RADON RESEARCH IN MULTI DISCIPLINES: A REVIEW

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COURSE OUTLINE

I. Fundamentals of radon physics: review
II. Radon research in geology
III. Radon research in radiation biology
IV. Radon research in medicine
V. Radon research in health physics
Earth & Planetary Science
Radon research in multi disciplines - summary
Student Presentations
Radioactivity Laboratory demonstration

DETAILED COURSE WORK

The course work involves the following:

1. **January 17, 18, 19, 22, 25 1-3 PM**
   5 sessions each of 2 hours - 25%
2. **Study Assignments - 4 - 20%**
3. **Project**
   Literature Survey – Writing a report - 30%
4. **Project Presentation - 25%**

Required percentage to pass this course is 95%
Grading: P/F

Session 3
Radon & Radiation Biology

Session 3 January 19, 2007

Objective

1. **Review of Radiation Biology Basics:**
   - **1.1 Introduction**
   - **1.2 Radioactivity and Absorbed dose – Dosimetry**
   - **1.3 Effects of radiation on cell – primary site of damage**
   - **1.4 Target theory**
   - **1.5 Linear No Threshold Theory**

2. **Examples of Some Current Research:**

   Current Research on Effects of Low Dose Ionizing Radiation

1. REVIEW OF RADIATION BIOLOGY BASICS

1.1 Introduction

1.2 Radioactivity and Absorbed dose dosimetry

1.3 Effects of radiation on cell – Primary site of damage

1.4 Target theory

1.5 Linear No Threshold theory

1.1 Introduction

Radiation biology research is in wide range of
subjects like

- detection of chemical or microscopic changes in irradiated organisms;
- observation and explanation of many changes at
  - gross or nano level,
  - lethal or non-lethal,
  - long term or short term,

  caused by ionizing radiations in biological materials;
- development of ultimate principles and procedures for radiation protection.

1.2 Radioactivity and Absorbed Dose Dosimetry

Radioactivity is measured in units of disintegrations per second.

1 Curie = 1 Ci = 3.7×10^{10} dps

1 Becquerel =1 Bq = 1 dps

Rad is a unit of absorbed dose for any ionizing radiation.

1 Rad = 1R = 100 ergs absorbed per gram of any substance

1 Gray = 1 Gy =100 Rads

1.2 Radioactivity and Absorbed Dose Dosimetry …

Roentgen:

Unit of exposure of X- or gamma radiation ionization produced in air.

1 Roentgen results 1 esu per cc of air at STP.

Roentgen Equivalent Man – Rem is dose equivalent

1.2 Radioactivity and Absorbed Dose Dosimetry ...

Roentgen Equivalent Man =

Rem = Rad x RBE (or QF) x DF

RBE = Relative Biological Effectiveness is a factor expressing relative effectiveness of radiations with differing linear energy transfer (limited to radiobiology usage)

QF = Quality Factor similar to RBE (used mostly in Radiation Protection)

DF = Dose Distribution Factor accounts biological effect due to non uniform distribution of internally deposited radionuclides.

1.2 Radioactivity and Absorbed dose – Dosimetry ...

Linear Energy Transfer – LET

The average energy released per unit track length traversed.

LET is useful in comparing radiations.

Comparisons are based on LET value.

Table 1. Comparison of LETs for different radiations

Radiation	**LET (keV/u)** **u = micron length in water**
3 MeV X-ray	0.3
^{60} Co gamma (1.3 MeV)	0.3
250 keV X-ray	3.0
5.3 MeV alpha	110.0
Fission Fragment	4000- 9000
Ref: Radiation Biology , A. P. Casarett pp 28	

1.2 Radioactivity and Absorbed Dose Dosimetry …

Dose

Dose relates to the effect on a material exposed to radiation.

Absorbed dose is the amount of energy absorbed by a material when exposed to radiation.

Equivalent dose (in unit Sievert) is the potential biological effect in tissue exposed to radiation = Absorbed dose x Quality Factor.

1.2 Radioactivity and Absorbed Dose Dosimetry ...

Irradiation damage to a cell:

Radiation may

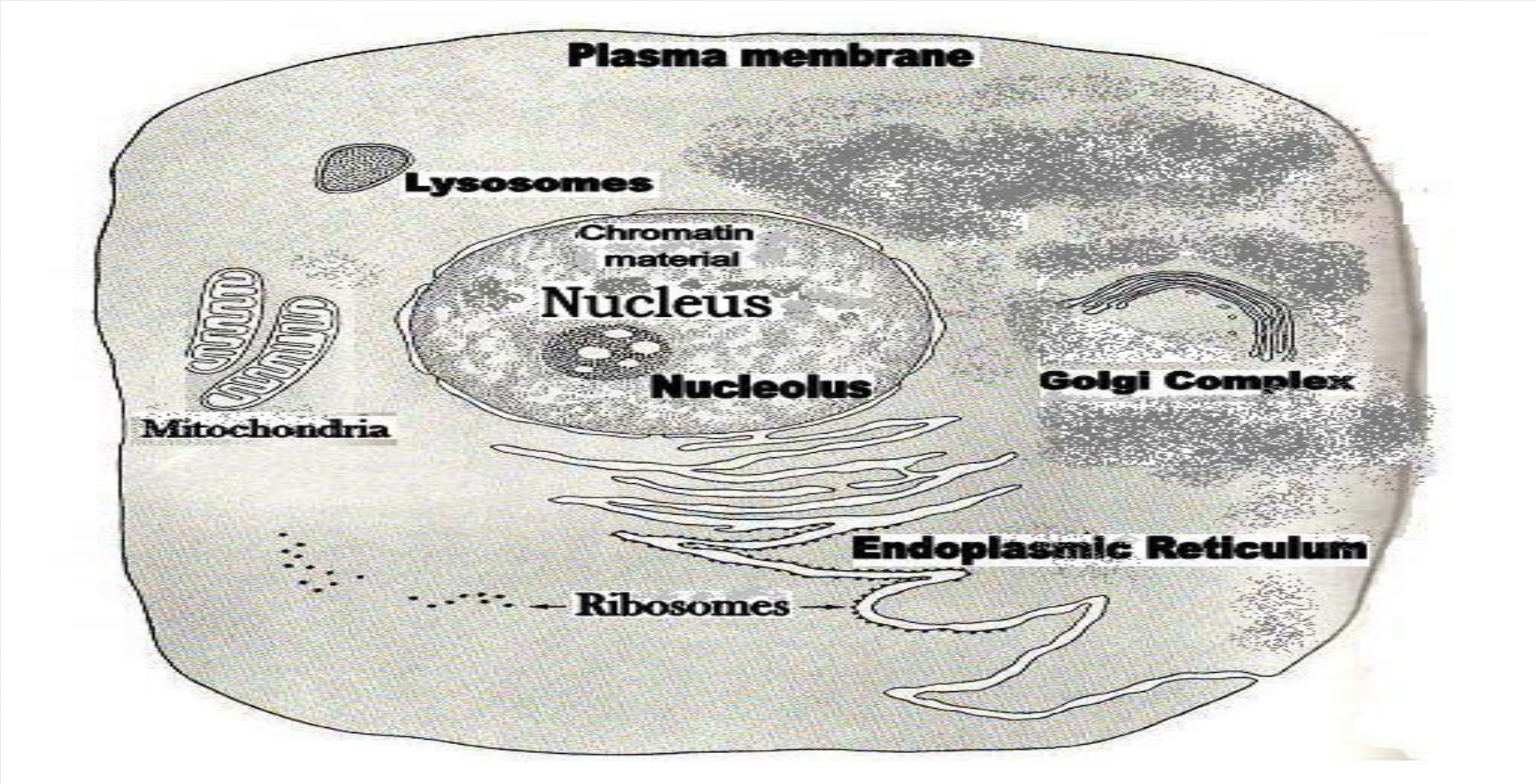
- **pass through the cell causing no damage;**
- **pass through the cell causing damage, but the cell still able to repair the damage before forming new cells**
- **pass through the cell causing damage, cell passes damage on to new cells;**
- **pass through the cell, completely destroying the cell.**

Table 2. Total body radiation exposure and effects	
Exposure	Effect
50 mGy (5 rads)	No significant symptoms
1 Gy (100 rads)	Possible symptoms of nausea and vomiting for about 2 days; temporary reduced activity of new blood cell formation
3 Gy (350 rads)	Initial symptoms of nausea and vomiting; after 3-4 weeks, possible development of deficiency WBC and platelets; recommended medical attention
Higher levels	Fatal; recommended immediate medical attention.

Ref: http://orise.orau.gov/reacts/guide/injury.htm

1.3 Effects of radiation on cell

Components of cell structures



Ref: Radiation Biology
by A. P. Casarett

1.3 Effects of radiation on cell …

Some functions of cell structures:

- Cell Membrane: Cell is contained by a membrane called plasma membrane consisting of lipoprotein complex of phospholipids and layers of protein molecules making it a semi-permeable membrane.
- Endoplasmic reticulum membrane can be viewed as a connecting net work.

1.3 Effects of radiation on cell ...

Functions of Cell structures ...

- Within the cytoplasm of the cell are ribosomes, mitochodria, golgi complex and lysosomes.
- Ribosomes: sites for important enzyme synthesis
- Mitochondria: also sites for the respiratory enzymes which couple oxidation and phosprylation reactions.
- Lysosomes: sites for a number of digestive enzymes of the cell.

1.3 Effects of radiation on cell ...

Functions of Cell structures ...

- Chromosomes: The nucleus consists of the nucleoli and the chromosomes.
- Chromosomes consist primarily of DNA and RNA.
- DNA consists of only four different nucleotides, replicating themselves.
- RNA is like a messenger providing blueprints for the cells.

1.3 Effects of radiation on cell ...

Radiation effects on membranes

Healthy membrane structure is vital to cell integrity.

Radiation damage:

- rupturing
- dilation of endoplasmic reticulum
- swelling of mitochondria
- disorganization of internal membrane
  - altering of permeability

1.3 Effects of radiation on cell ...

Radiation effects on enzymes:

- Higher doses of radiation are required , to induce enzyme activity alteration, causing reduction of cell growth; as compared to mutation effects or chromosome damage.

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1.3 Effects of radiation on cell ...

Radiation effects on DNA and RNA

Effect on DNA: Synthesis becomes reduced due to decrease in the activity of enzymes which regulate the synthesis of DNA. These effects seem to be more delayed rather than immediate.

Decrease in DNA causes changes in cell population.

Effect on RNA: The synthesis of RNA may be delayed or depressed by radiation. Also alteration of DNA synthesis effects RNA as the messenger for blueprint function.

1.3 Effects of radiation on cell ...

Radiation effects of chromosomes:

- Structural aberrations caused by lesions.
- Lesions may be single arm, inter am – intra arm.
- Chromatid type aberrations:
- Well presented diagrams or pictures of aberrations can be seen in radiobiology text books or on websites.

1.3 Effects of radiation on cell … Primary site of damage

Primary site of damage

- Vast data, both direct and inferential evidence, provide conclusion that cell nuclei are a major site of radiation damage leading to cell demise.
- Cell Division (not in present scope of this session)
- Genetic Effects (not in present scope of this session)
- Note: When a cell is exposed to radiation, the change depends both on the cell and the surrounding cells, their functions and activity at the time of radiation exposure.

1.4 Target Theory

- Model applied
- Biological effects vs dose, with constraints or criteria imposed
- States that

  the production or ionization in or near a structure called the target is responsible for the measured effect.

1.4 Target Theory ...

- The production of an effective event in the target is called a hit.
- In its simplest model, one hit is sufficient to produce a measured effect

  such as reduced growth or division or even cell death
- In its simplest model, random occurrence of event is assumed.

But in reality the probability may be

multi target – single hit.

So models become more complex and sophisticated.

1.4 Target Theory ...

- Alpha radiation has high LET, hence causes direct damage to the DNA.
- X-rays and gamma radiation have low LETs, however, generate free radicals, which are toxic.
- The end effect is that the DNA of the cell is altered.

1.5 Linear No Threshold Theory ...

The **linear no-threshold model** (**LNT**) **is a model of the dose by ionizing radiation and the response effect**

Assumptions of the LNT model:

- **The response is linear.**
- **Response / Effect is directly proportional to dose at all dose levels.**
- **There is NO THRESHOLD of exposure below which the response ceases to be linear.**

1.5 Linear No Threshold Theory

...

National Council on Radiation Protection and Measurements (NCRP) recently recommended that -

"radiation effects should be considered to be proportional to the dose an individual receives, regardless of how small that dose is, in order to be cautious."

1.5 Linear No Threshold Theory Alternative

- **An alternate model is radiation hormesis.**

Postulates that:

- **radiation is beneficial at low doses, and harmful at high doses.**

2. Current Research on Effects of Low Dose Ionizing Radiation

Current understanding of low dose ionizing effects and dialogue on Linear No Threshold Theory

2. Recent Research on Effects of Low Dose Ionizing Radiation ...

The most important aspect of radiation protection is : to provide protection, from low as well as high levels of ionizing radiation, to professionals as well as general public.

Many risk estimate studies are based on earlier studies such as ionizing radiation effects due to atom bomb exposure; uranium mining; recent studies such as exposure due to nuclear power plant accidents. Also many cohort studies are being conducted world wide. (Ref. BEIR Reports).

However, recently, there is a debate/dialogue going on about

- **damage to the human cells causing non-cancerous effects;**
- **no-damage and/or ability of cells to repair from damage;**
- **no effects for certain dose levels;**

from low dose ionizing radiations.

The dialogue about the appropriateness of LNT in radiation protection

According to 'in favor' discussion: (Ref: Brenner. D., 2001)

Low dose range may be considered as 10 – 100 mGy.

At this level, there is difficulty in measuring the signals with sufficient the precision and accuracy .

Yes, there may be three-four options of (non-linear) in the dose-response relationships.

The reason that could give solid weight to 'in-favor' scenario:

Ionizing radiation energy deposition is of unique nature; when dose is decreased, fewer cells may be hit by more than one radiation track which may be sufficient to damage cells, even at very low doses.

Quoting Dr. Brenner, to sum up:

"A risk not statistically distinguishable from background is not in itself evidence that the risk is or is not zero, so is not evidence for or against the applicability of LNT."

The dialogue about the appropriateness of LNT in radiation protection

Opposing the LNT: (Ref. Raabe, O.G., 2001):

The LNT model uses simple mathematical relationships that prorate higher dose-response down to lower and zero dose and risk. This is inappropriate in the context of current understanding of cancer risk estimates which showed non-linear threshold like phenomenon for ionizing alpha radiation. Also, studies of beneficial effects of low level ionizing radiation are now being reported frequently

(Luckey 1991, Jaworowski, 1995, Cohen 1995).

Linear No Threshold Theory & Low Dose Ionizing Radiation

Linear No Threshold model:

- **Major concern is damage to DNA**
- **Requires protection to DNA from ionizing radiation.**

Current understanding

- **Low-dose ionizing radiation interaction with DNA may be in contrast to the impairment by high-dose radiation.**
- **The ionizing radiation effect is not measured by the number of mutations, but by oxidative DNA damage.**

At low doses, radiation may

- **prevent cancer by increasing removal of premalignant or malignant cells with persistent DNA damage,**
- **in human radio immunotherapy, completely remove malignant tumors with metastases.**

Current Understanding of Low Dose Ionizing Effects

Three key effects observed:

- **genomic instability,**
- **adaptive responses and**
- **bystander effects.**

The understanding:

- **Low doses suggest significant non-linear responses.**
- **These new observations pose a significant challenge to understanding of low-dose exposure**

Conclusion:

Further research is needed to explain the mechanisms, and effects of ionizing radiation by low dose exposure and determine their relevance.

Internet Keywords

- Radiation dosimetry,
- Target Theory
- Single hit, Multi hit
- Linear No Threshold
- Ionizing radiation – Toxicology,
- Ionizing radiation -- Physiological effect.
- Ionizing radiation -- Dose-response
- Radiation -- Physiological effect

- Radon -- Health aspects.
- Radon -- Physiological effect.
- Radiation carcinogenesis.
- Health risk assessment

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