RADIOLOGICAL PROTECTION FROM COSMIC RADIATION IN AVIATION

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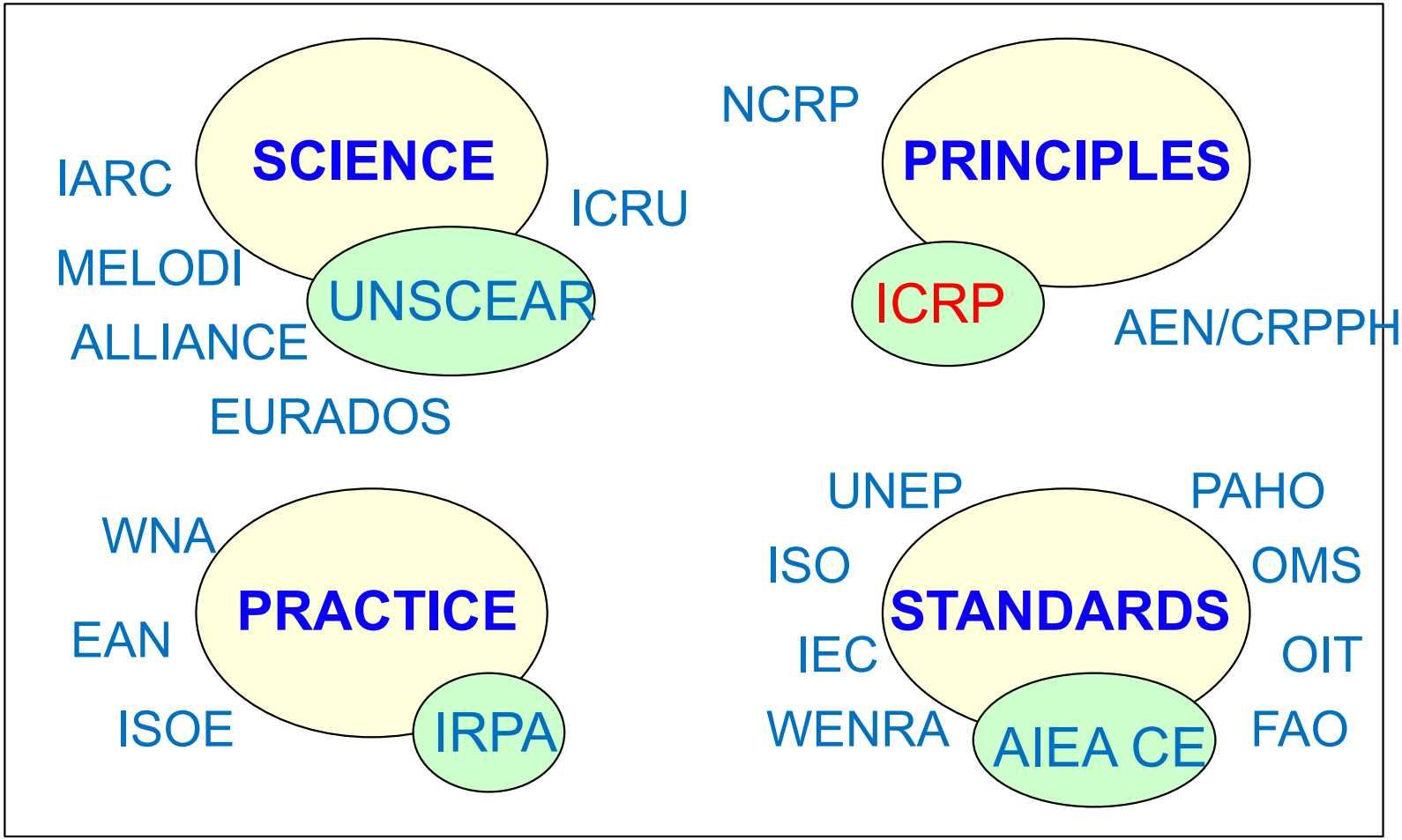
International organizations



ICRP (International Commission for Radiological Protection) Publications

ICRP is not an intergovernmental organization, such as ICAO. The main ICRP commission supervised the different subcommittee of international experts. It issues recommandations.

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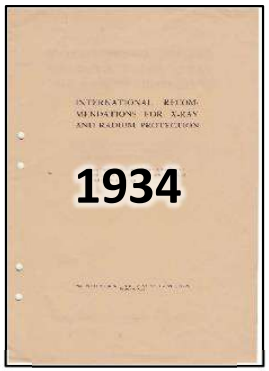

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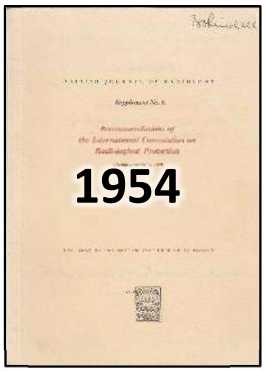

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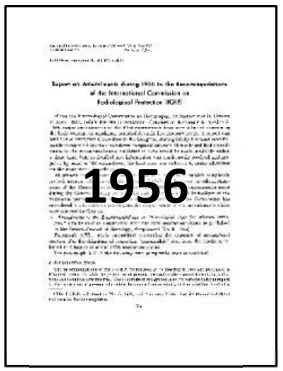

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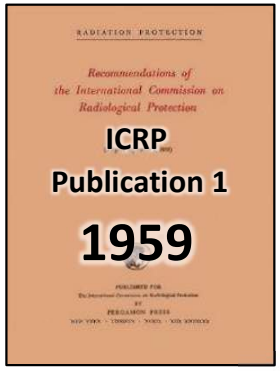

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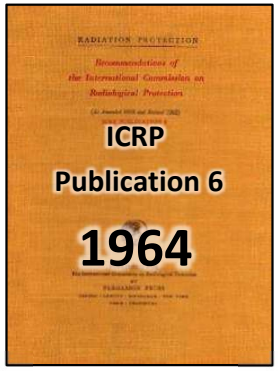

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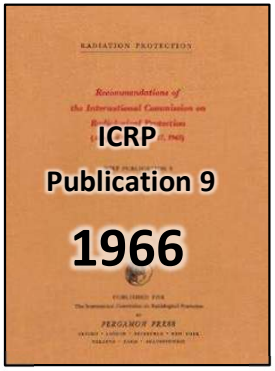

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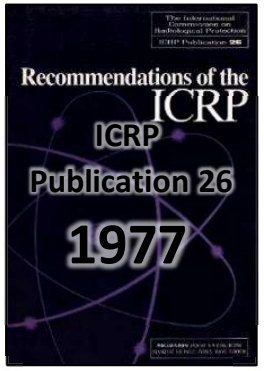

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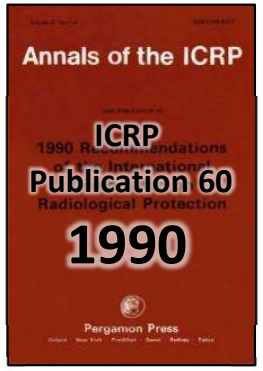

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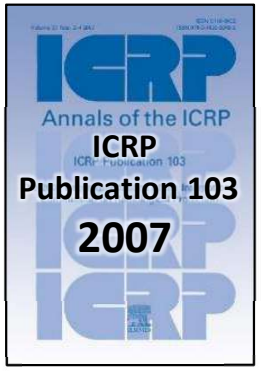

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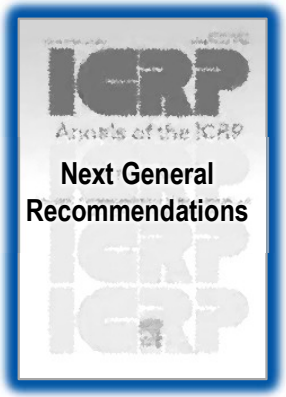
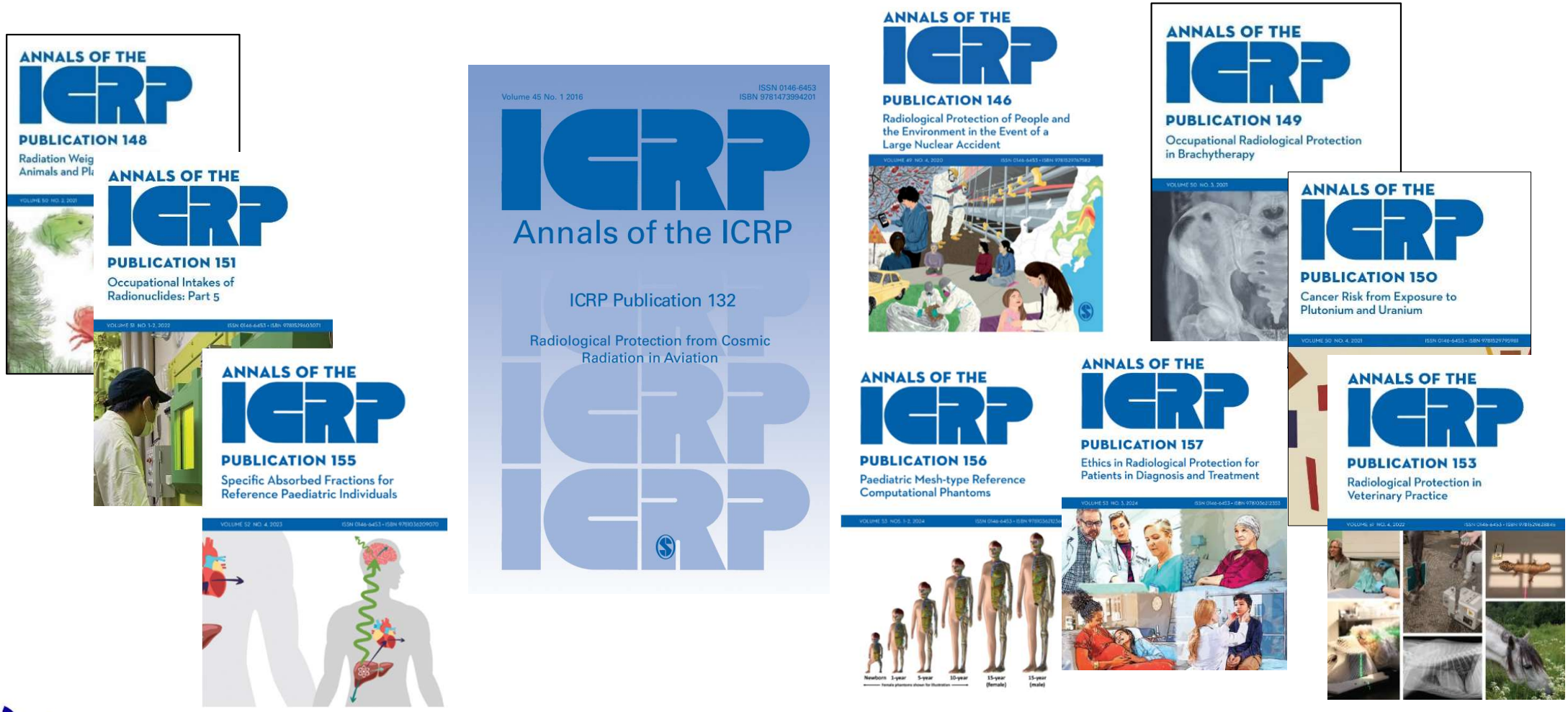


ASNR

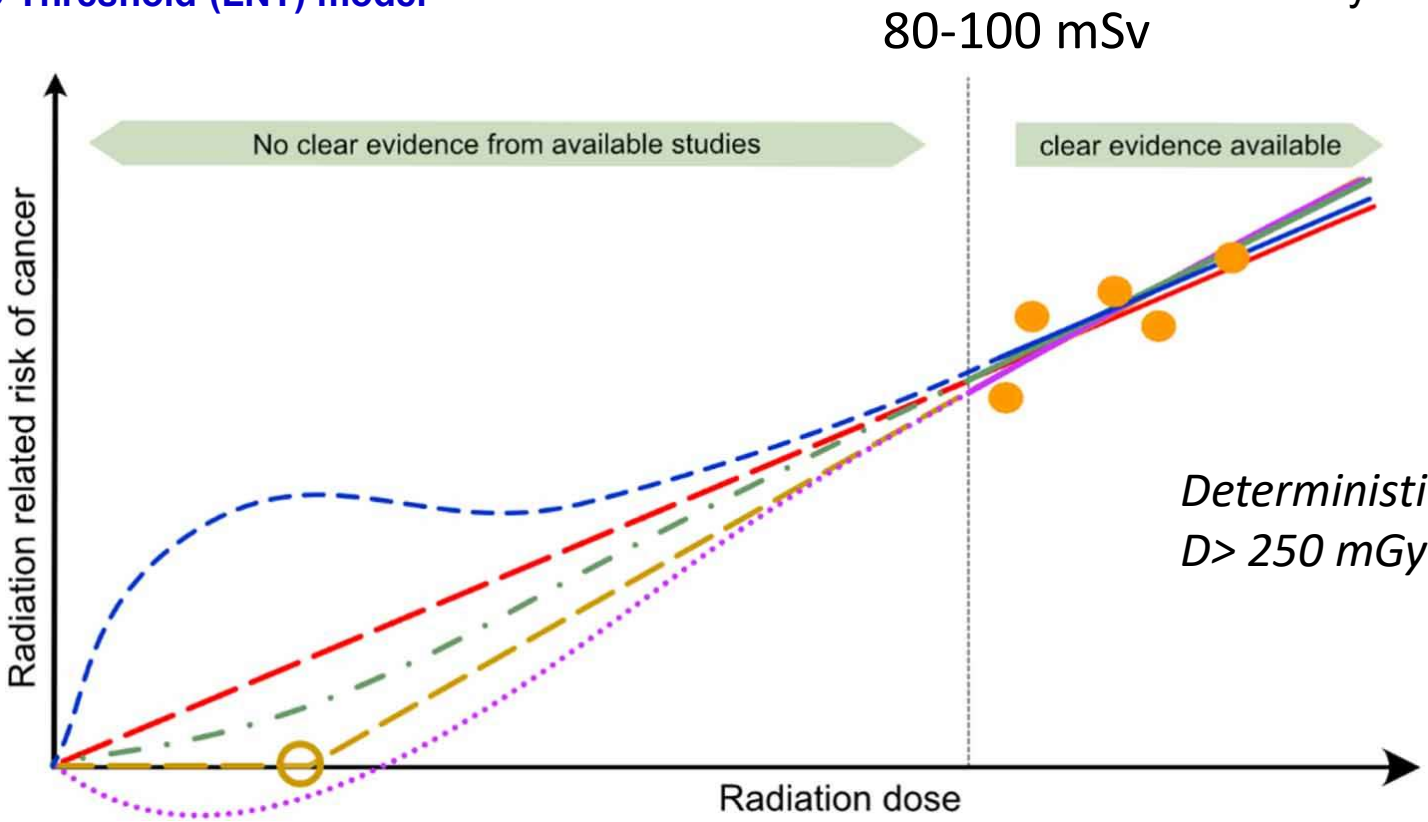
ICRP thematic recommandations



ICRP dogma in stochastic health effect

For adult workers a nominal probability coefficient for stochastic effects is estimated by the ICRP as 5.6×10^{-5} mSv^{-1}

Linear No-Threshold (LNT) model



Deterministic effect or tissue reaction:
D> 250 mGy for acute exposure

Basis of the radiological protection system

- Based on the recommendations of the International Commission on Radiological Protection (ICRP)
- Its overall objective is to contribute to an appropriate level of protection for people and the environment against the harmful effects of radiation exposure, **without unduly restricting desirable human activities that may be associated with such exposure**
- To prevent deterministic effects in humans and to **reduce the risk of stochastic effects as far as reasonably practicable**

Basis of the radiological protection system

- It applies to all situations involving exposure to **natural** or artificial radioactivity that can be controlled
- It is structured (based on exposure situations and categories of exposed individuals)
- It is based on a common approach: reducing exposures **as low as reasonably achievable** (optimization of protection) below a level chosen based on the characteristics of the situation and implemented with the involvement of stakeholders to the greatest extent possible

Categories of Exposure Situations:

- **Existing exposure situation**: Exposures resulting from sources that already exist when a decision regarding protection must be made. Characterizing exposures is a prerequisite for controlling them
- **Planned exposure situation**: A situation involving the deliberate introduction and use of sources for their radioactive properties; normal (anticipated) or potential (unanticipated) exposures
- **Emergency exposure situation**: Unintended situations (accidents, malicious acts) resulting from loss of control of the source and requiring an urgent and timely response

GCR and GLE are both considered as **existing exposure situations** by ICRP

Three Categories of Exposure

- **Medical** (patients + caregivers + research volunteers): Exposures resulting from diagnostic, interventional, and therapeutic procedures (Risks and benefits evaluation for the patient)
- **Occupational** (workers considered to be occupationally exposed): Exposures incurred at work that can reasonably be considered the responsibility of operational management (Ambiguity regarding existing and emergency situation)
- **Public** (other individuals): Exposures other than medical and occupational (Natural and artificial sources)

*"The Commission maintains its view that the **exposure of occasional and frequent flyers is public exposure**, and that the exposure of **aircraft crew is occupational exposure** (ICRP, 1991, 1997, 2007). However, the Commission is now proposing a graded approach for the protection of these three groups, taking into account the level of exposure expected for each group and the responsibilities that need to be considered (Section 4.2)."*

ICRP general recommandations on dose limits

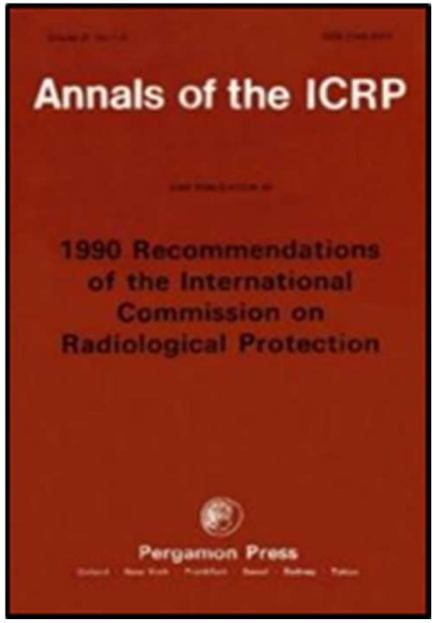
For occupational and public exposure (in effective dose (E)):

- Public or non exposed worker: <1 mSv/year, possibly averaged over 5 years
- Workers: 20 mSv/year, averaged over defined 5-year periods (**100 mSv/5 years**) with a **maximum of 50 mSv in any given year** and for pregnant workers **no more than 1 mSv to the conceptus** (from declaration to the end of the pregnancy)

Cosmic Radiation and ICRP

Before 1990: Cosmic Radiation not considered for occupational exposure and dose threshold to public at 5 mSv/year

In 1990, change of paradigm for exposure to Cosmic Radiation: the International Commission on Radiological Protection (ICRP) recommended that flight crews (FC) be classified as occupationally exposed (ICRP report 60, 1991).



Latest ICPR recommandations for aircrew and public exposure

“For protection against cosmic radiation in aviation, the Commission recommends that a reference level(*) in the 5–10 mSv/year range generally be selected (occupational and public).”

(*)The selected reference value is not a dose limit, but represents the level of dose below which exposure should be maintained and reduced as low as reasonably achievable, taking into account economic and societal factors. The principle of application of individual dose limits only applies in planned exposure situations [Paragraph 203 of Publication 103 (ICRP, 2007)]. Nevertheless, some regulatory bodies may decide to introduce occupational dose limits to aircraft crew as a procedure to impose legally binding values

Implementation in Europe:

This ICRP recommendation was transposed into European regulations by European Directive No. 96-29 EURATOM of May 13, 1996 (European Commission, 1996), which substantially amended the standards governing the health protection of workers against the effects of ionizing radiation in Europe.

With regard to the protection of flight crews, Article 42 stipulates:

« Each Member State shall make arrangements for undertakings operating aircraft to take account of exposure to cosmic radiation of air crew who are liable to be subject to exposure ***more than 1 mSv per year****. The undertakings shall take appropriate measures, in particular:*

- to assess the exposure of the crew concerned*,*

- to take into account the assessed exposure when organizing working schedules with a view to reducing the doses of highly exposed aicrew*,*

- to inform the workers concerned of the health risks their work involves,

- to apply Article 10 to female air crew. »

Implementation in Europe

For the special protection during pregnancy, Article 10 stipulates:

"As soon as a pregnant woman informs the undertaking; in accordance with national legislation and/or national practice, of her condition, the protection of the child to be born shall be comparable with that provided for members of the public. The conditions for the pregnant woman in the context of her employment shall therefore be such that the equivalent dose to the child to be born will be as low as reasonably achievable and that ***it will be unlikely that this dose will exceed 1 mSv during at least the remainder of the pregnancy****."*

Implementation in France

This directive was transposed into French law by Order No. 2001-270 of March 28, 2001 (Order, 2001). A French decree of December 2003 (J Off, 2003) provides that:

(1) the individual exposure of any flight crew member likely to be exposed to an effective dose >1 mSv per year must be assessed; the effective dose must be assessed for each flight using a calculation method based on flight data provided by the airlines (date, duration, location, etc.),

(2) and the calculation method must take into account the influence of normal solar activity and the effects of events related to solar energetic particles (SEPs) ~~classified~~.

A software (SievertPN) has been developed for those purposes, operational since 2001 (GCR and GLE). SievertPN is the sole tool authorized in France

Point of view of ICRP for Ground Level Enhancements (GLEs)

"Regarding exposure during a GLE, it could be envisaged to reduce the altitude of flying aircraft and delay flights that have yet to take off. The implementation of these actions requires the use of sophisticated information systems, which currently remain difficult to develop given technical and organisational considerations. These actions can also disrupt air traffic, which is already tightly scheduled, and increase the potential for accident."

"The Commission does not believe that the contribution of GLEs, in the context of an individual's cumulative exposure, warrants specific monitoring systems such as real-time alert systems. However, the Commission recommends that, whenever reasonably achievable, ***doses from GLEs be estimated retrospectively*** *and added to the annual exposure of the affected aircraft crew. The Commission also notes that international regulations contain specifications for monitoring equipment for aircraft operating above 15,000 m (ICAO, 2010)."*

TGF, GRG, FGF are not considered for aircrew exposure, nothing said about impact of radioactive goods transportation

Level of exposure in aviation

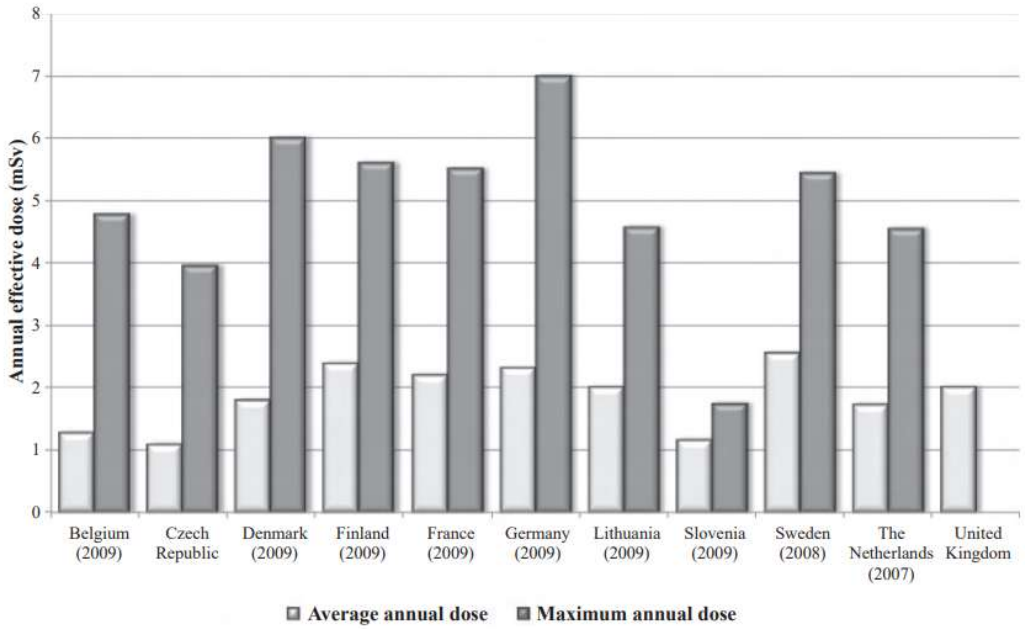


Fig. 2.6. Average and maximum annual effective dose for aircraft crew in European countries (Andresz and Croüail, 2015).

For GLEs, since 2000, 5 GLEs have been taken into account in France. Their maximal effect was the doubling of the dose on the most exposed flights

In France, 1 flight crew annual dose (GCR + GLE) reported to be above 6 mSv (6,2 mSv) since 2001.

Aircrew classified as Cat. B, (E< 6 mSv)

Doses from strongest GLEs of last century about a few mSv (see GLE5) but with low probability

In case of GLEs, exposure of crew and passengers is kept under control by actions taken to keep exposure of pregnant crew below 1 mSv.

To put things into perspective:

Dose from Whole Body scanner (10 mSv), from chest X-rays (0,1 mSv)

*In France, average dose to population 6.4 mSv [varies from **2.4 mSv to 14 mSv**]*

In nuclear emergency dose threshold for population evacuation (including children and pregnant individuals) is 50 mSv (a balance is struck, because evacuations take a toll on the most fragile individuals)

No dose limit for public pregnant individual regarding natural sources of exposure