



GOVERNMENT OF INDIA

AERB SAFETY MANUAL

HAND-BOOK FOR MEDICAL MANAGEMENT OF PERSONS EXPOSED IN RADIATION ACCIDENTS



ATOMIC ENERGY REGULATORY BOARD

AERB Manual No. SM/MED-2

HAND-BOOK FOR MEDICAL MANAGEMENT OF PERSONS EXPOSED IN RADIATION ACCIDENTS

Issued on December 23, 1989

**ATOMIC ENERGY REGULATORY BOARD,
Vikram Sarabhai Bhavan,
Anushaktinagar,
Bombay - 400 094, India.**

Price : Rs

This hand-book is available from :-

The Administrative Officer,
Atomic Energy Regulatory Board,
Vikram Sarabhai Bhavan,
(4th Floor, North wing)
Anushaktinagar, Bombay - 400 094.

FOREWORD

The Indian Atomic Energy Programme is poised for a quantum jump to reach 10,000 MWe of Nuclear power generation capacity by the turn of the present century. Increased scale and variety of medical, industrial and research applications of radioisotopes are envisaged as a sequel to the concerted efforts underway in this direction by the Department of Atomic Energy. Therefore, it is imperative that concurrently emergency response plans, including those for medical management of persons involved in radiation emergencies, should be made ready as a part of the overall safety strategy. With this view the Atomic Energy Regulatory Board has prepared a comprehensive guide on the medical management of persons exposed in radiation accidents. The said Guide describes in detail the diagnosis and treatment procedures to be followed for treating the cases of accidental irradiation and contamination, the facilities and equipment needed for the purpose and the education/training to be provided for the medical staff who will manage these facilities. The Guide also provides considerable basic information on related radiation physics, radiobiology, dosimetry and other health physics support necessary for the management of radiation accidents.

The present manual is an abridged version of the above Guide. It is prepared by a sub-committee consisting of the following members:-

1. Dr.(Miss) K.A. Dinshaw
(Chairperson) Head, Department of Radiation Oncology,
Tata Memorial Hospital,
Bombay-400 012.
2. Dr. S.H. Advani Head, Department of Medical Oncology,
Tata Memorial Hospital,
Bombay-400 012.
3. Dr. D.B. Mendhekar Hospital Superintendent,
TAPS Hospital, Tarapur.
4. Dr. G.K. Iyer Medical Officer, Trombay Dispensary,
Medical Division,
Bhabha Atomic Research Centre,
Bombay-400 085.
5. Shri Masood Ahmad Deputy Director,
(Member-Secretary) Radiation Safety Division,
Atomic Energy Regulatory Board,
Bombay-400 094.

This document is intended for rapid reference by the physicians who may be called upon to handle the cases of a radiation emergency. Therefore, it deals mainly with the diagnosis and treatment procedures which should be followed by medical officers. For further details on health physics, radiobiology and organisational aspects, the above AERB Guide should be consulted.

When the present manual was being finalised for printing, the latest 'Recommendations of the International Commission on Radiological Protection' were published as ICRP Publication - 60 (1991). This Publication now replaces ICRP's earlier 'Recommendations' contained in its Publication - 26 (1977). Consequent changes have been incorporated in this Handbook.



(S.D. Soman)
Chairman

Atomic Energy Regulatory Board

CONTENTS

	Page
1. BASIC RADIOBIOLOGY	1
2. CLASSIFICATION OF RADIATION ACCIDENTS AND PREPAREDNESS FOR MEDICAL INTERVENTION.	5
3. MANAGEMENT OF EXTERNAL RADIATION EXPOSURE	8
3.1 Whole body exposure	
3.2 Partial body exposure	
3.3 Localised exposure	
4. MANAGEMENT OF RADIOACTIVE CONTAMINATION	21
4.1 External contamination	
4.2 Internal contamination	
5. ACTION PLAN FOR HANDLING RADIATION CASUALTIES	27
Appendix - I Infrastructure and facilities	35
Appendix - II Physicians who advise on diagnosis and treatment of radiation injuries	38
Bibliography	41

1. BASIC RADIOBIOLOGY

1.1 IONISING RADIATIONS

The term "ionising radiation" is used when the radiation in question ionises the atoms of the matter through which it passes. These radiations also cause excitation of atoms they encounter. Both these effects are responsible for transfer of energy from the radiation to the exposed matter and for initiating the chemical reactions which ultimately show up as radiation effects or damage. Following are the most important ionising radiations and some of their properties.

1.1.1. X-rays :

High energy electro-magnetic radiations, e.g. those emanating from specially designed high voltage machines, are called x-rays. They can penetrate deep in human body and in other materials.

1.1.2. Gamma rays :

The electromagnetic radiations emitted by radioactive substances are called gamma-rays. Their nature and behaviour are exactly like those of X-rays - highly penetrating in matter and hence affecting even deep seated organs in the body.

1.1.3 Beta-rays :

High energy electrons emitted by radioactive substances such as tritium, Sr-90 etc., are called beta rays. Very high energy beta rays can penetrate nearly a centimetre deep in soft tissue. Skin is the most affected organ when a person is exposed to beta-rays externally, causing the so-called beta-burns in acute cases. When a beta emitting material is taken internally, the beta radiations transfer an overwhelming fraction of their energy to the organ in which the material concentrates preferentially.

1.1.4. Alpha-rays :

The nuclei of helium, emitted by radioactive atoms like uranium, plutonium etc., are called alpha-rays. These heavy charged particles ionise the matter densely and hence do not penetrate much. When the human body is externally exposed to alpha-rays, the penetration is limited to the outer epithelial cells. However, when the "intake" of an alpha-emitting material takes place, the cells of the organs in which the material gets metabolised, are directly and adversely affected - the damage being 20 times heavier than that due to the same dose of X-rays or gamma-rays.

1.1.5 Neutrons :

Neutrons are uncharged particles emitted by atoms under specific circumstances e.g. during fission of uranium in the core of a reactor. Neutrons are highly penetrating, transferring large amounts of energy by direct physical collisions with the nuclei of the atoms they encounter enroute. Their capacity for biological damage, relative to gamma or beta rays increases with increasing energy of the neutrons (upto 2MeV).

A comparison of the penetrating power of the above ionising radiations is shown in Fig.1.1.

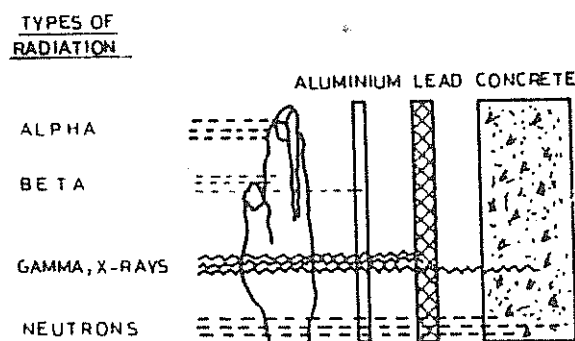


Fig. 1.1 PENETRATING POWERS OF THE VARIOUS TYPES OF RADIATION.

1.2. RADIATION UNITS AND QUALITY FACTORS

The radiation dose is measured in terms of the energy absorbed in the matter through which it passes. When an energy of one joule per kilogram is absorbed in a matter, it is said to have received an absorbed dose, D, of one gray (Gy). Earlier, the unit of absorbed dose was the rad. One gray equals 100 rad.

As stated above, certain ionising radiations are more damaging than others. The factor which represents this biological effectiveness is called radiation weighting factor (W_R). The radiation weighting factor of neutrons is 5 for thermal neutrons and 20 for fast neutrons, in the energy range 100 keV to 2 MeV. When the absorbed dose, D, is multiplied by W_R , the resulting biologically isoeffect quantity, $H = DW_R$ is called the equivalent dose. Its unit is the sievert (Sv). An absorbed dose of 10 Gy of fast neutrons is equal to $10 \times 20 = 200$ Sv. The earlier unit of equivalent dose was rem. One sievert is equal to 100 rem.

Table 1.1 lists the units of radiation and radioactivity in use now and earlier.

Table 1.1 QUANTITIES AND UNITS FOR MEASUREMENT OF RADIATIONS AND RADIOACTIVITY

Quantity	Name & symbol of current units	Old units & symbols	Conversion of units
Exposure	air kerma(Gy)	roentgen (R)	1 R = 0.0087 Gy
Absorbed Dose	gray (Gy)	rad	1 Gy = 100 rad 1rad = 1 cGy
Equivalent Dose	sievert (Sv)	rem	1 Sv = 100 rem 1rem = 10 mSv
Activity	becquerel(Bq)	curie (Ci)	1 Bq = 27 pCi 1 Ci = 3.7×10^{10} Bq 1mCi = 37 MBq 1 μ Ci = 37 kBq

1.3 DIRECT AND INDIRECT ACTIONS OF RADIATION

The radiation effects at the cellular level are initiated through two distinctly different mechanisms:-

1.3.1. Firstly, the radiation may hit the vitally sensitive targets in the cell nuclei causing direct damage to DNA molecules or resulting in breakage of chromosome strands. In case of incomplete repair of DNA molecule or a mismatch of the DNA fragments during repair, alteration in functional properties of the cell is likely to occur.

1.3.2. Alternatively, the radiation may ionise the cellular water releasing highly reactive radiolytic products like free radicals and hydrated electrons which in turn react with DNA molecules. This causes, indirectly, the molecular lesions and consequent impairment of cell functions in case the repair is partial or erroneous. The radiolytic products may also react with other cellular chemicals producing oxidising or reducing agents injurious to the cell.

Acute radiation damage to a cell, initiated by either of the two modes of action, leads to cell death.

1.4. BIOLOGICAL EFFECTS OF RADIATION ON TISSUES

The sensitivity of different tissues to radiation varies widely. Rapidly dividing cells like those of bone marrow and mucosa of GI tract are very sensitive to radiation damage. Highly differentiated cells, like those of nervous tissue are highly radio-resistant.

2. CLASSIFICATION OF RADIATION ACCIDENTS AND PREPAREDNESS FOR MEDICAL INTERVENTION

2.1 EXTERNAL IRRADIATION

External irradiation accidents are categorised as follows:

2.1.1 Whole-Body Exposure

In the case of whole body irradiation, most parts of the body, particularly the face and torso are affected. The clinical symptoms and the prognosis of the case will depend on the doses received, the type of radiation involved and whether the exposure is uniform or non-uniform. Above 1 Gy the patient will show the symptoms and signs of "Acute Radiation Syndrome (ARS)"

2.1.2 Partial Body Exposure

Partial body exposure involves the exposure of a large part of the body or vital organs like stomach, heart and head. In case of exposure to face, chest and abdomen, the symptoms of whole-body exposure may be seen.

2.1.3 Localised Irradiation (Radiation Burns)

In localised irradiation a small part of the body is exposed to radiation. Acute localised irradiation may lead to radiation burns. Most commonly hands, feet, legs and face receive high dose, but any other part of the body may also be involved.

The serious radiation injuries seen so far in our country are only radiation burns caused by malfunctioning of, or improper/unauthorised use of, industrial radiography equipment.

2.2 RADIOACTIVE CONTAMINATION

Radioactive contamination may occur when a person comes in contact with unsealed radioactive material. The contamination may be external or internal.

2.2.1 External Contamination

It involves the presence of radioactive material on the body or clothes of the person. Since radionuclides may take a long time to decay, the contamination is removed by washing etc. to minimise dose to the skin.

2.2.2. Internal Contamination

It results from accidental intake of radioactive material. When the intake is large enough to deliver a high dose to the organs, clinical manifestations of acute radiation syndrome or oropharyngeal syndrome are seen. However, low doses involve only long-term effects, e.g., incidence of malignancy, which may occur after 10-20 years of exposure.

2.3 CRITICALITY ACCIDENTS

In criticality accidents, such as may happen in reactors or assemblies of plutonium and enriched uranium, all types of radiation, like gamma rays, beta particles and neutrons may be involved, giving rise to a complex dose distribution within the body of the exposed individual. Therefore, in such cases, radiation injuries may have all the aspects mentioned above. In addition, traumatic injuries including thermal burns may be present.

2.4 SPECIFIC ACCIDENT HAZARDS

Neutron irradiated heavy water, e.g. from a pressurised heavy water reactor (PHWR), is a major source of tritium contamination. A large inventory of sodium, e.g. in a fast breeder reactor (FBR), poses an additional source of fire hazard. Hence, it is essential to be aware of the working conditions and specific health hazards existing in each individual installation and to ensure that the medical management facilities remain prepared to deal with them effectively.

2.5 POSSIBILITIES OF RADIATION ACCIDENTS

Various operations associated with the nuclear fuel cycle, viz. mining, milling, fuel fabrication, reactor operation, fuel reprocessing and waste management have widely differing radiation hazard potential. The probability and severity of the various categories of radiation injuries possible in these operations is tabulated in Table 2.1. The hazard potential for different categories of radiation accidents possible in the various applications of radiation and radioisotopes, e.g. in industry, medicine and research are shown in Table 2.2.

2.6 INDIAN AND WORLDWIDE EXPERIENCE OF RADIATION ACCIDENTS

The radiation safety record in the country has been quite good. No fatal radiation accidents have occurred in India. About 25 accidents have been reported in industrial applications during the period 1980-88, mainly involving Ir-192 and Co-60 industrial radiography sources. Fifty six persons were exposed to high doses of radiation in these accidents; among them four persons received high doses to the skin requiring medical treatment and surgical intervention. Eight incidents have been reported during the period 1967-88 in medical applications. Six of these incidents were associated with teletherapy units; twenty four persons received low radiation doses and one person received a high dose on the hand, requiring amputation. Two incidents were associated with X-ray fluoroscopy, the patients receiving radiation burns on the skin of their back.

TABLE 2.1, POTENTIAL FOR DIFFERENT CATEGORIES OF RADIATION ACCIDENTS IN NUCLEAR FUEL CYCLE OPERATIONS

Nuclear fuel cycle operation	External Irradiation		Radioactive Contamination	
	Acute whole-body irradiation	Partial-body or localised irradiation	External contamination	Internal contamination
Mining	-	-	-	-
Milling	-	-	+	+
Fuel fabrication (Uranium based)	-	-	++	++
Plutonium ²³⁹ fuel fabrication	+	+	++	++
Reactor operations	+	++	++	++
Irradiated fuel reprocessing	++	++	+++	+++
Radioactive waste management				
High-level	+	+	++	++
Low-level	-	-	+	+

Note : - indicates not applicable; + indicates low-potential;
 ++ indicates moderate potential and +++ indicates high-potential.

TABLE 2.2, POTENTIAL FOR DIFFERENT CATEGORIES OF RADIATION ACCIDENTS IN APPLICATIONS OF RADIATION AND RADIOISOTOPES

Radiation applications	External Irradiation		Radioactive Contamination	
	Acute whole-body irradiation	Partial-body or localised irradiation	External contamination	Internal contamination
Industrial radiography	-	+++	-	-
Industrial irradiators	+	-	-	-
Nucleonic gauges	-	+	-	-
Diagnostic radiology	-	+	-	-
Radiotherapy				
Teletherapy	+	++	-	-
Brachytherapy	-	+	-	-
Nuclear medicine	-	-	+	+
Radiotracer applications	-	-	+	+

Note : - indicates not applicable; + indicates low-potential;
 ++ indicates moderate potential and +++ indicates high-potential.

The global information available on radiation accidents which have occurred in other countries has been summarised in Table 2.3.

TABLE 2.3 SERIOUS RADIATION ACCIDENTS REPORTED (1945-1987)

Type of facility	No. of events	Overexposures ^a	Deaths
Nuclear facilities	27 (34%)	272 (64%)	35 (59%)
Non-nuclear facilities			
Industry	42 (52%)	84 (20%)	20 (34%)
Research	7 (9%)	10 (2%)	- (-)
Medical	4 (5%)	62 (14%)	4 (7%)
Total	80 (100%)	428 (100%)	59 (100%)

^a The table excludes patient related events and off-site exposures at Chernobyl. (Source: Nuclear Safety Review for 1987, IAEA, Vienna (1988) p.74)

2.7 MEDICAL INTERVENTION

The immediate action plan for rendering medical assistance has been indicated in Table 5.1. Further follow-up actions have been indicated in Fig 5.1. Specific medical management of external whole-body irradiation and localised irradiation have been summarised in Figs. 3.2 and 3.3 respectively. External decontamination and decorporation of internal contamination are summarised in Figs. 4.1 and 4.2 respectively. The information given in these six tables and figures should enable the physician to take prompt actions as appropriate. More information on specific medical aspects may be found in the text of the Handbook at relevant places.

3. MANAGEMENT OF EXTERNAL RADIATION EXPOSURE

3.1. WHOLE-BODY EXPOSURE

3.1.1. Introduction

When the whole body or most of it, including the face and torso, is exposed to a high dose of penetrating radiation, an Acute Radiation Syndrome (ARS) may result. Accidental external exposure may result from photon irradiation (X-rays or gamma rays), particle irradiation (electrons, protons, deuterons, heavy ions) or from mixed beams (gammas and neutrons).

Fortunately, these events occur very rarely, mainly as a result of events in nuclear plants or inadvertent exposure to radioactive sources.

The clinical effects, the severity of ARS and the final prognosis are dependant upon:-

- a. Dose rate and duration of exposure.
- b. Total accumulated dose.
- c. Nature of radiation.
- d. Pattern of dose distribution, uniform or non-uniform, in the body.

3.1.2 Acute Radiation Syndrome (ARS)

The ARS represents the clinical expression of damage to important organs and systems particularly those with a rapid cell turnover. Based on doses received, the following syndromes are seen:-

- a. Neurovegetative Syndrome
- b. Haematopoietic Syndrome
- c. Gastrointestinal Syndrome
- d. Neurological Syndrome.

If the radiation is delivered swiftly, it produces maximum biological effect. Alternatively, if delivered over a period of time, as in accidents involving radioisotopes or X-ray units, the resulting clinical effect is considerably less, for the same total dose.

The clinical manifestations of damage to important organs and systems unfold in four stages as follows:-

3.1.2.1. *Prodromal Phase*

The prodromal phase manifests itself with anorexia, nausea, vomiting, diarrhoea, weakness, apathy, prostration, perspiration, erythema, conjunctivitis, fever, respiratory distress, hyperexcitability and ataxia within one day to one week. These symptoms may also relate to a psychoneurotic reaction rather than a true over-exposure.

3.1.2.2. *Latent Period*

The above symptoms may subside in 3-4 days following which the latent period may extend from one to three weeks. It is usually shorter for high doses.

3.1.2.3. *Manifest Illness*

At very high doses there may not be any latent period at all; rather the patient deteriorates rapidly from the prodromal stage into the acute radiation syndrome, usually from the second or third week upto seventh week. The shorter the onset period the worse is the prognosis.

3.1.2.4. Recovery Phase

With adequate supportive care during the critical period a proportionate number of patients can be salvaged into the recovery phase, extending from eight to fifteen weeks.

3.1.3. Neurovegetative Syndrome

At around a dose of 1 Gy a Neurovegetative Syndrome manifests with vomiting in 5% of the cases, with minimal changes in the blood picture and the chromosomal patterns. All cases eventually recover completely.

3.1.4. Haematopoietic Syndrome

This results from doses ranging from 1-10 Gy. The severity of other clinical features may be graded as follows:-

3.1.4.1. 1-2 Gy: Mild degree of syndrome with nausea and vomiting occurring in a few patients within the first few hours after exposure. Neutropenia and thrombocytopenia will occur between four to six weeks. No major clinical problem is seen and most cases eventually recover. Careful haematological checks are required.

3.1.4.2. 2-4 Gy: Moderate degree of syndrome with nausea and vomiting within 2-3 hours. Vomiting is recorded within 3 hours in 50% of cases exposed to a dose of 2 Gy and in 100% of the cases receiving a dose of 3 Gy. Neutropenia and thrombocytopenia will occur, dipping towards nadir within two to three weeks; associated with fever and bleeding in all cases. All patients are likely to recover with supportive care.

3.1.4.3. 4-6 Gy: Severe degree of syndrome with nausea and vomiting occurring within 1/2 - 1 hour and associated with symptoms of early fever, erythema of skin and mucosa. Vomiting is recorded within 1 hour in 100% of cases. Neutropenia and thrombocytopenia occur at two or three weeks and may persist for six to eight weeks. Without supportive care and therapy the majority will die of infections and consequences of bleeding. If adequately supported the majority will recover.

3.1.4.4. 6-10 Gy: Very severe degree of syndrome with nausea and vomiting occurring within 1/2 hour followed by diarrhoea within a few hours after exposure. Maximal cytopenia occurs within 10-14 days with stomatitis and enteritis. Haemorrhage from the skin, mucous surface and internal organs will be seen. These patients are susceptible to infections. Blood examination will reveal leucopenia, lymphopenia, thrombocytopenia and anaemia after initial increase of polymorphs. The skin will show fixed erythema after 2-3 weeks and epilation after 3 weeks, which may be permanent.

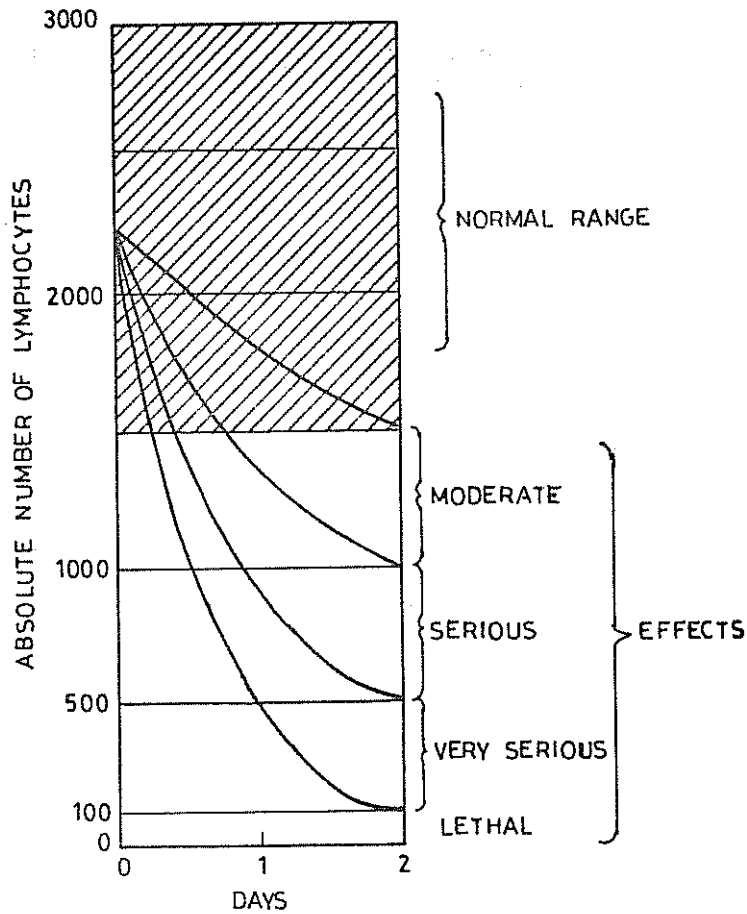
Death occurs due to haemorrhage and infection within two months. The critical period is two to six weeks. The median lethal dose is in the range of 4-6 Gy. Fig 3.1 summarises the haematological changes following radiation exposure.

3.1.5 Gastrointestinal Syndrome

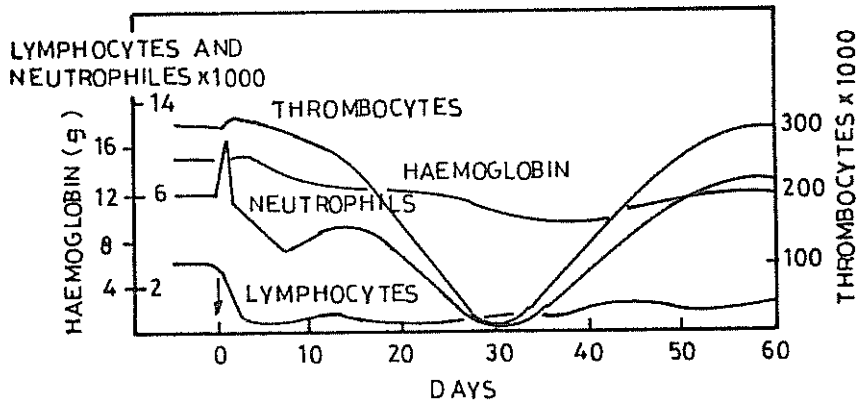
The symptoms may occur at a dose of 8 Gy and above.

3.1.5.1 8-10 Gy: Nausea and vomiting will occur within half an hour in the prodromal phase and is followed by a latent period which may last for a week. The third phase of manifest illness starts with vomiting, diarrhoea, severe fluid and electrolyte loss followed by intestinal ulcerations and haemorrhage. Severe gastrointestinal symptoms merge with the haematological syndrome resulting in haemorrhage from mucosal membranes and bacterial infections due to severe bone marrow depression. At the higher dose levels all these clinical phases may merge altogether.

3.1.5.2. 10-20 Gy: Symptoms of anorexia, nausea, vomiting, diarrhoea appear in less than half an hour to be followed by toxic shock syndrome due to severe electrolyte imbalance and haemorrhage from skin and gastrointestinal mucosal surfaces. The skin becomes erythematous with subepidermal injuries and



(a)-PATTERNS OF EARLY LYMPHOCYTE RESPONSE IN RELATION TO DOSE (FROM G.A. ANDREWS)



(b)-TYPICAL CHART OF BLOOD VALUES IN FAIRLY SEVERE HAEMATOPOIETIC SYNDROME (FROM G.A. ANDREWS)

Fig.3.1 CHANGES IN PERIPHERAL BLOOD FOLLOWING ACUTE RADIATION EXPOSURE.

permanent epilation. Blood tests reveal a rapid fall in absolute lymphocyte count to less than 100 cells/mm³ within 48 hours. The critical period lasts for one to two weeks during which death occurs due to circulatory collapse.

3.1.5.3. Oropharyngeal Syndrome, as described after the Chernobyl experience, is characterized by brisk radiation mucositis in the buccal cavity, vestibule of the larynx and in the nasopharynx resulting in accumulation of enormous quantities of rubbery mucous deposits in these sites.

3.1.6. Neurological Syndrome

At doses in excess of 50 Gy the predominant effect is on the Central Nervous System. Vomiting occurs immediately with complaints of a generalized severe burning sensation associated with parasthesia, tremors, ataxia and convulsions. This rapidly progresses to coma and death within 72 hours due to cerebral oedema, encephalitis and respiratory failure. Table 3.1 summarises the acute radiation syndrome of progressively increasing doses.

3.1.7. Medical Management

3.1.7.1. General Principles

Whole body exposure is characterized by a sudden burst of radiation and is likely to occur very rarely, under extreme accident conditions, in installations such as nuclear facilities and industrial irradiators. As no specialist doctor is permanently appointed on duty the local doctor may be called upon to assist in the management of these cases. His role will be to:-

- a. Institute life saving measures
- b. Assist with decontamination
- c. Record history and clinical assessment.
- d. Initiate investigations.
- e. Initiate minimal supportive treatment.
- f. Transfer patient to specialized units for further advanced therapy.

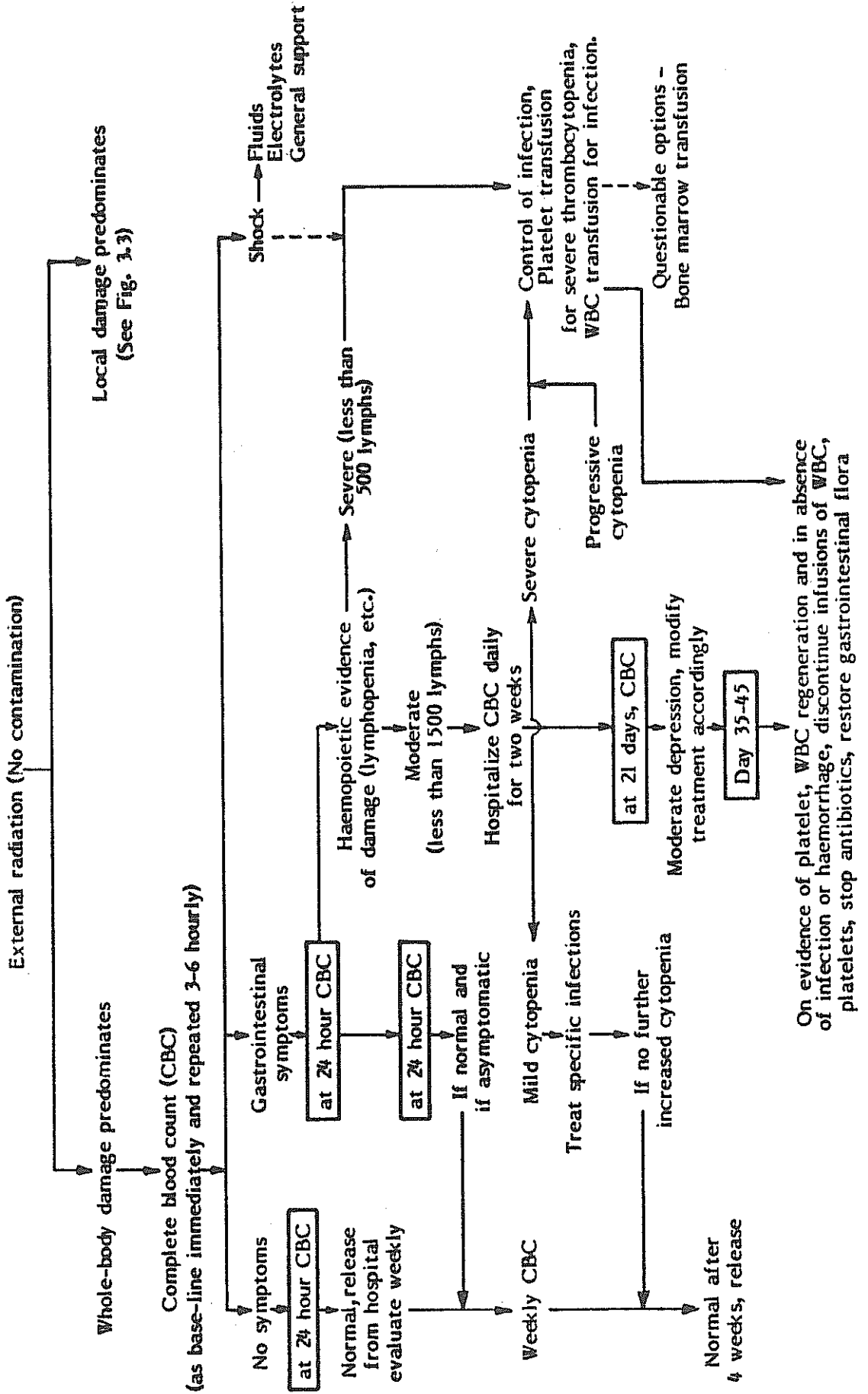
The above lines of treatment are discussed, seriatim, in the following sections and then summarised in Fig. 3.2:-

- (a) Life Saving Measures for injuries and trauma must be given first priority.
- (b) Decontamination Measures are then adopted including removal of clothing and external contamination and the administration of first aid for internal contamination.
- (c) The Accident History Recording and Clinical Examination is simultaneously carried out and immediate communication made with the appropriate Radiation Safety Officer (RSO) to evaluate the physical dosimetry. A reconstruction of the radiation accident scenario, accurate mapping of the dose distribution in the body using various accident simulation and dosimetry techniques will be helpful in deciding the line of treatment. The clinical history should include the prodromal symptoms, their period of onset and symptoms attributed to psychosomatic factors. The clinical examination must be efficiently and swiftly carried out and be as detailed as possible. It should include:-
 - i. Evaluation of the skin for erythema.
 - ii. Cardiovascular examination to record pulse and blood pressure.
 - iii. Evaluation of the digestive tract.
 - iv. Neurological examination for abnormal responses.

Table 3.1 ACUTE RADIATION SYNDROME

Effects	Dose (Gy)	0	1	2	3	4	5	6	7	8	9	10 +	>50
Incidence of Vomiting (%) & Time of Onset (hours)	5	50	100										
		3	2	1	<1								
Organs affected	Nil	Haemopoiesis											
Signs	Nil	Leucopenia, Haemorrhages, Infection											
		Diarrhoea, Electrolyte imbalance											
Critical period		4 - 6 weeks											
Skin reactions		Erythema											
		Transient (2 - 3 hours) Fixed (2 - 3 weeks) Epilation (Transient)											
Cause & time of death		Erythema, Subepidermal injury, Permanent epilation											
		Circulatory collapse											
Prognosis	Good	Haemorrhage, Infections, 2 months											
		50% deaths											
		100% deaths											
		Respiratory failure, Cerebral oedema 2 days											

Fig. 3.2 MANAGEMENT OF THE ACUTE RADIATION SYNDROME



- v. Ophthalmological examination with the slit lamp for base line evaluation of lens and anterior chamber.
 - vi. Photographs to be taken, when possible, for clinical evaluation, medico-legal purpose and research.
- (d) Following Investigations should be done immediately to serve as Biologic Indicators of radiation exposure :-

1. Blood Samples

- i. Haematological
 - Complete blood count (3-6 hourly for 24-48 hours)
 - Blood grouping
 - Bone marrow biopsies after 24 hours from multiple sites.
 - HLA Typing.

Changes in peripheral blood :-

The rate of depletion of the absolute lymphocyte count in the first two days after exposure can be accurately related to dose received as seen in Fig. 3.1. The level of lymphopenia is one of the best indicators of dose and of severity of radiation injury. A fall to less than 1000 cells/mm³ in 24 hours signifies a grave exposure. The granulocytes however show an early rise within 24 hours followed by a marked dip from 10-15 days to a nadir at 30 days after exposure. A spontaneous recovery after the fifth week signifies good prognosis. Platelets similarly show an early rise and a dip marked at 30 days after which they recover rapidly.

- ii. Biochemical
 - Blood sugar
 - Electrolytes
 - Liver function test
 - Renal function test

iii. Chromosomal aberrations in peripheral blood lymphocytes are a useful indicator of the absorbed dose. However, results are not available before 2-3 days after sampling. Diccetric counts in about 100-500 cells will give a good estimate of the whole body dose and its uniformity.

- 2. Bacteriology - Culture and antibiotic sensitivity from:-
 - Skin
 - Sputum
 - Stool
 - Urine
 - Septic Foci

3. ECG - shows non-specific ST changes if heart is irradiated.

4. EEG - distinct changes will be seen if doses are in excess of 4-5 Gy to the cranium.

(e) Initiate Minimal Supportive Treatment

Symptomatic treatment in the early stage should include the following:-

- Antiemetics
 - Chlorpromazine 25 mg im
 - Metoclopramide 10 mg im
- Steroids
 - Dexamethasone 4 mg iv 4 hourly.
 - Hydrocortisone 100 mg iv 4 hourly.
- Antidiarrhoeals
 - Codeine phosphate, Kaolin and Imodium.
 - Intravenous fluids
- Soft Vaseline or Petroleum Jelly dressings for dry skin.
- Sedation/Rest

(f) Triage, Evaluation and Transfer to Specialised Units

In large accidents the physician should perform triage of the exposed individuals by rapid dosimetric evaluation to identify cases who will need intensive care and transfer to various levels of hospitals.

In Chernobyl the patients were segregated according to degrees of primary reaction of prodromal symptoms after irradiation as follows.

- i. First Degree - If vomiting develops after 2 hours (doses upto 2 Gy)
- ii. Second degree - If vomiting develops after 1 hour.
- iii. Third degree - If vomiting develops after 30 minutes to 1 hour.
- iv. Fourth Degree - If vomiting occurs within 30 minutes (doses of > 6 Gy).

3.1.7.2. Specialised Medical Therapy

Patients who have received a low dose of radiation (around 1 Gy) usually do not need any hospitalisation, but will need medical surveillance. Patients who have received a dose of 2-3 Gy will need hospitalisation, while patients within the dose range of around 4-10 Gy may need isolation with sterile facilities, packed red cell transfusion, platelet transfusions and antibiotic therapy. When the bone marrow has received an uniform dose in excess of 9-10 Gy, bone marrow transplantation may be required which is to be done in Specialized Centres.

In the light of above observations, it is clear that a team of specialized medical staff will be needed to provide the following range of medical care and supporting facilities to the patients:-

a. Nursing Care

The nursing care of the irradiated person should be of the highest order. Intravenous feeding and drug administration casts a heavy burden on the nursing staff. All supplies entering the patient's room should be sterilised by heat or irradiation. Linen, blankets and all personal belongings of the patient should be sterile.

b. Isolation Facility

If infections are to be prevented or treated properly, some kind of isolation facility will be required. Single sterile room with a laminar air flow is best. Where these facilities do not exist, the patient can be isolated in a single room with reverse barrier nursing and room air sterilised by ultraviolet lamps. To minimise the risk of infection, all supplies entering the room should be sterilised. Visitors should be restricted and those going into the room should wear masks, clean gowns and plastic aprons.

c. Prevention and Treatment of Infections

Antibiotics should be administered at an early stage. These can be prophylactic and specific antibiotics. Fever should be treated promptly. For bacterial infections a combination of newer penicillin-like antibiotics such as piperacillin and mezlocillin give good results. Other newer drugs cephalosporin like ceftazidime and newer aminoglycoside like amikacin may also be tried.

Particular problems could arise due to viral and fungal infections. Cotrimoxazole can be used for prophylaxis of pneumocystis infection after bone marrow transplant (BMT) which can be continued for six months. Prophylactically, oral acyclovir prevents herpes simplex infection after BMT. Cytomegalovirus infection should be managed with hyperimmune serum. For antifungal therapy amphotericin B and nystatin along with the newer agents like miconazole and ketoconazole are used.

d. Haematologic Support

The haematopoietic system is mainly involved in the median lethal dose range. Haematopoiesis should be supported until spontaneous bone marrow recovery occurs which can be expected between 4-6 weeks post irradiation. Support is usually required around third week post-irradiation and should be given

in the form of packed red cell transfusion and platelet transfusion. The most likely time-frame will be 20-30 days for giving these transfusions for the cases in the dose range of 4 to 6 Gy, i.e. those who have a better chance for survival. Cell separator and cold centrifuge facilities will make it easy to provide platelet concentrate to reduce the risk of bleeding. All blood products should be irradiated to a gamma dose of 1.5 Gy to prevent onset of secondary disease.

e. Nutrition

Food should be prepared in a separate sterile kitchen. No uncooked food is supplied to the patient. Bread is rebaked and butter and chocolate are autoclaved. Frozen food, adequately stored and cooked, is satisfactory. Sterile water is needed. Drinks in cans do not usually require further sterilisation.

Intravenous hyperalimentation will be necessary in seriously sick patients who are unable to take adequate calories orally. For the success of I.V. hyperalimentation it is necessary to establish a permanent venous access (Central Catheter) and availability of intravenous lipids, amino-acids, concentrated glucose, vitamins and trace elements. Intravenous hyperalimentation has to be started early before the patient develops clinical features of catabolic state.

f. Bone Marrow Transplantation

Above 10 Gy, if the exposure is uniform, bone marrow transplant (BMT) should be considered. It may be noted that irradiation is rarely uniform and chances of normal regeneration of undamaged marrow stroma should be carefully considered. When dosimetry suggests complete sterilization of haematopoietic areas, BMT may be needed in the 1st week to counteract bone marrow aplasia.

Allogenic HLA matched bone marrow transplant from a family donor, ideally a twin or a sibling, is necessary. It is necessary to have the donor matched with the recipient at the major histocompatibility complex. The success of BMT is limited by various complications including graft rejection, infection (bacterial, fungal and viral), acute or chronic graft versus host disease (GVHD). Before taking a decision, the benefits expected from this procedure would have to be compared with the risk of bone marrow failure.

g. Follow-up

Plans should be made for rehabilitation of the patient, following successful treatment and discharge of the patient from the hospital. These should include plans for his future employment including engagement in radiation work. Medical follow-up (frequently in the first year after discharge from the hospital and half yearly or annually later on) should also be done to look for late sequelae and long-term effects. Proper medical records of the history of investigations done, with their results, treatments provided and results of follow-up study should be maintained, for medico-legal purposes as well as for use in bio-medical research of such cases.

3.2 PARTIAL BODY EXPOSURE

Partial body exposure occurs when a sizeable portion of the body is involved-mainly the head, chest and abdomen. The symptoms and signs will be those which occur after whole body irradiation like uncontrollable vomiting after 3 hours. If diarrhoea occurs, it signifies severe damage to GI tract. Besides this, skin will show erythema, oedema and blisters on the exposed area. Blood picture will show initial leucocytosis followed by lymphopenia and neutropenia. In case the dose is around 4-6 Gy the prognosis is good as the unirradiated parts of bone marrow help in recovery. The management of partial exposure is same as that of acute radiation sickness.

3.3 LOCALISED EXPOSURE/RADIATION BURN

In localised exposure a small part of body is exposed to radiation resulting in radiation burns in acute cases. Any part of the body can be involved, but most commonly hands and limbs are affected. These serious radiation injuries are either due to accidents in industrial radiography using Ir-192 and Co-60 sources or because of improper use of medical X-ray units and radiation equipment. Gamma rays are more commonly

involved than X-rays in the accidents seen so far in our country. Sometimes injury is caused to non-radiation workers, e.g. due to inadvertent picking of a radiation source by an unauthorised person.

3.3.1 Skin Damage

Damage to skin may vary from minimal damage to the epidermal basal layer to damage to hair follicles, sweat glands, nerve endings and damage to intima of blood vessels, which is the most critical pathological event leading to obliterative endarteritis. The clinical picture unfolds in a definitive sequence as follows:-

1. Prodromal period.
2. Latent period.
3. Crisis period
4. Restoration period
5. Period of after effects.

Skin effects following radiation will depend on:-

1. Type of radiation.
2. Energy of radiation.
3. Dose rate.
4. Absorbed dose.
5. Space - time distribution of the dose.

Beta particles give up their energy within a short range and hence are more hazardous. In the event of a high radiation exposure of the skin, the following dose dependent effects will unfold:-

3.3.2 Transient erythema

This erythema appears within 2-3 hours of the accident, following moderate exposure of 20-30 Gy at high dose-rates. The patient may complain of a sensation of warmth in the affected area. At very high dose of 50 Gy the symptoms may be severe pain and the feeling that the affected part is on fire. Transient erythema lasts for a short time (hours to days). Damage to germinal cells in the basal layer is critical in pathogenesis of erythema and desquamation. It is the dose to these cells that determines the severity of skin damage.

3.3.3 Fixed erythema

The transient erythema is followed, after 2-3 weeks, by fixed erythema which is similar to first degree thermal burns. Fixed erythema comes in waves and is much deeper and more prolonged than transient erythema. At dose levels of 3-8 Gy, the burn does not progress beyond the erythema stage.

3.3.4 Epilation

Loss of hair may occur after exposure to doses in excess of 3-4 Gy which is seen 2-3 weeks after the accident. With doses upto 7 Gy the hairs grow eventually. But at higher doses the hair follicles are destroyed and the hairs do not grow again.

3.3.5 Transepidermal burn

This is similar to second degree thermal burns with a latent period of 1-2 weeks. Initial symptoms and signs are pain, swelling, epilation, itching or tingling, erythema and ulceration. Radiation burns are sometimes deceptive on superficial appearance as damage to important organs in subcutaneous tissues, nerve endings, hair follicles, sweat glands, endothelium of blood vessels may not be obvious. Among these the injury to the endothelium of blood vessels is the most serious. It produces endarteritis obliterans, leading to necrosis of overlying tissues which continues to progress for several months. The severity of burns depends on the dose and around 30 Gy epilation, oedema, dry and moist desquamation, necrosis of epidermis, blistering and skin loss may take place. In such cases, besides subcutaneous tissues other internal structures are affected and may result in radiation necrosis of bone, muscle, and other internal organs.

3.3.6 Full thickness radiation burn

This is similar to third degree burns and a serious version of transepidermal injury. The injury extends upto the dermis and produces prompt and severe pain. In case damage to circulation is present, the healing will take a long time and surgical intervention may be required.

3.3.7 The doses causing various skin effects and the time frame of their manifestation may be summarised as follows :-

1. Fixed erythema	3 Gy - 8 Gy	(3 weeks)
2. Raw moist area	15 Gy -	(4-6 weeks)
3. Ulceration	20 Gy -	(4-6 weeks)
4. Radionecrosis	25 Gy -	(3-6 months)
5. Gangrene	30 Gy -	(after 6 months)

3.3.8 Management of Radiation burns

3.3.8.1 General

In some radiation accidents, particularly those involving X-ray machines, the patient may not be aware of the time of the accident and the dose may not be known. Similarly, after a criticality accident the patients may come with any of the stages described above. Under these circumstances the following information should be obtained for the management of the case:-

1. Nature of accident.
2. Date and time of accident (if known)
3. Radiation involved.
4. Possibility of whole-body exposure or its symptoms (anorexia, nausea, vomiting, diarrhoea)
5. Possibility of contamination by radioactive substances (dusts or liquids)
6. History of transient erythema.
7. Presence of fixed erythema, epilation, oedema or evidence of burns.

3.3.8.2 Diagnosis

In those instances in which the patient was not aware of the exposure, the appearance of the transient erythema and its timing will enable the physician to roughly estimate the dose. Later, with the appearance of fixed erythema the dose and ultimate prognosis can be confirmed. Even after the full area of the burns becomes apparent, the underlying damage cannot be observed with accuracy clinically. Thermography offers a means of detecting the areas affected significantly, due to localised irradiation, and determining the functional status of the organs. Vascular scintigraphy and impedance plethysmography help in assessing the status of circulation in blood vessels. This information is very helpful in planning any surgical intervention without waiting for the clinical symptoms to fully unfold. It will obviate much of the needless sufferings which the patient is subjected to.

3.3.8.3 Investigations

The following investigations and procedures are recommended :-

1. Complete Blood Count (CBC)
2. Chromosomal analysis in peripheral blood
3. Thermography
4. Sperm count
5. Culture and Antibiotic Sensitivity Test (AST)
6. Serial coloured photography
7. Vascular scintigraphy
8. Impedence plethysmography
9. Slit lamp examination of eyes
10. Reconstruction of accident for estimation of correct dose.

3.3.8.4 *Specific treatment*

a. **Mild erythema**

The skin may become dry and start itching in 3-4 weeks. A bland lotion or steroid ointment should be applied locally. No tight clothing should be worn on the affected part.

b. **Transepidermal burn**

Pain should be relieved by analgesics. Analgesics and medication which cause bone marrow depression should not be given, as there may be bone marrow depression due to whole body exposure. Sterile protective dressings should be used. Systemic antibiotics should be given for prevention of infection. Usually the burns will heal without skin grafting in the absence of infection.

c. **Full thickness radiation burn**

Here the burns may progress from initial blistering to skin loss and deep tissue necrosis, giving rise to severe pain, tissue loss and infections. This will require surgical intervention, the timing of which will be difficult to decide due to slow progression of burn. Bone marrow depression may further complicate the condition. In case there is leucopenia at one week, surgical treatment should be at minimum until haematopoietic recovery takes place (usually in about 8 weeks). In case the involved area is more than a few sq.cms, (2-3 sq. cm.) skin grafting will be required. Larger areas involving necrosis and gangrene of distal portions of fingers or extremities will require amputation. In beta-ray burns, early excision and skin grafting may spare the patient much pain and discomfort. Lastly, follow-up of such cases is important since there can be recurrent exacerbations. The time for amputation and reconstructive surgery depends on the following determinants:-

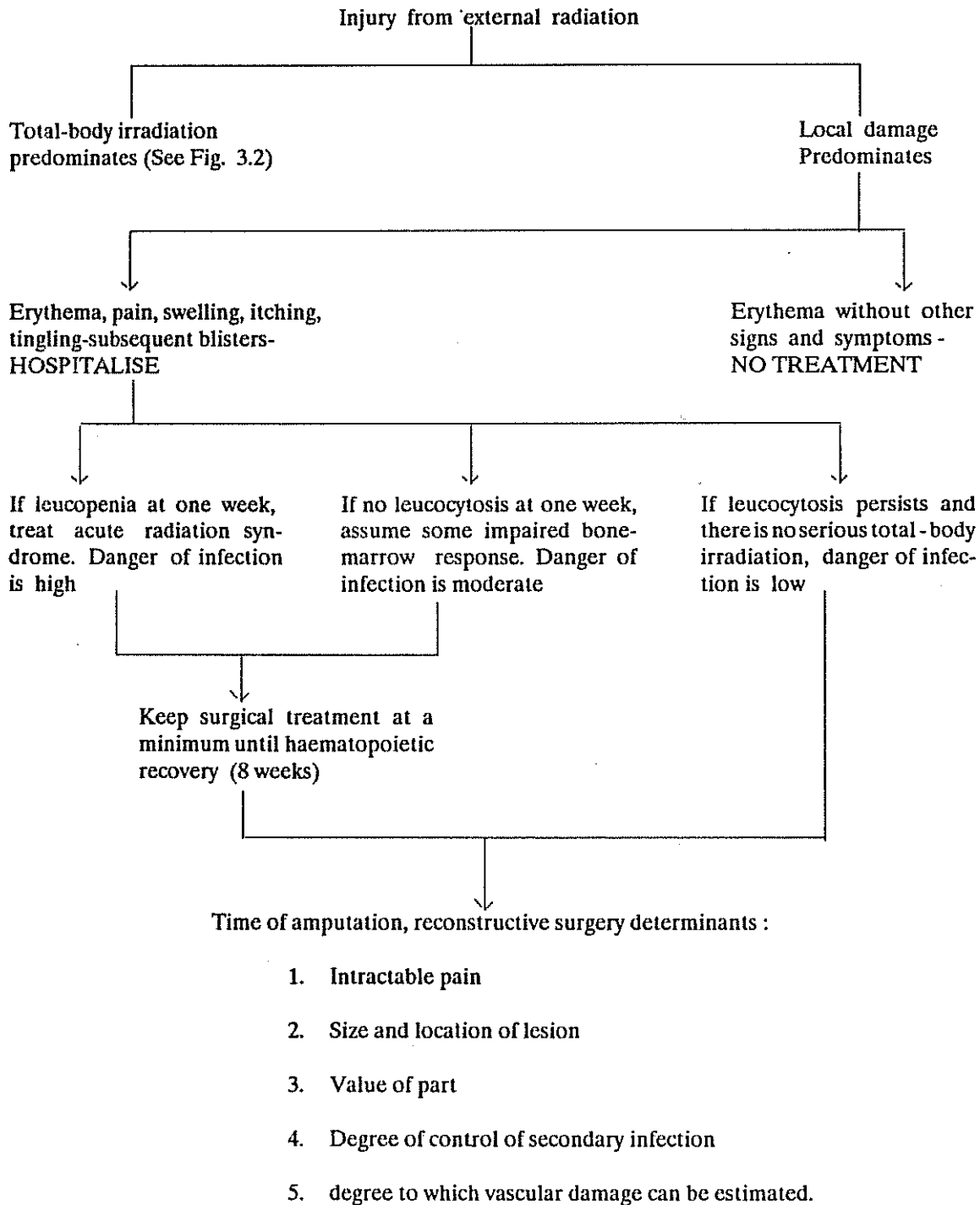
1. Intractable pain
2. Size and location of injury
3. Degree of control over infection
4. Degree to which vascular damage can be estimated
5. Value of the part

Fig. 3.3 summarises the management of injuries resulting from localised exposure

3.4 **LONG-TERM EFFECTS**

Long-term sequelae, developing months or years later, include changes in pigmentation, atrophy of epidermis, sweat glands, sebaceous glands and hair follicles, fibrosis of dermis and increased susceptibility to trauma and chronic ulceration. Chronic radiation dermatitis leads to basal cell carcinoma and squamous cell carcinoma. Cataract may develop if the eye lens receives an acute dose of the order of 3-5 Gy of beta or gamma rays or 0.7 Gy or more of neutrons. Fertility may be affected permanently if gonads receive a dose in excess of 2-3 Gy in case of females and 6-7 Gy in case of males. Lastly, these patients require psychological support because they can develop depression and anxiety due to the longdrawn course and painful nature of the radiation burns.

Fig. 3.3 MANAGEMENT OF THE LOCAL INJURY FROM EXTERNAL RADIATION



4. MANAGEMENT OF RADIOACTIVE CONTAMINATION

Persons may be exposed to radioactive dusts, liquids or gases occasionally released in work environment. Their deposition on skin can cause EXTERNAL CONTAMINATION, whereas their inhalation, ingestion, injection or absorption through skin causes INTERNAL CONTAMINATION. Usually radioactive contamination is not immediately life-threatening. The aim of treating such contamination is to reduce doses of various organs in order to minimise the chances of late effects such as carcinogenesis.

4.1 EXTERNAL CONTAMINATION

Contaminated patients may pose a potential hazard to those who come in their contact, due to the possibility of inhaling radioactive material which may become air borne as a result of movement or handling of casualty.

The effects of contamination depend on the type and energy of radiation emitted by the radio-nuclide. Alpha particles do not penetrate the basal layer of intact skin. However, their transfer to internal organs either from broken skin or through hands while eating may lead to internal contamination. Beta particles penetrate to deeper layers of skin or subcutaneous tissues and hence constitute major skin hazard. X-rays and gamma rays cause damage depending on their energy. The lesser the energy the greater is the superficial damage.

Maximum permissible levels of fixed contamination for skin are as follows:-

For alpha emitters	-	0.4 Bq.cm ⁻²
For beta, gamma emitters	-	4.0 Bq.cm ⁻² .

4.1.1 General Management of External Contamination

All nuclear facilities have a decontamination area where routine monitoring and decontamination are carried out by Health Physics staff. Services of medical officers may be required in case of (a) Persistent contamination, (b) Associated injury, (c) Involvement of sensitive parts like eyes, nose etc.

Formal Decontamination Procedures

This should be carried out as per the flow sheet in Fig. 4.1, in collaboration with the Health Physicist:-

- i) Monitor whole body to identify highly contaminated areas.
- ii) Carefully look for any abrasions/wounds and cover them with water proof adhesive plaster, to prevent absorption of radio-nuclide through wounds.
- iii) Contamination around body orifices - should be removed, first using dry wiping, followed by wet wiping. Wash with mild soaps or detergents for 2 - 3 minutes. Repeat the procedure if necessary.
Preserve all wipings, washings and nasal secretions for activity measurement.
- iv) Contamination of eyes : Wash with copious amount of water, using properly designed eye fountain.
- v) Contamination of hair & scalp - Shampoo with 4% cetrimide solution if necessary, taking care that contamination does not get into eyes, nose or mouth. Hair may require clipping to remove contamination.
- vi) Contamination of Skin - Start decontamination at the periphery of contaminated area working towards centre. Wash gently with soap and water for 2 - 3 minutes, taking care not to produce any damage to skin. If contamination persists, use 1% cetrimide solution in the same way.

For resistant contamination - 5% sodium hypochlorite solution (house hold bleach) may be used

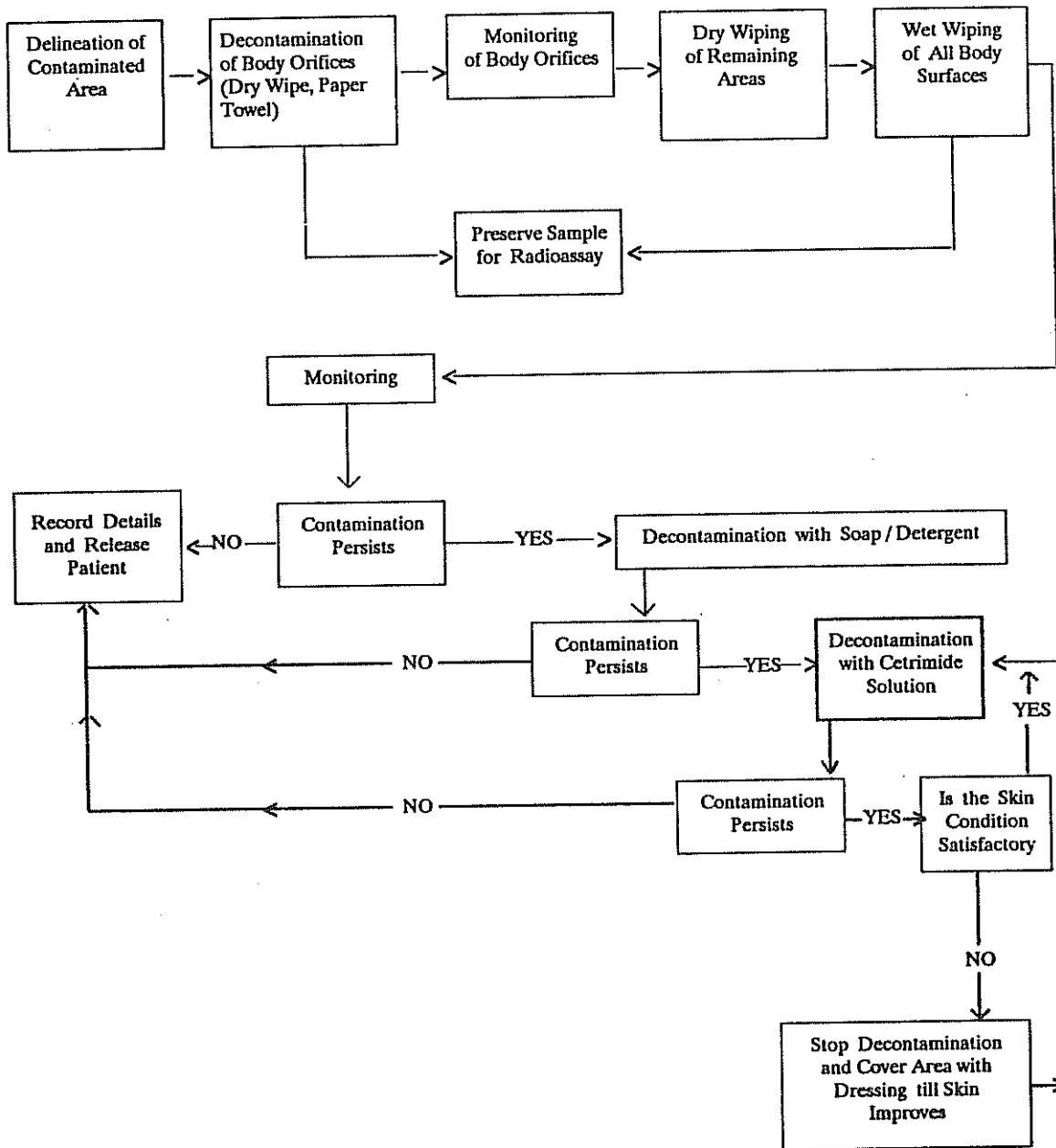


FIG : 4.1 FLOW CHART OF EXTERNAL DECONTAMINATION PROCEDURE

except for face where 1:5 dilution should be used. In some cases strong solution of potassium permanganate may be applied to persistent contamination for a few minutes. It is then washed and allowed to dry. Resulting pigmented area is treated with 10% Sodium metabisulphite solution.

Epidermis renews itself in 12 - 13 days and stubborn contamination comes out with shedding of dead cells of epidermis. Hence surgical removal of unruptured skin is not advisable even if fixed contamination persists above permissible level.

vii) Contamination of Wounds:-

- Remove all loose material around the wound.
- Isolate the wound from clean skin by plastic drapes.
- Irrigate wound with sterile water or saline.
- Encourage free bleeding by occluding venous return with a tourniquet.
- Carry out surgical excision of tissues for contaminants embedded in skin or tissues, taking care to preserve function and cosmetic appearance of the part.
- Concurrent steps should be taken to block systemic absorption.
- Monitor all washings, excised tissues and instruments after operation. Decontaminate instruments if necessary before using them again.
- Examine urine, faeces etc. for assessing possible internal contamination.

4.2 INTERNAL CONTAMINATION

4.2.1 Mode of Contamination

Internal contamination may occur by:-

- a) Ingestion
- b) Inhalation
- c) Through breaks in skin
- d) Absorption through intact skin - in case of tritium and some iodine compounds.

Internal contamination involves four successive stages:-

1. *Intake* - Possible ways are via GI tract (Ingestion), respiratory system (inhalation), through wounds or through intact skin.
2. *Uptake* - absorption of radioactive material in blood or lymph.
3. *Deposition* - in the target organ.
4. *Elimination* - of radioactive material from tissues, organs or whole body.

4.2.2 Treatment :

Treatment is theoretically possible at any of the above four stages, e.g.

1. by fixation of radio-nuclide at site of entry - thus preventing uptake by extracellular fluids.
2. by trapping radionuclide in blood allowing rerouting towards natural excretion.

3. by preventing deposition in target organ - possible in specific case of thyroid.
4. by encouraging elimination - possible in case of tritium which can be flushed from the body.

The treatments at first two stages, therefore, constitute the current effective methods of treatment. Both are more effective if started at the earliest time after the accident - preferably at the first aid post itself. However, it should be remembered that urgency associated with injury takes precedence over contamination and the first aim is to save life and preserve vital functions. Fig. 4.2. shows the general scheme of internal decontamination procedures.

4.2.3 Contamination of Respiratory Tract :

Absorption and deposition of radio-nuclide in target organ after inhalation depends on type of element, its solubility and particle size. For soluble particles of less than 5 μm size, translocation to blood and then to target organ takes place.

For insoluble particles of small size deposition takes place in lung parenchyma. The larger particles may get deposited in larger bronchi and then by bronchial ciliary mechanism enter the pharynx and are swallowed and passed on to GI tract.

a) Treatment of inhaled soluble radionuclide :-

Treatment is directed to trap the radio-nuclide in blood stream and to ensure its rapid natural excretion. Soluble contaminants may also be made insoluble e.g. - by administration of DTPA aerosol (50 mg) in case of inhalation of plutonium and transplutronics.

b) Treatment of inhaled insoluble radionuclides:-

Use of expectorants or inhalation of specific agents is advocated. Lung lavage may be undertaken as a last resort after weighing all pros and cons, in case the lung burden is 50-100 times the permissible limit.

4.2.4 Contamination of Gastro-intestinal Tract:

Insoluble radionuclides, entering GI tract either directly or from bronchial ciliary mechanism of respiratory system, pass through GI tract without any significant absorption. Their elimination can be hastened by giving cathartics.

Soluble radionuclide should be made insoluble to prevent systemic absorption. Different pH conditions in the lungs and stomach should be kept in mind in this regard.

General Treatment of Contamination of GI Tract :

- i) After a recent ingestion, empty the stomach or prescribe an emetic.
- ii) Give laxative to hasten elimination of radionuclide and minimise intestinal absorption and irradiation of intestinal epithelium.
- iii) Isotopic dilution may be employed. It consists of giving large quantities of non-radioactive ion which competes with radioactive material for absorption.
- iv) Specific therapeutic agents such as ion exchange resins, gels, antacids may be used to reduce absorption of radioactive material. Table No.4.1 gives mode of contamination and specific treatment in case of contamination by some radionuclides.

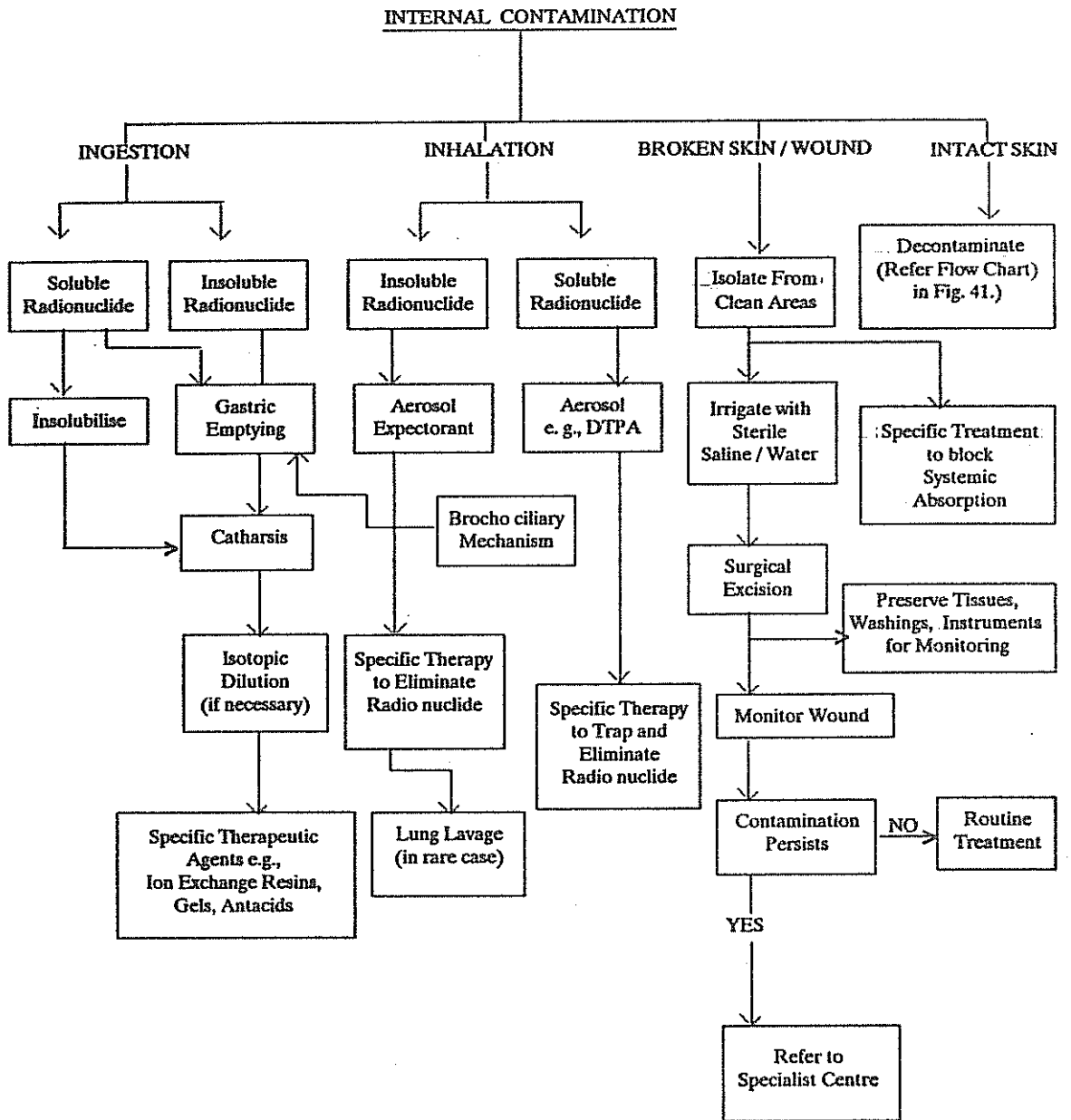


FIG : 4.2 GENERAL SCHEME OF INTERNAL DECONTAMINATION PROCEDURES

TABLE-4.1 - SOME RADIONUCLIDES, THEIR COMMON MODE OF CONTAMINATION AND SPECIFIC TREATMENT

S.N.	Radionuclide	Common mode of Contamination	Target Organ.	Specific Treatment
1.	Iodine	Inhalation, Ingestion	Thyroid	Potassium iodide - 130 mg bd for 7 to 14 days.
2.	Strontium	Ingestion, Wound	Bones	Calcium alginate-10 gm in sugared water or (single dose) Aluminium hydroxide gel or aluminium phosphate gel-100 ml For wound-Sprinkle with Potassium rhodizonate.
3.	Caesium	Inhalation, Ingestion	Muscles	Prussian blue-1-3 gm tds daily.
4.	Tritium	Ingestion, Inhalation, Skin absorption.	Whole-body	Forced fluids. Diuretics.
5.	Phosphorus	Ingestion	Bones	Isotopic dilution by stable phosphorus.
6.	Uranium	Ingestion, Inhalation, Wound.	Kidneys	1.4% sodabcarb infusion 250 ml.
7.	Rare Earths	Ingestion, Inhalation, Wound.	Bones	Inhalation of Ca-DTPA, Ca-DTPA-0.5 gm in 250 ml. saline i.v.
8.	Plutonium & Transplutonics	Inhalation, Wound,	Bones, Liver.	Inhalation of Ca-DTPA, Ca-DTPA-0.5 gm in 250ml saline i.v.

4.2.5 Contaminated Wounds

Contamination through wound/skin is dealt with in "External Contamination".

5. ACTION PLAN FOR HANDLING RADIATION CASUALTIES

5.1 In the event of a radiation accident a number of services and facilities are to be activated to render the required assistance in a coordinated manner. An overview of the response to an emergency call for rendering medical aid is shown in Fig. 5.1. The immediate actions taken at the First Aid Post and the Site Hospital are indicated in Table 5.1.

Table 5.1 IMMEDIATE ACTIONS TAKEN AT THE FIRST AID POST AND THE SITE HOSPITAL

Actions taken at First Aid Post	Actions taken at Site Hospital
<ol style="list-style-type: none"> 1. Call for health physicist and necessary monitoring equipment. 2. Give life saving first aid if needed for traumatic injuries and burns. 3. Call for ambulance from the Site Hospital and, if life threatening injury present, evacuate casualty to Site Hospital. 4. Secure pertinent information about the accident, including rough estimate of doses, from those in attendance. 5. Monitor the casualty for contamination. Discard clothing in a container if contaminated. Give prophylactic drugs for internal contamination. Survey the first-aid-post and cordon off the contaminated areas till they are decontaminated. 6. Attend to injuries and open wounds; cover with proper dressing. 7. Cover ambulance floor and stretcher, including pillow, with plastic sheets. Wrap patient with cotton sheet and plastic sheet to prevent spread of contamination. 8. Notify available information to Site Hospital, on telephone. Fill the "Accident Data Tag" and, evacuate casualty to the Site Hospital. 9. Survey the rescue squad and, if contaminated, clean by washing/shower till decontaminated. 10. Prepare a report of the accident as early as possible to prevent loss of information. 	<ol style="list-style-type: none"> 1. Notify responsible physician and the Health Physics staff. 2. Check patient on stretcher for contamination. If contaminated, start preparation to perform decontamination at the Personnel Decontamination Centre of the Site Hospital and handle patient like in a surgical procedure : Wear gown, gloves, cap, mask etc. 3. Perform a quick physical examination, look for skin erythema. Enquire about prodromal symptoms, like vomiting, diarrhoea and the timings of their onset. 4. If seriously injured, give emergency and life saving treatment immediately. 5. Perform simple decontamination procedures such as washing, scrubbing and shower. Attend to wounds. Save all the belongings, biological samples and washings for activity measurements. Tag them with radioactivity labels and other relevant details like date, time, body location and name of the patient. 6. Perform complete blood count and, if the patient is symptomatic, repeat every 3-6 hours. 7. Concurrently, ask the personnel monitoring devices to be processed to assess the actual doses. 8. Hospitalise the patient if symptomatic or psychologically upset, or if a whole body dose of more than 1 Gy is suspected. 9. Order the necessary cytogenetic examination, haematological and bio-chemical tests, bacteriological culture, antibiotic sensitivity tests, ECG and EEG to obtain the base line data. 10. Ask for thermography, impedance plethysmography and vascular scintigraphy, especially when localised irradiation is suspected. 11. Perform Triage on the basis of whole body dose: <ol style="list-style-type: none"> (a) Arrange OPD follow - up of sublethal cases - Dose < 1Gy. (b) Undertake terminal care of high dose cases - Dose > 15 Gy. (c) Send remaining cases to Specialised Hospital* for management of acute radiation syndrome.

*BARC Hospital,
Anushaktinagar,
Bombay-400 094.
(Ph:551 2271 or 551 8846)

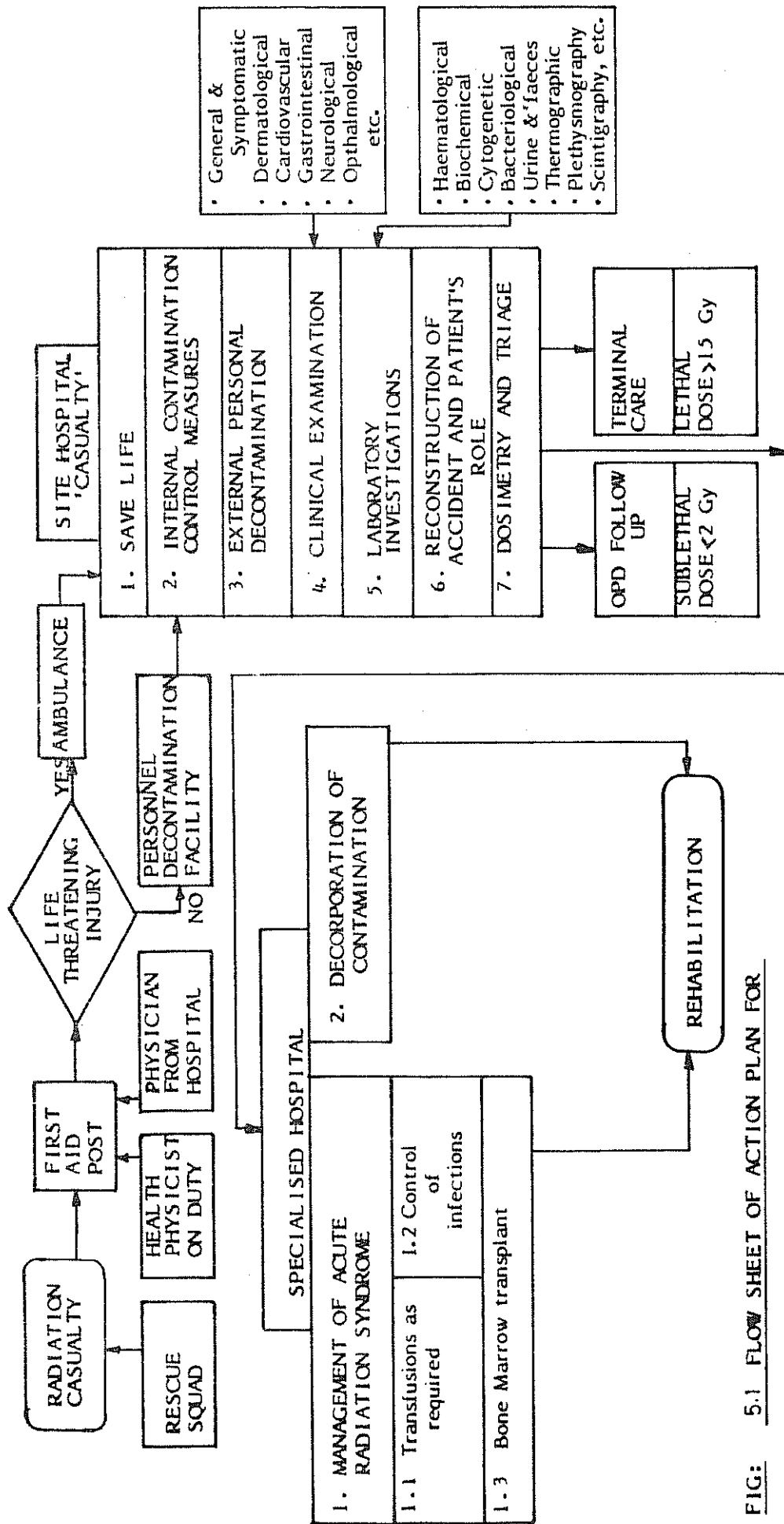


FIG: 5.1 FLOW SHEET OF ACTION PLAN FOR MEDICAL MANAGEMENT OF RADIATION CASUALTY.

5.2. IDENTITY TAG & INFORMATION FORMS :

These are essential for rapid unambiguous transfer of information about the casualty in the early phases of the management of a radiation accident. The immediate information required by the Site Hospital about the casualty should be obtained by the health physicist/person reporting and sent to the site medical unit/site hospital in a suitable form such as shown in Fig 5.2.

The specimen of an "Identity Tag" is shown in Fig.5.3. This tag is to be filled at the First Aid Post and tagged on to the radiation casualty.

A specimen of a "Medical Information Form" is shown in Fig.5.5. This is to be completed in the Site Hospital by the Medical Officer attending on the casualty.

5.3 MEDICAL INFRASTRUCTURE

A scheme showing the essential infrastructure, including the facilities, trained physicians, nursing and paramedical staff, physicists and other appropriate professionals needed for medical management of radiation casualties is given in Appendix-I. This may serve as a module that can be set-up at all important nuclear installations in the country and linked to the Central / Specialised Hospital mentioned in Appendix-I.

Physicians who specialise in the medical management of radiation injuries are on the staff of the Bhabha Atomic Research Centre (BARC) and the BARC Hospital Bombay. A number of DAE installations have physicians trained in "Occupational Radiation Medicine" to tender advice in case of a suspected radiation injury. Appendix-II lists the names, addresses of hospitals and the phone numbers of these physicians ; this information may change with time. Radiotherapists or nuclear medicine physicians in hospitals having facilities for radiotherapy / nuclear medicine may also offer initial advice to suspected cases of irradiation and contamination.

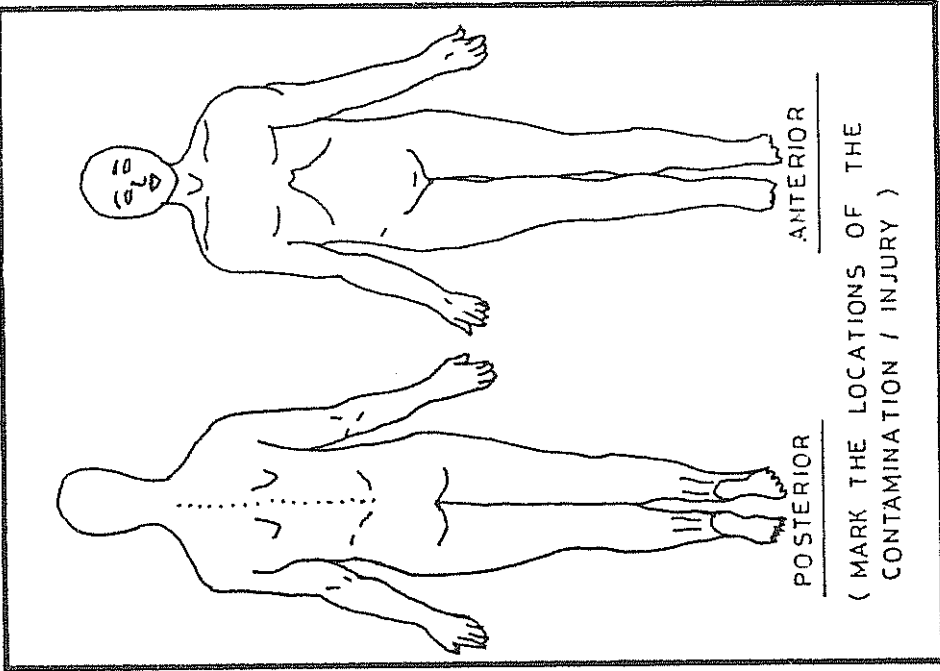
ACCIDENT INFORMATION FORM
(To be filled by health physicist/person reporting)

1. Identification of informer :
2. Number and condition of uncontaminated patients:
3. Number and condition of contaminated patients:
4. Location of accident:
5. Nature of accident:
 - (a) Irradiation condition :-
 - Source -
 - Distance-
 - Time -
 - Dose estimated -
 - (b) Contamination (external):-
 - Radioactive nuclides involved -
 - Activity level -
 - Body area involved -
 - (c) Contamination (internal):-
 - Ingestion-
 - Inhalation-
 - (d) Contaminated wound -
 - (e) Whether initial decontamination done -
6. Expected time of arrival of patients at the directed place-
(Hospital to direct the informer where to deliver the patient)

Date :

(Signature)

Fig.5.2 - Specimen for accident information form



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

Fig. 5.3 FRONT AND BACK VIEW OF THE IDENTITY TAG

Fig. 5.4 Specimen for medical information form

MEDICAL INFORMATION FORM

1. IDENTIFICATION OF THE PATIENT :

Full Name :
(In Block Letters)
Age : Sex :

2. IDENTIFICATION OF THE INDIVIDUAL WHO FILLS THE FORM

Name :
Designation :
Affiliation :

Date and hour of FORM FILLING

Date Hour

3. DATE AND TIME OF ACCIDENT :

Date of exposure Presumed hour :

4. EXPOSURE CONDITIONS

DURATION / / / / / /

If possible, time beginning : / / / / / /
end : / / / / / /

Position of the patient
Nature of work of the patient

4.1 DOSIMETRY INFORMATION

The patient had a dosimeter	yes	no
Dosimeter recovered	yes	no

If yes : Dosimeter No. / / / / / / / / / /

4.2 RESPIRATORY PROTECTION : yes no

4.3 CONTAMINATION OF CLOTHES (If detected) : yes no

5. FIRST SYMPTOMS

5.1 CLINICAL STATE OF THE PATIENT (Indicate time of appearance, number or duration, as applicable)

Nausea / / / / / / (time)

Vomiting

Wound

Trauma

Burn

5.2 MEDICAL FINDINGS (to be filled by the physician)

Name of physician :
(In Block Letters)

Name of Patient :
(In Block Letters)

Date of examination

Hour : / / / / / /

asthenia : yes no

headache : yes no

nausea : yes no

/ / / / / /
(time of appearance)
number :

vomiting : yes no

diarrhoea : yes no

quantity :

temperature : / / / / / /

pulse :

blood pressure :

consciousness : normal abnormal : agitation
 delirium
 sleepiness
 coma

equilibrium disturbance : yes no

co-ordination disturbance yes no

skin and mucosa :

oedema : yes no

erythema : yes no

other :

6. TREATMENT AND INVESTIGATIONS

6.1 MEASURES TAKEN

Undressing : yes no
 Decontamination : yes no
 DTPA : yes no

If yes, administration pathway : *aerosol
 *bathing
 *intravenous

Stable iodine : yes no

6.2 LABORATORY TESTS

BLOOD SAMPLES

*First sample (If possible, before the third hour)

Date / / / / / / Hour / / / / / /

* Blood cell count,platelets : yes no
 * Cytogenetic (10 ml) : yes no
 * Sample for spectrometry : yes no

* Second sample(If possible,2 hours after the first one) Hour / / / / / /

* Blood cell count, platelets : yes no
 * HLA typing : yes no

URINE SAMPLES : yes no
 (If possible, for gamma spectrometry)

Is it the first urination after the
 accident ? yes no

7. DESTINATION OF THE PATIENT (IF SENT FOR FURTHER TREATMENT)

8. PHYSICIAN'S CONCLUSIONS :

Date :

(Signature)

INFRASTRUCTURE AND FACILITIES

(MODULE FOR THE MANAGEMENT OF RADIATION INJURIES)

For efficient management of radiation casualties that may occur at nuclear facilities, evacuation of casualties from the site of accident and their proper management will require an efficient set-up of medical units. With this point in view, setting up of the following medical units is suggested. It is difficult to provide totally effective assistance with medical facilities recommended below in all the different types of nuclear establishments under all conceivable situations. Individual additional requirements will have to be planned as the need arises. But the set-up suggested below is essential to provide the needed infrastructure required to meet any eventuality.

FIRST AID POST

Location : This should be at the plant site. A room close to the change room of the plant will serve the purpose.

Function : To provide first aid to conventional injuries which are of every day occurrence.

To handle simple cases of external contamination. To provide first aid in cases of Internal Contamination by administration of :

- a) Tablets of potassium iodide
- b) DTPA through an inhaler

Screening of cases for evacuation to personnel decontamination centre, or site hospital.

Equipment and Supplies : The first aid post should have showers, and washing facilities like low level sinks and provision of hot and cold water and drier. The floor and the walls of this room should be easily washable, i.e. they should have epoxy paint.

The first aid post should have equipment like splints, dressing materials, paper towels, trays, oxygen cylinder etc; besides the usual conventional drugs needed for emergency, the following drugs should be available :

Potassium iodide tablets.
DTPA for inhalation.

Staff : This can be managed by a male nurse or a dresser, and in the absence of these, it can be managed by trained supervisory staff of the plant. In the event of a major accident generating mass casualties, the help of doctors, nursing staff and health physicists should be requisitioned for triage of the patients for evacuation to different units mentioned below.

PERSONNEL DECONTAMINATION CENTRE

Location : This should be near the plant site along with the occupational health clinic/dispensary, or near site hospital. Alternatively, the casualty ward of the site hospital can be used as the site decontamination centre in emergency.

Function : Treatment of cases referred from site first aid post or directly from the plant; Treatment of cases of various types of contamination; Collection of samples of blood, urine, stool, washings etc. of contamination cases; to perform minor surgery, if required; Classification of patients (triage) after a major radiation accident.

Equipment : It should be equipped with shower cubicles, wash basin, bath tub with drain facilities for collection of contaminated effluents for later disposal. Besides this, the following equipment should be available at the Centre.

1. **Protective Equipment :**

- Overall / Lab. Coats
- Surgical gloves
- Skull caps
- Cotton/plastic bags
- Roll of polythene sheet

2. **Radiation Instruments :**

- End Window GM contamination monitor
- Alpha scintillation monitor
- Contamination monitor with low energy gamma scintillator probe.
- Portable GM Surveymeter
- General Purpose Radiation monitor
- Check sources for both alpha and beta/gamma for testing of Instruments.

3. **Skin Decontamination Kit :**

- Cotton applicator for nasal swab
- Surgical cotton roll
- Masking tape
- Marking pens to mark contaminated areas
- Soft brushes
- Clipper with razor, shaving soap and brush
- Detergents
- 5% sodium hypochlorite solution
- Saturated solution of $KMnO_4$
- 5% Sodium-bi-sulphite solution
- Soda-bi-carb solution.
- Sample collection vials
- Adhesive labels.

4. **Internal Decontamination Kit:**

- Potassium iodide tablets
- Micronised powder of DTPA for inhalation
- Aerosol generator for inhaling DTPA
- DTPA ampoules
- Colloidal Prussian Blue
- Aluminium hydroxide gel
- Potassium rhodizonate
- Sodium bicarbonate ampoules
- Clear printed instructions for the use of above drugs.

Staff : Doctors and nursing staff from occupational health clinic, or dispensary or from site hospital and health physics support.

SITE HOSPITAL

Location : Outside the plant, near personnel decontamination centre, if there is one.

Function : Management of cases of external/internal contamination with or without injuries; treatment

of localised exposure (radiation burns); treatment of partial and whole body exposure cases with low doses upto 2 Gy; management of severe cases of whole body exposures of more than 10 to 15 Gy, which will require terminal care. Triage of patients after major radiation accident for evacuation to central and specialised hospital.

Equipment and Supplies : In addition to those in any general hospital, drugs and chelating agents required specially for radiation injuries should be available. Facilities for surgery, haematology and dosimetry, internal and external, should be available.

Staff : Doctors should be trained in occupational radiation medicine and nursing staff should have basic knowledge of radiation injuries and trained in barrier nursing. Health physicists should be available when required.

CENTRAL OR SPECIALISED HOSPITAL (BARC HOSPITAL)

Function : To co-ordinate with Site Hospitals and handle all cases of radiation casualties; should have special facilities for handling whole body exposure cases, in the range of 4 to 8 Gy. This will require separate beds and wards with special sterile facility and should be able to provide intensive care. Blood bank should be able to provide packed red cell, platelets and leukocyte transfusions.

No beds need be kept reserved for management of these cases but provision should be available to convert single rooms into isolation beds. Sterilization of the air should be provided by using ultraviolet lamps, and the use of antiseptic doormats. Separate pantry for supply of sterile food should be available. Facilities should be available for cytogenetic examination for chromosomal analysis.

Staff : Trained doctors and nursing staff to handle various types of radiation injuries.

SPECIAL TRAINING OF PERSONNEL

Since radiation accidents are relatively rare, personnel handling these cases cannot derive their skill from experience. They must receive careful training at formally held courses and by practice drills. Practice drills can identify deficiencies in preparations for an accident and suitable measures can be taken to improve emergency preparedness.

PHYSICIANS WHO ADVISE ON DIAGNOSIS AND TREATMENT OF RADIATION INJURIES

Names, addresses and telephone numbers of physicians who specialise in medical management of radiation injuries

Name	Address	Phone No.
1. Dr. S.M. Sharma, - Associate Director, Medical Group.	BARC Hospital, Anushaktinagar, Bombay-400 094. (Maharashtra)	5518846 & Res : 384269
2. Dr. G.K. Iyer, - Medical Officer.	Trombay Dispensary, Bhabha Atomic Research Centre, Bombay-400 085. (Maharashtra)	5514910 Ext. 2320 & Res : 5512322
3. Dr. B.J. Shankar, - Head, Surgical Unit,	BARC Hospital, Anushaktinagar, Bombay-400 094. (Maharashtra)	5512271 & Res : 5513538
4. Dr. D.B. Mendhekar, - Hospital Supdt.	TAPS Hospital, Tarapur, Dist. Thane Pin - 401 504. (Maharashtra)	239, 237 221(Tarapur) Ext. 224 Res. Ext. 284
5. Dr. B.M. Vachharajani- Medical Officer	- do -	Hospital. Ext.228 & Res : 283
6. Dr. A.S. Kanhere, - Medical Officer.	RAPS Hospital, Rajasthan Atomic Power Station, P.O. Rawatbhata, Via. Kota, Pin - 323 305.	4412 to 4416

DIRECTORY OF MEDICAL DOCTORS TRAINED IN RADIATION PROTECTION AND OCCUPATIONAL HEALTH

State & Address	Name	Phone Nos.
ANDHRA PRADESH		
NFC Dispensary, Nuclear Fuel Complex, ECIL P.O., Hyderabad, Pin - 500 762.	Dr. Dutta, M.C	852564 Res: 852224
BIHAR		
UCIL Hospital, Uranium Corporation of India Ltd., P.O. Jaduguda Mines, (Distt. Singhbhum) Pin - 832 102.	Dr. Mullick, A.N.	25253 Ext.72 Res: ext.66
GUJARAT		
Kakrapar Atomic Power Project Hospital, P.O. Anumala, (Distt. Surat) Pin - 394 651.	1. Dr. Ajmera, N.K. 2. Dr. Chaudhari, R.V.	55 (Vyara) Res: 331(Intercom)
KERALA		
i) IRE Dispensary, Indian Rare Earths Ltd., Udyogamandal, Pin - 683 501.	Dr. Nambidi, T.N.U.	656061
ii) IRE Hospital, Indian Rare Earths Ltd., Manavalakurichi, Pin - 629 252.	Dr. Gopakumar, P.V.	77408
MAHARASHTRA		
i) BARC Hospital, Anushaktinagar, Bombay, Pin - 400 094.	Dr. Ali, S.S.	551 2172, Res: 640 5972
ii) Trombay Dispensary, Bhabha Atomic Research Centre, Bombay, Pin - 400 085.	1. Dr. Bongirwar, P.R. 2. Dr. Sharma, N.	5514910, ext. 2003 5514910, ext. 2003
iii) 17-Vikram Jyoti Society, Opp. Telecom Factory, Deonar, Bombay - 400 088.	Dr. Lalchandani, G.A.	5551135, Res: 551 7430

State & Address	Name	Phone Nos.
iv) TAPS Hospital, Tarapur,(Dist. Thane) Pin - 401 504.	1. Dr. Sachdeo, R.T.	221 (Tarapur),ext. 228 Res: ext. 305
	2. Dr.(Mrs)Vachharajani,P.B	221(Tarapur)ext.222, Res.: ext. 283

ORISSA

IRE Dispensary, IRE Ltd., Matikhal, OSCOM Project, Chatrapur (GM) Pin - 761 020.	1. Dr. Mohanty, P.K.	
	2. Dr. Pattnaik, F.N.	2444 (Chatrapur) Res: 2334

RAJASTHAN

RAPS Hospital, Rajasthan Atomic Power Station, P.O. Rawatbhata, Via. Kota, Pin - 323 305.	1. Dr. Chaturvedi,H.C.	4412, ext.54
	2. Dr. Sharma, B.K.	4412 to 4416
	3. Dr.(Mrs)Veena Arora	4412 to 4416 Res:P&T-46 Auto-403

TAMILNADU

DAE Hospital, Madras Atomic Power Station, Kalpakkam, Pin - 603 102.	1. Dr. Mathiyalagan, K.	228, Res:677(Intercom)
	2. Dr. Thanaraj, R.	211

UTTAR PRADESH

Narora Atomic Power Project Hospital, NAPP Township, Narora, Distt. Bulandshahr, Pin - 202 389.	1. Dr. Chaturvedi,S.K.	22226
	2. Dr. Chowdhary, S.	Res : 22235
	3. Dr. Manuwal, A.K.	22261
	4. Dr. Trivedi, H.P.	Res:302(Intercom) 22261

WEST BENGAL

Medical Unit, Variable Energy Cyclotron Centre, (BARC), Sector-1, Block AF, Bidhan Nagar, Calcutta, Pin-700 064.	Dr. Bhattacharyya, D.K.	411397
--	-------------------------	--------

BIBLIOGRAPHY

1. Radioactive contamination of the skin, G.B. Schofield, J. Society of Cosmetic Chemists, 22 (1971), 535-545.
2. Handling of radiation accidents, G.A. Andrews et al, Proceedings of an IAEA symposium (1979).
3. Management of persons accidentally contaminated with radionuclides, NCRP Report No.65, Bethesda, MD, USA(1980).
4. Principles and general procedures for handling emergency and accidental exposures of workers, ICRP Publication No.28, Pergamon Press, Oxford (1980).
5. The medical basis for radiation accident preparedness, Ed. K.F. Hubner and S.A. Fry, Elsevier North Holland Inc., New York (1980).
6. Non-stochastic effects of ionizing radiation, ICRP Publication No.41, Pergamon Press, Oxford (1984).
7. What the general practitioner (MD) should know about medical handling of overexposed individuals, IAEA-TECDOC-366 (1986).
8. Medical handling of accidentally exposed individuals, I.A.E.A. Safety Series No.88 (1988).
9. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), Early effects in man of high doses of radiation, Annex G in "Sources, Effects and Risks of Ionizing Radiation", United Nations, New York (1988) pp 545-647.
10. AERB Guide on medical management of persons exposed in radiation accidents. S. Somasundaram et al,(1990).

AERB MANUAL NO. SM MED-2

Printed by: The Administrative Officer,
Atomic Energy Regulatory Board,
Vikram Sarabhai Bhavan,
Anushaktinagar,
Bombay – 400 094. (India)

Amalgamated Printers