Practical implementation of ALARA and ALARA tools

Vermeersch Fernand
Head of the Unit, Safety, Control and Environment
Contents

- Background to the ALARA concept
- The ALARA procedure
- Practical implementation
- Communication in ALARA
- Tools
- Organisation
Background to the ALARA concept
Risk and risk reduction
deterministic versus stochastic effects

linear dose-effect relationship
no threshold!

law of diminishing returns (glazing)

- \( X_1 - X_0 \rightarrow S_0 - S_1 \)
- \( X_2 - X_1 = X_1 - X_0 \rightarrow S_2 - S_1 \)
- \( S_2 - S_1 < S_0 - S_1 \)
Background to the ALARA concept reasonable risk reduction

• never infinite resources available!
  → need for optimisation

• two points are worthy to note:
  • it is not the minimisation of doses at all costs
  • even if there is a threshold
Background to the ALARA concept
Tolerable and Residual risk

Dose

Dose limit

Tolerable risk

ALARA Level

Residual Risk

→ To reach an agreement on the residual risks
Background to the ALARA concept

Starting points

→ first: everyone *safety conscious*

→ secondly: guidance on interpreting the ALARA principle

• *good practice*

• *real optimisation*

  (= systematic approach = ALARA procedure)

  + use of cost-benefit analysis

• = decision-aiding techniques
Where can I find some guidance

- ALARA from theory towards practice
  - CE, report EUR 13796 EN
- Information System on Occupational Exposure (ISOE)
  - Workshops
  - Publications
- European ALARA network
  - Workshops
  - Recommendations
  - Newsletters
  - Sub networks
- BVS ALARA training day

"I hear and I forget. I see and I remember. I do and I understand."

Confucius
How to we organise the work according to ALARA

Radiation protection
and
ALARA

Idea

The decision

The work
The ALARA procedure

1. Definition of the problem
2. Identification of options, factors and boundary conditions
3. Quantification of the options
4. Comparison and selection
5. Sensitivity analysis
6. Decision

Decision techniques

ALARA from theory towards practice
EUR 13796 EN
ALARA procedure
Definition of the problem

- Are the actions that we plan justified
- What are the actions that are planned
  - Size of the problem
  - Type of action (inspection, maintenance, decommissioning, installation, outage, ...)
  - Duration of the work
  - Number of people involved
  - Location of the work
  - Frequency of the actions
  - Sequence of the actions
- What are the radiological risks involved
- What are the industrial risks involved
To clearly define your ALARA problem
Communicate!

Radiation protection
• Radiological characterisation of the site

Planer
• Work description
• Site information

ALARA analyst

Workers and Technicians
• Work duration
• Technical realisation
Radiological characterisation of the workplace

• History of the site, return of experience
  - Information on the use of the site
  - Typical isotopic vectors

• Radiological measurements
  - Contamination
  - Air contamination
  - Dose rate measurements ($4\pi$)
  - Spectral analysis of sweeps, liquid samples,…
  - Gamma scanning, gamma camera’s
Results of the Radiological characterisation

- Dose rates at worker positions
- Dose maps
- Contamination levels
- Isotopic vectors
- Localisation of sources
- Determination of the relative strength of sources
Dose rates
Dose rate maps

Dose rate at worker position

Localisation of hotspots
Technical characterisation of the workplace

- Site history
- Geometry
  - Plans of the site
  - Geometric scanning or survey
- Materials
  - Technical description of the site
- Technical limitations
  - Technical description of the site
• Breakdown of the work description in smaller units
  ✓ Number of people
  ✓ Location
  ✓ Duration
  ✓ Techniques used

"Préparation" du chantier
- obturation des fenêtres de la piscine RC (7) 2 5
- Ventilation mobile BR2 3 8
- Stand de découpe (installation / check) 3 4
- Marquage tuyauteries 2 12

Modifications des circuits
- Eau de service 2 10
- Air comprimé
  - SOD 3 24
  - OD (niet) 2 10

Mise en sécurité NST
- vase d'expansion 2 2

Démantèlement points chauds + autres opérations
- Pompe MC n°2 2 2
- Herp's 2 2
- Ligne collecte d'effluents 2 3
- Déshabillage DDT supérieur 2 4
- Déshabillage SPHx 2 4
- Spray System 2 5
- Déshabillage DDT inférieur (dont L.O. + HDT) 2 3
- Piqûres tuyauteries primaires 2 3
- Déshabillage MBT + évacuation 2 4
- Piqûres GV 2 3
- Démantèlement ligne N° 2 2
Identification of dose reducing options

• What can we do to reduce the dose?

Reduce exposure time
- More efficient tools
- Better work conditions (light)
- Better design of components
- Optimising work sequences
- Training

Increase distance
- More efficient long handling tools
- Better design of components
- Optimising work sequences
- Training
- Move sources
- Decontamination

Shielding
- Introduction of shielding
- Better design of the installation towards shielding
Multidisciplinary approach

- Brainstorming
  - Dose evaluation and dose reducing options
  - Work planning, organization of the work place
  - Return of Experience
  - Expert of the installation
  - Expert of the specific technological solutions used

⇒ Ways to plan the work

Dose reducing options
How efficient are my dose reducing options

• Cost of protection
  - Direct capital cost
  - Indirect capital cost
  - Operational cost
  - Direct gain

• Radiation doses
  - Collective dose
  - Individual dose
  - Occupational versus public dose
  - Dose distribution over time
Dose Factors

- Collective dose

\[ S = \sum_i H_i P_i \]

- Individual dose

  - Avoid unequal distribution of the risks

- Avoid dose transfer
Means to assess dose

- Using tables based on the measured dose rates at the worker position
- Dose calculation programs to assess shielding effectiveness
- Work simulation programs
### Dose Tables

**Advantage**
- Quick assessment possible

**Disadvantage**
- Static, difficult to examine change in the environment
- Difficult to investigate dose reducing options, needs a combination with dose calculation programs (MicroShield, MCNP, ...) to reassess the dose rates changes.

\[ S = H \cdot T \cdot N \]

- **S** = dose
- **N** = number of workers
- **T** = task duration
- **H** = dose rate

<table>
<thead>
<tr>
<th>Task Description</th>
<th>Total Dose (Gy)</th>
<th>Task Duration (h)</th>
<th>Number of Workers</th>
<th>Rate (Gy h(^{-1}))</th>
<th>Total Dose (Gy)</th>
<th>Task Duration (h)</th>
<th>Number of Workers</th>
<th>Rate (Gy h(^{-1}))</th>
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</thead>
<tbody>
<tr>
<td>Task 1</td>
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<td>2</td>
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<td>2</td>
<td>2</td>
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<td>0.5</td>
<td>0.5</td>
<td>4</td>
<td>2</td>
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<tr>
<td>Task 3</td>
<td>0.75</td>
<td>3</td>
<td>2</td>
<td>0.25</td>
<td>0.5</td>
<td>3</td>
<td>2</td>
<td>0.25</td>
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<tr>
<td>Task 4</td>
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<td>2</td>
<td>0.75</td>
<td>0.5</td>
<td>6</td>
<td>2</td>
<td>0.25</td>
</tr>
</tbody>
</table>

*Note:* Calculations based on assumed conditions.
Simulation programs

- VR-Domain Rolls Royce Associates
- Virtual radiation field Un. Florida
- VR-dose Halden VR-centre
- HesPi UPM
- ErgoDose NNC
- CHAVIR (Chantier Virtuel)
- VISIPLAN
  3D ALARA planning tool (SCK•CEN)
Simulation programs

VRDose IFE Halden

VISIPLAN 3D ALARA planning tool SCK•CEN

ErgoDose NNC

CHAVIR CEA- Liste
Dose analysis

VISIPLAN 3D ALARA planning tool

Analysis of individual trajectories

Analysis of scenarios

Scenario comparison
Steps in the analysis

1. 3D Model building
2. General analysis based on dose maps
3. Detailed analysis based on trajectory simulation
4. Follow up of the dose uptake during the work
Example Fuel loading
ALARA assessment with VISIPLAN 3D ALARA planning tool

Characterization of the site

Model building

Development of the geometry and source changes in the project

Trajectory definitions

Scenario definition

Scenario comparison

Radiological

Geometry and materials

Validation of the model

Evaluation of shielding strategies

Evaluation of source reduction techniques

Dose evaluation on trajectories

Scenario dose evaluation

Scenario selection

Scenario comparison
Decision techniques

- Cost benefit
- Cost effectiveness

De monetary reference value of the avoided unit of exposure man.mSv

(More a baseline reference value then an operational tool → no regulatory status)

(Belgium 39-2200 Euro/man.mSv depending on the exposure conditions)
DOSE

\[ Y = \sum_{j} \alpha_j S_j \]

KOST

\[ C \]

Total cost of an option = \( Y + C \)

Optimisation
Sensitivity analysis

- Is my selection of the final scenario influenced by the uncertainties in my base assumptions
- Take into account the uncertainties in
  - Dose measurements
  - Determination of the source strength
  - Isotopic vector
  - Modelling as a whole
  - Alpha-value
- What if ? analysis
Decision

• ALARA results = support to the decision maker

• Needs a correct representation of
  • assumptions
  • reliability
  • ...
  • $\alpha$-waarde
  • pre-job studies (dose, dose rates, …)

• The decision needs traceability
Is our job done now?

• No

➢ Communicate the strategy or the selected option and the residual risk

<table>
<thead>
<tr>
<th>&quot;Préparation&quot; du chantier</th>
<th>man</th>
<th>h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obturation des fenêtres de la piscine RC (7)</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Ventilation mobile BR2</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Stand de découpe (installation / check)</td>
<td>3</td>
<td>4</td>
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<td>Marquage tuyauteries</td>
<td>2</td>
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<table>
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<tr>
<th>Modifications des circuits</th>
<th>man</th>
<th>h</th>
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<tbody>
<tr>
<td>Eau de service</td>
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<td>10</td>
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<tr>
<td>Air comprimé</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>SOD</td>
<td>3</td>
<td>24</td>
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<tr>
<td>OD (niet)</td>
<td>2</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Mise en sécurité NST</th>
<th>man</th>
<th>h</th>
</tr>
</thead>
<tbody>
<tr>
<td>vase d'expansion</td>
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<td>2</td>
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</tbody>
</table>

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<th>Démantèlement points chauds + autres opérations</th>
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</tr>
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<tbody>
<tr>
<td>Pompe MC n°2</td>
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</tr>
<tr>
<td>Herp'i's</td>
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<td>2</td>
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<td>3</td>
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</table>

Make the workers aware of the residual risk.
And now, is our job done?

• No
• follow up is needed
  ➢ Are the doses according to the predicted ones?
  ➢ If there are discrepancies why is this the case?
  ➢ Are corrective actions needed and can we install them
Follow up tools

- Operational dosimetry
- Feedback reports
- Feedback databases
Operational dosimetry

- Close follow up of the dose uptake for the specific actions
- Clear reporting, easier to establish REX
ALARA databases

- Allows to organize the information on the practices and their authorisations
- Allows easy consultation for REX
Implementing ALARA

- In order to implement and use ALARA tools you need to establish a set of procedures describing:
  - The structures and persons within the organisation that are responsible for the ALARA follow up
  - The extend of the means put into action for a given exposure level
  - The hierarchical level of the final decision
ALARA procedure at the SCK•CEN

Schatting van de te verwachten dosis
S (man.mSv) – MID (mSv)

S < 0.5 man.mSv
- Lokaal ALARA comité
- Aanvrager
- ALARA coördinator
- Agent SK
- Toelating SCK coördinator bij nieuwe procedure

0.5 man.mSv < S < 5 man.mSv
- SCK coördinator

S > 5 man.mSv of MID > 1 mSv
- SCK ALARA comité
- Vertegenwoordigers installaties
- Fysische Controle
- Industriële veiligheid
- Medische dienst
ALARA procedure and feedback put into practice

Workers and Technicians
- Work duration
- Technical realisation

Radiation protection
- Radiological characterisation of the site

Planner
- Work description
- Site information

ALARA analyst
Brainstorming
Evaluate options
Decision
Dose follow up
ALARA database
REX
Conclusion ALARA

- **Precaution**
  - The existing scientific evidence at this moment for exposures to the low doses leads us to adopt the LNT approach

- **Responsibility**
  - Limited resources
  - Residual risk

- **Transparency**
  - Decision based on a compromise
  - Clear indication of the exposure levels
  - The applied means put into practice to reduce the dose must be clear and verifiable