details; — Product and purpose of product; — Survey description; — Method of measurement; — Detection system identification (or reference to SS) including specification of: • Energy and efficiency calibration details; • Reference area, if applicable. — Environmental conditions (e.g. temperature, humidity) (optional); — Radiation type(s) reported (e.g. α, β, γ; — Uncertainties; • Uncertainty type(s) reported (e.g. 'Type A'); • Coverage factor (e.g. ' $k = 2$'); • Statement of Type B uncertainties (optional); — Assumptions about source geometry/depth (if applicable).
Each reading needs to include:
— Date and time (start time); — Latitude and longitude (or LIC, if applicable); — Measurement time (real and live times); — Actual height above ground (m); — Corrected height (m), if applicable; — Distance from source (m or km depending on nature of event and measurement), if applicable; — Radionuclides; — Count rate(s); — Activity per unit area; — Unit; — Preferably uncertainty.

Additional Information for Fixed Location Deposition Measurement Products
For fixed location measurements (e.g. in situ), it is preferred that the following additional information is provided when reporting deposition per site or measurement delivered: — Team identification (TID) (if applicable); — Location characteristics (LIC); — Spectrum file name; — Reference to samples taken (SID), if any; — Detector properties, including collimation and dose rate range of operation (or reference to SS); — Dose rate and variability within 10 m to avoid hotspots; — Radionuclide activities, preferably with uncertainties: • Anthropogenic in Bq/m^2; • Natural in Bq/kg (uniform depth distribution).

For fixed measurements, in addition to using the location characteristics (LIC) to describe the location, it is preferred to also record some of the optional details, e.g. a photograph or sketch.

3.3.3. Gamma spectrometry as intermediate products

Measurement and spectral data from an in situ measurement or from the analysis of environmental samples (see Section 4.2.3) may need to be sent to an EBS for analysis or confirmation and needs to contain the information listed below. The elements listed are also applicable for background and/or source check spectra accompanying the spectrum to be analysed.

Gamma Spectrometry as intermediate products
For a gamma spectrum (background or sample) with *N* channels:
— Spectral data: • Counts in channels 1, …, *N*; — System specification (SS); — Efficiency calibration for full energy range[3]: — Efficiencies and (preferably) uncertainties for energies 1, …, *k*; • Description of calibration efficiency geometry; — Energy calibration[4]: • Energies for channels 1, …, *k*; — Assumptions made, as appropriate; — Acquisition start and stop time; — Measured live time; — And preferably, if available: • Calibration total efficiency (coincidence summing correction): ▪ Efficiencies and (preferably) uncertainties for energies 1, …, *k*; • Full width at half maximum (FWHM) versus energy[1]: — FWHM for energies 1, …, *k*.

3.4. SOURCE SEARCH AND CHARACTERIZATION PRODUCTS

Mobile radiation survey techniques are commonly used when searching for a radioactive source. The products of such surveys may be used to delineate areas where there is a possibility that a source may be located against areas where the presence of a radioactive source is unlikely. The geography over which the search must take place and the characteristics of the source (if known) determine which method(s) to use. For example, search operations in large or rural areas might warrant aerial surveys, whereas for searches indoors or in smaller venues or areas in a city, ground based surveys may be the preferred method. Fixed location detectors may also be deployed and utilized in situations in which a radioactive source may be portable and could be moving between locations.

Depending on the situation, the results of a source search may not necessarily be compared with OILs, but rather used to locate and assist in the subsequent recovery of lost radioactive

[4] Efficiency calibration, energy calibration and FWHM tables could also be expressed as (logarithmic or linear) polynomial coefficients, e.g. for efficiency: $\ln \varepsilon = a + b \ln E + ...$

materials. After the location, characterization and recovery of the source(s), dose reconstruction for the exposed individuals may need to be performed. Assisting parties and the Requesting State need to have this workflow in mind from the start of the mission to facilitate the availability of data necessary for subsequent dose reconstruction (see Section 5.1).

Once a source has been found, the product will be the location or area, and, if available, the characteristics of the source, whether the source is damaged or leaking, and the status of any shielding or containment. An agreement needs to be made between the Requesting State and assisting parties on what actions need to be taken once a source is found and by whom. This could potentially include assistance with source recovery operations [5]. Source recovery activities need to be addressed on a case-by-case basis and hence are considered outside the scope of these guidelines.

3.4.1. Mapping products from source search activities

Independently of whether a source is located or not, visualization of results on a map can be a feasible way of reporting results from a search operation. Anomaly maps produced from radiation surveys may be produced to identify areas where a radioactive source may be located. If the search is successful and the source can be seen on the map, it gives a visual summary; in a search without any conclusive findings, the map can help in identifying areas yet to be covered or areas where the search would need to be refined (see Section 6 for more information on maps).

3.4.2. Time series

Another possible product to be used during source search and recovery is a time series from a monitoring post or hand-held instrument. If the source can be expected to be moving, such systems can be deployed at intersections, venue entries or other nodal points where a moving source might be detectable. Especially if the monitoring post is unmanned, where practicable it needs to be coupled with a video recording device, thus making later identification, for example of suspect vehicles, possible.

The time series may consist of total gross counts, counts in a region of interest or more advanced parameters, as appropriate. Registration of a significant increase in the signal, which in turn might trigger an alarm, depending on how the equipment is configured, needs to be recorded with a timestamp. The time, together with the magnitude of an increase or, preferably, the level of confidence of an alarm, constitute the intermediate product of the assistance. It is advisable that the signal or alarm is verified before further actions are taken.

3.4.3. Verification

As described above, possible intermediate products are alarms, time stamps or spectra at which a significant signal was detected, for example, by a monitoring post. Similar products are intermediate in the sense that they might trigger further investigation, resulting, if successful, in the final product (location and characteristics). The biggest challenges in configuring an alarm to yield the correct percentage of false positives are due to variations of the natural background and the influence of geometrical features, e.g. from surrounding buildings. Facilities producing or using radioactive materials or persons receiving medical treatment (diagnostic or therapeutic) with radiopharmaceuticals can also lead to false positives; it is therefore preferred that the team carrying out the verification is familiar with the most widely used radioisotopes in industry and medical procedures.

The intermediate product, as described above, may be sent to an analysis team (e.g. an EBS) for verification. The primary task for the verification team would then be to distinguish between sources of interest and others, while secondary tasks may include preliminary source characterization. The final product then comprises the intermediate product and the verification analysis.

3.4.4. Source characterization products

Once a source has been located, it needs to be characterized to the extent possible for the purposes of assessing its integrity, dose reconstruction and identification/confirmation if it was already known to be missing. Confirmation of the source isotope identification may be possible from spectral analysis during the survey and then be provided as a product of the assistance. If a measured gamma spectrum is to be analysed by an external party, the guidelines given for gamma spectrometry measurements in Section 3.3.3 are applicable.

Further products from the source search include any relevant contextual information which may contribute to successful recovery. Physical inspection, conducted in a safe and secure manner, may assist in the identification of the source through visual markings on the package, device or source. These could include a photograph(s) of the source/device/package and the area where the source is located or a written description of relevant factors. In conclusion, the products of source characterization are, as appropriate:

Source Characterization Products
Header information:
— Team identification (TID); — Measurement details; — Estimated source activity (if possible); — Shielding or packaging (package markings, UN number(s), transport index); — Technical information about container or source; — ID/reference numbers on the source (if possible); — Associated documentation, if available; — Physical status and integrity of source or device.
Each reading needs to include:
— Date and time of characterization; — Latitude and longitude (or LIC, if applicable); — Isotope identification; — Dose rate and contamination measurements; — Contextual information (e.g. photograph).

In addition to the information listed above, any measurement(s) from which the source characterization is derived need to be reported according to the description given in Section 3.3.

It is good practice for assisting parties and the Requesting State to ensure that a survey of the area is performed following the removal of the source(s). This is to confirm both that no additional sources are located in the area and that no contamination is present. The survey could also serve as background for dose reconstruction. The products of these surveys need to be as described above and in Section 3.3.1.

3.5. PERSONAL AND ITEM CONTAMINATION MONITORING PRODUCTS

3.5.1. Personal contamination monitoring

The provision of assistance by one or more teams monitoring potentially contaminated personnel or members of the public may require cooperation and coordination with first responders, law enforcement and medical personnel from the Requesting State. The teams need to be ready to assist with personal contamination monitoring as well as with giving advice or instructions concerning contamination monitoring[5].

National response and international assistance teams need to ensure that the contamination monitoring equipment is considered suitable for applying the operational criteria during the nuclear or radiological emergency.[6]

A suitable area to perform personal contamination monitoring needs to be chosen by the local authorities in consultation with the appropriate FATs. This includes establishing and identifying the background in the chosen area and monitoring for its changes over time. Teams need to ensure that the background does not affect their instrumentation in an improper way and need to establish routines to check for instrumentation contamination on a regular basis.

3.5.2. Personal external contamination monitoring products

The product of personal contamination monitoring assistance is an apt and correct delineation of individuals requiring decontamination (including the areas on the body and levels) or medical follow-up.

Possible incompatibility issues in personal contamination monitoring may include:

— Improper instrumentation selection (not searching for, or not sensitive to α, β and γ);
— Different generic and operational criteria;
— Difficulties in matching instrument responses to the above mentioned criteria.

It is important that the assisting parties are informed by the Requesting State about local or national criteria and reporting levels, including OILs used in personal contamination monitoring, in order to facilitate a suitable personal monitoring routine. To be able to assist in an effective manner, it may be necessary for teams to compare their instrument response with reporting levels.

Later dose assessment may need to be performed for contaminated individuals; therefore, teams performing personal contamination monitoring need to document their monitoring activities methodically. As a minimum, the worksheet used for documentation needs to depict both sides of the human body and give a clear indication of where the contamination was

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[5] Practical guidelines for the different radiological emergencies a first responder might encounter are given in EPR-First Responders 2006 [17], while guidelines on the radiological aspects of the medical response during a nuclear or radiological emergency are given in EPR-Medical 2005 [18].

[6] IAEA Safety Standards No. GSG-2, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency [2], Appendix II, provides information for determining the suitability of different field contamination monitoring equipment for applying the operational criteria.

found. In addition to the sketch, the following minimum information is to be recorded for each monitored individual:

Personal External Contamination Monitoring Products
— Team identification (TID); — Measurement details; — Type of instrument used (serial number, reference to SS); — Calibration coefficients used (or refer to SS); — Background measurement on instrument; — Environmental conditions (e.g. temperature, humidity) (optional); — Information about person (name, date of birth and sex); — Date and time; — Location on body or reference to an identifier on the sketch; — The presence of any skin damages (e.g. wounds, punctures, burns) should be recorded; — Type of contamination found (α, β, γ); — Value; — Unit; — Reference to bioassay or sample (SID), if collected; — Location where contamination occurred.

3.5.3. Products of the external contamination monitoring of operational equipment and personal effects

Monitoring of potentially contaminated items such as operational equipment for reuse and important items such as personal effects (e.g. wallets, documents, medicines, tools and pets) is similar to monitoring individuals. The following minimum information is to be recorded for each item monitored:

Operational Equipment and Personal Effects Monitoring Products
— Team identification (TID); — Measurement details; — Type of instrument used (serial number, refer to SS); — Calibration coefficients used (or refer to SS); — Background measurement on instrument; — Environmental conditions (e.g. temperature, humidity) (optional); — Item description (for example, a serial number); — Name of owner or recipient of item; — Date and time of monitoring; — Location of contamination (if possible, a sketch is provided); — Type of contamination found (α, β, γ), whether it is fixed or non-fixed; — Value; — Unit; — Location where contamination took place; — Description of decontamination attempts that were made, the outcome and a description of the advice provided to the recipient.

4. ENVIRONMENTAL SAMPLING AND ANALYSIS

4.1. FORMS OF ASSISTANCE FOR ENVIRONMENTAL SAMPLING AND ANALYSIS

Environmental sampling, including the sampling of foodstuffs with subsequent analysis of samples, forms an important part of the response to a nuclear or radiological emergency with a potential or actual release of radioactive materials to the environment. Samples are collected to ascertain the characteristics of any release of radioactive material and to help determine whether protective actions (e.g. restrictions on food or animal feed) need to be implemented or withdrawn.

The response to a nuclear or radiological emergency resulting in the potential or actual release of radioactive material to the environment may necessitate that a large number and variety of samples be collected and analysed. If environmental sampling is requested as part of an Assistance Mission, assistance could be provided in any or all of the following steps:

(a) Sample collection;
(b) Sample preparation;
(c) Measurement of samples;
(d) Analysis of results from analytical measurements performed in (c).

It is noted that one or more assisting parties may perform any or all of the above mentioned steps when providing assistance. As described in Sections 4.2, each of steps (a–c) generates outputs from the activities, considered here as intermediate products. Ultimately, as described in Section 4.3, the final product is provided to the Requesting State in step (d).

Samples collected need to be identified using a unique sample identification (SID). This SID needs to be referenced in all intermediate and final products generated to ensure traceability to the original sample(s). It is essential that the final product references the SID of the original sample.

Note: The transportation of samples is not considered an assistance product as the samples are subject to national and international standards for transport.

At the start of the Assistance Mission, involved parties need to consider issues related to the management of environmental samples, including collection, movement, handling, storage and disposal. Specific storage containers may be required, the supply of which may be limited. Capacity and facilities for storage, such as freezers or refrigerators, may be required to preserve samples, depending on the type of samples collected. It is good practice that a centralized inventory of the stored samples be established to keep track of all samples collected throughout the Assistance Mission, including those being sent to laboratories for analysis.

4.2. ENVIRONMENTAL SAMPLING: INTERMEDIATE PRODUCTS

4.2.1. Sample collection

The team collecting environmental samples needs to ensure that all the necessary information that may be required by laboratories performing subsequent measurements and analysis to produce meaningful results is recorded. The collected samples need to be clearly labelled with the necessary information to ensure identification and traceability of samples. The

information recorded, together with the collected samples, is considered the intermediate product of the environmental sampling step.

Note: Measurement and sample preparation methods used during an emergency may be different to those used in routine environmental monitoring operations. For instance, rapid methods possibly yielding larger uncertainties may be favoured in an emergency situation for faster results [10].

Sections 4.2.1.1 to 4.2.1.11 present the information that needs to be recorded and reported, as appropriate, when collecting different types of environmental samples. The header information may be recorded once per batch of samples collected, or once per sample. The sample specific information needs to be recorded and reported for each sample or measurement collected. It should be noted that some elements are identified as optional.

4.2.1.1.Air sampling

Air Sample Collection Products
Header information:
— Team identification (TID); — System specification (SS); — Description of sampling location (farmland, forest, etc.), if not described in LIC; — Weather (wind, rain, etc.) (optional); — Sampling method; — Filter medium; — Sample nozzle height above ground (m).
Sample specific information:
— Sample identification (SID); — Time and date sampling started; — Time and date sampling stopped; — Latitude and longitude (or LIC, as appropriate); — Sampling rate (m^3/h); — Sampled volume (m^3); — Relevant information that could affect the sample (e.g. wind direction relative to sample nozzle, rain, humidity, turbulence, etc.) (optional); — Photograph(s), picture or sketch around sampling location (if possible); — Other samples collected at the same location (if applicable); — Dose rate at sampling location before sample collection.

4.2.1.2.Soil sampling

Soil Sample Collection Products
Header information:
— Team identification (TID); — Description of sampling location (farm land, forest, whether vegetation was removed from area before sampling, etc.), if not described in LIC; — Weather (wind, rain, etc.) (optional); — Sampling method, including information regarding whether sample was mixed.
Sample specific information:
— Sample identification (SID); — Sampling date and time; — Latitude and longitude (or LIC, as appropriate); — Dose rate at sampling location (optional); — Type of soil (e.g. clay, sand, black); — Sample area (cm^2); — Sampling depth or range (cm); — Sample mass (original and sub-sample mass, if appropriate, and whether wet or dry); — Record if collected with grass sample (if applicable); — Photograph(s) or sketch of the surroundings of the sampling location (if possible); — Other samples collected at the same location (if applicable).

4.2.1.3.Grass sampling

Grass Sample Collection Products
Header information:
— Team identification (TID); — Description of sampling location (farm land, forest, etc.), if not described in LIC; — Weather (wind, rain, etc.) (optional); — Sampling method.
Sample specific information:
— Sample identification (SID); — Sampling date and time; — Latitude and longitude (or LIC, as appropriate); — Dose rate at sampling location (optional); — Description of sample; — Sample area (m^2, or cm^2 in case of conjunction with soil); — Height of cut above the surface (cm); — Sample mass (kg), as agreed (wet/dry); — Record if collected with soil sample (if applicable); — Photograph(s) or sketch of the surroundings of the sampling location (if possible) — Other samples collected at the same location (if applicable).

4.2.1.4.Deposition over time sampling

Deposition Over Time Products
Header information:
— Team identification (TID); — Description of sampling location (farm land, forest, etc.), if not described in LIC; — Weather (wind, rain, etc.) (optional); — Sampling method.
Sample specific information:
— Sample identification (SID); — Sampling date and time; — Latitude and longitude (or LIC, as appropriate); — Type of sample; — Weather (wind, rain, etc.) (optional); — Sampling method as agreed; — Sampling surface area (m^2); — Time period (h); — Sample method (wet/dry/adhesive); — Precipitation during the sampling period (optional) (mm or L/m^2).

4.2.1.5.Water sampling

Water Sample Collection Products
Header information:
— Team identification (TID); — Description of sampling location, if not described in LIC; — Weather (wind, rain, etc.) (optional); — Sampling method.
Sample specific information:
— Sample identification (SID); — Sampling date and time; — Latitude and longitude (or LIC, as appropriate); — Sampling depth (if not recorded in LIC); — Description of sample; — Sample mass (kg) and/or volume (L); — Water source (well, surface water, precipitation, drinking water and supply system, seawater, etc.); — Type of storage container; — Agents added to sample (optional); — Salinity, pH and/or temperature (optional); — Photograph(s), picture or sketch of the surroundings of the sampling location (if possible); — Dose rate at sampling location (optional); — Other samples collected at the same location (if applicable).

4.2.1.6.Milk sampling

Milk Sample Collection Products
Header information:
— Team identification (TID); — Description of sampling location (farm, shop, etc.), if not described in LIC; — Weather in the period prior to sample collection (wind, rain, etc.) (optional); — Sampling method.
Sample specific information:
— Sample identification (SID); — Sampling date and time; — Latitude and longitude (or LIC, as appropriate); — Sampling or production location; — Description of sample; — Type of animal ; — Date and time (or interval) of milking; — Single sample or combined sample; — Sample mass (kg) and/or volume (L), as agreed; — Origin of sample (producer, dairy processor or market); — Agents added to sample (optional); — Feed type, origin and storage (covered or not) (optional); — Water supply (optional); — Grazing location, if applicable.

4.2.1.7.Food sampling (including animal feed)

Food Sample Collection Products
Header information:
— Team identification (TID); — Description of sampling location (farm land, shop, etc.), if not described in LIC; — Weather during growing or production, as appropriate (wind, rain, etc.) (optional); — Sampling method.
Sample specific information:
— Sample identification (SID); — Sampling date and time; — Latitude and longitude (or LIC, as appropriate); — Food description (if applicable, indicate whether it is ready for consumption); — Sampling or production location; — Sample mass (wet or dry in kg); — Water source for irrigation (optional); — Dose rate at sampling location (optional).

4.2.1.8.Vegetation sampling

Vegetation Sample Collection Products
Header information:
— Team identification (TID); — Description of sampling location (farm land, shop, etc.), if not described in LIC; — Weather (wind, rain, etc.) (optional); — Sampling method.
Sample specific information:
— Sample identification (SID); — Sampling date and time; — Latitude and longitude (or LIC, as appropriate); — Type of sample; — Vegetation description; — Sampled area (m^2); — Sample mass (kg), as agreed (wet/dry); — Irrigation water source (optional); — Dose rate at sampling location (optional); — Photograph(s), picture or sketch of the surroundings of the sampling location (if possible).

4.2.1.9.Sediment sampling

Sediment Sample Collection Products
Header information:
— Team identification (TID); — Description of sampling location (e.g. lake, riverbed, type of water body, etc.), if not described in LIC; — Weather (wind, rain, etc.) (optional); — Sampling method; — Description of sampling device or instrument.
Sample specific information:
— Sample identification (SID); — Sampling date and time; — Latitude and longitude (or LIC, as appropriate); — Type of sample; — Sample mass (kg), as agreed (wet/dry); — Sampling depth and range (cm); — Depth below water surface (m); — Type of water body (optional); — Name of water body (optional); — Photograph(s), picture or sketch of the surroundings of the sampling location (if possible).

4.2.1.10. Snow sampling

Snow Sample Collection Products
Header information:
— Team identification (TID); — Weather (wind, rain, etc.) (optional); — Sampling method.
Sample specific information:
— Sample identification (SID); — Sampling date and time; — Latitude and longitude (or LIC, as appropriate); — Type of sample; — Description of sampling location (farm land, forest, etc.), if not described in LIC; — Sampled area (m^2); — Sample mass (kg); — Snow depth and sampled depth (optional); — Dose rate at sample location (optional); — Details of snowfall in the area prior to sample collection (optional); — Photograph(s), picture or sketch of the surroundings of the sampling location (if possible).

4.2.1.11. Smear sampling

Smear Sample Collection Products
Header information:
— Team identification (TID); — Weather (wind, rain, etc.) (optional); — Sampling method.
Sample specific information:
— Sample identification (SID); — Sampling date and time; — Latitude and longitude (or LIC, as appropriate); — Description of sampling location, if not described in LIC; — Type of sample; — Sample area (cm^2); — Type of smear material (e.g. filter paper, cloth) and area; — Chemicals/agents used; — Description of smeared surface; — Photograph(s), picture or sketch of the surroundings of the sampling location (if possible).

4.2.2. Sample preparation

Sample preparation can be done either by the team collecting the sample or by the laboratory measuring the sample. In theory, a third independent laboratory or field team could prepare the samples before shipping them to another laboratory for measurement. The following information needs to be recorded, if appropriate and applicable, and if sample preparation results are provided as an intermediate product:

Sample Preparation Products
— Team identification (TID); — Date and time when sample was received; — Sample identification (SID); — Receipt of sample or other chain of custody requirements, as appropriate; — Preparation method (preferably with a reference to a standard or procedure); — Time of radiochemical separation; — Tracers, activity and mass; — Particles and elements lost in separation process; — Subsampling (including splitting) (see Section 2.6.3); — If destructive method is used: • Fraction of original sample; • Preferably a reference to method, including known loss of activity and possible interferences; — Advice on target nuclides to be measured; — Preferably uncertainties related to sample preparation

4.2.3. Sample measurements

Measurements of environmental samples can be offered as an intermediate product during an Assistance Mission, with the final analysis of the measurements potentially being performed by another assisting party. In such circumstances, a team preparing products documenting the sample measurements will need to provide the details necessary so that another team performing subsequent analysis will be able to properly evaluate the results.

The information from the collection and preparation of the samples listed in Sections 4.2.1 and 4.2.2 may also need to be relayed as part of the intermediate product. In addition, the following information is to be reported by the team measuring the samples:

Sample Measurement Products

— Team identification (TID and statement of roles);
— Date and time when sample was received;
— Sample identification (SID);
— Latitude and longitude (or LIC, as appropriate);
— Receipt of sample or other chain of custody requirements, as appropriate;
— Detector system identification and geometry (may refer to system description):
    - Validity (expiry date) of calibration, if applicable.
— Acquisition time start and stop;
— Measured live time;
— Reported results (for each radionuclide):
    - Reference time;
    - Measurement result quantities;
    - Measurement results unit;
    - Combined uncertainties with coverage factors (expanded uncertainties);
    - Statement of detection limit (or reference to system description);
    - Separation yield, if applicable.
— Observations/comments, e.g. sample condition on arrival (optional).

Section 3.3.3 provides additional information to be reported to an external laboratory providing assistance in analysis of gamma spectrum.

4.3. ENVIRONMENTAL SAMPLING: FINAL PRODUCTS

The information reported in the final product, irrespective of how many of the above steps the reporting laboratory performed itself, needs to include only information for external parties. Internal laboratory information such as laboratory sample ID, the chemical separation method used and uncertainties connected to sample preparation are in most cases redundant and need not be part of the final product provided to the Requesting State. However, it is necessary for the report to include some fundamental information about the analysis procedure, such as the analytical technique (e.g. gamma spectrometry) that was used.

Note: When reporting results using a reference time, i.e. where decay or ingrowth correction has been applied to the measurement results, it is important that it is clearly stated in the final product that a reference time is used and which decay or ingrowth correction was applied. For example, the decay constant or the half-life for an exponential decay could be stated along with the reference and measurement dates so that the quantity arrived at can be understood by the receiver of the final product.

It is preferred that reports refer to subsamples or split samples only if necessary, and then preferably in conjunction with a reference to the original sample via the SID. The SID reported in the final product needs to use the SID from the original sample to ensure traceability.

For the laboratory based radionuclide analysis of environmental samples, the information to be provided as part of the final product includes:

Environmental Sampling Final Products
— Team identification (TID); — Reference date and time; — Sample identification (SID); — Latitude and longitude (or LIC, as appropriate); — Detector system identification (serial number or SS); — Sample type; — Sample collection and measurement dates; — Analytical technique used; — Elements or particles sample preparation method was focusing on (optional); — For each radionuclide: • Measured value and unit, combined with sampling data; • Measurement uncertainty and coverage factor; • Statement of detection limit, if applicable. — Other samples collected at the same location, if applicable; — Other comments or observations, as appropriate; — Results compared to the agreed reporting level, if applicable.

5. DOSE ASSESSMENT

5.1. RETROSPECTIVE DOSE RECONSTRUCTION

Following a nuclear or radiological emergency, Requesting States may need assistance in estimating doses to potentially exposed individuals. An estimation based on available collected information is referred to as retrospective dose reconstruction. The primary purpose of retrospective dose reconstruction is to determine which, if any, individuals or populations require medical attention.

As described in Section 2.3, one of the fundamental items to agree upon before or at the start of an Assistance Mission are the standards and relevant dose models to be used, i.e. the system of radiological protection. These need to be applied to the retrospective dose reconstruction, as appropriate.

There are potentially several steps between the collection of a sample and the final product (dose estimate or dose reconstruction); hence, compatibility issues may arise, especially if different teams are involved.

Prior to the performance of a retrospective dose reconstruction there may be a need, based on the situation, to determine dose criteria to delineate population groups. Based on these criteria defined by the Requesting State in coordination with involved parties and the nature of the event, it is necessary for a screening process to be developed to identify potentially affected individuals.

The case history forms a crucial component in dose reconstruction; it needs to include the location and time, the presence or location of a source, possibly in different places, as well as exposure pathways to individuals or population groups and occupancy time. It may be noted that the information collected may also contribute to the localization of other sources.

Biological and physical dosimetry techniques can be used to estimate radiation exposure after a nuclear or radiological emergency where personal dosimeters were not used or were unavailable.

Pathways other than external exposure all involve intakes of radioactive substances. Bioassay techniques aim at inferring the presence of radionuclides after a potential intake, using either direct or indirect measurements [19]. Direct measurements include in vivo bioassays, e.g. by whole body or organ counting, whereas indirect methods include in vitro bioassays, e.g. measuring samples from excreta, blood [20] or other biological samples. Results from the bioassay will serve as input for further analysis using internal dose calculation, where an estimate of the committed dose from internal exposure will be assessed.

A dose reconstruction may need to consider the following elements listed below, where applicable and available, to produce a case history. Privacy issues may also need to be considered.

- Presence (or absence) of a source in location(s) over time (e.g. sketch);
- Source characterization;
- Exposure pathways;
- Timeframe of interest of potentially exposed individuals or population groups by location;

— Radiological monitoring data;
— Dosimetry data (external and internal dosimetry);
— Dose reconstruction model(s) to be used;
— Medical data (e.g. symptoms);
— Use of iodine thyroid blocking, if appropriate;
— Record of any interviews with potentially exposed individuals, including photographs (free text or recorded file);
— Dietary habits (specify food intake model);
— Names of individuals' medical doctors;
— Information needed to distribute results from dose reconstruction to individuals.

The outputs (products) of a dose reconstruction may include:

— Delineation of individuals or population groups of interest, based on agreed reporting levels;
— Dose estimation (dose or ranges);
— Advice on other response actions;
— Advice for public reassurance.

5.2. DOSE ASSESSMENT FOR POPULATION GROUPS

Apart from retrospective dose reconstruction for individuals as described above, a dose assessment (or prediction) may be performed for the public. Generally, the dose assessment does not focus on the population as a whole, but rather on one or more specific groups within the population. The specific groups need to be selected by considering the nature of the emergency, areas affected, potential exposure pathways, and the habits of the different groups within the population, taking into account those that are most vulnerable to radiation exposure (i.e. pregnant women and children).

The assessment of the dose to a population group in an area over a specified period of time needs to be performed by carefully selecting the exposure pathways and characteristics typical representative person [21] for each of the population groups considered and subsequently performing the dose assessment [22].

Note: The Representative Person should be an individual receiving a dose that is representative of the more highly exposed individuals in the population [23].

5.3. DOSIMETRY PRODUCTS

Different techniques for dose estimation from biological samples or samples from materials with certain characteristics may be utilized as part of performing a dose assessment Considering exposure from external sources, the final product will be an estimate of the effective dose to an individual or typical for the representative person; an absorbed dose weighted by relative biological effectiveness (RBE) and/or equivalent dose to an individual tissue or organ or body part [22]–[24].

The objective of the dose assessment sampling data needs to be identified and teams need to be informed of the objective in each of the different steps in the analysis chain.

5.3.1. Samples for dose assessment

Methods and considerations for samples collected by medical personnel at hospitals etc. are outside the scope of these guidelines. However, certain samples could also be collected by a field team as part of a dose estimation or reconstruction. The team may need to have the adequate medical qualifications needed to collect biological sample(s).

Teams also need to obtain the consent of the individual(s) to collect the sample(s) and have information material available, in a language understood by the individual(s), that describes the purpose of the sampling and explains it in plain language.

Regardless of the type of sample(s), the team collecting them must be experienced and aware of the limitations of the subsequent analysis technique in order to avoid destroying the information contained in the sample(s). It is good practice that the teams collecting and analysing the samples agree on a sampling method and on the handling of samples before they are collected.

The following minimum information is to be recorded for all samples collected:

Sample Collection
— Team identification (TID); — Sample identification (SID); — Sampling date and time; — Type of and description of sample; — Relevant information concerning origin of sample, as appropriate; — Sampling method, as appropriate; — Full name and/or personal ID or code of the person from whom the sample is taken, if available; — Date of birth of the person from whom the sample is taken (age); — Weight, height and sex of the person from whom the sample is taken; — Emergency history of the person from whom the sample is taken (e.g. type of exposure, time of exposure, nature of event, radiation sources, radioactive materials involved, chronology of events); • Potential or actual intake pathway; • Intake pattern (acute or chronic); • Date(s) of intake (if known); • Information on application of decorporation therapy; • Indication of pregnancy; — Note: If the sample is part of a later dose reconstruction, additional minimum information is needed, as described in Section 5.1.

5.3.2. Internal dose assessment products

Biokinetic models describe the biological behaviour of radioactive materials entering the body. Dosimetric models describe the radiation transport from the point of decay to deposition of ionizing energy in tissues. For the provision of assistance of internal dose assessment, it is preferred to use the methodology of the International Commission on Radiological Protection (ICRP), including the model of the human respiratory tract [25], [26], the model of the gastrointestinal tract [25] and age dependent dose coefficients [27] as default

options. Models for dose assessment to the embryo and the fetus, e.g. from intakes of radionuclides by the mother, have also been published by the ICRP [28].

The information immediately below is to be provided for internal dose assessment products, in addition to the information collected with the sample.

Internal Dose Assessment Products

— Team identification (TID);
— Person responsible for measurement;
— Measurement data:
    - Sample identification (SID);
    - Type of measurement(s) or sample(s) (e.g. in vitro or in vivo: urine, organ counting, etc.);
    - Date and time of measurement;
    - Radionuclide, chemical and physical form;
    - The spectrum obtained from the measurement (as appropriate).
— Specification of the methodology and biokinetic model used for intake or radionuclide estimation (default: ICRP [25], [26], [28]);
— Intake (Bq);
— Dosimetric model used (and agreed) for dose estimation (default: ICRP [27]);
— List with organ or tissue absorbed doses:
    - Radionuclide;
    - Organ or tissue considered;
    - Time and intake (days);
    - RBE-weighted absorbed dose;
— Committed effective dose.

The following descriptions are provided for the products from specific forms of biological dosimetry. Note that not all the personal information included below may be made available to the laboratory performing the measurements. Consequently, the information may not be included appropriately in the product reported. The final dose estimation product needs to reconcile the information from sample collection and sample analysis.

5.3.2.1. Cytogenetic bioassay

Cytogenetic Bioassay Sampling Products
— Team identification (TID); — Person responsible for measurement; — Sample identification (SID); — Information about individual or characteristics typical of the representative person, as applicable: • Full Name and/or personal ID or code, if available; • Date of birth (age), if available; • Weight, height and sex, if available; • Emergency history (e.g. type of exposure, time of exposure, nature of event, radiation sources, radioactive materials involved, chronology of events); • Indication of pregnancy; — Date and time of measurement; — Date of blood sample; — Cell scoring results: • Number of scored cells; • Frequency of dicentrics; • Frequency of centric rings; • Frequency of acentrics (optional); • Estimated absorbed dose; • Dose distribution (homogeneity or partial body); • Uncertainty — Radiation data: • Radiation type (R); • Radiation quality (Q); • Absorbed dose; • RBE; — Calibration data: • Reference in vitro calibration curve; • Calibration curve; • Coefficients of calibration curve used for dose assessment; • Preferably uncertainties of results with coverage factor.

5.3.2.2.In vivo bioassay

In Vivo Bioassay Sampling Products
— Team identification (TID); — Person responsible for measurement; — Information about individual or characteristics typical of the representative person, as applicable: • Full name; • Personal ID or code, if available; • Date of birth (age); • Weight, height and sex; • Emergency history (e.g. type of exposure, time of exposure, nature of event, radiation sources, radioactive materials involved, chronology of events); ▪ Potential or actual intake pathway; ▪ Intake pattern (acute or chronic); ▪ Date(s) of intake (if known); ▪ Information on application of decorporation therapy; • Indication of pregnancy; — Sample identification (SID); — Date and time of measurement; — Radionuclide(s) measured; — Activity in organ, whole body or wound (specify); — Unit (Bq); — Preferably uncertainty with coverage factor; — Intake; — Committed effective dose.

5.3.2.3.In vitro bioassay

In Vitro Bioassay Products
— Team identification (TID); — Person responsible for measurement; — Information about individual or characteristics typical of the representative person, as applicable: • Full name; • Personal ID or code, if available; • Date of birth (age); • Weight, height and sex; • Emergency history (e.g. type of exposure, time of exposure, nature of event, radiation sources, radioactive materials involved, chronology of events); • Potential or actual intake pathway; • Intake pattern (acute or chronic); • Date(s) of intake (if known); • Information on application of decorporation therapy (type, date and time of administration); • Medical history; • Indication of pregnancy; — Sample identification (SID); — Date and time of measurement; — Radionuclide(s) measured; — List of daily urine or faeces measurement (Bq/day); — List of daily measurements from other biological samples, e.g. hair, blood, nasal swabs, mouth swabs or excised tissue (Bq/g or Bq/L); — Preferably uncertainty with coverage factor; — Intake; — Equivalent dose to organ(s) and accumulation time; — Committed effective dose.

5.3.3. External dose assessment products

In the case of a nuclear or radiological emergency that occurs when traditional dosimeters (e.g. thermoluminescent dosimeters) were not worn by individuals such as the public, techniques such as electron paramagnetic resonance and optically stimulated luminescence may be used to perform retrospective dosimetry to estimate the absorbed dose in biological samples such as tooth enamel [29], bones and nails, or from personal items such as electronic chips (e.g. in mobile telephones), buttons and jewellery. Alternatively, a neutron dose may be assessed by analysing the activation of sodium in blood samples [30].

5.3.3.1. Electron paramagnetic resonance and optically stimulated luminescence measurement products

Electron Paramagnetic Resonance and Optically Stimulated Luminescence Measurement Products
— Team identification (TID); — Person responsible for measurement; — Details of the measurement system or reference to SS including measurement parameters, methodology, calibration, correction or fading factors and calculation method; — Sample identification (SID); — Measurement type (e.g. in vivo or in vitro); — Sample description: • Type of sample; • Mass of sample; • Location where the sample was collected; • Time and date sample was collected. — Information on the individual from whom the sample was taken: • Full name and/or personal ID or code, if available; • Date of birth (age); • Weight, height and sex; • Emergency history (e.g. type of exposure, time of exposure, nature of event, radiation sources, radioactive materials involved, chronology of events); • Indication of pregnancy. — Sample preparation details, if appropriate (e.g. for in vitro measurements); — Date and time of measurement or assessment; — Electron paramagnetic resonance spectrum or optically stimulated luminescence signal; — Absorbed dose in the sample; — Uncertainty with coverage factor.

5.3.3.2.Neutron dose assessment

Neutron Activation Dosimetry Products
— Team identification (TID); — Person responsible for measurement; — Information about individual or characteristics typical of the representative person, as applicable: • Full name; • Personal ID or code, if available; • Date of birth (age); • Weight, height and sex; • Emergency history (e.g. type of exposure, time of exposure, nature of event, radiation sources, radioactive materials involved, chronology of events); • Indication of pregnancy. — Sample identification (SID); — Date and time of measurement or assessment; — Concentration of stable Na in blood (g/cm^3); — Specific activity of Na-24 in blood ($Bq_{Na\text{-}24}/g_{Na}$) at time of exposure; — Fluence of the incident neutrons (cm^{-2}) at the time of exposure; — Organ (colon, lung, red marrow and thyroid) absorbed doses list: • Absorbed dose per unit fluence; • RBE-weighted absorbed dose per unit fluence; • RBE-weighted absorbed dose. — Effective dose of neutron exposure; — Results of photon dose assessment; — Preferably uncertainty with coverage factor.

5.3.4. Dose estimation products

The following information is to be provided by the team reporting the final dosimetry product (i.e. the dose estimation):

Dose Estimation Products
Header information:
— Team identification (TID); — Person responsible for measurement; — Information about individual or characteristics typical of the representative person, as applicable: • Full name; • ID or code, if available; • Date of birth (age); • Weight, height and sex; • Emergency history (e.g. type of exposure, time of exposure, nature of event, radiation sources, radioactive materials involved, chronology of events); • Indication of pregnancy.
Each sample needs to include:
— Sample identification (SID); — Sample type; — Type of measurement(s); — Sample collection and measurement dates; — Timeframe of interest and exposure pathway; — Date and time of assessment; — Dose estimation: • External dose (personal dose equivalent); • Internal dose (committed effective dose); • Total effective dose; — Organ or tissue RBE-weighted absorbed dose estimations: • External dose; • Internal dose; • Combined exposure index [18]; • Integration time for internal dose estimation. — Advice on other response actions (optional).

For whole body or organ counting using in vitro gamma spectrometry as well as other methodologies using gamma spectrometry, the intermediate product described in Section 3.3.3 may be applicable.

6. GUIDELINES FOR THE GENERATION OF MAP PRODUCTS

6.1. GENERAL CONSIDERATIONS FOR THE DEVELOPMENT OF MAP PRODUCTS

Maps are a convenient way to present survey results and use them as a tool to aid in the evaluation of radiation survey data in a space-time context. Data visualization on a map is often associated with one or more data sources. When producing a map, the data used need to be archived for further analysis, verification or giving advice. The radiation survey maps discussed in this section are expected to be delivered to technical experts in the Assistance Mission or the Requesting State, who could use them as input when creating maps for decision makers or for the public.

Note: It is good practice that one team be designated to collect and compile the monitoring data from all assisting parties and produce the radiation map(s), in order to ensure a consistent product.

Map production during an emergency situation may, depending on the scale of the emergency, be an iterative process between the team(s) collecting the monitoring data, the team producing the map and decision makers. For example, the map production team needs to ensure that the data density is appropriate before performing interpolation. This can in turn serve as decision support for the field teams' activities during the next step of the Assistance Mission as gaps in the data set may need to be filled in.

6.2. MAP PRODUCTS

A wide range of map products can be envisaged, each with their defined objective, data source and target audience (or 'customer'). Some of the types of maps are discussed in Sections 6.2.1–6.2.4.

6.2.1. Radiation survey and environmental analysis maps for decision makers

Maps for decision makers displaying radiation survey results need to assist the Requesting State to determine the appropriate protective actions or other response actions to implement. These maps need to present the information in a manner that it can be readily compared with the relevant operational criteria.

The number of categories is preferred to be five or fewer plus background, and the colours used need to be easily distinguishable from the map background and from one another. Depending on the nature of the event, and as appropriate, the categories and colour could reflect the OILs provided by the Requesting State. IAEA default OILs [2], [31] can be used if no national OILs have been determined.

Point data (e.g. from monitoring points) need to be presented using an agreed symbol of a fixed size, with a colour corresponding to the appropriate category. If no such agreement has been made, the use of a coloured circle (opaque if needed) per data point may be used. When displaying dense point data, e.g. from mobile radiation survey systems, it is advisable not to hide data points of importance (i.e. high values). It is necessary for such points to have priority over neighbouring low value points if map space or resolution is limited.

Interpolated areas may be displayed as coloured bands, with colours directly corresponding to the appropriate category. Areas without sufficient data need to be excluded from the interpolation and to be clearly distinguishable as areas where readings were not obtained.

Maps for decision makers need to present information such as local terrain features, infrastructure, administrative boundaries, rivers, roads and national or regional borders. Other information that may be displayed includes population density, communities, farms and industries, and other private or public services that may be affected by the emergency and need special consideration in the implementation of protective actions, such as schools, hospitals, retirement homes and other populated areas.

The following information needs to be included on maps, either printed next to the map or attached as part of the briefing material:

Map Products

— Reference ID of the map that links to the data collected;
— Date and time (range) of measurements;
— Reference time (time stamp when map is valid), if applicable;
— Reference, relative or actual height, if applicable;
— Radiation type(s) (α, β, γ, n), if applicable;
— Dose rates and units, if applicable;
— Radionuclide and units, if applicable;
— Map with overlay markers or bands with fixed (agreed) colours referenced to respective categories (OILs, if applicable);
— Scale and orientation (e.g. north arrow);
— Source of reference of the geographical map;
— A legend with:
    - Categories displayed and their units, clearly linked to the colours presented;
    - Statement if map is based on radiation surveys or modelling.

The map needs to be accompanied by supporting material including a statement of assumptions and methods used in measurements and to generate the map, as appropriate. Maps for public communication may be supported by descriptive text in plain and understandable language that places health hazards in perspective.

This information, along with the presentation of measurement results, may be presented as map layers, as shown in Fig. 1.

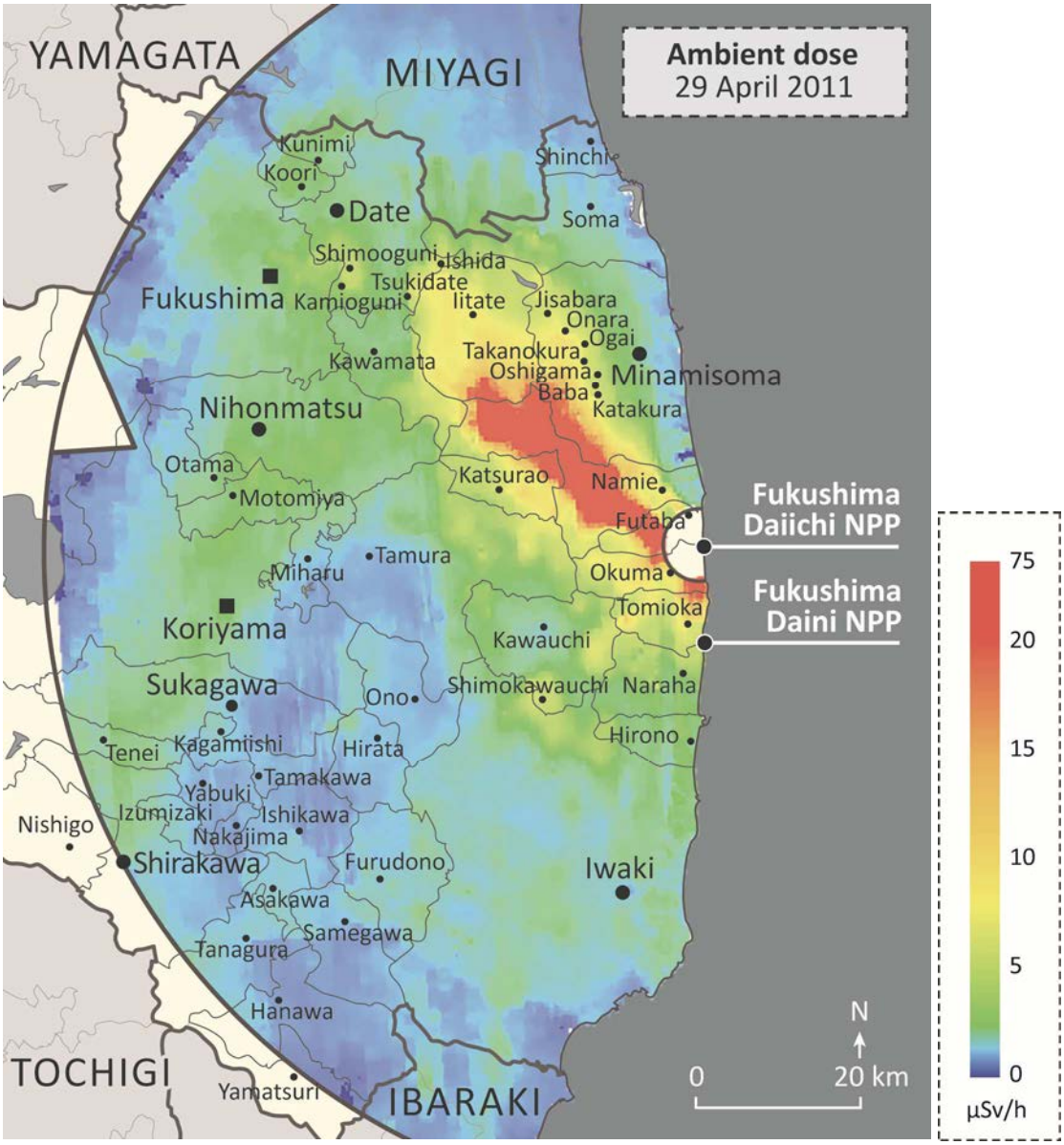

FIG. 1. Example of radiation monitoring map, showing measured ambient dose rate for the reference date 29 April 2011. Modified from [32].

6.2.2. Small scale map

For some operations, a simple sketch or diagram may be sufficient, depending on the scale and findings of the survey.

If the survey was conducted outdoors, the map may display buildings or roads, while indoor survey maps may display information including easily identifiable features such as room numbers, walls, desks and other objects, depending on the situation.

The measured values may be displayed directly on the map, or alternatively the map may include easily identifiable reference points such as LIC(s) and a table of the measured results at each LIC. A scale or approximate distances between relevant objects needs to be included in the map for readability.

6.2.3. Anomaly maps

An anomaly map showing elevated radiation levels or areas where a radioactive source may be located is one of the possible products in a source search operation. Depending on the specifics of the agreement between the Requesting State and the assisting parties, the anomaly map could also be an intermediate product. Due to the fact that the source characteristics and geometry may not be known, the radiation monitoring system used may not be able to determine the activity. However, the monitoring system may still be able to discern different radioisotopes using spectral analysis, which may be especially useful if the radioisotope is known before the search begins. A map showing background subtracted counts in a region of interest, or a ratio between spectral regions, can thus be a useful product, or intermediate product, in a source search.

6.2.4. Maps for the public

In many cases, a map for the public, along with an appropriate descriptive text, is the final product of the Assistance Mission. Maps intended for public use need to focus on the decisions made, e.g. delineation of areas where protective actions have been implemented or are being considered (see, for example, Fig. 2, below). As such, the maps need to present the decisions and advice made by authorities in the Requesting State along with their basis, i.e. the radiation situation leading to the decision. As for other types of maps described above, the categories, colour coding and scale need to be consistent throughout the emergency to avoid misunderstandings resulting from the use of different map layouts.

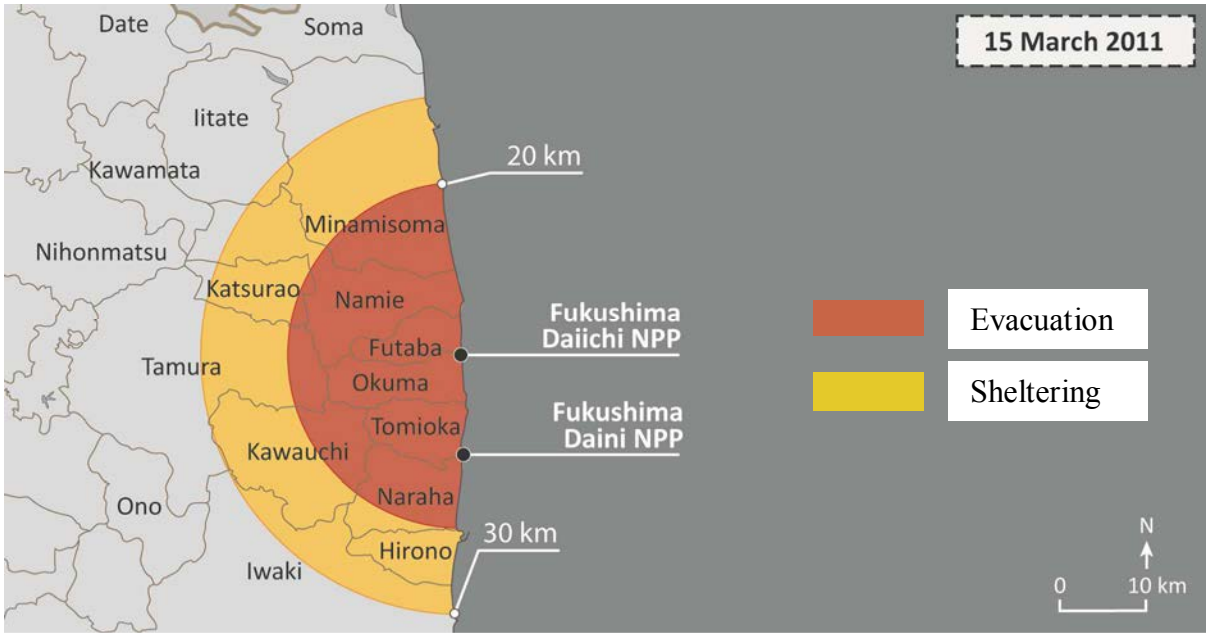

FIG. 2. Example of map for the public with protective actions indicated and explained. Modified from [32].

If maps for the public are created as part of the Assistance Mission, the team producing the maps would have to cooperate closely with the Requesting State to ensure that decisions are communicated in an appropriate manner in plain and understandable language that places health hazards in perspective.

APPENDIX I
IRIX COMPATIBLE EXAMPLES

I.1. IMPORT FUNCTIONS

The UTC ISO string used in data exchange is not recognized by default by common spreadsheet software. Table 5 lists import formulas (functions) that may be used in spreadsheet software to parse the ISO string to date and time cells respectively.

Table 5 - IMPORT EXAMPLES OF THE ISO 8601 STRING

Import functions	UTC ISO string: 2016-05-29T13:00:00Z
Spreadsheet software	=DATEVALUE(MID(*cell*; 1; 10)) =TIMEVALUE(MID(*cell*; 12; 8)) or leave as text field
IRIX format	Recognized by default
C style programming language	string aDate = isoStr.Substring(0, 10); string aTime = isoStr.Substring(11, 8);

Note that the syntax and function names in Table 5 may vary depending, for example, on the language, and that the time import functions do not work across different dates.

I.2. DOSE RATE REPORT

In this example, a dose rate measurement using a hand-held instrument (SRV-2000) is reported by a field team. It is necessary to note that IRIX uses the unit Sv/s internally rather than the conventional Sv/h used in this publication. The countries, locations and reported values used in this example are purely fictional and used for illustrative purposes only.

```
<?xml version="1.0" encoding="UTF-8"?>
<irix:Report version="1.0"
   xmlns:irix="http://www.iaea.org/2012/IRIX/Format"
   xmlns:base="http://www.iaea.org/2012/IRIX/Format/Base"
   xmlns:id="http://www.iaea.org/2012/IRIX/Format/Identification"
   xmlns:meas="http://www.iaea.org/2012/IRIX/Format/Measurements"
   xmlns:loc="http://www.iaea.org/2012/IRIX/Format/Locations">
   <id:Identification>
      <id:OrganisationReporting>XF-FAT-1</id:OrganisationReporting>
      <id:DateAndTimeOfCreation>2017-01-15T10:00:00Z</id:DateAndTimeOfCreation>
      <id:ReportContext>Exercise</id:ReportContext>
      <id:ReportUUID>550e8400-e29b-41d4-a716-446655440000</id:ReportUUID>
      <id:Identifications>
         <base:OrganisationContactInfo>
            <base:Name>Field Assistance Team no. 1, Fantasyland</base:Name>
            <base:OrganisationID>XF-FAT-1</base:OrganisationID>
            <base:Country>XF</base:Country>
         </base:OrganisationContactInfo>
```

```
      </id:Identifications>
   </id:Identification>
   <meas:Measurements ValidAt="2017-01-15T10:00:00Z">
      <meas:DoseRate>
         <meas:DoseRateType>Gamma</meas:DoseRateType>
         <meas:MeasuringPeriod>
            <meas:StartTime>2017-01-15T09:00:00Z</meas:StartTime>
            <meas:EndTime>2017-01-15T09:00:00Z</meas:EndTime>
         </meas:MeasuringPeriod>
         <meas:Measurements>
            <meas:Measurement>
               <loc:Location>
                  <loc:Name>MPFL-Fantasytown-1</loc:Name>
                  <loc:GeographicCoordinates>
                     <loc:Latitude>60.403300</loc:Latitude>
                     <loc:Longitude>18.166602</loc:Longitude>
                     <loc:Height Above="Sea" Unit="m">50</loc:Height>
                  </loc:GeographicCoordinates>
                  <loc:Municipality>Fantasytown</loc:Municipality>
                  <loc:Country>XF</loc:Country>
               </loc:Location>
               <meas:Value Unit="Sv/s">1.2e-9</meas:Value>
               <meas:Uncertainty Unit="%">5</meas:Uncertainty>
               <meas:Description>park grass field; hand-held SRV-2000, serialNo=”bcd456”;
               1m above ground; uncert. type A, k=1</meas:Description>
            </meas:Measurement>
         </meas:Measurements>
      </meas:DoseRate>
   </meas:Measurements>
</irix:Report>
```

I.3. ENVIRONMENTAL AIR SAMPLE REPORT

In this example, an air sample collected by a field team from one county (Fantasyland) is measured, analysed and reported by a laboratory from another county (Tomorrowland). The example uses the LIC defined in the previous example for reporting location rather than reporting the same information again. The countries, locations and reported values used in this example are purely fictional and used for illustrative purposes only.

```
<?xml version="1.0" encoding="UTF-8"?>
<irix:Report version="1.0" xmlns:irix="http://www.iaea.org/2012/IRIX/Format"
   xmlns:base="http://www.iaea.org/2012/IRIX/Format/Base"
   xmlns:id="http://www.iaea.org/2012/IRIX/Format/Identification"
   xmlns:meas="http://www.iaea.org/2012/IRIX/Format/Measurements"
   xmlns:loc="http://www.iaea.org/2012/IRIX/Format/Locations">
   <id:Identification>
      <id:OrganisationReporting>XT-EBS-1</id:OrganisationReporting>
      <id:DateAndTimeOfCreation>2017-01-15T14:30:00Z</id:DateAndTimeOfCreation>
      <id:ReportContext>Exercise</id:ReportContext>
```

```
    <id:ReportUUID>550e8400-e29b-41d4-a716-446655440001</id:ReportUUID>
    <id:Identifications>
      <base:OrganisationContactInfo>
        <base:Name>External Based Support no. 1,Tomorrowland</base:Name>
        <base:OrganisationID>XT-EBS-1</base:OrganisationID>
        <base:Country>XT</base:Country>
        <base:Description>Sample measurement/analysis</base:Description>
      </base:OrganisationContactInfo>
      <base:OrganisationContactInfo>
        <base:Name> Field Assistance Team no. 1, Fantasyland </base:Name>
        <base:OrganisationID>XF-FAT-1</base:OrganisationID>
        <base:Country>XF</base:Country>
        <base:Description>Sample collection</base:Description>
      </base:OrganisationContactInfo>
    </id:Identifications>
  </id:Identification>
  <meas:Measurements ValidAt="2017-01-15T14:30:00Z">
    <meas:Sample>
      <meas:SampleType>A11</meas:SampleType>
      <meas:Volume Unit="m3">15</meas:Volume>
      <meas:SamplingPeriod>
        <meas:StartTime>2017-01-15T09:00:00Z</meas:StartTime>
        <meas:EndTime>2017-01-15T09:30:00Z</meas:EndTime>
      </meas:SamplingPeriod>
      <loc:Location>
        <loc:Name>MPFL-Fantasytown-1</loc:Name>
      </loc:Location>
      <meas:Description>SID="AA0001"; airsampler serialNo=”abc123”; filter paper
      ”FP4.0”; Sampling rate 30 (m3/h); sample head 1 m above ground;
      </meas:Description>
      <meas:Measurements>
        <meas:Measurement>
          <meas:Nuclide>Cs-137</meas:Nuclide>
          <meas:Value Unit="Bq/m3">6.1e2</meas:Value>
          <meas:Uncertainty Unit="%">20</meas:Uncertainty>
          <meas:MeasuringPeriod>
            <meas:StartTime>2017-01-15T13:00:00Z</meas:StartTime>
            <meas:EndTime>2017-01-15T14:00:00Z</meas:EndTime>
          </meas:MeasuringPeriod>
          <meas:ApparatusTypeDescription>HPGe, serialNo=”123abc”
          </meas:ApparatusTypeDescription>
          <meas:Description>Combined standard uncertainty, k=2</meas:Description>
        </meas:Measurement>
      </meas:Measurements>
    </meas:Sample>
  </meas:Measurements>
</irix:Report>
```

APPENDIX II
EXAMPLES OF SYSTEM SPECIFICATIONS

The following are examples of the type of information that could be presented in a system specification for the respective types of equipment. The actual content may vary depending on the equipment being used and the purpose of the measurements being performed.

II.1. DOSE RATEMETER

Dose Ratemeter System Specification
— The measured quantity: e.g. ambient dose equivalent rate, $H^*(10)$/unit time; — Radiation types detected (e.g. β, γ, n); — Energy range; — Measurement range and units; — Efficiency calibration factors: e.g. at 662 keV or other energies, if appropriate; — Calibration certificate or reference with issue and expiry dates; — Specification of energy range and dose rates for which the instrument is reliable; — Model number and type of detector: e.g. GM tube(s), NaI(Tl), etc.; — Sampling time and integration time of reading, if applicable; — Specification of external equipment (e.g. probes) connected to the meter (including serial numbers of probes); — Estimates of uncertainties (e.g. systematic uncertainties); — Other relevant information about meter or equipment, as appropriate (e.g. operating temperatures).

II.2. IN SITU GAMMA SPECTROMETRY SYSTEM

In Situ Gamma Spectrometry System Specification
— Schematic system set-up (orientation, mounting, tripod, etc.); — Detector properties, including: • Type, e.g. HPGe p-type, BEGe, LaBr(Ce), etc.; • Crystal shape, dimensions (cm) and relative efficiency at 1.33 MeV; • Resolution (FWHM) at normal operation at 1.33 MeV; • Cooling mechanism and Dewar or battery operation time; • Collimator used and its properties; • Operating environment dose rate range for normal operation. — Calibration procedures and parameters, including: • Efficiency versus photon energy calibrations and their respective geometries; • Angular response (or assumptions thereof); • Energy calibration; • Other calibration procedures and parameters, as appropriate; • Quality assurance procedures; • Software for spectrum acquisition and processing; • Report format(s); • Operating temperatures (optional); • Other relevant information about the acquisition system or methodology, as appropriate.

II.3. GROUND BASED MONITORING SYSTEM

Ground Based Monitoring System Specification
— Schematic diagram of system set-up; — Relevant detector specifications, including: • Measurement range and units; • Calibration factors: e.g. at 662 keV or other energies, if appropriate; • Sampling time and date; • Position acquisition. — Correction procedures, including: • Background subtraction(s); • Dose rate calculation from spectral data, if applicable; • Calibration and quality assurance procedures; • Result data format(s); • Operating temperatures; • Other relevant information about the acquisition system or methodology, as appropriate.

II.4. VEHICLE-BORNE MONITORING SYSTEM

Vehicle-Borne Monitoring System Specification
— Schematic diagram of system set-up in vehicle; — Relevant detector specifications, including: • Measurement range and units; • Calibration factors: e.g. at 662 keV or other energies, if appropriate. — Sampling time and date, if applicable, standard vehicle speed; — Position acquisition; — Correction procedures, including: • Background subtraction(s); • Dose rate calculation from spectral data, if applicable. — Calibration and quality assurance procedures; — Result data format(s); — Operating temperatures; — Other relevant information about the acquisition system or methodology, as appropriate.

II.5. AERIAL MONITORING SYSTEM

Aerial Monitoring System Specification
— Schematic diagram of system set-up in aircraft; — Relevant detector specifications, including: • Measurement range and units; • Calibration factors: e.g. at 662 keV or other energies, if appropriate. — Sampling date and time and, if applicable, standard aircraft speed; — Position acquisition, coordinates, using agreed system, showing spatial corrections; — Height above ground of the acquisition; — Correction procedures, including: • Background subtraction(s); • Altitude correction from actual to nominal height; • Dose rate calculation from spectral data, if applicable. — Calibration and quality assurance procedures; — Result data format(s); — Operating temperatures; — Other relevant information about the acquisition system or methodology, as appropriate.

II.6. AIR SAMPLER

Air Sampler System Specification
— Schematic diagram of system; — Height of sample head; — Type and size sampling medium (charcoal, filter paper, etc.); — Particles or elements filtered by filter material; — Filter efficiency (specify nuclide); — Regulated flow rate (or not); — Sampling rate (m^3/h); — Operation time (if battery supplied); — Other relevant information about meter or equipment, as appropriate.

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ANNEX
AERIAL MEASURING SYSTEMS FOR RESPONSE TO NUCLEAR OR RADIOLOGICAL EMERGENCIES

A–1. INTRODUCTION

Aerial radiation measurements have proven to be very effective in support of responses to nuclear or radiological emergencies resulting in the dispersal of radioactive material over a large area [A–1–A–3]. In order to be effective, the measurements must be performed with a system that will collect the data with sufficient detail and quality to support the needs of the response to the emergency. This annex outlines the technical specifications and functions of a system to be used on an aerial platform (aeroplane or helicopter) to measure widespread radioactive material (radioactive contamination) on the ground. The information contained within this annex is intended to help ensure that measurements conducted by multiple aerial measuring systems (AMSs) during an emergency are both technically compatible and comparable with each other and with measurements taken on the ground.

The primary situations in which the use of AMSs is considered are responses to a large release to the environment of radiological or nuclear material with a strong gamma ray component such as might occur in nuclear power plant or nuclear fuel processing accidents or in incidents involving radiological dispersal devices. In this scenario, AMS data can be used to quickly assess the radiological conditions and help in determining where urgent and early protective actions and other response actions may be needed. AMSs can quickly perform detailed radiological monitoring of identified areas of interest. The results obtained from AMSs may also be used to estimate the amount of radioactive material contained in the release.

A secondary application of an AMS would be in assessing an area for the presence of radioactive materials out of regulatory control, such as a large, unsecured radioactive source (Category I, II or III), where the activity is potentially dangerous to human health.

The sensitivity of an AMS will depend upon the number and size of radiation detectors used, as well as the manner in which it is operated.

The AMS described here is not intended to be used when airborne radioactive material is present. The system does not conduct sampling of the air, and it is not meant to be intentionally flown through a cloud containing radioactive material. The main reason for this limitation is because these activities have a significant potential of contaminating the aircraft. Furthermore, the system described here will overestimate the ground level contamination in these situations, because it does not discriminate or correct for the presence of airborne radioactive plumes.

A-1.1. Aerial radiation measurements in an emergency

In an emergency, aerial radiation measurements are very effective in quickly providing an overview of the radiological conditions. The data will be processed, and the results of the analyses may be used by decision makers for the purpose of determining where urgent and early protective actions and other response actions may be needed. In situations that involve a release of radiological or nuclear material to the environment, the information may be used by decision makers to:

— Confirm whether a release of radioactive material to the environment has occurred;
— Identify the areas where:
    - The dose rates from widespread contamination exceed the operational criteria and warrant the implementation of protective actions;
    - Contamination is present, but the operational criteria have not been exceeded;
    - There is no contamination above background levels detectable by the system.

In emergency situations involving the search for radioactive materials out of regulatory control, the information from an AMS may be used to identify areas where the radiation levels are elevated (i.e. anomalies from natural background levels) and then:

— Identify areas where radioactive materials out of regulatory control may be located;
— Identify where elevated levels are due to variations in natural background radioactivity.

Because of the capability for providing a broad area view, the operators of an aerial system need to be prepared to support the response to the emergency by producing some analysis results for the emergency command and stakeholders within hours of collecting the data. The analysis results will preferably include a map that shows the ground level dose rate, a map showing the relative concentration of the gamma emitting radioactive contamination and an identification of the primary radionuclides that were observed. The AMS operators need also to be prepared to produce maps showing the ground level activity concentration for any or all of the radionuclides present.

During the recovery phase following a nuclear or radiological emergency, aerial radiation measurements may be used to help validate decontamination efforts.

A-1.2 Aerial measuring system

An AMS typically comprises a gamma ray detector and other systems that report the geographical location (latitude and longitude) and time of the collected radiological information, together with a data acquisition unit. Optionally, radar or laser altimeter, barometer and thermometer are added. For on-line data analysis, a data processing unit can be added.

In almost all AMSs, one or more sodium iodide (NaI) scintillator crystals and accompanying multichannel analysers are used to detect gamma rays. Occasionally, high purity germanium (HPGe) semiconductor detectors are integrated in the system, but because of the vibrations in the aircraft and the need for cooling, the integration is complex.

An AMS normally acquires data over a 1 s interval.

The system will normally not detect neutrons. Alpha or beta detection is not relevant owing to the particles' range.

A system that records gamma ray energy spectra is preferred over a non-spectroscopic system because of the ability to use the data to identify which radionuclides are present and to discriminate between contamination and elevated natural background activity. The system needs to be capable of recording the information so that it is available for further detailed processing and analysis. The recorded information includes the following components:

— Date and time of the measurement:
    - Coordinated Universal Time (UTC) by default, GPS, or similar global atomic clock conventions;
    - Date and time needs to be recorded if short lived radionuclides may be present in the contamination, and the data needs to be corrected for radioactive decay to an agreed reference time;
— Measurement location with coordinate system specified. (Note: These need to be specified and agreed in advance of the start of the mission.)
    - The World Geodetic System 1984 (WGS 84 by default), Universal Transverse Mercator (UTM) and the Military Grid Reference System (MGRS) are some different conventions for reporting a location.
    - Data may be collected in different coordinate systems, and it must be possible to translate to a common system in order to properly show spatial correlations.
    - The final reported data products need to be in the geographical datum used by the State using the final product(s).
— Measurement height with reference system specified:
    - The height above ground level is the relevant quantity in equation [A–1] below, which will be used when deriving ground level activities from aerial survey measurements.
    - GPS receivers report the height above an ellipsoid (smooth surface earth model) or geoid or mean sea level (gravimetrically determined smooth surface), depending upon their configuration.
    - Ellipsoid or geoid referenced data can be corrected to height above ground level with the use of digital elevation models.
    - Radar or laser altimeters report the height above the ground level (actual terrain, treetops, buildings).
— Measured gamma ray energy spectrum:
    - 30–3000 keV is the typical energy range of the spectrum.
    - Spectral information may help discriminate contamination dispersed during an emergency from high natural background.
    - Spectral information may reveal different deposition patterns for different radionuclides.
— Gamma ray detector live time, dead time and sample time:
    - Higher count rates in the detector will lead to less time available to record the counts (i.e. higher dead time).
    - Analyses will use gamma ray count rates when determining ground level activities, and the live time allows for a proper calculation of the rate.

The system ideally needs to be designed so that it can reliably report the synchronized gamma ray spectrum, location and live time information. Synchronization errors may result when requests for data are made to subsystems that are not ready and available to provide new data. A system that is not synchronized will have frequent errors at unpredictable intervals. Depending on how the system is constructed, synchronization errors can lead to different problems. Ways in which synchronization issues have been apparent in the past have included missing, incomplete or random data. In some cases, the synchronization error may result in repeated data. Data records with synchronization errors are typically discarded if they are identified during analysis. Discarded records can result in gaps in a survey.

The GPS location of a measurement should be taken in the middle of the spectrum acquisition interval and assigned to the corresponding spectrum. In systems where the

location is recorded at the start of the measurement, this needs to be corrected to avoid spatial errors.

The gamma ray detector would ideally be gain stabilized so that the locations of the gamma ray peaks do not shift dramatically. Analyses may focus on portions of the gamma ray energy spectrum, and erroneous results may be obtained if there are changes to the energy calibration of the spectrum. While it may be possible to correct for gain shifts in analyses, this tends to be very difficult and labour intensive. It is worth noting that an automatic gain stabilization process can result in undesired gain drifts, when the stabilization procedure relies on natural background radioactivity and the radioactivity being measured has strong peaks in the 1400–1600 keV range. An automatic gain stabilization based on the natural background may also fail when the signal from the ground contamination overwhelms the background signal. For these reasons, the option to disable the gain stabilization ideally would be part of the system.

The quality (stability, energy resolution) of the spectra has the highest priority. Bad quality spectra cannot be improved by data processing.

The detector system needs to be perform well when subjected to high count rates. When the count rate is high, there are three things that can lead to undercounting. The first effect is that the energy spectrum slides towards lower energies. The drop in energy comes from depleted capacitors not having sufficient time to be fully restored before the arrival of the next pulse. The drop can result in pulses being pushed below the thresholds for converting and counting a pulse. A related phenomenon is when a new pulse arrives before the signal from the preceding pulse has dropped below a discriminator threshold. The third effect is that the dead time (the time when the system is not available to process new pulses) may be underestimated. In a poorly behaving system, the observed count rate may appear to be lower, while the dose rate at the detector has increased, even after correcting for live time.

A system may be built so that it comprises of multiple gamma ray detectors to increase its sensitivity, dynamic range, or both. When multiple detectors are used to increase the system's sensitivity, the individual detectors are of the same size and similar in performance so that they can all be treated in the same way. The energy calibrations for all the detectors need to be such that the spectra can be added with minimal degradation of the energy resolution. If the energy calibration can be matched, it is sufficient to record a single summed spectrum along with a map indicating which detectors contributed to it. If the purpose of the multiple detectors is to increase the dynamic range, the detectors are typically of different sizes, so that any saturation effects observed will occur at different dose rates. When the different detectors are used to extend the dynamic range, the spectra from the detectors must be recorded individually, since the counts in each detector will have a different meaning with regard to the radioactivity on the ground.

Table A–1 compares three different AMSs designed for aerial radiological measurements, which are currently in use. One of the primary differences between the AMSs is in the front end electronics used to record the signals from the detectors. The first system uses traditional analogue pulse integration circuitry, while the others use digital signal processing. This difference leads to fewer spectral drift problems and higher potential data rates.

Table A-1. SPECIFICATIONS OF THREE AERIAL MEASURING SYSTEMS

	System 1	System 2	System 3
Detectors	4 detectors: • One 25 mm diameter × 25 mm • Two 50 mm × 100 mm × 50 mm • One 50 mm × 100 mm × 50 mm	1 to 4 detectors 100 mm × 100 mm × 400 mm	4 detectors 100 mm × 100 mm × 400 mm
Spectrometer channels	1024	1024	256 or 512
Gain stabilization	Automatic	Automatic	Automatic
Stored spectra	Independent and summed detectors	User defined summed detectors	Method not defined
Energy resolution at 661 keV	<10%	<8%	Not defined
Energy linearity	<10%	<1%	< 0.5%
Pulse integration electronics	Analogue	Digital signal processor	Digital signal processor
Sample rate	1 sec^{-1}	0.1–10 sec^{-1}	0.1–1 sec^{-1}
Maximum pulse rate	50 000 cps	>250 000 counts/sec[7]	22 000 counts/sec per detector
Energy range	40–3000 keV	25–3000 keV	50–3000 keV
Power	9–40 VDC, 40 W	9–40 VDC, 50 W	10–30 VDC, 50 W
Position measurement	GPS receiver	GPS receiver	GPS receiver
Timing synchronization	GPS or internal synchronization	GPS or internal synchronization	GPS or internal synchronization
Elevation measurement	GPS or analogue input for radar altimeter	GPS or analogue input for radar altimeter	Radar altimeter with an antenna

A-1.3 Data analysis process

The analysis will need the application of multiple corrections to the data to produce a count rate at a nominal height above the ground. The nominal height is an average height at which the data is collected, and to which it will be corrected. The equation for the corrected count rate is:

$$N' = \left(\frac{N}{t} - B\right) e^{-\mu(H-h)} \quad \text{(A-1)}$$

where

N is the observed counts in the detector;
t is the measurement live time;
B is the count rate due to the non-terrestrial background (e.g. natural background activity of the aircraft, cosmic rays, airborne radon);
μ is the apparent attenuation coefficient for the gamma rays in the air:

[7] In some early measurements over the Fukushima Daiichi nuclear power plant following the accident there, the count rate in a detector exceeded 500 000 counts per second. The spectrum was devoid of distinguishing features in part owing to the high count rate in the detectors and the effects of scattering in the air.

H is the nominal survey height;
h is the actual measurement height above the ground [A–4].

This analysis may be performed over any portion of the energy spectrum of the gamma rays detected by the system. μ may be determined for multiple energy ranges and is derived from data collected in flights at multiple altitudes over a test area identified for the survey. B is determined from flights at multiple altitudes over a large body of water (e.g. a lake[8]). From Eq. (A–1), it can be seen that the sensitivity of the measurements will depend upon the size of the detectors used and the height at which the data is collected.

A-1.4 Operational considerations

A-1.4.1. Mission objectives and products

The types of missions that might be conducted using an AMS will depend on the nature of the emergency, the phase and evolution of the emergency and the information and products required for the relevant authorities within a State to make appropriate decisions related to protective actions and other response actions.

The following are the most common types of surveys that may be conducted:

— Deposition assessment: To quickly determine the location and extent of the radioactive material deposited on the ground. It is assumed that the release has ceased and that the radioactive material has all been deposited. Because the material is presumed to be on the ground, it is safe to fly across the affected area without concern for contaminating the aircraft. Flights are conducted at a fixed altitude above the ground. Measurements performed upwind of the release point are used to determine the background count rate in the detector system. The flight pattern typically involves flying across the impacted area by going from background to background in a serpentine pattern. The product from the survey is an initial map providing data related to the deposition area on the ground and the relative radiation levels.
— Detailed area survey: The purpose of such a survey is to characterize the ground activity in a designated area. This fight pattern is appropriate for two different types of missions: (1) to characterize and show the variations of the radioactivity in an area; and (2) to assist in locating and identifying a lost radioactive source. The survey area is usually defined by a polygon, and the aircraft is flown over the survey area in parallel lines at a constant altitude above the ground. The distance between the lines is typically equal to twice the altitude. The correlation between the measurement height and the spacing of the flight lines is related to the field of view of the detection system. The system sees an area on the ground that is roughly equal to a circle with a radius equal to the measurement height. If the flight lines are offset by a distance equal to twice the height, all the ground in the survey area will be measured. Complete coverage of the defined area is important when performing surveys related to displaced radioactive sources. If there has been a release of radioactivity that has affected a very large area, it would be reasonable to assume that the activity would be smoothly varying. Based on this, it may be appropriate to fly with wider

[8] A lake is used because the water lacks the natural background radioactivity typically found in rocks and soil. A lake is preferred over an ocean or sea, because the radon in the air would be more representative of what will be seen over the ground of the survey areas.

line spacing and to interpolate between the measurements. This would be done to reduce the amount of time needed to survey the affected area.

— Road survey: The conduct of aerial measurements may be performed over roads for two different purposes, depending on the nature of the event. In situations where there has been a dispersal of radioactive material to the environment, the conduct of aerial surveys over roads may be conducted to help determine whether the use of the road(s) is considered safe either for unrestricted travel within the affected area or for the possible evacuation of people from the area. Alternatively, aerial monitoring over roads may be performed as part of the search for radiative sources that may have been lost from regulatory control.

A less common type of survey that may be conducted is a plume survey to determine the location and extent of a radioactive cloud. This may be performed during an active or recent release such that there may be radioactive material still in the air. The output of the survey is the outline and height(s) of the plume. The system is not flown through the plume but rather detects the edges of the plume through identifying increases against natural background.

A-1.4.2. Measurement height

The range of heights that might be used with an AMS is 50–1000 m above ground level. The actual range employed for a particular system is dependent on the aerial platform (aeroplane or helicopter). The lower bound is driven by flight safety. The upper bound is due to the increasing contribution from cosmic rays and the reduction of the signal from the ground due to attenuation in the air. The upper bound on the altitude range may also be driven by the mechanism used for determining the measurement height. Laser altimeters are not effective above 300 m, while radar altimeters may operate up to 500 m.

The measurement height may also be determined depending on the ground activity and the detection limits needed. In high contamination areas, the flight altitude may be at the higher range to avoid saturation.

A-1.4.3. Aircraft speed

The speed of the aircraft needs to be correlated with the measurement height and sampling time. The field of view for an aerial detector system can be approximated by a circle on the ground with a radius equal to the measurement height. For good coverage of the ground, the aircraft would ideally not be moving so fast that it moves a distance equal to or greater than the measurement height in the time it takes for a measurement to be performed. For example, if the system measures at one second per sample and the aircraft is at a height of 100 m above the ground, the aircraft would ideally be travelling at less than 100 m/s (360 km/h).

A-1.4.4. Measurement (dose rate) range

The range of activity levels encountered in an event where an AMS may be employed can be quite large. During the course of the accident at the Fukushima Daiichi nuclear power plant, the highest ground level dose rates recorded were greater than 10 mSv/h. This was compared with uncontaminated areas where the dose rates were approximately 50 nSv/h from natural background radioactivity.

Appropriate consideration needs to be given for the operational criteria that may be applied during a nuclear or radiological emergency, so that the measurements may be compared with

these criteria to help contribute to the process of determining the implementation of the protection strategy.

With this wide range of potential dose rates, some thought and planning must be given to how measurements might be performed. It is commonly accepted that a system that is designed for the low dose rate range can be employed in the high dose rate range areas by operating at higher altitudes.

A-1.4.5. Operational range of the system

An example operational range for an AMS is presented in Fig. A–1. The shaded band represents the operating range for a system comprising 12 L of NaI(Tl) over ground contaminated with ^{137}Cs.

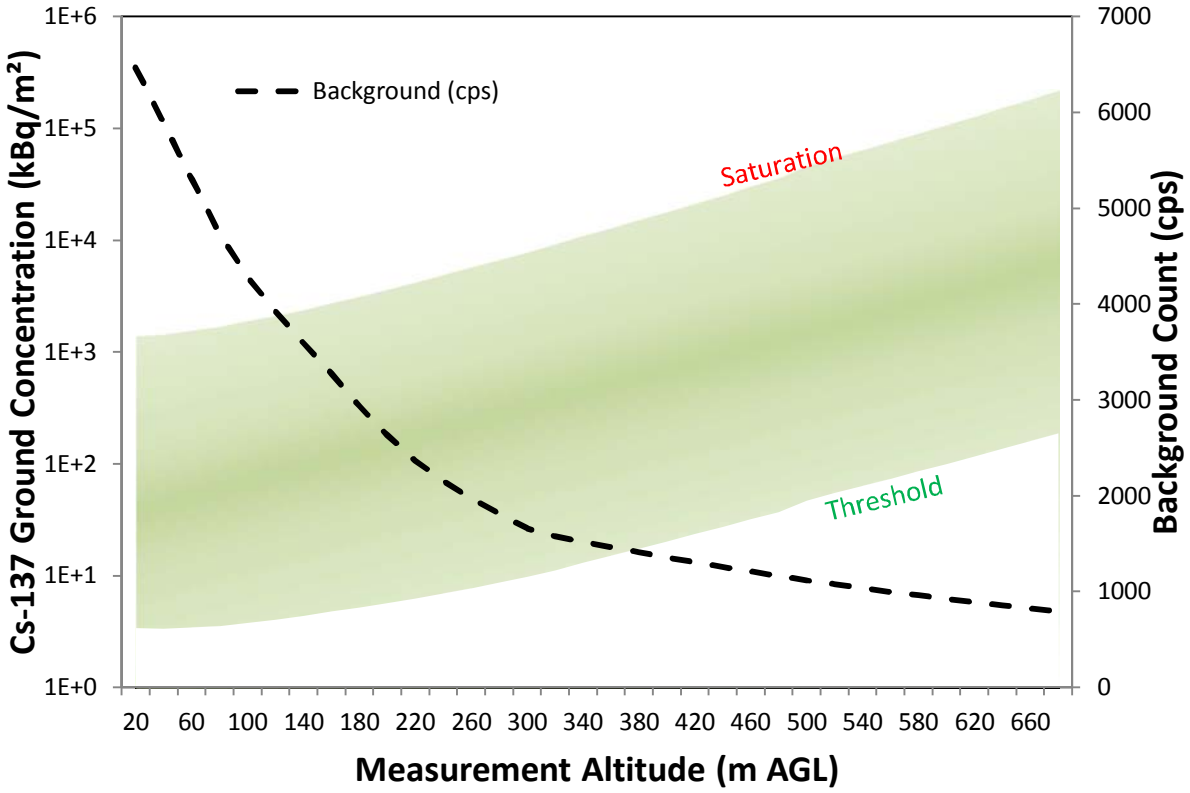

FIG. A-1. Example operational range for an aerial radiological system. The dashed line represents the count rate in the detector from the natural background radioactivity in the soil. Below the shaded band, the count rate in the detector from the ground contamination cannot be distinguished from the natural background. Above the shaded band, the count rate exceeds the range over which the system can reliably record the gamma rays. The shading of the band represents the fact that the threshold and saturation points are going to depend upon the system used, the way it is employed and the way in which the data is analysed.

A-1.5 Considerations on the use of unmanned aerial vehicles

There is interest in using unmanned aerial vehicles (UAVs) for conducting aerial radiation measurements. This interest is usually motivated by the expectation that the systems can be built at a low cost, and that they would be simple to operate. If the systems were available at an affordable price, it is expected that local emergency response organizations would acquire them, and it would be easier to quickly assess radiation hazards.

If affordability is the leading design parameter for a UAV based radiation measuring system, there will be limitations in performance.

— The limits on the cargo weight for the UAV will result in the use of a small radiation detector. A small radiation detector will lead to a decrease in the sensitivity of the system.
— The system will usually need to be operated within the line of sight of the control station. This will limit the size of the area that can be studied.
— Longer flight times may result in more stops for fuel, and more time needed to survey an area.

If these limitations were accepted, there could be operations within an emergency response where UAVs could prove useful. For example:

— A dose ratemeter on a UAV could be sent into an incident site to perform a quick assessment of the radiological conditions. The information gathered may help responders plan actions to mitigate the emergency.
— When operated in this manner, it is not so important to collect spectroscopic data for analysis and assessment.
— Unmanned helicopters have been used to conduct surveys of small sections of the area contaminated after the release of radioactive material from the Fukushima Daiichi nuclear power plant [A–5, A–6]. The systems used for those studies were designed and operated in a fashion similar to that described above, but they were employed over limited areas well after the emergency phase.

It is possible to use large unmanned aircraft to conduct operations with a system designed to the specifications provided in this publication. These aircraft are likely to have their own issues that will need to be considered, as appropriate. For example:

— These aircraft are not as readily available as manned aircraft.
— Operation of these aircraft often requires more supporting personnel than a manned aircraft.
— The sensor equipment must be shown to not interfere with the operation of the aircraft.
— The aircraft are usually limited to altitudes greater than 300 m above the ground. This is to avoid crashes that might result during brief gaps in communication between the pilot and aircraft.

A-1.6 Interoperability and compatibility

In a large scale emergency, it is possible that multiple teams will be used to conduct aerial radiation measurements. It is desirable that the aerial data from all the teams be combined to produce a unified map of the radiation environment. When a combined data map is produced, it is necessary that all the relevant parameters exist in the data so that it can be processed in a consistent manner. The data parameters are described in Sections A–1.2–A–1.4 on technical attributes presented above. If all the teams are using the same hardware for their data collection, it is relatively simple to share the raw data files. In situations where different systems are being used, the different teams need to supply detailed descriptions of their raw data formats, and/or all teams need to be prepared to convert their data to comma separated text files that include all the relevant elements. Alternatively, it could be agreed that each team processes its own data and delivers the defined data products included the desired measurements of dose rates, activity concentration or both.

In addition to sharing raw data, it is also necessary that quality assurance procedures are adhered to by all the teams that conduct the aerial measurements. The implementation of such procedures will help to ensure the quality of the data, and it will support the determination of many of the corrections that are applied in the data analysis. Below is a list of quality assurance procedures to be considered for each system:

— Collection of pre- and post-flight background spectra each day at a defined location at a team's own base of operations. The purpose of these measurements is to determine whether there has been a change to the system over the course of the flight. For this reason, the same location needs to be chosen for this measurement. Potential changes may be contamination of the aircraft or a change in response by one or more of the detectors.
— The collection of a pre-flight spectrum of a known source. This is performed to confirm that the spectrum is properly calibrated for energy and there are no unexpected features in the spectrum.
— Performing pre- and post-flight measurements over a test line. The test line is a simple linear feature that can easily be flown over at a consistent altitude before and after a flight. Sometimes, an adjacent runway will be used for this. The purpose is to assess whether there have been significant changes to the radon background that must be corrected over the course of the flight.
— Conduct of flights at multiple altitudes over a designated calibration line. A calibration line is a simple linear feature 3–5 km long within a flat and radiologically homogeneous area that can easily be flown, and can be accessed from the ground. Unpaved roads or fences are commonly used for calibration lines. The use of the same calibration line for all systems will reduce the likelihood of inconsistent results among systems. The data from the multiple altitudes needs to be collected daily if possible, and will be used to derive the attenuation coefficient (μ in Eq. (A–1) above).
— Performing flights at multiple altitudes over a body of water. A lake 3–5 km long, and sufficiently wide so that the shoreline will not significantly contribute to signal in the system, is recommended, because the concentration of radon in the air will be similar to the concentration over ground. The data from the multiple altitudes would ideally be collected whenever the calibration line is flown. The data will be used to determine the background (B in Equ. (A–1) above) from the aircraft and detection system, radon in the air and cosmic rays.
— Ground truth measurements need to be collected along the calibration line. The ground truth measurements ideally need to be reported in the same terms as those in which the analysed aerial data will be presented (gamma ray dose rate and deposited activity concentrations). The ground measurements may be collected by a group different from the aerial measurement teams. The conduct of ground measurements needs to occur close to the time of the aerial measurements.

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ABBREVIATIONS

AAP	Assistance Action Plan
AMS	aerial measuring system
EBS	external based support
EPR	emergency preparedness and response
FWHM	full width at half maximum
FAT	field assistance team
GPS	global positioning system
ICRP	International Commission on Radiological Protection
IRIX	International Radiological Information Exchange
IRMIS	International Radiation Monitoring Information System
ISO	International Organization for Standardization
LIC	location identification code
MGRS	Military Grid Reference System
MP	monitoring point
OIL	operational intervention level
RANET	IAEA Response and Assistance Network
RBE	relative biological effectiveness
RID	report identification
SID	sample identification
SS	system specification
TID	team identification
UAV	unmanned aerial vehicle
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
WGS	World Geodetic System
XML	Extensible Markup Language

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