



NATIONAL DISASTER MANAGEMENT MANUAL ON MEDICAL MANAGEMENT OF NUCLEAR & RADIOLOGICAL EMERGENCIES



February 2019



NATIONAL DISASTER MANAGEMENT AUTHORITY
GOVERNMENT OF INDIA

**NATIONAL DISASTER
MANAGEMENT MANUAL**

on

MEDICAL MANAGEMENT

of

**NUCLEAR AND RADIOLOGICAL
EMERGENCIES**

Manual on Medical Management of
Nuclear and Radiological Emergencies

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National Disaster Management Authority
Government of India

PREFACE

There are a number of Nuclear and Radiological facilities operating in the country. These nuclear and radiological facilities are designed, built and operated with utmost care and safety. Possibilities of emergency situations arising out of operations of these facilities leading to radiation exposure to public are very remote but cannot be entirely ruled out. Similarly, members of the public may receive high radiation doses as a result of handling or being in the vicinity of lost, stolen or orphan radiation sources. Moreover, the general public and also emergency workers could be exposed to radiation or may get contaminated as a consequence of malicious acts involving radioactive material. Without adequate awareness, training and preparedness of the medical community for such radiation emergencies, medical management of the situation could be ineffective.

Radiological accidents and disasters can have a prolonged impact on public health. Hospitals should, therefore, be prepared to respond to radiation emergencies, as determined by risk assessment, based on local and regional radioactive hazards, threats and vulnerabilities. Approach to medical management of multiple combined radiation injury victims requires attention to casualty triage, decontamination and prevention of secondary contamination, radiation safety of healthcare personnel, trauma care system, availability of medical staff trained in the treatment of radiation-related injuries and also availability of pharmaco-therapeutic options.

This manual aims to serve as a practical resource guide for management of a nuclear or radiological emergency. It also explains the roles and responsibilities of the members of the emergency medical response organization which includes the Response Initiation Team, the Emergency Medical Personnel on scene and the Hospital Radiological Response Team (HRRT).

The confidence of the members of the public is of paramount importance while managing such emergency situations. It is needless to say that the medical fraternity has an edge over others in building this confidence. It is necessary that the members of the public affected or likely to be affected, by the radiological emergencies are made aware of not only the effects of the radiation, but also of the fact that the fear arising out of ignorance is far greater than that the effects of the radiation. This information may be given by the medics and paramedics of the state, on a regular basis, during their door-to-door visits for various governmental programs viz. immunization, family planning, hygiene drives etc.

Since the radiological emergencies due to 'orphan radioactive sources' leading to cases of inadvertent exposure to members of public is considered more likely and is a concern internationally, the preparedness by the medical community, though addressed for dealing with nuclear emergencies through this manual, will also help in handling such issues and in strengthening national level preparedness. Incidents similar to the Mayapuri, (New Delhi), in the year 2011 and many radiological incidents reported internationally, have led to severe radiation injuries and casualties to the public, due to lack of timely medical support. This document includes information on Acute Radiation Syndrome (ARS), and its medical management, internal decontamination, Radiation Burns, Bio-dosimetry etc. Some of these may not be feasible at the level of Primary Health Centre (PHC) or Community Health Centre (CHC) and may need specialised designated hospitals/facilities.



राष्ट्रीय आपदा प्रबंधन प्राधिकरण
National Disaster Management Authority
भारत सरकार
Government of India

Foreword

The National Disaster Management Authority has undertaken numerous initiatives for Disaster Risk Reduction and capacity building for disaster management in conformity with its mandate under the DM Act, 2005.

The manual on Medical Management of Nuclear and Radiological Emergencies can be seen as an effort to provide guidance for precise handling of patients related to mass or sentinel incident of acute or chronic illnesses resulting from radiation exposure, be it intentional or accidental. The manual which has been reviewed by several experts, will be a very handy compendium on this important aspect.

Though Nuclear and Radiological Emergencies have a low probability of occurrence, managing of such incidents require expertise and skills. This document is intended to boost the capacity building of the professionals specializing in the area.

The first draft of the manual was single handedly, prepared by Late Dr. Raghavendra Deolalikar, Certifying Surgeon, NAPS, NPCIL.

We take this opportunity to express our deep appreciation of the commitment to the team of experts from NDMA, DAE, BARC, AERB, DRDO and various stakeholders who extended their willing support and cooperation to our efforts and cause by devoting their professional approach and for their valuable contributions in developing and reviewing this document.

We are sanguine that this effort will go a long way in enhancing preparedness and Disaster Risk Reduction in the country for Nuclear and Radiological emergencies.

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DISCLAIMER

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As this is an educative material, the trade names of any medicines used in this document are for purpose of easy reference and do not, in any way, advocate or promote the use of the same brand of medicines.

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1

Introduction

Medical management of radiological emergencies involves the medical fraternity and the emergency response organization. Although the cause of emergencies arising from Radiation and Nuclear facilities may be different, the management of exposure cases may be similar. The most important consideration in the medical evaluation and preparedness for response of a radiation event is the relative magnitude of the situation i.e. quantum of exposure, number of persons involved and the resources needed to address the emergency. In a radiation emergency, victims may have been harmed by one or more of the following causes: external exposure (localized, partial and whole body), contamination (external/internal) and conventional trauma. The same general principles of medical care apply at the scene of the emergency as at hospital, but the details and extent of medical care differ.

Patients contaminated by radioactive material generally pose no danger to healthcare personnel, if adequate precautions are taken. However, contaminated excreta or vomit can spread contamination to equipment, environment and attending staff. Using appropriate procedures could, therefore, prevent spreading of contamination. Hence, medical professionals must be prepared to provide prompt treatment for conventional trauma complicated by exposure to ionizing radiation or radioactive contamination. Two principles are of paramount importance in the medical management of the contaminated patient: early estimation of the magnitude of the radiation exposure and identification of the radioisotope(s) in question. These principles strongly influence subsequent treatment decisions.

Following a Radiological Mass Casualty Incident (RMCI), a surge of patients is expected and hospitals will need to rapidly reorganize and systematically manage their resources for patients' care. Recognised documents on the subject describe a concept of surge capacity which is known as the "3 S System" — the 3 "S" standing for "Staff", "Stuff" and "Structure". By considering these key components when preparing for disaster, health care facilitators can respond better during such exigencies.

This manual is intended to act as operational guidance to doctors and other healthcare professionals for the proper medical management of persons affected or suspected to be exposed in a nuclear or radiological emergency.

2 Types of Events, Effects of Radiation and Types of Exposure

2.1 Types of events

The nuclear and radiation facilities operating in the country are designed, built and operated with utmost care and safety. Possibilities of emergency situations arising out of operations of these facilities involving high radiation exposure to public are very remote, but cannot be entirely ruled out. Similarly, members of the public may receive high radiation doses as a result of handling, or occupancy in the vicinity, of lost or stolen radiation sources. Moreover, the general public and also emergency workers could get exposed to radiation or be contaminated as a consequence of malicious acts involving radioactive material.

2.2 Health Effects of radiation

Radioactive materials and radiation generating equipment like accelerators and x-ray machines are widely used in industries, in medicine and in research. Radiation have wide spread applications such as in radiotherapy for cancer treatment, food and seed preservation, radiological studies, sterilization of medical disposables by gamma radiation, sewage treatment etc.

2.2.1 Radiation effects:

When human cells come into contact with ionizing radiation, sufficient to cause cellular damage, one of the following possible actions will occur.

- i Cell completely repairs itself
- ii If the cell is not severely damaged, it might be able to repair itself and continue functioning, but could lose its ability to divide. This is known as *reproductive (mitotic) cell death*.
- iii A damaged normal cell might mutate, which may cause stochastic effects like cancer or genetic effects.
- iv If the damage is too severe, the cell may die. The death of large no of cells of an organ/ tissue may lead to failure of the organ and is called deterministic effect.

2.2.2 Modifying Factors:

Numerous physical, chemical and biological factors influence the response to radiations. Packed ionizing radiations are generally more hazardous and have relatively higher biological effectiveness. Exposure rate is an important factor. Low dose rate exposure, protracted exposure and fractionated exposure produce far less damage as compared to acute exposure. Nature of irradiated tissue also determines the severity of effect. Age, gender, physiological status and immune status of the

individual also determine the extent and severity of radiation effects. Infants and children are more sensitive to effects of radiation, particularly due to the active process of division of cells and development of organs occurring in early childhood.

Radiation effects depend upon large no of factors and amount of dose of radiation. The details are discussed in ANNEX-1. The following table gives exposure ranges for different effects.

Table 1: Different Levels of Radiation Exposure and their Significance:

Exposure	Significance
1-2 mSv / year	Background Radiation at sea level outdoors
0.5 – 5 mSv	Most Diagnostic Radiological Examinations
1 mSv / year	Limit for Non-Occupational Exposure
20 mSv / year	Limit for Occupational Exposure - Whole Body
150 mSv / year	Exposure Limit for Eye Lens [Under Review]
500 mSv / year	Limit for exposure of skin and extremities
10 mGy (in utero)	2 childhood cancers in 10,000 pregnancies
100 mGy whole body	Detectable increase in chromosomal aberrations. No detectable clinical injury
100 – 200 mGy (in utero)	Malformations and 1 st trimester abortions
1 Gy acute whole body	Threshold for Radiation sickness in 5-10%
1 Gy Reproductive System	Doubling dose Temporary Sterility in Males
2-3 Gy acute whole body	Threshold for Epilation, Cataract [Under Review], Radiation sickness for most, Transient Erythema and Leukopenia Death 20-30%
3-5 Gy acute whole body	LD 50/60 untreated. Severe Leucopenia, Purpura, Hemorrhage, Epilation, Infection
6 Gy	Permanent Sterility both the genders, Fixed Erythema 50% Death with best Rx
> 10 Gy - Skin	Dry Desquamation
> 20 Gy - Skin	Wet Desquamation
40-60 Gy	Total Radiation dose used in Fractional Radiotherapy of Cancer

2.3 Types of Accidental Exposure

Types of radiation exposure which could occur during an emergency situation are discussed in the following sections.

- i External contamination
- ii Internal contamination
- iii Skin injury and radiation burns (Cutaneous radiation injury)
- iv Acute radiation syndrome (Whole body irradiation)
- v Combined injury (Concomitant conventional and radiation injury)

3

Organization and Structure with Roles and Responsibilities

3.1 Pre-Hospital Organogram:

It is imperative to have defined organizational levels (Organogram) for medical response in emergencies. There has to be one organizational level for tackling the pre-hospital response and another for managing the hospital response.

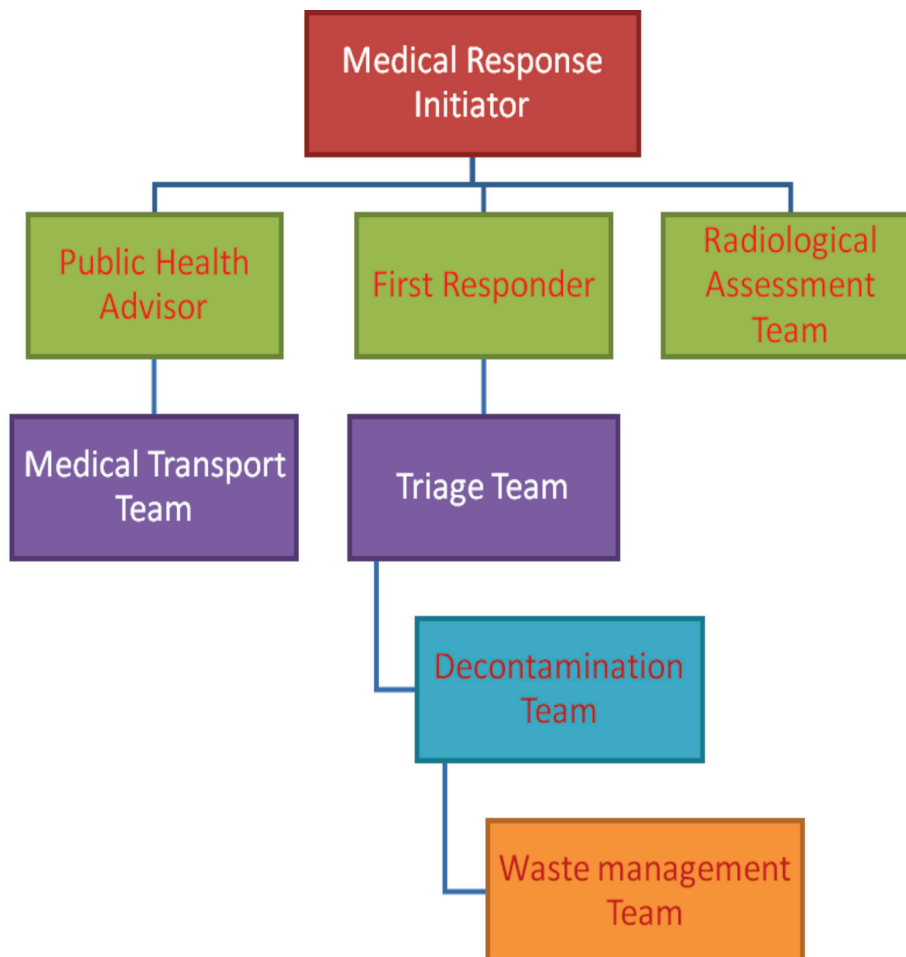


Fig. 1: Pre Hospital Organogram

- i **Medical Response Initiator:** As the name suggests, is the person who initiates the emergency response after notification of a real or suspected radiation emergency. In case of off-site emergency arising from a Nuclear Power Plant [NPP], it will be the District Chief Medical Officer [CMO] on orders from the District Magistrate /

District Collector who is the Responsible Officer / Incident Commander. In case of emergency arising from other than NPP as in the case of detonations or orphan sources, the Doctor will notify the Chief Medical Officer (CMO) of the District. The CMO will get the cases confirmed and inform the District Magistrate [DM] / District Collector [DC]. The DM/DC will get the source traced and initiate the emergency response in concerned areas.

- ii **First Responder:** First Responder(s) are the people who will proceed to the field under instructions from the Response Initiator. They will be responsible for informing the people about the dos and don'ts, the precautions and the distribution of Tab Potassium Iodide, if required.
- iii **Public Health Advisor:** S/he will be the person who will instruct the people about sanitation, food and grain handling, proper storage, proper care of water resources and its storage etc. S/he will in association with the first responders, arrange to facilitate the evacuation of the people to Resting Shelters.
- iv **Radiological Assessment Team:** Will carry out the external radiological assessment with the help of dosimeters and quick frisking. Internal dose assessment will be carried out by portable Whole Body Counter [vehicle mounted].
- v **Triage Team:** Triage team will comprise of trained para-medics and with the help of the Radiological Assessment Team they will categorize the patients based on urgency of treatment and level of care required. Depending upon these factors, they will shift the patient either to the Decontamination Centre in a Primary Health Center [PHC] / Community Health Center [CHC] or to a District Hospital [DH] or directly to a tertiary care hospital.
- vi **Medical Transport Team:** This team will be responsible for transport of patients to shelters, PHC/CHC or to District Hospitals or to tertiary care hospitals on the advice from the Triage Team and under instructions from the Public health advisor.
- vii **Decontamination Team:** This will comprise of Doctors who are trained in decontamination. They will carry out the external or internal decontamination of the people. This team will again decide in association with the Radiological Assessment Team whether the patient, after decontamination, needs to be sent to a specialized center.
- viii **Waste Management Team:** Will be responsible for proper collection of solid waste, liquid wastes, proper labeling of bags / bins / tanks etc. and proper disposal, as per national regulatory requirements.

3.2 Hospital Organogram:

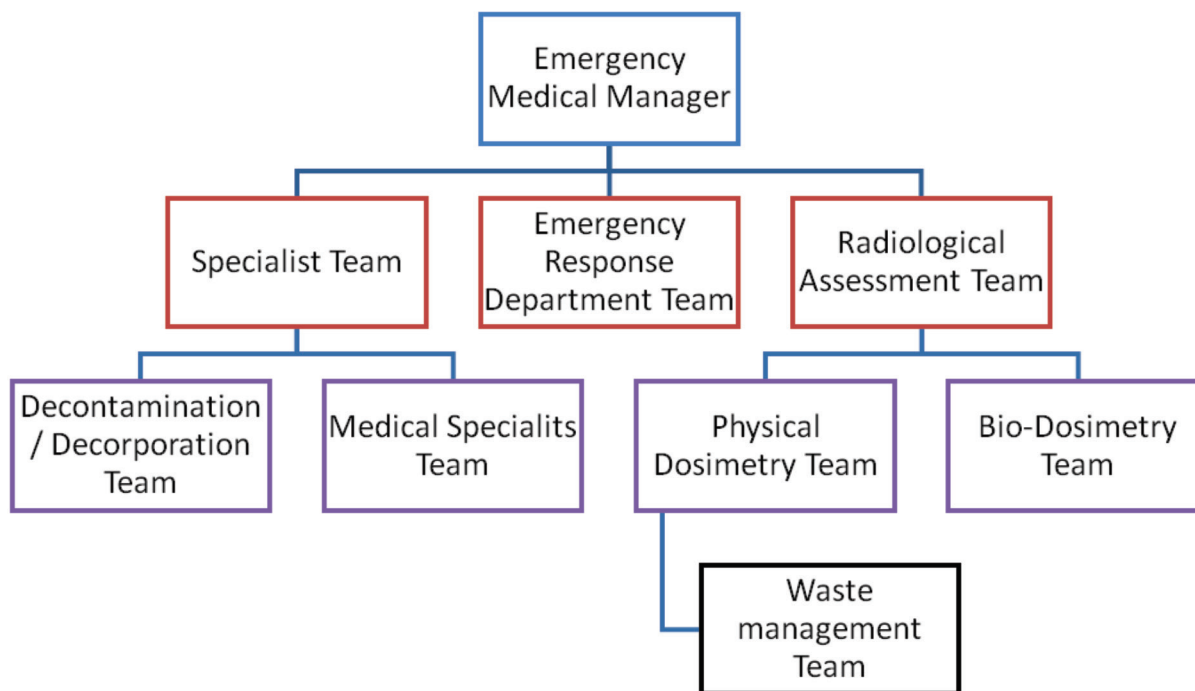


Fig. 2: Hospital Organogram

- i **Emergency Medical Manager:** At the hospital level, the Emergency Medical Manager is In-Charge of the concerned medical facility. S/he could be the Medical Officer in-charge of PHC / CHC, or the Medical Superintendent of the District Hospital or the tertiary care hospital. Upon instruction from the Chief Medical Officer of the district, the Emergency Medical Manager of the concerned facility will prepare the health center / hospital in complete readiness, for managing the patient. He/ She will ensure that all the teams under him/her will set the ball rolling.
- ii **Emergency Response Department Team:** This is normally the Casualty Team, the Blood Bank and the Operation Theatre Teams. These Teams will be responsible for taking care and managing cases where medical emergencies override radiological emergencies. This team, upon receiving instructions from the Emergency Medical Manager, shall keep all the paraphernalia in the Casualty, Blood Bank and Operation Theatre in a complete state of readiness.
- iii **Specialist Team:** This will comprise of doctors and para-medics. This team will have two components – (a) Decontamination / Decorporation Team which will be responsible for the decontamination and decorporation of radionuclides, both external and internal; and (b) Specialist team which will comprise of doctors from other specialties viz. Surgeon, Physician, Anesthetist, Ophthalmologist, Gynecologist, Pediatrician etc. for managing the co-morbid conditions of respective faculties. They will be assisted by the para-medics.

- iv **Radiological Assessment Team:** This team will comprise of people trained in monitoring the doses among suspected exposure cases. They will help the doctors in deciding the radiological assessment of reduction of contamination levels during the decontamination process. This team will have two components – (a) Physical dosimetry team, which will monitor the dose rate with the help of the monitors and estimate likely exposure; and (b) Bio-Dosimetry team which will collect the biological samples of the patients viz. Urine, Feces, Swabs from orifices, hair and nail samples, Blood sample etc., label them properly and send them to concerned bio-assay laboratories. Every District should have at least one such lab which will have facilities for bio-assay. This team will be responsible for proper dispatch of samples and receipt of reports. On receiving the reports, this team will intimate and hand over the reports to the Decontamination Team.
- v **Waste Management Team:** Will be responsible of proper collection of solid and liquid wastes and its proper labeling and disposal, as per the national regulatory requirements.

4

Resources and Infrastructure

4.1 Personnel Monitoring Devices and Protective Clothing:

Personnel monitoring devices are of various types, but the most useful in field purposes would be the Thermo-Luminescence Dosimeter [TLD]. This has to be encased in a plastic apron. Details of its usage are elaborated in Section-5

Protective clothing have also been detailed layer wise in Section-5.

4.2 Decontamination Facilities:

The decontamination (Brief description is given in Annex-2) of the affected people needs to be done at the level of the nearest PHC / CHC / District Hospital. Referrals, only for decontamination, to other places are to be avoided for two reasons:

- 4.2.1 The earlier the decontamination is done the better it is for the individual and hence the nearest facility should be capable of doing this, and
- 4.2.2 Sending the contaminated individuals elsewhere means spreading the contamination to newer areas instead of containing it.

For developing capabilities to effect successful decontamination, the medical centers should be equipped with the following:

- i **Infrastructure capable of catering to a volume of patients:** Space and infrastructure needed here, will mainly be bathing facility, decontamination tables in a large hall and another hall for waiting-in patients. Care should be taken that the outlet drain of these bathrooms should be connected to make-shift collection tanks like PVC tanks which can be transported to a suitable radioactive waste collection facility of the state government approved by the AERB.
- ii **Necessary Decontamination Consumables:** Paraphernalia needs to be adequate to meet the demand. Stock all paraphernalia in wooden/ metal boxes; store them in a room safely under lock and key, at these hospitals. This paraphernalia are herein referred to as “Decontamination Kits – External decontamination and internal decontamination kits”. (See Annex-3)

The Facility needs to be under the charge of the Medical Officer in Charge of that PHC/CHC/Hospital. This will ensure proper upkeep and accountability.

- iii **Trained manpower:** All the doctors and para-medics should be trained to manage medical aspects of radiological / nuclear emergencies. There should

be refresher training for all the staff every three years. Mock-patients should be handled during off-site emergency exercises. There should be a Physician and a Surgeon posted at all PHCs / CHCs. In addition, One Hematologist at District Hospitals and Civil Hospitals (available on call from tertiary care centers as needed) and mandatory in Medical colleges.

iv Investigation Facilities:

- a All PHCs/ CHCs should have laboratory facility for complete blood count including platelet count, complete biochemistry investigations, blood grouping, Rh typing, urine and stool examination for routine and microscopic, urine-test for pregnancy and semen analysis.
- b All District and Civil Hospitals should have the following facilities over and above available at the PHC/CHC: Blood Bank facility with component facility, burns ward, I.C.U. with ventilators, monitors and ABG analysis.
- c There should be bone marrow transplant facility with proper Isolation wards one each in 5 regions of the country i.e north, south, east, west and central region.
- d Every district/ a cluster of districts should have an accredited laboratory for bio-dosimetry and bio-assay which can reverse assess the blood / urine / stool.
- e Every district / a cluster of districts should have a BARC Accredited TLD reading laboratory
- f Every district or a cluster of districts should develop a radiological waste disposal facility for solid and liquid wastes, as per national regulatory requirements.

4.3 Identification Labels:

While decontamination is under process, the samples collected need to be correctly labeled in order to attribute the correct dose received by an individual after the dosimetry is done.

4.3.1 Individual Patient’s Waste collecting bag Label:

Name:	Age:	Sex:
Resident of:	Relief Camp No:	Patient No:
Type of Waste: (Please specify Linen, gauge, etc.)		
Quantity:	Date and Time of Collection:	
Whether suspected Radioactive	Yes/No	
Name and Signature of Paramedic PHC/CHC:	Bag No:	

4.3.2 Individual Patient's **Bio-Assay sample Collection Label:**

Name:	Age:	Sex:
Resident of:	Relief Camp No:	Patient No:
Date and Time of Event:		
Type of Specimen: (Please specify Blood, Stool, Urine, Swabs, etc.)		
Quantity:	Date of Collection:	Time of Collection:
Name and Signature of Paramedic on Duty:		
Sample No:		

4.4 Solid and Liquid Wastes:

Decontamination requires a lot of water and other chemical solutions along with consumables. Liquid waste generated as a result of decontamination need to be collected in waste tank and its proper disposal is equally important. As mentioned earlier, the outlet of the bathrooms used for bathing should be connected temporarily to PVC tanks of sufficient capacity. Also all liquids - water or chemical solutions – used during the process of decontamination should be discharged / drained into these tanks. These tanks will contain all the liquid wastes. Similarly, Solid wastes generated during the decontamination including the contaminated clothing of individuals should be collected in large **yellow colored plastic bags** as it is the standard accepted color to denote radioactive demarcation. They should be sealed. The waste tank and plastic bags should be labeled, as given below, on filling and the same shall be collected by the designated district authorities for proper and safe disposal / delivery to the nearest Radioactive waste management facility.

4.4.1 Label for waste collecting tank/bag following decontamination:

CHC* / Place of collection / MM / YYYY / RDD# / SW‡ / SI. Number

* Community Health Centre [Alternating – PHC for Primary Health Centre, DH for District Hospital, MC for Medical College]

Radiological Dispersal Device [Alternating – NPP for Emergency arising from Nuclear Power Plant or OS for Orphan Source]

‡ Solid Waste [alternating LW for Liquid waste]

Necessary instructions vide below should be printed on opposite surfaces in Hindi / Regional Language

- i Radio-active waste
- ii Do not break the seal
- iii To be handled only by Authorized Staff

iv Public should maintain safe distance.

The movement of all the waste collecting bags / tanks should be properly logged. There should be signed worksheet that should accompany the bag/tank and should serially move along with the bag/tank until proper disposal. (Please see Work Sheet 4 [WS.4] for details). The waste facility should report back to MO I/c Health Centre. All districts should develop such a waste decontamination / disposal facility.

5

Medical Management Principle and Plan

5.1 General Principles and Protective Clothing

Table 2: General Principles and Protective Clothing

i	Life saving measures will take precedence and preference over decontamination procedures.
ii	Principles of Triage should be followed
iii	Stabilize the patients' vital parameters first
iv	Treat any acute exacerbations / exaggerations of any chronic illness and their complications which you feel need attention on priority basis
v	Treat Injuries
vi	External Decontamination procedures to be carried out
vii	Internal Decontamination procedures to be carried out. This will take precedence over external decontamination if contamination is suspected with Iodine or confirmed for any other radionuclide.
viii	Any medical/paramedical personnel who are going to handle the patients should wear protective clothing.
ix	Remove all ornaments, wrist watches or any other artifacts from the upper limbs, elbow downwards and from the foot
x	Remove footwear and keep them aside, wear the canvas shoes / slippers provided in the PHC/CHC. This is in your interest. If your own shoes get contaminated, you may have to part with them
xi	Wear shoe covers.
xii	Wear a cap to cover your head completely
xiii	Wear a face mask
xiv	Wear a plastic apron over it
xv	Wear a surgical gown over it
xvi	Wear surgical / latex gloves / polypropylene. Pull the cuffs of the gloves up in order to tuck into the sleeves of the gown
xvii	Pin the Thermo-Luminescence Dosimeter [TLD] on your chest, inside the plastic apron
xviii	Please enter your name and TLD number in the TLD Register along with other details as specified in Worksheet [W.S. 1]
xix	If the decontamination process continues for another day, the same TLD is to be used. This will maintain the continuity of monitoring.
xx	If on the next day a new member joins the team s/he should use a new TLD
xxi	Once all the decontamination procedures are over and the activities are termed as "Closed" the TLDs should be sent to the TLD reading laboratories which are BARC accredited.

xxii	Designated TLD reading laboratory will determine the dose levels of each individual TLD and record the same assigned to the respective individual. The lab I/c will fill in Worksheet 2 [WS 2] and send it back to the original health centre. A copy of this shall also be sent to O/o CMO of the district.
xxiii	CMO will maintain the data base of such records and will also forward a copy of the same to the D.M. of the District.

5.2 Radiation Emergency – Types of Casualties

A Doctor working with the health care unit during a nuclear / radiological emergency would be dealing with the following types of contaminations among Adults, Senior Citizens or Children

- i only External Contamination
- ii without External Contamination but with only Internal Contamination – likely to occur only by route of inhalation or Ingestion or cuts/ wounds by shrapnel with contamination
- iii Both External Contamination and Internal Contamination
- iv Open Wounds [Injuries] with or without contamination
- v Co-Morbid Conditions with or without Contamination
- vi Only Exposure and no contamination whatsoever.

All the patients would be referred to the doctors only by the RSO or by the radiation monitoring staff after confirmation. As a doctor, one would have to prioritize the treatment plan for a large number of patients following a specified plan.

5.2.1 Triage: Triage should be conducted based on traditional Medical and Surgical considerations. Generally, radiation dose is not immediately life threatening, hence co-morbid medical/surgical conditions requiring priority attention should be addressed first.

Injuries will amplify the effects of radiation due to concomitant damage. For externally irradiated patients without trauma, patients receiving a high dose can be differentiated from those with a dose < 1Gy using two criteria – (a) Neutrophil / Lymphocyte [N/L] ratio; and (b) Whether Emesis has occurred. A Triage Score “T” is assigned as follows

$$T = N / L + E,$$

where E = 0 if no emesis, E=2 if emesis.

In a normal healthy human population, N/L ratio from a Complete Blood Count [CBC] with differential has been found to be approximately 2.1. For time > 4h post event, T is significantly elevated for doses > 1Gy.

5.2.2 Case Priority

- i **Medical Triage Overriding – no matter what the T score is**
 - a Priority One: Any Medical / Surgical Life Threatening Condition
 - b Priority Two: Any Medical/ Surgical instability.
- ii **Radiological Triage Overriding – Higher the T value, more the priority. Following priorities assuming T is same.**
 - a Priority Three class A: Patient Stable with only Exposure, no contamination – treatment on the lines of Acute Radiation Syndrome – send immediately to higher centers if dose estimation is more than 1 Gy
 - b Priority Three class B: Patient Stable but with Internal Contamination
 - c Priority Four: Patient Stable with External Contamination with Open wounds. All wounds are to be considered contaminated unless proven otherwise.
 - d Priority Five: Patient Stable with only External Contamination and without any wounds. Here decontamination of natural orifices should be done first.
- iii **Bio-dosimetry helps in monitoring and categorizing these cases efficiently.**
 - a Baseline CBC with Differential count. Repeat every 6 hours for first 48 hours - Lymphocyte depletion is dose-dependent, whereas N/L ratio increases over the first few days.
 - b Time to Emesis [TE] is another good clinical dose estimator for whole body doses. At doses 3Gy and more TE is less than 2 hours, whereas for 4-6 Gy it is less than 1 hour.
 - c Serum amylase baseline reading every 24 hours. Dose-dependent increase in amylase is expected after 24 hours.
- iv **Investigations which can add value at district centres/cluster of centres are –**
 - a Blood FLT-3 ligand levels – Markers for Hematopoietic damage
 - b Blood Citrulline: Decreasing citrulline indicates GI damage
 - c Cytogenetic studies with over-dispersion index to evaluate for partial body exposure
 - d Interleukin-6 [IL-6]: Marker increased at higher radiation dose
 - e Quantitative G-CSF: Marker increased at higher radiation dose
 - f C-reactive protein [CRP]: Increases with dose, capable of discriminating patients for cases between minimally and heavily exposed.

5.3 Treatment Plan Flow Chart

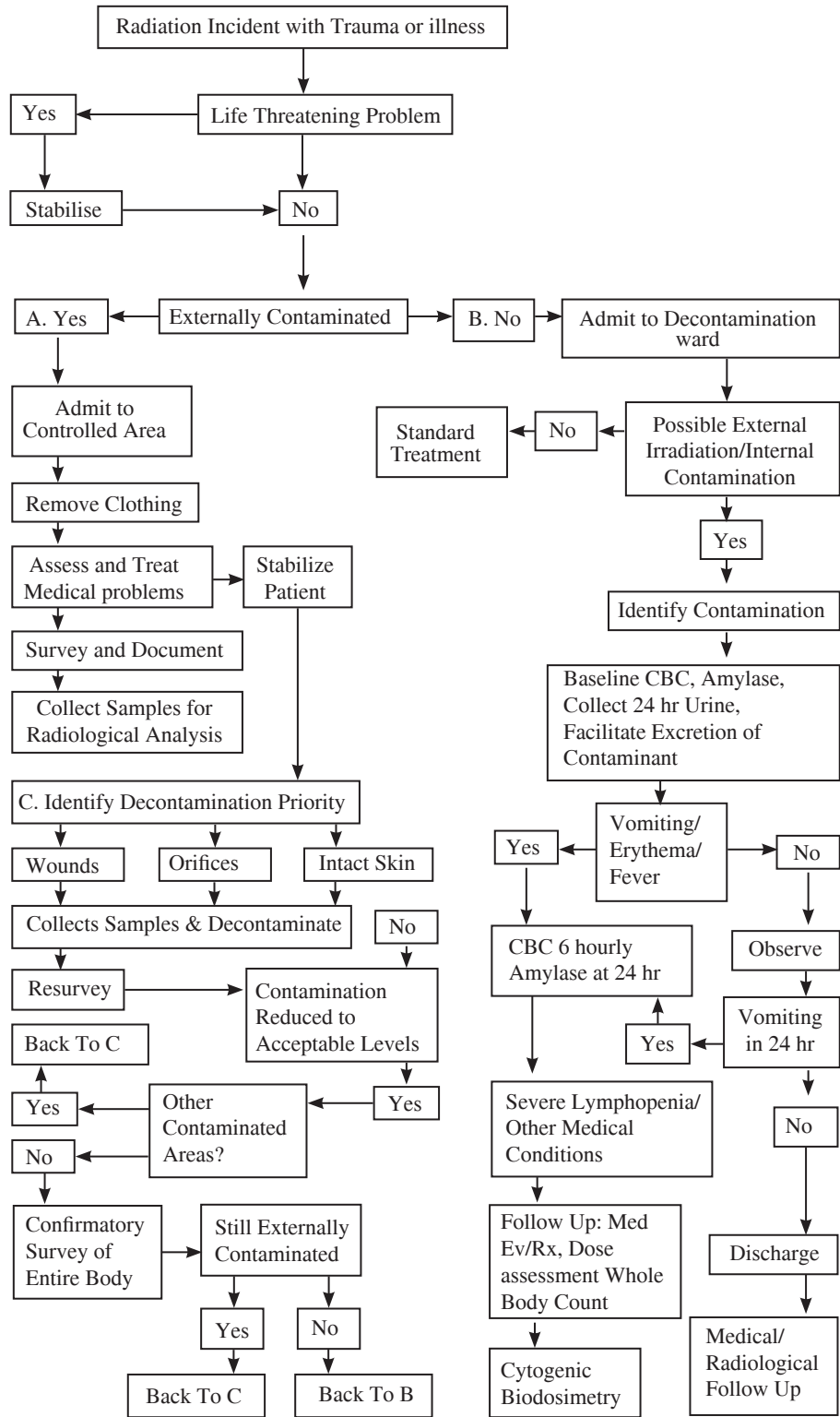


Fig. 3: Treatment Plan Flow Chart

Table 3: Whole Body Irradiation from Acute Photon Equivalent Doses

Phases of Syndrome	Survivability:		High Survivable		Survivable to Lethal		Lethal	
	Degree of ARS:		Mild	Moderate to Severe	Very Severe	Lethal		
	Dose Range [centi Gy]*		0-100	100-200	200-600	600-800	800-3000	>3000
Initial or Prodromal	Vomiting:		5-50% of Total Cases Exposed	50-100% of Total Cases Exposed	75-100% of Total Cases Exposed	98-100% of Total Cases Exposed	100% of Total Cases Exposed	
	Time of Onset:		3-6 Hours	1-6 Hrs	< 2 Hrs	< 1 Hr	< 1 Hr	
	Duration:		< 24 Hrs	< 24 Hrs	< 48 Hrs	< 48 Hrs	< 48 Hrs	
	Lymphocyte Count [cells/mm ³]:		< 1400 at Day 4	< 1400 at 48 Hrs	< 1000 at 24 Hrs	< 800 at 24 Hrs		
	CNS Function:	No Impairment	No Impairment	Routine Task Performance. Cognitive Impairment for 6-20 Hrs	Simple and Routine Task Performance. Cognitive Impairment for > 24 Hrs	Transient Incapacitation		
Latent	Duration:	N/A	7-15 days	0-21 days	0-2 days	0-2 days		
Manifest (Obvious) Illness	Signs and Symptoms:	None	Moderate Leukopenia	Severe leucopenia, purpura, haemorrhage, pneumonia, Hair Loss after 300Rads [cGy]		Severe Diarrhoea, Fever, Electrolyte Imbalance	Convulsions, Ataxia, Tremor, Lethargy	
	Time of Onset:		>2 weeks	2 days - 2 weeks		0-2 days		
	Critical Period:		None	4-6 weeks		5-14 days	1-48 Hrs	
	Principal Organ System:	None	Haemotopoetic	Haemopoetic and Gastro-intestinal		Gastro-Intestinal - Mucosal Surface	CNS	
Hospitalisation:	%, Duration:	0	< 5% 45-60days	90% 60-90days	100% 90 + days	100% 2 weeks	100% 2 days	
Fatality:		0%	0%	0-80%	80-100%	98-100%		
Time of Death:				3 - 12 weeks		1-2 weeks	1-2 days	
Adapted from TM 8-125 Nuclear Handbook for Medical Service Personnel, US Army, 1969. Tabulated data for Fatality incidence assumes No Treatment.								

6

External Decontamination

6.1. Generally, removing the suspected contaminated clothing and a proper bath gives as much as 90% successful external decontamination. Only patients with persistent contamination or stubborn contamination will normally be sent to the treatment area of PHC / CHC etc.

6.2 Decontamination procedure – both external and internal, will be done only after confirmation of respective contamination, the area/ body part affected, and the radionuclide involved by the radiation safety expert staff monitoring the contamination.

6.3 The Objective:

The objective of decontamination is to remove as much of radionuclide as practicable in order to –

- a Reduce the surface dose
- b Prevent activity from entering the body
- c Prevent spread of contamination to others/ area

6.4 Getting Started:

6.4.1 If the make shift decontamination facility has Fans or Blowers then please turn them off. They will spread the contamination from the surface of the patient to the surrounding.

6.4.2 To start with, take the patient into the bathroom of the decontamination area.

6.4.3 Normally all ornaments like rings, chains, wrist-bands or wrist-watches are to be removed at relief camps. However, if they are still on the body, ask him/her to remove them. Give him/her a polythene pouch to keep them. Ask the monitoring staff to monitor the same. If they carry contamination on them, inform the patient about it while handing them over, so that he can co-ordinate with the authorities for proper decontamination/ disposal.

6.4.4 Remove his contaminated clothes that he has come in.

6.4.5 Collect these clothes in a yellow collection bag, seal the bag after collecting all the clothes, tag it well and label it with date and time. Note: this bag will be sent either for proper decontamination and laundering, or for disposal. Label it as “Contaminated Linen”

6.4.6 Cover the open wounds with water proof dressing while bathing.

- 6.4.7 If the patient desires to pass urine, give the individual a 2.5 or 3.0 liter plastic container with a proper lid. Ask him to collect 24 hours urine, thereafter, in the same container. This may be needed for Bio-assay. Secure the lid properly and label it before handing over to concerned authorities.
- 6.4.8 Similarly, give the individual a large mouthed plastic container that fits into the aluminum container of the bed-side commode. This is to collect the stool sample. Seal the lid properly and label it. This also may be needed for bio-assay. Hand over the container to concerned authorities.
- 6.4.9 If the monitoring staff finds high contamination levels entrapped in the hair, then shave the concerned area with razor. Use Shaving foam / gel to minimize the trauma to the skin. Shaving may be done by the concerned individual on accessible areas, or he may be assisted in doing it. *N.B: Care should be taken while shaving to prevent any cuts or injuries, which may convert the external contamination to internal contamination.*
- 6.4.10 Collect the shaved hair in small polythene bag. Label the bag properly. This may be required by monitoring staff for purpose of dosimetry. If not, then they may be discarded in solid waste collection bags.
- 6.4.11 Discard the razor and the blade in the solid waste collection bag. Note that shaving for each patient should be done with a separate razor and the blade.
- 6.4.12 Give the patient a thorough bath in the bathroom / or designated make-shift bath area. Patient is to be provided with a soap and a soft brush or a loofah.
- 6.4.13 After the thorough bath, give a towel for drying.
- 6.4.14 After proper drying, give a set of new boiler suit / to wear.
- 6.4.15 Keep the brush and the loofah separately, in a small polythene pouch. These should also be sent for disposal as solid waste.
- 6.4.16 If there is evidence of contamination entering through the body orifices, take the swabs from the respective orifices. Use sterile swab sticks for this. Collect these swabs in sterile test tubes. Collect them in separate test tubes if multiple orifices are involved. Label each test tube (for labels see section 4.3). These test tubes may be collected by the dosimetry monitoring staff if required for dosimetry. If monitoring staff does not need them, they can be discarded in solid waste collection bags.
- 6.4.17 Similarly take a swab from open wounds and follow the same procedure as detailed in the preceding paragraph.
- 6.4.18 Position the patient either on a stool, chair, stretcher or examination table as per body areas requiring decontamination. Decontamination is a repetitive procedure

and hence it is essential that both – the patient and the doctor – should be in a comfortable posture to avoid fatigue.

6.5 The Procedure

- 6.5.1 Identify the areas of contamination – called as Hot Spots - and mark them out. This demarcation will help you to carry out the procedure within the specified area and thus prevent the spread of contamination while attempting decontamination. Radioactive substances are usually trapped in a thin film of oil which covers the skin. Decontamination procedure is therefore aimed on removal of this film first.
- 6.5.2 Simplest measures which are less harmful to the skin should be used first.
- 6.5.3 Decontamination should be done from periphery to the center. Remember this is just the opposite of Surgical scrubbing which is carried out from the center to the periphery.
- 6.5.4 **Areas with abrasions or wounds will take priority over other areas. This is because the absorption of radionuclide is faster from an open wound than the intact skin. All wounds should be considered as “Contaminated” unless proven otherwise.**
- 6.5.5 Decontamination of orifices and peri-orifices should then be done with paper napkin i.e. dry wiping, to be followed by wet wiping.
- 6.5.6 Coming to decontamination of Hot Spots, wash with soap and water. Do it for 3-5 minutes. The area is then dried and monitored. Continue doing the same in spells of 3-5 min each until there is no further appreciable drop in successive reading
- 6.5.7 Next, clean with 1% cetrimide solution in the same manner. For the hair, 4 % cetrimide shampoo can be used.
- 6.5.8 Next use 5 % sodium hypochlorite solution (household bleach) for resistant contamination. For the face, the same solution should be used in 1:5 dilution (with water?). Remember this is further dilution of the 5 % solution.
- 6.5.9 If contamination still persists, use saturated solution of Potassium permanganate (KMnO_4). This is an oxidizing agent and removes the horny layer of the skin. The solution is left to stand for a few minutes and then washed with water.
- 6.5.10 Skin pigmentation or stains of KMnO_4 if any, are treated with 10% solution of Sodium bi-sulphite. Care should be taken that this solution is not allowed to remain in contact for more than 2 minutes. **This however should not be used on face and perineal region.**
- 6.5.11 These procedures should be continued, till they fail to yield substantial reduction in levels of contamination.

6.6 Specific External Decontaminants

- 6.6.1 If radioactive contamination is with rare earths, e.g., plutonium and transplutonics, use 1% DTPA solution for cleaning the area. Aqueous HCl of pH 1 may also be used if DTPA is not available. Continue as long as you get appreciable reduction in contamination status each time.
- 6.6.2 For alkalis (Na, Cs, K) and alkaline earths (Ca, Sr, Br) washing with soap and water is enough. However if there is wound contamination with Strontium, then use Potassium Rhodizonate crystals to in-solubilize Sr. (**N.B.:** Solution of Potassium Rhodizonate is unstable)
- 6.6.3 For contamination with Uranium, use 1.4 % Soda-bicarb solution
- 6.6.4 For contamination with radionuclides (viz.: Cesium ¹³⁷Cs, Barium ¹⁴⁰Ba,) use 1% DTPA or dilute HCl
- 6.6.5 For contamination with Iodine, use Lugol's solution. It has to be followed by application of sodium hyposulphite and then rinsed with water.
- 6.6.6 Contamination with Phosphorous ³²P, use Acetic Acid solution (5%, pH 4 to 5) or simply Vinegar. Wash and then rinse with water.
- 6.6.7 For contamination with Cobalt, use dilute acid solution of 1% DTPA (pH 4)
- 6.6.8 After completion, dress the area with Lanolin containing sterile dressing.

6.7 Stubborn Contaminations on skin

- 6.7.1 For stubborn contaminations, saturated solution of KMnO₄ and 0.2 N H₂SO₄ is used.
- 6.7.2 In some cases, localized hot spots of insoluble material embedded in the horny layer of the skin can be removed by sand paper or by sticking tape. Apply the sticking tape on the area, adhere it closely and then peel it off.
- 6.7.3 Skin clears itself by shedding the horny layer every two-three weeks, therefore residual skin contamination will gradually vanish over the time.

6.8 External Decontamination – Broken Skin/ Open Wounds

- 6.8.1 Initial assessment of severity of injury and degree of contamination should be done.
- 6.8.2 Decontamination of broken skin or wounds should always take precedence over the intact skin

6.9 Uptake and deposition

- 6.9.1 The contaminant from the wound may get absorbed into the circulatory system and may get deposited in regional lymph nodes. The speed of uptake from the wound would depend on –

- a pH
- b solubility of the radionuclide
- c tissue reactivity
- d particle size

6.10 Abrasions

- 6.10.1 For Abrasions, clean with soap and water. If the process is painful, apply local application of 4% Xylocaine. The residual contamination if any would come out with the scab which should be monitored for the activity.

6.11 Lacerations

- 6.11.1 In lacerations, the contamination may be along the irregular margins or edges. It may also be in deeper planes and make detection little difficult. At times surgical excision of wounds may be necessary.

6.12 Wounds

- 6.12.1 The contaminated wound should be isolated from a clean skin by plastic drapes.
- 6.12.2 Obtain wound biopsy, remove wound exudates, blood etc. and collect them in a sterile container or vials for evaluation and analysis
- 6.12.3 Wound is then irrigated, cleaned and debrided as per normal surgical procedures.
- 6.12.4 If necessary, trim the wound edges to remove contaminant. This yields significant reductions in contamination levels.
- 6.12.5 If the wounds are severe in nature and if you feel that attempts to further decontaminate them would further aggravate the injury, then the wound may be first closed and decontamination attempted later.
- 6.12.6 For wounds contaminated with plutonium and americium, irrigate the wound with 25%DTPA solution. Excision of wounds may be required after the chelation is over.
- 6.12.7 For wounds contaminated with uranium, irrigate the wound with soda-bicarb solution
- 6.12.8 For wounds contaminated with strontium or radium, sprinkle the wound with the crystals of potassium rhodizonate. This will insolubilize the strontium and it can be flushed out of the wound by irrigating it with water. Always remember that once a radioactive contaminant is rendered insoluble, its absorption and systemic distribution gets delayed or discontinued. For best results, begin treatment in first 15 minutes.
- 6.12.9 For wounds contaminated with iodine, use Lugol's solution to irrigate the

wound. Carry out irrigation with Lugol's and then with copious amounts of water. Repeat if necessary.

- 6.12.10 For wounds contaminated with cobalt, use 25 % DTPA solution to irrigate the wounds. Later flush with water.
- 6.12.11 For wounds contaminated with tritium, copious irrigation with water is necessary. Continue irrigation until satisfactory reductions in levels are noted.
- 6.12.12 For wounds contaminated with phosphorous, use 5% acetic acid solution (pH 4 to 5) or simply vinegar to irrigate adequately. Then rinse with water.
- 6.12.13 Close the wound after decontamination / termination of procedure. Suture the wound if necessary. Alternatively, dress the wound with a proper anti-septic ointment.
- 6.12.14. In certain cases, at a later stage, split skin removal or a full thickness skin removal may become necessary along with a suitable skin graft. While considering this, preservation of function and cosmetic appearance should be taken into account. Before subjecting to such a surgical procedure, the monitoring staff should always be consulted to weigh the pros and cons.

6.13 Termination of Decontamination procedure:

- 6.13.1 Decontamination procedure of intact skin should be terminated if -
 - a the area is successfully decontaminated to an acceptable level and so approved by the monitoring staff
 - b 3-4 successive washings and drying procedures do not decrease the contamination levels,
 - c If severe redness or irritation occurs.

In such a situation, cover the area with sterile Lanolin containing dressings, and attempt decontamination the next day or when the skin shows signs of proper recovery.

- 6.13.2 Decontamination procedure of broken skin or wounds should be terminated if –
 - a The area is successfully decontaminated to an acceptable level and so approved by the Health Physics staff.
 - b 3-4 successive washings and drying procedures do not decrease the contamination levels,
 - c If wound starts bleeding and shows signs of deepening or worsening
 - d If surgical interventions like skin grafting etc. are required

In such a situation, suture the wound if required, or cover the wound with a

sterile anti-septic dressing. Attempt decontamination the next day or when the wound shows signs of proper recovery.

- 6.13.3 Record the readings of contamination monitoring at the termination time, and make a note of it. The difference of reading between the starting and termination time will give us the level of decontamination achieved.
- 6.13.4 On the next sitting for decontamination, again obtain the starting contamination reading. It may so happen that the starting reading at the second sitting may be higher than the termination reading of the first sitting. Do not get worried about this. It is because the lower layers of stratum corneum possess a sponge-like capacity to fill and empty. Hence, the contamination trapped there at the end of day one, may resurface at the start of day two, thus giving a higher reading. This is more common with alpha emitters.

At times certain hot particles, beta / gamma emitters, which are insoluble in water like Cobalt ^{60}Co , have a tendency to move from one surface to another due to their electrostatic charges. This also explains the change in values for two different sittings.

7 Internal Contamination – Principles of Uptake and Clearance

7.1 Before we proceed on to the internal decontamination, a brief account of Internal contamination will help us understand the decontamination procedures better.

7.2 It occurs due to accidental intake of radioisotope.

7.3 Radioisotope can enter the body by any of the following routes

(a) Inhalation, (b) Ingestion, (c) Injection, (d) Absorption through intact / broken skin and eyes

7.4 The hazards and their impact will depend upon the following:

- a Amount of activity
- b Site of deposition
- c Type and energy of radiation emitted
- d Sensitivity of specific tissues to penetration
- e Effective half life
- f Physico-Chemical nature of the contaminant

7.5 Effective Half Life is calculated by the formula

$$\text{Effective Half Life} = \frac{\text{Radioactive half Life} \times \text{Biological Half Life}^{\neq}}{\text{Radioactive half Life} + \text{Biological Half Life}}$$

* **Radioactive Half Life:** the time required for a quantity of a radioisotope to decay by half. e.g.: The radioactive half life of I^{131} is Eight days, hence if a sample of I^{131} has 10 m Ci of activity on January 1st, then Eight days later, i.e. on January 9th, its activity will be 5 mCi.

≠ **Biological Half Life:** the time required for one half amount of the substance, such as a radionuclide, to be expelled from the body by natural metabolic processes, not counting the radioactive decay, once it has been taken in through inhalation, ingestion or absorption.

7.6 Internal contamination includes the following successive stages

- a **Deposition** along the route of Entry – for e.g. respiratory tract, G.I. tract, Skin, Mucosa etc.
- b **Translocation** – this is the movement of radionuclide from the site of entry into the blood stream or Lymph
- c **Retention** – in the Target Organ or Tissues
- d **Clearance or Excretion** – Occurs directly by the filtration of radionuclide carrying blood by the Kidneys and indirectly by re-circulation of blood from the target organ getting re-filtered by the Kidneys.

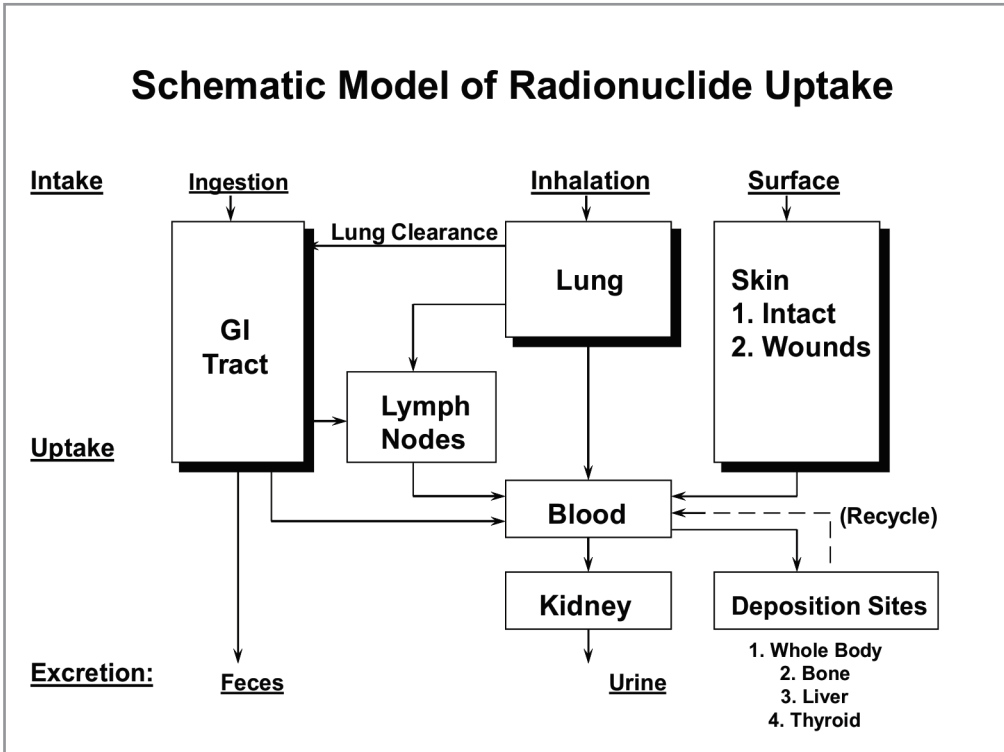


Fig. 4: Schematic Model of Radionuclide Uptake

7.7 Having understood the mechanism of internal contamination, we can now proceed to decontamination procedures.

8

Internal Decontamination

8.1 General treatment Plan

- 8.1.1 General treatment plan of internal decontamination will depend on the contamination route.
- 8.1.2 Contamination should be dealt with at the point of entry, particularly for those elements for which there is no effective therapy available. Hence, fixation or blocking of the radionuclide at the site of entry should be attempted so that blood uptake does not occur
- 8.1.3 Next, trapping it in blood during translocation and re-routing it towards its natural excretion should be attempted. This is important because the deposition in target organs starts as soon as the radionuclide circulates in the blood. Effectiveness of this treatment decreases with time, as more and more deposition will take place with passage of time.
- 8.1.4 The above two plans are the best methods, none the less, a third step of prevention of deposition in target organs can be most valuable at times, as in the case of ^{131}I where, administering stable Potassium Iodide blocks the Thyroid and prevents the uptake of ^{131}I .

8.2 Methods of Systemic Treatment

8.2.1 Decontamination of G.I. Tract:

- i Radioactive material may enter the G.I. tract either by ingestion through oral route or as a result of broncho-ciliary clearance mechanism following the inhalation.
- ii As a principle it would be appropriate to remove or enhance the transit of the gastro-intestinal contents. Carry out the following to achieve this.
- iii Carry out a Gastric Lavage through a Naso-Gastric tube. Emesis can be attempted in a conscious patient. However this may be done as a First Aid method in the absence of Medical help. Gastric Lavage is preferable. This is because, during gastric lavage, the radionuclide is removed through the tube, thereby preventing its possible re-deposition along the upper G.I. mucosa that may occur during the attempted emesis. Laxatives may be used to hasten the elimination of the radionuclide and to minimize the intestinal irradiation and absorption.
- iv Magnesium Sulphate is a saline purgative which produces a relatively insoluble sulphate with radium and thus reduces its absorption.

- v Enemas may be considered where quick emptying of colon is desired.
- vi Isotopic dilution method consists of giving large quantities of non-radioactive ion which competes with radioactive materials for absorption e.g. KI for Radioactive Iodine or Stable Phosphate for ³²P.
- vii Displacement therapy is a special form of dilution therapy. In this, a non-radioactive element of different atomic number, competes with the radionuclide for up take sites, e.g. Oral or IV Calcium increases excretion of Strontium
- viii Specific therapeutic agents such as ion exchange resins, gels, antacids are also used to reduce intestinal absorption of radioactive material.
- ix Certain mobilizing agents, increase natural turn-over process and help in enhancing elimination of radionuclide from the body tissues. e.g.
 - a Chelating agents like Ca DTPA, Zn DTPA are used for Plutonium contamination.
 - b Anti-thyroid drugs as Propyl thiouracil or Methimazole are administered when treatment with stable iodine may not be considered to be effective in advanced cases or if radioactive doses are high enough to justify their use.
 - c Ammonium chloride given orally is effective in mobilizing radio-strontium. Its effectiveness can be increased by simultaneous use of I.V. Ca gluconate.

8.2.2 Decontamination of Respiratory Tract:

- i It is important to note that soluble particles (less than 5 microns) are translocated to blood and are deposited in the appropriate target organ
- ii Insoluble particles get deposited in lung parenchyma and may get translocated to other organs at a low rate over many months or years or they may migrate to regional Lymph nodes by phagocytosis and the lymphoid channels
- iii Contamination by inhalation may occur with Krypton, Xenon, radioactive Iodine and Plutonium. Krypton and Xenon need no treatment as they are short lived
- iv In case of soluble particles which may be rapidly translocated to blood, treatment may be directed to trapping the radionuclide in the blood stream and enhancing their natural excretion.
- v Use of inhalation with specific antidotes may be advocated e.g. DTPA aerosol inhalation in Plutonium.
- vi Pulmonary lavage may be considered in cases of heavy non transportable radionuclide inhalation. However, risk benefit assessment should be done. The procedure should be considered only in high exposure cases in which reduction of dose can be expected to prevent acute or sub-acute effects such as radiation Pneumonitis or Fibrosis.

- vii Before we proceed to the internal decontamination procedure for specific radionuclides, following is a table of the Radionuclides and their treatment.

Table 4: Radioactive Contaminants with Medical Significance and Possible Treatment

Radioactive Contaminant	Radiation Type	Target Organ	Contamination Mode*	Treatment
Americium-241	α, γ	Bone	I / W	Ca-DTPA, Zn-DTPA [†]
Californium-252	γ, α, η	Bone	I / W	Ca-DTPA, Zn-DTPA [†]
Cerium-141, 144	β, γ	GI, lung	I / GI	Ca-DTPA, Zn-DTPA [†]
Cesium-137	β, γ	Total body	I / S / GI	Prussian blue [£]
Cobalt- 60	B, γ	Total body / Lung	I / S / G.I.	DTPA, D-Penicillamine
Curium-244	α, γ, η	Bone	I / GI	Ca-DTPA, Zn-DTPA [†]
Iodine-131	β, γ	Thyroid	I / GI / S	KI [¥] KIO ₃ Lugol's iodine
Plutonium-239, 238	α, γ	Bone	I / W	Ca-DTPA, Zn-DTPA [†]
Polonium-210	α	Lung	I	Dimercaprol [‡]
Phosphorous-32	B	Bones	I / S / G.I.	Stable Phosphate, Aluminum hydroxide antacid
Strontium-89, 90	β, γ	Bone	I / GI	AlPO ₄ ^{**}
Tritium (³ H)	β	Total body	I / S / GI	Forced H ₂ O [§]
Uranium-238, 235, 239	α, β, γ	Bone	I / S / W	NaHCO ₃ ^{***}
* Contamination Mode: I - inhalation; GI - gastrointestinal absorption; S- skin absorption; W-wound absorption				
** The antacid aluminum phosphate in gel form used as a gastrointestinal adsorbent for radio strontium				
*** Sodium bicarbonate to maintain alkalinity of urine used in conjunction with diuretics				
† Calcium- and Zinc-DTPA, metal complexes of di-ethylene-tri-amine-penta-acetate. The calcium form is recommended for the first decontaminating dose, followed with the zinc form for subsequent doses.				
‡ A mercury and arsenic poisoning chelation agent (very toxic)				
¥ Agent blocking radioiodine absorption in tissues resulting in its dilution				
§ Simple forced intake of water, resulting in tritium dilution				
£ A dye used as an ion exchanger.				

- viii Facilities for Internal decontamination of specific radionuclides may not be available at PHC/CHC
- ix Decision for transfer to higher centers shall be taken by the Doctor I/C of the PHC/CHC.
- x Decontamination of Individual Radionuclide:

It is important to note that there is NO SINGLE ALL-PURPOSE DECORPORATION DRUG (COCKTAIL) that will protect against all internal radio contamination possibilities

Various radionuclides could be categorized into two groups, based on the probability of contamination occurring – (A) Common and (B) Less Common. Once the body gets internally contaminated by these, the decontamination/removal from the body needs to be carried out using specific decontaminants and decorporation agents., Their properties, deposition in the body organs and the clearance using specific agents is given in Annex-4.

9

Follow Up of Internally Decontaminated Patients

- 9.1** For patients who were shown to have internal contamination levels below the ALI, no medical follow-up is required as there is no evidence of adverse effects. They need reassurance, possibly repeated reassurance, but no further studies or work-up.
- 9.2** Those who received decorporation drugs should have repeat measurements to determine whether or not treatment needs to be continued. These measurements may also help to establish biological half-life or half-lives, which could later be used in making dosimetry estimates.
- 9.3** Patients who received contamination levels above the ALI, and those to whom decorporation drugs were administered, need fairly accurate measurements of internal radioactivity levels and then calculated dosimetry estimates.
- 9.4** Health Physicist / Designated Monitoring staff will co-ordinate for these dosimetry.
- 9.5** In the event of some patients absorbing high doses of radiation, high enough to manifest the acute radiation syndrome, the patient should be referred to a Hematologist-Oncologist, as this is the specialty most capable of treating the acute bone marrow syndrome.

10

Radiation Burns

- 10.1** The most common form of radiation burn is Sun Burn, caused due to over exposure to UV radiation which is a non-ionizing radiation.
- 10.2** However, the term “Radiation burn” used in this chapter is the damage to skin or other biological tissues caused by exposure to ionizing radiation.
- 10.3** Caused mainly due to localized over exposure to ionizing radiation, e.g. in Industrial Radiography, inadvertent manual handling of Radioactive source or in cases of Radiotherapy.
- 10.4** Radiation burns evolve slowly over weeks to months. Hence detailed history of event and physical dosimetry may help in their management.
- 10.5 Effects of Ionizing Radiation on Skin:**
- 10.5.1 Alpha particles do not penetrate the horny outer layer of skin, i.e. the epidermis. The main problem associated with the alpha emitters is the possibility of transfer into the body by absorption through intact or broken skin, inhalation or ingestion while eating with contaminated hands.
- 10.5.2 Beta particles penetrate the epidermis and cause intense irradiation of tissues and structures beneath the epidermis and therefore are a major health hazard.
- 10.5.3 Electro-magnetic radiation [X-Rays and Gamma rays] can cause damage, but because of their greater penetration they deposit less energy locally than beta rays. Low energy rays can cause more biological damage superficially than gamma rays.
- 10.6 Symptoms:** Symptoms usually are
- i Sensation of warmth
 - ii Onset of pains and paresthesia, pain could be intense and continuous
 - iii Disturbances to tactile and heat sensitivity
- 10.7 Signs:** Following an acutely delivered single dose for 3 cm diameter fields, the threshold doses are in the following ranges:
- i Erythema (Transient) : Between 2 and 3 Gy
 - ii Fixed Erythema : 6 Gy

iii	Dry Desquamation	:	10 Gy
iv	Blisters	:	12 Gy
v	Wet Desquamation	:	15 Gy
vi	Ulceration	:	20 Gy
vii	Necrosis	:	25 Gy
viii	Gangrene	:	30 Gy

10.8 Severity : severity of burns depends on

- i Total dose received,
- ii Type of Radiation, i.e. based on photon energy, e.g. Gamma radiation causes deep Gamma Burns, whereas Beta particles are not able to penetrate deep, hence produce shallow burns.

10.9 Investigations : Whenever a suspected case of Radiation Burns is under study, carry out the following investigations :

- i Complete Blood Count
- ii Chromosomal Aberration Analysis (Biological Dosimetry)
- iii Color Doppler Studies / thermography / vascular scintigraphy
- iv Semen Analysis within few days [earlier the better], second sample after 60 days post exposure.
- v Slit Lamp examination of eyes, serially done at regular intervals to assess development of cataract
- vi Collection of material from septic foci for culture and antibiotic sensitivity tests
- vii Serial Color Photography to assess development and evolution of signs
- viii Physical re-construction of accident – Physical dosimetry.

Most of these investigation facilities are available only in advanced centers, hence such cases may be referred there.

10.10 Medical Management: Medical management entails a comprehensive clinical approach with a team of Certifying Surgeon, General Surgeon, Dermatologist, Plastic surgeon, Hematologist, Oncologist, Ophthalmologist and Health Physicist.

10.10.1 Management involves a prolonged follow up spread over weeks and months, not only for treatment reasons but to assess the development of late sequelae if any and their treatment.

10.11 Specific treatment

10.11.1 For Erythema, both transient and fixed, use bland lotion such as calamine lotion, or Steroid Ointment, or Steroid with anti-biotic ointment like Neosporin Hydrocortisone.

10.11.2 Sterile protective dressings with silver sulphadiazine / Framycetin ointment /

any other anti-septic solution or ointment. Dressings should ideally be changed twice a day. In treatment of Radiation Burns following Radiotherapy, change of dressings have helped in reducing pain.

10.11.3 Pain can be reduced by the use of analgesics, those which do not cause bone marrow damage. Morphine at times is necessary.

10.11.4 Use of systemic broad spectrum antibiotics for control and treatment of any bacterial infections

10.11.5 Use of anti-fungal drugs like Fluconazole in standard doses to control or treat fungal infections if any.

10.12 Surgical treatment

10.12.1 Based on the nature of burn, following surgical interventions may be necessary

- i Excision of wound
- ii Escharectomy
- iii Ulcerectomy
- iv Necretomy
- v Amputation

10.12.2 If the involved area is more than 2-3 sq.cm, skin grafting will be necessary. Partial or full thickness graft may be necessary depending upon the severity.

10.12.3 In cases with beta burns, early excision and skin grafting helps in relieving the pain

10.12.4 Larger areas involving extremities with necrosis or gangrene may require amputation.

10.12.5 Amputation, which is usually the terminal resort, is determined by the following factors –

- i Intractable pain due to Ischemia
- ii Size and Location of burn
- iii Associated secondary infections
- iv Extent of vascular damage
- v Loss of functional value of the body part

10.12.6 Late Sequelae of radiation Burns: Following lesions may develop over a period of several months to years. They constitute the late sequelae, and hence long term follow up patients with Radiation burns is necessary.

- i Chronic Radio-dermatitis – particularly if the dose is around 10 Gy and above
- ii Keratosis

- iii Dry, fragile and brittle skin which may show areas of hypopigmentation / hyperpigmentation
- iv Squamous or Basal cell carcinoma of skin,
- v Cataract – if there is localized exposure to face or eyes
- vi Sterility – if there is localized exposure to Gonads.

11

Admission

- 11.1** Admission to higher center/s will depend on the following factors:
- a General condition of the patient
 - b Dose more than 1Gy
 - c Underlying chronic conditions exaggerated by the event directly or indirectly due to fear
 - d Level of radioactive contamination left behind on / in the body at the end of decontamination procedures. This will be viewed as “Risk to self” and as “Risk to others”.
 - e Concomitant injuries and infections needing Isolation.
 - f Social conditions like – presence of infants or pregnant lady at home.
- 11.2** Decision for admission will be jointly taken by doctors and health physicists/monitoring staff.
- 11.3** Once the admission is advised, the patient will be referred to center with admission facilities. Admission paper in that hospital will be made as routinely done for any indoor patient.
- 11.4** Patient will be kept in isolation.
- 11.5** Patient will be provided with hospital linen including the patient’s clothing. Kindly note that the linen will be changed daily and for internally contaminated patients, the soiled linen will be collected in separate yellow polythene bags. These will be sent to concerned authorities for proper decontamination and subsequent cleaning.
- 11.6** One nurse shall be deputed in around-the-clock shift for attending to the admitted patient(s).
- 11.7** These nurses will practice “barrier nursing techniques” while attending to the patient(s).
- 11.8** The adjoining ward shall be the supply station for these patients’ requirements.
- 11.9** The movement of equipment / consumables into this isolation ward shall be uni-directional. No material brought into this isolation ward will go back to general use, unless the material is properly decontaminated and certified to be contamination-free by the radiation monitoring staff. If any material continues to remain contaminated, it shall be disposed, as radioactive contaminated solid waste.

- 11.10** All entries in the admission papers should be made with proper date and time. All instructions should be carried out *ad-verbatim*.
- 11.11** No visitors should be allowed inside the isolation area. This also includes the hospital staff that is not on duty in the isolation ward at a given point in time.
- 11.12** The ward personnel should also be told to wear protective clothing while attending to the requirements in the isolation ward. They should be properly instructed to preserve the urine and stool samples for investigations.
- 11.13** Treatment of admitted patient will include:
- a Treatment for any specific co-morbid medical conditions
 - b Decontamination treatment,
 - c Any specific / specialized treatment – like transfusion, grafting etc.
 - d Medicines for any chronic illness, if the patient is taking them,
 - e Suitable antibiotics and supportive treatment
 - f Antacids, Laxatives as needed
 - g Vitamins and Anti-oxidants
 - h Pain killers and Anxiolytics
 - i Any others as per requirement.
- 11.14** Food provided to the patient should be –
- a Fresh and nutritious
 - b Fully cooked. **No uncooked food** like salads, *raita*, fruits etc. should be given
 - c Food specifications of his / her underlying illness, viz. Salt restricted, Diabetic, etc. should be borne in mind
 - d Water should be properly filtered and boiled for at least 20 minutes to kill all the spores in it. It should be preserved in proper container and given to patient as needed. Authenticated sterile sealed Mineral water may be used as a safe alternative.
- 11.15** Based on the patient(s)'condition and the decontamination success, s/he may be either referred to higher center for further treatment, or may be discharged from the ward.
- 11.16** All papers such as case papers, investigation reports, radiological films (if any) etc. will be handed over to the state health authorities for proper filing.
- 11.17** Discharge papers – elaborately written - will be handed over to the patient. One copy of the same will be retained by the state health authorities and one copy will be sent to the Medical Superintendent / Certifying Surgeon of the nearest NPP Hospital.

12

Writing Notes

- 12.1** While writing notes make detailed entry of areas and readings (level) of contamination before starting the decontamination procedure. Mark the body areas on the figure on the card – both on anterior and posterior surfaces.
- 12.2** Enter the notes regarding general examination, systemic examination, injuries if any.
- 12.3** Make a note of any past history and past medications.
- 12.4** Make a note of any drug allergies.
- 12.5** Write down step wise, each procedure carried out.
- 12.6** Make an entry of all the specimens collected and sent for bio-assay.
- 12.7** Make an entry of all investigations ordered.
- 12.8** Make entries of progressive developments.
- 12.9** Keep the spouse of the patient informed. This helps in reducing undesired anxiety.
- 12.10** At the end of each sitting of decontamination procedure, make detailed entry of areas and readings (level) of contamination before starting and at the end of the decontamination procedure. Mark the body areas on the figure on the card – both on anterior and posterior surfaces.
- 12.11** Keep all the investigation reports intact. Make a note of the reports in daily case sheet. Draw trends for investigation. It gives a good estimate of the prognosis.
- 12.12** All papers of the decontamination procedures and admission papers, discharge summary, investigations and follow up records should be neatly filed separately for each patient and submitted to the Office of Chief Medical Officer of the District.
- 12.13** All patients requiring follow up should be properly instructed regarding the time, the date and the place of follow-up. The follow-up should be done at the place of last decontamination / decorporation.
- 12.14** O/o the Chief Medical Officer of the district will retain these papers in hard copies and soft copies – scanned and converted into PDF files, until the death of the person / 30 years beyond the treatment completion / Age of 90 years of the person, whichever is later.
- 12.15** Please fill in all the Work sheets given at the end of this document meticulously. WS 3 deals with treatment of the patient from initial reporting to discharge.

13

Acute Radiation Syndrome (ARS)

- 13.1** The acute radiation syndrome occurs after whole-body or significant partial-body irradiation of greater than 1 Gy delivered at a relatively high-dose rate. The most replicative cells are the most sensitive to the acute effects of radiation, particularly, lympho-hematopoietic elements and intestinal crypt cells. The inherent sensitivity of these cells results in a constellation of clinical syndromes that predominate within a predictable range of doses of whole-body or significant partial-body exposure.
- 13.2** Clinical components of the acute radiation syndrome include the hematopoietic, gastrointestinal and neurovascular syndromes. The time course and severity of clinical signs and symptoms for the component syndromes at different dose ranges have been elaborated in Section. Each syndrome can be divided into 4 phases: prodromal, latent, manifest illness and recovery or death.
- 13.3** The following diagram is a Reference from: Annals of Internal Medicine. CLINICAL GUIDELINES. Medical management of the Acute Radiation Syndrome: Recommendations of the Strategic National Stockpile Radiation Working Group. Jamie K. Waselenko et al; 15 June 2004/ Vol 140/Issue 12/ Pg 1037 – 1051).

Approximate time course of clinical manifestations: Shown in the diagram is the approximate time for hematopoietic, gastrointestinal (GI), and central nervous system (CNS) symptoms at different ranges of dose of whole-body radiation for exposed, living persons. Hematopoietic changes include development of lymphopenia, granulocytopenia or thrombocytopenia. Gastrointestinal symptoms include nausea, vomiting or diarrhea and may also be accompanied by headaches. Cerebrovascular signs and symptoms include headache, impaired cognition, disorientation, ataxia, seizures, prostration and hypotension. Note that the signs and symptoms of different organ systems significantly overlap at each radiation dose and that cerebrovascular symptoms do not appear until exposure to a high whole-body dose. The relative severity of signs and symptoms is measured on an arbitrary scale.

- 13.4 Phases of ARS:** Depending on the absorbed dose, symptoms appear within minutes, hours to weeks, following a predictable clinical course.
- i **Prodromal Phase:** The prodromal phase of the acute radiation syndrome usually occurs in the first 48 hours but may develop up to 6 days after exposure.
 - ii **Latent phase:** The latent phase is a short period characterized by improvement of symptoms, as the person appears to have recovered. Unfortunately, this effect is transient, lasting for several days to a month.

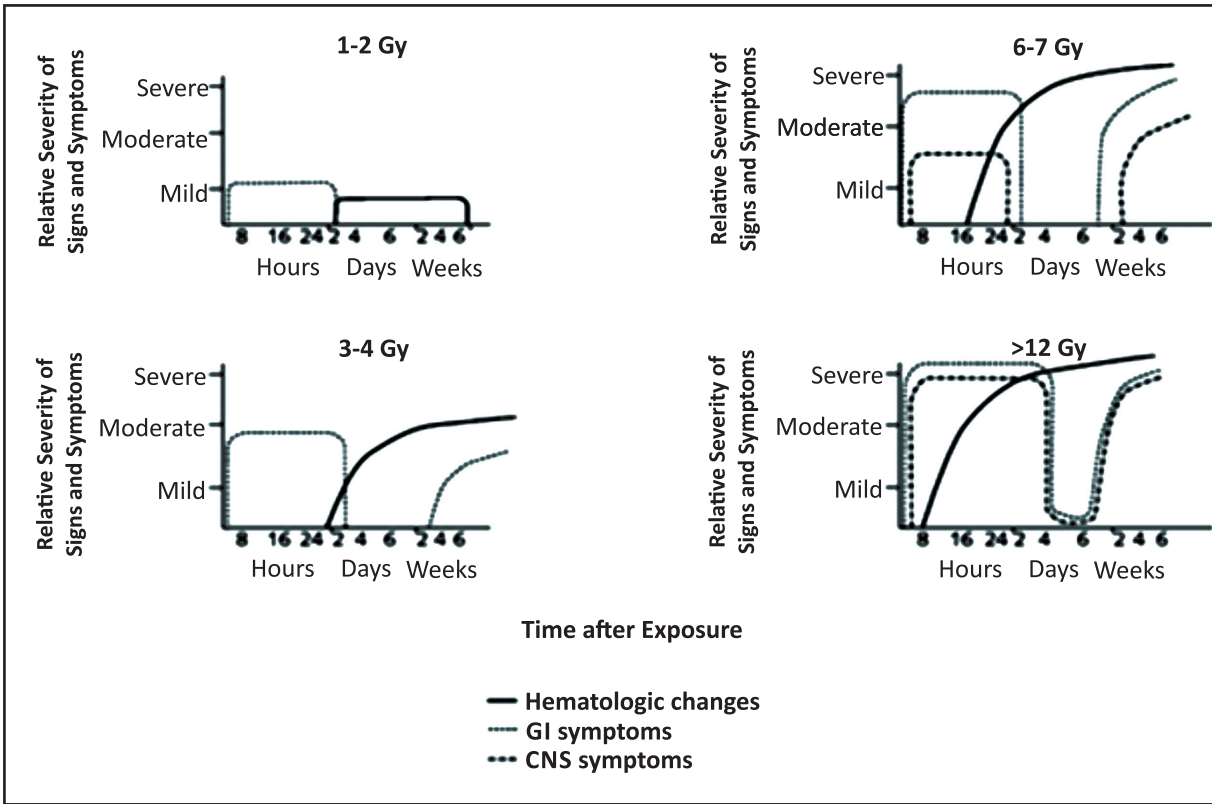


Fig. 5: Phases of ARS

- iii **Manifest Illness Phase:** Symptoms of manifest illness then appear and may last for weeks. This stage is characterized by intense immuno-suppression and is the most difficult to manage. If the person survives this stage, recovery is likely. Individuals exposed to a supra-lethal dose of radiation may experience all of these phases over a period of hours, resulting in early death.
- iv **Recovery Phase:** This phase shows signs of recovery and patients regain normal health over a period of time.

These phases under different acute exposure conditions leading to various syndromes are detailed in Annex-5.

14

Bio-Dosimetry in Acute Radiation Syndrome

- 14.1** Individual bio-dosimetry is essential for predicting the clinical severity, treatment and survivability of exposed individuals and triaging those with minimal or no exposure. The 3 most useful elements for calculating the exposure dose are (a) time to onset of vomiting, (b) lymphocyte depletion kinetics and (c) the presence of chromosome dicentrics.
- 14.2** The rate of decline and nadir of the absolute lymphocyte count (ALC) over the initial 12 hours to 3 days after exposure is a function of cumulative dose. Lymphocyte depletion kinetics predict dose assessment for a photon-equivalent dose range between 1 and 10 Gy with an exposure resolution of approximately 2 Gy. Ideally, a complete blood cell count with leukocyte differential should be obtained immediately after exposure, 3 times per day for the next 2 to 3 days and then twice a day for the next 3 to 6 days. Day of 500 (of ALC) can be used to identify the severity of hematopoietic syndrome and its prognosis.
- 14.3** It is recommended that 6 (and a minimum of 3) complete blood counts with differential be obtained within the initial 4 days after exposure, to calculate a slope for lymphocyte decline that can be used to estimate exposure dose. Complete blood counts with differential should then be obtained weekly or twice weekly until a nadir in neutrophil count is defined.
- 14.4** The chromosome-aberration cytogenetic bioassay, primarily the lymphocyte dicentrics assay introduced by Bender and Gooch, remains the gold standard for bio-dosimetry. A peripheral blood sample should be obtained without delay (for uniform whole body exposure) or at 24 hours after exposure (in cases of suspected non-uniform exposure) or later. The results will be available after 48 to 72 hours. The blood sample has to be collected in Li-heparin vials (color coded as green-cap vial).
- 14.5** Table showing Bio-dosimetry (Ref: Annals of Internal Medicine. CLINICAL GUIDELINES. Medical management of the Acute Radiation Syndrome: Recommendations of the Strategic National Stockpile Radiation Working Group. Jamie K. Waselenko et al; 15 June 2004/ Vol 140/Issue 12/ Pg 1037 – 1051)

Table 5: Biodosimetry based on Acute Photon-Equivalent Exposures*

Dose Estimate	Victims with Vomiting	Time to Onset of Vomiting	Absolute Lymphocyte Count†						Rate Constant for Lymphocyte Depletion‡	Dicentric in Human Peripheral Blood Lymphocytes §	
			Day 0.5	Day 1	Day 2	Day 4	Day 6	Day 8		Per 50 Cells	Per 1000 Cells
Gy	%	<i>h</i>	← $\times 10^9$ cells/L →						<i>K</i> ‡	<i>n</i>	
0	–	–	2.45	2.45	2.45	2.45	2.45	2.45	–	0.05-0.1	1-2
1	19		2.30	2.16	1.90	1.48	1.15	0.89	0.126	4	88
2	35	4.63	2.16	1.90	1.48	0.89	0.54	0.33	0.252	12	234
3	54	2.62	2.03	1.68	1.15	0.54	0.25	0.12	0.378	22	439
4	72	1.74	1.90	1.48	0.89	0.33	0.12	0.044	0.504	35	703
5	86	1.27	1.79	1.31	0.69	0.20	0.06	0.020	0.63	51	1024
6	94	0.99	1.68	1.15	0.54	0.12	0.03	0.006	0.756		
7	98	0.79	1.58	1.01	0.42	0.072	0.012	0.002	0.881		
8	99	0.66	1.48	0.89	0.33	0.044	0.006	<0.001	1.01		
9	100	1.56	1.39	0.79	0.25	0.030	0.003	<0.001	1.13		
10	100	0.48	1.31	0.70	0.20	0.020	0.001	<0.001	1.26		

*Depicted above are the 3 most useful elements of biodosimetry. Dose range is based on acute photon-equivalent exposures. The second column indicates the percentage of people who vomit, based on dose received and time to onset. The middle section depicts the time frame for development of lymphopenia. Blood lymphocyte counts are determined twice to predict a rate constant that is used to estimate exposure dose. The final column represents the current gold standard, which requires several days before results are known. Colony-stimulating factor therapy should be initiated when onset of vomiting or lymphocyte depletion kinetics suggests an exposure dose for which treatment is recommended (see Table 7 (of reference 13)). Therapy may be discontinued if results from chromosome dicentrics analysis indicate a lower estimate of whole-body dose.

† Normal range, $1.4\text{--}3.5 \times 10^9$ cells/L. Numbers in boldface fall within this range.

‡ The lymphocyte depletion rate is based on the model $L_t = 2.45 \times 10^9 \text{ cells/L} \times e^{-k(D)t}$, where L_t equals the lymphocyte count ($\times 10^9$ cells/L), 2.45×10^9 cells/L equals a constant representing the consensus mean lymphocyte count in the general population, k equals the lymphocyte depletion rate constant for a specific acute photon dose, and t equals the time after exposure (days).

§ Number of dicentric chromosomes in human peripheral blood lymphocytes.

15

Medical Management of Acute Radiation Syndrome

- 15.1** Treatment of acute radiation syndrome is not indicated when exposure dose is very low (<1 Gy) or very high (>10 Gy). Supportive and comfort care is indicated for people with an exposure dose greater than 10 Gy because their prognosis is grave.
- 15.2** Thus the medical management shall be applicable largely to the Hematopoietic Syndrome which falls between doses more than 1 Gy and less than 10 Gy.
- 15.3** Medical Management of Hematopoietic Syndrome
- 15.3.1 Treatment of radiological victims with hematopoietic syndrome varies with dose estimates, exposure scenarios and presenting symptoms.
- 15.3.2 Short-term therapy with cytokines is appropriate when the exposure dose is relatively low (<3 Gy).
- 15.3.3 Prolonged therapy with cytokines, blood component transfusion and even stem-cell transplantation may be appropriate when exposure dose is high (>7 Gy) or when traumatic injury or burns are also present.
- 15.3.4 Cytokine Therapy: Colony Stimulating Factors (CSFs) are the Hematopoietics which are widely used. The rationale for the use of CSFs in the radiation setting is derived from enhancement of neutrophil recovery in patients with cancer on chemotherapy who are treated with CSFs.
- i Treatment should commence when the Absolute Lymphocyte Count drops to 500/ cu.mm and should continue until the Absolute Neutrophil Count rises to 1000/cu. mm
 - ii Others used are recombinant forms of (a) granulocyte macrophage colony-stimulating factor (rhGM-CSF) e.g. Sargramostim in dose 5-10 µg/Kg/d subcutaneously or equivalent dose of 200-400 µg/m²/d, and (b) granulocyte colony-stimulating factor (rhG-CSF) e.g. Filgrastim in dose 2.5 – 5 µg/Kg/d subcutaneously or equivalent 100-200 µg/m²/d. Also the mg pegylated form of G-CSF (pegylated G-CSF or pegfilgrastim) can be used in the dose of 6 once subcutaneously.

Note: (Kindly note that treatment of Acute Radiation Syndrome requires specialized centers., Hence, such patients are to be referred to Tertiary Care Facilities for expert management. However, the details of ARS in earlier chapters and the management mentioned here are for purpose of knowledge sharing).

iii The value of CSFs in the treatment of radiation-induced myelo-suppression of the bone marrow lies in their ability to increase the survival, amplification, and differentiation of granulocyte progenitors. Both rhGM-CSF and rhG-CSF activate or prime neutrophils to enhance their functions, such as microbicidal activity. Both have been shown to hasten neutrophil recovery by approximately 3 to 6 days in humans after intensely myelotoxic therapies, including bone marrow and stem-cell transplantation.

15.3.5 Doses of Cytokines: (Ref: Annals of Internal Medicine. CLINICAL GUIDELINES. Medical management of the Acute Radiation Syndrome: Recommendations of the Strategic National Stockpile Radiation Working Group. Jamie K. Waselenko et al; 15 June 2004/ Vol 140/ Issue 12/ Pg 1037 – 1051)

Table 6: Recommended Doses of Cytokines*

Cytokine	Adults	Children	Pregnant Women †	Precautions
G-CSF or filgrastim	Subcutaneous administration of 5 µg/kg of body weight per day, continued until ANC > 1.0x10 ⁹ cells/L	Subcutaneous administration of 5 µg/kg per day, continued until ANC > 1.0x10 ⁹ cells/L	Class C (same as adults)	Sickle-cell hemoglobinopathies, significant coronary artery disease, ARDS; consider discontinuation if pulmonary infiltrates develop at neutrophil recovery
Pegylated G-CSF or pegfilgrastim	1 subcutaneous dose, 6 mg	For adolescent >45 kg: 1 subcutaneous dose, 6 mg	Class C (same as adults)	Sickle-cell hemoglobinopathies, significant coronary artery disease, ARDS
GM-CSF or sargramostim	Subcutaneous administration of 250 µg/m ² per day, continued until ANC > 1.0x10 ⁹ cells/L	Subcutaneous administration of 250 µg/m ² per day, continued until ANC > 1.0x10 ⁹ cells/L	Class C (same as adults)	Sickle-cell hemoglobinopathies, significant coronary artery disease, ARDS; consider discontinuation if pulmonary infiltrates develop at neutrophil recovery

*ANC = absolute neutrophil count; ARDS = acute respiratory distress syndrome; G-CSF = granulocyte colony-stimulating factor; GM-CSF = granulocyte-macrophage colony-stimulating factor.

† Experts in biodosimetry must be consulted. Any pregnant patient with exposure to radiation should be evaluated by a health physicist and maternal-fetal specialist for an assessment of risk to the fetus. Class C refers to U.S. Food and Drug Administration Pregnancy Category C, which indicates that studies have shown animal, teratogenic, or embryocidal effects, but there are no adequate controlled studies in women; or no studies are available in animals or pregnant women.

i People at extremes of age (children < 12 years and adults > 60 years) may be more susceptible to irradiation and have a lower LD50/60. Therefore, a lower threshold exposure dose (2 Gy) for initiation of CSF therapy is

appropriate in such persons and in those who have major trauma, injuries or burns.

15.3.6 **Transfusion:**

Transfusion of cellular components, such as packed red blood cells and platelets, is required for patients with severe bone marrow damage. Fortunately, this complication does not typically occur for 2 to 4 weeks after the exposure, thereby permitting time for rapid mobilization of blood donors. Blood component replacement therapy is also required for trauma resuscitation. All cellular products must be leuko-reduced by irradiating to 25 Gy to prevent transfusion-associated graft-versus-host disease in the irradiated (and therefore immune-suppressed) patient. It may be difficult to distinguish transfusion-associated graft-versus-host disease from radiation-induced organ toxicity, which may include fever, pancytopenia, skin rash, desquamation, severe diarrhea and abnormalities on liver function tests (in particular, hyper-bilirubinemia).

15.3.7 **Stem-Cell Transplantation:**

Matched related and unrelated allogeneic stem-cell transplantations are life-saving and potentially curative treatments in patients with certain predominantly hematologic malignant conditions. A small number of radiation accident victims have undergone allogeneic transplantation from a variety of donors in an attempt to overcome radiation-induced aplasia.

If resources allow, transplantation should be considered in people with an exposure dose of 7 to 10 Gy who do not have significant burns or other major organ toxicity and who have an appropriate donor. Individuals with a granulocyte count exceeding 0.500×10^9 cells/L and a platelet count of more than 100×10^9 cells/L at 6 days after exposure may appear to have residual hematopoiesis and may not be suitable candidates for transplantation.

In the unusual circumstances where a syngeneic donor is available or previously harvested autologous marrow is available, a stem-cell infusion may be considered in patients with exposures exceeding 4 Gy.

15.4 **Medical Management of Other Conditions and Special Care**

15.4.1 **Supportive Care:** Supportive care includes the administration of antimicrobial agents, anti-emetic agents, anti-diarrheal agents, fluids, electrolytes, analgesic agents and topical burn creams. Transfusion of fresh irradiated platelets can be done.

15.4.2 **Infections:**

Susceptibility to infection results from a breach in the integument or mucosal barriers, as well as immune suppression consequent to a decline in lympho-hematopoietic elements. Several studies have indicated that administration

of antibiotics reduces mortality rates in irradiated dogs in the LD50/30 range. Controlling infection during the critical neutropenic phase is a major contributing factor for successful outcome. In non-neutropenic patients, antibiotic therapy should be directed towards foci of infection and the most likely pathogens. Fluoroquinolones have been used extensively for prophylaxis in neutropenic patients. In patients who experience significant neutropenia (absolute neutrophil count $< 0.500 \times 10^9$ cells/l), broad-spectrum prophylactic antimicrobial agents should be given during the potentially prolonged neutropenia period. Prophylaxis should include a fluoroquinolone with streptococcal coverage or a fluoroquinolone without streptococcal coverage plus penicillin (or a congener of penicillin), antiviral drugs (acyclovir or one of its congeners) and antifungal agents (fluconazole).

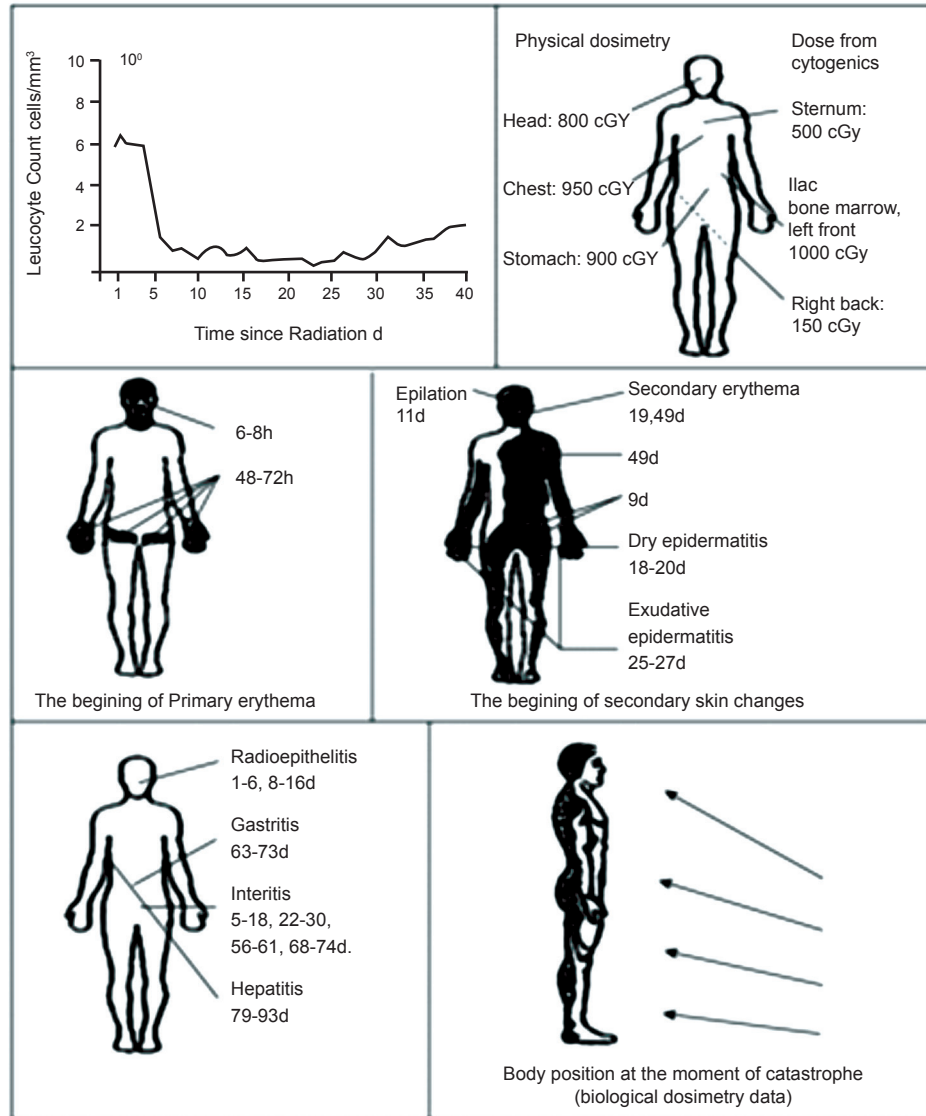


Fig. 6: Time Dependent Effects of ARS

Antimicrobial agents should be continued until they are clearly not effective (for example, the patient develops neutropenic fever) or until the neutrophil count has stabilized, i.e. absolute neutrophilic count more than 1.000×10^9 cells / l.

15.4.3 Comfort Measures

People with a high exposure dose, whose outcome is grim, must be identified for appropriate management. Since there is no chance of survival after irradiation with a dose of more than 10 to 12 Gy, it is appropriate for definitive care to be withheld from such individuals. Rather than being treated aggressively, these patients should be provided with comfort measures. This includes attention to pain management and general comfort as well as administration of anti-emetic and anti-diarrheal agents. In this devastating situation, psychological support is essential not only for the patient but also for family and friends, who may experience traumatic grief.

15.5 Summary of Medical Record of a radiation exposed patient:

Shown are the absolute leukocyte count (top left panel), estimated organ dose (top right panel), areas of skin injury (middle panels), injury to oral cavity and gastrointestinal system (bottom left panel), and body position relative to the radioactive source (bottom right panel) as a function of time after the exposure. To convert cells/mm³ to x10⁹ cells/l, multiply by 0.001.

(Ref: Annals of Internal Medicine. CLINICAL GUIDELINES. Medical management of the Acute Radiation Syndrome: Recommendations of the Strategic National Stockpile Radiation Working Group. Jamie K. Waselenko et al; 15 June 2004/ Vol 140/ Issue 12/ Pg 1037 – 1051)

16

Post Disaster Counselling

16.1 Introduction: It has been found that people who have witnessed the disaster, or have been victims of it, have a long lasting impression on their minds. The disaster catastrophe, the losses during the disaster and the post disaster scene of destruction and the ensuing epidemics, all make their lasting impressions on one's mind. This can happen even after individual calamities in the family, but are significantly pronounced in large scale disasters where the canvas of destruction is larger than expected. Compounding the effect is the sense of hollowness / emptiness that creeps in when one has lost everything s/he had. It is indeed a horrifying experience, when one has to restart life all over again amidst the pain of losing everything, at times even the pain of losing loved ones. These are very trying times and they affect practically every neighbor of the victim. The degree of pain and the tolerance of an individual to absorb the shock is what make the difference. It is during these times if apt help is rendered in the form of psychological support through means of counselling, it can help many to tide over the losses rather stoically. Hence by now PTSD (Post Traumatic Stress Disorder) is an accepted entity and all efforts should be taken to minimize the effects of PTSD.

16.2 Effects of Disaster: Effects of disaster can be

- i Psychological: Impact includes loss of house or loved ones, fear, anxiety and uncertainty in facing one's future and that of the family; trauma, and feeling of helplessness.
- ii Physical impact is obvious in the form of crippling and physical dysfunction (which may cause psychological problem such as loss of self-confidence).
- iii Social impact appears as a feeling of insecurity, a feeling of being treated unfairly, anxiety caused by uncertainty and higher sensitivity to rumor.
- iv Economic impact is the loss of living resources, marketplace and customers.
- v Housing and Environmental impact appears as the damage to buildings and environmental setting and facilities.

16.3 Post-Traumatic Stress Disorder: It is an anxiety disorder which some people suffer from, after living through a traumatic event. Fortunately all people who are exposed to traumatic events do not develop PTSD. Disaster and crisis counseling serve to prevent the development of PTSD through safety, stabilization, self-care and coping skills.

16.4 Aim: The Aim of counseling is to create a sense of safety and security in the midst of chaos. People who are affected may react with severe emotions or remorse. There can be sadness and aloofness both together. People should be convinced that Time is a Great Healer.

Judith Herman's triphasic model of trauma recovery should be borne in mind by every counselor. The elements of triphasic model are (a) safety and stabilization, (b) remembering and mourning, and (c) reconnecting and healing.

16.5 Helping clients cope:

In the immediate aftermath, always make the person feel safe and secure. S/he should be emotionally stabilized by helping him/her regain his/her confidence.

Subsequently help the client to remember the role and responsibilities played by his/her deceased dear ones and the need for the client to understand that a part of those roles and responsibilities now need to be performed by him/her. Life ahead has to be lived and lived productively.

It is important to remember that counselors should emotionally support the client but should never become emotionally a part of the client's world.

All counselling activities should be continuous. WHO does not recommend single-session psychological debriefing to the general population as an early intervention. Most acute mental health problems during the acute emergency phase are best managed without medication following the principles of 'psychological first aid' (i.e., listen, convey compassion, assess needs, ensure basic physical needs are met, do not force them to talk, provide or mobilize company from family or friends).

Psychological debriefing as an early intervention after trauma is likely to be ineffective and some evidence suggests that some forms of debriefing may be counterproductive by slowing down natural recovery.

In order to assist the counselors, a very established and world-wide accepted tool is a scale called CAPS, i.e. Clinician Administered PTSD Scale. It is a questionnaire based analysis wherein 30 standard questions are to be asked and graded. This has been developed by the National Centre for Post-Traumatic Stress Disorder, Behavior Science Division, Boston VA Medical Centre and the Neurosciences Division West Haven VA Medical Centre, USA.

CAPS is highly recommended by all Psychologists and Psychiatrists world-wide to diagnose and grade the PTSD.

In developing mutual aid within the affected people as the care givers, one should always keep in mind that it is essential to help and guide rather than do the things for the victim. Care should be taken to see that the person is not shifted from one disaster to another, i.e. disaster of dependency.

17

Maintenance and Records

- 17.1** All medicines, kits, disposables, decorporating agents, chemicals, protective clothing, waste bags/ baskets/ containers, stationery, shall be maintained at every PHC/ CHC/ District Hospital/ Civil Hospital/ Medical College/ Super-specialty Medical College/ Hospital.
- 17.2** It shall be ensured by the CMO of every district that each medical centre under her/ his jurisdiction is in a state of readiness round the clock.
- 17.3** All materials and staff shall be provided by the CMO of the district.
- 17.4** The Medical Officer I/c or the Medical superintendent of the hospital shall in turn keep her/ his centre in a state of readiness.
- 17.5** The M.O I/c or Medical superintendent shall carry out monthly inspection in the last week of every month of all requisite things, check stock taking, and submit a report to District CMO latest by the 7th of the next month. S/he shall make a list of all material requiring replacement and send it to the District CMO who, in turn, shall ensure prompt and timely replacement. It shall be ensured by the District CMO that, at no point of time, the centers fall deficient on any account.
- 17.6** All inspections and actions taken should be properly logged.
- 17.7** CMO shall prepare a plan of mock exercises between the health centers of her/ his district.
- 17.8** CMO shall in turn keep the DM of the district informed of every development.
- 17.9** All patient related documents are to be retained in the O/o CMO until 30 years post completion of treatment of an individual (Mandatory) if patient is alive and regular follow up is on, or Death of the patient.

Appendix – I

General Instructions for Awareness in a Large Scale Radiological Emergency Scenario

In the event of an emergency situation, it is natural that apprehensions and panic will override rationality. It will be the onus of the medics and the paramedics to alleviate these fears. These can be achieved by – (i) educating the people, distributing information booklets through interactions with school / college children and (ii) dissemination of correct information during the crisis hours.

As for the first part, the state health department may do this as part of their weekly activities and along with other health programs on Immunization, Family welfare, Sanitation and Hygiene etc.

As for the second part, the doctors and para-medics should correctly dissipate the information they receive from the emergency centres. They should discourage gossip and speculative talk, and instead instill confidence in the public. All non-governmental channels of public media, both print and mass media, should co-operate with governmental agencies in broadcasting the information given to them by governmental agencies only, and refrain from broadcasting speculative news or views.

During regular interactions with the public through various programs, they should inform the people about the following dos and don'ts:

- Firstly it should be emphasized that the precautions to be taken are similar to those which would be required to be taken during any chemical/ industrial releases/ leaks.
- The only difference in the situation is that, unlike chemical releases, air borne radioactive releases cannot be seen, cannot be smelt and cannot be physically felt.
- Thus any person would find it hard to believe that there is any radioactive spread, but none the less, they should follow instructions.
- Whenever there is information about air borne spread, all the people who are outdoors should cover their mouths and noses with a wet handkerchief. This will prevent any air borne contamination from entering the respiratory and gastro-intestinal tracts.
- While being outdoors, they should not eat anything, particularly food bought from open shops or vendors.
- All those who are outdoors, should try and return home as soon as possible or else enter into the nearest available closed shelters/ homes.

- Before one runs away from the emergency area, one has to ascertain the wind direction. This can be done by a simple method. Take a piece of cloth or a handkerchief and suspend it in the air by holding one corner tip. The cloth will sway towards the wind direction. One should always run perpendicular to this direction to be least affected.
- Shop keepers should close down their shops. Shops selling open eatables like vegetables, fruits, cooked food etc. should immediately cover their goods with a plastic sheet or a tarpaulin, as is commonly done during the rainy season to prevent the goods from getting wet. Therefore shop keepers and vendors should realize the importance of this plastic sheet, and thus keep it with them round the year instead of only for the rainy season.
- After reaching the shelter, please discard the handkerchief in a plastic pouch / polythene bag and keep it aside. The relief officers may require this for assessing the contamination levels. Do not use it again. Keep it out of reach of children, in particular.
- While indoors, please close all the windows and doors.
- Cover all the open food and water cans. Please also cover open food drums/ cans for cattle fodder.
- The village elders or the members of the panchayat should cover any open well with a large tarpaulin and properly secure it with ropes so that it is not displaced by blowing winds. A placard bearing the message “This well is covered on the orders of the Village Panchayat / competent authority can be placed near the well. Please do not remove the cover or consume water for drinking / washing / irrigation / any other purpose until authorized by the Government agencies / Panchayat”. This sign should be in vernacular and pictorial for easy understanding.
- Please listen to Public information notices issued by government agencies only given on Radio, Television or by rescue officers over loud speakers. Please follow the instructions given by them ad verbatim, as they will be relaying the most authentic information and in your interest.
- The information will normally be dynamic, meaning that the instructions will change as per the change in situation. The personnel issuing notices over loudspeakers should number every announcement along with the time of issue. So that villagers do not get confused as to which instruction they are supposed to follow.
- As a standard procedure, the following sequence is to be adhered to: Stay Indoors > Tab Potassium Iodide Distribution > Sheltering > Evacuation > Relief Centres.

a Stay Indoors:

- Whenever there is an announcement for staying indoors, all members of the family should be indoors.
- If possible, keep your cattle inside.
- If the cattle cannot be kept inside, cover their sheds with a plastic sheet or tarpaulin sheet on the windward side so as to block the air borne contamination from settling on and around the cattle.

- Villagers store grains for the family's year-long requirement, and farmers store the harvested grain before it is shifted to open markets for sale. Please cover all such stored grains with plastic sheets or tarpaulin.
 - While indoors, please, use power (electricity consumption) sparingly. Only use those appliances as required. Power supply interruption is expected. If you have multiple cell phones in your family, keep only one in use at a time to conserve battery power. If there is power supply, all cell phones should be charged. This will ensure battery availability in emergency.
 - Do not panic.
 - One should keep listening to radio / T.V. / Public announcements on loudspeakers for further instructions.
- b **Tab Potassium Iodide Distribution:** The relief team may visit the houses to distribute the Tablets of Potassium Iodide, if such a situation is warranted.
- These tablets will protect from developing the ill effects of Radioactive Iodine. This is not a panacea for all radioactive agents. Hence after taking this, one should not have a false sense of confidence that they are fully protected and don't need to follow any further instructions.
 - When the relief teams enquire about the number of family members available in the house, one should say the exact number. The dose of this tablet is one full tablet for adults – both genders, half tablet for children between age from 3 years to fourteen years – both genders, and one fourth tablet for children below the age of three years for both the genders.
 - This medicine is not to be used for cattle. This information is particularly important for members of the public in rural areas where cattle are treated like family members. Pregnant ladies can and must take this tablet.
 - This medicine is safe, and does not have any adverse effects, hence should be taken as and when asked to take. At the time of actual distribution, the person advising may not be a Doctor, but could be any member of the relief team authorized to carry out the task.
 - These tablets are normally available at the nearest PHC or CHC. (The actual number of tablets, based on the population of the affected sectors will be made available through the Emergency control centres for distribution in the target sectors only.
- c **Sheltering:** Sheltering is a step prior to evacuation. People from the affected sector are asked to gather at temporary shelter areas. This is a pre-designated place, viz. a school, college, or any government office building large enough to house the population. Whenever there is an announcement, people should be asked to gather at the shelter area and observe the following:
- They should not run and cause a stampede.
 - They should keep calm. This step is generally taken as a preventive measure and it does not mean that everyone is in danger.
 - All the family members should stay together. Particular care should be taken of the

children, so that they are not far away from the elders of the family. It would be better if an identity badge is pinned on the clothes of children with their names, parents' names, addresses and one contact telephone (cell) number if available.

- Cattle should be left behind. They will be evacuated through suitable means by the veterinary authorities. As a routine practice, evacuation of cattle should precede evacuation of humans, so that the cattle owners have an idea as to who has taken their cattle and where they have been kept for safety. The cattle owners should also be informed about the collection / delivery of their cattle after the emergency. The cattle owners should be encouraged to suitably tag their cattle with identification so that while receiving them back, there are no disputes. Bar coding for identification should be used wherever possible. Safe evacuation of cattle before humans will instill confidence amongst the villagers and their co-operation and compliance with state orders will be better.
- Houses should be locked properly; police force should be deputed to protect the belongings of the evacuated people.
- During evacuation from homes to shelter areas, if possible, plastic or rubber raincoats / rain suits along with cap should be worn. Raincoats / rain suits are advisable, because they cover the complete body and thus any airborne particles settling down would settle on this and would not come in contact with the body. Also, they have an added advantage that radiation (α and β) emitted from the released particles can be blocked by these plastic raincoats.
- Raincoats/ rain suits are to be disposed of when told to do so by authorities in a Yellow colored collection bin. Plastic/ rubber is easier to be decontaminated, hence they are preferred.
- From the shelter point, one should go to relief camps in buses arranged for the purpose by the authorities.
- At the entry to relief camps, raincoats should be removed. They should be disposed properly, without dusting, into the containers placed for the purpose.
- Removing the raincoat will remove most of the externally deposited air borne contamination, if any.
- After this, frisking by radiation detection monitors is to be done.
- All people should maintain calm, and should not try to jump the queue, so that the frisking can be completed in an orderly manner and within a shorter time frame. Any person found with external contamination, should be sent to the nearest PHC / CHC / district hospital for decontamination.
- Decontamination is discussed in the main document (Section 6).
- Others should continue to stay in relief camps until governmental orders to return to their places of residence.
- While in relief camps, instructions are to be strictly followed and hygiene maintained at personal level so that cumulatively the place is maintained clean and hygienic. It is to be

borne in mind that crowded places, if unhygienic, form an ideal platform for the spread of infectious diseases.

- d **Return / Relocation:** After the government gives the green signal to return to respective residences, the following procedures need to be observed.
- Take a proper bath with soap and water.
 - Do not consume the food left behind.
 - Do not consume stored water.
 - Do not pluck fresh vegetables from the shrubs and consume, unless they are cleared for consumption by suitable agencies.
 - Please remove the covers (plastic sheets / tarpaulin sheets) with which you had covered the stored grain / harvested crop / fodder etc., only when permitted by the authorized monitoring agencies.
 - Keep these sheets neatly folded, so that the exterior surface is turned inwards, and dispose them in suitable containers. While folding them, care should be taken to see that the sheets are not dusted. This will prevent the settled contaminated dust from spreading around.
 - Please ensure that the cattle are given a proper bath after they are returned.
 - These cattle will also be monitored by suitable agencies.
 - If the cattle is internally contaminated, the authorities may advise not to consume the milk in case of Cow, Buffalo, Goat, Camel etc. In that case, please avoid consumption of milk and also do not sell it. Care should also be taken to see that the offspring of the cattle are not allowed to suckle. This is because radioactive elements are secreted in the milk in case of internally contaminated animals.
 - The same don'ts are applicable to cattle meant for meat consumption / trading.
 - Water from wells should be consumed only after it is approved for consumption.
 - It may so happen that, the authorities may advise to avoid consumption of hand pumps/ submersible pumps after a lapse of a few days. This delay will be due to delay in contamination of ground water. Normally it may take a few days for the ground water to get contaminated. In this case, do not panic if you have already consumed the water earlier in the interim period. In all probability, it was not contaminated.

Appendix – II

Table of Half Lives

Isotope	Half-lives(days)		
	T Physical	T Biological	T Effective
³ H	4.5 x 10 ³	12	12
¹⁴ C	2.1 x 10 ⁶	40	40
³² P	14.3	1155	14.1
³⁵ S	87.4	90	44.3
⁶⁰ Co	1.93 x 10 ³	10	10
⁸⁶ Rb	18.8	45	13
⁹⁰ Sr	1.1 x 10 ⁴	1.8 x 10 ⁴	6.8 x 10 ³
^{99m} Tc	0.25	1	0.20
¹²³ I	0.54	138	0.54
¹³¹ I	8	138	7.6
¹³⁷ Cs	1.1 x 10 ⁴	70	70
²¹⁰ Po	138	60	42
²²⁶ Ra	5.8 x 10 ⁵	1.6 x 10 ⁴	1.5 x 10 ⁴
²³⁵ U	2.6 x 10 ¹¹	15	15
²³⁹ Pu	8.8 x 10 ⁶	7.3 x 10 ⁴	7.2 x 10 ⁴

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WORK SHEET - 1

Month / YEAR

WORKSHEET FOR ISSUE OF THERMO-LUMINESCENCE DOSIMETERS [TLD]

N.B.: TLD are to be numbered as: No: Type of Health Care Facility*/Name of Place or Location/ Name of District/ Number * PHC / CHC / DH/ MC for Primary Health Center; Community Health Center; District Hospital; Medical College respectively

To be sent to TLD Lab in Duplicate. Second copy to be signed by TLD lab I/c and returned back to the Principal Dispatcher

Sl.No	TLD No. [Example given below]	Name of the Person	Date of Issue	Time of Issue	Date of Return	Time of Return	Total No of Hours Used in Hours & Minutes HH:MM	Signature	Remarks
1	CHC/Dibai/BSR/1								
2	- do - /2								
3									
4									
5									
6									
7									
8									
9									
10									

N.B: (1) This Worksheet needs to be filled for Each day of the Use. (2) If the Decontamination exercise continues on subsequent days, the employees should use the same TLD on each successive day. (3) If a new member joins the team on successive day, s/he should use new TLD. (4) Once the complete decontamination is over for all patients and the Medical Procedures termed as "Complete", the TLDs should be sent to TLD reading Laboratories authorized by Atomic Energy Regulatory Board. These labs will receive the used TLDs for analysis and issue fresh TLDs to the user. Re-numbering of TLDs should be same as mentioned earlier. (5) In event of "no use", these TLDs should be sent to the same laboratories on last working day of every month for issue of fresh TLDs.

Signature of the I/c
Decontamination Team

DD/MM/YYYY

[Date of Dispatch of all Above TLDs to TLD Lab authorized by AERB]

DD/MM/YYYY

[Date of Receipt of all Above TLDs by TLD Lab authorized by AERB]

Signature of

TLD Lab In-Charge

WORK SHEET - 2

REPORT FOR THE: Month / YEAR

WORKSHEET FOR THERMO-LUMINESCENCE DOSIMETERS [TLD] ANALYSIS REPORT

N.B.: TLD are to be numbered as: Type of Health Care Facility*/Name of Place or Location/ Name of District/ Number * PHC / CHC / DH/ MC for Primary Health Center; Community Health Center; District Hospital; Medical College respectively

To be sent to I/c Decontamination Team/ Principal Dispatcher from whom received in Duplicate. Second copy to be signed by Decon Team I/c and returned back to the TLD lab

Sl.No	TLD No. [Example given below]	Name of the Person	Total No of Hours Used in Hours & Minutes HH:MM	Date of Receipt of TLD	Date of Analysis of TLD	Dose in mSv	Signature	Remarks
1	CHC/Dibai/BSR/1							
2	- do - /2							
3								
4								
5								
6								
7								
8								
9								
10								

N.B: (1) This Worksheet needs to be filled for each day of the Use. (2) If the Decontamination exercise continues on subsequent days, the employees should use the same TLD on each successive day. (3) If a new member joins the team on successive day, s/he should use new TLD. (4) Once the complete decontamination is over for all patients and the Medical Procedures termed as "Complete", the TLDs should be sent to TLD reading Laboratories authorized by Atomic Energy Regulatory Board. These labs will receive the used TLDs for analysis and issue fresh TLDs to the user. Re-numbering of TLDs should be same as mentioned earlier. (5) In event of "no use", these TLDs should be sent to the same laboratories on last working day of every month for issue of fresh TLDs.

Signature of the I/c TLD Lab	DD/MM/YYYY [Date of Dispatch of Report of TLDs t I/c Decon Team]	DD/MM/YYYY Date of Receipt of all Above TLD Reports by I/c Decon Team	Signature of I/c Decon Team
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WORKSHEET 3**DECONTAMINATION / TREATMENT CASE SHEET**

- 1 Name of Decon / Treatment Facility : [e.g] CHC / Dibai / BSR [short for District Bulandshahr]
- 2 Nature of Emergency : NPP / RDD / OS [Nuclear Power Plant / Radiological dispersal Device / Orphan source]
- 3 Likely radio-Isotopes Involved :
- [Information to be provided by Radiological Monitoring Authorities]*
- 4 Date & Time of Emergency Declared : DD/MM/YYYY at HHMM in 24 hour clock
- 5 Name of the Patient :
- 6 Sex : M / F If Female: Pregnancy : Yes / No
- 7 Age : _____ Years Date of Birth [If Av] : DD/MM/YYYY
- 8 Address :
- 9 Sector around NPP : "A" to "P"
- [mention mandatorily in event of Emergency due to NPP]*
- 10 Identification Document no : _____
[If Av. Viz. Aadhar/Voter ID etc] _____ (Specify type)
- 11 Patient Number : CHC/Dibai/BSR/REM*/OPD/Number dated DD/MM/YYYY
* radiological emergency management
- 12 Likely Date & Time of Exposure : DD/MM/YYYY at HHMM Hrs in 24 hour & [T1] Minute mode *[This shall be provided by the Authorities tracking the spread of contamination in association with Environmental Survey Reports]*
- 13 Change of Clothes and Bath Given : Yes / No If Yes: mention place If No : Do it
- 14 Oral Tablet Potassium Iodide : Yes / No If Yes: mention Date & Time Given Dose Given: 1 Tab / ½ Tab / ¼ Tab If No : Give stat
- 15 Whether Wet Cloth Used to cover the Nostrils : Yes / No
- 16 Past History : DM / HT / Chronic Pulmonary Diseases / CVA / IHD / Hypothyroid / Hyperthyroid / Malignancies / Congenital Anomalies / Others / NIL
- Details if Yes : _____
- 17 Additional History for Females : L.M.P.: DD/MM/YYYY
LCB. : DD/MM/YYYY
Obstetrics History : G__P__A__L__ [M__, F __]

- 18 History of Known Drug allergies : _____
- 19 Regular Treatment : (if any) _____

- 20 Classify Present Case as : (Please Tick the relevant Box)
- Only External Contamination [Take up for Decontamination]
 - No External Contamination but with only Internal Contamination – likely to occur only by route of inhalations or Ingestion [Internal Decontamination at Primary/Secondary Health Center if Dose <1Gy, at Tertiary Center if Dose ≥ 1 Gy. Initiate decontamination before transfer]
 - Both External Contamination & Internal Contamination [Simultaneous External & Internal Decontamination at Primary/Secondary Health Center if Dose <1Gy, at Tertiary Center if Dose ≥ 1 Gy. Initiate decontamination before transfer]
 - Open Wounds [Injuries] with contamination [Decontaminate wounds as priority]
 - Open Wounds [Injuries] without contamination [Clean & Cover wounds with waterproof dressing to prevent contamination from entering]
 - Only Exposure and no contamination whatsoever [OPD Treatment if Dose < 1 Gy; transfer to tertiary care center if Dose > 1 Gy.]
 - Co-Morbid Conditions with Contamination [Attend to Co-morbid Life threatening conditions first, Take up Decontamination when patient is stable]
 - Co-Morbid Conditions without Contamination [Attend to medical emergencies, if no emergency treat on OPD with counseling]
- 21 Possible Routes of Exposure : Absorption / Inhalation / Ingestion
- 22 Physical Dosimetry Doses : External _____ m Sv; Internal ____ m Sv; Total ____ m Sv
- 23 Present Complaints : Nausea / Vomiting / Loose Motions / fever / Headache / Tingling Numbness
- Nausea : Yes / No Time of Onset _____
- Vomiting : Yes / No [T2] Time of Onset _____ Frequency: ____ nos / hr
- Loose Motions : Yes / No Time of Onset _____ Frequency: ____ nos / hr
- Fever : Yes / No Time of Onset _____
- Headache : Yes / No Time of Onset _____
- Headache Location : Frontal / Temporal / Occipital / Parietal / Complete
- Side affected : Unilateral - Right / Left; OR Bilateral
- Associated Neck Pain : Yes / No

Giddiness : Yes / No

24 Clinical Findings:

General condition : Healthy / Weak / Debilitated

Level of Consciousness : Conscious / Drowsy / Stupor / Confabulated / Coma / Unconscious

Breathlessness : Yes / No

Pulse : _____ / min

B.P. : _____ mm Hg

Temp. : _____ ° F

Body Weight : _____ Kgs

Cyanosis : Yes / No

Pallor : Yes / No

Clubbing : Yes / No

Congenital Anomalies : Yes / No Details: _____

Breath Sounds : Normal / Adventitious

Heart Sounds : Normal / Added Sounds
If Normal – Rhythm: Regular / Irregular

Goitre : Yes / No

25 Send Following Sample for Assessment: *Please tick the tests for which the samples are sent as checklist*

Sample	Investigation Advised	Quantity	Container	First Sample At what Time	Frequency thereafter	Dispatch To
Blood	CBC; including Differential Count and Absolute Lymphocyte Count	2 cc	Ethyl Diamine Tetra Acetic acid [EDTA] Vacutainer	Within 3 Hrs of Exposure	Once every 6 Hourly upto 48 Hrs. Thereafter as per need	Can be done locally in PHC also
- do -	RBS,	2 cc	Sodium Flouride Vacutainer	On Admission	Clinician's Decision	- do -
- do -	Urea, Creatinine, LFT, Electrolytes	3 cc	Plain Vacutainer OR SST[Serum Separation Tube]	On Admission	Clinician's Decision	- do -

Urine	Routine Microscopic & Creatine – creatinine clearance ratio	5 cc	Clean Plain Test Tube	On admission	Clinician's Decision	- do -
- do -	Baseline metabolites of Radionuclide	10 cc	In a Sterile Test Tube	On Admission	24 hour collection every 24 Hourly until internal decontamination successfully termed as OVER	To Laboratories Authorized by CMO
Stool / Faeces	Baseline metabolites of Radionuclide	Complete Void	Clean Container	First Sample after admission	24 hour collection every 24 Hourly until internal decontamination successfully termed as OVER	To Laboratories Authorized by CMO
Swabs from body orifices	To assess possibility of Internal contamination–	Single swab	Clean Test Tube	Before Decontamination	After decontamination,	Radiological Monitoring Team
Swabs from Wound	- do -	Single swab	- do -	- do -	- do -	- do -

26 Additional Tests :

- ECG for elderly or if clinical condition warrants
- Oxygen saturation by Pulse Oximetry – if Contamination by Inhalation is suspected or if clinical condition warrants
- Penicillin sensitivity Test before commencing treatment with Cap DPenicillamine.
- Semen Examination for Males:
 - a First sample within Forty days of Exposure [for base line studies. Earlier the better] dt _____
 Total Sperm count _____ Live Sperm Count _____, Dead Sperm Count _____
 Motility Percentage _____
 - b Second sample after 60 days of exposure: dt _____
 Total Sperm count _____ Live Sperm Count _____, Dead Sperm Count _____
 Motility Percentage _____
- Serial colored photography for Skin Burns: [Please number each photo serially with date for respective patients]

- Plethysmography
 - Thermography
 - Color Doppler of the affected limb in case of skin Burns
 - EEG
 - Electron Spin Resonance
 - Chromosomal Aberrations Studies. Send the patient to the lab for sample collection
- 27 Based on the requirement commence decontamination procedures as detailed in respective chapters of the main document. You can also refer to Checklist 1 for external Decontamination and Checklist 2 for Internal Decontamination as ready reckoner
- 28 Proceed and Fill in the Supplements to this WS 3 for easy management

Supplement 1 of WS 3
DETAILS OF WOUNDS AND CONTAMINATION

Name :

Patient No:[vide No11 on Pg 1]

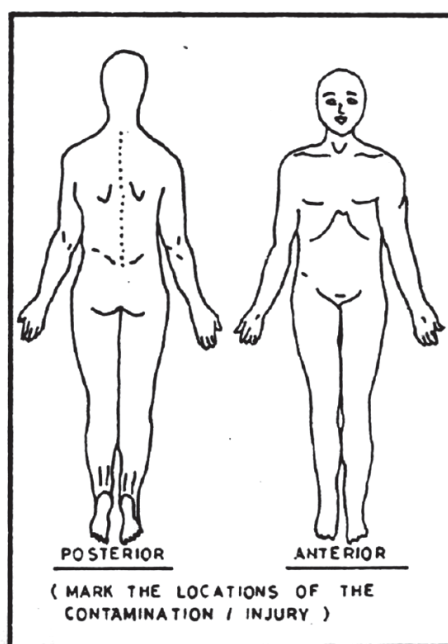
Before Decontamination / After Decontamination

Date: DD/MM/YYYY Decontamination Attempt No: _____

Time of Commencement: HHMM Time of Termination: HHMM

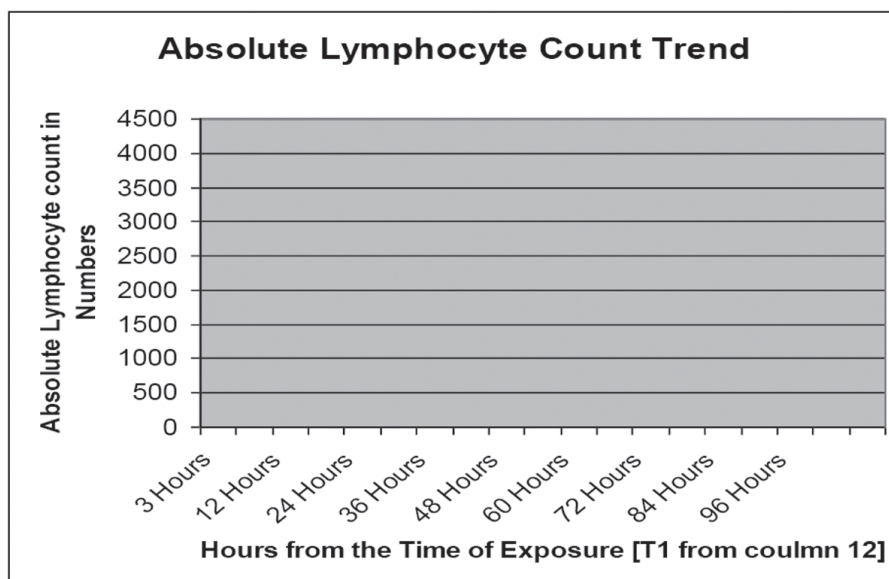
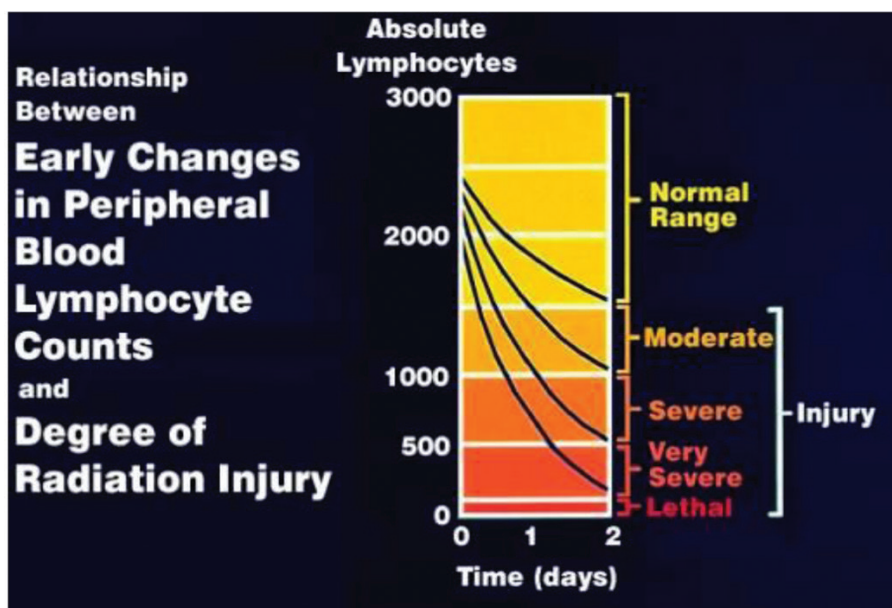
Reasons for Termination: _____

<u>IDENTITY TAG</u> (FIRST-AID POST)	
NAME :	
DEPT :	DIVN. :
CONTAMINATION :	Y / N
SITE OF CONTAMINATION :	
INJURY :	Y / N
SITE OF INJURY :	
OVEREXPOSURE :	Y / N
NAUSEA : Y / N , VOMITING: Y / N	
<u>PRELIMINARY ACTIONS TAKEN :</u>	
TREATMENT :	
FIRST AID :	
DECONTAMINATION :	
TO: PERSONNEL DECONTAMINATION CENTRE / SITE HOSPITAL	



- Please mark on the diagram the areas of wounds / injuries and contamination.
- Please fill this supplement 1 at the start and end of Each sittings [attempts] of Decontamination
- For Detailed Decontamination Procedure refer to the main document

Supplement 2 of WS 3



N.B.: Please plot the Absolute Lymphocyte Count of the patient and compare with the standard Andrew's nomogram given above to ascertain the extent of Radiation Injury

WORKSHEET 3

Supplement 2 of WS 3

Ready Reckoner for Dose Probability & Treatment Decision From Whole Body

Exposure Based on Time To Vomiting

i.e. Time of Occurrence of Vomiting [T2 from Column 23] – Time of Exposure [T1 from Column 12]

Whole Body Exposure		Decision
Clinical Signs	Absorbed Dose – Gy	
No Vomiting	< 1 Gy	Decontaminate if needed. OPD with 5 weeks surveillance period. Skin and Blood Examinations
Vomiting 2-3 Hrs after Exposure	1 – 2 Gy	Decontamination and Surveillance in General Hospital like CHC / District Hospital
Vomiting 1 -2 Hrs after Exposure	2 – 4 Gy	Decontamination and hospitalization in Burns ward / Haematological ward. Civil Hospitals / Medical Colleges
Vomiting earlier than 1 Hr after Exposure [and / or other severe symptoms, e.g.: Hypotension]	> 4 Gy	Hospitalization in a Tertiary Hospital with Haematological & Surgical Departments. Super Specialty Medical Colleges / Hospitals

Probable Dose Estimation of this patient _____ Gy

- Findings of Supplements 1 and 2 of WS 3 on initial assessment will decide on the requirement of Admission
- Supplements 1 and 2 may be required to be filled in even after admission. Continue to do that as additions to indoor sheet
- If Admitted Fill in the Supplement 3 as Indoor Paper
- If the patient is transferred to other hospital, please send a copy of the complete WS 3 along with the patient so as to maintain the continuity of information and treatment between two health care centers
- Transferred to _____

Place

Date

(Signature of the I/c Decontamination Team)

WORKSHEET 3

Supplement 3 of WS 3

INDOOR ADMISSION PAPER

*Imp.: This should always be filled in as a continuation to the WS 3 with its Supplements 1 & 2.
Not to be filled as a stand-alone form*

Admitted from the OPD of the same Center	: Yes / No
If No – Center from where transferred In	: _____
Date and Time of Transfer in	: DD/MM/YYYY at HHMM
Patient Number [OPD Treatment]	: [vide column 11]

Name of Indoor Admitting Center : [e.g.] CHC / Dibai / BSR [short for District Bulandshahr]
 Date and Time of Admission : DD/MM/YYYY at HHMM Hrs
 Indoor Admission Number : CHC/Dibai/BSR/REM*/IPD/Number
 * Radiological emergency Management

 Status of External Contamination – Yes / No.

Decontamination Successful : Yes / No

If Yes : Treat for the effects of radiation if dose exposure > 1 Gy

If No : Carry out Decontamination until successful

 Status of Internal Contamination – Yes / No Probable Route of Entry: Inhalation / Ingestion / Absorption

If Yes : Respiratory / G.I.

Decontamination Done : Yes / No

Decontamination successful : Yes / No

If Yes : Management of Effects of Radiation depending upon Dose

If No : Carry out Internal Decontamination until successful

 For Procedures of Decontamination follow the main document chapters

Supplement 4 of WS 3

CONTINUATION SHEET FOR DAILY NOTES FOR INDOOR SHEET

[Please make your daily clinical notes entry with date and time. Use additional sheets of this supplement 4 as needed until discharge]

WORKSHEET 3

Supplement 5 of WS 3

DISCHARGE PAPER

- 1 Name of Discharging Hospital : [e.g.] CHC / Dibai / BSR [short for District Bulandshahr]
- 2 Name of the Patient :
- 3 Sex : M / F If Female: Pregnancy : Yes / No
- 4 Age : _____Years Date of Birth [If Av] : DD/MM/YYYY
- 5 Address :
- 6 Indoor Admission Number : CHC/Dibai/BSR/REM*/IPD/Number
*Radiological emergency Management
- 7 OPD Patient Number : CHC/Dibai/BSR/REM*/OPD/Number
* Radiological emergency Management
- 8 Date of Admission : DD/MM/YYYY
- 9 Date of Discharge : DD/MM/YYYY
- 10 Nature of Emergency : NPP / RDD / OS [Nuclear Power Plant / Radio-Logical dispersal Device / Orphan source]
- 11 Likely radio-Isotopes Involved :
[Information to be provided by Radiological Monitoring Authorities]
- 12 Date & Time of Emergency Declared: DD/MM/YYYY at HHMM in 24 hour clock
- 13 Sector around NPP : "A" to "P"
[mention mandatorily in event of Emergency due to NPP]
- 14 Identification Document no : _____
[If Av. Viz. Aadhar/Voter ID etc] _____(Specify type)
- 15 External Contamination : Yes / No
- 16 Successful Decontamination : Yes / No
- 17 If No -Residual Contamination : _____(Plz Specify)
- 18 Residual Contamination Acceptable : Yes / No : If No – Advice Regular Follow Up
- 18 Internal Contamination : Yes / No
- 19 Decontamination Successful : Yes / No
- 20 If No -Residual Contamination : _____(Pl. Specify)
- 21 Residual Contamination Acceptable : Yes / No : If No – Advice Regular Follow Up
- 21 Clinical Condition:

WORKSHEET 3

Parameter	Presenting Initially [on OPD]	On Admission	On Discharge
Pulse Rate			
B.P.			
Resp. Rate			
Level of Consciousness	Conscious/ Drowsy/Stupor/ Confabulated/Coma/ Unconscious	Conscious/ Drowsy/Stupor / Confabulated/Coma/ Unconscious	Conscious
Body Weight	Kgs	Kgs	Kgs
Cyanosis	: Yes / No		
Pallor	: Yes / No		
Clubbing	: Yes / No		
Congenital Anomalies [Specify]			
Breath Sounds			
Heart Sounds	Normal/ Added Sounds	Normal/ Added Sounds	Normal/ Added Sounds
If Normal – Rhythm:	Regular / Irregular	Regular / Irregular	Regular / Irregular
Goitre			
TLC	/ c.c		
DC	P L M E B	P L M E B	P L M E B
Absolute Lymphocyte Count			
Absolute Neutrophil Count			
Platelets			
Hb			

22 Radiological Condition:

a On Initial Reporting on OPD

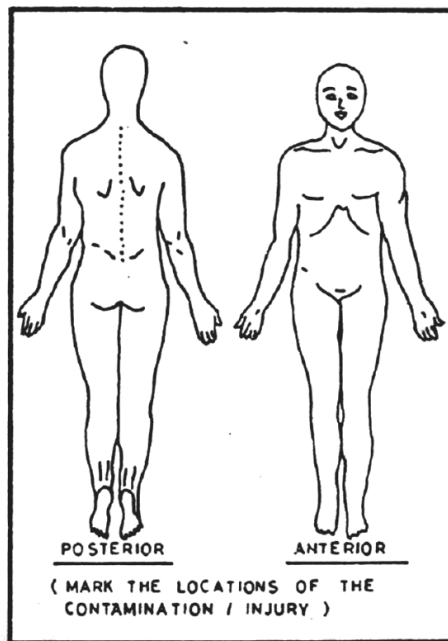
IDENTITY TAG
(FIRST-AID POST)

NAME :
 DEPT: DIVN.
 CONTAMINATION : Y/N
 SITE OF CONTAMINATION :
 INJURY : Y/N
 SITE OF INJURY :
 OVEREXPOSURE : Y/N
 NAUSEA: Y/N , VOMITING: Y/N

PRELIMINARY ACTIONS TAKEN :

TREATMENT :
 FIRST AID :
 DECONTAMINATION :

TO: PERSONNEL DECONTAMINATION
 CENTRE /SITE HOSPITAL



b On Admission

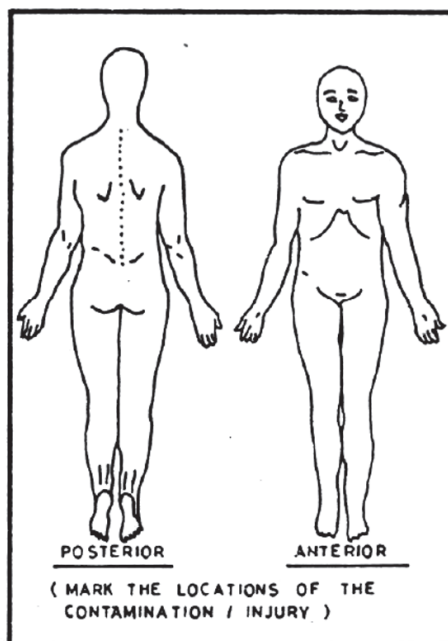
IDENTITY TAG
(FIRST-AID POST)

NAME :
 DEPT: DIVN.
 CONTAMINATION : Y/N
 SITE OF CONTAMINATION :
 INJURY : Y/N
 SITE OF INJURY :
 OVEREXPOSURE : Y/N
 NAUSEA: Y/N , VOMITING: Y/N

PRELIMINARY ACTIONS TAKEN :

TREATMENT :
 FIRST AID :
 DECONTAMINATION :

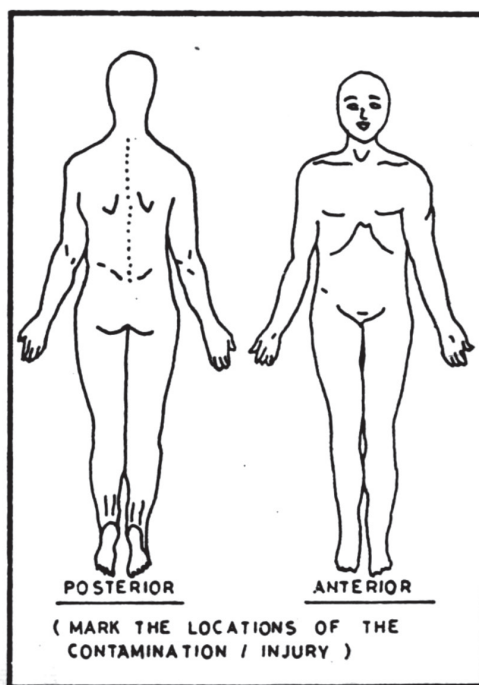
TO: PERSONNEL DECONTAMINATION
 CENTRE /SITE HOSPITAL



c On Discharge

IDENTITY TAG
(FIRST-AID POST)

NAME :
 DEPT: DIVN.
 CONTAMINATION : Y/N
 SITE OF CONTAMINATION :
 INJURY : Y/N
 SITE OF INJURY :
 OVEREXPOSURE : Y/N
 NAUSEA: Y/N , VOMITING: Y/N
PRELIMINARY ACTIONS TAKEN :
 TREATMENT :
 FIRST AID :
 DECONTAMINATION :
 TO: PERSONNEL DECONTAMINATION
 CENTRE /SITE HOSPITAL



23 Status of External Contamination:

Area of the Body [including orifices]	Radionuclide	Type of Radiation	On Initial Reporting on OPD in cps	On Admission in cps	On Discharge in cps

24 Status of Internal Contamination:

Area of the Body	Radionuclide	Type of Radiation	On Initial Reporting on OPD		On Admission		On Discharge	
			In cps	In K Bq	In cps	In K Bq	In cps	In K Bq

Compare the findings with Effective Half life to ascertain the level of elimination of the radionuclide from the body.

25 Treatment on Discharge:

26 Advice on Discharge: Keep in account the co-morbid conditions

Food: _____

Water: _____

Investigations at what frequency: _____

27 Advice for Follow Up:

Place: *(Specify where the patient is supposed to follow up at original PHC/CHC or the Discharging hospital)*

Scheduled Date & Time of First Follow up: _____

Subsequent Follow up Frequency: Weekly / Monthly / Yearly

Place
Date

Signature of the Treating Doctor

- a For follow up plain continuation sheets can be used or any of the supplement's page can be used. Specify date of follow up and the Number of follow up at the Top of the page. Always give [and note it on the paper] the next date and time of follow up as a part of advice
- b Original Discharge sheet will remain in continuation with the WS 3 with all its supplements
- c The complete set will remain with the hospital discharging the patient [i.e where the patient is last admitted in the chain of transfers]
- d A Copy of the complete set of WS 3 with all its supplements including supplement 5, will be dispatched to each of the health centers attending to the respective patient prior to last admission/treatment; one copy of the same will be sent to the O/o Chief Medical Officer of the District; and one copy should be submitted to the Atomic Energy Regulatory Board.
- e All investigation reports are to be enclosed with the original case sheet
- f If photographs are taken for assessment of skin damage including burns, they should be properly laminated and retained with the original case sheet until treatment is over. After which they may be submitted to the O/o CMO of the District.
- g O/o CMO shall retain all the papers until 30 years from the time of completion of treatment / 90 years of age or the death of the person which ever is later.

Finally all papers Submitted to the O/o C.M.O. of the District

By: _____ on Date DD/MM/YYYY
Signature with Name and Designation of the I/c of the last Treating
Health care facility

Received in the O/o CMO

By _____ on Date: DD/MM/YYYY
Signature with Name and Designation of the person receiving
The papers in the O/o CMO

Final Remarks by the C.M.O.: _____

Date
Place Official Seal
Filed in File No:

Signature of the CMO

Checklist 1 for WS 3 - External Decontamination

- 1 Wounds : Clean with wet swabs, dose assessment of swabs, discard as solid waste. Flush wounds with normal saline, Evert the edges to clean undersurface of edges. Flush until decontamination is complete or e/o imminent bleeding from the wound floor is observed. Flush specific decontamination solution depending upon radio-nuclide. If painful use 4% Xylocaine jelly. All scabs should be collected for Dose assessment.
- 2 Ears : Dry wipe with Ear Buds. Wet wipe with Moist Ear bud [moist--ioned with Distilled water / NS. Collect in labeled plastic pouch. Dose assessment. Discard as solid waste. Do not syringe the ear. In Case of perforated Tympanic membrane, contamination from External Ear will enter Middle ear. Decontaminating Middle Ear Would be difficult
- 3 Nose : Blow the nose on Tissue paper, dose assessment, discard in labeled plastic pouch as solid waste. Dry wipe with Buds followed by wet buds as above. Dose assessment and discard as solid waste
- 4 Oral cavity : Rinse with water. Collect the liquid, dose assessment, discard as Liquid waste. Repeat rinse with medicated gargles. Discard all Collections as liquid waste.
- 5 Eyes : Eye wash with distilled water or Normal saline. Wash from Medial canthus to Lateral canthus as opening of lacrimal duct is close to medial canthus. Through lacrimal duct contamination can spread to pharynx and further to GI tract. While Eye wash cover the Ipsilateral ear complete with a water proof covering. Collect the eye wash liquid and discard as Liquid waste.
- 6 Hair : Decontaminate using 4% Cetrimide Shampoo / Shave and collect in labeled plastic pouch. Dose assessment. Discard as Solid waste
- 7 Nails : Nail Clipping – collect in labeled plastic pouch. Dose assessment. Discard as solid waste
- 8 Nail Beds : Decontamination with 1% Cetrimide solution
- 9 Hot Spots : Mark the hot spots. Clean from periphery to center. Priority to areas with higher contamination. All gauze pieces, cotton balls etc used are to be discarded as solid waste. If any solutions are used, discard them as liquid waste.

Order of General cleansing to be done with

- a 1% cetrimide solution,
- b 5 % Sodium hypochlorite [for face further dilution to 1:5 ratio],
- c Saturated solution of Potassium Permanganate,
- d For removing stains of KMnO₄ use 10% solution of Sodium bisulphite

For specific Cleansing –

- a 1% DTPA solution for Plutonium & transplutonics, Iodine, Cesium, Ruthenium, Barium, Lanthanum, and Cobalt
- b Potassium Rhodizonate crystals for Wounds with Strontium
- c 1.4% Soda-Bicarbonate solution for Uranium
- d Lugol's Solution for Iodine
- e Acetic acid solution at pH 4 to 5 OR Vinegar for Phosphorous.

Finally dress the area with Lanolin dressings

Checklist 2 for WS 3 – Internal Decontamination

- | | | |
|-------------|---|---|
| G.I. Tract | : | <ul style="list-style-type: none"> a Insert Ryle's Tube. Give Gastric Lavage with normal saline or Water. Collect all lavage liquid. Dose assessment. Discard as Liquid waste. Discard RT as solid waste. b Start I.V. Line – Normal saline / Isolyte M / 5 % DNS c Give Mucaine gel / Magaldrate / Sucralfate antacid 30 ml d Mag Sulph solution [saline purgative] for Radium. e Give Enema for enhancing elimination from colon f Potassium Iodide for Iodine. Propyl thiouracil or Methimazole if very high contamination g Stable phosphate for ³²P h Oral / I.V. Calcium Gluconate for Strontium. Oral ammonium chloride along with IV Cal Gluconate is more effective i Ca DTPA / Zn DTPA for Plutonium contamination j Discard all tubing and disposables as solid waste |
| Resp. Tract | : | <ul style="list-style-type: none"> a DTPA aerosol for Plutonium inhalation b Monitor Oxygen Saturation by Pulse Oximeter c Oxygen Inhalation SOS. d Pulmonary Lavage weighing Risk V/s Benefits Decision jointly to be taken by Surgeon/Physician/Anaesthetist For patients with Age below 30 yrs a maximum permissible Lung burden [MPLB] of 100 shall be the safe criterion. Can Also be done with MPLB of 50 with due risks explained. First lavage ideally within 1 hour or after 2-3 days. Thereafter twice a week for two weeks, followed by once a week for total ten lavages. Lavage with Normal Saline [9gms NaCL / Ltr]. DTPA [1gm / Litre] may be added to lavage fluid. Each washing should be for 3 minutes. Collect all lavage fluid in labeled containers and send for Histological and Radio-toxic studies. e discard all tubing and catheters as solid waste. |

WORKSHEET 4

Movement Record of Radio-active Waste Material

Name of Health Centre Generating Waste : CHC/Dibai/BSR

Waste Consignment No. : _____

Date of Dispatch : DD/MM/YYYY

Sl.No.	Bag / Container No	Type of waste – Solid / Liquid	Date of Collection	Remark – Decontaminate / Dispose

Date _____ Signature of Sister I/c _____ Sent To: Name of AERB Authorized Waste Decontamination / Disposal OR MO I/c Health Centre of the District [WDC]

Received at WDC : On : DD/MM/YYYY _____ Signature of the I/c WDC

N.B: Fill this in Duplicate. One copy should be signed by I/c WDC on receipt of bags/containers and sent back to MO I/c Of the Health centre sending the waste. One copy of this should be sent to O/o CMO by the I/c WDC along with the report after analysis on WS 5

WORKSHEET 5

Report of Status of Radio-active Waste Material

Name of AERB Authorized Waste Decontamination / Disposal Centre of the District [WDC]: _____

Name of Health Centre Generating Waste : CHC/Dibai/BSR Waste Consignment No: _____

Date of Dispatch of report : DD/MM/YYYY Report No: _____

Sl.No.	Bag / Container No	Type of waste – Solid / Liquid	Date of Decontamination/ Disposal	Material Decontaminated & Returned for reuse	Remark – Decontaminated/ Disposed

Date Signature of I/c WDC Dispatched to : Health Centre Generating Waste

Report Received at Health Centre : On: DD/MM/YYYY Signature of the M.O. I/c Health Centre

N.B: Fill this in Duplicate. One copy should be signed by M.O. I/c Health Centre on receipt of this and sent back to I/c WDC One copy should be submitted o O/o CMO by MO I/c Health Centre

Annex-1

Radiation Effects

Deterministic Effects:

These effects are known to occur at high radiation doses received over a short period. They have a threshold dose below which they do not occur. The severity of these effects is proportional to the dose and is generally associated with the death of large fraction of cells in a specific organ or tissue e.g. Radiation Sickness, Hematopoietic/Gastro-Intestinal/Neuro-Vascular Syndromes, Cataract, Sterility- either temporary or permanent, and Skin Burns.

Stochastic Effects:

They are probabilistic in nature and are observed for exposures in excess of 100mSv but as a conservative estimate treated as not having any threshold. Probability of incidence increases with dose rather than severity. If the non-lethal genetic alteration occurs in somatic cells, it is a precursor for carcinogenesis, and if it occurs in germ cells, it may result in genetic disorders in progeny of exposed individuals.

Radio-sensitivity:

Radio-sensitivity varies in different types of tissue. While all cells can be destroyed by a high enough radiation dose, highly radiosensitive cells or tissue exhibit deleterious effects at much lower doses than others. As stated in the Bergonié-Tribondeau law, rapidly dividing, undifferentiated cells in tissue are most sensitive to radiation effects. Several of the most sensitive tissues and systems follow this law.

Highly radiosensitive tissue- lymphoid, bone-marrow elements, gastrointestinal epithelium, gonads (testis and ovary) and foetal tissue.

Moderately radiosensitive tissue- skin, vascular endothelium, lung, kidney, liver, lens and thyroid glands in childhood.

Least radiosensitive tissue- central nervous system, endocrine (except gonad), thyroid glands in adults, muscle, bone and cartilage and connective tissue. The least radiosensitive tissue, although radio-resistant, is less capable of cell renewal than highly sensitive tissue. Some - especially neurons, glial cells of the brain and muscle cells - have essentially no ability to regenerate. Once these cells are killed, the area is repaired by fibrosis or scarring.

Effects on Hematopoietic System:

Most sensitive are the stem cells of the bone marrow, which give rise to all circulating blood cells and platelets and the lymphoid tissue found in the spleen, liver, lymph nodes and thymus.

Normal cellularity of bone marrow is characterized by a hetero-cellular population consisting of progenitor cells, fat (or adipose) cells and supporting reticular cells and stroma. The progenitor cells include the erythroid, myeloid and megakaryocytic stem cell series.

Normal bone marrow cellularity appears under the microscope as clear spaces that are fat cells, pink-stained angular bodies that are spicules on normal bone and diffuse haematopoietic tissue.

Haematopoiesis takes place in the bone marrow, except for T-lymphocytes, which are generated in the thymus. All haematopoietic lineages arise from the stem cell. The stem cell progressively differentiates towards the stage of progenitor until the mature cells are released in the blood.

Bone marrow kinetics - The bone marrow contains three cell renewal systems: the erythropoietic (red cell), the myelopoietic (white cell) and the thrombopoietic (platelet). The time cycles, the cellular distribution patterns and post-irradiation responses of these three systems are quite different. Studies show that a pluripotential stem cell gives rise to these three main cell lines in the bone marrow. Besides this stem cell, each cell renewal system consists of stem cell compartments for the production of erythrocytes, leukocytes (lymphocytes, granulocytes, monocytes, etc.) or platelets; a dividing and differentiating compartment; a maturing (non-dividing) compartment; and a compartment containing mature functional cells. Research studies suggest that each of these cell renewal systems operates under the influence of regulating factors, primarily at the stem cell level, through a negative feedback system initiated in large measure by the level of mature circulating cells in the peripheral blood. Normally, a steady state condition exists between new cell production by the bone marrow and the number of functional cells. Morphological and functional studies have shown that each cell line, i.e. erythrocyte, leukocyte and platelet, has its own unique renewal kinetics. The time related responses evident in each of these cell renewal systems after irradiation are integrally related to the normal cytokinetics of each cell system.

Modifying Factors:

Numerous physical, chemical and biological factors influence the response to radiations. Packed ionizing radiations are generally more hazardous and have relatively higher biological effectiveness. Exposure rate is an important factor. Low dose rate exposure, protracted exposure and fractionated exposure produce far less damage as compared to acute exposure. Nature of irradiated tissue also determines the severity of effect. Age, gender, physiological status and immune status of the individual also determine the extent and severity of radiation effects. Infants and children are more sensitive to effects of radiation, particularly due to the active process of division of cells and development of organs occurring in early childhood.

Cartilage in early childhood is seriously affected by a fractionated dose of 10 Gy. This can result in stunted growth and defective skeletal development. Irradiation during puberty can impair development of breasts in females. Children subjected to brain irradiation during radiotherapy have been observed to have suffered from loss of memory, and personality disorders.

Annex-2

Some information on contamination with radioactive material/isotopes

Radioactive Contamination

Brief information about contamination with radioisotopes are:

1	Radioactive contamination is the presence of radioactive material – either in the form of dust particles, suspended particulate matter or liquid or gas – on or in the body of a person.
2	When the radioactive dust, particles, liquids or gases are deposited on the external part of human subject or on the skin, it is termed as External Contamination
3	When the radioisotopes had gained entry inside the body through ingestion, inhalation or absorption through wounds or intact skin, it is called as Internal Contamination.
4	A contaminated person is a source of radiation to himself and to others in the vicinity and may lead to the spread of contamination.
5	Usually, radioactive contamination is not immediately threatening to life and its effects will depend upon the type and energy of radiation.
6	Alpha particles are heavy and positively charged and ionize the matter densely and do not penetrate much. Alpha particles have a propagation range of no more than about 5 cm in the air and can be obstructed even by a moderately thin sheet of paper. The stratum corneum layer of the skin effectively shields the basal layer of skin since alpha particles have a range of 0.04 mm in soft tissue and, hence, do not reach Basal layer of skin. Contamination with alpha emitters can be of concern if inhaled, ingested or absorbed through broken skin. Internal contamination with alpha emitters poses a severe hazard because they affect the target organs severely.
7	Beta particles comprise of negatively charged particles with a little mass. The propagation range of beta particles in air is approximately 3.65 m / MeV of kinetic energy. Beta particle of 70 KeV energy or more can penetrate the Epidermis and can cause the irradiation of subcutaneous tissues and can also cause “Beta Burns”. It is important to note that passage through one millimeter of tissue will reduce most beta radiation by a factor of 2 or more. Hence the dose of beta radiation in the subcutaneous tissue is much less than that recorded on surface. Internal contamination with beta emitters poses hazard because they transfer a significant fraction of their energy to the organ in which they penetrate, i.e., the target organ.
8	X-rays and Gamma rays are non-particulate electromagnetic radiation having no mass and charge. They can penetrate deep into the body tissues and deep seated organs. Higher the energy absorbed in the target tissue, greater is the damage caused.
9	Maximum permissible level allowed for fixed skin contamination is – 0.4 Bq / cms ² - For Alpha emitters and 4.0 Bq / cms ² - For Beta and Gamma emitters.

Annex-3

External Decontamination Kit

External decontamination Kit should have the following:

a	Cotton long handle swabs and forceps	n	5 % Sodium bi-sulphite solution
b	Cotton balls, Surgical cotton roll	o	Soda-bicarbonate solution
c	Surgical Gloves	p	Sodium bisulphite powder
d	Sterile gauze, roller bandages	q	Potassium Rhodizonate crystals
e	Marking pens to mark contamination areas	r	Dilute Hydrochloric acid
f	Masking Tape	s	Lugol's solution
g	Soft brushes / Loofahs	t	Sodium Hyposulphite
h	Nail cutters, Razors, Shaving foam gel, soap, brush, Shampoo, Scissors	u	Acetic acid (pH 4-5) or Simple Vinegar
i	Detergents	v	0.2 N Sulphuric acid
j	1 % Cetrimide solution	w	4% Xylocaine Jelly
k	5% Sodium Hypochlorite solution	x	Sample collection vials
l	Saturated solution of KMnO ₄	y	Adhesive labels
m	1% DTPA solution and 25% DTPA	z	Adequate number of Plastic zipper pouches for collecting solid wastes viz. hair and nail samples, contaminated personal belongings viz. wrist watches, rings, etc

Adequate large yellow plastic bags to collect waste arising out of decontamination procedure wastes viz. contaminated gauze, cotton, blades, etc.

Internal Decontamination Kit

Internal decontamination kit should have the following things

A	Potassium Iodide/ Iodate tablets
B	Micronized powder of DTPA for inhalation

C	Aerosol generator (Nebulizer) for inhaling DTPA
D	Ca DTPA / Zn DTPA ampoules and DTPA aerosols
E	Colloidal Prussian Blue or Cap Radiogardase
F	Aluminium hydroxide gel Antacids- e.g. Gelusil Plus, Logacid etc
G	Potassium Rhodizonate
H	Inj. Soda bicarbonate ampoules
I	Oral Magnesium Sulphate / Barium sulphate
J	Oral Strontium lactate / Strontium Gluconate / Oral or Inj. Calcium Gluconate
K	Stable Phosphates – Aluminum phosphate
L	Propyl thiouracil OR Methimazole
M	Oral Ammonium chloride
N	Cap. D- Penicillamine 50 mg
O	Inj. Dimercaprol
P	Inj. Lasix
Q	I.V. Fluids – Normal Saline, 5 % Dextrose, 5 % Dextrose Normal Saline, Ringer’s Lactate, Isolyte M/P
R	Inj. Avil and Inj. Hydrocortisone – for treating any allergic reactions
S	Syr. Cremaffin or Proctoglycerine Enema

Group A - Common

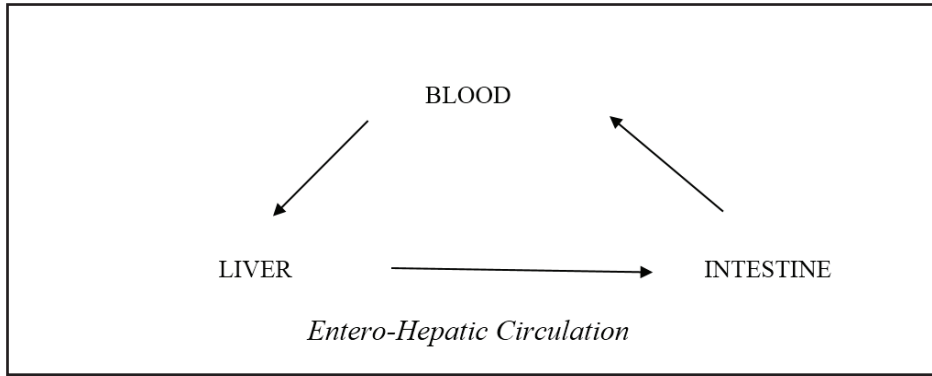
1 Americium (Am)-241:

- 1.1 **Half Life:** Am-241 has a physical half-life of 432.2 years and decays by α emission (it emits several photons which can be detected, most notably a gamma ray with an energy of 59.54 keV).
- 1.2 **A.L.I.:** The annual limit of intake (ALI) for ^{241}Am due to inhalation for type M compound is 740 Bq as per limits prescribed by the Atomic Energy Regulatory Board (AERB).
- 1.3 **Deposition and Clearance:** Americium is deposited in the pulmonary parenchyma after inhalation of the oxide and is mostly cleared with a half-time of 10-20 days (80%), but the clearance half-time of the remaining material has been estimated to vary between a few tens of days to almost 1000 days. These differences may reflect the degree of solubility of the Am-241 in lung fluids which, in turn, is a reflection of the composition of the oxide. According to ICRP 30, a clearance half-time of 28 days was estimated in a worker who had inhaled Am-241 in the oxide form.
- 1.4 **Recommended Treatment:** Parenteral Ca-DTPA, Zn-DTPA. (For details of regime and administration of Ca and Zn DTPA please see 8.28.5.).

2 Cesium (Cs)-137:

- 2.1 **Half Life:** Cs-137 has a physical half-life of 30 years and decays by β and γ emission. Dosimetry methods used for radio- cesium are based on the concepts of ICRP 30. From the blood, the activity is distributed uniformly in the body with no organ or tissues exhibiting a higher concentration.
- 2.2 **A.L.I.:** The annual limit on intake (ALI) for ^{137}Cs due to inhalation for Type F compound is 3000 kBq as per Atomic Energy Regulatory Board (AERB) limits.
- 2.3 **Deposition and Clearance:** Cesium-137 is assumed to be completely and rapidly absorbed into the systemic circulation from both the respiratory and GI tracts. Some of the cesium is passed into the intestine, absorbed from the gut into the blood, then goes to the liver, where some of it is excreted via bile into the intestine, reabsorbed from the gut into the blood, then to the liver again, where some is excreted again into the gut (entero-hepatic circulation).

The body retention of ^{137}Cs is described as consisting of two components. Using the ICRP 30 model - two component bio-kinetic model with 10% of the initial intake exhibiting a clearance half-time of 2 days and 90% exhibiting a longer half-time of 110 days.



The ICRP 30 systemic model is also used in the more recent ICRP publications 68 and 78. Publication 78 notes that the biological clearance half-time from the transfer compartment to the systemic compartment is 0.25 days and that, females may exhibit significantly shorter retention half-times in the long-term compartment than males. For systemic excretion, according to ICRP 54, it is assumed that 80% of the ¹³⁷Cs intake is excreted in the urine and 20% in feces since the main pathway of ¹³⁷Cs excretion is known to be through glomerular filtration in the kidneys.

2.4 Treatment Recommended: Oral Prussian blue. Insoluble Prussian blue for Human consumption is available by the name Radiogardase. It is available as capsules.

2.4.1 Effects of treatment are promising. The untreated mean whole body effective half-life of Cs-137 is 80 days in adults, 62 days in adolescents and 42 days in children. Insoluble Prussian blue reduces the mean whole body effective half-life of Cs-137 by 69% in adults, by 46% in adolescents and by 43% in children. Dose and clearance ratio observed in cases after 1987 incident in Goiânia are as follows -

Cesium-137 Effective Half life during and after treatment with insoluble Prussian blue (In Days, by age, and dose of Insoluble Prussian blue)

Group	Age (Years)	Insoluble Prussian blue dose (grams/day)	No. of Pts.	During Insoluble Prussian blue Treatment - ¹³⁷ Cs T _½	Off Insoluble Prussian blue Treatment - ¹³⁷ Cs T _½
Adults	>18	10	5	26 ± 6 days	18 ± 15 days (all 21 adult patients)
Adults	>18	6	10	25 ± 15 days	
Adults	>18	3	6	25 ± 9 days	
Adolescents	12 - 14	<10	5	30 ± 12 days	62 ± 14 days
Children	4 - 9	<3	7	24 ± 3 days	42 ± 4 days

2.4.2 **Indication and Usage:** Insoluble Prussian blue is indicated for treatment of patients with known or suspected internal contamination with radioactive cesium and /or radioactive or non-radioactive thallium to increase their rates of elimination.

- 2.4.3 **Pharmacokinetics:** 99% of the administered Insoluble Prussian blue is excreted unchanged in Feces.
- 2.4.4 **Food Effects:** The effect of food was not identified through published literature. In animal studies, insoluble Prussian blue was not significantly absorbed. Food may increase the effectiveness of insoluble Prussian blue by stimulating bile secretion. Food is known to increase the bile production and entero-hepatic circulation. The increase in entero-hepatic circulation may increase the amount of cesium and thallium in the gastrointestinal lumen and may increase the amounts available for binding with insoluble Prussian blue.
- 2.4.5. **Renal and Hepatic Functions:** Insoluble Prussian blue is not systemically bio-available and does not rely on renal elimination or hepatic metabolism; therefore, the use of insoluble Prussian blue is not contraindicated in groups of patients having deranged hepatic or renal functions. However, insoluble Prussian blue may be less effective in patients with impaired liver function due to decreased excretion of cesium and thallium in the bile.
- 2.4.6 **Contra-indications:** None
- 2.4.7 **Precautions:** Insoluble Prussian blue can cause constipation. Decreased gastrointestinal motility will slow the transit time of ¹³⁷Cs bound to insoluble Prussian blue in the gastro-intestinal tract and may increase the radiation absorbed dose to the gastrointestinal mucosa. Constipation occurring during insoluble Prussian blue treatment may be corrected with a fiber-based laxative and /or a high fiber diet. Insoluble Prussian blue should be used with caution in patients with disorders associated with decreased gastrointestinal motility.
- 2.4.8 **Information to patient:**
- a Cesium-137 is excreted in the urine and feces. Appropriate safety measures should be taken to minimize radiation exposure to others. When possible, a toilet should be used instead of a urinal and it should be flushed several times after each use. Spilled urine or feces should be cleaned up completely and patients should wash their hands thoroughly. If blood or urine gets onto clothing, such clothing should be washed separately.
 - b In patients with constipation, a fiber-based laxative and /or high fiber diet is recommended during treatment with insoluble Prussian blue.
 - c Patients taking insoluble Prussian blue should be informed that their stools might become blue colored.
 - d In patients who cannot swallow capsules, the capsules are opened and the contents are mixed with food and eaten. The mouth and teeth might become blue colored.
- 2.4.9 **Caution:** Insoluble Prussian blue may bind electrolytes found in the gastrointestinal tract. Asymptomatic hypokalemia, with serum potassium values

of 2.5-2.9 (normal 3.5-5.0), were observed in 7% cases after 1987 incident in Goiânia. Hence, serum electrolytes should be closely monitored during insoluble Prussian blue treatment. Caution should be exercised when treating patients with pre-existing cardiac arrhythmias or electrolyte imbalances.

2.4.10 Pregnancy and treatment: Since insoluble Prussian blue is not absorbed from the gastro-intestinal tract, effects on the fetus are not expected. In one case, the patient became pregnant 3 years and 8 months after being treated with insoluble Prussian blue for internal contamination with ^{137}Cs (8 mCi). No complications or birth defects were identified through published reports.

- i Cesium-137 is known to penetrate the human placenta. One patient, in Goiânia was contaminated with 0.005 mCi ^{137}Cs during her 4th month of pregnancy. She was not treated with insoluble Prussian blue. During delivery, the concentration of ^{137}Cs was the same both in the mother and the infant.
- ii Thallium penetrates the human placenta. Reported fetal effects in the reviewed literature include fetal death, failure to thrive, alopecia or in some instances outwardly normal development. The risk of toxicity from untreated radioactive cesium or thallium exposure is expected to be greater than the reproductive toxicity risk of insoluble Prussian blue.

2.4.11 Nursing Mothers: Studies to determine if insoluble Prussian blue is excreted in human milk have not been conducted. Since insoluble Prussian blue is not absorbed from the gastrointestinal tract, its excretion in milk is highly unlikely. However, cesium and thallium are transmitted from mother to infant in breast milk. Women internally contaminated with cesium or thallium should not breast feed.

2.4.12 Doses and Administration :

Adults and Adolescents: The recommended dose of insoluble Prussian blue is 1 to 3 grams orally three times a day.

Pediatrics (2 - 12 years):

- i The recommended dose of insoluble Prussian blue is 1 gram orally three times a day.
- ii In patients who cannot tolerate swallowing a large number of capsules, the capsules may be opened and mixed with bland food or liquids. This may result in blue discoloration of the mouth and teeth.
- iii Insoluble Prussian blue capsules may be taken with food to stimulate excretion of cesium or thallium through bile.
- iv When the internal radioactivity is substantially decreased the insoluble Prussian blue dose may be decreased to 1 or 2 grams TID to improve gastro-intestinal tolerance.

2.4.13 **Adverse Reactions:** Only constipation and undefined gastric distress have been reported. Severe adverse reactions or death have not been reported with Insoluble Prussian blue.

2.4.14 **Drug Availability:** Radiogardase™ is supplied as 0.5 gram blue powder in gelatin capsules for oral administration. It is packaged in brown glass bottles containing 30 capsules each. The product is manufactured by Haupt Pharma Berlin GmbH for distribution by HEYL Chemisch-pharmazeutische Fabrik GmbH and Co. KG, Berlin.

2.5 Bio-assay:

The radioactivity counts in urine and fecal samples should be measured and recorded weekly to monitor ¹³⁷Cs elimination rate.

3 Iodine:

3.1 **Half Life:** I-131 has a physical half-life of 8.04 days and decays by β , γ - emission

3.2 **A.L.I.:** The annual limit on intake (ALI) for ¹³¹I due to inhalation for Type F compounds is 2 MBq as per AERB limits.

3.3 **Deposition and Clearance:** The gastrointestinal uptake (f₁) factor for all forms of iodine is 1.0. Of the iodine entering the systemic compartment, a fraction, 0.3, is assumed to be translocated to the thyroid, while the remainder (0.7) is assumed to go directly to excretion. Iodine in the thyroid is assumed to be retained with a biological half-life of 80 days. Inhaled Iodine reaches equilibrium with the body fluids within 30 minutes and 30 % of this is in the Thyroid gland.

3.4 **Treatment:** Potassium Iodide within first 4 hours. If KI or its equivalent (Lugol's Iodine) isn't used within four to six hours, it will have significantly decreased effectiveness and that effectiveness will approach zero after about 12-24 hours. This blocks the thyroid. (Stable) Iodine works by saturating the uptake mechanism in the thyroid gland and "competes" with radioactive iodine (I-131). Early administration of antidotes is the key element for successful therapy.

OR

3.4.1 Lugol's Iodine consists of 5% Iodine (I₂) and 10% Potassium Iodide (KI) in 85% distilled water with a total iodine content of 130 mg/ml. Potassium iodide makes the iodine water soluble through the formation of the I₃⁻ ion. Synonyms for Lugol's solution are IKI (Iodine-Potassium Iodide); Iodine, Strong solution (Systemic); Aqueous Iodine Solution BP. Lugol's Iodine 2% has a composition of Iodine 2%, Potassium Iodide 4% and distilled water 94%.

3.4.2 Treatment can be done by mobilization of the radio-iodine through the use of anti-thyroid drugs.

3.4.3 Doses:

- a Adults and children above the age of 1 : KI 130 mg daily for 7 –1 4 days
- b Children below the age of 1: 65 mg per day, daily for 7 –1 4 days.

4 Phosphorous (P)- 32

- 4.1 **Half Life:** P-32 has a physical half-life of 14.26 days and decays by β -emission (its bremsstrahlung photons may be detectable); specific bremsstrahlung constant, $\tilde{A}P-32 = 4.05 \times 10^{-3} \text{ R cm}^2 / \text{mCi h}$ in soft tissue and $1.08 \times 10^{-2} \text{ R cm}^2 / \text{mCi h}$ in bone (Zanzonico et al. JNM 1999; 40:1024-1028).
- 4.2 **A.L.I.:** The annual limits on intake (ALI) for ^{32}P due to inhalation for Type F compounds is 20 MBq, and for Type M compound is 7 MBq as per AERB.
- 4.3 **Deposition and Clearance:** The bio-kinetic model described in ICRP 30 (Full form with reference) is used to estimate the whole body retention, $R(t)$, of phosphorus. Phosphorus entering the transfer compartment is assumed to be retained there with a half-life of 0.5 days. Of this, 15% is assumed to go directly to excretion, 15% to intracellular fluids where it is retained with a half-life of 2 days, 40% to soft tissue where it is assumed to be retained with a half-life of 19 days and 30% to mineral bone where it is assumed to be permanently retained. P-32 going either to intracellular fluids or to soft tissues is assumed to be uniformly distributed throughout all organs and tissues of the body excluding mineral bone, where it is assumed to be retained on the bone surfaces.
- 4.4 **Treatment:**
- a Oral stable phosphates are given. Sodium phosphate or Potassium phosphate or Glycerol phosphate is given.
 - b Aluminum Hydroxide can be given to reduce the G.I. uptake.
- 4.4.1 **Dose:** Stable Phosphates are given 1 gram orally on daily basis for as long as required.

5 Plutonium (Pu)-239

- 5.1 **Half Life:** Pu-239 has a physical half-life of 24,110 years and decays by α emission.
- 5.2 **A.L.I.:** The annual limit on intake (ALI) for ^{239}Pu due to inhalation for Type M compounds is 625 Bq and for Type S compounds is 2400 Bq, as per AERB.
- 5.3 **Deposition and Clearance :** For dissolved (ionic form) plutonium reaching the transfer compartment (i.e., the bloodstream), the ICRP 30 model distributes 45% to the bone surfaces from which it clears with a biological half-time of 50 years and 45% to the liver with a biological clearance half-time of 20 years.
- 5.3.1 The activity deposition in bone is assumed to be uniformly distributed over the bone surfaces of both cortical and trabecular bone. A small radioactivity fraction is permanently retained in the gonads (0.035% for testes and 0.011%

for ovaries). The remaining 10% is assumed to go directly to excretion; for purposes of dosimetry, this component is considered to be an insignificant contributor to effective dose equivalent and is generally ignored.

5.4 Treatment: Parenteral Ca-DTPA, Zn-DTPA. Di-ethylene-Tri-amine-Penta-Acetate (DTPA). DTPA is available only in parenteral form. Ca DTPA and Zn DTPA should not be administered together. DTPA may be given through intravenous infusion or as aerosol therapy of Zn DTPA in cases of internal contamination of lungs only by inhalation. The safety and effectiveness of the intramuscular route have not been established for Ca-DTPA or Zn-DTPA.

5.4.1 If both products are available, then the treatment should be started with Ca DTPA within 24 hours. If additional treatment becomes necessary then it should be changed to Zn DTPA. This is because Ca DTPA is more effective (roughly 10 times) in the first 24 hours than Zn DTPA. After 24 hours the efficacy of both is similar, but Ca-DTPA causes more loss of essential metals, such as zinc, from the body. Therefore, Zn-DTPA is preferred for maintenance therapy.

5.4.2 **Mode of Action:** DTPA is a chelating agent. It chelates plutonium (also americium, and curium) and then excretes them through urine. Treatment should be started as soon as possible. It is observed that if started within 1 hour, the retention of Plutonium in Liver is reduced from 14 % in control to 0.47 % in treated cases. Similarly retention of plutonium in skeleton is reduced from 57% in control to 5.9% in treated cases. The removal of plutonium from bones can be as high as 90% if treated within one hour.

5.4.3 **Limitations:** DTPA cannot bind all of the radioactive materials that might get into a person's body. DTPA cannot reverse the health effects caused by radioactive materials once these materials have entered the body. After 24 hours, plutonium, americium, and curium are harder to chelate. However, DTPA can still work to remove these radioactive materials from the body several days or even weeks after a person has been internally contaminated.

5.4.4 **Treatment plan:** The treatment plan should be jointly drawn out by the doctors and the health physicists. For various categories of patients it should be as follows:

i *Infants (including breastfed infants) and children <12 years of age*

Either Ca-DTPA or Zn-DTPA may be given to infants and children. The dosage of DTPA to be given should be based on the child's size and weight.

ii *Adults and adolescents*

Adults and adolescents internally contaminated with plutonium, americium or curium should receive Ca-DTPA within the first 24 hours after contamination. After 24 hours, if additional treatment is needed, adults should receive Zn-DTPA. If Zn-DTPA is not available, patients may receive

Ca-DTPA together with a vitamin and mineral supplement that contains zinc.

iii *Pregnant women*

Unless a pregnant woman has very high levels of internal contamination with plutonium, americium or curium, treatment should begin and continue with Zn-DTPA. Ca-DTPA should be used in pregnant women only to treat very high levels of internal radioactive contamination. In this case, doctors and public health authorities may prescribe a single dose of Ca-DTPA, together with a vitamin and mineral supplement that contains zinc, as the first treatment. However, after the first dose of Ca-DTPA, treatment should continue 24 hours later with a daily dose of Zn-DTPA, as needed.

iv *Breast feeding women*

Radioactive materials can and do get into breast milk. For this reason, CDC (Center for Disease Control) recommends that women with internal contamination should stop breastfeeding and feed the child, baby formula or other food if available. If breast milk is the only food available for an infant, nursing should continue. Breastfeeding women who are internally contaminated with plutonium, americium or curium should be treated with DTPA.

5.4.5 **Duration of treatment:** DTPA treatment may be needed for a prolonged period. In the past, most people who have needed treatment with DTPA have only needed one dose. However, internal contamination with very high levels of plutonium, americium or curium may require treatment with DTPA every day for weeks or months. The length of treatment with DTPA will depend on a) the amount of radioactive material in patient’s body and b) how well your body gets rid of the radioactive material. Collect samples of blood, urine and feces during your treatment with DTPA. These samples can tell how much radioactivity the patient has passed and how much still remains in the body. For this, help from health physicists and the concerned laboratory is essential.

5.4.6 **Dose Regime:**

S r. No.	Time from the event	Dose	DTPA Product and Pathway	Frequency
1	ASAP	1 gm	Ca DTPA I.V. or Zn DTPA aerosol only if Inhalation contamination	Start dose
2	After day 1 to day 7 i.e First week	0.5 gm	Zn DTPA I.V.	OD - three days per week
3	After 1 week to 8 weeks	0.25 – 0.50 gm	Zn DTPA I.V.	OD – twice per week

4	8 weeks To 12 weeks	-	-	-
5	Subsequently	0.25 – 0.50 gm	Zn DTPA I.V.	Once per week for 4 weeks. Cycle to be continued with a pause of 2-3 weeks after each 4 weeks of treatment.

5.4.7 For large quantities of Plutonium inhalation, (50 times the maximum permissible lung burden in patients aged 30 years or less) or more than 1.5 μ Ci, bronchial lavage is recommended soon after second or third day. This should be undertaken in specialized centers only where expertise exists.

5.4.8 **Caution:** There are no medical reasons why a person who is internally contaminated with plutonium, americium or curium should not be treated with Ca-DTPA or Zn-DTPA, except nephritic syndrome. However, keep the following guidelines in mind:

- i Because radioactive materials chelated to DTPA are passed out of the body in the urine, DTPA must be used carefully in people whose kidneys do not function properly.
- ii Ca-DTPA should be used carefully in people who have a disease called “hemochromatosis.” (Hemochromatosis is a genetic disease that causes the body to absorb too much iron from foods and other sources, such as vitamins containing iron.)
- iii Aerosol treatments using DTPA may not be safe for some people with asthma. If a person with asthma requires treatment with DTPA, the drug should be injected.
- iv DTPA should not be used to treat people who are internally contaminated with the radioactive materials uranium or neptunium.

5.4.9 **Side Effects:** DTPA does not build up in the body or cause long-term health effects. People who are given repeat doses of Ca-DTPA within a short period of time may have nausea, vomiting, diarrhea, chills, fever, itching and muscle cramps. Other side effects may include headache, lightheadedness, chest pain and a metallic taste in the mouth. Ca-DTPA (and Zn-DTPA) can chelate certain important minerals that the body needs (zinc, magnesium and manganese). For example, the body needs zinc to make red blood cells, white blood cells and platelets. Therefore, DTPA treatment may interfere with the normal production of blood cells. As a precaution, patients receiving long-term treatment with DTPA should be given a vitamin and mineral supplement containing zinc.

5.5 **Bio-assay samples:** Blood, urine and stool samples need to be collected for bio-assay.

6 Strontium 90

6.1 **Half Life** : As regards Sr-90, it is important to realize that Sr-90 decays into Yttrium Y-90, that Y-90 is radioactive and much easier to detect than Sr-90, that Y-90 has a much shorter half-life (64 hrs) than Sr-90 (28 yrs) and that Sr-90 and Y-90 activities reach equilibrium after about two weeks starting with pure Sr-90. This means that if you start with a 1000 Ci source of Sr-90, after about two weeks the source will also contain about 1000 Ci of Y-90 and that this equilibrium will remain the same as the Sr-90 decays. Sr-90 has a physical half-life of 29.12 years.

6.2 **A.L.I:** The annual limit on intake (ALI) for ⁹⁰Sr due to inhalation for Type F compounds is 670 kBq and for Type S compounds is 260 kBq, as per AERB.

6.2.1 **Deposition and Clearance:** The bio-kinetic model used for the distribution, retention and excretion of stable strontium is the ICRP alkaline earth model. It is assumed that stable strontium is uniformly distributed throughout the bone volume, where it is retained and internally recycled according to a series of exponential terms. The alkaline earth excretion model assumes that the fraction of excreted uptake occurring by the urinary pathway and by the fecal pathway is 0.8 and 0.2 respectively.

6.3 Treatment:

- a Reduction of absorption : Aluminum phosphate gel antacids or sodium / calcium alginate or Barium sulphate
- b Blockage: strontium lactate or Strontium gluconate
- c Displacement: Oral phosphate
- d Mobilization: ammonium chloride or parathyroid extract (dynamics)

6.3.1 Doses:

- i Sodium / Calcium Alginate in a single dose of 10– 20 gm dissolved in sugared water orally. Sugared water, because it is otherwise very unpalatable.
- ii Aluminum phosphate 60 gm colloidal gel 20% orally
- iii Barium sulphate 300 gm in aqueous solution orally as a single dose.
- iv Oral Strontium Lactate 500 mg OR Slow infusion of Strontium gluconate 600 mg in 500 ml of 5 % Dextrose solution.
- v Although stable strontium is the ideal choice, but as Strontium is quite toxic, it cannot be used for clearing skeletal strontium. Calcium, besides being a congener of strontium, is also an important and major component of skeleton. Thus Calcium compounds have been considered a better choice in curtailing Strontium uptake. Commonly used Calcium compounds are easy to administer and do not have any untoward effect on body metabolism even at a higher dose.

- vi Oral Calcium gluconate 6-10 gm in divided doses over the day OR Inj Calcium gluconate 1-5 gm in 500 ml of 5 % Dextrose solution as slow infusion.
- vii Acidification by oral Ammonium chloride 6 gm in 3 divided doses (4 tabs each dose) over the day will help mobilization of Strontium.
- viii Newer drug – newer chelating agent - Phosphoric acid derivative (APDA) developed by the Shanghai Institute of Materia Medica has worked well. Parenteral Ca APDA in doses of 600 mg / Kg body weight for three days. Excretion route post Ca APDA is through kidneys and hepato-biliary system.

Oral Ca APDA in the dose of 600mg/ Kg body weight is also effective in chelating the GI intake. Excretion is through Feces.

6.3.2 **Contraindications:** Same as for Radium (Pl. see Section 8.32.4.2)

6.3.3 **Caution:** Same as for Radium (Pl. see Section 8.32.4.3)

6.3.4 **Side Effects:** Same as for Radium (Pl. see Section 8.32.4.4)

6.3.5 **Bio-assay Sample:** Urine and Feces.

7 Tritium (H)-3

7.1 **Half Life:** H-3 has a physical half-life of 12.33 years and decays by β - emission.

7.2 **A.L.I.:** The annual limit on intake (ALI) for 3H due to inhalation is 1 GBq, as per AERB.

7.3 **Deposition and Clearance:** The metabolic model for tritium is described in ICRP 30. (Complete reference). Tritiated water is assumed to be uniformly distributed among all soft tissues at any time following intake. Its retention, R(t), is described as a single exponential with an effective clearance half-time of 10 days:

7.4. **Treatment:** Force water to promote diuresis

7.4.1 **Dose:**

- a Oral fluids 6-8 L / day OR Intravenous fluids 4-6 L per day with forced diuresis. Excess fluids help dilution and forced diuresis helps renal clearance.
- b For forced Diuresis, use Inj Lasix 40 mg i.v. or more if necessary. Use Inj Lasix 40 mg i.v. for every 2-3 l of fluids. Use Lasix and Fluids alternatively.

Treatment should be continued for 1 week.

7.4.2 **Investigations:** Monitor Electrolytes, particularly Sodium, if hypotonic solutions are used.

7.4.3 **Caution:** Assess cardiac status of the patient before loading extra fluids. If the patient is already in Congestive Cardiac Failure (CCF), extra caution is needed.

7.5 **Bio-assay Samples:** Urine sample.

8 Uranium (U)-234, 235, and 238

8.1 **Half Life:** U-234 has a physical half-life of 2.455×10^5 years and decays by α emission; U-235 has a physical half-life of 7.038×10^8 years and decays by α emission; and U-238 has a physical half-life of 4.468×10^9 years and decays by α emission.

8.2 **A.L.I.:** The annual limits on intake (ALI) for ^{234}U due to inhalation is for Type F compounds 31250 Bq, for Type M compounds 9500 Bq, and for Type S compounds 2900 Bq as per AERB.

The annual limits on intake (ALI) for ^{235}U due to inhalation is for Type F compounds 33333 Bq, for Type M compounds 11111 Bq and for Type S compounds 3280 Bq, as per AERB.

The annual limits on intake (ALI) for ^{238}U due to inhalation is for Type F compounds 34500 Bq, for Type M compounds 12500 Bq and for Type S compounds 3500 Bq, as per AERB.

8.3 **Deposition and Clearance:** For material entering the systemic circulation, fractions of 0.2 and 0.023 are assumed to enter the bone mineral and remains there with half-lives of 20 and 5000 days, respectively; fractions of 0.12 and 0.00052 are assumed to enter the kidneys and remains with half-lives of 6 and 1500 days, respectively; and fractions of 0.12 and 0.00052 are assumed to enter all other tissues of the body. The remaining fraction of the uranium entering the systemic circulation, 0.54, is assumed to be excreted directly.

8.4 **Metabolic Pathway of Uranium:** Uranium is nephrotoxic with predominant changes described by necrosis in the proximal convoluted tubule and a moderate degree of inflammatory and fibrotic changes, resulting in scarred kidneys. In cases of non-lethal poisoning, damaged tubular epithelium is rapidly regenerated, with subsequent tolerance to large doses of uranium. Regenerated epithelium is of metaplastic histologic type, different from the normal epithelium and the postulated tolerance mechanism was the inability of uranium compounds to interact with renal tubular cells.

Toxic effects were also observed in the liver, central nervous system and blood.

There are three major routes of internal contamination with uranium: 1) gastrointestinal system; 2) skin and wounds; and 3) inhalation and trans-alveolar transfer to the blood stream.

Gastrointestinal Absorption: Gastrointestinal absorption of uranium isotopes is relatively low in the adult human, but still presents a considerable biomedical hazard because of their long half-lives, nephrotoxicity and retention in skeletal tissue being the main hazards. It was recognized that, although uranium predominantly enters the animal or human organism by the respiratory route, it may be swallowed, gaining entry to the gastrointestinal system. Fasting state enhances the absorption of uranium.

Inhalation: About 25% of the radioactive particles are deposited in the bronchial tree, 25% are immediately exhaled, whereas 50% are translocated to the naso-pharynx and swallowed, with subsequent handling by the mechanisms of gastrointestinal absorption. The intestinal absorption of Depleted Uranium (DU) is negligible, placing the respiratory pathway in the category of major radio-toxicological hazard. One of the therapeutic aims in internal DU contamination should include the movement of the inhaled particles to the extra pulmonary pathways. The deposition of DU particles on the alveolar surfaces will result in their absorption, depending on their solubility, with approximately 10% of the particles retained in the lungs and reaching systemic circulation, and the remaining 15% ascending to the naso-pharynx by expectoration and ending in the gastrointestinal tract. Soluble components of uranium absorbed from the pulmonary tree are deposited in the skeleton within a few weeks, with a biological half-life in the lungs of 120 days. A considerably longer pulmonary retention of 1,470 days is expected in the case of inhalation of uranium oxides.

8.5 Treatment: The principal aim in the therapeutic management of patients with internally deposited uranium is to prevent the absorption from the site of entry and eliminate uranium from the blood stream or target organs.

8.5.1 The method of gastric lavage is very useful in therapy or early exposure by ingestion. Wash the stomach several times with water or physiological saline by negative pressure, until the aspirate is declared free of the contaminant.

8.5.2 The use of laxatives is a common therapeutic approach in reducing internal contamination. Laxative use is contraindicated in acute abdominal syndrome or non-diagnosed pain in the stomach. Numerous side effects include tachypnea, dyspnea, tachy-arrhythmias, intestinal irritation, exanthema and syncopal attacks.

8.5.3 Treatment of patients who have been contaminated by inhalation of uranium compounds includes the use of therapeutic agents which decrease viscosity of endobronchial mucosa. The use of mucolytic substances, which have the effect on muco-polysaccharides and nucleoproteins in the respiratory tree, enable the elimination of actinides by expectoration. Mucolytics like, Carbocysteine (e.g. Syr. Mucodyne), Bromohexine HCL (e.g Syr Bromohexine) or Ambroxol HCL (e.g. Syr Ambrodil ct) are very effective.

8.5.4 Ethylene-diamine-tetra-acetic acid (EDTA) has proven efficacy in the treatment of lead, zinc, copper, chromium, manganese and nickel poisoning and in contamination with transuranic elements. Na-EDTA is used in a dose of 50 mg/kg. The total quantity should not exceed 300 mg during 6 days of treatment. It is not administered by oral or intramuscular application. Parenteral use of Na-EDTA may lead to hypocalcemia. The use of Ca-EDTA in the therapeutic dose of 15-30 mg/kg does not have a hypocalcemic effect, and hence is preferred. It is essential to evaluate kidney function before the beginning of the treatment because its use is contraindicated in patients with renal disease.

8.5.5 Inj Soda Bicarb 1.4 % in 250 ml as slow infusion. This forms a stable complex with uranyl ions which is excreted through kidneys.

8.5.6 **Caution:** Kidney functions and electrolyte monitoring is needed.

8.5.7 **Bio-assay:** Urine and Feces. Also Gastric Lavage of contents.

Group B – Less Common

9 Cobalt 60

9.1 Cobalt- 60 is beta / gamma energy emitter.

9.2 **A.L.I.:** The annual limits on intake (ALI) for ⁶⁰Co due to inhalation for Type M compound is 2800 kBq and for Type S compound is 1200 kBq as per AERB.

9.3 **Treatment:**

9.4 There is no good decorporation agent recognized for radionuclides of cobalt.

9.4.1 Results using Penicillamine were notconclusive in mice.

9.4.2 Cobaltous DTPA reduced radioactive cobalt concentration by about 1/3 in mice, but it has never been tried in humans and is not presently available.

9.4.3 However, for treatment with Ca and Zn DTPA, please refer to Plutonium decontamination (Section 8.31.5).

9.4.4 Aerosol therapy for decorporation of inhalation contamination is done using DTPA aerosol. 1gm/ 4 ml amp. or 100 mg of micronised powder.

9.4.5 Before giving Penicillamine, carry out the following tests. Complete Blood Count [CBC], Liver Function Tests [LFT], Kidney Function Tests [KFT] and Penicilline sensitivity test.

9.4.5.1 D-Penicillamine is given in a dose of 250 mg Four times daily, in between meals. Better results are obtained when given as early as possible.

9.4.5.2 D-Penicillamine is a chelating agent and will chelate other metals and minerals. Hence it is given in between meals, so that the dietary minerals are not chelated.

9.4.5.3 None the less supplements of Muti-vitamins, minerals containing zinc and calcium supplements are recommended.

10 Iridium (Ir) 192

10.1 **Half Life:** Ir-192 is a photon emitter which may be identified by its spectrum. Ir-192 has a physical half-life of 73.831 days and decays by electron capture and α emission. The bio-kinetic model described in ICRP 30 is used to estimate the whole body retention, R(t), of iridium.

10.1**A.L.I.:** The annual limits on intake (ALI) for ¹⁹²Ir due to inhalation for Type F

compounds is 9 MBq, for type M compound is 5 MBq, and for Type S compound is 4 MBq, as per AERB.

10.3 Deposition and Clearance: It is assumed that, of the iridium leaving the transfer compartment, 20%, 4 % and 2 % is translocated to liver, kidney and spleen respectively. A further 54 %, is assumed to be uniformly distributed throughout all other organs and tissues of the body. The remaining 20% of iridium leaving the transfer compartment is excreted directly. Of iridium deposited in any organ or tissue of the body, 20 % and 80 % are assumed to be retained with biological half-lives of 8 and 200 days respectively.

10.3.1 Treatment: Unfortunately, there is no known decorporation drug for Iridium. However Oral Penicillamine might work. For details of dose and administration please refer to Section 3.4.

11 Palladium (Pd) 103

11.1 Half Life: Pd-103 has a physical half-life of 16.991 days and decays by electron capture (it emits x-rays that may be detectable with energies of approximately 20 keV). The bio-kinetic model described in ICRP 30 is used to estimate the whole body retention, R(t), of palladium.

11.1.1 A.L.I : The annual limits of intake (ALI) for ¹⁰³Pd due to inhalation for Class D compounds is 1 x 10⁸Bq, for Class W compounds is 5 x 10⁷Bq, and for Class Y compounds is 4 x 10⁷Bq. Whereas for Ingestion, the A.L.I. is 7 x 10⁷Bq for Class D, Class W and Class Y compounds, as per ICRP 61.

11.1.2 Deposition and Clearance: The retention of palladium in the body is assumed to be approximated by a single exponential with a biological half-life of 15 days. Of the palladium leaving the transfer compartment, it is assumed that 30% goes directly to excretion, 45% is translocated to the liver, 15% is translocated to the kidneys, 7% is translocated to mineral bone (Pd-103 is assumed to be uniformly distributed throughout the volume of mineral bone) and 3% is uniformly distributed throughout all other organs and tissues of the body. Palladium translocated to any organ or tissue is assumed to remain there with a biological half-life of 15 days.

11.1.3 Treatment: There is no known decorporation drug for palladium. However oral penicillamine could be tried. For details of doses etc. please refer to Section 3.4.

12 Radium (Ra)-226

12.1 Half Life: Ra-226 has a physical half-life of 1600 years and decays by α emission

12.2 A.L.I.: The annual limit on intake (ALI) for ²²⁶Ra due to inhalation for Type M compounds is 1700 Bq.

12.3 Deposition and Clearance: Since radium is an alkaline earth element, it can be assumed that the bio-kinetic model is the same as for strontium.

12.3.1 Treatment

- a Oral calcium to reduce gastrointestinal absorption and increase urinary excretion.
- b Alginates are also useful to reduce gastrointestinal absorption.
- c Oral Magnesium Sulphate forms sulphates with Radium.

12.3.2 Doses

- a Magnesium Sulphate: Single dose of 10 gm in 100 ml of water produces insoluble sulphate with radium and thus reduces its absorption.
- b Barium Sulphate can also be used instead of Mag. Sulphate. This drug is commonly used in Radiography and hence is easily available. A single dose of 200 ml of 100% barium sulphate should be administered.
- c Calcium gluconate orally 6-10 g in 3 divided doses over a day can be given. Or else Inj. Calcium gluconate 1-5 g in 500 ml of 5% Dextrose solution as a slow infusion.
- d Oral colloidal Aluminum phosphate 60 gm colloidal gel also works similar to Barium Sulphate.
- e Acidification by oral administration of Ammonium chloride 6 g in 3 divided doses over a day.

12.4 Contra-indications

* While using Barium sulphate / magnesium sulphate or Aluminum phosphate, care should be taken to ascertain that the patient is not suffering from suspected colonic obstruction, acute GI hemorrhage, inflammation and perforation. Hypersensitivity to any of these products is a contra-indication.

12.4.1 Caution:

* While using Ba Sulphate or other similar drugs caution should be exercised in following cases - Pregnancy, appendicitis, diverticulitis, intussusception, malignancy, granuloma, ulcerative colitis and helminthiasis and any condition with a risk of GI perforation. Also marked hypertension or advanced cardiac disease, severe debility, history of food aspiration, bronchial asthma and atopy.

* Administration of Inj. Calcium gluconate should always be done under cardiac monitoring. Observe for any arrhythmias. Go slow while infusion. If arrhythmias are significant and likely to be fatal, discontinue infusion until cardiac rhythm reverses to normal. Restart infusion only if cardiac conditions permit.

12.4.2 **Side Effects:** Side effects of use of Barium sulphate or other similar to it are - Transient diarrhea, abdominal pain, constipation, anal pain and hemorrhage, borborygmus and aggravation of hemorrhoids.

12.5 **Investigations to be done:** While on treatment, carry out – Electrolytes, Sr. Calcium levels, Blood pH and other tests for assessment of internal contamination.

12.6 **Bioassay samples:** Urine and Feces samples.

13 Drugs Used for Decorporation

Some of the drugs mentioned here in this chapter have already been dealt with in the previous pages, however duplication here is with an intent of ready reckoner for those who desire to read this chapter in isolation. It is recommended that readers read the previous chapters in details for a better in-sight.

13.1 Oral Insoluble Prussian blue

13.1.1 Insoluble Prussian blue for Human consumption is available by the name Radiogardase. It is available as capsules.

13.1.2 Used for treatment of Cesium contamination.

13.1.3 Effects of treatment are promising. The untreated mean whole body effective half-life of ^{137}Cs is 80 days in adults, 62 days in adolescents and 42 days in children. Insoluble Prussian blue reduced the mean whole body effective half-life of ^{137}Cs by 69% in adults, by 46% in adolescents and by 43% in children. Dose and clearance ratio observed in cases after 1987 incident in Goiânia are as follows:

Cesium-137 Effective Half life during and after treatment with insoluble Prussian blue (In Days, by age, and dose of Insoluble Prussian blue)

Group	Age (Years)	Insoluble Prussian blue dose (grams/day)	No. of Pts.	During Insoluble Prussian blue Treatment - ^{137}Cs $T_{1/2}$	Off Insoluble Prussian blue Treatment - ^{137}Cs $T_{1/2}$
Adults	>18	10	5	26 ± 6 days	18 ± 15 days (all 21 adult patients)
Adults	>18	6	10	25 ± 15 days	
Adults	>18	3	6	25 ± 9 days	
Adolescents	12 - 14	<10	5	30 ± 12 days	62 ± 14 days
Children	4 - 9	<3	7	24 ± 3 days	42 ± 4 days

13.1.4 **Indication and Usage:** Insoluble Prussian blue is indicated for treatment of patients with known or suspected internal contamination with radioactive cesium and /or radioactive or non-radioactive thallium to increase their rates of elimination.

- 13.1.5 **Pharmacokinetics:** 99 % of the administered Insoluble Prussian blue is excreted unchanged in Feces.
- 13.1.6 **Food Effects:** Food effect studies were not identified through published literature. In animal studies, insoluble Prussian blue was not significantly absorbed. Food may increase the effectiveness of insoluble Prussian blue by stimulating bile secretion. Food is known to increase bile production and entero-hepatic circulation. The increase in entero-hepatic circulation may increase the amount of cesium and thallium in the gastrointestinal lumen and may increase the amounts available for binding with insoluble Prussian blue.
- 13.1.7 **Renal and Hepatic Functions:** Insoluble Prussian blue is not systemically bioavailable and does not rely on renal elimination or hepatic metabolism; therefore, the use of insoluble Prussian blue is not contraindicated in groups of patients having deranged Hepatic or Renal functions. However, insoluble Prussian blue may be less effective in patients with impaired liver function due to decreased excretion of cesium and thallium in the bile.
- 13.1.8 **Contra-indications:** None
- 13.1.9 **Precautions:** Insoluble Prussian blue can cause constipation. Decreased gastrointestinal motility will slow the transit time of ¹³⁷Cs bound to insoluble Prussian blue in the gastrointestinal tract and may increase the radiation absorbed dose to the gastrointestinal mucosa. Constipation occurring during insoluble Prussian blue treatment may be treated with a fiber-based laxative and /or a high fiber diet. Insoluble Prussian blue should be used with caution in patients with disorders associated with decreased gastrointestinal motility.
- 13.1.10 **Information for the patient:** (should be a part of patient Dos and Dont's separately)
- a Cesium-137 is excreted in the urine and feces. Appropriate safety measures should be taken to minimize radiation exposure to others. When possible, a toilet should be used instead of a urinal, and it should be flushed several times after each use. Spilled urine or feces should be cleaned up completely and patients should wash their hands thoroughly. If blood or urine gets onto clothing, such clothing should be washed separately.
 - b In patients with constipation, a fiber-based laxative and /or high fiber diet is recommended during treatment with insoluble Prussian blue.
 - c Patients taking insoluble Prussian blue should be informed that their stools might become blue colored.
 - d In patients who cannot swallow capsules, the capsules are opened and the contents are mixed with food and eaten. The mouth and teeth might become blue colored.
- 13.1.11 **Caution:** Insoluble Prussian blue may bind electrolytes found in the

gastrointestinal tract. Asymptomatic hypokalemia, with serum potassium values of 2.5-2.9 (normal 3.5-5.0), were observed in 7% cases after 1987 incident in Goiânia. Hence Serum electrolytes should be closely monitored during insoluble Prussian blue treatment. Caution should be exercised when treating patients with pre-existing cardiac arrhythmias or electrolyte imbalances.

13.1.12 Pregnancy and treatment: Since insoluble Prussian blue is not absorbed from the gastrointestinal tract, effects on the fetus are not expected. In one patient that became pregnant 3 years and 8 months after being treated with insoluble Prussian blue for internal contamination with ^{137}Cs (8 mCi), complications or birth defects were not identified in the literature report.

- a Cesium-137 is known to cross the human placenta. One patient, in Goiânia, was contaminated with 0.005 mCi ^{137}Cs during her 4th month of pregnancy. She was not treated with insoluble Prussian blue. At birth the concentration of ^{137}Cs was the same in the mother and the infant.
- b Thallium crosses the human placenta. Reported fetal effects in the reviewed literature include fetal death, failure to thrive, alopecia, or in some instances outwardly normal development. The risk of toxicity from untreated radioactive cesium or thallium exposure is expected to be greater than the reproductive toxicity risk of insoluble Prussian blue.

13.1.13 Nursing Mothers: Studies to determine if insoluble Prussian blue is excreted in human milk have not been conducted. Since insoluble Prussian blue is not absorbed from the gastrointestinal tract, its excretion in milk is highly unlikely. However, cesium and thallium are transmitted from mother to infant in breast milk. Women internally contaminated with cesium or thallium should not breast feed.

13.1.14 Doses and Administration:

Adults and Adolescents:

The recommended dose of insoluble Prussian blue is 3 grams orally three times a day.

Pediatrics (2 - 12 years):

- a The recommended dose of insoluble Prussian blue is 1 gram orally three times a day.
- b In patients who cannot tolerate swallowing large numbers of capsules, the capsules may be opened and mixed with bland food or liquids. This may result in blue discoloration of the mouth and teeth.
- c Insoluble Prussian blue capsules may be taken with food to stimulate excretion of cesium or thallium through bile.
- d When the internal radioactivity is substantially decreased the insoluble

Prussian blue dose may be decreased to 1 or 2 grams TID to improve gastrointestinal tolerance.

13.1.15 **Adverse Reactions:** Only constipation and undefined gastric distress are reported. Death or any severe adverse reactions are not reported with Insoluble Prussian blue.

13.1.16 **Drug Availability:** Radiogardase™ is supplied as 0.5 gram blue powder in gelatin capsules for oral administration. It is packaged in brown glass bottles containing 30 capsules each. The product is manufactured by Haupt Pharma Berlin GmbH for distribution by HEYL Chemisch-pharmazeutische Fabrik GmbH and Co. KG, Berlin.

13.1.17 **Bio-assay:** The radioactivity counts in urine and fecal samples should be measured and recorded weekly to monitor ¹³⁷Cs elimination rate.

14 Potassium Iodide / Potassium Iodate / Lugol's Iodine

14.1 Used for treatment of Iodine contamination.

14.2 **Treatment:** Potassium Iodide within first 4 hours. If KI or its equivalent (Lugol's Iodine) isn't used within four to six hours, it will have significantly decreased effectiveness and that effectiveness will approach zero after about 12-24 hours. This blocks the thyroid. (Stable) Iodine works by saturating the uptake mechanism in the thyroid gland and "competes" with radioactive iodine (I-131). Early administration of radionuclide antidotes is the key element for successful therapy.

OR

14.3 Lugol's Iodine consists of 5% Iodine (I₂) and 10% Potassium Iodide (KI) in 85% distilled water with a total iodine content of 130 mg/ml. Potassium iodide makes the iodine water soluble through the formation of the I₃⁻ ion. Synonyms for Lugol's solution are IKI (Iodine-Potassium Iodide); Iodine, Strong solution (Systemic); Aqueous Iodine Solution BP. Lugol's Iodine 2% has a composition of Iodine 2%, Potassium Iodide 4% and distilled water 94%.

14.3.1 Treatment can be done by mobilization of the radio-iodine by use of anti-thyroid drugs

14.4 **Doses:**

a Adults and children above the age of 1 : KI 130 mg daily for 7 –1 4 days

b Children below the age of 1 : 65 mg per day, daily for 7 –1 4 days

15 Diethylene-triamine-penta-acetate (DTPA)

15.1 **Used:** Used in the treatment of contaminations with Americium - ²⁴¹Am and Plutonium ²³⁹Pu

15.2 **Treatment:** Parenteral Ca-DTPA, Zn-DTPA. Di-ethylene-Triamine-Penta-Acetate (DTPA).

DTPA is available only in parenteral form. Ca DTPA and Zn DTPA should not be administered together. DTPA may be given intravenous infusion or as aerosol therapy of Zn DTPA in cases of internal contamination of lungs only by inhalation. The safety and effectiveness of the intramuscular route have not been established for Ca-DTPA or Zn-DTPA

15.2.1 If both products are available, then the treatment should be started with Ca DTPA if within 24 hours. If additional treatment is necessary then it should be changed to Zn DTPA. This is because Ca DTPA is more effective (roughly 10 times) in the first 24 hours than Zn DTPA. After 24 hours the efficacy of both is similar, but Ca-DTPA causes more loss of essential metals, such as zinc, from the body. Therefore, Zn-DTPA is preferred for maintenance therapy.

15.2.2 **Mode of Action:** DTPA is a chelating agent. It chelates plutonium (also americium, and curium) and then excretes them in urine. Treatment should be started as soon as possible. It is observed that if started within 1 hour the retention of Plutonium in Liver is reduced from 14 % in control to 0.47 % in treated cases. Similarly retention of plutonium in skeleton is reduced from 57% in control to 5.9% in treated cases. The removal of plutonium from bones can be as high as 90% if treated within one hour.

15.2.3 **Limitations:** DTPA cannot bind all of the radioactive materials that might get into a person's body. DTPA cannot reverse the health effects caused by radioactive materials once these materials have entered the body. After 24 hours, plutonium, americium, and curium are harder to chelate. However, DTPA can still work to remove these radioactive materials from the body several days or even weeks after a person has been internally contaminated.

15.3 **Treatment plan:** The treatment plan should be jointly drawn out by the doctors and the health physicists. For various categories of patients it should be as follows

a *Infants (including breastfed infants) and children <12 years of age*

Either Ca-DTPA or Zn-DTPA may be given to infants and children. The dosage of DTPA to be given should be based on the child's size and weight.

i *Adults and adolescents*

Adults and adolescents internally contaminated with plutonium, americium, or curium should receive Ca-DTPA if treated within the first 24 hours after contamination. After 24 hours, if additional treatment is needed, adults should receive Zn-DTPA. If Zn-DTPA is not available, patients may receive Ca-DTPA together with a vitamin and mineral supplement that contains zinc.

ii *Pregnant women*

Unless a pregnant woman has very high levels of internal contamination with plutonium, americium, or curium, treatment should begin and continue with Zn-DTPA. Ca-DTPA should be used in pregnant women only to treat very high levels of internal radioactive contamination. In this case, doctors and public health

authorities may prescribe a single dose of Ca-DTPA, together with a vitamin and mineral supplement that contains zinc, as the first treatment. However, after the first dose of Ca-DTPA, treatment should continue 24 hours later with a daily dose of Zn-DTPA, as needed.

iii *Breastfeeding women*

Radioactive materials can—and do—get into breast milk. For this reason, CDC recommends that women with internal contamination stop breastfeeding and feed the child baby formula or other food if it is available. If breast milk is the only food available for an infant, nursing should continue. Breastfeeding women who are internally contaminated with plutonium, americium, or curium should be treated with DTPA.

15.4 Duration of treatment: DTPA treatment may be needed for a prolonged period. In the past, most people who have needed treatment with DTPA have only needed one dose. However, internal contamination with very high levels of plutonium, americium, or curium may require treatment with DTPA every day for weeks or months. The length of treatment with DTPA will depend on - a) the amount of radioactive material in patient’s body and b) how well your body gets rid of the radioactive material. Collect samples of blood, urine, and feces during your treatment with DTPA. These samples can tell how much radioactivity patient has passed and how much remains in the body. For this, help from health physicists and the concerned laboratory is essential.

15.5 Dose Regime:

Sr. No.	Time from the event	Dose	DTPA Product and Pathway	Frequency
1	ASAP	1 gm	Ca DTPA I.V. or Zn DTPA aerosol only if Inhalation contamination	Start dose
2	After day 1 to day 7 i.e First week	0.5 gm	Zn DTPA I.V.	OD - three days per week
3	After 1 week to 8 weeks	0.25 – 0.50 gm	Zn DTPA I.V.	OD – twice per week
4	8 weeks To 12 weeks	-	-	-
5	Subsequently	0.25 – 0.50 gm	Zn DTPA I.V.	Once per week for 4 weeks. Cycle to be continued with a pause of 2-3 weeks after each 4 weeks of treatment.

- 15.6 For large quantities of Plutonium inhalation, (50 times the maximum permissible lung burden in patients aged 30 years or less) or more than 1.5 μ Ci, bronchial lavage is recommended soon after second or third day. This should be undertaken in specialized centers only where expertise exists.
- 15.7 **Caution:** There are no medical reasons why a person who is internally contaminated with plutonium, americium, or curium should not be treated with Ca-DTPA or Zn-DTPA, except nephritic syndrome. However, keep the following guidelines in mind:
- i Because radioactive materials chelated to DTPA are passed out of the body in the urine, DTPA must be used carefully in people whose kidneys do not function properly.
 - ii Ca-DTPA should be used carefully in people who have a disease called "hemochromatosis." (Hemochromatosis is a genetic disease that causes the body to absorb too much iron from foods and other sources, such as vitamins containing iron.)
 - iii Aerosol treatments using DTPA may not be safe for some people with asthma. If a person with asthma requires treatment with DTPA, the drug should be injected.
 - iv DTPA should not be used to treat people who are internally contaminated with the radioactive materials uranium or neptunium.
- 15.8 **Side Effects:** DTPA does not build up in the body or cause long-term health effects. People who are given repeat doses of Ca-DTPA within a short period of time may have nausea, vomiting, diarrhea, chills, fever, itching, and muscle cramps. Other side effects may include headache, lightheadedness, chest pain, and a metallic taste in the mouth.
- 15.8.1 Ca-DTPA (and Zn-DTPA) can chelate certain important minerals that the body needs (zinc, magnesium, and manganese). For example, the body needs zinc to make red blood cells, white blood cells, and platelets. Therefore, DTPA treatment may interfere with the normal production of blood cells. As a precaution, patients receiving long-term treatment with DTPA should be given a vitamin and mineral supplements containing zinc.
- 15.9 **Bio-assay samples:** Blood, urine and stool samples need to be collected for bio-assay. Repeat of earlier Sections).
- 15.10 Some other drugs of decontamination include DMPS (Di-mercapto-propan-sulphonate), DMSA, Dimercaprol (also called as BAL), Desferoxamine (DFOA). These are used for heavy metals like, Mercury, Lead, etc. and also for Polonium contamination.

16 DMPS

- 16.1 This is a mercury chelator, like DMSA.
- 16.2 More dangerous since it can pull other useful metals out of the body (e.g. zinc and

copper) and it can dump much mercury into the kidney and liver and permanently damage them.

- 16.3 Start with several small test doses to make sure that patient can tolerate them (e.g. 10mg 1st time, 50mg 2nd time, 250mg 3rd time; and wait 2wks between each test).
- 16.4 It is recommended that DMPS is not to be used unless there are very compelling reasons to do so, since it is dangerous and has damaged many people.

17 DMSA

- 17.1 This is a drug chelator (binds to mercury and then pulls it out of the body).
- 17.2 It is recommended to take several small test doses first to make sure that the patient can tolerate them (e.g. 20mg 1st time, 100mg 2nd time, 500mg 3rd time; and wait 2wks between each test).
- 17.3 LONG TERM treatment approach is to take 100mg a day for 3days and then wait 3weeks, and then repeat the cycle; and do this for a year or so.
- 17.4 While doing this, take a zinc/copper tablet each day (e.g. 25mg zinc, 2.5mg copper; the 10:1 ratio is important).
- 17.5 DMSA is sometimes coupled with Lipoate, however, if one has multiple sclerosis (MS), DMSA is to be used with caution since those with MS are at a greater risk of a bad reaction.
- 17.6 Also, if one has high levels of methyl-mercury (inorganic mercury from fish), the Lipoate can hurt as well.

18 Dimercaprol (BAL – British Anti-Lewisite)

18.1 Synonyms:

Dimercaprol, Dicaprol, Sulfactin, Dithioglycerol, British Anti-Lewisite, BAL

18.2 Presentation/formulation:

- i Ampoules (2 ml) containing 50 mg/ml (100 mg/ampoule) (BAL- Boots) (Dimercaprol 5% solution in peanut oil and 10% benzyl benzoate).
- ii Ampoules (3 ml) containing 100 mg/ml (300 mg/ampoule) (BAL- Hynson, Westcott and Dunning, Inc.) (Dimercaprol 10% solution in peanut oil and 10% benzyl benzoate)
- iii Ampoules (2 ml) containing 100 mg/ml (200 mg/ampoule) (BAL- Sociéte'l'Arguenon) (Dimercaprol 10% solution in peanut oil with butacaine 1 mg).

18.3 First Aid Measures and treatment principles:

- i Interrupt parenteral administration by lowering the dosage or increasing the time between doses.

- ii Anti-histamines may possibly alleviate some of the adverse effects.
- iii Strict clinical observation and monitoring of blood pressure and diuresis.

Note: Dimercaprol should be given with caution in hypertensive patients and in patients who have renal and hepatic dysfunction.

18.4 Storage conditions

18.4.1 Stability in light

Dimercaprol must be protected from light. The addition of benzyl benzoate increases its stability (and solubility).

18.4.2 Thermal stability

Dimercaprol must be stored at between 2°C and 10 °C in small vials that are hermetically sealed and completely filled.

18.5 Indications: Dimercaprol may be found useful in the treatment of poisonings due to:

- i arsenic (organic and inorganic)
- ii gold
- iii inorganic mercury.

It should be noted that in any of the above types of poisoning the use of dimercaprol (even if DMSA/DMPS are not available) is not an absolute indication.

18.6 Doses:

i Adults

Dimercaprol should always be administered as soon as possible by deep intramuscular injection (never intravenous or subcutaneous) and rotating sites. The generally recommended doses are similar for arsenic, gold and inorganic mercury poisoning

ii Mild cases

- 2.5 mg/kg every 4 hours on the 1st day
- 2.5 mg/kg every 6 hours on the 2nd day
- 2.5 mg/kg every 12 hours on the 3rd day
- 2.5 mg/kg every 24 hours for 10 days (or until clinical recovery).

iii Severe cases

- 3 to 4 mg/kg every 4 hours on the first 2 days
- 3 to 4 mg/kg every 6 hours on the 3rd day
- 3 to 4 mg/kg every 12 hours for 10 days

(doses of 5 mg/kg can be employed in the most severe cases).

(IPCS dimercaprol antidote monograph, 1994).

iv *Children*

Dimercaprol is well tolerated by children. The dosage should be calculated according to body weight, using the same unit-dose per kilogram of body weight as for adults under similar clinical conditions.

18.7 **Contra-indications:**

- i Dimercaprol cannot be used in poisonings due to iron, cadmium, tellurium, selenium, vanadium and uranium. It is also contraindicated in poisonings due to elemental mercury vapor, because it can further increase the metal in the brain (Berlin and Ullberg, 1963).
- ii Dimercaprol should not be given in case of acute renal failure (anuria) or extensive hepatic insufficiency (Cameron et al., 1947), and should be used with special care in hypertensive patients.

Note: Dimercaprol is not effective in massive, severe poisonings because its antidotal effect is surpassed by the toxicity of the toxic metal.

If given 7 days after arsenic exposure, it has little or no effect on the subsequent course of the neuropathy.

Phases of Radiation Injury

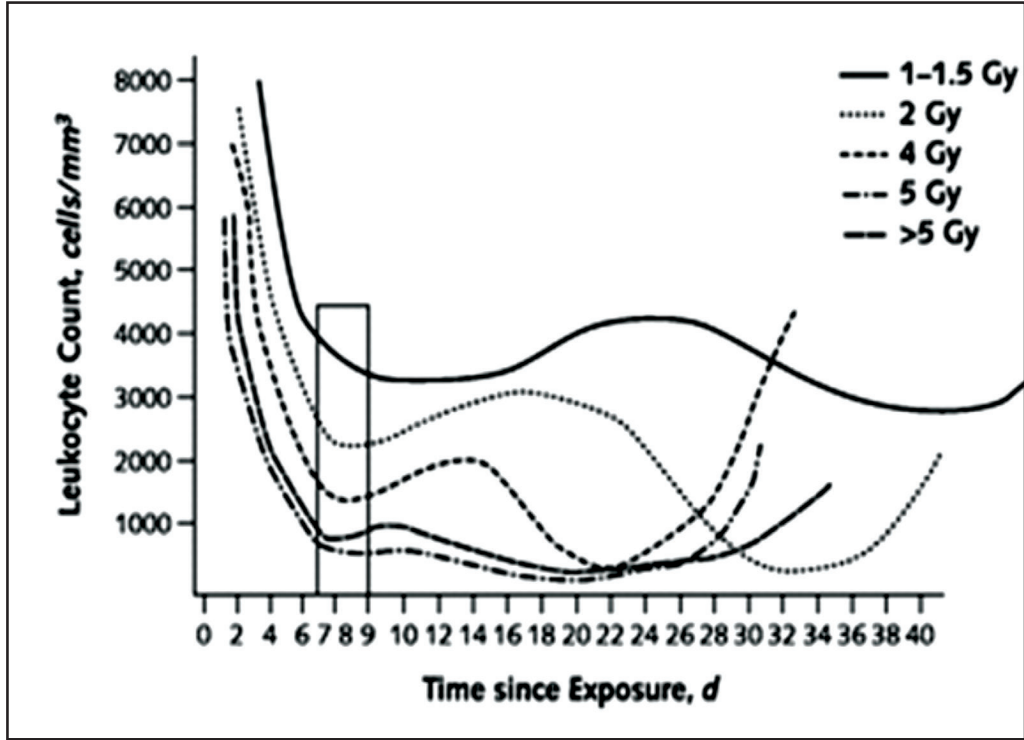
Dose Range, Gy	Prodrome	Manifestation of Illness	Prognosis (without Therapy)
0.5-1.0	Mild	Slight decrease in blood cell counts	Almost certain survival
1.0-2.0	Mild to moderate	Early signs of bone marrow damage	Highly probable survival (>90% of victims)
2.0-3.5	Moderate	Moderate to severe bone marrow damage	Probable survival
3.5-5.5	Severe	Severe bone marrow damage; slight GI damage	Death within 3.5-6 wk (50% of victims)
5.5-7.5	Severe	Pancytopenia and moderate GI damage	Death probable within 2-3 wk
7.5-10.0	Severe	Marked GI and bone marrow damage, hypotension	Death probable within 1-2.5 wk
10.0-20.0	Severe	Severe GI damage, pneumonitis, altered mental status, cognitive dysfunction	Death certain within 5-12 d
20.0-30.0	Severe	Cerebrovascular collapse, fever, shock	Death certain within 5-12 d

* Modified from Walker RI, Cerveny RJ, eds. (21). GI = gastrointestinal.

1 Hematopoietic Syndrome:

- 1.1 Irradiation of bone marrow stem and progenitor cells at increasing doses results in exponential cellular death. The hematopoietic syndrome is seen with significant partial-body or whole-body radiation exposures exceeding 1 Gy and is rarely clinically significant below this level. Mitotically active hematopoietic progenitors have a limited capacity to divide after a whole-body radiation dose greater than 2 to 3 Gy. In the ensuing weeks after exposure, a hematologic crisis occurs, characterized by hypoplasia or aplasia of the bone marrow. These changes result in pancytopenia, predisposition to infection, bleeding, and poor wound healing, all of which may contribute to death.
- 1.2 While most bone marrow progenitors are susceptible to cell death after sufficiently intense radiation doses, subpopulations of stem cells or accessory cells are selectively more radio resistant, presumably because of their largely non-cycling state. These radio resistant cells may play an important role in recovery of hematopoiesis after exposure to doses as high as 6 Gy, albeit with a reduced capacity for self-renewal. Another critical determinant for reconstitution is inhomogeneity of the dose with sparing of marrow sites that become foci of hematopoietic activity.

1.3 Lymphopenia is common and occurs before the onset of other cytopenias. A predictable decline in lymphocytes occurs after irradiation. In fact, a 50% decline in absolute lymphocyte count within the first 24 hours after exposure, followed by a further, more severe decline within 48 hours, characterizes a potentially lethal exposure.



The above figure shows Leukocyte count based on exposure dose in patients exposed to radiation in Chernobyl. Note the abortive rise (transient increase before the fall) in counts of leukocytes, which are primarily composed of granulocytes, in doses less than 5 Gy. Neutropenia may not occur for weeks, especially with lower exposures and its duration may be prolonged. To convert cells/mm³ to x10⁹ cells/litre, multiply by 0.001. Due to large inter-individual variation of leuco-counts, it is necessary to observe the kinetics. However, in severe cases, bone marrow cellularity needs to be checked to ascertain the viability of bone marrow and its recovery.

(Ref: Annals of Internal Medicine. CLINICAL GUIDELINES. Medical management of the Acute Radiation Syndrome: Recommendations of the Strategic National Stockpile Radiation Working Group. Jamie K. Waselenko et al; 15 June 2004/ Vol 140/Issue 12/ Pg 1037 – 1051)

2 Gastro-Intestinal Syndrome:

2.1 Radiation induces loss of intestinal crypts and breakdown of the mucosal barrier. The onset of gastro-intestinal syndrome is at 6-8 Gy whole body and results in abdominal pain, diarrhea, nausea and vomiting and predispose patients to infection. At doses

exceeding 12 Gy, the mortality rate of the gastrointestinal syndrome exceeds that of the hematopoietic syndrome. Severe nausea, vomiting, watery diarrhea and cramps occur within hours after high-dose (>10 Gy) irradiation.

Latent period follows, lasting for 5 to 7 days, during which symptoms reduce.

- 2.2 During manifest illness, vomiting and severe diarrhea associated with high fever occur. Systemic effects may include malnutrition from mal-absorption, bowel obstruction from ileus, dehydration, cardiovascular collapse and electrolyte derangements from fluid shifts. Damage to the intestinal mucosa and microcirculation, causing gastrointestinal bleeding, leads to anemia. Subsequently it can cause sepsis and acute renal failure.

3 The Neurovascular Syndrome

- 3.1 The Neurovascular syndrome is less well defined than other syndromes, and its stages are compressed. Individuals presenting with fever, hypotension and major impairment of cognitive function will most likely have had a supra-lethal exposure. These symptoms may be observed in those receiving more than 15 to 30 Gy of radiation.
- 3.2 The prodromal phase is characterized by disorientation, confusion and prostration and may be accompanied by loss of balance and seizures. Physical examination may show papilledema, ataxia and reduced or absent deep tendon and corneal reflexes.
- 3.3 During the latent period, apparent improvement occurs for a few hours and is followed by severe manifest illness. Within 5 to 6 hours, watery diarrhea, respiratory distress, hyperpyrexia and cardiovascular shock can occur. This rapid decline mimics the clinical course of acute sepsis and septic shock, both of which must be considered. The ensuing circulatory complications of hypotension, cerebral edema, increased intracranial pressure and cerebral anoxia can lead to death within 2 days.

4 The Cutaneous Syndrome

- 4.1 Cutaneous injury from thermal or radiation burns is characterized by loss of epidermis and, at times, dermis. Injuries to the skin may cover small areas but extend deeply into the soft tissue, even reaching underlying muscle and bone. They may be accompanied by profound local edema and place the patient at risk for a compartment syndrome. Patients presenting with burns immediately after exposure may have had thermal rather than radiation burns. Significant injuries to the integument decrease the LD50/60 and amplify the risk of death at any radiation exposure dose. Patients with the hematopoietic syndrome have a more complicated course of the cutaneous syndrome as a result of bleeding, infection and poor wound healing.
- 4.2 Table showing the Grading system for Response of Neurovascular, Gastro-Intestinal Systems.

(Ref: Annals of Internal Medicine. CLINICALGUIDELINES. Medical management of the Acute Radiation Syndrome : Recommendations of the Strategic National Stockpile

Radiation Working Group. Jamie K. Waselenko et al; 15 June 2004/ Vol 140/Issue 12/
Pg 1037 – 1051)

Grading System of Response of Neurovascular, Gastrointestinal and cutaneous Systems*

Symptom	Degree 1	Degree 2	Degree 3	Degree 4
Neurovascular System				
Nausea	Mild	Moderate	Intense	Excruciating
Vomiting	Occasional (once per day)	Intermittent (2-5 times per day)	Persistent (6-10 times per day)	Refractory (>10 times per day)
Anorexia	Able to eat	Intake decreased	Intake minimal	Parenteral nutrition
Fatigue syndrome	Able to work	Impaired work ability	Needs assistance for ADLs	Cannot perform ADLs
Temperature, °C	<38	38-40	>40 for <24 h	>40 for <24 h
Headache	Minimal	Moderate	Intense	Excruciating
Hypotension	Heart rate>100 beats/min; blood pressure > 100/170 mm Hg	Blood pressure <100/70 mm Hg	Blood pressure <90/60 mm Hg; transient	Blood pressure <80/?mm Hg; persistent
Neurologic deficits†	Barely detectable	Easily detectable	Prominent	Life-threatening, loss of consciousness
Cognitive deficits†	Minor loss	Moderate loss	Major impairment	Complete impairment
Gastrointestinal system				
Diarrhea				
Frequency, stools/d	2-3	4-6	7-9	≥10
Consistency	Bulky	Loose	Loose	Watery
Bleeding	Occult	Intermittent	Persistent	Persistent with large amount
Abdominal cramps or pain	Minimal	Moderate	Intense	Excruciating
Cutaneous system				
Erythema §	Minimal, transient	Moderate (<10% body surface area)	Marked (10%–40% body surface area)	Severe (>40% body surface area)
Sensation or itching	Pruritus	Slight and intermittent pain	Moderate and persistent pain	Severe and persistent pain

Swelling or edema	Present, asymptomatic	Symptomatic, tension	Secondary dysfunction	Total dysfunction
Blistering	Rare, sterile fluid	Rare, hemorrhage	Bullae, sterile fluid	Bullae, hemorrhage
Desquamation	Absent	Patchy dry	Patchy moist	Confluent moist
Ulcer or necrosis	Epidermal only	Dermal	Subcutaneous	Muscle or bone involvement
Hair loss	Thinning, not striking	Patchy, visible	Complete, reversible	Complete, irreversible
onycholysis	Absent	Partial	Partial	Complete

* Modified from Flicdner TM, Fricsccke I, Beyrcr K (39). ADL = activity of daily living.

+ Reflex status (including corneal reflexes), papilledema, seizures, ataxia, and other motor signs or sensory signs.

‡ Impaired memory, reasoning, or judgement.

§ The extent of involvement is decisive and should be documented for all skin changes.

4.3 Table showing Levels of Haemopoetic Toxicity

(Ref: Annals of Internal Medicine. CLINICAL GUIDELINES. Medical management of the Acute Radiation Syndrome: Recommendations of the Strategic National Stockpile Radiation Working Group. Jamie K. Waselenko et al; 15 June 2004/ Vol 140/ Issue 12/ Pg 1037 – 1051)

Levels of Hematopoietic Toxicity:

Symptom or Sign	Degree 1	Degree 2	Degree 3	Degree 4
Lymphocyte changes [†]	$\geq 1.5 \times 10^9$ cells/L	1- 1.5×10^9 cells/L	0.5- 1×10^9 cells/L	$< 0.5 \times 10^9$ cells/L
Granulocyte changes [‡]	$\geq 2 \times 10^9$ cells/L	1- 2×10^9 cells/L	0.5- 1×10^9 cells/L	$< 0.5 \times 10^9$ cells/L
Thrombocyte changes [§]	$\geq 100 \times 10^9$ cells/L	50- 100×10^9 cells/L	20- 50×10^9 cells/L	$< 20 \times 10^9$ cells/L
Blood loss	Petechiae, easy bruising, normal hemoglobin level	Mild blood loss with $< 10\%$ decrease in hemoglobin level	Gross blood loss with 10%-20% decrease in hemoglobin level	Spontaneous bleeding or blood loss with $> 20\%$ decrease in hemoglobin level

* Modified from Dainiak N (24).

† Reference value, $1.4-3.5 \times 10^9$ cells/L

‡ Reference value, $4-9 \times 10^9$ cells/L

§ Reference value, $140-400 \times 10^9$ cells/L

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