Radiation Safety Instructions

https://www.iph.uni-mainz.de/intern/arbeitssicherheit/strahlenschutz/

Karl Geib, Peter Blümler

Physics, University Mainz

Radiation Safety Regulations

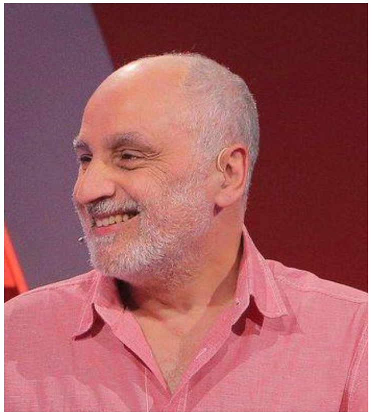
- Defines the legal framework for the purchase, storage, handling and disposal of radioactive substances (natural or artificial)
- Regulates the operation of instrumentation which generates ionizing radiation >5keV (electrons ≥ 1MeV)
- Photons in the range from 5keV-1MeV are covered by the regulations for X-rays
- Defines precautions for working with or in the vicinity of radioactive sources
- Sets the rules for transportation of radioactive sources

- Aim: Protection of humans and nature from any harm by ionizing radiation

Responsibilities

- The person which is legally responsible in terms of radiation safety is the owner of the installations. In our case ultimately the president of the university
- S/he forwards this responsibility to the radiation safety officers of the local installations to ensure working safety

Karl Geib
Room 04-217
Build. 2.412
fon. 39-23660
karl.geib@uni-mainz.de



Peter Blümler
Room 02-325
Build. 2.413
fon.: 39-24240
bluemler@uni-mainz.de

Radioactivity

	penetration in air
– γ-radiation	many meters
– ß-radiation (electron or positrons)	3 meters (E = 1MeV)
– α-radiation (He-nuclei)	6 cm (E = 5MeV)
– neutrons from nuclear fissions	many meters

– cosmic radiation (mainly muons)

- Artificially generated radiation
  - gammas (e.g. bremsstrahlung from electrons)
  - charged particles from accelerators
  - particles originating from secondary processes (neutrons, protons, α-particles, pions, muons …)

Units

- activity: decays per second
  - Unit: Bequerel: 1Bq = 1 decay/s
- Deposition of energy per kg: $D = \Delta E/\Delta m$ ➡ energy dose
  - Unit: Gray: Gy = J/kg

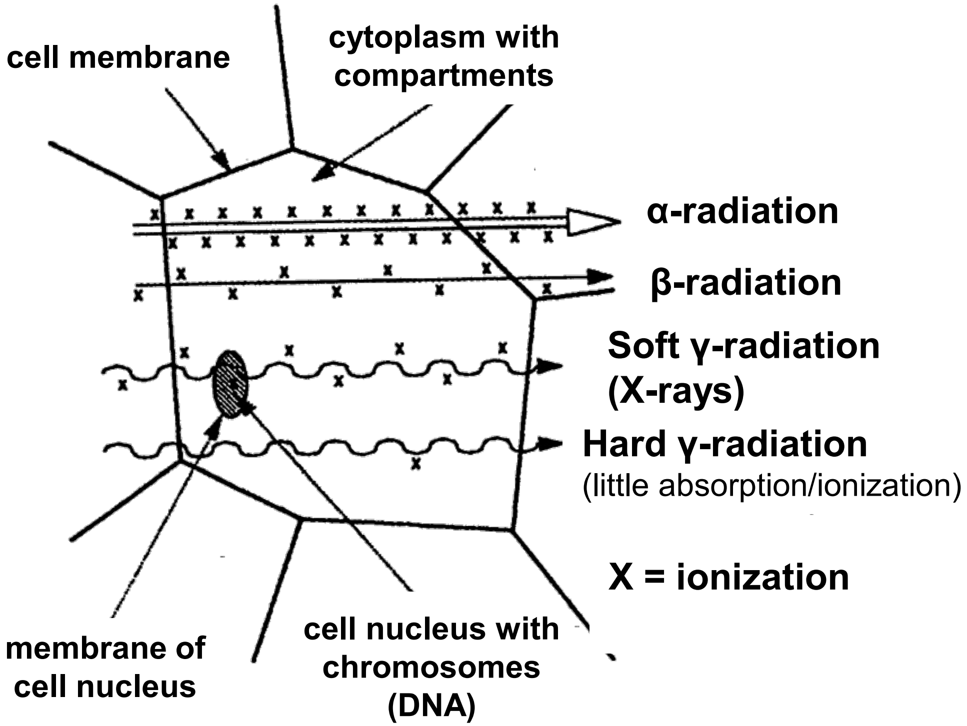
- equivalent dose $H = w_R \cdot D$ takes biological effects into account
  - Unit: Sievert: Sv = J/kg
  - Weighting factors (quality factor, QF)

type of radiation	**energy(MeV)**	**keV/µm**	**QF**
α-particles	5	90	20
fast neutrons	6	20	10
protons	2	17	10
X-rays	0.2	2.5	1
^{60}Co	1.25	0.3	1
β-radiation	2	0.3	1

effects of ionizing radiation

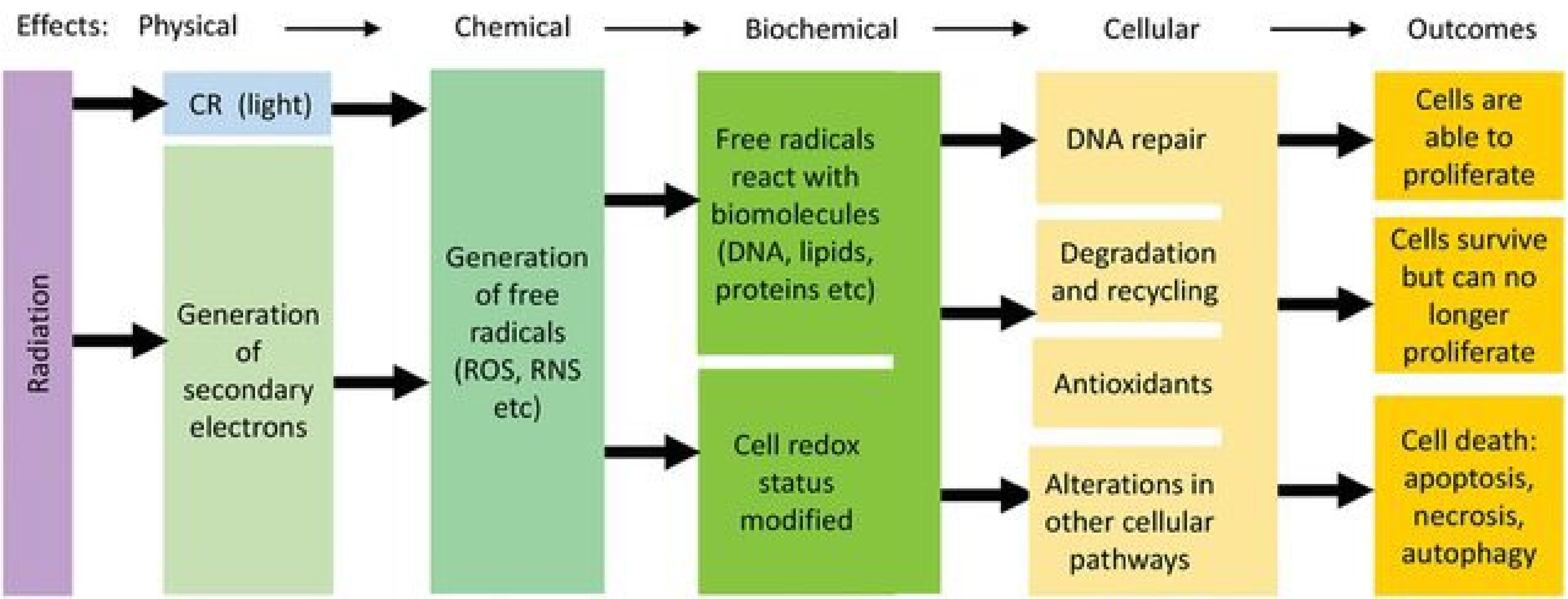
Direct effects:

- transfer of high energy (excitation) to molecules (mainly water) resulting in direct dissozation
- proteins, polysaccharides, fatty acids are quite resistant, or will be quickly metabolized and replaced
- Higher risk: nucleic acids, but efficient repair mechanicsm exist



ca. 10^{14} pairs of ions due to exposition to abundant radiation per year and kg body mass

Biological effects – damages

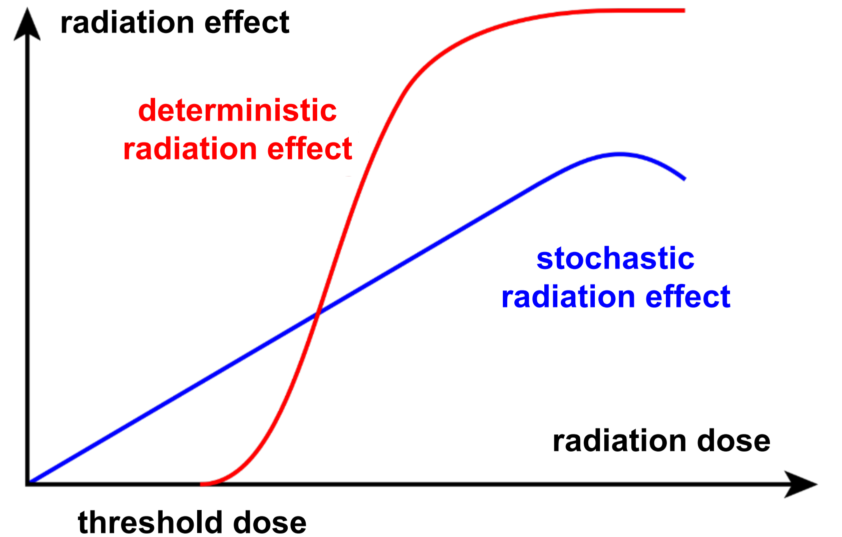


radiation damage

Stochastic damage (e.g. tumors)

Random damages (e.g. mutations).
Height of dose doesn't influence the severity but likelihood of the damage.

There is no threshold dose!



Deterministic damage

- **Individual threshold** up to which there are no long-term radiation damages
- Below the threshold (ca. 0.5 Sv): repair mechanisms in the cells prevent damage, no directly observable effects.
- Beyond the threshold biological damages/effects increase proportional to dose.
  E.g. radiation disease (most sensitive: skin, hair, colon)

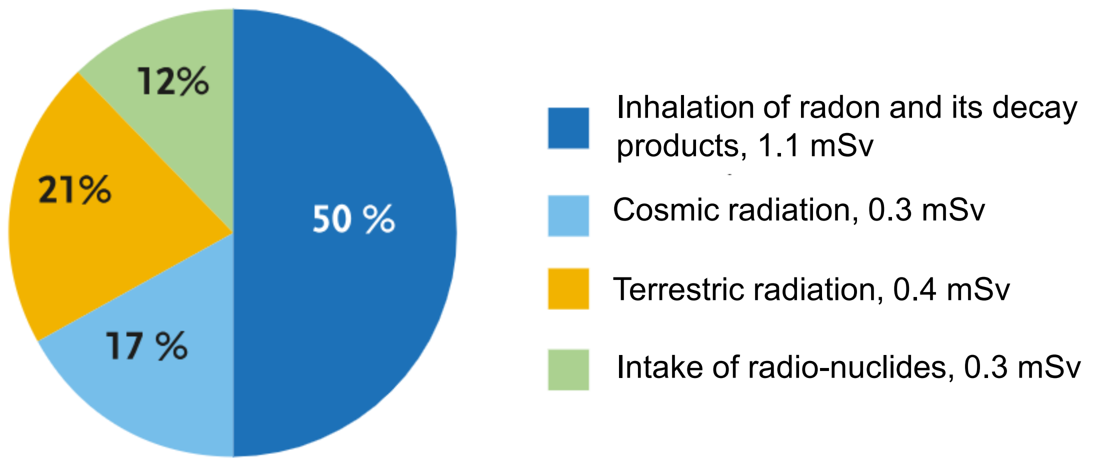
Typical values and damages

RADIATION DOSES Millisieverts (mSv)

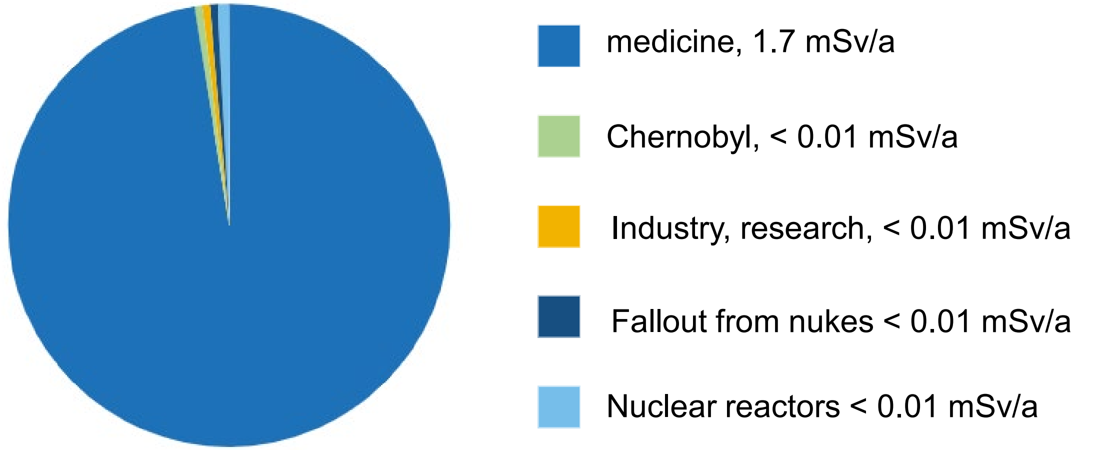
10,000	Acute radiation poisoning – death within weeks
6,000	Typical dose received by Chernobyl nuclear plant workers who died within one month of accident
3,000	Survival rate approximately 50 percent
2,200	Reading found near tanks used to store radioactive water at Fukushima plant, Sep 3, 2013
1,000	Causes radiation sickness and nausea, but not death. Likely to cause fatal cancer many years later in about 5 of every 100 persons exposed
700	Vomiting, hair loss within 2-3 weeks
500	Allowable short-term dose for emergency workers taking life-saving actions
400 per hour	Peak radiation level recorded inside Fukushima plant four days after accident
350 per lifetime	Exposure level used as criterion for relocating residents after Chernobyl accident
250	Allowable short-term dose for workers controlling 2011 Fukushima accident
100	Lowest level linked to increased cancer risk
20 per year	Average limit for nuclear industry workers
10	Full-body CT scan
2.4 per year	Person's typical exposure to background radiation
0.01	Dental x-ray

radiation exposure (Germany)

exposure of the German population by **natural** radiation sources



and such from **civilisation**



Long-Term Effects

Most frequent long-term effects due to

Local exposure:

- Cataract cloudy areas in the lens due to disturbed cell division
- skin damage pigmentation, ulcers, cancerous degeneration

Whole body exposure:

- Tumors in every organ possible (different probabilities for each organ and individuum)

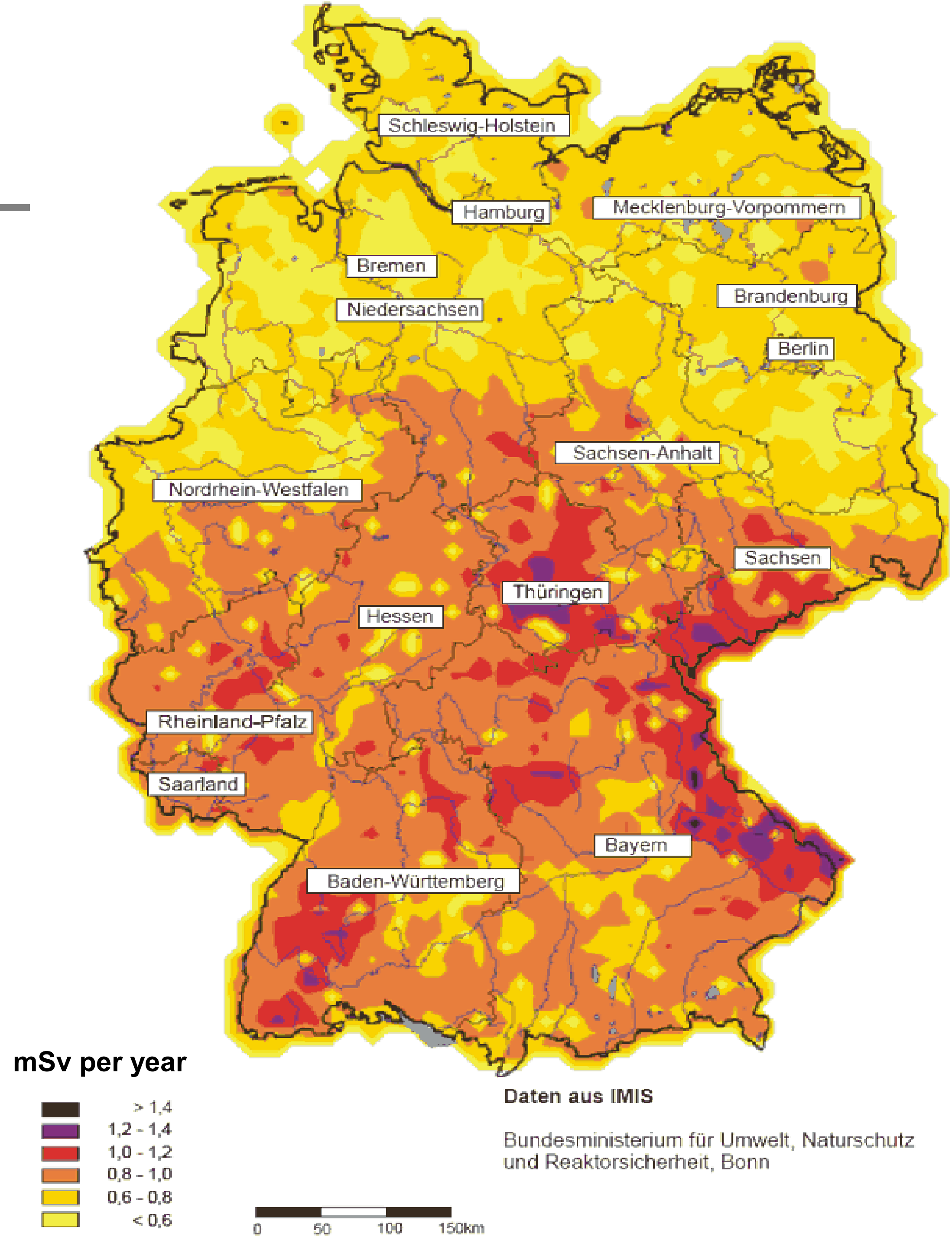
Duration: 10-15 years for leucemia and 25 – 40 years for skin cancer

5% additional risk for cancer per Sv

(has to be added to the general 20% risk)

Type of cancer	Risk coeff. [% per Sv]	Lethal percentage [%]
stomach	1.1	90
liver	0.15	95
lung	0.85	95
Bone marrow/leucemia	0.5	99
thyroid	0.08	10
mamma	0.2	50
skin	0.02	0.2
Total additional risk	**5**	**80**

Abundant terrestric radiation



Terrestrial Radiation

Soil content of natural radio-nucleids

nuclide (half life)	Concen-tration	Type of soil: granite	loam	lime	sand
Ra226 ($1.6 \cdot 10^3$ a)	µg/t (ppb)	1.7	1.3	0.44	0.15
Th232 ($1.4 \cdot 10^{10}$ a)	g/t (ppm)	18	12	1.1	1.7
K40 ($1.3 \cdot 10^9$ a)	g/t (ppm)	3.8	1.7	0.2	0.6

- Natural radiation on earth varies tremendously!
- In Germany: high in Black Forest and Ore Mountain areas (former uranium mining)
- Lowest in northern Germany (sandy sediments)
- Main radiation burden from U-238 decay chain: mainly radon-gas in cellars

Terrestrial radiation (natural background) dose rate in various regions

Region	Inhabitants [million]	Dose rate [mSv/a] average	Dose rate [mSv/a] maximum
Germany	80	0-5	5
France (granite regions)	7	2.5	4
France „hot spot“	0	--	900
Brazil, atlantic coast	0.04	8	170
Brazil, Poce de Caldas	0	--	250
Iran, Ramsar	0.002	6	260

Influence of construction materials on dose rates in buildings

Construction material	**add. exposition [µSv/a]**
wood	0
lime-, sandstone	0-100
bricks, concrete	100-200
natural stone, glass	200-400
slag bricks, granite	400-2000

Occupational radiation safety

Labeling / signs

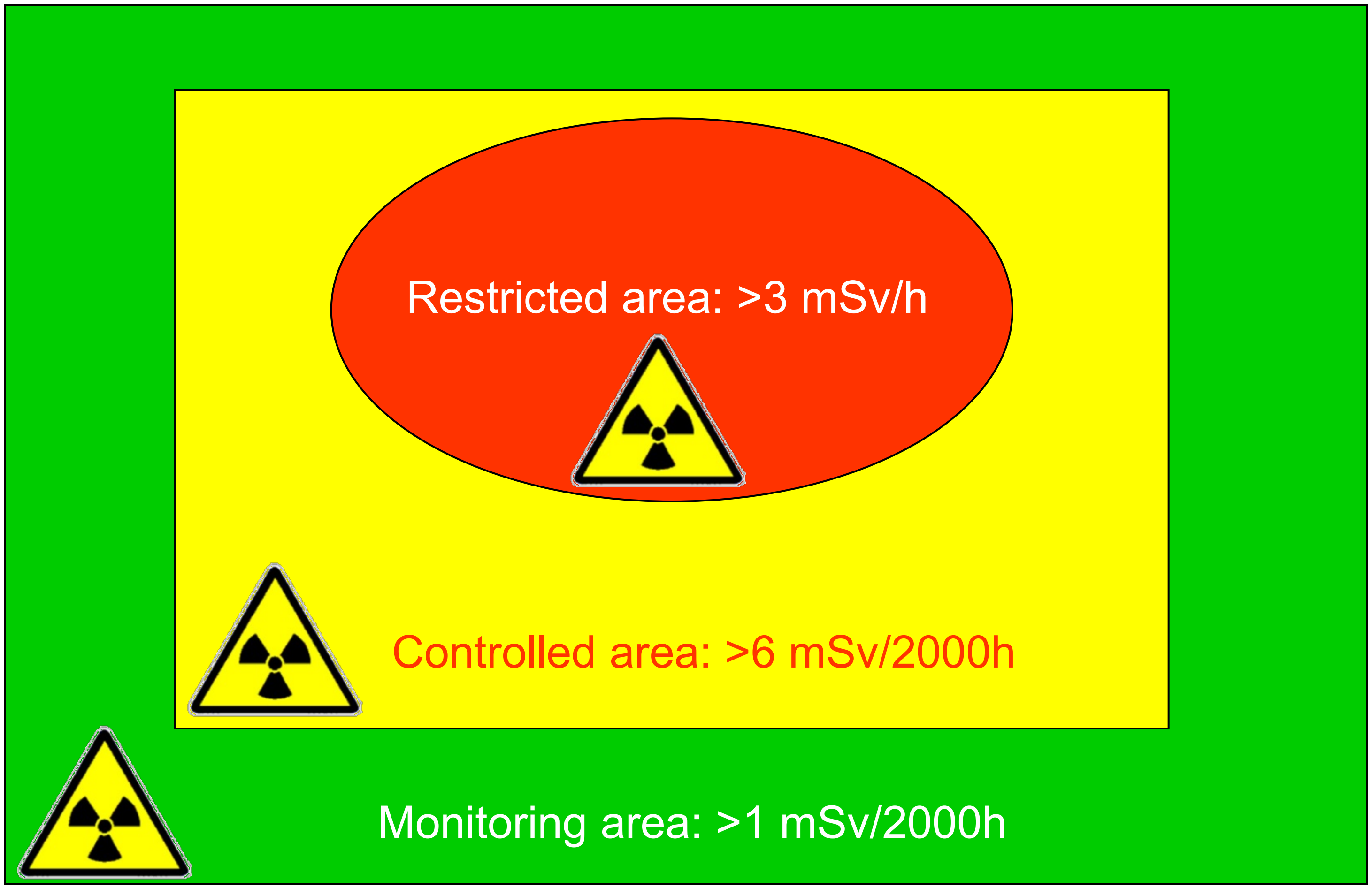
- Radiation safety regulation
  - Label source
  - Label rooms / instruments
  - Never dump these labels in the yunk!

- X-ray
  (no specific sign!)

Röntgenstrahlung – kein Zutritt

X-rays – no admittance

Radiation safety areas



Abundance: <1 mSv/a

Guidelines for handling radioactive substances

All rooms in which radioactive substances (or other source of ionizing radiation) are permanently or occasionally handled or stored IMPERATIVELY need a **HANDING PERMISSION** (gr. *„Umgangsgenehmigung*“**)** and **IDENTIFICATION!** (labelling via the radiation safety officer)

- The Handling Permission details how to work with the present sources
- Eating, drinking and smoking are generally not permitted!!
- Before you work with radioactive sources: **THINK!**

“4S-rules”:

- **SPACE** (distance) to source as big as possible
- Duration of **STAY** in its vicinity as short as possible
- **STRENGTH** (activity) of the source as weak as possible
- **SHIELDING** of source as thick as necessary

Guidelines for handling OPEN radioactive substances

- OPEN SOURCE (CONTAMINATION!)
  - Arrange your working space in such a way that the risk of contamination is minimized (e.g. when working with liquids use a drip pan)
  - Use protective clothing and gloves
  - Any contamination must IMMEDIATELY be reported to the radiation safety officer!

IMPORTANT: Inform yourself about local conditions!

dose limits for human bodies

Body dose	Limit (mSv) / a	
	Personell professionally exposed	Personell not exposed due to job
effective dose (weighted average)	20	1
Organ specific dose (**OSD**): gonades, womb, red bone marrow	50	NA
OSD: eye lens	150*)	15
OSD: thyroid, bone surface	300	NA
OSD: extremities (hands, forearms, feet, ankle, skin)	500	50
OSD: colon, lung, stomach, bladder, liver, etc.	150	NA

Dosimetry

Surveillance via dosimeters is requested for persons who work in controlled areas (> 6 mSv, Cat A)

Dosimeters **must be worn** when handing radioactive sources

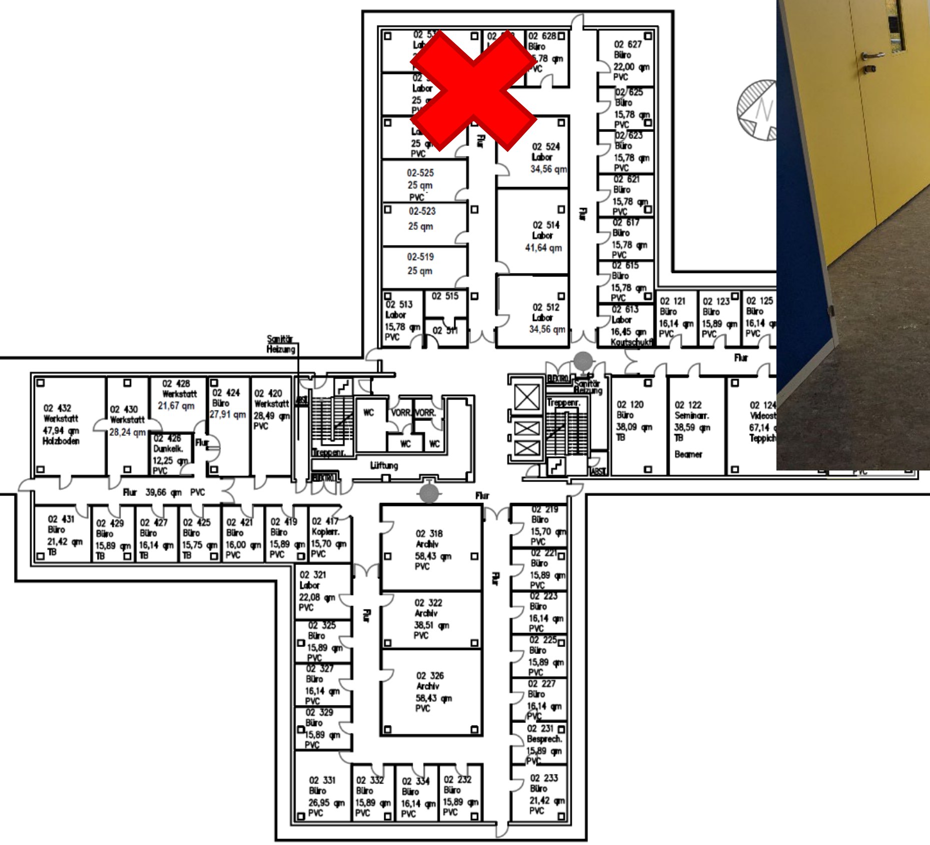
Film dosimeter
(β) γ x-ray

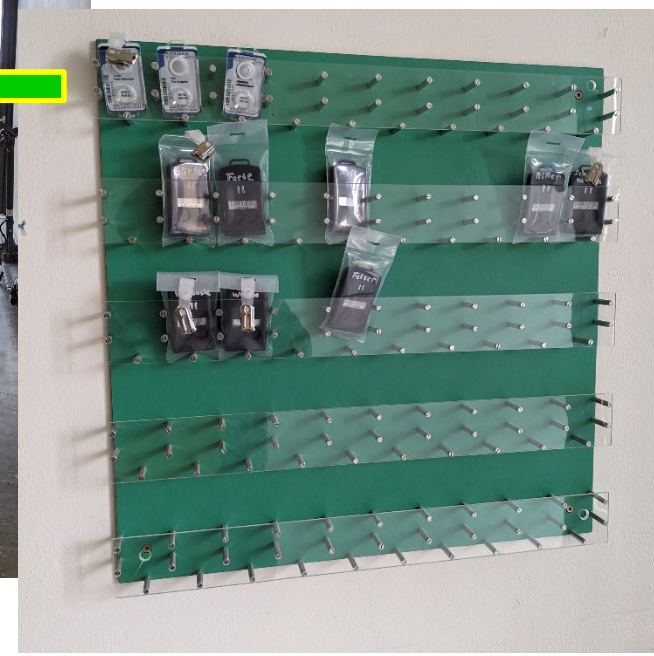
Albedo- (Thermoluminescence)
Dosimeter: n (β) γ x-ray
Neutrons > 0.5 eV

Special dosimeters
(finger, wristband, head)

Dosimeters in Physics

Buiding 2.412
2. Level (North wing)





Surveilance

…of every person who due to **professional activity** may exceed a **yearly dose of 1 mSv**

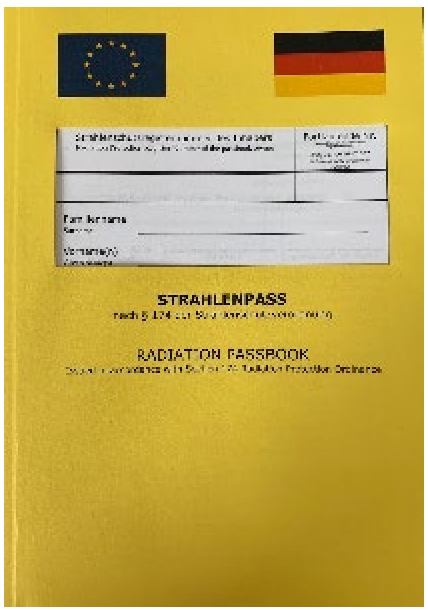
Category	A	B
Possible yearly dose	> 6 mSv	1 – 6 mSv
Occupational physical exam	yearly*	not mandatory, initial/aptitude exam*
Surveilance by dosimeters	yes	possibly

*paid by employer

Radiation Safety

- This instruction (yearly!)
- Surveilance (since 2019: SSR-No.)
  - Physical/medical exam (Hematolgy of Uni-clinics)
  - Radiation Passport: Documentation of exposure/dose in other places
  - Dosimeters (Control areas): monthly analysis
  - Instruments to measure dose (rates)
- Absolute limits of effective dose for persons who are occupationally exposed to radiation
  - 20 mSv/a (new 2019: also organ dose for eye lens)
  - 400 mSv during entire professional life
- Working prohibition
  - Persons younger than 18 years (exception: part of education)
  - Pregnant and breastfeeding women

Radiation passport



„New“ design (since 7/20)
old versions still valid

Needed for using external instrumentation with potential radiation exposition (e.g. BESSY, DESY, CERN, etc.)

Documentation of accumulated dose

Application via P. Blümler (ca. 1 month before). Instructions are on this website.

Purchase via secretary of research group

You need a SSR no.

SSR-No.

SSR = Strahlen**S**chutz**R**egistrier-Nummer

(**radiation protection registration number**)

Requested for owners of radiation passports and dosimeter surveilance.

Can be obtained via: https://ssr.bfs.de/ssr/

(there is an English version, you will need your German social security number)

You will receiver a certificate (PDF) please print and save (→email to P. Blümler)

Radiation safety at the Institute of Physics?

- Radioactive sources in research groups
  - For each source a HANDLING PERMISSION is requested for each room it is used in! The sources must be used in these rooms and nowhere else. Rooms and experiments must be LABELED.
  - Storage: a special lead safe or steel cabinet (for weaker). Source must be locked away when not in use!
  - Documentation on who used the source when (and where) → “Tresorbuch” (Safe logbook)
- Radioactive sources in student lab courses
  - Same restrictions and regulations!
- Purchase/disposal of radioactive materials must happen via the radiation safety officers (P. Blümler, Karl Geib)
- New or changes to handling permissions are organized via the radiation safety officers (P. Blümler, Karl Geib)

Confirmation of attendance

After watching the entire video, fill the answers to the following quiz (in the form on this webpage) and send/give it to the institute‘s secretary or directly to Peter Blümler (bluemler@uni-mainz.de.)

A correctly answered quiz allows you to work with radioactivity of another year.

If you have further questions do not hesitate to contact the radiation safety officers

QUIZ

a) Which units are used for the biological effective dose?
b) Which effective dose must not be exceeded per year due to your work with radioactive materials?
c) Name at least one radiation safety officer of the institute of physics?
d) Which radiation type has the highest weighting factor?
e) What is the 4S rule?
f) What should be never done with a label for radioactivity?
g) What must be fulfilled to use a radioactive sample in a certain room?