Guidelines for Planning and Design

of

Mobile Radiological Units

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INTRODUCTION

A significant number of mobile radiological units are in operation worldwide aiming at to provide reliable radiological data. They mainly have been designed and constructed on a national basis according to the particular needs and commitments of the specific laboratory or country. In most cases, these units are intended to be used in emergency situations for in-situ radiological measurements of accidentally released radioactivity, sometimes for monitoring environmental pollution. As the purpose of these units is very diversified in regard to the kind of vehicle and its in-built measuring equipment the varying outfit of these units cannot be adopted in general for other countries aiming at to improve their capability for in-situ radiological measurement.

In order to achieve harmonizaton of equipment and comparability of radiological data being obtained from field measurements it is necessary to have general guidelines available for designing mobile radiological units taking into account different scenerios and tasks to be achieved.

PURPOSE

In the very early stages of an accident most of the information available on the quantity of radioactive material being released, its radionuclide composition and the likely progression of the accident will come from the operator, and will be based on the conditions in the plant. Few environmental monitoring results from off-side can be expected within the first few hours. In this very early phase, decisions on the application of protective measures will therefore, be based largely on plant status and forecasts of changes in that status as well as on meteorological data. As time progresses, results will increasingly become available from the monitoring of radionuclides in the environment (e.g. dose rates and concentration of radionuclides in air and particular materials such as water, food etc). Monitoring results can be used to estimate potential doses to people and the need for further protective measures can thus be determined from a comparison with intervention level of dose. Decision making in an emergency will however be more rapid and effective if the intervention levels of dose are expressed in terms of level of radionuclides presented in an appropriate environmental materials. The latter are termed "derived intervention levels (DILs)" and are the practical expression of the intervention level of dose. Contamination of an environmental material at the derived level is predicted to result an exposure at the intervention level of dose. The need for, and extend of, protective measures can be determined by direct comparison of the monitoring results with the derived levels.

GOAL

GENERAL GUIDELINES

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for designing a mobile radiological unit taking into account different scenarios and tasks.

OPTIONS FOR MOBILE RADIOLOGICAL UNITS

- Sattelite
- Space shuttle
- Helicopter
- Ship, boat
- Train, waggon
- Truck, car
- Robots
- Portable devices

MOBILE RADIOLOGICAL UNIT

WHY ?

IMMEDIATE RESPONSE IN AN EMERGENCY RESULTING IN DOSE LIMITATION TO THE PUBLIC

PROBLEM:

Exposures resulting from controlled radiation sources under normal operating conditions.

GUIDANCE TO DOSE LIMITATION:

1. International Commission on Radiological Protection (ICRP) Recommendations of the International Commission on Radiological Protection No. 26, 1977

2. International Atomic Energy Agency, Basic Safety Standards for Radiation Protection, Safety Series No. 9, IAEA, Vienna, 1982.

PROBLEM:

Source of exposure not under control and potential exposure will disrupt normal living:

Accident situations

GUIDANCE TO DOSE LIMITATION:

1. **International Atomic Energy Agency, Basic Safety Standards for Radiation Protection, Safety Series No. 81, IAEA, Vienna, 1986**

Accident Situations

INTERVENTION

Application of appropriate protective measures to restrict the exposure of individuals

INTERVENTION LEVELS OF DOSE

At which the introduction of appropriate measures for the protection of the public should be considered.

Decision making in an emergency will be more rapid and effective if the

INTERVENTION LEVEL OF DOSE

is expressed in terms of levels of radionuclides

present in appropriate environmental materials:

DERIVED INTERVENTION LEVELS (DILs)

contamination of an environmental material at the derived levels is predicted to result in exposure at the intervention level of dose.

GUIDANCE TO

DERIVED INTERVENTION LEVELS (DILs)

1. IAEA, Safety Series No. 9
2. IAEA, Safety Series No. 72
3. IAEA, Safety Series No. 81
4. ICRP No. 40
5. Codex Alimentarius

MONITORING

- NEED FOR

- EXTENT OF

protective measures can be determined by direct comparison of the monitoring result with the derived levels

Monitoring results can be used to estimate potential doses to people

ACCIDENT PHASES

EARLY a. before a release

b. majority of release occurs

INTERMEDIATE

LATE

ACCIDENT PHASES

EARLY	FIRST RELEASE TO FEW HOURS
INTERMEDIATE	FIRST FEW HOURS - SEVERAL DAYS
LATE	SOME WEEKS TO YEARS (DAYS)
	Concerned with return to normal living conditions

PATHWAYS OF EXPOSURE

EXTERNAL	from plume or facility deposition on ground or skin	
INTERNAL	**INHALATION**	
	in the plume or resuspended material	
	INGESTION	
	consumption of food and water	

TABLE I. EXPOSURE PATHWAYS, ACCIDENT PHASES AND PROTECTIVE MEASURES FOR WHICH INTERVENTION LEVELS MAY BE ESTABLISHED [3]

Potential exposure pathway	Accident phase	Protective measure
1. External radiation from facility	Early	Sheltering Evacuation Control of access
2. External radiation from plume	Early	Sheltering Evacuation Control of access
3. Inhalation of activity in plume	Early	Sheltering Administration of stable iodine Evacuation Control of access
4. Contamination of skin and clothes	Early Intermediate	Sheltering Evacuation Decontamination of persons
5. External radiation from ground deposition of activity	Early Intermediate Late	Evacuation Relocation Decontamination of land and property
6. Inhalation of resuspended activity	Intermediate Late	Relocation Decontamination of land and property
7. Ingestion of contaminated food and water	Intermediate Late	Food and water controls

Note: The use of stored animal feed to limit the uptake of radionuclides by domestic animals in the food-chain can be applicable in any of the phases.

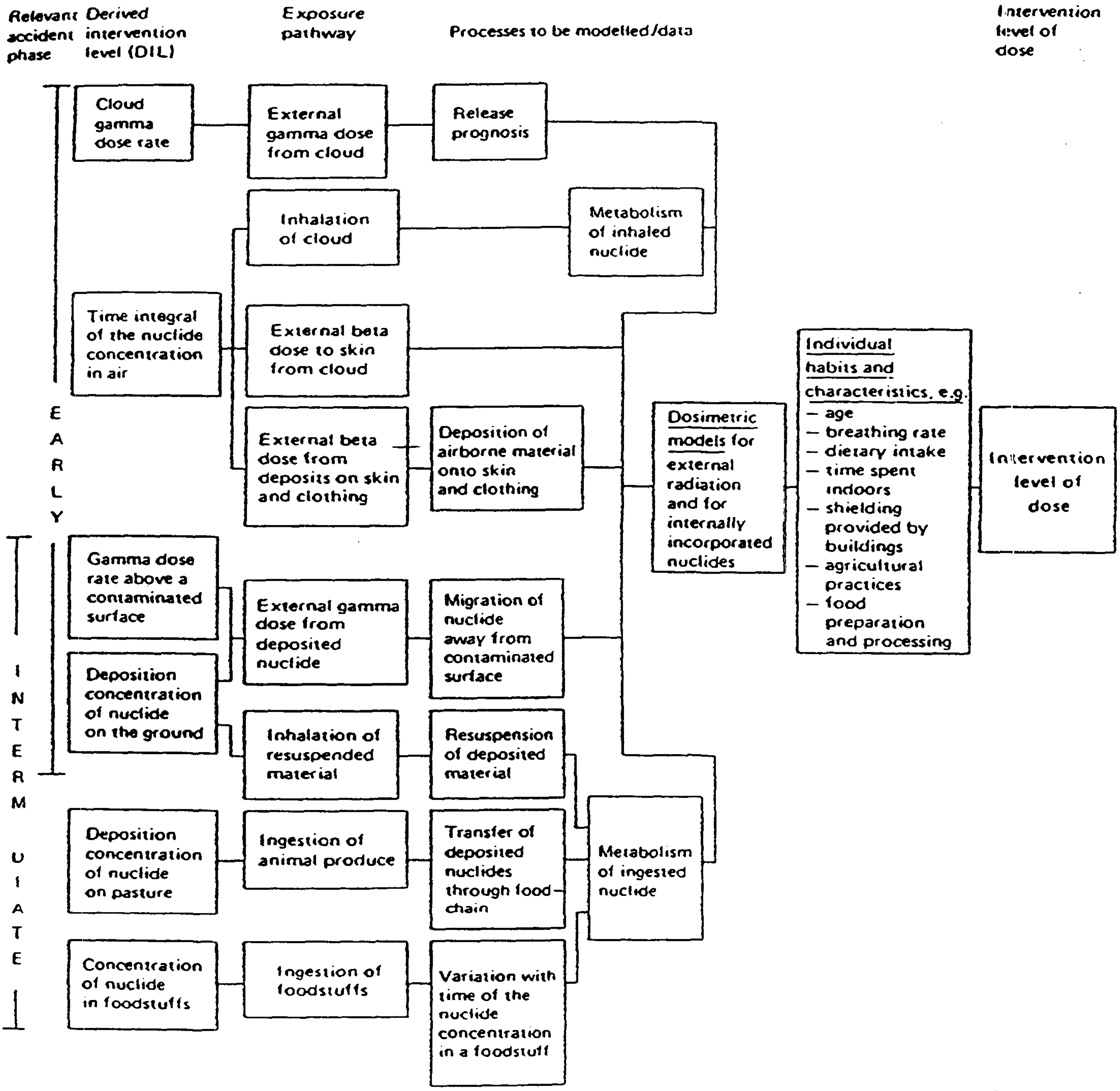

FIG. 1. Processes that need to be modelled in establishing derived intervention levels for single nuclides: DIL = IL/DCF, where DIL is the derived intervention level; IL is the intervention level of dose; and DCF is a dose conversion factor which relates the two quantities via the processes/models shown.

TABLE II. INTERVENTION LEVELS FOR PROTECTIVE MEASURES IN THE EARLY AND INTERMEDIATE PHASES OF AN ACCIDENT [3][a–e]

Early phase

Protective measure	Dose[a] (mSv or mGy)	
	Whole body[b]	Lung[c], thyroid and any single organ preferentially irradiated
Sheltering	5 - 50[d]	50 - 500
Administration of stable iodine		50 - 500[e]
Evacuation	50 - 500	500 - 5000

Intermediate phase

Protective measure	Dose equivalent committed in first year (mSv)	
	Whole body	Individual organs preferentially irradiated
Control of foodstuffs and water	5 - 50[d]	50 - 500
Relocation	50 - 500	Not expected

[a] Dose projected in the short term (see para.416).

[b] Where several organs or tissues are irradiated at low levels of dose the effective dose equivalent should also be calculated and compared with the whole body dose.

[c] In the event of high dose alpha irradiation of the lung, the numerical values apply to the product of the relative biological effectiveness (RBE) and the absorbed dose in milligrays. For planning purposes, an RBE of 10 is suggested.

[d] Or effective dose equivalent.

[e] Thyroid only.

Note: Special consideration should also be given to the implications of irradiation of pregnant women and other specially sensitive groups.

TABLE III. USEFUL QUANTITIES FOR DERIVED INTERVENTION LEVELS (DILs)

Derived quantity	Relevant exposure pathways	Relevant protective measure
External gamma dose rate ($Sv \cdot s^{-1}$)	External gamma irradiation from plume and from deposited material	Evacuation, sheltering, relocation
Time integral of radionuclide concentration in air ($Bq \cdot s \cdot m^{-3}$)	Inhalation of plume	Sheltering, evacuation, stable iodine
	External beta irradiation from plume	Sheltering, evacuation
	External beta irradiation from deposition on skin	Sheltering, evacuation
Ground deposits of radionuclides ($Bq \cdot m^{-2}$)	External beta and gamma irradiation from deposited material	Evacuation, relocation
	Inhalation of resuspended material	Evacuation, relocation
Concentration of radionuclides in foodstuffs, pasture or drinking water ($Bq \cdot kg^{-1}$)	Ingestion of foodstuffs or drinking water	Restrictions on production or consumption

COMPARTMENTS OF INTEREST

AIR

WATER

MILK

MEAT

OTHER FOODS

VEGETATION

SOIL

RADIONUCLIDES OF INTEREST

- FISSION PRODUCTS

- ACTIVATION PRODUCTS

- NATURAL RADIOACTIVITY

TABLE I. FISSION AND ACTIVATION PRODUCTS WHICH MAY BE OF CONCERN IN HUMAN EXPOSURE [4]

	Nuclide[a]	Half-life[b]	Fission yield %	Major decay
Fission products	Sr-89	50.5 d	4.77	β^-
	Sr-90*, Y-90	28.7 a, 64.1 h	5.76	β^-, β^-
	Zr-95, Nb-95	64.09 d, 35.0 d	6.51	$\beta^-\gamma$, $\beta^-\gamma$
	Mo-99*, Tc-99m*	2.747 d, 6.006 h	6.09	$\beta^-\gamma$, $\beta^-\gamma$
	Ru-103*, Rh-103m*	39.272 d, 56, 116 min	3.03	$\beta^-\gamma$, $\beta^-\gamma$
	Ru-106, Rh-106*	372.6 d, 29.92 s	0.4	β^-, $\beta^-\gamma$
	Te-129m	33.6 d	0.661	$\beta^-\gamma$
	I-131*	8.021 d	2.875	$\beta^-\gamma$
	Te-132*, I-132	76.856 h, 2.3 h	4.282	$\beta^-\gamma$, $\beta^-\gamma$
	Cs-137, Ba-137m	30.0 a, 2.55 min	6.136	β^-, γ
	Ba-140*, La-140*	12.751 d, 1.6779 d	6.134	$\beta^-\gamma$, $\beta^-\gamma$
	Ce-144*, Pr-144	284.45 d, 17.28 d	5.443	$\beta^-\gamma$, $\beta^-\gamma$

[a] An asterisk indicates that half-life has been revised according to Ref. [VII.2].

[b] Half-life is given in minutes (min), hours (h), days (d) and years (a). One year = 365.25 days.

TABLE I. FISSION AND ACTIVATION PRODUCTS WHICH MAY BE OF CONCERN IN HUMAN EXPOSURE [4]

Activation products	H-3*	12.35 a	β^-
	C-14	5730 a	β^-
	Fe-55*	2.75 a	EC
	Fe-59*	44.53 d	$\beta^-\gamma$
	Mn-54	312.5 d	EC, γ
	Co-60	5.27 a	$\beta^-\gamma$
	Zn-65*	243.9 d	EC, γ
	Cs-134*	754.2 d	$\beta^-\gamma$
	Np-239*	2.355 d	$\beta^-\gamma$
	Pu-241, Am-241*	14.35 a, 432.0 a	β^-, $\alpha\gamma$
	Cm-242*	162.94 d	α
	Pu-238*	87.7 a	α
	Pu-239*	2.411×10^4 a	α
	Pu-240*	6.563×10^3 a	α
	Pu-242*	3.735×10^5 a	α

[a] An asterisk indicates that half-life has been revised according to Ref. [VII.2].

[b] Half-life is given in minutes (min), hours (h), days (d) and years (a). One year = 365.25 days.

RADIONUCLIDES OF INTEREST

Focus on fission and activation products which contribute significantly to human exposure.

Taking into account different accident scenarios

Guidance: IAEA Technical Reports Series No. 295

ACCIDENT SCENARIOS

(Source: IAEA Technical Reports Series No. 295)

Uranium-fuelled reactor

- Meltdown with failed containment
- Meltdown with particle containment

Nuclear fuel reprocessing plant release

Plutonium fuel fabrication plant release

VI-2. POTENTIAL RADIONUCLIDE RELEASES

Other nuclear accidents which may result in major atmospheric emissions but which are not specifically discussed here include the following:

- Plutonium fuelled reactor meltdown
- Breeder reactor meltdown
- High flux radionuclide production reactor meltdown
- Fast flux reactor meltdown
- Nuclear powered ship/submarine reactor meltdown
- Satellite re-entry and burnup of satellite nuclear power source
- Nuclear weapon destruction by chemical explosion
- Criticality at nuclear materials processing plant
- Fusion reactor fuel loss.

Each of these possible accidents may release a unique spectrum of radionuclides and this should be considered in developing radioanalytical capabilities.

Nuclear weapon detonation would be a major source of fission products. Some of the possible scenarios for atmospheric release are:

- Venting from underground tests
- Venting from underwater nuclear tests
- Above ground nuclear testing
- Nuclear war.

RADIONUCLIDES OF INTEREST

Although several hundred radionuclides are produced by nuclear explosions or are present in irradiated reactor fuel, only a limited number contributes significantly to human exposure. Radionuclide produced in fission and activation processes which may contribute significantly to human exposure in the event of an accident are listed in Table...

In regard to internal exposure from ingestion of food and water and to the contamination of environmental materials, which are part of the immediate path ways leading to contamination of food, the most important radionuclides to be assessed following a release of radionuclides from a uranium fuelled reactor to the environment are: Cs-134, Cs-137, I-131 and other gamma emitters, the beta emitters Sr-89, Sr-90, and tritium, and the alpha emitters Pu-238, Pu-239+240, Am-241 and Cm-242.

Many other radionuclides would be present in debris from a nuclear accident, and their potential contribution to human exposure depends on the type of accident and the circumstances at the time of the accident. Since there are several types of fuel, the spectra of radionuclides that would be present accidental releases could be somewhat different.

RADIONUCLIDES OF SPECIFIC INTEREST

The most important radionuclides to be assessed following a release of radionuclides from a uranium-fuelled reactor to the environment are:

Gamma emitters:	Cs-134, Cs-137(Ba-137m), I-131, others
Beta emitters:	Sr-89, Sr-90, H-3
Alpha emitters:	Pu-238, Pu-239+240, Am-241, Cm-242

CONCLUSION

MEASURING CAPABILITY OF MOBILE RADIOLOGICAL UNIT

External gamma dose rate		$Sv \cdot s^{-1}$
Time intergral of radionuclide concentration in air	—	$Bq \cdot m^{-3}$
Ground deposit of radionuclides		$Bq \cdot m^{-2}$
Concentration of radionuclides in food, pasture or water		$Bq \cdot kg^{-1}$

Meteorological data: temperature, humidity, wind speed and direction etc.

GUIDELINES

should include recommendations on

- kind of truck / car and its design for:
  - emergency situations
  - routine radiological monitoring
- equipment for
  - sampling
  - sample preparation
  - measuring radioactivity
  - measuring meteorological data
  - data acquisition and evaluation
  - data transmission

(FIRST APPROACH)

SUGGESTIONS FOR DESIGNING A MOBILE RADIOLOGICAL UNIT

Taking into account the underlying basics mentioned above a Mobile Radiological Unit for monitoring of food and environmental samples should include:

Truck

- preferably air-cooled engine, all-wheel driven,

  suitable for operating independently and

  self-sustaining even in a hot climate

  (e.g. air-condition, special tyres, generator)

Mobile Unit to house:

Radiological laboratory, working and sample storage area

Design may include a movable laboratory container.

BASIC EQUIPMENT

- gamma dose rate devices
- gamma dose rate probe connected to a telesonde or mounted on a meteorological mast.
- pen dosimeters
- contamination monitor
- gamma dose rate instrument: sensitivity 10^{-7} - 10^{-2} Sv/h.
- digital rate meter with external power supply
- gamma proportional counter
- hand monitor for surface contamination monitoring
- air pollution sampler and filters (glass fibre)
  Flow rate: $80m^3/h$. including iodine sampling, charcoal cartridges to be used with the air sampler.

INDOOR EQUIPMENT

- measuring device for iodine cartridges comprising of digital rate meter, NaI detector (3"x3") and lead shielding coupled to a PC, printer and software for evaluation of gamma spectra.
- measuring device for air_filter total beta and gamma measurements.

- NaI bench-top gamma spectrometric system comprising of NaI detector (8% resolution), lead shielding to house Marinelli beakers and polyethylene bottles (0.5 or 1 liter), amplifier, high voltage devices etc. PC aided system with printer, plotter and software for spectra and data evaluation.

* Optional:

HP Ge detector; rel. efficiency >20%, minimum resolution: 1,9 keV

Additional Equipment

- provision of meteorological mast comprising of devices for measurement of :
  - temperature
  - atmospheric pressure
  - humidity
  - wind direction
  - wind speed
  - data transmission to indoor recording stations
- acoustical and optical alarm system for in- and outdoor radioactive contamination
- protective clothings and masks
- refrigerator
- homogenizer (kitchen blender)
- grinder
- balance

DATA

- recording station for meteorological data.
- recording station for radiological data.
- transmission station: telefax (wireless) or modem.