Amirkabir
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A Standardized Individual Dose System for Epidemiology and Dose Limitation of Public and Workers by "Universal Radiation Protection System Hypothesis"

PART II:

Universal Radiation Protection System (URPS) Hypothesis

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Prerequisite

Before viewing this lecture please see PART I:

on

A Standardized Individual Dose System for Epidemiology and Dose Limitation of Public and Workers by a "Universal Radiation Protection System (URPS) Hypothesis"

Curent Radiation Protection System

Contents

Continuation;
Some Questions from PART I

Background

In Part I of this lecture, the status of the Curent Radiation Protection (RP) System and natural background (NBG) radiation were discussed.

Accordingly, some questions were raised:

- **Is health risks/unit dose of NBG and man-made radiation exposures different?**
- **Should we apply "Risk Limit" to set "Dose Limit"?**
- **Should a member of public have same "Risk Limit" in different parts of the world?**
- **Should a worker have same "Risk Limit" working in different parts of the world?**
- **Is Public "Dose Limit" standardized considering all exposures including medical?**
- **Is "Dose Limit" of a worker, also as a member of public, standardized?**
- **Is the risk in LNT response above UNSCEAR mean global NBG radiation dose Justified?**

Continuation;
Some Questions from PART I

- Should we apply a **"Fractionation Factor (FF)"** to equalize exposure risks per unit dose?
- Is 1 mSv.y^{-1} public **"Dose Limit"** from planned exposure situations on top of UNCEARS's 2.4 mSv.y^{-1} global mean NBG dose justified?
- Is Reference Level of 1 mSv.y^{-1} for gamma exposures and 10 mSv.y^{-1} for radon and progeny indoors practical?
- Could we bridge the LNT Model and Hormesis?
- Do we need to evolve RP philosophy, concepts and procedure?
- Can the **"Universal Radiation Protection System (URPS) Hypothesis"** evolve the current RP system?

- Then let's see what is the **"URPS Hypothesis"**.

“Universal Radiation Protection System Hypotheis”

What is

“Universal Radiation Protection System (URPS) Hypothesis”?

"Universal Radiation Protection System (URPS) Hypothesis"

"URPS Hypothesis" was proposed by this author at a keynote opening talk at 8th ICHLNRRA in Prague, 1-5 Sept 2014, and also as an invited talk at 14th Int. Congress of Int. Radiation Protection Association, Cape Town, South Africa, May 2016.

The following publications discuss the principles in detail:

- M. Sohrabi A Universal Radiation Protection System based on Standardized Individual Integrated Doses, Radiation Protection Dosimetry, 164 (4), 459–466 , (2015).
- M. Sohrabi, Editorial, Eighth International Conference on High Levels of Natural Radiation and Radon Areas. Radiation Protection Dosimetry V. 164, No. 4, pp. 457–458 May (2015).
- M. Sohrabi, On Dose Reconstruction for the Million Worker Study: Status and Guidelines. Health Physics, 109 (4) 327-329, October (2015).
- M. Sohrabi, Editorial, A Standardized Individual Dose System for Epidemiology of Public and Workers by "Universal Radiation Protection System Hypothesis", J Epidemiol Public Health Rev 1 (3) (2016).
- M. Sohrabi, Editorial, Conservation of "Cause-Effect" by Using Integrated Individual Radiation Doses towards Standardization of Epidemiology Health-Risk Estimates of Nuclear/Radiation Workers. J. Nucl Ene Sci Power Generat Technol, 6;2 (2017).
- M. Sohrabi, Editorial, Dose Fractionation Concept in Radiation Protection to Standardize Health Risks/Dose Limits. J Epidemiol Public Health Rev. Accepted for Publication (2017).
- M. Sohrabi, Editorial, Education Standards and Standards Education (ESSE) Process in National Education Cycle for Global Public Health Sustainability. SF J Pub Heal 1:1 (2017).

"URPS Hypothesis"

"URPS Hypothesis" is based on a novel philosophy, concepts and methodology with the following principles. It:

- **Assigns equal health risks per unit dose of NBG radiation and per unit dose of man-made radiation exposures,**
- **Applies a "Standardized Integrated Dose System" (SIDS) for public and for a worker, (also as a member of public) for doses received from different exposure situations,**
- **Assigns "health risk limit" for public and workers (no matter where they live and work in the world)**
- **Sets "Risk Limit" to establish "Dose Limit" for workers and public,**
- **Applies "Dose Fractionation Concept" in RP for the first time to equalize and standardize health risks/dose limits, and**
- **Applies "Fractionation Factor" (FF) to "fractionated exposures" (e.g. Occupational Exp.) and chronic "unfractionated exposures" (e.g. NBG Exp.) in setting integral health risk-based dose limits**
- **Considers any other confounding factors affecting an individual's health risks in setting integral health risk-based dose limits, reference levels, etc. in RP in general and in any epidemiological studies or workers and public in particular.**

"URPS" Hypothesis"

- **For workers** (including also for epidemiology):
  URPS by applying SIDS integrates effective doses received from occupational exposure, national NBG exposure, planned exposure situations (within public dose limit of 1 mSv/y), and possibly medical exposure (yet to be studied), to equalize "radiation health risks" worldwide.

- **For Public** (including also for epidemiology):
  URPS by applying SIDS integrates public doses from planned exposure situations within a dose limit (e.g. 1 mSv/y), natural national effective dose (internal and external), and possibly medical exposure, or any other possible exposures.

Definitions of Exposures (ICRP; IAEA Glossary)

- **Occupational Exposure**

  All exposure of workers incurred in the course of their work, with the exception of excluded exposures and exposures from exempt practices or exempt sources.

- **Public Exposure**

  Exposure incurred by members of the public from radiation sources, excluding any occupational or medical exposure and the normal local natural background radiation but including exposure from authorized sources and practices and from intervention situations.

“

Definition of a Radiation Worker

- **ICRP; IAEA Glossary**

  "Any person who works, whether full time, part time or temporarily, for an employer and who has recognized rights and duties in relation to occupational radiation protection".
  (A self-employed person is regarded as having the duties of both an employer and a worker)"

- **URPS Hypothesis**

  defines a "radiation worker" an individual member of public who receives ionizing radiation exposures in daily life and additionally from occupational exposure as an employee or
  - **simply defines a "radiation worker" an individual receiving occupational exposure" plus exposures as a member of public in daily life .**

SIDS; Integrates all Exposures a Member of Public Receives in Daily Life

Man-made

(As Public)

- Medical (unfractionated)?
- Military
- Nuclear Power
- Accidents

Natural

(As Public)

- Cosmic rays
- Terrestrial
  - External (e.g. Gamma)
  - Internal (Inhalation of Radon), Ingestion (Radium, etc.)

SIDS; Integrates all Exposures a Worker Receives at work and in Daily Life (as a member of public)

Natural +
(As Public unfractionated)
- Cosmic rays
- Terrestrial
  - External (Gamma)
  - Internal (Radon, and others
- indoors)

Man-made +
(As Public unfractionated)
- Nuclear Power
- Military
- Accidents
- Medical (unfractionated)?

Occupational
(As Worker)
- Daily work but highly fractionated.

Public Dose According to URPS

Planned Exposure Situations

(Practices)

Dose Limit

(<1 mSv.y-1)

+

Existing Exposure Situations:

Env. National Background Dose

(Internal and External)

e.g. mean national NBG Dose (for dose limitation) and doses from the past retrospectively (for epidemiology), + other exposures such as medical exposure

Present Dose Limit of Public by Considering URPS

Dose Limit$_{(public)}$ = 1 mSv.y^{-1} on top of E$_{(nmbg)}$

note; presently on top of ≈2.4 mSv.y^{-1}

Where:

E$_{(nmbg)}$ = Annual national mean NBG (or environmental dose) dose (mSv.y^{-1}), or Annual environmental dose in case of the country has past practices

Workers' Doses According to URPS

↑

Dose Received Occupationally

(Internal and External)

+

Dose received as a member of public such as:

- **existing exposure situation (national environmental Background Dose such as NBG)** (Internal and External) **+**
- **Dose from Planned Exposure Situation (< 1mSv.y^{-1} Dose Limit of Public), +**
- **medical exposure (in particular for epidemiology)**

Examples of Some Excellent Current Epidemiology Studies of Workers:

- US Million Nuclear Workers Study (Bouville et al., Health Phys 108 (2): 206-220, 2015), based on external and internal occupational doses.

- International Nuclear Worker Study (INWORKS) (Richardson et al. Br Med J 1-8, 2015), based on only external doses.

- Risk of basal cell carcinoma in US radiologic technologists (1983-2005) (Lee et al. Occup Environ Med 72(12):862-9, 2015), based on only occupational eternal doses.

- In order to obtain more actual risk factors, new methodologies are needed.

Epidemiology in Normal NBG Radiation (e.g.)

- Exposures from terrestrial gamma and cosmic rays have been applied to the studies on the risk of childhood cancer among 2,093,660 children < 16 y in a census-based nationwide cohort study.
- suggested that exposures from terrestrial gamma and cosmic rays may contribute to the risk of cancer in children, including leukemia and central nervous system tumors.
- Exposures not included:
  - Radon internal exposure (NBG)
  - Medical
  - Nuclear Power
  - Etc.
- According to URPS Hypothesis and SIGD, the risks are overstimated.

Spycher B, et al. (2015) Background ionizing radiation and the risk of childhood cancer: a census-based nationwide cohort study. Environ Health Perspect 123(6): 622-628.

Epidemiology studies of workers (e.g.)

- Bouville A, et al.. (2015) Dose reconstruction for the million worker study: status and guidelines. Health Phys 108 (2): 206-220.
- Lee T, et al. (2015) Occupational ionising radiation and risk of basal cell carcinoma in US radiologic technologists (1983–2005). Occup. Environ. Med. 72(12): 862-869.
- Laurier D, et al. (2016) The international nuclear workers study (INWORKS): a collaborative epidemiological study to improve knowledge about health effects of protracted low-dose exposure. Radiat Protect Dosim, doi:10.1093/rpd/ncw314

Epidemiology studies of workers only total or partial dose equivalent of occupational exposure of workers from man-made sources are considered; e.g.:

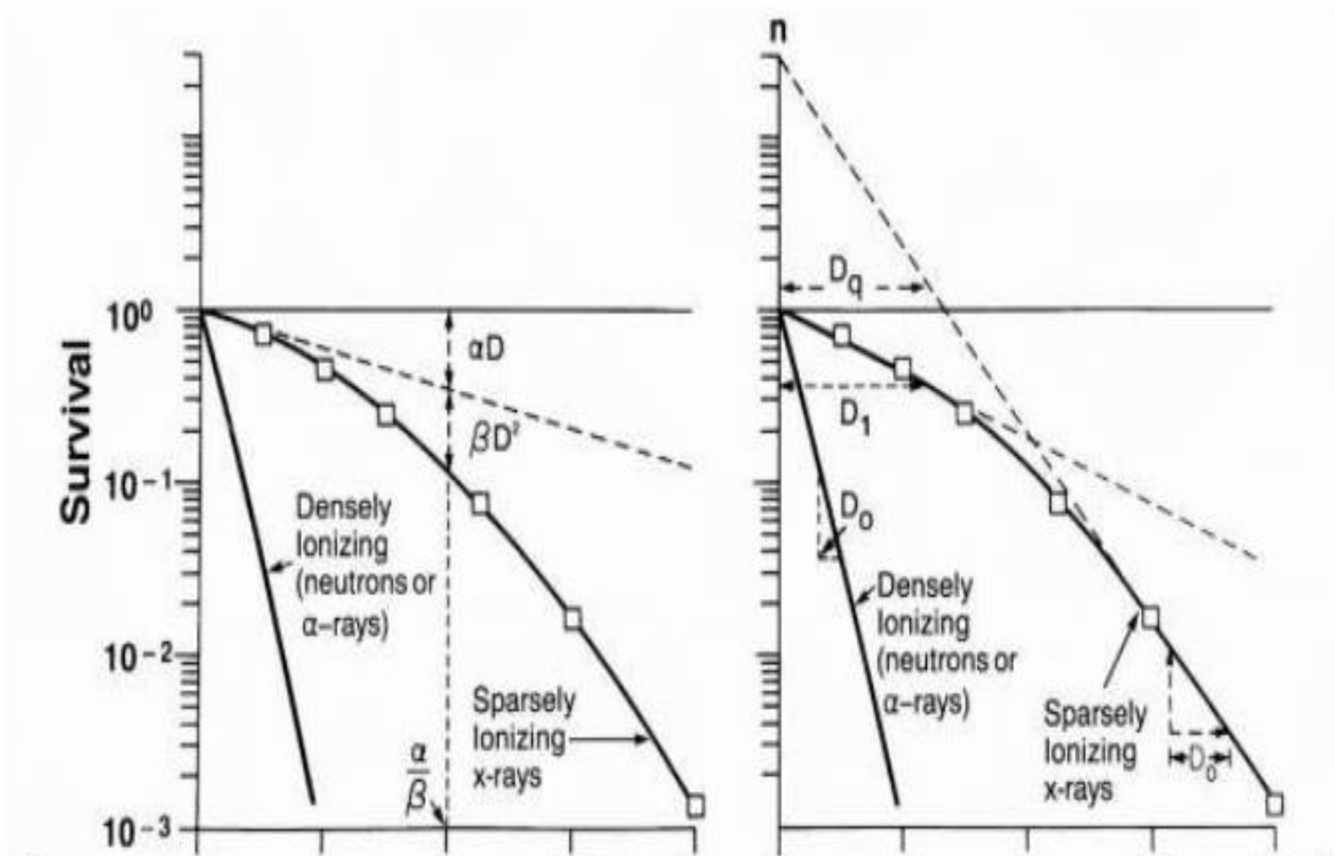
- **"External & internal occupational exposures" in present US Million Nuclear Workers Study,**
- **Only "external occupational exposure" of the US radiologic technologists (1983-2005) in the risk estimate of basal cell carcinoma,**
- **only "external occupational exposure" with mean individual cumulative external dose of 25 mSv in international nuclear workers study (INWORKS) with relatively large cohort size of 308 297 workers of USA, UK and France over the period 1945–2005 with a mean attained of 58 y age at the end of a mean duration follow-up of 27 years.**
- **Exposures not included in the studies:**
  - **Occupational internal (e.g. INWORKS),**
  - **Radon internal exposure (NBG),**
  - **Medical,**
  - **Nuclear Power,**
  - **Etc.**
- **According to URPS Hypothesis and SIDS, the risks are overestimated.**

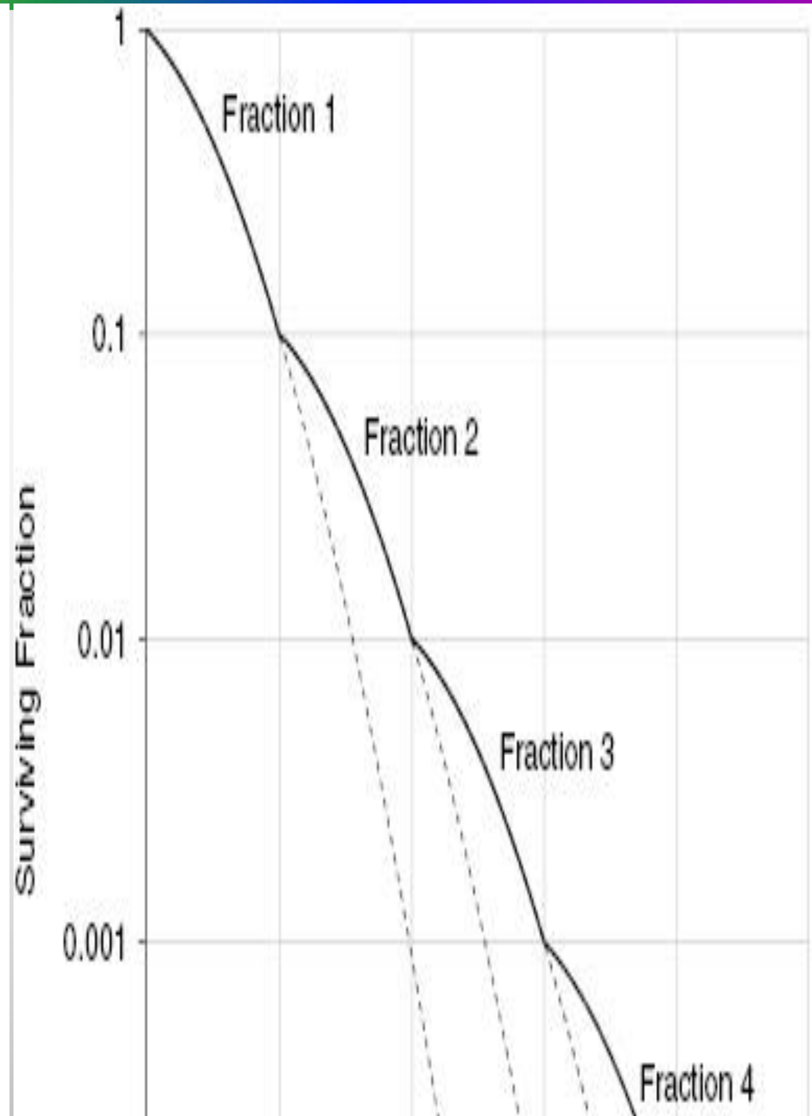
Survival Curves

- A cell survival curve is a curve used in radiobiology.
- It depicts the relationship between the fraction of cells retaining their reproductive integrity and the radiation dose.
- Conventionally, the surviving fraction is depicted on a logarithmic scale, and is plotted on the y-axis against dose on the x-axis.
- Cell survival fractions are exponential functions with a dose-dependent term in the exponent due to the poison statistics underlying the stochastic process.

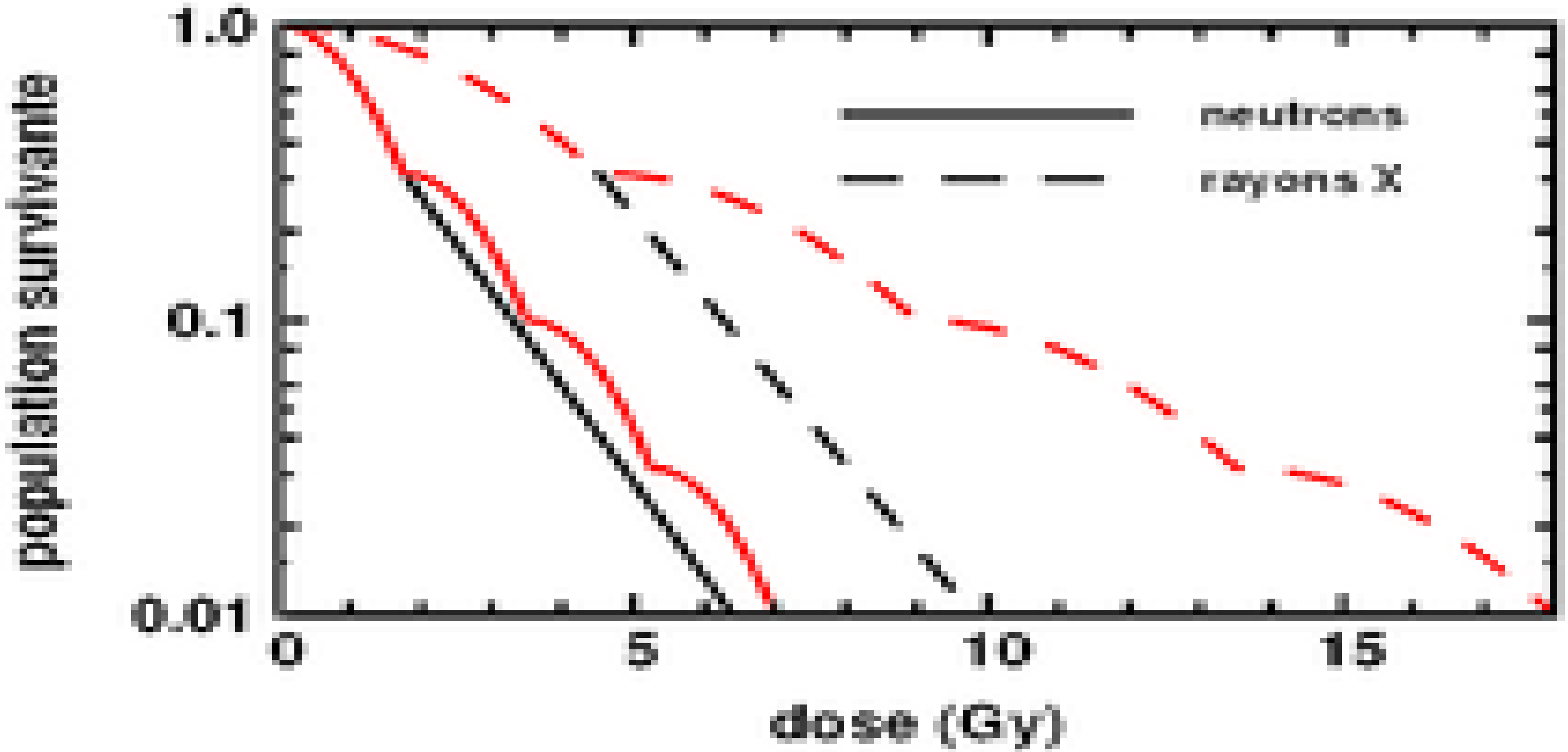
Survival Curves and Dose Fractionation

Shape of the Curve





Dose Fractionation



Dose Fractionation

- For cell killing, a prescribed dose is required with a known dose rate within a period of time.
- As a known principle in experimental radiobiology, as radiation dose delivered to cells increases, number of cells survived or survival fraction decreases.
- Shape of survival curves depends on radiation type and energy, LET, dose and dose rate, state of fractionation of doses, oxygenation, temperature, etc.
- When the same prescribed dose is divided in several fractions, the total dose to be given in order to observe the same effects, e.g. for cell killings, should be increased.
- This is due to self-repair mechanisms in a damaged cell within few hours post irradiation depending on factors as discussed above.

Dose Fractionation

- In radiotherapy, dividing a prescribed dose to a tumor to kill cancerous cells into multiple smaller doses is referred to as “Dose Fractionation”.
- “Dose Fractionation” is applied in order to maximize positive effects of radiation to destroy or kill cancerous cells and to protect normal cells by minimizing any negative effects.
- On a cellular level and at doses concerned in radiotherapy, five important biological processes occur after each radiation dose delivery, which produce benefit of fractionated dose. These biological processes usually include:
- repair of the sublethal DNA damage by normal cells;
- repopulation of normal healthy cells,
- reassortment of tumor cells into more radiosensitive phases of the cell cycle;
- reoxygenation of tumor cells and
- radiosensitivity.

Such processes have been well studied at high doses and dose rates in radiotherapy. However, it seems data on such effects occurring at low radiation protection doses and dose rates need to be developed.

Dose Fractionation

- **At low doses and dose rates in particular for low-LET radiation such as gamma rays occurring in daily radiation protection, the interactions of radiation with the DNA molecule in a cell usually cause single-strand breaks which are more susceptible to be repaired as well noted on the shoulder of the gamma survival curves.**

- **While in radiotherapy at high doses, double-strand DNA breaks are common which make the cells more probable to be killed rather than repaired.**

- **Self-repair of cells at very low doses and dose rates common in radiation protection can then effectively occur, as is observed on the shoulder of the survival curves.**

Dose Fractionation Corrections

"Dose Fractionation" corrections should be applied in different exposure situations in radiation protection

Why Occupational Dose is Fractionated?

- A worker, e.g., in France, the UK and the USA or many other countries worldwide works 250 days in 50 weeks/year, 8 hours/day and a total of 2000 man-hours work per year.

- There is at least 16 hours between two periods of work in week days and about 68 hours during weekends, at least 15 days annual leaves in developed countries and very long durations in developing countries due to many holidays.

- Accordingly, a Fractionation Factor (FF<1) is extremely important to be applied for occupational doses to estimate health-risks or setting dose limits.
- "FF" can be applied to both workers and public integrated doses.

Conservation of “Cause-Effect”

The “Cause” and “Effect” should be conserved according to “URPS Hypothesis” by applying “SIDS” towards Standardization of Epidemiology Health-Risk Estimates of Nuclear/Radiation Workers and Public in particular for “Dose Limitation”.

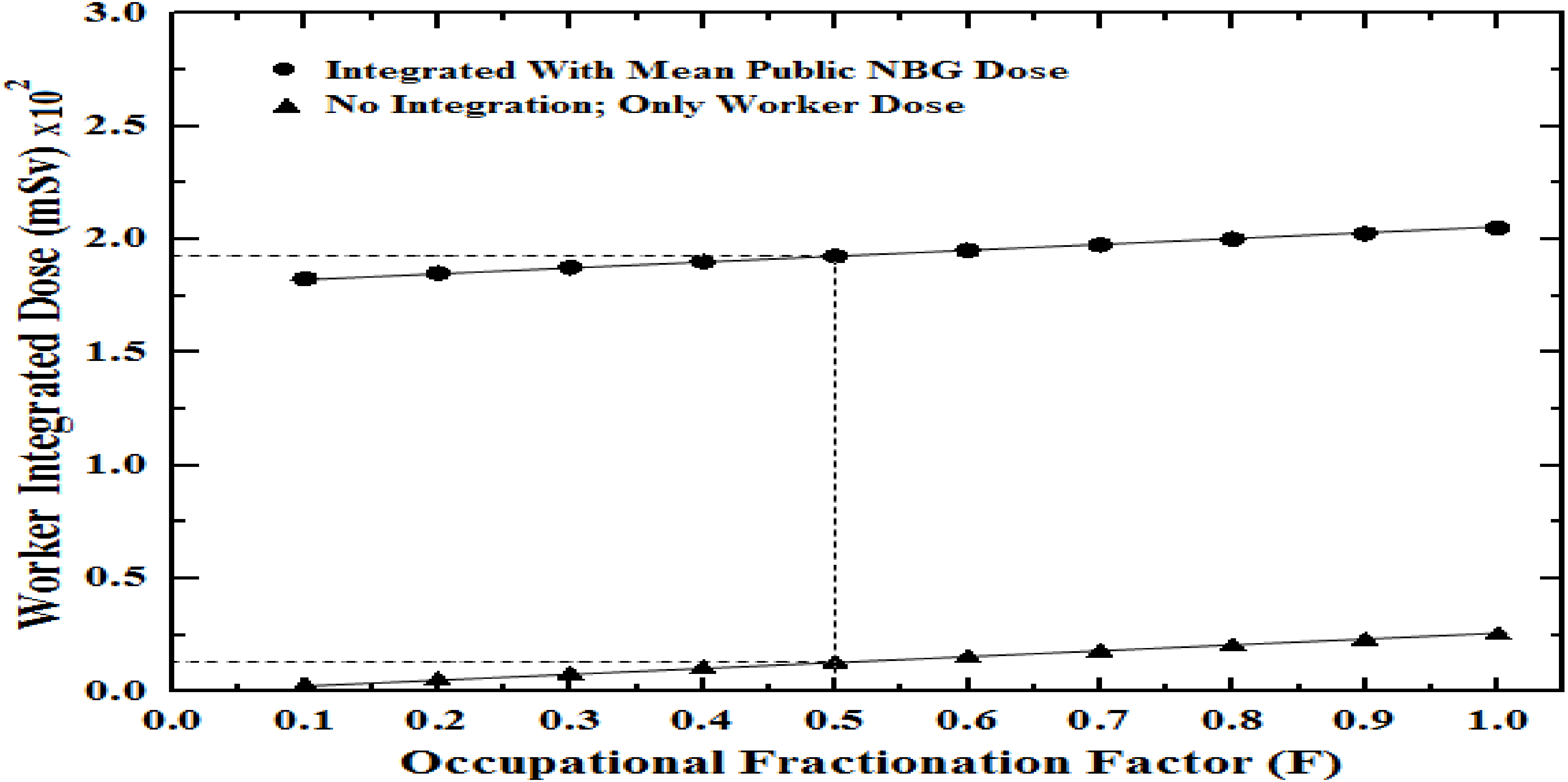
Reference: M. Sohrabi, Invited Editorial, Conservation of “Cause-Effect” by Using Integrated Individual Radiation Doses towards Standardization of Epidemiology Health-Risk Estimates of Nuclear/Radiation Workers. J. Nucl Ene Sci Power Generat Technol, 6;2 (2017).

Fractionated Low Occupational Dose vs Lifetime Chronic NBG Doses

- Fractionation of high doses in radiotherapy increases total dose delivered locally to a patient.
- Fractionation of low doses in radiation protection is also important in radiation protection?
- Do we have data available for fractionation at low doses/dose rates occurred in radiation protection? No.
- Should the dose limit of occupational workers be increased due to fractionation of radiation exposure from occupational exposure?
- Fractionation effect should be considered in occupational radiation protection doses ; if data not available, a factor of 0.5 can be applied, meanwhile.

Applying Dose Fractionation

- An individual participant in INWORKS (France, UK, USA) received a mean cumulative dose 25 mSv occupational dose in mean attained 58 y age.
- The worker, as a member of public, additionally received 6.2 $mSv.y^{-1}$ mean national public exposure; 3.1 $mSv.y^{-1}$ from chronic NBG and 3.1 $mSv.y^{-1}$ from other sources (medical dose is major part), but only NBG dose is considered in this demonstration.
- This worker received from birth 58 y x 3.1 $mSv.y^{-1}$ = 180 mSv from "unfractionated" NBG doses with F_{nbg} =1.0 and lifetime occupational dose of 25 mSv applying a variable occupational FF (F_o) of 0.1 to 1.0.
- By equation (2) using relevant dose and F values, Fig1 demonstrates the worker's integrated lifetime dose vs occupational F_o; once only mean cumulative "fractionated" dose of 25 mSv (lower response) and once by integrating these values with a mean attained of 58 y age lifetime "unfractionated" NBG dose (180 mSv) (upper response).



A worker integrated lifetime dose as a function of the occupational fractionation factor (F_o) once considering only the mean cumulative "fractionated" occupational dose of 25 mSv (lower response) and once by integrating these values with a mean attained of 58 y age lifetime "unfractionated" NBG radiation dose (180 mSv) (upper response).

Effective Dose of a Worker

The effective dose received by a "worker" can be formulated in equation below, as follows:

$$ {}^{w}I_{aid}\ (mSv.y^{-1}) = E_o \times F_o + E_{nbg} \times F_{nbg} + E_{pes} \times F_{pes} + E_{po} \times F_{po} \qquad (1) $$

Where;

$^{w}I_{aid}$ = Annual integrated dose of a worker ($mSv.y^{-1}$),

E_o = Annual occupational dose ($mSv.y^{-1}$),

F_o = Fractionation factor for occupational dose,

E_{nbg} = Annual national mean NBG dose ($mSv.y^{-1}$),

F_{nbg} = Fractionation factor for NBG dose,

E_{pes} = Annual dose from planned exposure situation as a member of public ($mSv.y^{-1}$),

F_{pes} = Fractionation factor for planned exposure situation effective dose,

E_{po} = Annual public other dose, and

F_{po} = Fractionation factor of other doses.

Effective Dose of a Worker

Therefore, the annual integrated dose of a worker $^{w}I_{aid}$ (mSv.y^{-1}) can be given as a general equation (2):

$$^{w}I_{aid} = \sum_i E_i \cdot F_i \qquad (2)$$

Where;

$^{w}I_{aid}$ = Worker annual integrated dose (mSv.y^{-1}),

E_i = Effective dose of exposure type (i) (mSv.y^{-1}), and

F_i = Fractionation factor of exposure type (i).

Dose Limit of a Worker by Considering SIDS

URPS integrates doses of a worker either received occupationally or as a member of public within a dose limit, independent of the sources of origin:

$$\text{Dose Limit}_{(w)}\ (\text{mSv.y}^{-1}) \geqq E_o \times F_o + E_{nbg} \times F_{nbg} + E_{pes} \times F_{pes} + E_{po} \times F_{po}$$

Where;

${}^{w}I_{aid}$ = Annual integrated dose of a worker (mSv.y^{-1}),

E_o = Annual occupational dose (mSv.y^{-1}),

F_o = Fractionation factor for occupational dose,

E_{nbg} = Annual national mean NBG dose (mSv.y^{-1}),

F_{nbg} = Fractionation factor for NBG dose,

E_{pes} = Annual dose from planned exposure situation as a member of public (mSv.y^{-1}),

F_{pes} = Fractionation factor for planned exposure situation effective dose,

E_{po} = Annual public other dose, and

F_{po} = Fractionation factor of other doses.

Advantages of Applying URPS

The "URPS Hypothesis" has a novel philosophy, concept and methodology to solve existing shortcomings in RP of workers, public and the environment in particular epidemiology for 21th century. It

- standardize the RP system in a simple manner.
- integrates all doses a member of public or a worker (as a member of public receives through a "Standardized Integrated Dose System" (SIDS),
- defines a "radiation worker" a member of public who additionally receives occupational exposure.
- Standardizes "risk limits" to set dose limits for public and workers.
- assigns equal health risk limits to workers & public by integrating doses an individual receives no matter where living and working in the world,

Advantages of Applying URPS

- **assigns equal health risks to individuals, whether from existing exposure situations (e.g. NBG doses) or from planned exposure situations (e.g. nuclear power),**
- **applies “SIDS” by integrating all doses an individual receives no matter what the sources of radiation are.**
- **scientifically consistent, practical, convincing and understandable to all by simply applying a 2x2 = 4 concept,**
- **considers exposures such as occupational doses as highly “fractionated” and chronic NBG doses approximately “unfractionated”; this might bring new increased “dose limits”,**
- **easy to convince workers and public to understand; assists in reducing or remove radiophobia,**

Advantages of Applying URPS

- makes epidemiological studies of workers standardized based on actual doses by conservation of “Cause and Effects”
- Prevents overestimation of risk factors as presently being practiced worldwide in particular in epidemiology studies,
- bridges the gaps between the “Hormesis” and “LNT” Models to minimize controversies in radiation protection implementation.
- makes decision making for regulatory bodies simple,
- Makes all doses received by public and workers unified.
- Is a user-friendly universal system by simple philosophy, concept and methodology understandable by public, workers and regulatory bodies.
- Might even increase “dose limit” by considering “fractionation of doses”.

Advantages of Applying URPS

Many countries in the world;

- Have not yet measured the national environmental background radiation doses,
- Do not know the exact internal and external doses received by the public, and
- They should study and measure the doses if the URPS has to be applied.
- This is towards global health sustainability.

Main Conclusion;
Need a Change in *Current Radiation Protection System*

Current Radiation Protection Philosophy, Concept and Methodology Need to be Evolved Universally;

"URPS Hypothesis" is the a standardized Mechanism for the 21st century for protection of workers, patients, public and the environment

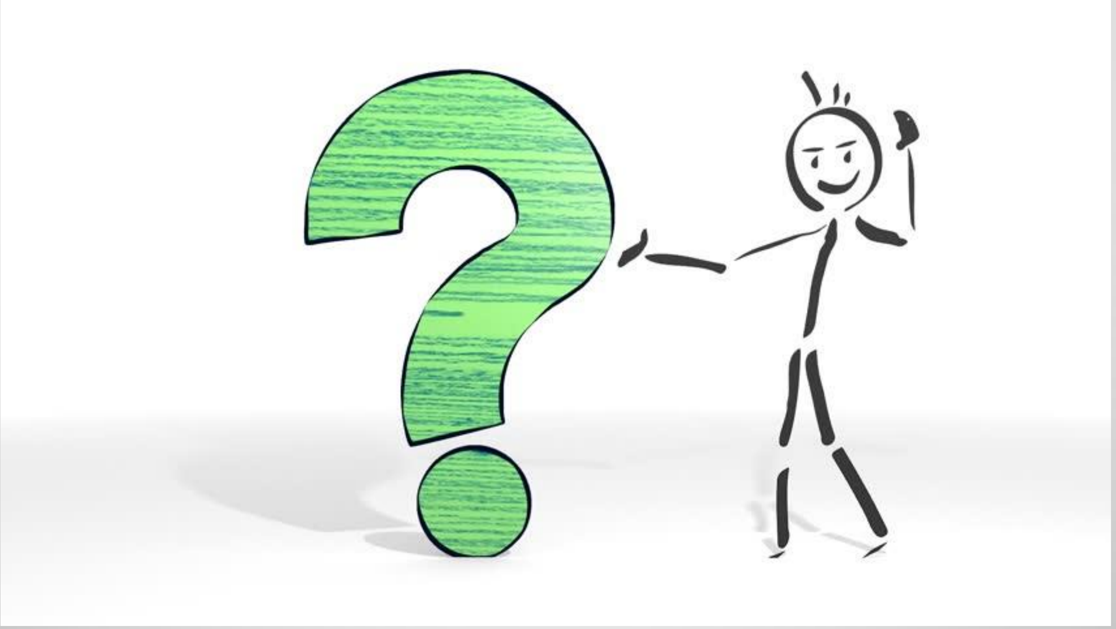
Do you agree with me?

Main Conclusion

I believe this proposed
"Universal Radiation Protection System Hypothesis"
is the stepping-stones in the promotion of a
"Global Standardized RP Approach"
for protection of workers, public
and the environment in 21st Century.

If not,

What do you think?
What are the disadvantages?



Please Tell me Frankly

Need to Brainstorming

URPS philosophy, concept and methodology are hoped to ignite more thoughts and ideas through braining storming, feedbacks, supports, etc. towards protecting workers and public against harmful effects of ionizing radiation

Thank You