IAEA Post Graduate Educational Course in Radiation Protection and Safety of Radiation Sources

Intervention for Chronic and Emergency Exposure Situations

General Principles and Types of Events

Accidents History and Lessons Learned

Lecture

Introduction

- Despite considerable development of radiation safety, radiation accidents do happen
- The objective of this lesson is to
  - present selected cases of radiation accidents
  - discuss causes and main consequences of these accidents
  - present principle lessons learned

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Content

- Case studies
- Lessons learned
- Conclusions
- Summary

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Case Studies

- Goiânia accident
- San Salvador accident
- Recent accidents



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Goiânia Accident
Brazil



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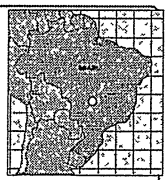
Background



- Goiânia: the capital of Goiâs State, Brazil
- Population: about one million
- The accident happened in a poor section of the city, in an old abandoned radiotherapy facility

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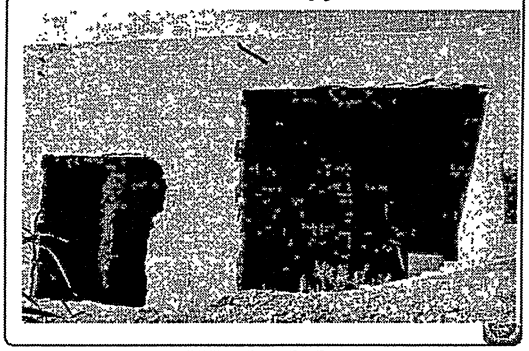
What Happened

- End of 1985, a private radiotherapy institute moves to new facilities
  - They forget a Cs-137 teletherapy unit in the old facility
  - They do not notify the licensing authority
  - The old facility is partly demolished

What Happened

- September 13, 1987 two persons enter the old facility
  - They remove the source assembly from the radiation head of the machine
  - They take home the source assembly and try to dismantle it
  - In the attempt the source capsule is ruptured
  - Fragments of the source the size of rice grains were distributed to several families
  - The rest of the source assembly is sold for scrap to a junkyard owner

Abandoned Radiotherapy Clinic



The Source

• Nuclide	Cs-137
• Activity (Sept.87)	50.9 TBq (1375 Ci)
• Chemical form	CsCl
• Physical form	powder
• CsCl mass	93 g
• Cs-137 mass	19.3 g
• Physical half-life	30 years

Discovering the Accident

- Within five days, people were showing gastrointestinal symptoms
- One of them realizes that it may be caused by the object found
  - He takes the pieces to the public health department in the city
- Investigation leads to the discovery of the accident
- CNEN is notified and responds

The Response

- Monitor a large number of people
- Decontaminate
- Medical triage and treatment
- Survey a large area
- Isolate and confine contaminated areas
- If possible, decontaminate
  - Main areas, in order of priority (houses, public places, vehicles, etc.)
- If not possible, destroy and remove
- Remove contaminated soil

Response Statistics

- Individuals surveyed = 112,800
- Persons contaminated = 271
  - contamination on clothing and shoes = 120
  - internal and external contamination = 151
- Local radiation injuries (burns) = 28
- Hospitalisation required = 20
- Bone marrow failure = 14
- Acute radiation syndrome = 8
- Fatalities = 4

More Response Statistics

- Decontamination of the city: 730 workers required
- Houses affected: 98
  - 41 evacuated
  - 6 demolished
  - 53 repaired
- Decontaminated public places: 58
  - pavements, squares, shops and bars
- Number of vehicles decontaminated: 64

More Response Statistics

- Waste storage site:
  - 20 km from the city
  - Designed to accommodate 4,000-5,000m^3 of waste
- Types of waste packaging used:
  - 4,500 metal drums (200L)
  - 1,400 metal boxes (5 tonnes)
  - 10 shipping containers (32m3)
  - 6 sets of concrete packaging
- Volume of waste stored: 3,500 m^3, or more than 275 construction lorry loads

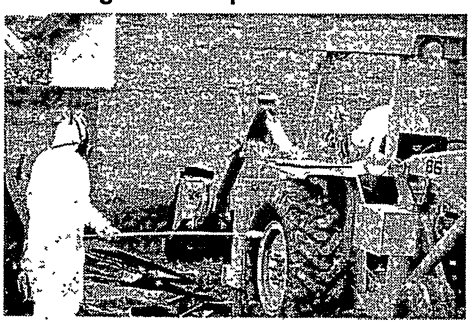
The Consequences

- Four early fatalities
- A large number of persons contaminated
- The environment severely contaminated
- Large quantities of radioactive wastes generated
- Significant economic loss and burden
- Substantial physiological impact

Contamination Check



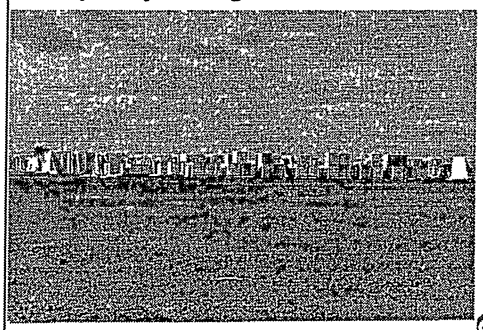
Looking for Hot Spots



Removing Contaminated Items



Temporary Storage Site



Lessons Learned

- Regulatory controls could have prevented this accident
- An adequate system of information is essential to avert panic
- Emergency workers should be instructed on how to convey information to the population
- Response to the psychological impact is a major element of the response strategy

Lessons Learned

- Must be prepared to work in all relevant climatic conditions
  - Monitoring equipment to be used in the field should be capable of being adjusted for use in high humilities/temperatures and unstable environmental conditions
  - Personnel and equipment must be adequate for the potential harsh conditions that can be experienced (e.g. extreme high temperature)

Lessons Learned

- Prompt access to coordinated resources is an asset (this should be considered at the planning stage)
  - e.g. civil engineering infrastructure was needed for decontamination and reconstruction operations

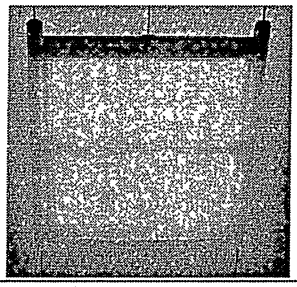
More Lessons Learned

- International assistance can be timely and extremely useful
- The effectiveness of international assistance depends on the infrastructure of the country concerned
  - This should be considered at the planning stage
- Customs regulations should be amended to facilitate the import and return of goods
  - This will accelerate international assistance

Goiânia - Conclusions

- Radioactive sources taken out of the regulatory system can present a serious hazard
- Recognition by the general public of the potential danger of radiation sources is an important factor in lessening the likelihood of radiological accident
- Good plans can accelerate response and significantly reduce health impacts

San Salvador Accident El-Salvador



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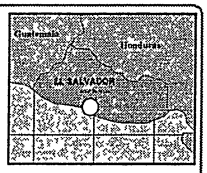
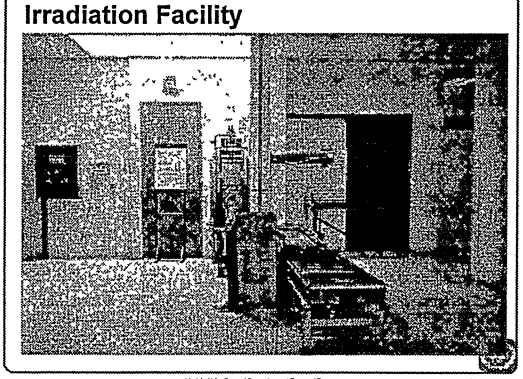


- Accident location: San Salvador (El Salvador)
- Facility: industrial irradiation facility
- Date: 5 February 1989
- Source: Co-60 in a movable source rack
- Activity: 0.66 PBq (18 kCi) at the time of the accident

Irradiation Facility

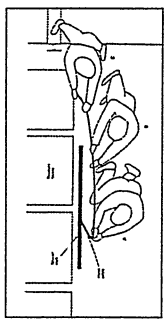
- The product packages to be sterilized are loaded into large product boxes and moved by pneumatic cylinders around a centrally located, vertical rectangular source rack
- The source rack contains Co-60 source elements in the form of rods contained in 'source pencils'

Irradiation Facility

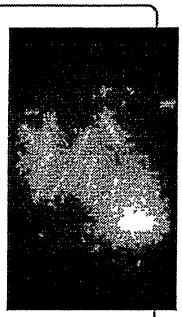


What Happened

- Sunday 5 February: the source rack becomes stuck in the irradiation position "ON"
- The operator bypasses the irradiator's already degraded safety systems and enters the radiation room, soon followed by two other workers, to free the source rack manually



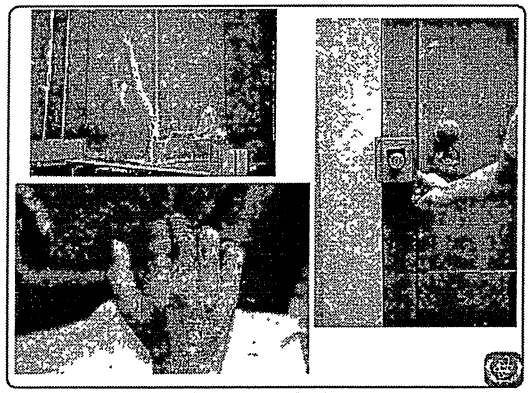
What Happened Next



- On the following Thursday or Friday, some pencils fell from the upper source module into the pool
- Four of the pencils from the top module, an active source pencil and tree dummy pencils, were subsequently found to have fallen into the radiation room; the others has fallen into the pool

Consequences

- Three workers developed acute radiation syndrome
- Two of them had their legs and feet amputated
- One died six and a half months after the accident
  - His death is attributed to residual lung damage due to irradiation



Response

- Dose assessment
  - Worker A 8.1 Gy
  - Worker B 3.7 Gy
  - Worker C 2.9 Gy
- Medical assessment and treatment
- Source recovery in slow time

Causes

- Component failure
  - The company did not implement measures detailed in notices from supplier designed to upgrade the safety of the facility
  - The installed safety systems had degenerated or been bypassed over the years

More Causes

- Operator error
  - Operators trained by the supplier of the irradiators had left at an early stage and subsequent training was only oral and informal
- Violation of procedures
  - There was no regulatory control of radiological protection matters nor any readily available expertise in El Salvador

San Salvador - Conclusions

- Regulatory controls could have prevented this accident
- Prompt access to qualified medical resources is a requirements
- Arrangements for prompt international assistance can improve the response effectiveness

Notable Recent Accidents

Year	Location	Source of Exposure	Consequences
1997	Georgia	Abandoned military sources	11 exposed soldiers
1999	Peru	Ir-192	exposed worker
	Japan	Criticality	2 fatalities
	Turkey	Co-60	10 persons exposed
2000	Thailand	Co-60	10 persons exposed, 3 fatalities (so far)
	Egypt	Ir-192	2 fatalities (?), ? exposed

Learning From Experience

- The first lesson: Better to learn lessons from past experience than from your own
  - Competent authority should organize collection of histories of accidents
  - National competent authorities should publish their evaluation of their accidents; the international community can learn from that experience
- The second lesson: Most accidents are preventable

Learning From Experience

- Main causes of accidents
  - Human error
    - Lack of training, complacency, lack of safety culture
  - Equipment error
    - Bad maintenance, lack of essential repairs, lack of equipment condition monitoring, design flaws
  - Others
    - Even in the best cases, accidents can happen

Learning From Experience

- Factors that can prevent radiation accidents:
  - Effective regulatory controls
  - Training
  - Hazard awareness
  - Safety culture, supported by management culture

Learning From Experience

- Factors that can mitigate radiation accidents
  - Good emergency plans and procedures
  - Prompt notification
  - Radiological emergency plans that are well-integrated with conventional plans
  - Prompt access to the right expertise and international assistance
  - Effective public information arrangements
  - Training and exercises

Conclusions

- In conclusion, the major causes of radiation exposure accidents are:
  - 8% - procedural failure
  - 15% - equipment failure
  - 68% - operator error
- Therefore, the greatest potential for achieving an overall reduction in all accidents lies in reducing operator error



Summary

- Better to prevent than to respond
- Be prepared to respond
- Co-ordinate and integrate
- Exercise
- Learn from others' mistakes



Where to Get More Information

- IAEA reports on radiation accidents
  - You can find the references on the IAEA web side

    http://www.iaea.or.at/



IAEA Post Graduate Educational Course in Radiation Protection and Safety of Radiation Sources

Intervention for Chronic and Emergency Exposure Situations

General Principles and Types of Events



Nuclear and Radiological Accidents

Lecture

Introduction

- Radiation sources are an integral part of our technology-based life
- The potential for accidents is there and it is not disappearing
- We will examine the potential for accidents that could lead to radiological consequences



Module X.1 - General Principles and Type of Events 2

Content

- Types of radiation accidents
- Where they can happen
- Accident consequences
- Statistics of radiation accidents
- Summary



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What is a Radiation Accident

- A situation in which there is an unintentional exposure to ionising radiation or radioactive contamination
- Exposure may be real or suspected



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General Classification

- The range of potential emergencies involving ionizing radiations is enormous
  - From a major reactor accident to accidents involving small amounts of radioactive material
- In general, emergencies may be classified into two broad categories:
  - Nuclear accidents
  - Radiological accidents



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Nuclear Accidents

- The term *nuclear accident (emergency)* applies to
  - Reactor accident
  - Accident at reprocessing plants
  - Accidents at other large nuclear facilities
  - Accident involving the detonation with partial nuclear yield of a nuclear weapon
- It is one that involves the nuclear fuel cycle and the potential for criticality



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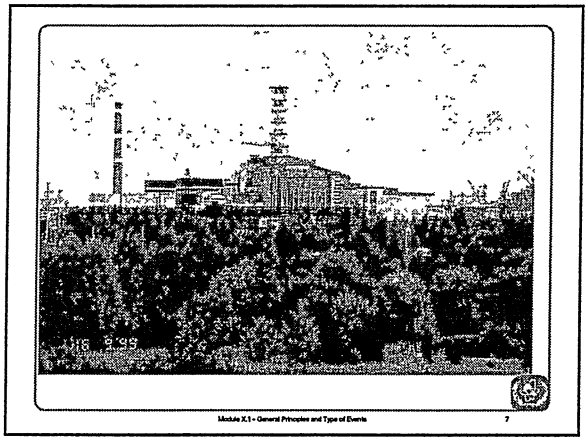

Where Can They Occur

- The highest risk of severe health effects resulting from a radioactive release comes from nuclear power plants or facilities storing large amounts of nuclear waste from reprocessed nuclear fuel
- By far the most common facility containing very large amounts of radioactive material is a *nuclear power plant*
- There are over 400 commercial nuclear power plants (NPP) operating in the world

Reactor Accidents

- NRX, Canada, 1952
- Windscale, UK, 1957
- NRU, Canada, 1957
- Westing House test reactor, USA, 1960
- SL-1, USA, 1961
- Enrico Fermi, USA
- Lucens, Switzerland, 1976
- Browns Ferry fire, USA
- TMI, USA, 1979
- Chernobyl, USSR, 1986

Radiological Accidents

- A *radiological accident (emergency)* is one that involves
  - Sources other than nuclear fuel
  - The dispersion of material from a nuclear weapon without a nuclear yield
  - Radiological emergencies that could result from deliberate acts, such as terrorist activities or illicit trafficking



Types of Radiological Accidents

- Radiological accidents can be classified in three major categories:
  - Accidents with radiation sources or radioactive material
  - Accidents outside the country with trans-boundary effects, and
  - Nuclear powered satellite re-entry

Accidents With Radioactive Sources

- Discovery of a source or contamination
- Missing source (lost or stolen)
- Damaged source or loss of shielding
- Fire involving radioactive source(s)
- Dispersion of alpha emitter
- Transport accident with radioactive sources
- Accident involving nuclear or radiological devices (research reactor, neutron generator, accelerator...)

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Where Can They Occur



- Medical institutions
- Industrial facilities
- Research and educational institutions
- Transport involving radioactive material
- Nuclear fuel cycle
- Field applications with gamma radiography





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Where Else

- Almost anywhere
  - In the field (gamma radiography sources)
  - Terrorist or criminal activities
  - Illicit trafficking
  - In scrap yards (wrongly disposed source)
  - On military premises
  - Basically, in many places where they should not be

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Transboundary Accidents

- Impact from a severe accident at a nuclear installation far from the country's border
- Most significant threat: contamination of the environment through deposition
  - Deposition is highest if rain is present at the time of plume passage
- Most significant challenge: the media perception

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Nuclear Powered Satellite Re-entry

- Nuclear power sources are used in space vehicles such as satellites and deep space probes
  - Satellites may carry a small nuclear reactor, radioisotopic thermoelectric generators and heating units contain plutonium
- Launch accidents are not a significant threat
- Accidental re-entry is a possible threat
  - Crash on ground may lead to wide-spread of contamination (e.g. COSMOS 954, Canada, 1979)

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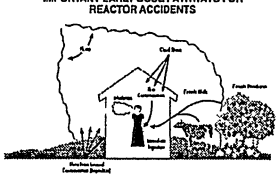
Possible Radiological Hazards

- External irradiation
- Internal contamination through inhalation or ingestion

IMPORTANT EARLY DOSE PATHWAYS FOR REACTOR ACCIDENTS



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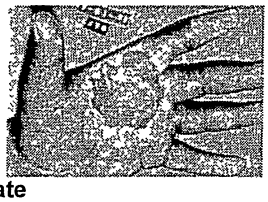
Possible Health Consequences

- Acute radiation syndrome
- Local burns
- Combined injuries
- Death
- Increased risk of late effects (e.g. cancer)



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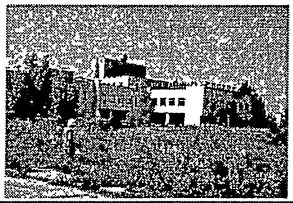
Other Potential Consequences

- Environmental
- Economic losses
- Psychological
- Legal



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Historical Facts

- When did a radiological accident first happen
  - Radiological accidents started with the discovery of radiation – early mishaps occurred shortly after the discovery of x-rays and radioactivity in 1895
  - First case of skin injury due to radiation: 1896

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However

- Radiation does not cause:
  - Immediate death
  - Immediate burns, wounds
- Irradiation alone is not a medical emergency

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Statistics

- According to DOE-REAC/TC, from 1944 to March 2000:
  - 414 major accidents
  - 133,742 persons involved
  - 2,998 significantly exposed (by DOE/NRC accident dose criteria)
  - 127 fatalities

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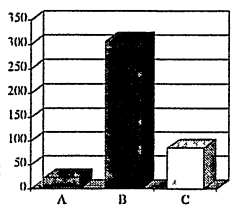
Major Radiation Accidents

- The 414 major radiation accidents include:
  - Criticalities (A): 22
  - Radiation devices (B): 307
  - Radioisotopes (C): 85



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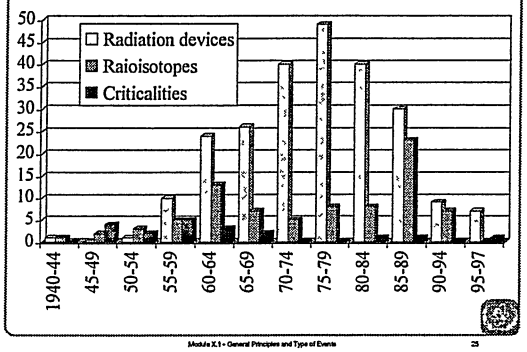
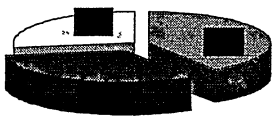
More Statistics



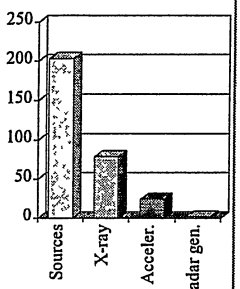
Criticalities

- Critical assemblies: 9
- Reactors: 7
- Chemical operations: 6



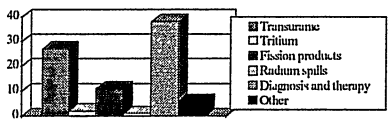
Radiation Devices

- Sealed sources: 203
- X-ray devices: 79
- Accelerators: 24
- Radar generators: 1



Radioisotopes

- Transuranic: 27
- Tritium: 2
- Fission products: 11
- Radium spills: 1
- Diagnosis/therapy: 38
- Other: 6



Summary

- Radiation accidents can happen
- Serious radiological consequences are rare but they can occur
  - Stochastic effects
  - Severe injuries
  - Death
- Therefore, emergency response plans are required

Where to Get More Information

- Lesson X.1.3
- Generic Procedures for Assessment and Response During a Radiological Emergency, IAEA-TECDOC-1162 (2000)
- Lessons learned from Accidents in Industrial Radiography, IAEA Safety Reports Series No.7 (1998)