Dosimetry

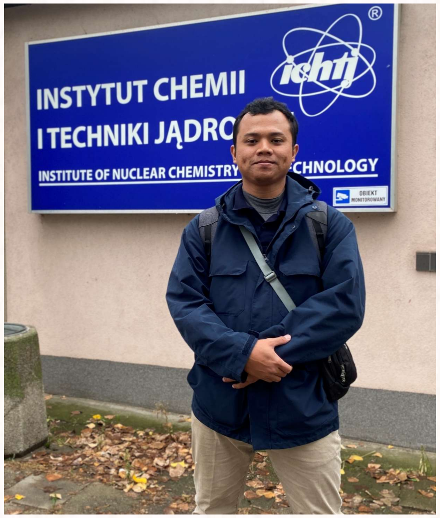
Okky Agassy Firmansyah
oafirmansyah@gmail.com
okky001@brin.go.id
+6281-210-698-624

Pelatihan Petugas Iradiator

Direktorat Pengembangan Kompetensi BRIN - 2025

Profile

- Nama: Okky Agassy Firmansyah S.T., M.Sc.
- Kota Kelahiran: Nganjuk
- Riwayat Pendidikan:
    - D3 Metrologi dan Instrumentasi, ITS Surabaya
    - S1 Teknik Fisika, ITS Surabaya
    - S2 Medical Physics, UST South Korea
    - S3 Ilmu Fisika, Universitas Indonesia (on-going)
- Bidang minat: **Metrologi Radiasi Pengion**
- Email: oafirmansyah@gmail.com
- Phone: 081210698624



- Pengalaman terkait Dosimetri
    - Staff Peneliti di Laboratorium Dosimetri Standar Sekunder (LDSS) BATAN (2018-2021)
    - Global Metrology Academy (GMA), Korea Research Institute of Standard and Science (2019)
    - Mahasiswa Peneliti di Laboratorium Dosimetri Standar Primer KRISS South Korea (2021-2023)
    - Fellowship Dosimetry Institute Nuclear Chemistry and Technology, Poland (2023)
    - Expert Mission program on High-dose rate, Florent Kuntz, Aerial France (2023)
    - Expert Mission program on High-dose rate, Marta Walo, INCT Poland(2023)
    - Expert Mission program on Puffin Monte Carlo modelling from PNNL US, Serpong (2024)

PELATIHAN PETUGAS IRADIATOR
PT Jayamas Medica Tbk, 10 - 21 Februari 2025

Waktu	Hari ke-1 10 Februari 2025	Hari ke-2 11 Februari 2025	Hari ke-3 12 Februari 2025	Hari ke-4 13 Februari 2025	Hari ke-5 14 Februari 2025
07.45 ~ 08.30	Pembukaan	Besaran dan Satuan Bisma Barron P	Dasar Proteksi Radiasi Mahrus	Manajemen Fasilitas Iradiasi ISO 11137 Bimo	Uji Kualifikasi Bimo
08.30 ~ 09.15	Tes Awal	sda	sda	sda	sda
09.15 ~ 09.30		*ISTIRAHAT*			*ISTIRAHAT*
09.30 ~ 10.15	Penjelasan Pelatihan Bimo	Pengukuran dan Pemantauan R[illegible] A[illegible]	sda	Teori Iradiator Taufik	sda
10.15 ~ 11.00	Peraturan Perundangan ketenaganukliran Mahrus Salam	sd[illegible]	Penanggulangan keadaan Darurat Afida	sda	Dasar-dasar Perawatan Agus Dwiatmaja (PRTA)
11.00 ~ 11.45	sda	sda	sda	Dosimetri Iradiasi Okky	sda
11.45 ~ 12.45		*ISTIRAHAT*			*ISTIRAHAT*
12.45 ~ 13.30	Dasar Fisika Radiasi Nofriady Aziz	Efek Radiasi bagi Manusia Arie	Sistem Manajemen [illegible]daya ke[illegible] Mahrus	sda	sda
13.30 ~ 14.15	sda	sda	sda	sda	Manajemen Perawatan Iradiator Saefurrochman
					ISTIRAHAT
14.30 ~ 15.15					sda
15.15 ~ 16.00					

Tujuan Pembelajaran

Hasil Belajar: peserta mampu menjelaskan mengenai sistem dosimetri

- **Indikator Hasil Belajar:**
  - mampu menjelaskan **teori dasar dosimetri.**
  - mampu menjelaskan **jenis dosimeter.**
  - mampu menjelaskan **sistem kalibrasi dosimeter.**

Scan QR dengan gadget Anda

Ayo interaktif!

https://www.menti.com/alhfnpkn4dax

Outline

1. Teori Dasar Dosimetri
2. Kalibrasi dan Ketertelusuran
3. Faktor-Faktor yang mempengaruhi pengukuran
4. Ketidakpastian pengukuran

Pertanyaan Pendahuluan?

1. What is Dosimetry?

as part of the total quality system - provides quality assurance and documentation, that the irradiation procedure has been carried out according to specifications

2. What type of dosimeter do you use?

Ion Chamber, Calorimeter, Alanine, B3 Film, PMMA Harwell, CTA Film, etc.

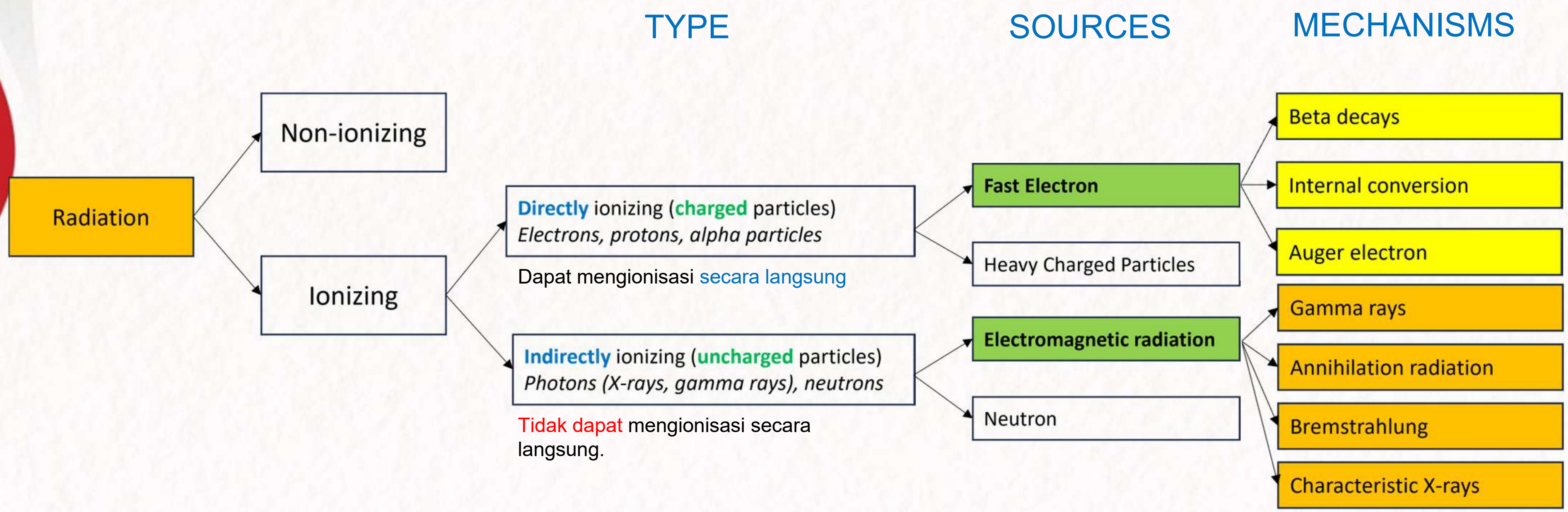
1	Ari Halimatus Z	PT Jayamas Medica Industri Tbk	Kimia/Petugas Dosimetri
2	Ismi Putri M	PT Jayamas Medica Industri Tbk	Elektronika Instrumentasi/Petugas Dosimetri
3	Iswatun Hasanah	PT Jayamas Medica Industri Tbk	Teknik Biomedik/Petugas Dosimetri
4	Aisyah Ayu R	PT Jayamas Medica Industri Tbk	Teknik Biomedis / Petugas Dosimetri
5	M. Fajar Bahari	PT Jayamas Medica Industri Tbk	Teknik Biomolekular/ Petugas Dosimetri

1 Fundamental Dosimetry (Penyegaran)

Kenapa penting?

Kita harus tau terlebih dahulu, besaran fisika apa yang hendak kita ukur? ➡ **Biar tidak salah ukur**

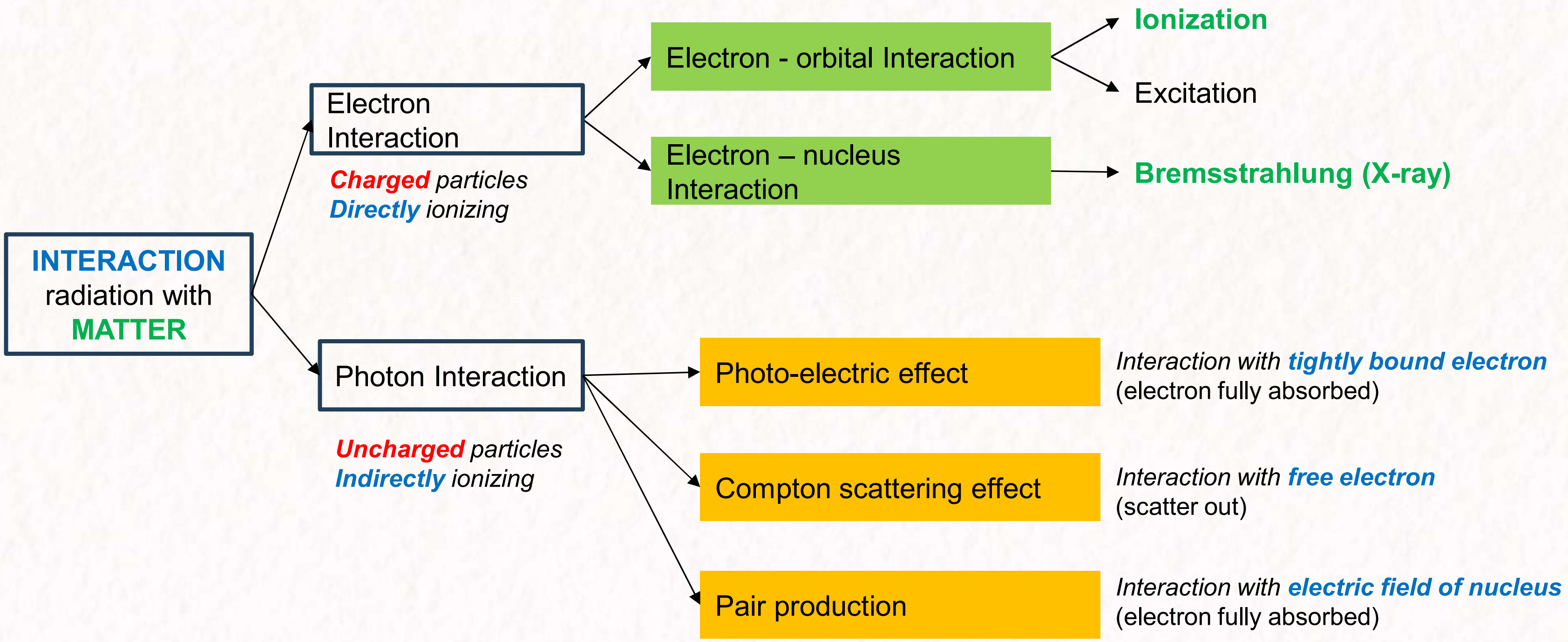
Jenis-jenis Berkas Radiasi



Berkas radiasi yang digunakan di level Industri

Berkas **elektron**	Digenerasi oleh **Mesin berkas elektron** (MBE)
Sinar **Gamma**	**Radionuklida** Cobalt-60
Sinar-**X**	MBE dengan tambahan **konverter**

Interaksi Radiasi dengan Materi



Alur Transfer Energi

Through several mechanisms

1. Photo-electric
2. Compton scattering
3. Pair production

Create

Uncharged Particles → Charged Particles

Gamma
X-ray

Electron

Energy deposited in any medium

Through several interaction

1. Mass-collisional stopping power
2. Mass-radiative stopping power

Measurand:

ABSORBED DOSE

High **atomic number**, high-**density materials** will consequently result in the greatest linear stopping power

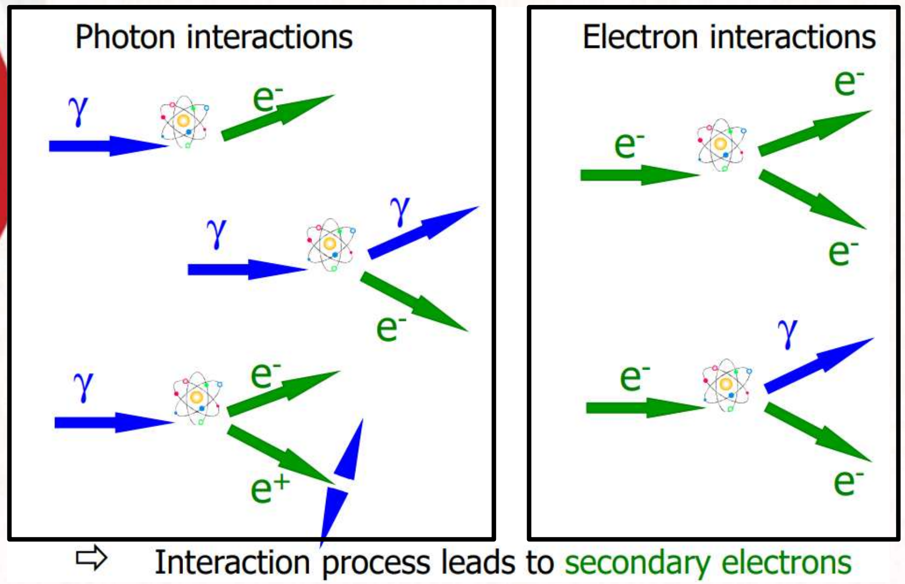
Dose D in the medium:

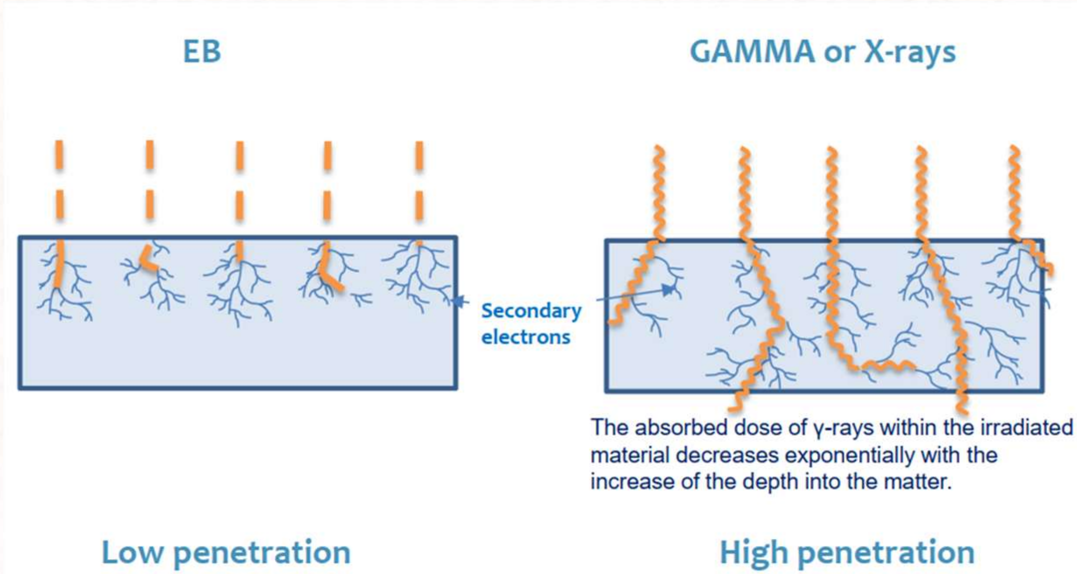
$$D = \phi(S/\rho)_{col}$$

Φ = fluence

The type of material is **IMPORTANT!**

Interaksi Radiasi dengan Materi





Yang berkontribusi terhadap dosis adalah **Charged Particles.**

Kerma vs Absorbed Dose

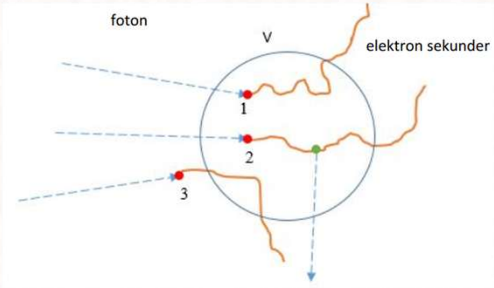
The unit is joule per kilogram (J/kg)
Name: **Gray (Gy)**

KERMA (*kinetic energy release per unit mass*)

Average amount of energy **TRANSFERRED** from the indirectly ionizing radiation to directly ionizing radiation ***without concerns*** to what happens after this transfer.

$$K = \frac{d\bar{E}_{tr}}{d_m}$$

Energy transfer (energy yang ditransfer)

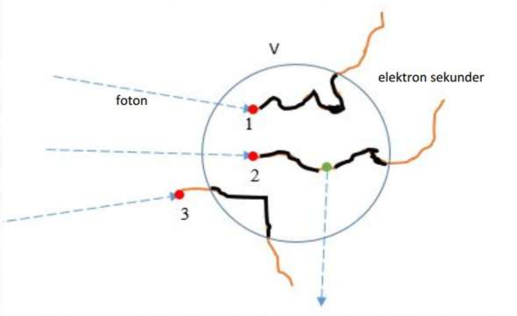


ABSORBED DOSE

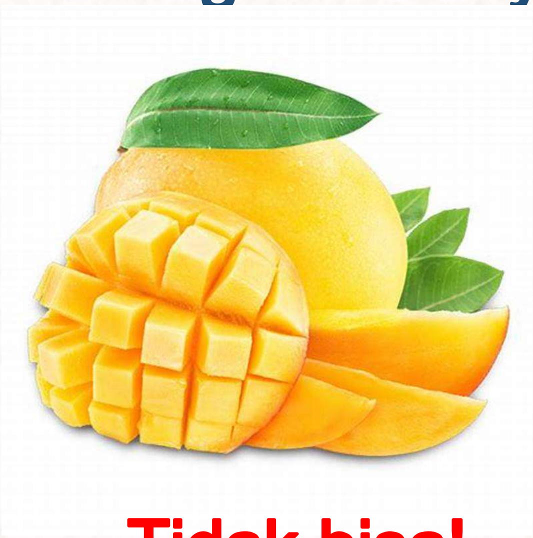
The absorbed dose is defined as the mean energy **IMPARTED** by ionizing radiation to matter of mass *m* in a finite volume *V*

$$D = \frac{d\bar{\varepsilon}}{d_m}$$

Energy imparted (energy ter-serap)



Apakah dosis pada objek yang diiradiasi dapat diketahui dengan survey meter?



Tidak bisa!

Kerma vs Absorbed Dose

KERMA (*kinetic energy release per unit mass*)

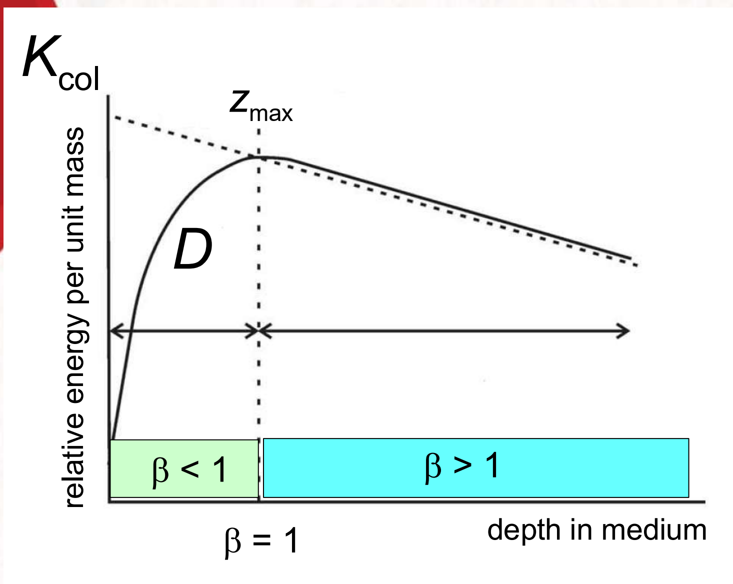
1. Average amount of energy **TRANSFERRED**
2. Transfer energy from **UNCHARGED PARTICLES** to charged particles by KERMA collision
3. Characterized by **mass-energy TRANSFER** coefficient and
4. using **ENERGY FLUENCE** Ψ
5. The matter of **SENDER**

ABSORBED DOSE

1. Average amount of energy **ABSORBED**
2. Energy loss by **CHARGED PARTICLES** by collision interaction
3. Characterized by **STOPPING POWER** and
4. Using **PARTICLE FLUENCE** Φ
5. The matter of **RECEIVER**

Kerma vs Absorbed Dose

Grafik Percentage Depth Dose (PDD) –
Distribusi Dosis di kedalaman sebuah materi

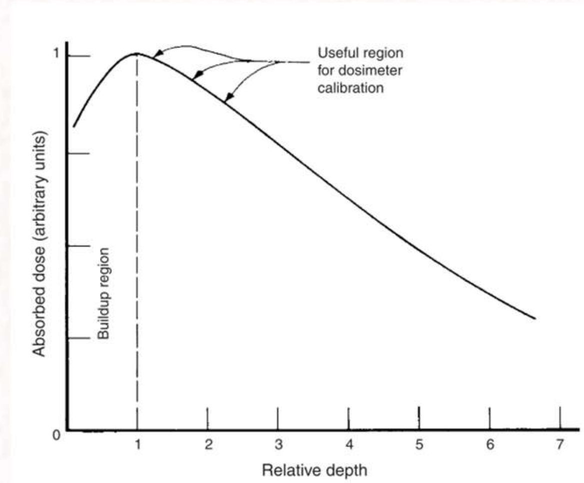


Radiation Oncology Physics: A Handbook for Teachers and Students. Podgorsak, Ervin B. (2004)

In the buildup region:
$\beta < 1$

In the region of a transient charged particle equilibrium:
$\beta > 1$

At the depth $z = z_{max}$, a true charged particle equilibrium exists.
$\beta = 1$

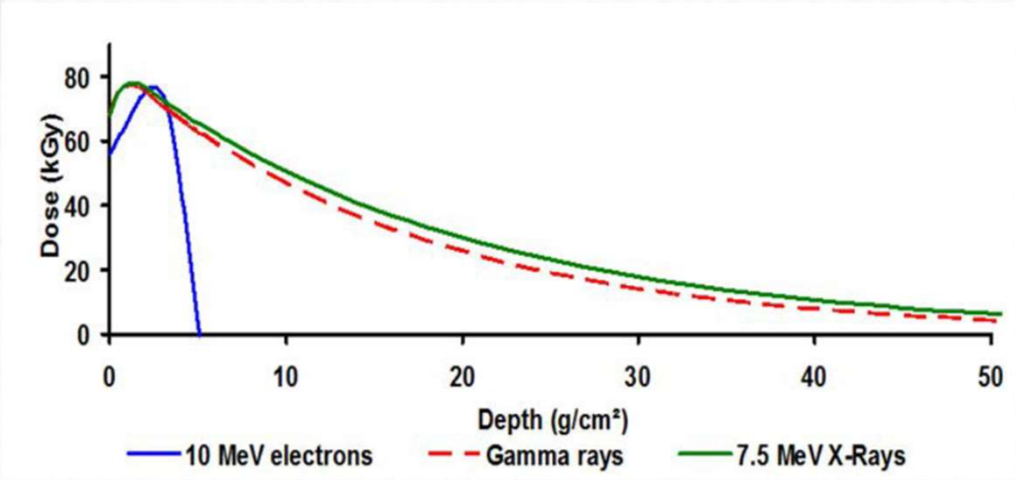


^{137}Cs γ rays (E_γ = 0.66 MeV)	3 mm of water (= 0.3 g/cm^2, 3 kg/m^2)
^{60}Co γ rays ($E_\gamma \approx$ 1.25 MeV)[5]	5 mm of water (= 0.5 g/cm^2, 5 kg/m^2)
4 MeV X rays	10 mm of water (= 1.0 g/cm^2, 10 kg/m^2)
6 MeV X rays	16 mm of water (= 1.6 g/cm^2, 16 kg/m^2)
10 MeV X rays	30 mm of water (= 3.0 g/cm^2, 30 kg/m^2)

IAEA TRS No. 409: Dosimetry for Food Irradiation (IAEA, 2002)

Note:
1. Kalibrasi **HARUS** dilakukan di daerah **CPE**
2. Dosis MAKSIMUM tidak terletak di PERMUKAAN

Kerma vs Absorbed Dose



IAEA TRS No. 481 Manual of good practice in food irradiation: sanitary, phytosanitary and other applications

- Bahwa masing-masing modalitas iradiasi memiliki **karakterisasi depth dose** yang berbeda.
- **Mass density** dari material akan mempengaruhi dari distribusi dosis di kedalaman
- Hubungannya adalah **estimasi dosis** untuk treatment/proses iradiasi yang akan kita lakukan

Pit Stop

- Apa perbedaan mendasar antara Kerma dan Absorbed Dose?

2 Kalibrasi dan Ketertelusuran

Guidance for Dosimetry

- ISO/ASTM 51702:2013 Practice for dosimetry in a gamma facility for radiation processing
- ISO/ASTM 51649:2015 Practice for dosimetry in an electron beam facility for radiation processing at energies between 300 keV and 25 MeV
- ISO/ASTM 51261:2013 Practice for calibration of routine dosimetry systems for radiation processing
- ISO/ASTM 51707:2015 Guide for estimation of measurement uncertainty in dosimetry for radiation processing
- IAEA TRS No. 409: Dosimetry for Food Irradiation
- IAEA TRS No. 481 Manual of good practice in food irradiation: sanitary, phytosanitary and other applications
- Guidelines for the Calibration of Routine Dosimetry Systems for use in Radiation Processing. NPL. 2009

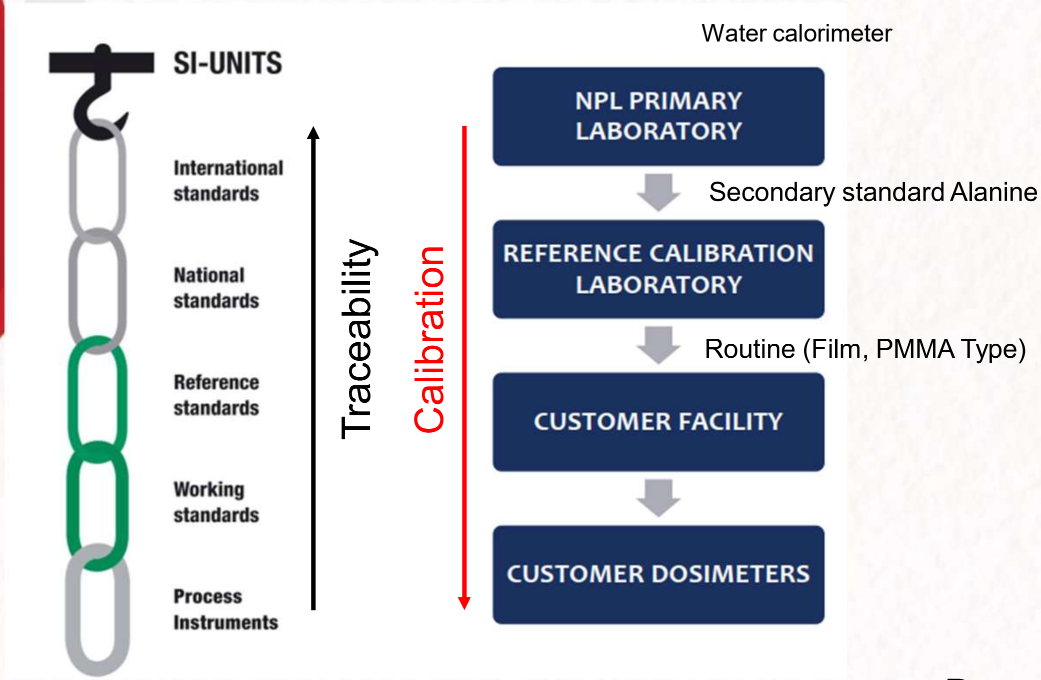
What is important about dosimetry

- Calibration
- Traceability
- Uncertainty Measurement
- Selection Criteria
- Influence Factor

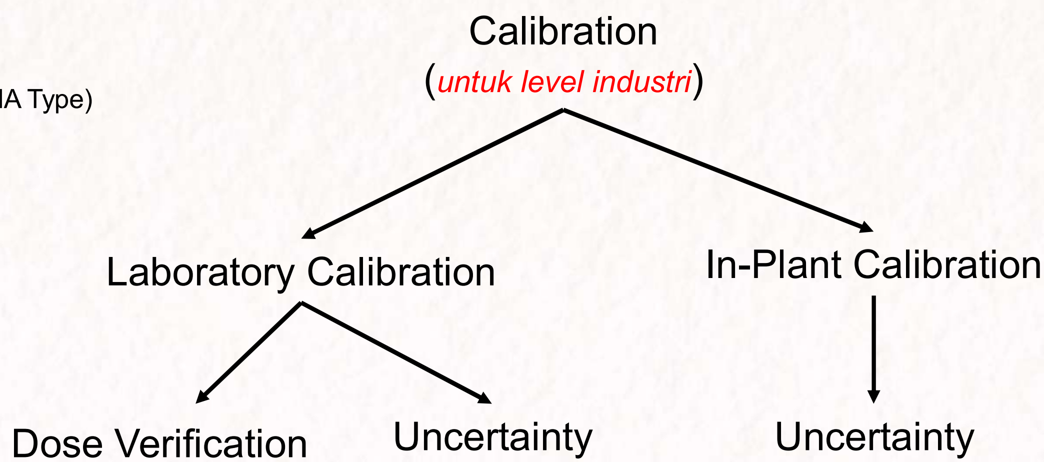
IMPORTANT References!

- ISO/ASTM 51261:2013 Practice for calibration of routine dosimetry systems for radiation processing
- ISO/ASTM 51707:2015 Guide for estimation of measurement uncertainty in dosimetry for radiation processing
- CIRM 2009 NPL Guidelines for the Calibration of Routine Dosimetry Systems for use in Radiation Processing

Calibration



ISO/ASTM 51261:2013
Calibration (3.1.2) Establishes, under specified conditions, the relationship between the value of a quantity by a measurement system or the value through a reference material



Note:

1. Di Indonesia **BELUM ADA** laboratorium kalibrasi untuk level industry (high-dose)
2. **BUKTI KALIBRASI** adalah sertifikat kalibrasi yang tercantum hasil kalibrasi dan ketidakpastian pengukurannya

Calibration

Reference (Primary and Secondary): standard systems (type I) used to calibrate dosimeters for routine use, therefore high metrological qualities, low uncertainty and traceability to appropriate national or international standards are needed.

Uc +/- 3 % (k = 2);

Routine systems: Used for routine absorbed dose measurements (i.e. dose mapping and process monitoring). Traceability to national or international standards is needed.

Uc +/- 5 % (k = 2);

Calibration

Laboratory Calibration
(***in-our-calibration laboratory***)

- ❑ Irradiation of dosimeters in the reference radiation field of a calibration laboratory (or of an in-house calibration facility) followed by "calibration verification" in the irradiation plant.

✓ Advantages
- easy to obtain full dose range;
- irradiation to accurately known doses under controlled and documented conditions;

✓ Disadvantages:
- different conditions from real use (uncertainties);
- transport of dosimeters (pre- and post-irradiation storage effects - uncertainties);

In-Plant Calibration
(***in-your-plant***)

- ❑ Routine dosimeters are irradiated together with reference or transfer standard dosimeters in "calibration phantoms" in the irradiation plant.

✓ Advantages
- calibration and production conditions are similar (environmental conditions);

✓ Disadvantages:
- difficult to obtain full dose range in certain plants;
- Use thermos label

✓ Care must be taken:
- to ensure that all dosimeters irradiated together receive the same absorbed dose;

Calibration

	Laboratory Calibration (in-our-calibration laboratory)	In-Plant Calibration (in-your-plant)
Pengiriman ke fasilitas user di awal	N/A	Yes
Iradiasi	Dikerjakan di laboratorium standar	Dosimeter dari lab. Standar diiradiasi Bersama dosimeter user di fasilitas user
Pembacaan Respon		Dosimeter user dibaca respon-nya di fasilitas user
Pembacaan Dosis		Dosimeter lab dibaca dosisnya di laboratorium standar
Pengiriman ke laboratorium standar	N/A	Yes
Pengiriman ke fasilitas user di akhir	Yes	N/A

Alanine dosimeter sebagai dosimeter transfer

B3 film dosimeter

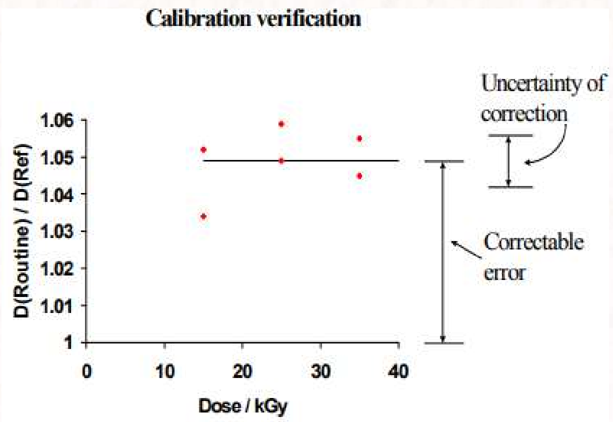
Verification Dose

Why need calibration verification

1. Perbedaan kondisi lingkungan (suhu, laju dosis, dll.) antara iradiator kalibrasi dan pabrik industri dapat menyebabkan kesalahan sistematis.
2. Transportasi dosimeter antara iradiator kalibrasi dan pabrik industri juga dapat menimbulkan sumbangsih kesalahan.
3. Sumbangsih kesalahan ini dapat dideteksi dengan mengiradiasi dosimeter rutin bersama dosimeter referensi di pabrik industri – **Verifikasi Kalibrasi**.

Best practice

I. Iradiasi dosimeter rutin bersamaan dosimeter referensi di fasilitas user
II. Gunakan setidaknya tiga titik dosis dengan dua dosimeter referensi dan empat dosimeter rutin di setiap titik.
III. Tentukan perbedaan antara pembacaan dosis dari dosimeter rutin dan dosimeter referensi.
IV. Periksa hasil untuk melihat adanya perbedaan sistematis



Calibration

Determine relationship between response of a dosimeter and absorbed dose.

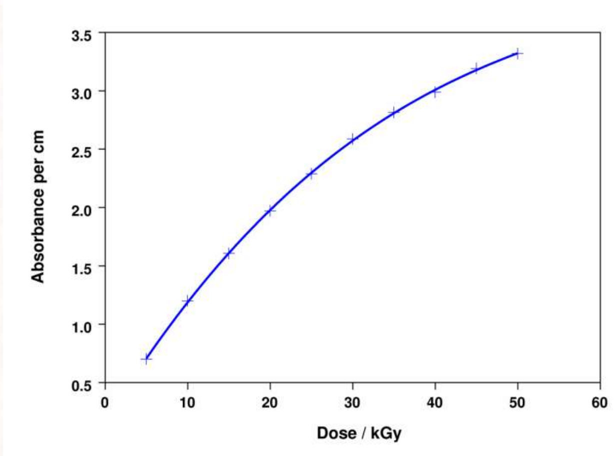
Influence factors:
- dose rate
- Temperature
- storage (time, conditions)
- Humidity
- light

The aim of the calibration is to ensure that dose measurements can be related to accepted standards.

through a series of known steps, each with a defined level of uncertainty, i.e. to ensure traceability.

Regulatory standards, such as ISO 11137, impose specific requirements:

"Dosimetry used in the development, validation and routine control of the sterilization process **shall have measurement traceability** to national or international standards and shall have a known level of uncertainty." (4.3.4)



Kurva kalibrasi:
Respon dosimeter (sumbu-Y)
Dosis (sumbu-X)

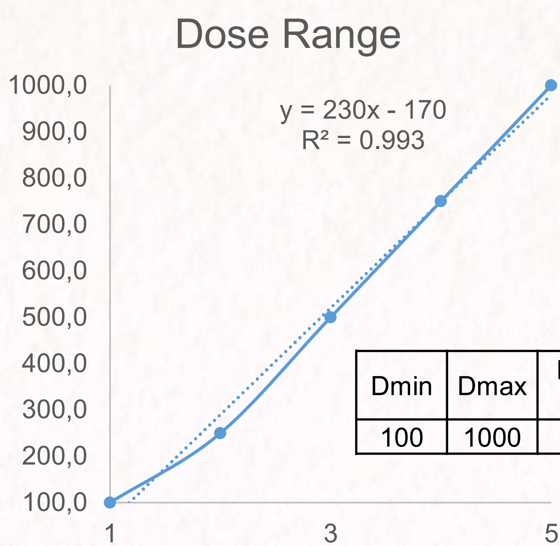
Best Practice!

DOSIS ITU TIDAK DIUKUR, NAMUN DIHITUNG.

Yang kita ukur adalah respon dosimeter

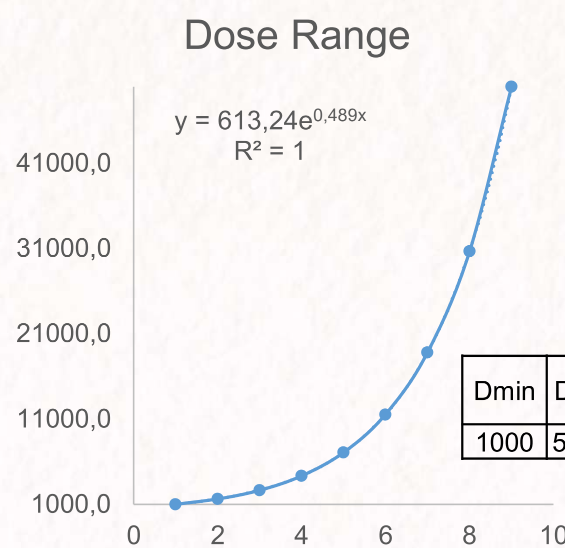
Calibration

Calibration over less than one decade of dose:
Use at least five dose points distributed arithmetically, e.g. 10, 20, 30, 40, 50 kGy.



Dmin	Dmax	Dmax/ Dmin	Log D	Log D x 5
100	1000	10	1	5

Calibration over more than one decade of dose:
Use at least five dose points per decade distributed geometrically e.g. 1, 1.5, 2.3, 3.4 …… 38, 58, 87 kGy.



Dmin	Dmax	Dmax/ Dmin	Log D	Log D x 5
1000	50000	50	1.69	8.5

Use at least four replicate dosimeters at each dose point.

Calibration

Kapan kita butuh? Saat kita sedang akan request titik dosis untuk dikalibrasi di Lab. Standar

Pemilihan antara **distribusi aritmetika** atau **geometrika** dapat dijustifikasi menggunakan hubungan logaritmik antara dosis maksimum D_{max} dan D_{min}.

$$\text{Jumlah Dekade} = \log_{10}\left(\frac{D_{max}}{D_{min}}\right)$$

✅ **Gunakan distribusi aritmetika jika**

$$\log_{10}\left(\frac{D_{max}}{D_{min}}\right) < 1$$

✅ **Gunakan distribusi geometrika jika**

$$\log_{10}\left(\frac{D_{max}}{D_{min}}\right) \geq 1$$

Kriteria	Distribusi Aritmetika	Distribusi Geometrika
Rentang dosis	Jika $D_{max}/D_{min} < 10$	Jika $D_{max}/D_{min} \geq 10$
Polanya	Selisih tetap antar dosis	Rasio tetap antar dosis
Respons sistem	Linier terhadap dosis	Eksponensial atau logaritmik terhadap dosis
Contoh	10, 20, 30, 40, 50 kGy	1, 1.5, 2.3, 3.4, 5.3, 8.3, 13, 20, 31, 50, 79 kGy

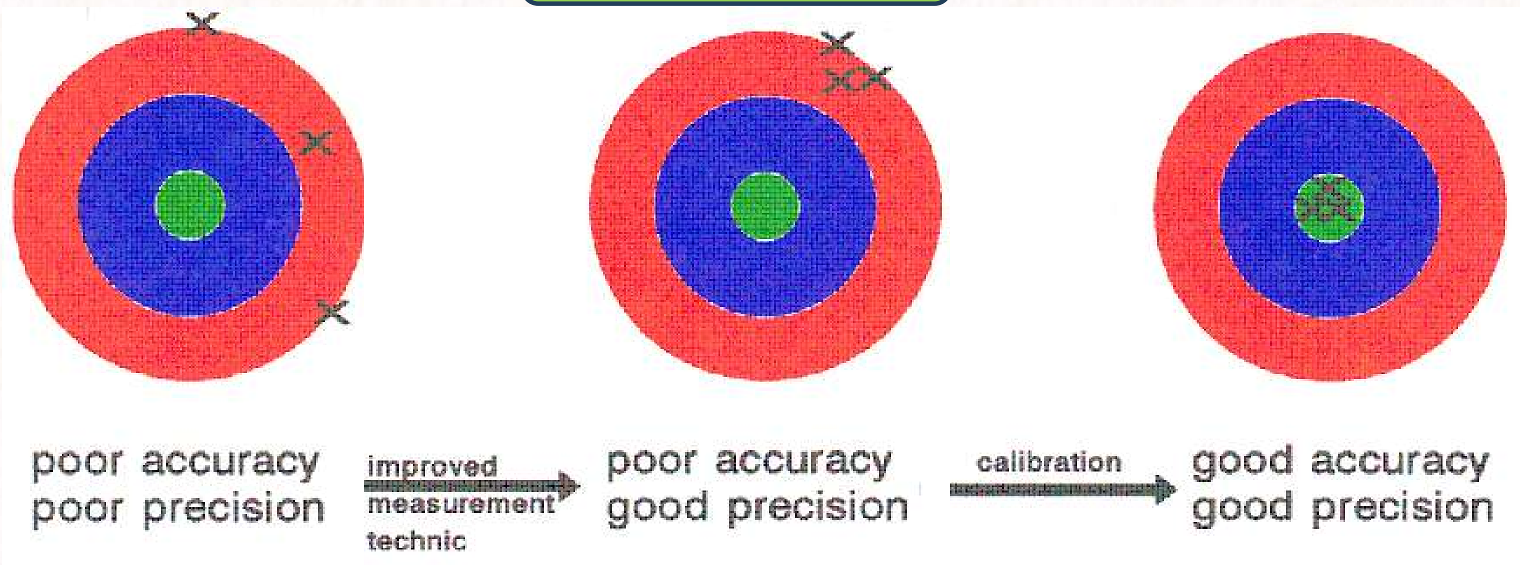
Pit Stop

- Apakah kalibrasi bisa dilakukan oleh internal?
- Sebutkan perbedaan kalibrasi in-plant dan in-lab?
- Apa bukti sudah dilakukan kalibrasi?

3 Faktor-Faktor yang mempengaruhi pengukuran

Influence Factor

Accurate vs Precision



- ACCURATE – Near the true value/ reference value
- PRECISION – Good repeatibilty (**standard deviation/square root of number of measurements)**

Influence Factor

Equipment

- ❑ All measurement equipment must be calibrated and be traceable to national standards, include equipment. E.g. spectrophotometer
- ❑ Certain measurement equipment cannot be calibrated (e.g. signal amplitude from an EPR spectrometer) therefore
- ❑ The stability of the equipment has to be demonstrated by the use of measurement standards (e.g. stable EPR spin standards).

- Spectrophotometer:
  absorbance and wavelength scale with calibrated optical filters;
- Thickness gauge:
  calibrated gauge blocks;
- Thermometers:
  calibrated thermometers;
- Resistance measurement (Ohm-meter for calorimeters):
  calibrated reference resistor;
- Humidity meters:
  saturated salt solutions;

Influence Factor

Dose measurements depend on various methods:

- Temperature increase (calorimeters);
- Colour change (perspex, radiochromic systems);
- Free radical concentration (alanine);
- Conductivity change (ECB, alanine solution);
- Radiation chemical oxidation (Fricke);
- Radiation chemical reduction (dichromate, ceric-cerous);
- Optically stimulated luminescence (Sunna);

Influence Factor

- Irradiation conditions are different from calibration conditions:

Temperature, dose rate, relative humidity, energy spectrum, irradiation geometry, etc.

- Storage conditions:

before and after irradiation; (apakah ada *dry cabinet* di fasilitas?)

- Instrumental errors:

absorbance and wavelength scale, scattered light, transfer of calibration curve from one instrument to another one, etc. (apakah instrument disimpan pada ruang dengan suhu yang dijaga di fasilitas?)

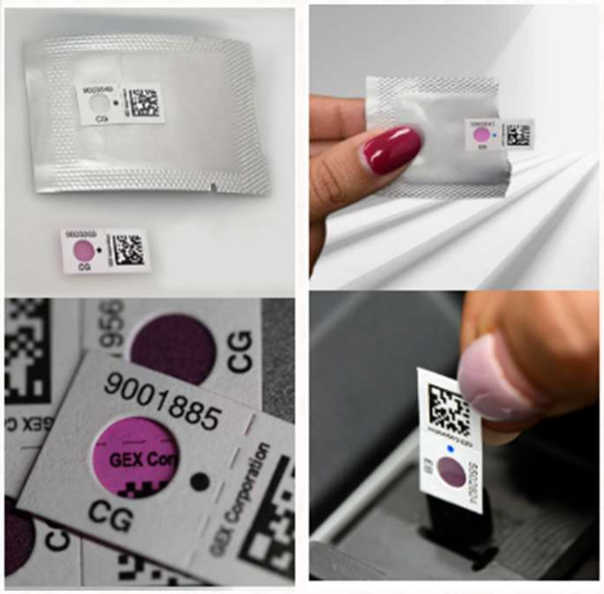
Influence Factor

Dosimeter system	Method of analysis	Dose Range	References
Fricke solution	UV – spectro-photometry	40 Gy – 400 Gy	ASTM E 1026 - 04
Ethanol-mono-chlorobenzene	Titration,or HF oscillometry	400 Gy – 80 kGy	ISO/ASTM 51538
Alanine	EPR	1 Gy – 100 kGy	ISO/ASTM 51607
Perspex systems	VIS - spectro-photometry	5 kGy – 50 kGy	ISO/ASTM 51276
FWT – 60 film	VIS - spectro-photometry	0.5 kGy – 200 kGy	ISO/ASTM 51275
B3 film	VIS - spectro-photometry	3 kGy – 100 kGy (1 kGy by GEX)	ISO/ASTM 51275
Cellulose triacetate	UV – spectro-photometry	10 kGy – 300 kGy	ISO/ASTM 51650
Calorimetry	Resistance/ temperature	1.5 kGy – 50 kGy	ISO/ASTM 51631

Influence Factor

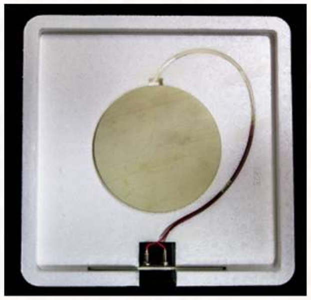
Dosimeter	Measurement time after irr.	Humidity	Irradiation temp. coeff., $(^{o}C)^{-1}$
Alanine	24 hours	yes	+ 0.25 %
Dichromate	24 hours	no	- 0.2 %
Ceric-cerous	immediately	no	conc. dep.
ECB	immediately	no	+ 0.05 %
Calorimeters	immediately	no	-
Perspex	24 hours	yes	+ 1 %
FWT-60	5 min/60 ^{o}C	yes	+ 0.2 %
B3	15 min/60 ^{o}C	yes	+ 0.3 %
Sunna	20 min/70 ^{o}C	no	+ 0.2 %

Influence Factor

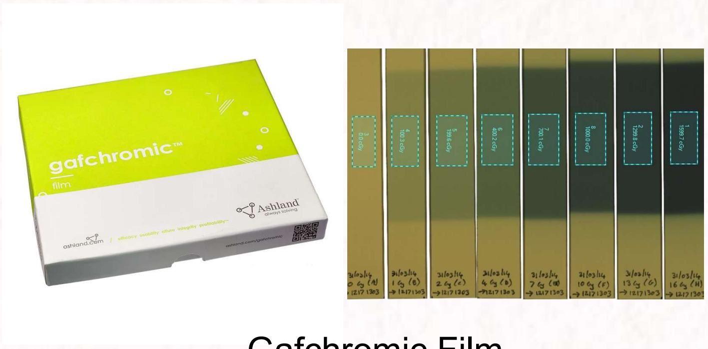


B3 Film GEX

Alanine Dosimeter



Calorimeter



Gafchromic Film

Pit Stop

- Berapa rentang pengukuran dosimeter B3 film?
- Berapa lama post-processing untuk alanine dosimeter?

4 Ketidakpastian pengukuran

Uncertainty

Metrologia

KEY COMPARISON

APMP Key comparison report of reference air kerma rate for HDR ^{192}Ir brachytherapy sources (BIPM KCDB: APMP.RI(I)-K8)

J Ishii, T Kurosawa, M Kato, P Toroi, W-H Chu, C-Y Yi, Y H Kim, Y M Seong, S A Ngcezu, E Mainegra-Hing Show full author list

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[a]*National Metrology Institute of Japan, Tsukuba, Japan*

[b]*International Atomic Energy Agency, Vienna, Austria*

[c]*Institute of Nuclear Energy Research, Longtan, Taiwan*

[d]*Korea Research Institute of Standards and Science, Yusong, Korea*

[e]*National Metrology Institute of South Africa, Pretoria, South Africa*

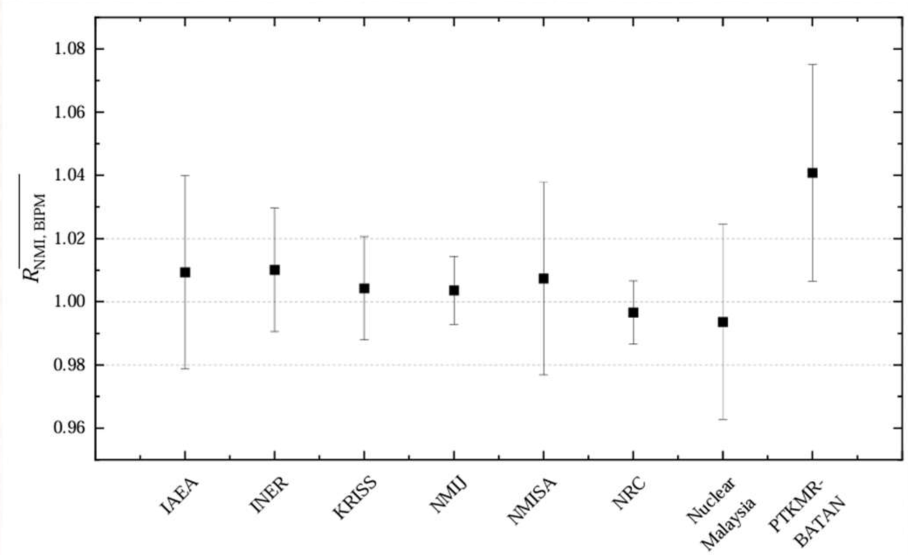
[f]*National Research Council of Canada, Ottawa,Canada*

[g]*Malaysian Nuclear Agency (Nuclear Malaysia), Kajang, Malaysia*

[h]*National Atomic Energy Agency (BATAN), Jakarta, Indonesia*

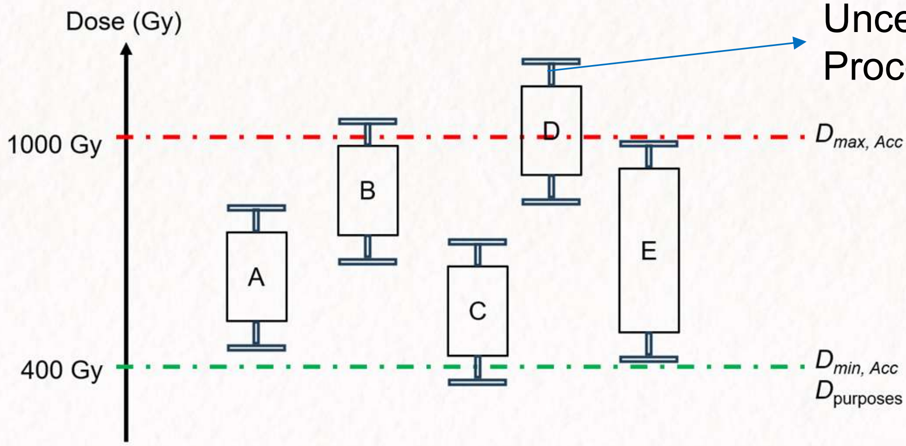
Manakah hasil pengukuran yang **TERBAIK**?

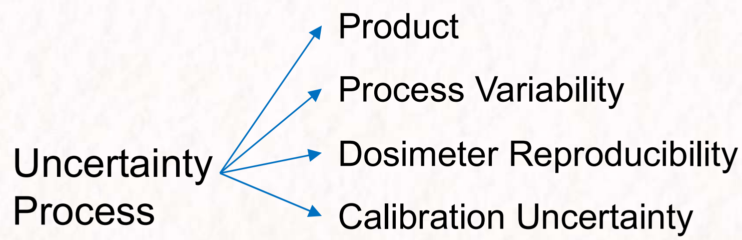
Apakah hasil PTKMR BATAN itu **SALAH**?



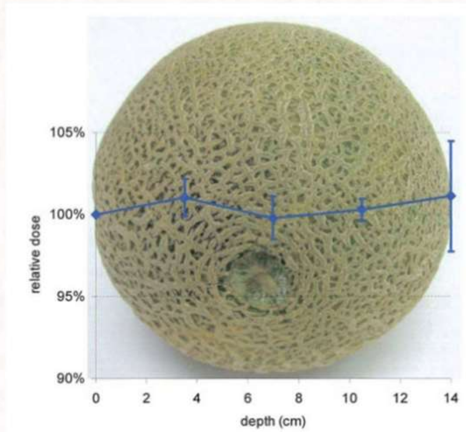
Penggunaan error bar dalam penampilan data statistik yang merepresentasikan **ketidakpastian pengukuran** sangatlah penting!

Process Control

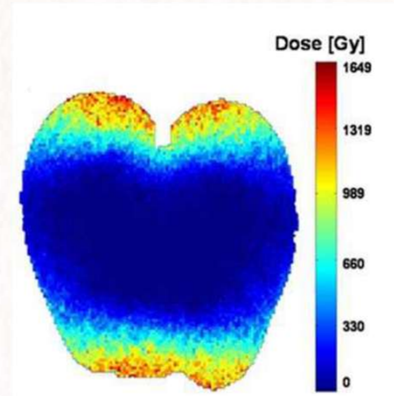




8.3.1 *Absorbed Doses Required to Accomplish Specific Effects*—Food irradiation specifications provided by the owner of the product should include minimum and maximum absorbed dose limits: a minimum necessary to ensure the intended effect, and a maximum to prevent product degradation. One or both of these limits may be prescribed by regulation for a given application. See, for example, FDA and



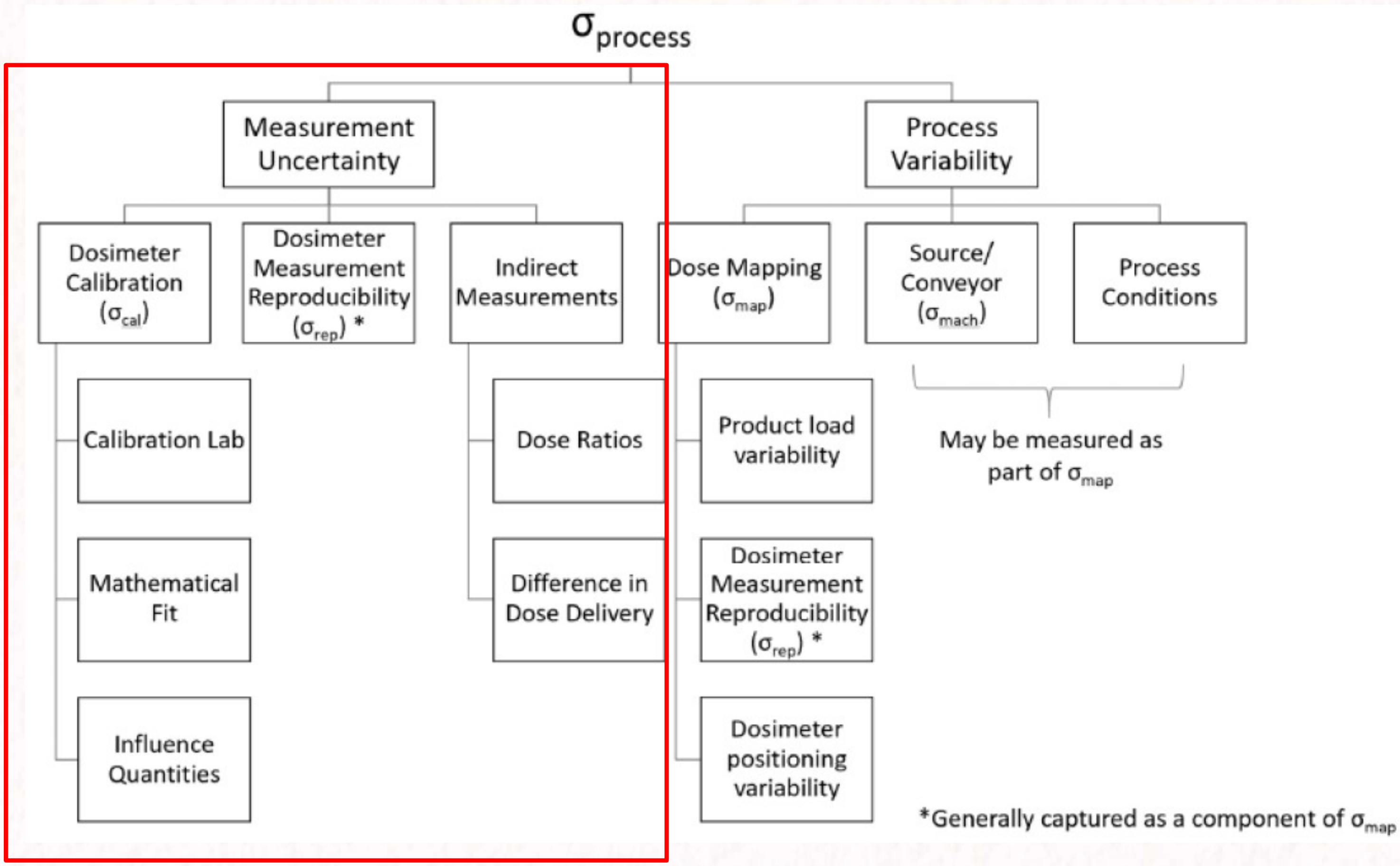
Average of three dose profiles after double sided gamma irradiation in an experimental irradiator where dose distribution is more uniform than in a commercial irradiator.
REF. IAEA TRS No. 481 (2015)



(Jongsoon Kim, 2005)
Distribusi dosis pada buah apel

Uncertainty

Process total uncertainty, from ISO 11137-4



Uncertainty

The result of a (dose) measurement is only an approximation or estimate of the (dose) value and it is complete only when accompanied by a quantitative statement of **its uncertainty:**

Example: **Absorbed dose = 27.4 +/- 0.55 kGy**

Uncertainty

- ❑ The uncertainty of the result of a measurement consists of several components, which have to be investigated from calibration to routine use.

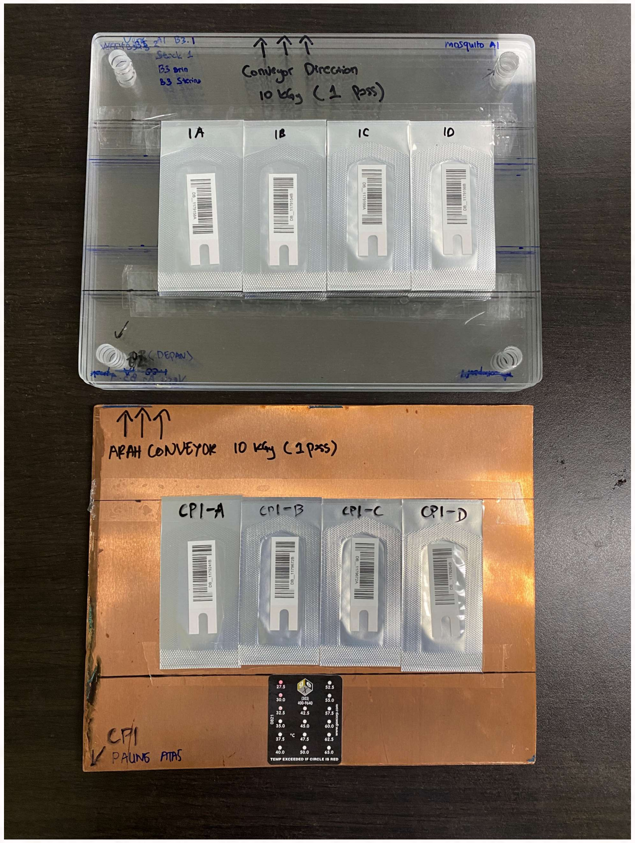
Types of uncertainties:

- ❑ Evaluated by statistical methods – A type (random)
  - (e.g. standard deviation of the mean) – related mainly to precision (i.e. reproducibility) of the dosimeter response.

- ❑ Evaluated by other means (based on scientific judgement, e.g. previous experimental data) – B type (non-random, systematic)
  - related mainly to calibration (accuracy).
  - Systematic errors e.g. instrumental errors (bandwidth, absorption peak or shoulder, calibration curve „transfer”), irradiation conditions different from calibration conditions;

- ❑ A and B can be combined if they do not depend on each other

Uncertainty



Contoh:

Reproducibility Positioning of dosimeter

- Penempatan pada tempat yang sama untuk setiap pengukuran
- 1 titik dosis, minimal menggunakan empat dosimeter

Uncertainty

- ❑ Uncertainties in preparing the calibration function

- uncertainty in calibration doses;
- uncertainty due to fit of calibration function;
- uncertainty due to environmental influence factors.

- ❑ Uncertainty in use of dosimeters

- uncertainty due to dosimeter to dosimeter scatter;
- uncertainty due to variation in plant environmental conditions;
- uncertainty due to instability of dosimeter reading;
- uncertainty due to instability of instrumentation.

Uncertainty

Table A.5: NPL uncertainty budget

Component of uncertainty	Type A (%)	Type B (%)
Calibration of secondary standard ionisation chamber.		0.6
Use of chambers to calibrate alanine dosimeters in therapy-level ^{60}Co beam*	0.3	
Transfer of alanine calibration from therapy-level beam to high dose irradiator beam	0.3	0.5
Use of high dose irradiators to irradiate customer dosimeters	0.7	
Timing		0.05
Combined standard uncertainty (k=1)	1.1	

* Theratron - NPL ^{60}Co therapy irradiator. Dose rate 0.9 Gy / min January 2019

Table A.4: NIST uncertainty budget

Component of uncertainty	Type A (%)	Type B (%)
Reference dose rate	0.37	0.56
Alanine response	0.60	0.15
Dose rate effect		0.10
Temperature correction		0.10
Calibration curve	0.5	0.10
Combined standard uncertainty (k=1)	1.05	

Source: Supplementary comparison CCRI(I)-S3 of standards for absorbed dose to water in 60Co gamma radiation at radiation processing dose level

Data Analysis

- Analysis of dosimeters
  - use of calibrated instrumentation
  - time of analysis after irradiation (potential changes of dosimeter response after irradiation)

- Analysis of calibration data
  - mean response and sample standard deviation
  - calculation of coefficient of variation (std/ mean)

- Preparation of calibration curve
  - signal = f(dose)
  - evaluation of mathematical expression (e.g. calculation of "percentage residuals") to select best fit

Data Analysis

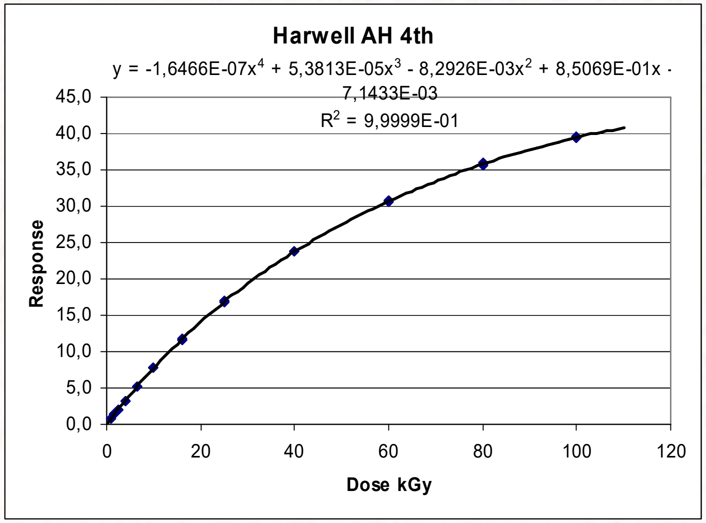
- Select the mathematical expression for the *dose=f(signal)* relationship (e.g. lowest order polynomial);
- Determine the coefficients of the polynomial (use individual dosimeter points);
- Calculate the dose for each calibrated dosimeter;
- Calculate "percentage residuals":

$$(D_{calculated} - D_{delivered}) / D_{delivered} \times 100$$

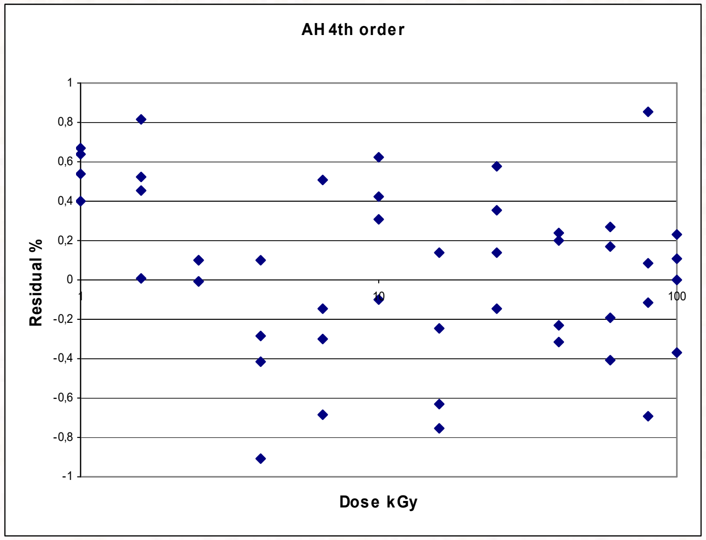
- Plot "percentage residuals" against dose and examine data for any systematic trends;

Data Analysis

Calibration curve and function



Percentage residual



Data Analysis

Best Practice for daily process

No	Dose Setting (kGy)	ID	Measured Dose (Gy)	Dose Average (kGy)	Deviasi (%) (measured/setting)	STD DEV	RSD (CV)
1	2	D1-1	2.200	1.995	**-0.25%**	0.164	0.082
		D1-2	1.800				
		D1-3	1.970				
		D1-4	2.010				
2	10	D2-1	10.030	9.908	**-0.93%**	0.189	0.019
		D2-2	9.700				
		D2-3	9.800				
		D2-4	10.100				
3	15	D3-1	14.700	15.03	**0.17%**	0.275	0.018
		D3-2	15.200				
		D3-3	15.300				
		D3-4	14.900				

- Satu titik dosis terdiri empat dosimeter
- Hasil yang dibaca adalah hasil nilai rata-rata dosis
- Perhatikan untuk deviasi antara dose setting dan measured dose

Data Analysis

Best Practice for daily process – (stabilitas pengukuran)

No	Date	Dose Setting (kGy)	ID	Measured Dose (Gy)	Dose Average (kGy)	Deviasi (%) (measured/setting)	STD DEV	RSD (CV)
1	Februari	2	D1-1	2.200	1.995	-0.25%	0.164	0.082
			D1-2	1.800				
			D1-3	1.970				
			D1-4	2.010				
2	Maret	2	D1-1	1.980	2.005	0.25%	0.083	0.042
			D1-2	1.900				
			D1-3	2.050				
			D1-4	2.090				
3	April	2	D1-1	2.100	2.015	0.75%	0.155	0.077
			D1-2	1.800				
			D1-3	2.150				
			D1-4	2.010				
4	Mei	2	D1-1	2.160	2.018	0.88%	0.194	0.096
			D1-2	1.800				
			D1-3	1.910				
			D1-4	2.200				
5	Juni	2	D1-1	2.030	2.073	3.62%	0.087	0.042
			D1-2	2.050				
			D1-3	2.200				
			D1-4	2.010				
6	Juli	2	D1-1	1.980	2.005	0.25%	0.083	0.042
			D1-2	1.900				
			D1-3	2.050				
			D1-4	2.090				
7	Agustus	2	D1-1	1.980	2.008	0.37%	0.087	0.043
			D1-2	1.900				
			D1-3	2.050				
			D1-4	2.100				
8	September	2	D1-1	1.980	2.010	0.50%	0.075	0.037
			D1-2	1.920				
			D1-3	2.050				
			D1-4	2.090				

- Dilakukan pada satu titik dosis
- Dipantau/dicatatan per-periode waktu

QUIZ

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Rangkuman

1. **Teori Dasar Dosimetri**
   - KERMA dan absorbed dose
   - Fenomena build up dose

2. **Kalibrasi dan Ketertelusuran**
   - Dosimetry standard sekunder
   - Kalibrasi in-plant dan in-laboratory
   - Aturan number of decade (untuk titik dosis kalibrasi)

Rangkuman

3. Faktor-Faktor yang mempengaruhi pengukuran
   - Suhu
   - Kelembaban
   - Temperatur
   - Post-irradiation time

4. Ketidakpastian pengukuran
   - Ketidakpastian pengukuran dosimeter dan proses radiasi
   - Ketidakpastian tipe A dan B

Terima Kasih

THANK YOU

B.J. Habibie Building
Jl. M.H. Thamrin 8, Jakarta 10340, Indonesia
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