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9. Case Study 6: Optimization of occupational radiation protection in managing disused radioactive source category 3

Implementing optimization for managing disused Category 3 sources

What to do with category 3 sealed sources (SRS) when disused?

- What is the situation?
- What are the doses and risks stakes?
- What are the possible technical strategies?
- What does it mean “implementing optimization in selecting “the” strategy”?
- What does it mean “implementing optimization for the selected strategy?”

What is the situation? Category 3 sources

Increasing Risk

Category	Practice	Activity Ratio A/D
1	RTG's; Irradiators; Teletherapy; Gamma Knife	A/D>1000
2	Gamma radiography Brachytherapy (HDR/MDR)	1000>A/D>10
3	Fixed industrial gauges (e.g.: level, dredger, conveyor gauges) Well logging	10>A/D>1
4	Brachytherapy (LDR except eye plaques & perm implants) Portable gauges; Static eliminators; Bone densitometers	1>A/D>0.01
5	Brachytherapy (eye pl. & perm implants); XRF; ECD	0.01>A/D>Exempt/D

A = source activity; D = radionuclide-specific "dangerous" activity

Examples of category 3 sources:

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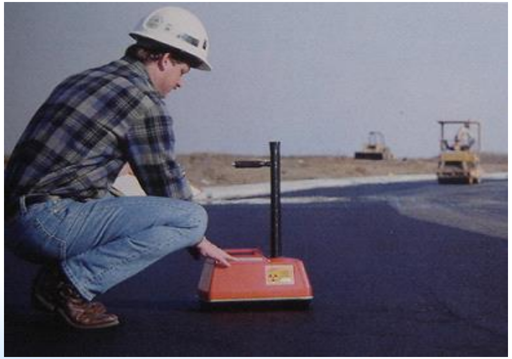
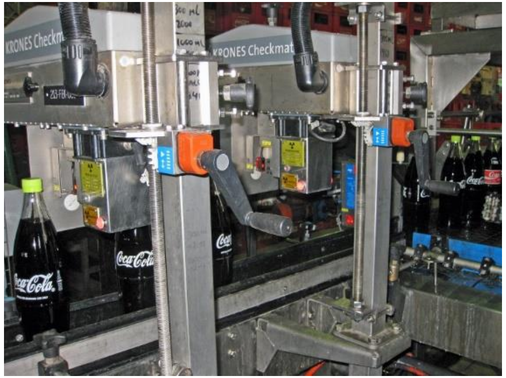
fixed and mobile gauges for different situations

Disused density gauge Cs-137

Disused density gauges Cs-137



Mobile moisture/density gauge
with Am-241/Be and Cs-137



Fixed level gauges Am-241

What is the situation?

Sources are very widely used throughout the world

1 For many reasons they may become disused (accident, obsolescence, change of target, firm bankruptcy, source activity decrease,…)

2 Regularly disused radioactive sources of category 3 are recovered by one national organisation, through campaigns of recovery.

3 When around a few tens or hundreds have been recovered they are “managed” for being stored at least “temporarily”

4 Let consider we are at the design stage of the strategy for managing on the long term these disused sources at a country level, we will follow the already presented scheme

What is the situation?

first global approach of the stakes

↓

integration of radiation protection into selecting technical scenarios

↓

second detailed approach of the stakes for the selected scenario

First global approach of the (radiological) stakes

1. Even after a few decades of operation, disused gauges may still contain:

   Cs-137 of a few GBq (a few hundreds of mCi)
   Co-60 0.1-1 GBq (a few tens of mCi)

2. When all these sources are enclosed in their shielding, there is nearly no occupational exposure.

3. However there are situations where occupational exposure may occur: *when the sources are unshielded and this can happen either accidentally or on purpose*

4. What should then be the doses?

First global approach of the (radiological) stakes

Unshielded sources may deliver a dose rate

Cs-137 of 3.7 GBq (100 mCi)	at 1m	0.29	mSv/h
	at 10cm	28	mSv/h
Co-60 of 0.37 GBq (10 mCi)	at 1m	0.11	mSv/h
	at 10cm	11.4	mSv/h

Annual dose limit for workers 20 mSv/y through five consecutive years or 50 mSv in a single year (GSR Part 3)

Annual dose may be delivered within minutes or hours !

This is not trivial !
It has to be taken into account in selecting the strategy.

The possible strategies? (1)

Is it worthwhile envisaging to keep the sources on each industrial site?

If not, which alternates/options can be envisaged?

Which criteria should be taken into account?

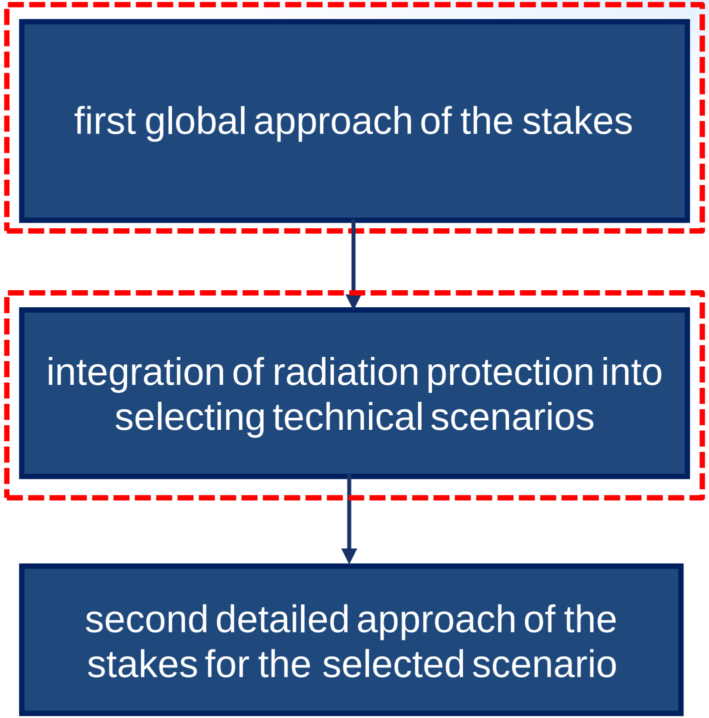
The possible strategies? (2)

Two basic methods for conditioning disused sealed radioactive sources have been proposed.

Scenario 1: It corresponds to the emplacement of the devices containing the radioactive sources into concrete lined steel drums (with big hole inside); 10 drums for a campaign of 100 recovered sources

Scenario 2: The other method involves the removal of the radioactive sources from their devices or containers, over-encapsulating them (five to ten sources per capsule) and emplacing the capsules in a package providing both shielding and physical protection. The packages are then put into a drum; only 2 drums are needed then (1 for Co-60 sources and 1 for Cs-137 sources)

The possible strategies? (3)

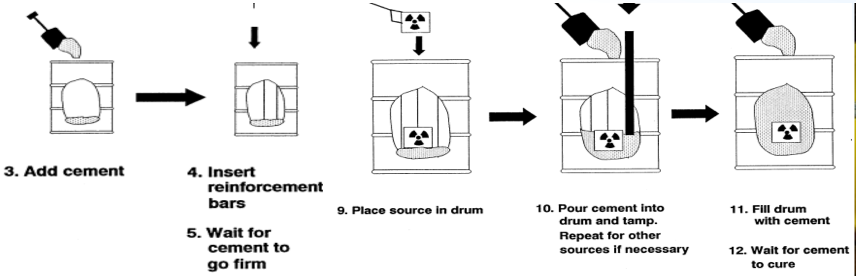


Strategy one: embedding into concrete lined steel drums

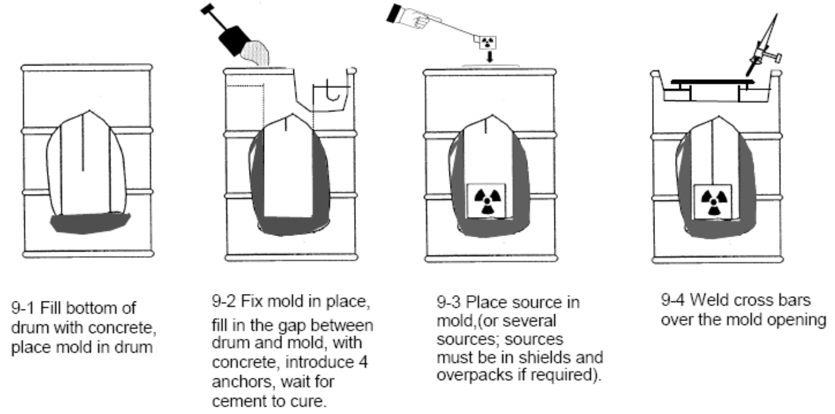
- Simple and well established technique
- A 200 l steel drum filled (non retrievable) or lined (retrievable) with concrete and closed is suitable for a Type A package for transportation – total activity limitation
- Provides barrier against loss of containment due to mechanical shock
- Provides for some degree of security, unauthorized removal (e.g. theft) would be difficult due to weight and robustness
- May be acceptable for near surface disposal
- Typical for Category 3 sources, without removing sources from their shielding containers

Strategy one: ”Irretrievable” and ”retrievable” versions – i.e. grouting or prefabricated cavity

”Irretrievable” Conditioning (filled)
Short-lived ($T_{1/2} \leq 30y$) gamma gauges and other smaller sources



”Retrievable” Conditioning (lined)



Strategy two (1) :
Removal of sources from devices

This means removal from shielding! ; here it is “on purpose”.

Encapsulation of bare sources in stainless steel capsule

Due to dose rates, one can expect that special tools, equipment and expertise will be used

Strategy two (2) : Removal of sources from devices

Strategy two (3) : Removal of sources from devices

significant volume reduction

capsules may be accepted for disposal (e.g. for bore hole disposal)

manipulation of unshielded sources of Cat.3 may increase the risk due to radiation exposure, the most relevant when operators are inexperienced

Selection of the strategy

Which criteria should be taken into account?

Selection of the strategy

Technical feasibility

Room availability

Easiness and safety for transport

Protection against robbers

Costs

- investment cost for the land
- Investment cost for the infrastructure
- costs of the drums
- cost of the manipulation (man power)
- cost of shielding
- Cost of (special) tools
- costs of workers training

Doses

- in normal operation
- in accidental situations

Selection of the strategy: rough estimation of costs

Criteria	Strategy 1	Strategy 2
Investment cost for the land	150000 €	0
Investment cost for infrastructure	150000 €	0
Total investment cost	300000 €	0
costs of the drums	X	X/5
manpower	Y	Y x 10
Shielding	0	Z
Special tools	0	W
training	0	T
Total operation cost	5000 €	40000 €
Total annual cost (if 1 to 3 operations per year)	20000 to 60000	40000 to 120000 €

From a strict economical point of view S1 is always less costly; but one has to remind the actual expenses for S1 the first year will exceed 300000 € which is maybe not available for the operator !

Selection of the strategy : rough estimation of dose stakes

Criteria	Strategy 1	Strategy 2
in normal operation	0	Dose very quickly > dose limit if not optimised
in accidental situations	Dose very quickly > dose limit Quite low probability (risk1)	Dose very quickly > dose limit Probability higher Risk 2 > risk 1

From a strict exposure point of view **S1** is often worth

What to say about the other criteria ?

Selection of the strategy (synthesis) (1)

Criteria	Strategy 1	Strategy 2
Technical feasibility	+++	++
Room availability	- -	+++
Easiness and safety for transport	++	++
Protection against robbers	++	++
Easiness to be agreed for a final storage	++	++
Investment costs	- -	+
Operation costs	++	- -
Doses in normal operation in accidental situations	 +++ - -	 - - - - -

Quotation of each criteria : from - - - very bad to +++ excellent

What is for you the best solution?

Selection of the strategy (synthesis) (2)

As often at the design stage of an operation or installation the decision is done using explicitly or implicitly a multi criteria approach.

Here no strategy can be said "a priori" as globally better than the other

The appreciation of the criteria is depending of the waste management firm or country context and can be different from one country to another, one firm to another. It is a managerial decision.

Selection of the strategy (3)

Who makes the decision? The waste management operator under the control of the regulatory body and giving explicitly or implicitly some weights to the different criteria.

Does what has been done fits with the ALARA approach?

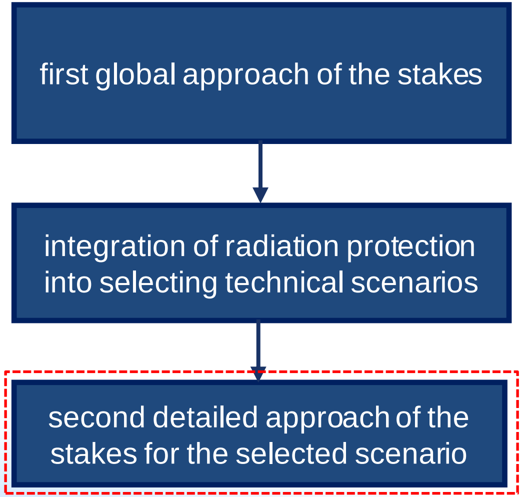
What is important from the ALARA point of view is that radiation protection is actually taken into account within the decision with ad hoc arguments on the stakes; if possible well, even if roughly and quickly, estimated (quantified).

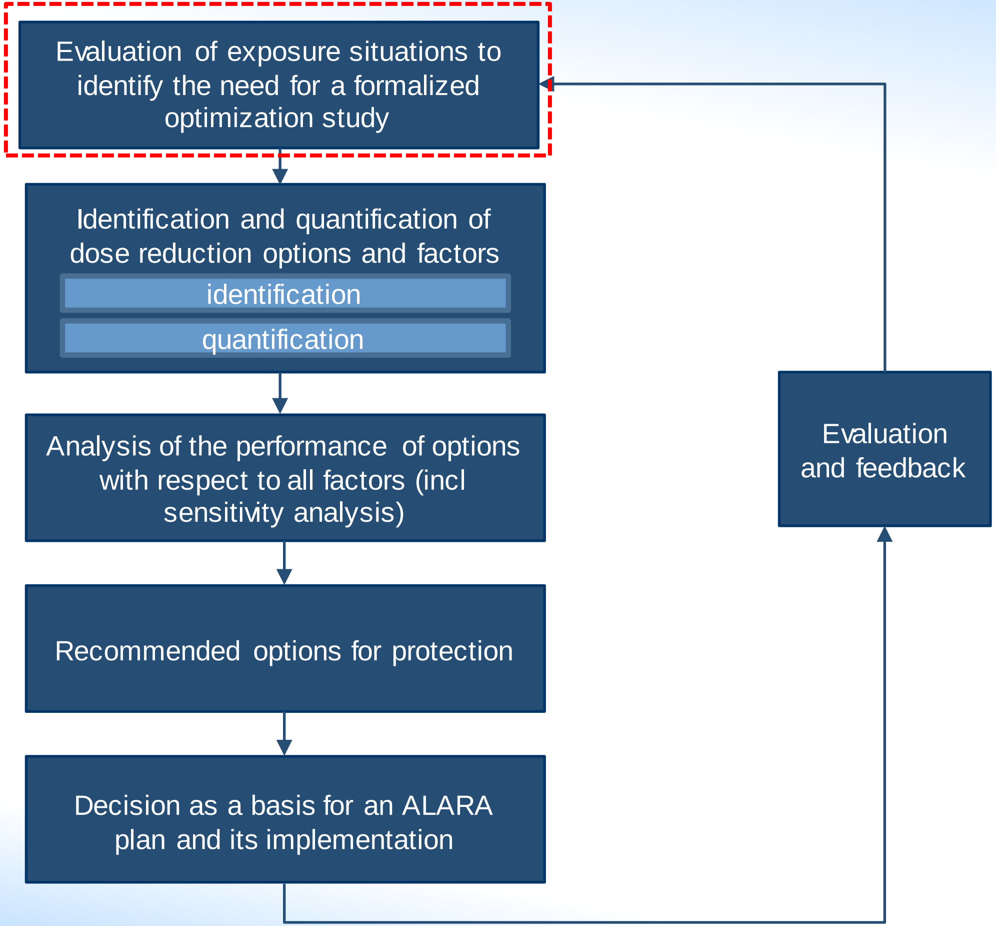
That is where the RPO and QE have a role to play.

And after?

When the strategy one (no “on purpose” breaking of the shielding) has been selected, one can consider implementing optimization will mainly consist in implementing good practices during operations for avoiding any accidental breaking of the shielding.

When the strategy two (waste package reduction) has been selected, then the Optimization procedure must be implemented much more formally.





We have then to evaluate the reference situation when no shielding is used but only good practices such as being at a distance through the use of one or several forceps and other long handled tools for manipulating the source, opening the shielding …

Evaluation of the reference

The waste treatment needs 2 workers during 10 working days ± 50 % for one campaign (average to 100 sources); 3 campaigns are performed each year.

The full "actual" work time is 6h x 2 x 10 = 120 h ± 60 h
3/4 of the time one source is out of shielding i.e 45 hours ± 22,5

The **worker 1** stands at one meter from the source **45 hours**, while the second one is only needed 30 hours (the other 10 hours he is supposed to be in a "no dose" room). If not well trained he stays the **whole time besides the first. Then the total Exposed Work Time** (EWT) **for the reference** is **90 man hours ± 50 %** at one meter from the source out of shielding..

Making use of long handled tools they never go closer to the source than one meter (they have been informed about and they do it).

Per hypothesis, half of the sources are Cs-137, the other half being Co-60

One can then calculate the individual and collective doses

Evaluation of the reference

Cs-137 of 3.7 GBq (100 mCi) at 1m	*0.29 mSv/h*
Co-60 of 0.37 GBq (10 mCi) at 1m	*0.11 mSv/h*

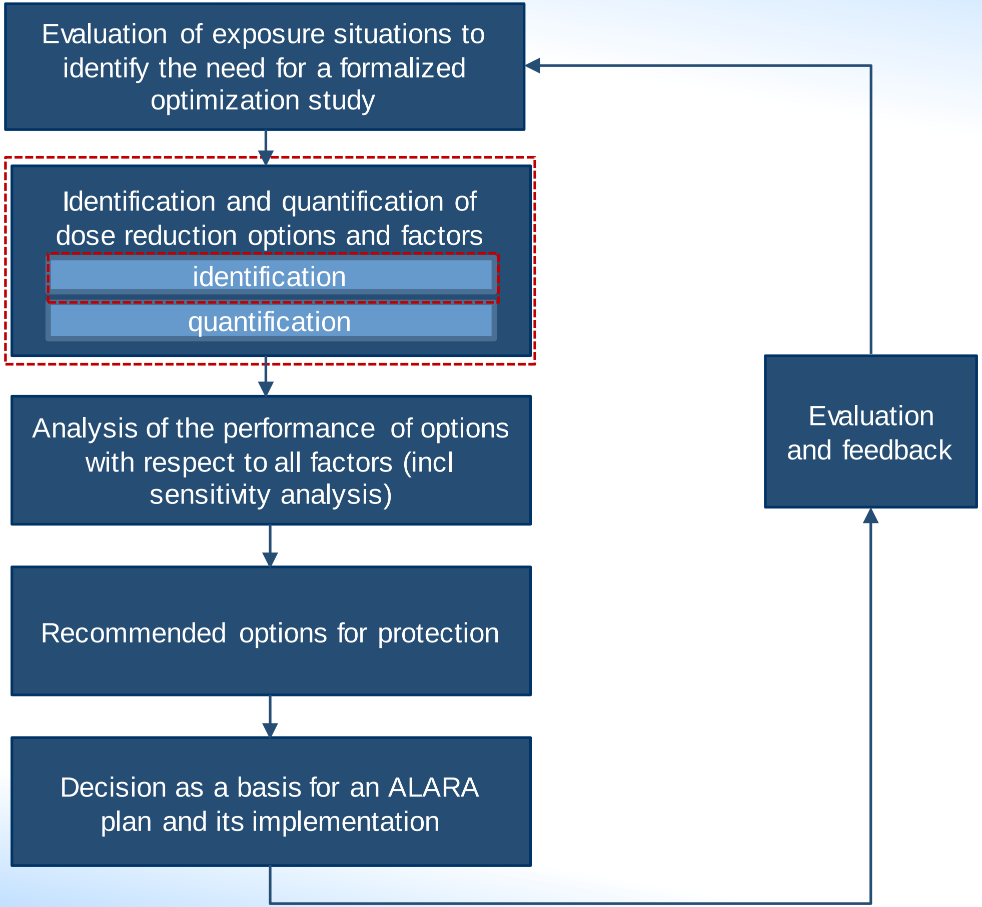
Worker 1	*22,5 h x 0.29 mSv/h + 22,5 h x 0.11 mSv/h =*		
	6,5 mSv + 2,5 mSv	*=*	*9 mSv*
Worker 2	*idem worker 1*	*=*	*9 mSv*

The doses of the each individual, taking into account the uncertainty correspond to (9 ± 4,5) mSv; i.e nearly half of the annual dose limit per campaign (10 days). With that rhythm, the dose limit will be exceeded after the 3 campaigns, which is totally unacceptable. If the workers are not well trained it will be even quicker as they stay may be closer. Of course this does not take into account other activities of the workers.

The collective dose for one campaign is 18 man mSv

For 3 campaigns a year the annual collective dose reaches 54 man mSv

And after?



What options do you propose for optimizing the workers' doses?

Possible options

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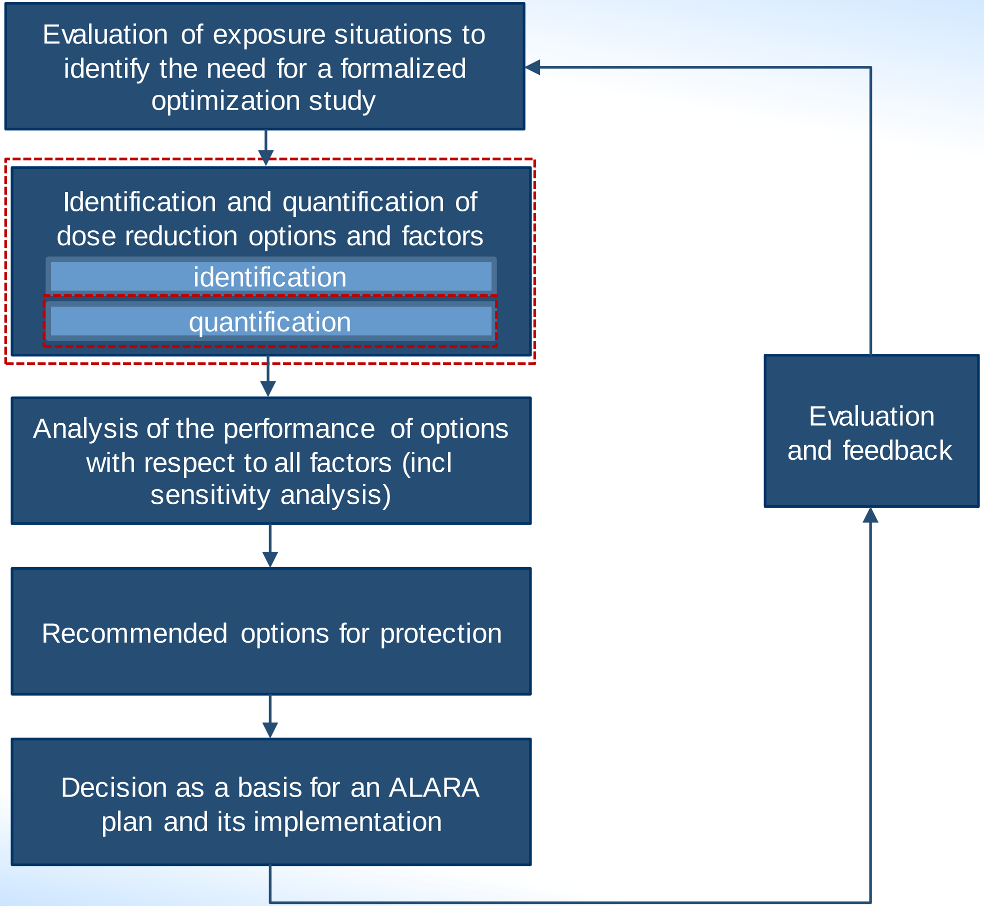
We will keep 3 of them:

Improved training to reduce working time (IT),

A shielded box with remote manipulators (SB)

A closed room with robots plus control outside the room and video surveillance (RCV)

Possible options



Quantifying (1)

Improved training to reduce working time (IT)

This should be an additional training to the basic technical one, more specific to avoid bad gestures, bad positions … and allowing to be more efficient; this will reduce by 20% the EWT due to the increase of efficiency of both workers, plus a decrease of 33% of the dose of the second worker who will go then to the “green” place :

First worker dose 9 x 0.8 = 7,2 mSv
Second worker dose 9 x 0.8 x 0.66 = 4,6 mSv
Collective dose per campaign =11, 8 man mSv

For 3 campaigns per year one of the individuals will remain above the dose limit, which remains totally unacceptable; the annual collective dose will be reduced to 47,2 man mSv.

A one week training (maximum) will be enough for 2 workers
Cost 3000 € each = 6000 € (to be renewed every 5 years) i.e per year 6000/5 =1200 €

Quantifying (2)

A shielded box with remote manipulators (SB)

This can be performed in the same facility as the work just with long handled tools

The efficiency will depends on the width of the shielding
it can reduce by 50 up to 100 the dose rates
doses range then between 0,36 to 0,18 man mSv per campaign.
There is not anymore a risk to exceed the dose limit

The number of campaigns per year is 3
The annual collective dose ranges from 2,16 to 1,08 man mSv

Cost is (partly) depending on the width of the shielding from 50000€ to 60000 € which means for an amortisation on 10 years
Between 5000 and 6000 € per year.

The workers should qualified which adds 2000 € per year

Quantifying (3)

A closed room with robots plus control outside the room and video surveillance (RCV)

The dose will be totally avoided during the operation; but in case of breakdown of the robot with the source out of its container; where it will reach 0.1 to 0.2 mSv for removing the robot outside; the probability of occurrence of that situation is equal to 10% per year

ICRP consider then that we should take 10% of the dose for the year

(*ICRP recommends when the probability of occurrence is higher than 1% to consider as certain the dose multiplied by the probability of occurrence*)

i.e 0,01 to 0,02 mSv per year

Quantifying (4)

A closed room with robots plus control outside the room and video surveillance (RCV)

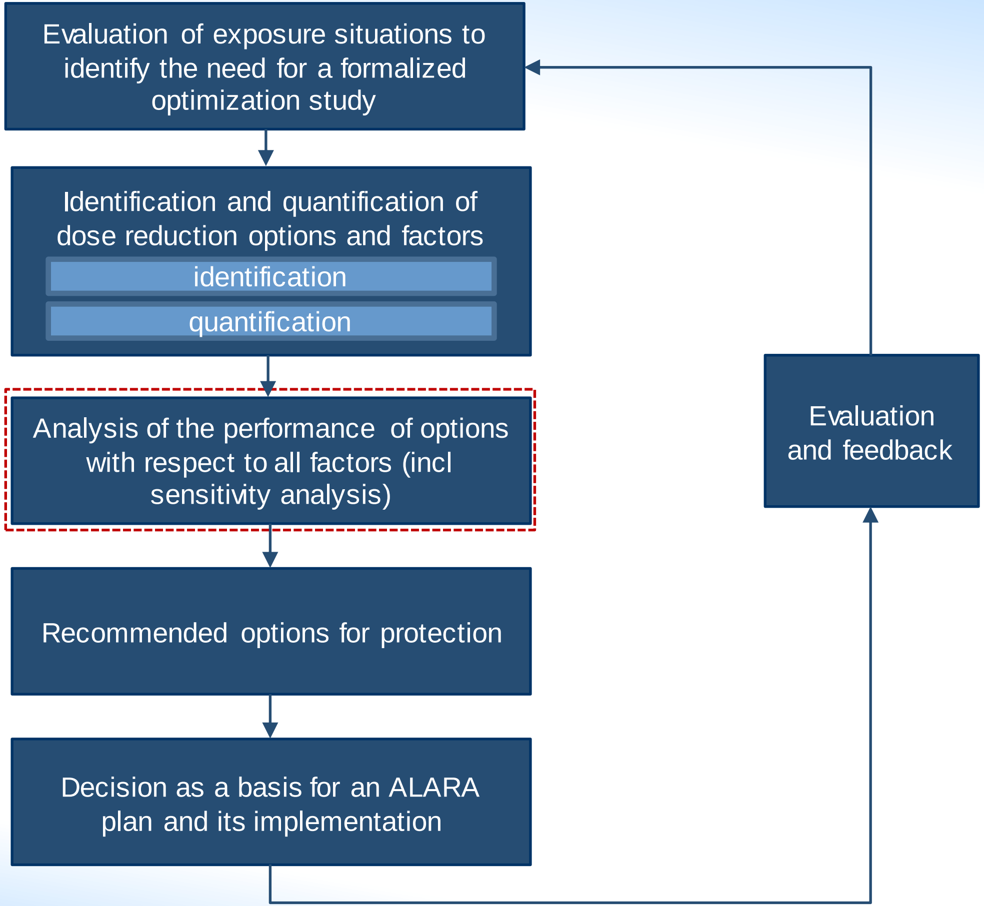
The cost should include the investment cost

- room building 100000 € (for 20 years of life)
- robot acquisition 150000 € (for 10 years)
- video system 50000 € (for 10 years)

And the maintenance cost for the robot and the video : 20000 € per year. The total cost per year should then be:

	100000/20 =	5000 €
+	150000/10 =	15000 €
+	50000/10 =	5000 €
+		20000 €

45000 € per year


Evaluation of exposure situations to identify the need for a formalized optimization study
Identification and quantification of dose reduction options and factors
identification
quantification
Analysis of the performance of options with respect to all factors (incl sensitivity analysis)
Recommended options for protection
Decision as a basis for an ALARA plan and its implementation
Evaluation and feedback

Analyzing (1)

	3 campaigns a year / Red Factor shield is 100				3 campaigns a year/ Red Factor shield is 50			
	Annual dose	Delta dose	Annual cost	Delta cost	Annual dose	Delta dose	Annual cost	Delta cost
REF	54		0		54		0	
IT	47,2	- 6,8	1200	1200	47,2	-6,8	1200	1200
SB	1,08	- 46,12	7500	6300	2,16	-45,04	7500	6300
IT+SB	0,87	-0,21	8700	1200	1,73	-0,43	8700	1200
RCV	0,01	-0,81	45000	36300	0,02	-3,58	45000	36300

Analyzing (2)

	3 campaigns a year / Red Factor shield is 100			3 campaigns a year/ Red Factor shield is 50		
	Delta dose (1)	Delta cost (2)	2 / 1 €/man mSv	Delta dose (1)	Delta cost (2)	2 / 1 €/man mSv
REF						
IT	- 6,8	1200	176	-6,8	1200	176
SB	- 46,12	6300	136	-45,04	6300	140
IT+SB	-0,21	1200	5714	-0,43	1200	2790
RCV	-0,81	39500	48765	-3,58	39500	11033

Analyzing (3)

Having in mind that in developed countries the monetary value used by the “rich” nuclear facilities is at a maximum of the order of 1 to 2000 € per man mSv, whatever the hypothesis

The training is interesting and reasonable but does not fit with dose limitation

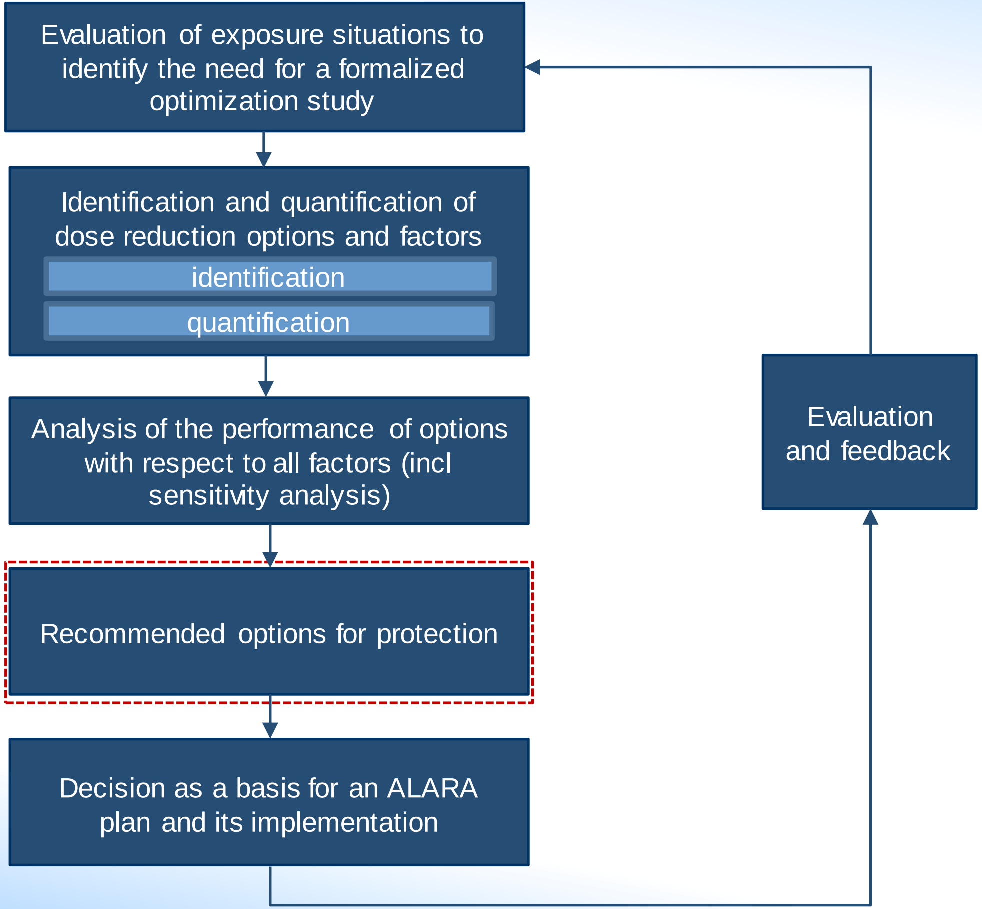
The shielded box is also reasonable

The combination of both is not really reasonable; *One can even think that the training is not anymore adapted to the job performed when the shielding is available*

Going to the robots and its environment is not at all reasonable.

Therefore the optimal option is the shielded box with remote manipulators

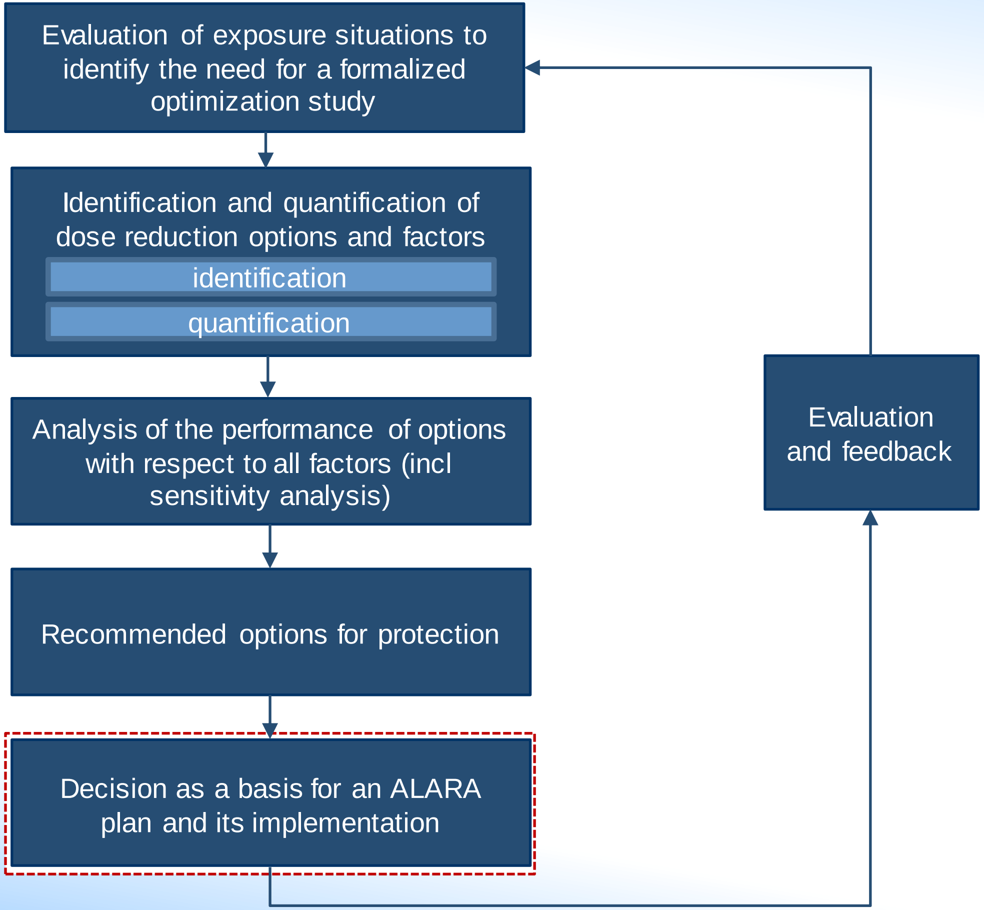
Analyzing (4)



Recommending

When strategy 2 is selected then the optimal solution is the use of the shielded box; this will be the recommended option.

Analyzing (5)



The shielded box with remote manipulators is the option recommended by the Agency and which has been selected in most cases on the spot.

Deciding

The formalization of the Optimization procedure in that case study just confirms then that such a decision is good and optimal