IAEA
International Atomic Energy Agency
*Atoms for Peace and Development*

# ASSESSMENT OF OCCUPATIONAL EXPOSURE DUE TO INTERNAL RADIATION SOURCES

## UNIT 2

## CRITERIA FOR THE NEED FOR MONITORING

# CRITERIA FOR THE NEED FOR MONITORING

- **CONTENTS OF LECTURE**
  - ✓ QUANTITIES FOR INTERNAL DOSE ASSESSMENTS
  - ✓ MONITORING PROGRAMMES
  - ✓ SUGGESTED CRITERIA TO DEFINE THE NEED FOR MONITORING.
    - Need for monitoring
    - Examples of monitoring cases

# Quantities for Internal Dose Assessment

# CRITERIA FOR THE NEED FOR MONITORING

- **QUANTITIES FOR INTERNAL DOSE ASSESSMENT**

  ✓ Physical quantities - Directly measurable.

  ✓ Protection quantities - Defined for dose limitation purposes, but not directly measurable.

  ✓ Operational quantities - Measurable for demonstration of compliance with dose limits.

# CRITERIA FOR THE NEED FOR MONITORING

- **QUANTITIES FOR INTERNAL DOSE ASSESSMENT**

✓**Absorbed dose, D**

The fundamental dosimetric quantity *absorbed dose*, D, is defined as:

$$D = dE / dm$$

where dE is the mean energy imparted by ionizing radiation to matter in a volume element and dm is the mass of matter in the volume element.

The energy can be averaged over any defined volume, the average dose being equal to the total energy imparted in the volume divided by the mass in the volume.

The SI unit of absorbed dose is the joule per kilogram (J/kg), termed the gray (Gy).

# CRITERIA FOR THE NEED FOR MONITORING

- **QUANTITIES FOR INTERNAL DOSE ASSESSMENT**

**ICRP has defined Protection Quantities for dose limitation**

✓ **Equivalent dose**

To be used for individual tissues or organs

✓ **Effective dose**

To be used for the whole body

# CRITERIA FOR THE NEED FOR MONITORING

- **QUANTITIES FOR INTERNAL DOSE ASSESSMENT**

**Primary physical quantities are not used directly for dose limitation**

✓ The same dose levels of different radiations (ie photons and neutrons) do not have the same level of biological effect

*Radiation weighting factor, $w_R$* *(related to radiation quality)*

✓ Different body tissues have different biological sensitivities to the same radiation type and dose

*Tissue weighting factor, $w_T$ (multipliers of the equivalent dose to an organ or tissue to account for the different sensitivities to the induction of stochastic effects of radiation).*

# CRITERIA FOR THE NEED FOR MONITORING

- **QUANTITIES FOR INTERNAL DOSE ASSESSMENT**

✓ **Equivalent dose, $H_T$**

The absorbed dose in an organ or tissue multiplied by the radiation weighting factor $w_R$: $H_{T,R}$ (Sv)= $w_R \cdot D_{T,R}$

where $D_{T,R}$ is the average absorbed dose in the organ or tissue T,
$w_R$ is the radiation weighting factor for radiation R.

When the radiation field is composed of different radiation types with different values of $w_R$, the **Equivalent Dose** is: $H_T\ (Sv) = \sum_R w_R D_{T,R}$

The unit of equivalent dose is J/kg, termed the Sievert (Sv).

# CRITERIA FOR THE NEED FOR MONITORING

- **QUANTITIES FOR INTERNAL DOSE ASSESSMENT**
  - ✓ **Effective Dose E:** $E\,(Sv) = \sum_T w_T H_T$
    - A summation of the tissue equivalent doses, each multiplied by the appropriate tissue weighting factor. The unit of E is the Sievert (Sv).
  - ✓ **Committed Effective Dose E(50) Sv**
    - Internal exposure continues for some time after intake
    - Actual internal exposure duration depends on the radionuclide.
    - The exposure is said to be “committed” (prolonged in time)
    - Assess the *committed effective dose* over a 50 year period (occupational exposures).

# CRITERIA FOR THE NEED FOR MONITORING

- **QUANTITIES FOR INTERNAL DOSE ASSESSMENT**

**Operational quantity for internal dose assessment**

**Intake I(Bq)** - The activity of a radionuclide taken into the body.

To be used to determine the **Committed Effective Dose E(50) Sv,** considering the dose coefficients e(50) Sv $Bq^{-1}$ for radionuclide "j" for ingestion $e(50)_{j,ing}$ and inhalation $e(50)_{j,inh}$ (occupational exposures):

$$E(50) = \sum_j I_{j,ing} e(50)_{j,ing} + \sum_j I_{j,inh} e(50)_{j,inh}$$

# CRITERIA FOR THE NEED FOR MONITORING

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- ## QUANTITIES FOR INTERNAL DOSE ASSESSMENT

  - **Intake vs. Uptake**

    Do not confuse *intake* with *uptake!*

    ✓ **Uptake**

    *“The processes by which radionuclides enter the body fluids from the respiratory tract or gastrointestinal tract or through the skin, or <u>the fraction of an intake</u> that enters the body fluids by these processes.” (RS-G-1.2)*

# CRITERIA FOR THE NEED FOR MONITORING

- QUANTITIES FOR INTERNAL DOSE ASSESSMENT

  - **Intakes corresponding to Dose Limits**

In case of
- Exposure from a single radionuclide
- Exposure by inhalation or ingestion
- No external exposure
- Relevant effective dose limit, L (Sv)

Intake $I_{j,L}$ (Bq) corresponding to dose limit L (Sv) is given by: $$I_{j,L} = \frac{L}{e(g)_j}$$

where $e(g)_j$ is the relevant dose coefficient ($SvBq^{-1}$)

# CRITERIA FOR THE NEED FOR MONITORING

- **QUANTITIES FOR INTERNAL DOSE ASSESSMENT**

✓ **Intake Fraction**

*Intake fraction*, m(t), is the amount of material remaining or being excreted from the body at time t (days) after intake, divided by the intake quantity.

The *intake fraction* depends on:

- the radionuclide,
- its chemical and physical form,
- the route of intake,
- time after intake

# CRITERIA FOR THE NEED FOR MONITORING

- **QUANTITIES FOR INTERNAL DOSE ASSESSMENT**
  - ✓ **Derived Air Concentration (DAC)**

The concentration of airborne activity (in $Bqm^{-3}$) that would result in the limit on intake of $I_{j,inh,L}$ by a worker exposed continuously at that level for one year:

$$\mathbf{DAC\ (Bqm^{-3}) = I_{j,inh,L}\ (Bq) / (2000\ h * 1.2\ m^3h^{-1})}$$

2000 working hours in 1 year; breathing rate 1.2 $m^3h^{-1}$

EXAMPLE: Airborne $^{137}Cs$ with a particle size of 5 µm AMAD.
Dose coefficient (inhalation) $e(g)_{inh}$ = 6.7 E-9 Sv/Bq

Annual dose limit: Committed Effective Dose= 20 mSv = 0.02 Sv

$I_{j,inh,L}$ = 0.02 / 6.7 E-9 = 3 E+6 Bq

DAC = 3E+6/ (2000*1.2) = 1.3 E+3 $Bqm^{-3}$

# CRITERIA FOR THE NEED FOR MONITORING

- **QUANTITIES FOR INTERNAL DOSE ASSESSMENT**
  - ✓ **Use of DAC·h**

The measured airborne activity concentration, expressed as a fraction of the DAC, multiplied by the exposure time in hours gives an estimate of intake expressed in DAC·h.

EXAMPLE: 1 week at the 0.1 DAC would be 4 DAC·h, or an intake of 4/2000 = 0.002 $I_{j,inh,L}$.

2000 DAC·h corresponds to an intake of $I_{j,inh,L}$.

# Monitoring Programmes

# CRITERIA FOR THE NEED FOR MONITORING

- **NEED FOR MONITORING SPECIFIED IN THE GSR Part. 3**

The General Safety Requirements require that:

*“For any worker who usually works in a controlled area, or who occasionally works in a controlled area and may receive a significant dose from occupational exposure, individual monitoring shall be undertaken where appropriate, adequate and feasible.*

*In cases where individual monitoring of the worker is inappropriate, inadequate or not feasible, the occupational exposure shall be assessed on the basis of the results of workplace monitoring and information on the locations and durations of exposure of the worker.”*

Req. 25, Para 3.100

# CRITERIA FOR THE NEED FOR MONITORING

- **Monitoring programme**

  ✓ **Direct measurement** techniques:

  Measurements of radionuclides in the whole body or specific organs;

  ✓ **Indirect measurement** techniques:

  - Measurements of radionuclides in biological samples e.g. excreta samples
  - Measurement of radionuclides in physical samples e.g. filters from air samplers

**Interpretation of monitoring data allows the assessment of Intake I(Bq) and Committed Effective Dose E(50)**

# CRITERIA FOR THE NEED FOR MONITORING

- **Designing a monitoring programme:**

Depends on the:

- ✓ amount of radioactive material
- ✓ radionuclide(s) involved,
- ✓ physical and chemical form of the radioactive material,
- ✓ type of containment used,
- ✓ operations performed, and
- ✓ general working conditions.

# CRITERIA FOR THE NEED FOR MONITORING

- **EXAMPLES OF WORK ENVIRONMENTS**
  - ✓ Maintenance of reactors, exposure due to fission and activation products.
  - ✓ Handling of large quantities of gaseous or volatile materials, e.g. $^{3}H$ in large scale production processes, in heavy water reactors and in luminizing;
  - ✓ Processing of plutonium and other transuranic elements;
  - ✓ Mining, milling and processing of thorium ores, and the use of thorium and its compounds. Mining, milling and refining of high grade uranium ores.
  - ✓ Working in mines and other workplaces where radon levels exceed specified action level
  - ✓ Processing of natural and slightly enriched uranium, and reactor fuel fabrication;
  - ✓ Production of radioisotopes; handling large amounts of radiopharmaceuticals, e.g.$^{131}$

# Suggested Criteria for Individual Monitoring

# CRITERIA FOR THE NEED FOR MONITORING

- **NEED FOR MONITORING**
  To follow ISO 20553:2006 Radiation Protection – *Monitoring of workers occupationally exposed to a risk of internal contamination with radioactive material*

INTERNATIONAL STANDARD

**ISO 20553**

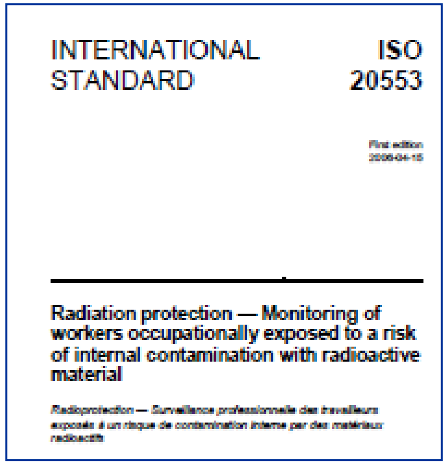
First edition
2006-04-15

**Radiation protection — Monitoring of workers occupationally exposed to a risk of internal contamination with radioactive material**

*Radioprotection — Surveillance professionnelle des travailleurs exposés à un risque de contamination interne par des matériaux radioactifs*

# CRITERIA FOR THE NEED FOR MONITORING

- **NEED FOR MONITORING***


INTERNATIONAL STANDARD

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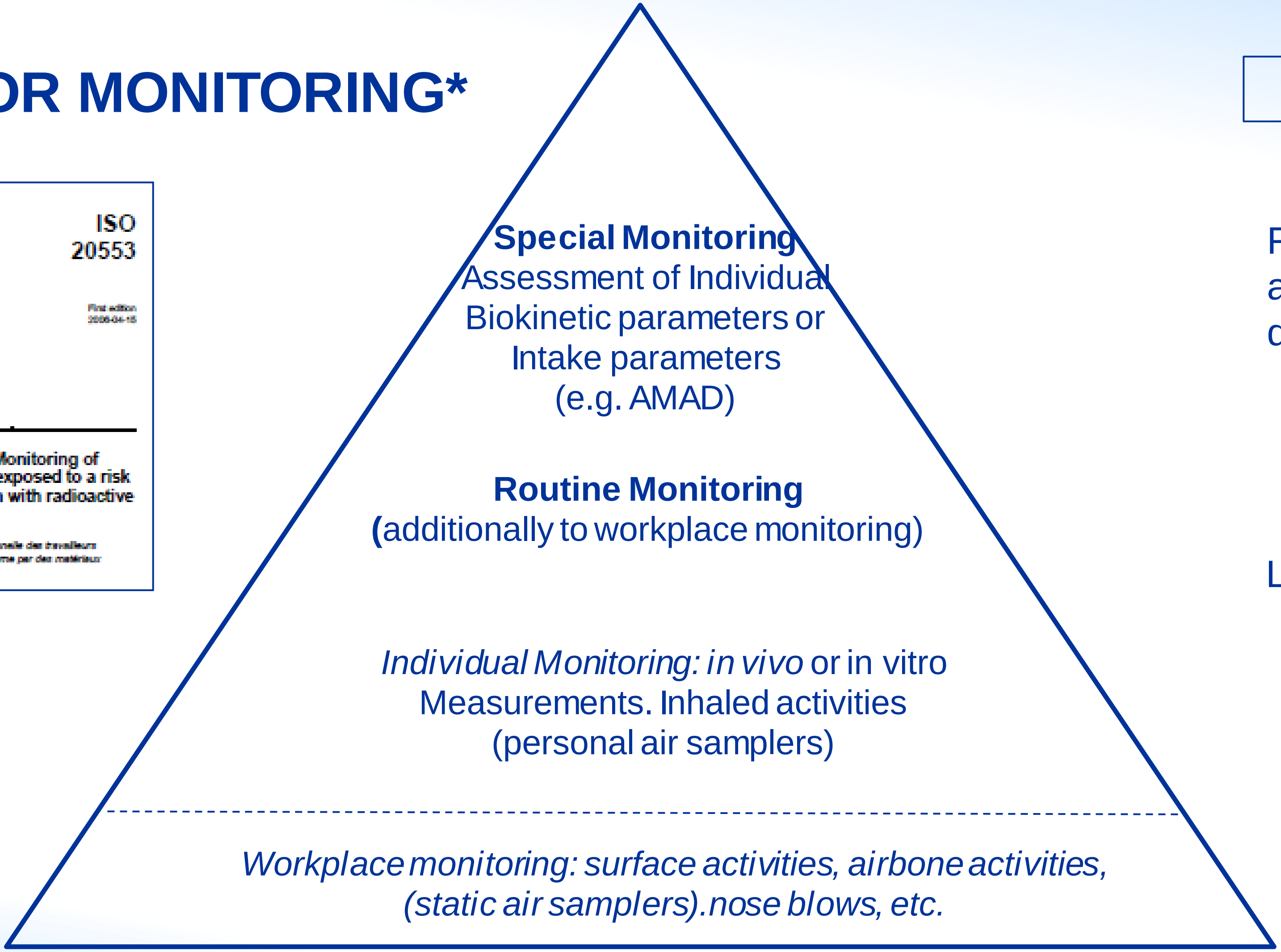


**Recommended criteria**

Following actual or suspected abnormal events, especially if the dose potentially exceeds dose limits

Likely annual total dose ≥ 6 mSv

Likely annual committed effective dose ≥ 1 mSv

* Figure 1 of ISO20553:2006 Radiation Protection “*Monitoring of Workers Occupationally Exposed to a Risk of Internal Contamination with Radioactive Material*”

# CRITERIA FOR THE NEED FOR MONITORING

- **NEED FOR MONITORING – a proposed methodology based on "<u>decision factor</u>"**

  ✓ **Individual monitoring is based on exposure potential.**

  | |
  |---|
  | **Committed effective dose E(50) ≥1 mSv in a year?** |

  - Consider various factors, including:
    - The physical form safety factor $f_{fs}$,
    - The handling safety factor $f_{hs}$,
    - The protection safety factor $f_{ps}$.
  - Material form (e.g. volatile liquid, powder) may be taken into account :
    directly (i.e., $f_{fs}$) and
    indirectly, through the protective measures being taken
    (i.e. $f_{hs}$ and/or $f_{ps}$)

# CRITERIA FOR THE NEED FOR MONITORING

- **NEED FOR MONITORING – a proposed methodology** (cont.)

**Physical form safety factor** $f_{fs}$

Based on the physical and chemical properties of the material being handled. In the majority of cases, should be given a value of 0.01.

**Handling safety factor** $f_{hs}$

Based on experience of the operation being performed and the form of the material.

# CRITERIA FOR THE NEED FOR MONITORING

- **NEED FOR MONITORING – a proposed methodology** (cont.)

**Handling safety factors, $f_{hs}$**

| | |
|---|---|
| Storage (stock solution) | 0.01 |
| Very simple wet operations | 0.1 |
| Normal chemical operations | 1 |
| Complex wet operations (spills) | 10 |
| Simple dry operations | 10 |
| Handling of volatile compounds | 100 |
| Dry and dusty operations | 100 |

# CRITERIA FOR THE NEED FOR MONITORING

- **NEED FOR MONITORING – a proposed methodology** (cont.)

**Protection safety factor** $f_{ps}$

Based on the use of permanent laboratory protective equipment (e.g. glove box, fume hood).

| | |
|---|---|
| Open bench operations | 1 |
| Fume hood | 0.1 |
| Glove box | 0.01 |

# CRITERIA FOR THE NEED FOR MONITORING

- **NEED FOR MONITORING – a proposed methodology** (cont.)

**Specific radionuclide <u>‘decision factor’</u>**

$$d_j = (A_j \bullet e(g)_{j,inh} \bullet f_{fs} \bullet f_{hs} \bullet f_{ps}) / 0.001$$

$A_j$ - cumulative activity of radionuclide j in the workplace over a year,

$e(g)_{j,inh}$ - inhalation dose coefficient (Sv/Bq) for inhalation of radionuclide j,

0.001 - conversion from Sv to mSv.

# CRITERIA FOR THE NEED FOR MONITORING

- **NEED FOR MONITORING – a proposed methodology** (cont.)

  ✓ **Use of decision factor - an example**

  - Single radionuclide handled on the open bench ($f_{hs}$ = 1).
  - Normal chemical operations ($f_{ps}$ = 1).
  - Default value of $f_{fs}$ = 0.01.
  - For $d_j = 1$, $A_j = 0.1/e(g)_{j,inh}$
  - $I_{j,inh,L} = 0.02/e(g)_{I,inh}$
  - $A_i = 5\ I_{j,inh,L}$

# CRITERIA FOR THE NEED FOR MONITORING

- **NEED FOR MONITORING – a proposed methodology** (cont.)

**<u>Cumulative</u> decision factor**

✓ Cumulative decision factor, D, for **<u>all radionuclides</u>** in the workplace;

$$D = \sum_j d_j$$

✓ **If D is 1 or more, a need for individual monitoring would be indicated,**

✓ **If D is less than 1, individual monitoring may not be necessary.**

# CRITERIA FOR THE NEED FOR MONITORING

- **NEED FOR MONITORING – a proposed methodology** (cont.)

  ✓ **More than one radionuclide in the workplace?**

  **Decisions to conduct individual monitoring for the separate radionuclides** may be based on the **following criteria**:

  - All radionuclides for which $d_j \geq 1$ shall be monitored;
  - When $D \geq 1$, radionuclides for which $d_j \geq 0.3$ should be monitored; and
  - Monitoring of radionuclides for which $d_j$ is much less than 0.1 is unnecessary.

# CRITERIA FOR THE NEED FOR MONITORING

- **NEED FOR MONITORING – a proposed methodology** (cont.)

## *Workplace example*

- ✓ Insoluble Pu-239
- ✓ Normal chemical operations in a fume hood.
- ✓ Default AMAD (particle size) for workplaces of 5 µm.
- ✓ Values of $f_{fs}$, $f_{hs}$, and $f_{ps}$ are taken to be 0.01, 1.0, and 0.1, respectively.
- ✓ Then the decision factor:

$$d_{Pu239} = 10 A_{Pu239} \times 8.3 \times 10^{-6} \times 1 \times 0.1 = 8.3 \times 10^{-6} A_{Pu239}$$

# CRITERIA FOR THE NEED FOR MONITORING

- **NEED FOR MONITORING – a proposed methodology** (cont.)

***Workplace example – $^{239}$Pu***

- ✓ Individual monitoring would be required if $A_{Pu239}$, the activity of $^{239}$Pu, is greater than:

$$\frac{1}{8.3\times10^{-6}}=1.2\times10^{5}\,Bq$$

- ✓ Otherwise, individual monitoring would not be required.

# CRITERIA FOR THE NEED FOR MONITORING

- **NEED FOR MONITORING – a proposed methodology** (cont.)

***Workplace example - $^{239}Pu + ^{137}Cs$***

- ✓ Cs-137 is handled in the same workplace,
- ✓ $d_{Pu239}$ remains the same, and
- ✓ *D*ecision factor for Cs-137 is given by:

$$d_{Cs137} = 6.7 \times 10^{-9} A_{Cs137}$$

- ✓ where $A_{Cs137}$ is the activity of Cs-137 present in the workplace.

# CRITERIA FOR THE NEED FOR MONITORING

- **NEED FOR MONITORING – a proposed methodology** (cont.)

***Workplace example - $^{239}$Pu + $^{137}$Cs***

- ✓ If $$D = 8.3 \times 10^{-6} A_{Pu\,239} + 6.7 \times 10^{-9} A_{Cs\,137} \geq 1$$
- ✓ Individual monitoring should be performed for any nuclide for which, $d_{j \geq 0.3}$, for:
  - Pu-239: if $A_{Pu239}$ is greater than 36 kBq,
  - Cs-137: if $A_{Cs137}$ is greater than 45,000 kBq.
- ✓ Individual monitoring is unnecessary for Pu-239 if $A_{Pu239}$ is much less than 12 kBq and for Cs-137 if $A_{Cs137}$ is much less than 15,000 kBq.

# REFERENCES – UNIT 2 - CRITERIA FOR THE NEED FOR MONITORING

IAEA


EUROPEAN COMMISSION, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna (2014).

INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR OFFICE, Occupational Radiation Protection, IAEA Safety Standards Series No.GSG-7, IAEA, Vienna (2018).

INTERNATIONAL ATOMIC ENERGY AGENCY, *Indirect Methods for Assessing Intakes of Radionuclides Causing Occupational Exposure, Safety Guide,* Safety Reports Series No. 18, ISBN 92-0-100600-4 (2000).

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, *Individual Monitoring for Internal Exposure of Workers: Replacement of ICRP Publication 54*, ICRP Publication 78, *Annals of the ICRP* 27(3-4), Pergamon Press, Oxford (1997).

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. RADIATION PROTECTION – *Monitoring of Workers Occupationally Exposed to a Risk of Internal Contamination with Radioactive Material*. ISO 20553:2006. (ISO:Geneva) (2006)