Uncertainty considerations and validation

Workplace monitoring of photon H*(10) dose rate.

JH, 2005-06-28

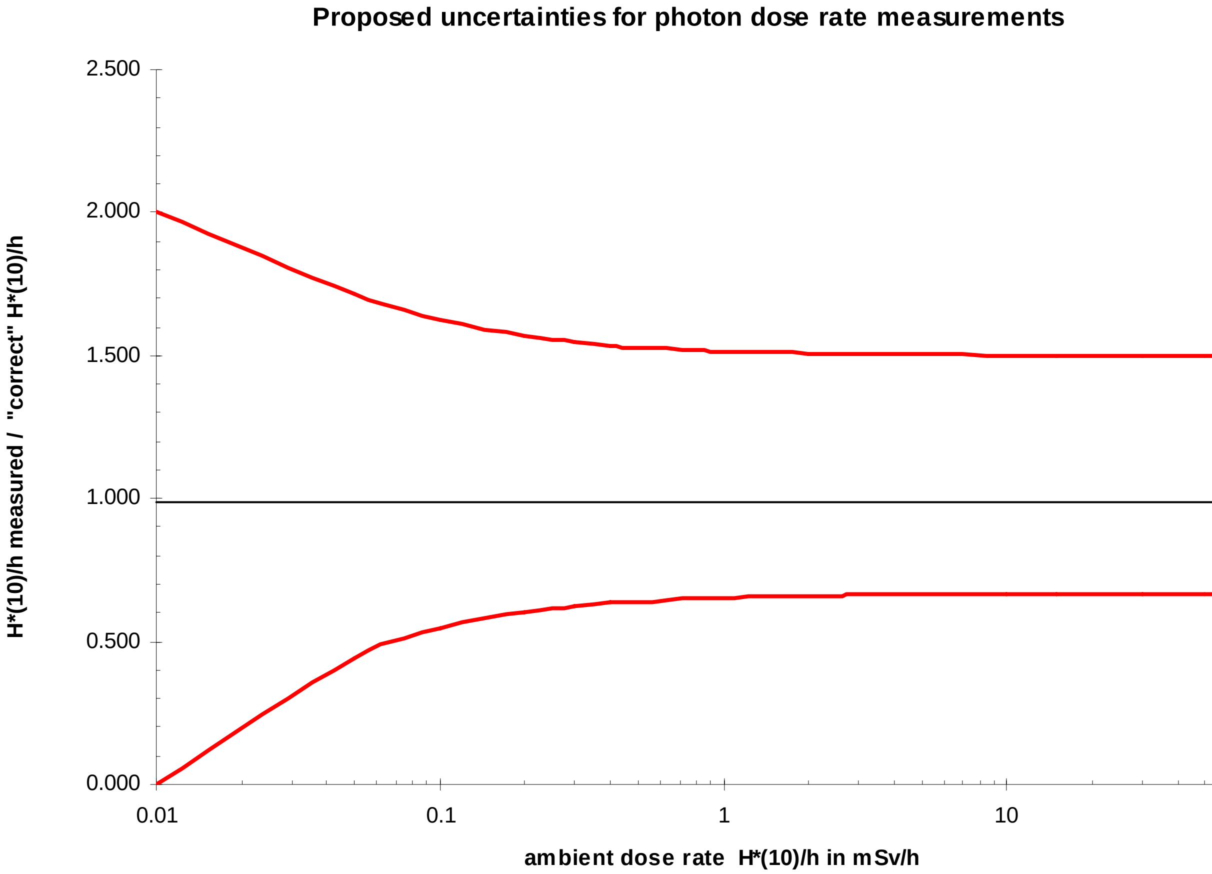
1) **Introduction**

Dose rate measurements in the workplace are used to characterize the working conditions from the point of view of radiological protection. They are also used to establish whether equipment or materials may be released from controlled areas or to evaluate the transportation conditions. The working conditions may vary from well-characterized workplaces to temporary controlled areas established to deal with sources under emergency conditions.

The question of acceptable uncertainties in workplace dose rate measurement has been discussed in national norms and standards(1,2). These standards suggest that a ± 100% uncertainty is acceptable for H*(10) dose rate measurement near background levels (H*(10)/h < 1 μSv/h). The standard also recommends that, for photon dose-rates above say 100 μSv/h, the acceptable uncertainty should fall to ± 30%.

The measurement of photon dose rates in the workplace is subject to many sources of uncertainty. These sources of uncertainty are discussed in the next section, and include: energy and angular dependence, calibration uncertainties, uncertainties in the conversion factors, non-linearity, and so on. It would be more realistic to adopt the accepted uncertainties for individual monitoring for photons. These are characterized by the "trumpet curve" suggested by the PTB, which start at an uncertainty of ±100% near the detection limit of 200 μSv, and at around the 1 mSv level out at + 50% and – 30%.

For portable dose rate monitors, the proposed adaptation would be as in the figure below. The acceptance limits are at ±100% near the detection limit of 0.1 μSv/h, and at around the 1 mSv/h level out at + 50% and – 30%.



2) Uncertainty evaluation

Due to the large number of dose rate meters used at the IAEA, each with its own measurement characteristics and display devices, the uncertainty evaluation conducted here is made for a “typical” instrument.

2.1 Instrument reading

At high, constant dose rates, the reading will be quite steady. At low dose rate measurements, the reading may change considerably. For dose rate measurements in the IAEA workplaces, dose rates near background levels may be evaluated with a larger uncertainty. It is therefore not necessary to make a series of measurements and then calculate their mean and the standard deviation.

The maximum and minimum values should be observed over a time equal to at least 20 times the response time of the instrument (time required to reach 90% of the final reading). The average value should be recorded. For a confidence level of 95%, the standard deviation of the mean may be calculated as:

$$u(y_1) = \frac{y_m}{2\sqrt{n}}$$

where Y_m is the average value of the maximum and minimum values, n is the number of response time periods used for the observation and $u(y_1)$ is the standard uncertainty (Type A, normal distribution)

2.1.1 Analogue instruments – parallax and scale resolution

A maximum uncertainty of 5% may be assumed for errors due to parallax. The maximum uncertainty due to linear analogue displays may be estimated as being around 5%. The probability distributions are to be rectangular, type B uncertainties. Analogue quasi-logarithmic scaled instruments are not used in the IAEA.

2.1.2 Digital instruments

For digital instruments, it can be considered that the uncertainty due to parallax and scale resolution is zero.

2.2 Field uniformity

For area dose rate measurements, the uncertainty due to field uniformity may be considered to be zero. For measurements made at the surface of containers such as transport containers, the detector should be placed at the point that shows the highest values. At this measurement point, the source is usually still quite close to the detector. However, for Geiger Muller or proportional counters with small detector volumes, it may be considered that the uncertainty due to field uniformity is less than 2%. Large volume ionisation chambers are not used to make this kind of dose rate measurement. This Type B uncertainty has a rectangular probability distribution.

2.3 Energy and angular dependence

Each dose rate instrument shows a different energy and angular dependence, the IEC standard "Radiation protection instrumentation - Ambient and/or directional dose equivalent (rate) meters and/or monitors for beta, X and gamma radiation" will be used to derive a general uncertainty for all equipment.

The IEC standard says that dose rate instruments should be made and type tested to show that the uncertainty of measurement in the energy range of 80 keV to 1.25 MeV and for angles less than 45^0 be less than 40% of the conventionally true vale. This Type B uncertainty has a rectangular probability distribution.

2.4 External electromagnetic fields

It is assumed that the dose rate measurements are made in areas with very low RF, microwave or electric or magnetic fields. The uncertainty from these fields may therefore be considered to be zero.

2.5 Environmental factors

Each dose rate instrument shows a different sensitivity to environmental factors,. However, the IEC standard "Radiation protection instrumentation - Ambient and/or directional dose equivalent (rate) meters and/or monitors for beta, X and gamma radiation" specifies a rather large range of acceptable uncertainties due to temperature, atmospheric pressure and humidity variations from the reference values. Based on work experience, the uncertainty caused by environmental factors over normal working conditions, should not be more than 10%. This is a Type B, rectangular probability distribution. For work in extreme environmental conditions, below 0^0C or above 40 ^{0}C, the operating manual of the instrument should be consulted for the estimate of the uncertainty.

2.6 Rate (dead time) effects

Rate effects may arise due to the meter having a dead time (Geiger-Muller based instruments). The compensation is normally provide electronically, so the uncertainty from this effect may be considered to be zero.

3 Uncertainty Budget

The summary of the uncertainty budget may be seen in the spreadsheet below.

Quantity	(i)	Uncertainty	Probability	Divisor	u(i)	$[u(i)]^2$
		dx(i) %	distribution		%	
Calibration factor	1	10	normal	1	10.00	100.00
Scale reading	2	5	rectangular	1.73	2.89	8.35
Parallax	3	5	rectangular	1.73	2.89	8.35
Field uniformity	4	NA				
Energy and angle	5	40	rectangular	1.73	23.12	534.60
Electromagnetic fields	6	NA				
Environmental factors	7	10	rectangular	1.73	5.78	33.41
Rate (dead time) effects	8	NA				
		Combined	standards	uncertainty	%	26.17
		Expanded	uncertainty	(k=2)	%	52.33

It can therefore be said that the dose rate measurements may be made with an uncertainty of 52 %

(k = 2 for a 95% confidence limit).

5. References

American National Standards Institute, *Radiation Protection Instrumentation Test and Calibration*, ANSI N323A, (New York) (1997).

National Council on Radiation Protection and Measurements (NCRP), *Instrumentation and Monitoring Methods for Radiation Protection*, NCRP Report 57, (Bethesda, Maryland) (1978)

National Physical Laboratory, *The assessment of uncertainty in Radiological Calibration and Testing*., Measurement Good Practice Guide 49, (Teddington) (2005)

International Electrotechnical Commission, *Radiation protection instrumentation - Ambient and/or directional dose equivalent (rate) meters and/or monitors for beta, X and gamma radiation*, IEC Standard 60846-Ed2, (Geneva) (2002).

International Standards Organization, *Guide to the Expression of Uncertainty in Measurement,* (Geneva) (1993)