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A BETTER UNDERSTANDING FOR AN IMPROVED EMERGENCY RESPONSE: DEVELOPMENTS AND WAY FORWARD.

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Abstract:

Communication and information exchange is probably one of, if not, the key process in emergency management. A good information exchange must be rapid, targeted to the right users and as informative and relevant as possible. With such conflicting properties, the information exchange will necessary be a compromise between promptness and completeness. It is also essential that the right information reaches the right recipient, in understandable terms taking into account his expertise, role, responsibilities and expectations.

In order to improve the information exchange efficiency between the various stakeholders, from the licensee, through the federal cells and committees, down to the operational level, the media and the general public, communication tools and mechanisms have been developed within stakeholders groups and tested during exercises to improve the process.

In the framework of the Belgian nuclear emergency plan several actions have been taken to improve the information exchange between:

- the licensee of nuclear emergency affected site and off-site authorities and other bodies, namely the experts group in charge of the evaluation of the consequences of a nuclear emergency (so-called "evaluation cell"),
- the evaluation cell and the decision makers,
- the decision makers and the operational level in charge of the implementation in the field of the decided protective actions and, finally,
- towards those responsible for the information of the population.

This paper illustrate to progress made since about ten years and the way forward improving the mutual understanding of involved bodies and consequently improving the nuclear emergency response.

1 INTRODUCTION

Nuclear emergency exercises have regularly identified problems and difficulties in the process of information exchange between the different stakeholders, from the licensee, through the federal cells and committees, down to the operational level. These difficulties contribute to delay the evaluation of the situation, the decision process, the operationalization by the local authorities of the decisions taken at federal level and the associated information to the media and the population.

The information exchange process starts at the level of the Licensee of a nuclear site affected by an emergency who, according to the Belgian regulation, is responsible for providing a prompt notification and regular updates about the on-going situation to off-site authorities and other bodies. The information provided must allow an as accurate as possible evaluation of the situation and of the expected radiological consequences, the identification of relevant protective actions and their implementation.

The following examples highlight some findings issued from past nuclear emergency exercises:

- when technical or radiological information or data are transmitted to non-experts in that fields, they are often misunderstood or misinterpreted, leading to inappropriate response, sometimes in contradiction with the advises of the evaluation expert group and/or decisions taken by the response authority;
- the compilation of a full set information and data (general, technical, radiological…) in a same form, waiting for any form field to be duly documented, leads to transmission delays;
- similar information or data are presented in different ways in the specific forms developed and used by each particular Licensee, complicating the task of the evaluation cell, an expert group in charge of advising the decision makers on protective actions based on technical and radiological assessment of the situation.

In order to improve the information fluxes from the licensee, a working group, starting from existing notification and information forms, developed a coherent set of standardized documents, in first step, for the NPP’s of Doel and Tihange and propose to the other nuclear facilities of concern

(Belgoprocess, SCK•CEN and IRE) to transpose them to cope for their specific needs in the respect of "steering principles" as defined by the working group.

A second important step in nuclear emergency response is the clear delimitation of the zone were protective actions are needed (the intervention zone) based on:

- the assessment of the situation (technical and radiological) and influenced by the source term (actual or potential, in amount and quality),
- the meteorological conditions (presence of rain, atmospheric stability…),
- the land relief
- and the reference intervention guidelines (for evacuation, sheltering, thyroid blocking …) as stated by the Royal Decree [1].

Once delimited, the intervention zone has to be communicated to local authorities and bodies for implementation. Essentially based on the analysis of the radiological consequences the experts of the evaluation cell (CELEVAL) propose to the decision makers (COFECO) an intervention sector (Fig. 1). COFECO integrates other elements into their analysis and decide where protective action should actually be implemented. Often it was noticed that, in exercises, the decision makers extend the area proposed for consideration by the evaluators, often to better fit administrative divisions of the territory and to make sure that no part of the affected area is forgotten and that every person is duly protected. The contours of the resulting intervention zone are then communicated for implementation to the local authorities (provinces and communes) and to the first responders. At the local level, where the best knowledge of the terrain is present, the zone decided by the federal level is revisited to meet field constraints and other operational issues.
Lack of common understanding among this process and steps (evaluation/ assessment – decision – implementation) could also explain the successive extensions of the intervention zone. By the end of day, the size of the intervention area, increased at each step, could be not justified anymore by the actual risk.

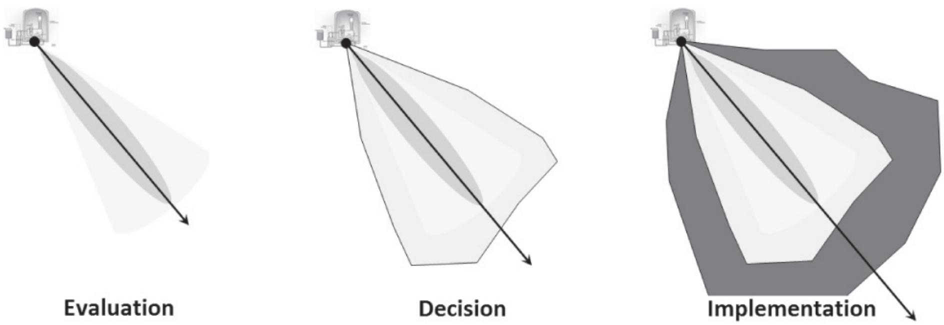


Fig. 1: Intervention zones grow through the process “evaluation (left) – decision (centre) – implementation (right)”.

During exercises, difficulties are also recurrently encountered that delay the process. The reasons are: (i) the transposition of a geometric sector at risk as defined by the evaluation experts into geographic zones where actions are decided and into operational areas where they need to be implemented increasing conservatism at each step, as described above, (ii) the fact that circular planning zones of predefined radius are considered in emergency response plans which do not necessarily coincide in distance with the sector identified for protective actions, (iii) the necessity to translate an area on a map into words for spoken messages when addressing the public and the first responders.

In order to propose mechanisms which would speed up and improve the communication process and common understanding, a working group was set up with representatives of federal and local bodies and intervention teams. The planning zone around the Tihange NPP was used as a case study.

Finally, a web-based platform was established for CELEVAL to submit situation reports and advises regarding the protective actions and the zone were they should be implemented to COFECO. In the future the part of this report describing the action areas will be further transmitted on the same platform to the local authorities for implementation and they will provide the attached maps to inform back the federal authorities on the progress in implementation.

2 HARMONIZATION OF INFORMATION EXCHANGE FORMS

The dedicated working group developed on this first topic six “steering principles” that are discussed and described hereafter.

2.1 Steering principles n°1: self-supported forms

Each set of information or data must be self-supporting and addressed to one (or more) specific recipient(s) who need it and is able to use them appropriately. This offers the threefold advantage of (i) a better targeted information, (ii) a relevant distribution only to those who really need them to perform their duties and (iii) avoids unnecessary delays of their transmission. On the other hand, a drawback might be a larger number of forms.

2.2 Steering principles n°2: a distribution cover page

As result of the application of the first principle, a distribution cover page accompanies each form. This cover page specifies whether the recipient receives the form for “Action” or for “information only”. The expected advantage is to speed up and facilitate the effective dissemination of information and data. The duties meant by “for Action” or “for information only” stated on the cover page of the different forms should be crystal clear to the recipient in order to avoid misunderstandings or displacement of responsibility during emergencies.

2.3 Steering principles n°3: provide sufficient flexibility

By definition, the notification and information forms are intended to cover many situations and aspects. However, it is impossible to cover, in such forms, all possible aspects. Therefore, the forms should provide enough flexibility to cope with unexpected situations and/or items. Therefore, a free text area is systematically included allowing the input of any information or precision in connection with the actual situation. This area should be large enough to allow 2 or 3 sentences. Instructions & guidance’s concerning the type and format of the information or data to be introduced in the free text areas are suggested. Finally, care must be paid to the readability of the text (often manuscript) introduced in these free text areas.

Similarly, it should be obvious that all items or areas of the forms do need not to be necessarily fully filled or completed, as they could be not relevant, nor appropriate or available.

2.4 Steering principles n°4: avoid any duplication of information or data

To optimize human and time resources, the forms should be designed to avoid any unnecessary duplication of information or data. This implies therefore to identify the information or data specific to each topical form.

2.5 Steering principles n°5: possible guidance using the verso/back

In each form, the (not transmitted) verso/back could be valuably used to provide useful hits and tricks to the person in charge of filing it, such as background, instructions, guidance's (how often should I complete and submit the form?, what information or data should be included?, how could I identify data not available?...), context (purpose of the form, identified recipient(s)...), tips or tricks (what should be done particular attention...).

With the expected progressive replacement of the fax transmission by more modern means, such as emails, the proposed guidance could be included in a dedicated User's Guide (or Modus Operandi) specifically designed for each licensee.

2.6 Steering principles n°6: definition of forms categories

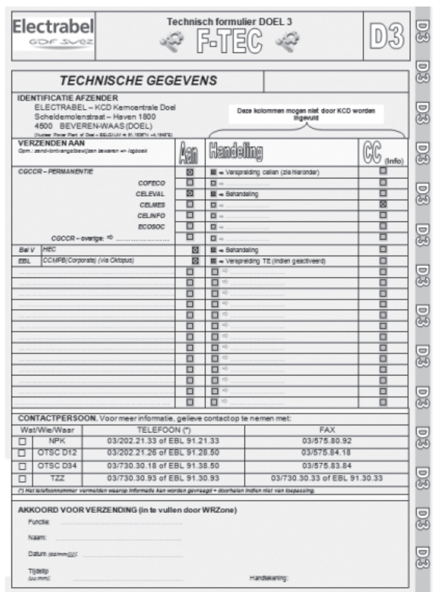
As result of the application of the first steering principle, six categories of forms are identified, as follows:

- **F-NOT** (NOTification): this set of forms includes the initial notification and developments/subsequent notifications. The end of the emergency situation is integrated in the latter one.
- **F-TEC** (TEChnical): This form contains the technical data.
- **F-RAD** (RADiological): This form contains the radiological data, including those associated with the consequences assessments (hypothesis, essential results from the models...) or with field measurements.
- **F-MED** (MEDical): This form contains the medical information concerning the health impact on the site (wounded, dead, involved...). Protective actions (gathering, accounting, stable iodine intake, site evacuation...) taken on-site by the Licensee are also included in this form.
- **F-CONV** (CONventional): This form contains information and data on conventional risk (non-radiological), such as fire, chemical pollution, ...

- **F-COM** (COMmunication): This form contains information relating to communication (press releases schedule and content, identification of spokesperson(s), communications strategy, key messages...)

2.7 Examples of revised forms

Fig. 2 and Fig. 3 give two examples of revised forms developed according to the above described steering principles.



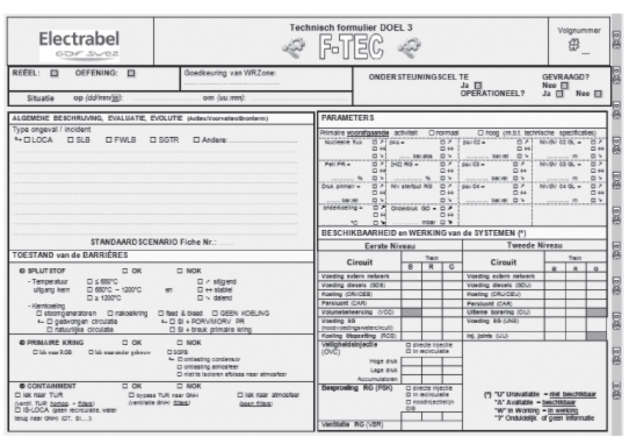
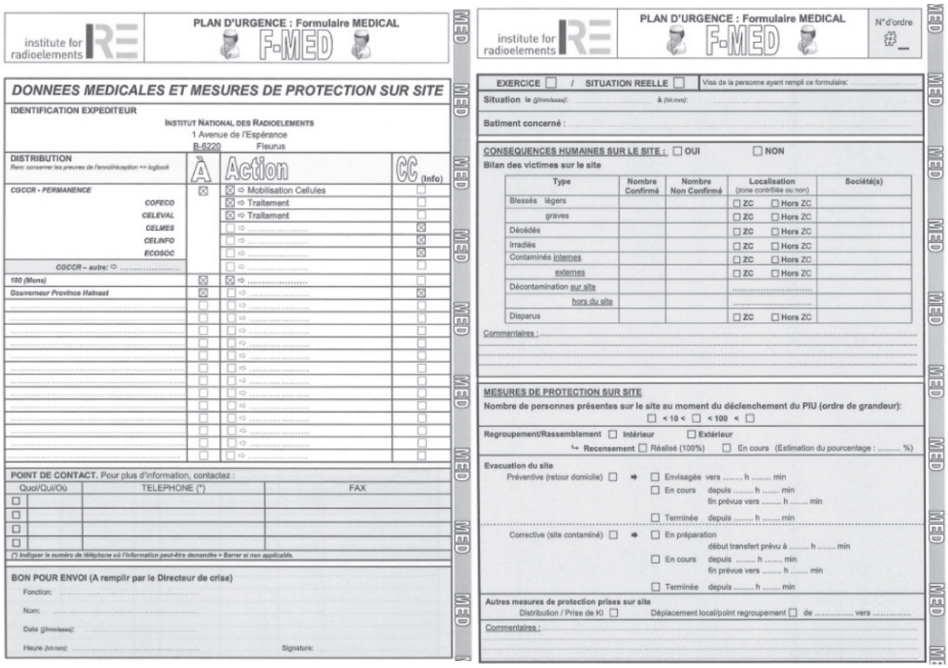


Fig. 2 : Technical Form for the Doel 3 NPP – Cover page & Main form


institute for radioelements IRE

PLAN D'URGENCE : Formulaire MEDICAL

F-MED

DONNEES MEDICALES ET MESURES DE PROTECTION SUR SITE

IDENTIFICATION EXPEDITEUR

INSTITUT NATIONAL DES RADIOELEMENTS
1 Avenue de l'Espérance
B-6220 Fleurus

DISTRIBUTION	À	Action	CC (Info)
CGCCR - PERMANENCE	☒	☒ ⇨ Mobilisation Cellules	☐
COFECO		☒ ⇨ Traitement	☐
CELEVAL		☒ ⇨ Traitement	☐
CELMES		☐ ⇨ …………	☒
CELINFO		☐ ⇨ …………	☒
ECOSOC		☐ ⇨ …………	☒
CGCCR – autre: ⇨ …………		☐ ⇨ …………	☐
100 (Mons)	☒	☒ ⇨ …………	☐
Gouverneur Province Hainaut	☒	☐ ⇨ …………	☒

POINT DE CONTACT. Pour plus d'information, contactez :

Quoi/Qui/Où	TELEPHONE (*)	FAX
☐		
☐		
☐		
☐		

BON POUR ENVOI (A remplir par le Directeur de crise)
Fonction:
Nom:
Date:
Heure: Signature:

institute for radioelements IRE

PLAN D'URGENCE : Formulaire MEDICAL

F-MED

N°d'ordre #_

EXERCICE ☐ / SITUATION REELLE ☐ Visa de la personne ayant rempli ce formulaire:

Situation le à

Batiment concerné :

CONSEQUENCES HUMAINES SUR LE SITE : ☐ OUI ☐ NON

Bilan des victimes sur le site

Type	Nombre Confirmé	Nombre Non Confirmé	Localisation (zone contrôlée ou non)	Société(s)
Blessés légers			☐ ZC ☐ Hors ZC	
graves			☐ ZC ☐ Hors ZC	
Décédés			☐ ZC ☐ Hors ZC	
Irradiés			☐ ZC ☐ Hors ZC	
Contaminés internes			☐ ZC ☐ Hors ZC	
externes			☐ ZC ☐ Hors ZC	
Décontamination sur site				
hors du site				
Disparus			☐ ZC ☐ Hors ZC	

Commentaires :

MESURES DE PROTECTION SUR SITE

Nombre de personnes présentes sur le site au moment du déclenchement du PIU (ordre de grandeur):
☐ < 10 < ☐ < 100 < ☐

Regroupement/Rassemblement ☐ Intérieur ☐ Extérieur
↳ Recensement ☐ Réalisé (100%) ☐ En cours (Estimation du pourcentage : …… %)

Evacuation du site
Préventive (retour domicile) ☐ ➜ ☐ Envisagée vers …… h …… min
☐ En cours depuis …… h …… min
fin prévue vers …… h …… min
☐ Terminée depuis …… h …… min

Corrective (site contaminé) ☐ ➜ ☐ En préparation
début transfert prévu à …… h …… min
☐ En cours depuis …… h …… min
fin prévue vers …… h …… min
☐ Terminée depuis …… h …… min

Autres mesures de protection prises sur site
Distribution / Prise de KI ☐ Déplacement local/point regroupement ☐ de …… vers ……

Commentaires :

Fig. 3 : Medical & on-site protective actions Form for the IRE–
Cover page & Main form.

After some early difficulties and nuanced reactions of Licensees ("*there are too many forms to be filled*", "*it takes too much time to fill in the forms*"*)*, largely due to a lack of 'ownership' of these new information exchange forms and associated steering principles, the experience feedback from nuclear emergency exercises are quite positive. In particular, at the recipients' level, a clear improvement has been perceived both in terms of optimization of information fluxes as of their easy and efficient usage (the same types of information or data can be retrieved more easily and more efficiently).

To take into account the difficulties encountered by the Licensees and to allow a better 'ownership' of the revised forms, it was decided to develop a "*modus operandi"* summarizing the main objectives of the information exchange forms, the steering principles and the key instructions (general or specific to each particular form). This *modus operandi* can of course be supplemented later on the basis of feedback and observations made by users during emergency exercises, training or real emergency situations.

3 DELIMITATION OF THE PLANNING ZONES

3.1 The theoretical concept

To improve the process of defining the area for intervention, the best solution is that the same concept is used at the three levels of evaluation, decision and implementation: if everyone could "speak the same language", i.e. use the same approach built together and shared between all actors, evaluators could already incorporate this knowledge into the assessment process and propose intervention zones that could be directly transposed on the field and fit the reality of the terrain. Moreover, the description of the areas of concern could already be prepared and communicated to the public and the first responders with only minor adaptation in real emergency situation.

The solution proposed and developed by the working group is to divide the emergency planning zone (EPZ) into blocks of reasonable dimensions, not too large but also not too small, in order to allow enough flexibility when defining the area where protective actions are needed. To make sure that this cutting up could be applied in a similar way around all Belgian nuclear sites, driving rules have been stated.

3.2 Rule 1: make use of 30° sectors

The cutting up will be based on sectors around the source point, starting from the North (0°). The angle of these sectors has been set at 30° because already used in most emergency plans in Belgium. The twelve sectors will be numbers using one single digit, from 1 to 9 and A to C (Fig. 4).

Using this pattern, nuclear emergency sectors are in line with the cutting up and the numbering used by the Civil Protection for the selective activation of the 'SEVESO' sirens.

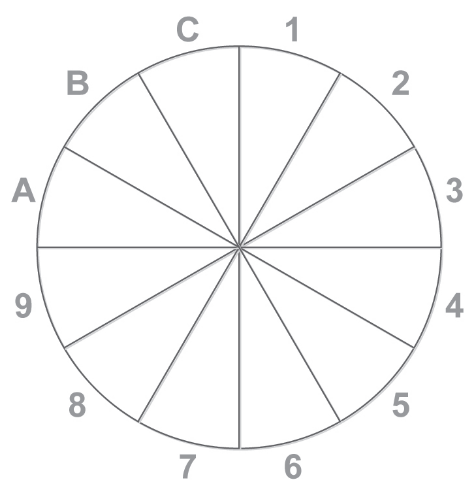


Fig. 4 : Cutting up based on 30° sectors.

3.3 RULE 2: THE 'KEYHOLE' CONCEPT

Protective actions decide in one or more sector(s) will systematically be implemented in a keyhole shaped area i.e. also within a 'circular' zone centred on the release point (Fig. 5).

This approach is also applied in other countries such as France, Germany or USA. However there are apparently no international guidance (IAEA, EC …) for the dimensioning of the keyhole.

The round part should mainly cope with the diffusion uncertainties due to local eddies created by the presence of buildings and enhanced diffusion at low-speed winds. The radius of this circular area has been set at 500 m around each source point (i.e. each stack). It was also decided to consider one single 'circular' zone for each nuclear site even where multiple source points are present. The result is that the 'circular' part, is not a circle anymore and that its largest dimension can easily extend to 1 km (Fig. 6). Moreover the final shape needs to be adapted to the local peculiarities as described later in this paper (see § 3.7).

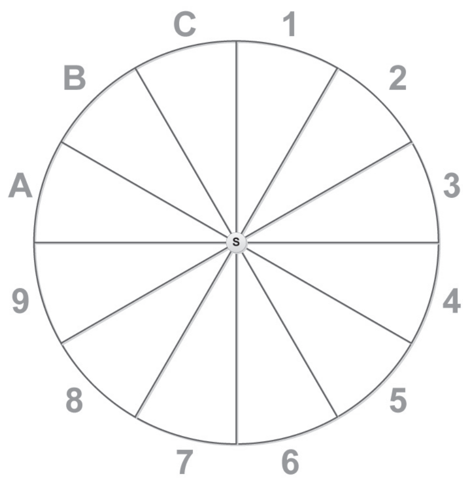


Fig. 5 : Keyhole and 30° sectors.

It is noteworthy that for operational reasons (accessibility to rescue and intervention vehicles) the nuclear emergency plan developed by the province of Antwerp for the Doel NPP systematically considers a circular area of 1 km. In France this area extent to 2 km and corresponds to the 'reflex' zone around the EDF NPP's. In Germany the dimension of the circular part of the keyhole is also 2 km without being associated with a 'reflex' zone.

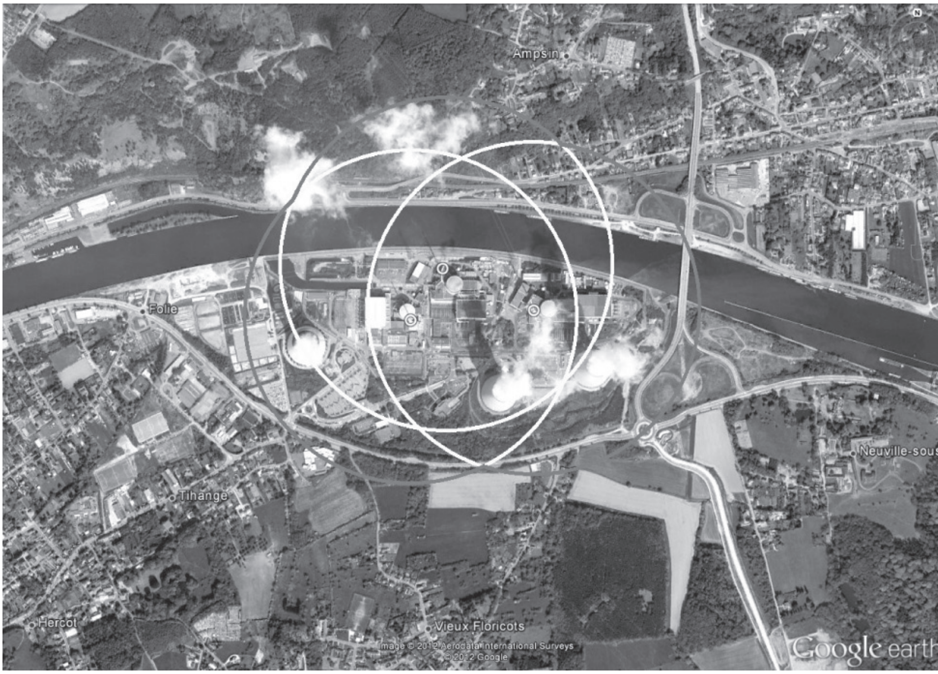


Fig. 6: The theoretical ‘circular’ part of the keyhole around the Tihange NPP.

3.4 Rule 3: make use of the ‘reflex’ zone as the first crown.

Accidents could evolve quickly without leaving enough time for the mobilization of the experts and decision makers and for a thorough evaluation of the expected consequences. In the meantime the population nearby the affected site could already be at risk and request precautionary actions.

To avoid this temporary lack of leadership the Belgian nuclear emergency plan has foreseen a so-called ‘reflex’ phase during which the local authority (the governor of the province hosting the nuclear site) is endorsed of informing the population, recommending them to shelter and to listen to the media.

These precautionary protective actions must be implemented within a circular area (the 'reflex' zone) up to a distance that has been calculated considering the source terms associated with selected quick kinetic scenarios. Around NPP's, the 'reflex' zone has been set to 3.5 km from each source point (i.e. the stack) and combined to consider one single 'reflex' perimeter for NPP. The final perimeter had also to be adapted to the local peculiarities of the terrain and urban tissue. The 'reflex' zone defined for rapid implementation of protective action in the case of accident leading to rapid and significant releases of radioactivity into the atmosphere does already exist and will be used as the first crown of blocks closed to the nuclear site (Fig. 7).

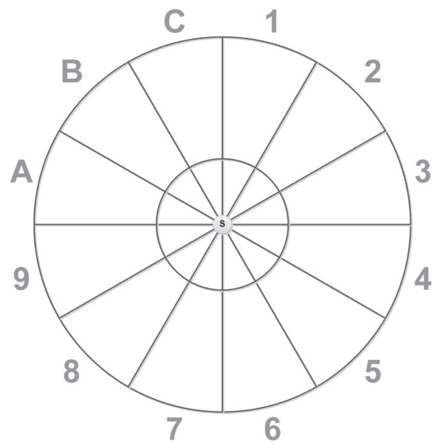


Fig. 7 : The 'reflex' zone is used as the first crown

3.5 Rule 4: intermediate crown(s)

The EPZ for sheltering and evacuation is 10 km around Belgian NPP's [Ref.1]. However, according to the evaluated risk, the intervention zone could less or extent beyond 10 km.

In order to be more flexible, but reasonable, an intermediate limit was decided, half way between the 'reflex' perimeter and the 10 km limit of the EPZfor sheltering and evacuation (Fig. 8).

Beyond the limits of the EPZ, it was decided that entire administrative entities (i.e. communes) will be considered.

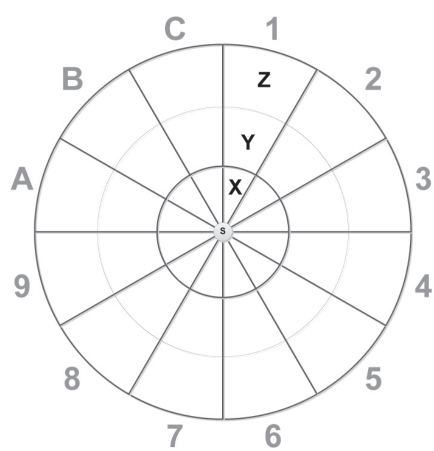


Fig. 8 : Introduction of several intermediate crowns.

3.6 RULE 5: NUMBERING OF THE BLOCKS

A numbering pattern is suggested to ensure coherency of denomination for all nuclear sites and to improve accordingly the common understanding among involved bodies and authorities (Fig. 9).

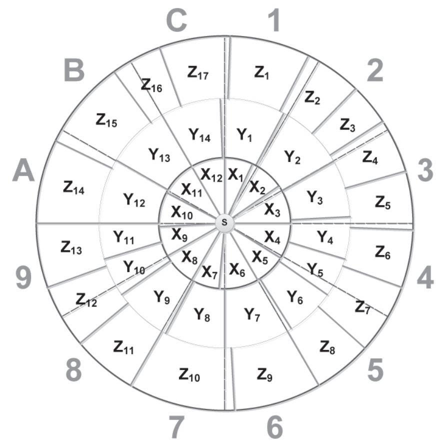


Fig. 9 : Numbering of the blocks.

Beyond the circular part of the keyhole, the planning zone is divided into several crowns. The circular part of the keyhole is coded ‘S’; other crowns are coded from the most external one ‘Z’, ‘Y’, ‘X’ and further downwards if needed.

In each crown, blocks are identified by the letter of the crown and a sequential figure starting from ‘1’ from the North (i.e. from sector 1). Depending on peculiarities there might be a different number of blocks than sectors; especially the outermost crowns will often have more blocks than sectors.

3.7 APPLICATION OF THE CONCEPT

The driving rules having been stated, they have to be applied to the geographical and sociological specificities of the terrain around the nuclear site. In other words, the cutting up of the “jigsaw puzzle” must consider among other items the soil use (namely the distribution of the habitat, industry, agriculture and forests), the administrative structure (limits of communes, province’s …) and other landscape characteristics such as the presence of rivers. It is also essential that blocks are contiguous (no overlap) and that they stick as much as possible

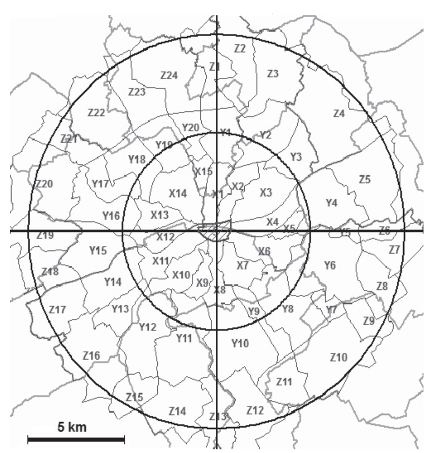


Fig. 10 : Cutting up of the 10 km planning zone around the Tihange NPP.

to the limits of the 12 sectors and crowns drawing a regular and continuous area were remedial actions will be taken.
In an iterative process, the concept was applied to the 10 km EPZ around the Tihange NPP leading to the final results presented in Fig. 10, agreed by and known to all stakeholders.

3.8 The selection of the blocks

Depending on the trace of the (potential) plume, the expected time integrated concentration in air (governing the doses and deposits) and according to the guidelines specific for a given protective action, the evaluation experts will determine the area ‘at risk’. The evaluation cell generally ends up with a geometric area: an angle on both side of the average wind direction up to a certain distance from the source. The sizes of the angle and distance are defined in an ALARA process (justification and optimisation) to cope with the many uncertainties, especially in threatening situations, about the source term, the time and time length of the release (if any), the meteorological prognoses and the accuracy of the dispersion model used.
In a second step, using the cutting up of the planning zone, the evaluation experts will translate the sector for a given protective action into a list of blocks where actions are strongly recommended and blocks at the edges for the decision makers to decide whether they will include them or not (Fig. 11).

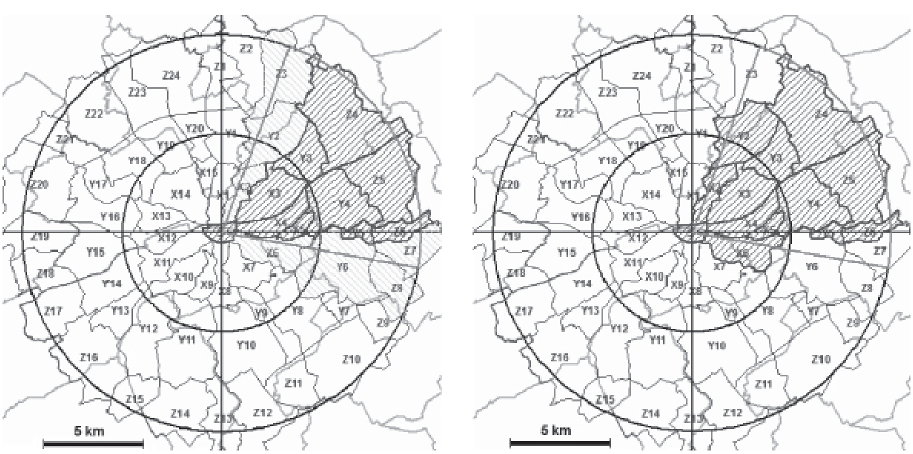


Fig. 11 : Example of intervention area (left) proposed by experts and (right) decided by the decision makers.

Once the protective action areas are stated, the decision is conveyed to the local authorities and first responders for implementation. The decided areas are also communicated to the public and media.

3.9 Testing the concept in exercise

The yearly nuclear exercise conducted in 2011 with the Tihange NPP had as main objective the test of the cutting up concept. From the debriefing with the federal and local stakeholders the experience was very positive: the overall process of evaluation, recommendation, decision and communication to all interested groups was much more straightforward (less time consuming and less ambiguous) than it was in the past. This was fully confirmed by the last large scale exercise, called PEGASE Tihange 2012, organised on 20 & 21 November 2012.

3.10 The way forward

The driving rules having been defined and applied in a case study to the planning zone around the Tihange NPP (Province of Liège), the concept has been presented to other provinces dealing with other nuclear site(s) (East-Flanders and Antwerp for the Doel NPP, Antwerp for nuclear installations in Mol-Dessel, Hainaut for IRE and Namur for the French Chooz NPP) for application to their own situation. Lessons learned at each step and for each nuclear site have been integrated step by step into the implementation process, recognizing the specificities of each site (urban around Tihange, industrial around Doel, forest and agricultural around Chooz …).
This on-going process is expected to be finalized in the beginning of next year for all nuclear sites of concern.

4 WEB-BASED PLATFORM FOR INFORMATION EXCHANGE

At regular intervals the information gathered and assessed by CELEVAL is summarized into an advice report to the attention of COFECO. The first part of the advice report consists of the synthesis of the situation (Fig. 12) describes the most recent data available regarding the technical situation at the level of the installation (based on the F-TEC from the licensee, the input of the technical experts at CELEVAL and exchange with the licensee on-site by phone or videoconference), the meteorological observations and forecast (based on the input of the Royal Institute of Meteorology and the data from the Telerad meteorological stations) and the (expected) radiological consequences (based on the F-RAD, the on line measurements from the Telerad monitoring stations and from the mobile measurement teams and the input of the radiological experts at CELEVAL).

Synthèse de CELEVAL

TI-TIHANGE (50.534775°N, 5.272962°E)
Exercice
Niveau d'alarme actuel : N1

Avis n° 1

SITUATION TECHNIQUE	Diagnostic - Pronostic - Aggravation - Récupération - Délai(s) - ...

Fuite de réfrigérant primaire dans l'enceinte du bâtiment réacteur (brèche sur le circuit primaire). Primaire "propre".
Réacteur à l'arrêt (SCRAM)
Système d'injection de sécurité compense actuellement la fuite.
La situation technique est sous contrôle et la température de l'eau primaire reste inférieure à 650 °C = pas de dégât au combustible.
Les systèmes de filtration sont en service.
L'asperion d'enceinte n'est pas disponible (maintenance des équipements et défaillance d'une voie électrique). Actuellement, l'aspersion d'enceinte n'est toutefois pas requise (la pression dans l'enceinte reste inférieure à la pression de mise en service de ce système).
L'enceinte est isolée (isolement complet des pénétrations) et globalement étanche (fuites de conception uniquement).
(Scénario technique n° 5)

Dégradation possible en cas de perte d'étanchéité de l'enceinte suite p.e. à la défaillance d'une pénétration. (---> Scénario technique n° 9).

SITUATION METEOROLOGIQUE

Direction du vent stable venant du 240°.
Vitesse du vent stable : 5 m/s.
Précipitation : OUI sous forme de pluie
Stabilité atmosphérique : Bultynck-Malet : - Pasquill-Gifford : D

SITUATION RADIOLOGIQUE	Menace - Rejets significatifs en cours - Post-rejets - Délai(s) - Caractère conservatif

Faible rejet en cours dus aux fuitex de conception de l'enceinte) avec un impact faible sur la population.
Dans la situation actuelle (scénario 5):
les doses attendues sont inférieures à 0,02 nSv (dose effective) et 7 nSv (dose thyroïde enfant)
les dépôts attendus en iodes (I-131) sont de l'ordre de 2 000 Bq/m² la clôture, 280 Bq à 1 km, 50 Bq à 4 km et 10 Bq à 10 km.

En cas de dégradation (scénario 9)
les doses attendues seraient inférieures à 5 nSv (dose effective) et 2,5 µSv (dose thyroïde enfant)
les dépôts attendus en iodes (I-131) seraient de l'ordre de 660 000 Bq/m² la clôture, 92 000 Bq/m² à 1 km, 18 000 Bq/m² à 4 km et 4 000 Bq/m² à 10 km.

COMMENTAIRES & POINTS D'ATTENTION	Limitations modèles - Informations attendues, à quelle échéance - ...

Les actions de protection proposées prennent en considération une aggravation possible du scénario et sont donc des actions de protection recommandées par pure précaution. Il n'y a en effet actuellement aucune indication relative à une quelconque aggravation de la situation qui est actuellement sous contrôle.

Fig. 12 : Example of synthesis part of the advice report prepared by CELEVAL.

Based on this synthesis CELEVAL proposes to COFECO protective actions aimed at the direct protection of the public, the protection of the emergency workers and the protection of the food chain (Fig. 13). These proposals are introduced in the next parts of the advice report and include the identification of the concerned area for each protective action by selecting the concerned "blocks" on a local map showing the planning zone according to the method explained in §3.8 above (Fig. 14). The blocks of interest are selected with the mouse and the list is automatically created.

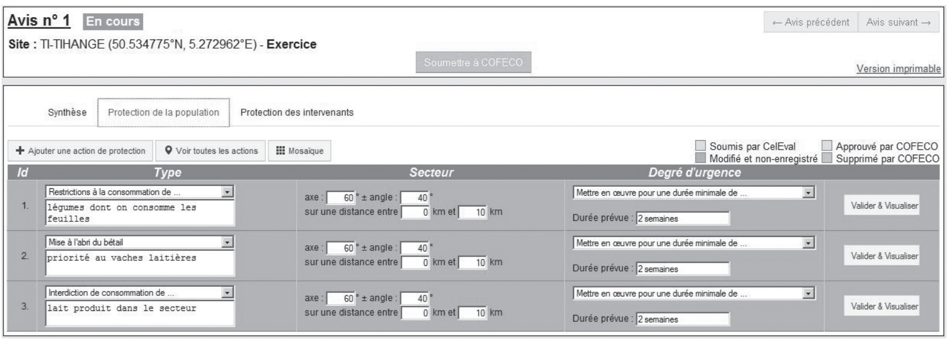


Fig. 13 : Example of protective actions as proposed by CELEVAL.

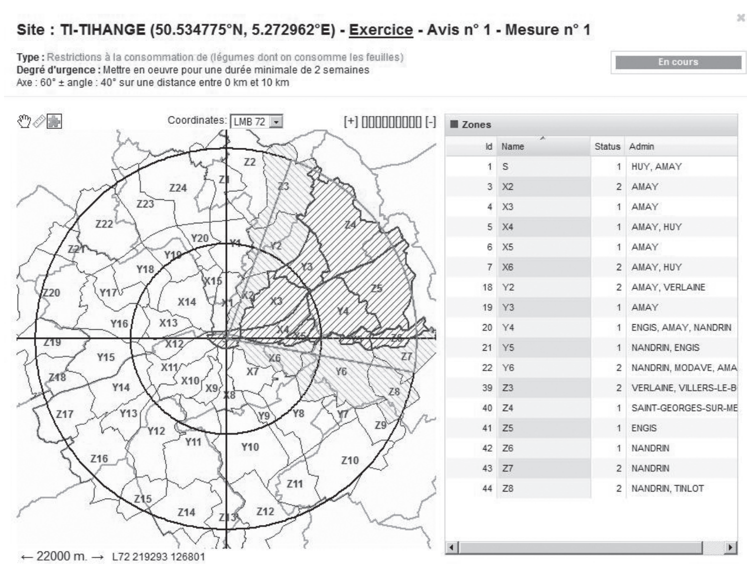


Fig. 14: Example of map showing the area recommended by CELEVAL for a specific protective action.

After approval by COFECO the final maps can be transmitted to the local authorities for implementation and later be used for reporting the progress of the implementation.

5 SOME CONCLUSIONS

The results issued from initiatives and dedicated working groups initiated several years ago to improve and facilitate the transmission and use of information provided by the Licensee of a nuclear emergency affected site to off-site authorities and other bodies as well as the development of proposed protective actions are already globally positive. Indeed, these developments contribute undoubtedly at improving the common understanding among the different stakeholders involved in the management of a nuclear emergency.

But they are not an end in itself and aiming to achieve an appropriate level of mutual understanding, key-factor for a successful emergency response, the developments presented in this paper should be continued and strengthened in a same spirit.

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INFLUENCING PUBLIC PERCEPTION ON RADIATION PROTECTION ISSUES

A few examples from UNSCEAR reports

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Brussels, 19 June 2015

1. Overview of the presentation

The presentation I have given at the BVS-ABR meeting on *Ethical issues in radiological protection* of 19 June 2015 was mainly based on the slides I made for the round table discussion of the EU article 31 seminar on *Lessons learned from the Fukushima accident*, which took place in Luxembourg on 18 November 2014 [1].

Three examples were given – all based on published UNSCEAR data – on how people's perception of radiation risk can be influenced by the choice of the dataset and the way the data is presented and discussed.

- The first example compares the population exposure from the nuclear fuel cycle in normal situations *versus* the situation after a nuclear accident.
- The second looks at the population exposure in the most contaminated areas from the Chernobyl accident *versus* what if the wind at the time of the explosion blew to Pripyat city instead of to the red forest.
- The last example is more a personal observation on the protection of plants and animals in the environment in normal operating conditions *versus* our experience on the effects from accidental discharges.

2. Introduction

It is well known that the way we perceive a risk influences our behavior, and radiation protection is no exception in that respect. I illustrated the importance of risk judgments on the public perception in my presentation on the occasion of the 50th anniversary of the BVS-ABR in April 2013 by a number of examples taken from the area of radiation protection. All the examples had to do with an aversion of the public to a particular exposure situation [2]. People have a strong aversion to:

- An internal contamination, much more than for external irradiation
- Having to live in an area contaminated by a nuclear accident
- Buying slightly contaminated food, even if the contamination level is below the natural background radiation level of the food
- Exposure to artificial radioactivity, much more than to technologically enhanced natural radioactivity

In this presentation, I would like to elaborate on a related issue, which is the fact that public perception can be considerably influenced by the way in which we approach a particular subject, the dataset we select and the comparisons we make. All these aspects can influence people's perception significantly. I developed three examples, all based on UNSCEAR data, to make my point clear.

3. Population exposure during normal operation versus **reactor accidents**

The first example has to do with the public exposure from the nuclear fuel cycle. The UNSCEAR estimates of the collective effective doses to members of the public from the different stages of the nuclear fuel cycle are given in table 1 per unit of electrical energy generated [3]. For the whole nuclear fuel cycle, the collective dose for the local and regional population groups is estimated at 0.72 manSv/GWyear.

Table 1. Collective effective doses to the local population due to radionuclides released in effluents of the nuclear fuel cycle per GWyear (world average, 1998-2002) [3]

The large Belgian nuclear power plants have an electrical capacity of 1 000 MW or 1 GW.

Source (stage of the nuclear fuel cycle)	**Collective dose** manSv/GWyear
Mining of uranium ore	0.19
Milling of uranium ore	0.008
Mine and mill tailings (releases of radon over five years)	0.04
Enrichment and fuel fabrication	0.003
Reactor operation: airborne effluents	0.22
Reactor operation: liquid effluents	0.05
Reprocessing: airborne effluents	0.028
Reprocessing: liquid effluents	0.081
Transportation	<0.1
Whole nuclear fuel cycle during normal operation (rounded)	**0.72**

Combining this value with the average nuclear electricity production of 278 GW per year worldwide in the 1998-2002 period results in an annual collective dose of about 200 manSv for all operations related to nuclear energy production.

The UNSCEAR estimates of the individual dose from the nuclear fuel cycle are in the µSv range. The exhalation of radon gas from mining and milling results in a few tens of µSv per year to the local population, while the doses from reactor operation are less than 1 µSv per year. Typical values for the most exposed members of the public are:

- Mining and milling 25 µSv/year
- Fuel fabrication 0.2 µSv/year
- Reactor operation 0.1 µSv/year
- Reprocessing 2 µSv/year

Nuclear accidents are the biggest threat, but these small risks with far-reaching consequences are not included in the UNSCEAR figures of the nuclear fuel cycle. Over the years, UNSCEAR has calculated the population exposure from all major nuclear accidents. The collective doses are given in table 2.

Table 2. The collective effective dose to the population of all the major nuclear accidents worldwide (manSv)

Year the accident took place	**Accident**	**Collective dose** manSv
1986	Chernobyl (reactor)	360 000
2011	Fukushima (reactor)	48 000
1957	Kyshtym (reprocessing)	2 500
1964	SNAP 9A (satellite)	2 100
1957	Windscale fire (reactor)	2 000
1983	Ciudad Juarez (^{60}Co source)	150
1987	Goiânia (^{137}Cs source)	60
1979	TMI (reactor)	40
1978	Cosmos 954 (satellite)	20
1966	Palomares (A-bomb accident)	3
1999	Tokai-mura (criticality accident)	< 0.6
1993	Tomsk (criticality accident)	0.02

UNSCEAR has estimated the collective doses from the Chernobyl and Fukushima accidents at 360 000 and 48 000 manSv [4]. With a collective dose for normal operation of 200 manSv/GWyear, this corresponds to respectively 1800 years and 240 years of exposure from the nuclear fuel cycle. So looking at the public exposure from a normal operation point of view or including reactor accidents changes the perspective significantly and consequently influences the subjective judgment that people make about the severity of the risk posed by the nuclear fuel cycle.

One could make other comparisons. For instance, the UNSCEAR estimate of the collective dose from atmospheric weapons testing from the 1950s and the 1960s is 22 000 000 manSv, which is equal to 110 000 years of exposure from the nuclear fuel cycle. On the other hand, the medical exposure in Belgium, calculated with the UNSCEAR methodology and the number of procedures from the Belgian social security system (RIZIV/INAMI), in 2006 was 22 000 manSv [5]. This means that the collective dose of 16 years of medical exposure in Belgium equals the collective dose from the Chernobyl accident.

4. **Population exposure in the most contaminated areas** versus **the Chernobyl red forest**

Large areas in Ukraine, Belarus and Russia suffered high levels of radioactive contamination due to the Chernobyl accident. Cesium-137 is the most important radionuclide over the long term. In total, an area of about 150 000 km² *(5 times the surface area of Belgium)* was contaminated with more than 37 kBq/m² cesium-137 and 3100 km², mainly in Belarus, with more than 1480 kBq/m² (table 3) [6]. The contamination of the soil is not homogeneous at all, as can be seen in figure 1, because it is driven by the variable weather conditions (wind direction, precipitation...) during the atmospheric releases.

For comparison, the current soil contamination in Belgium with cesium-137 is a few kBq/m², more or less in equal measure from the Chernobyl accident and from the atmospheric nuclear weapons testing more than 50 years ago.

Table 3. Surface area contaminated with cesium-137 in the three most affected republics of the former Soviet Union [6]

Country	**37 - 185** kBq/m²	**185 - 555** kBq/m²	**555 - 1480** kBq/m²	**> 1480** kBq/m²	**Total** kBq/m²
Belarus (km²)	30 000	10 000	4 200	2 200	46 400
Russia (km²)	50 000	5 500	2 100	300	57 900
Ukraine (km²)	37 000	3 200	900	600	41 700
Total (km²)	**117 000**	**18 700**	**7 200**	**3 100**	**146 000**

Figure 1. The radioactive contamination of the soil with ^{137}Cs after the Chernobyl accident in 1986. Kiev is located 110 km south of Chernobyl [6].

UNSCEAR's estimates of the total effective dose accumulated during the first 10 years by the 5 million people living in the most contaminated areas around Chernobyl are not so high, despite the very high contamination levels of the soil:

- 0 - 5 mSv: 59 % (less than the annual average exposure in Belgium: 4.6 mSv)
- 5 - 10 mSv: 20 % (about one CT-scan)
- 10 - 20 mSv: 13 %
- 20 - 50 mSv: 6.9 % (more than the annual limit for radiation workers: 20 mSv)
- 50 -100 mSv: 0.9 %
- 100 - 200 mSv: 0.02 %
- > 200 mSv: 0.002%

These values do not take the thyroid doses from the short lived iodine isotopes into account, which dominated the exposure during the first few months.

The additional exposure from the Chernobyl accident can be compared to the exposure from natural radiation sources. The natural exposure in Belgium is on average 2 mSv/year higher in the Ardennes than in the Campine region. The difference is mainly due to the high radon concentration in the Ardennes, with a minor contribution from the higher external exposure. So the average exposure to natural radiation sources in the Ardennes is over a period of 10 years about 20 mSv higher than in the Campine region, which is more than the additional exposure received by the people in the contaminated areas around Chernobyl.

This comparison is rather reassuring for the people in the contaminated areas. But what if the wind at the time of the explosion blew to Pripyat city instead of to the red forest. The dose rate in the red forest during the first days of the Chernobyl accident was about 1 Gy/h killing the pine trees; hence the name red forest [6]. Pripyat, which was built primarily to house workers from the Chernobyl nuclear power station, is located at the same distance from the exploded reactor but in a slightly different direction (45 degrees difference). How many of the 49 000 inhabitants of Pripyat would have survived the initial dose rate of 1 Gy/h if the wind blew in their direction?

5. Protection of the environment: routine versus **accidental discharges**
The UNSCEAR estimate of the atmospheric release of cesium-137 from the Fukushima accident is 8.8 PBq ($8.8\ 10^{15}$ Bq), which is an order of magnitude less than the amount released from the Chernobyl accident [4]. The resulting soil contamination is shown in figure 2. High values, above 3.8 MBq/m², are found in the northwest, where it rained when the cloud came over. The Fukushima prefecture has the same surface area (13 783 km²) as Flanders (13 522 km²) but a lower population of 2 million compared to 6 million in Flanders. Okuma town is delineated on the map. As it is located in the 20 km zone, its population of 11 500 in 2010 was evacuated shortly after the accident.

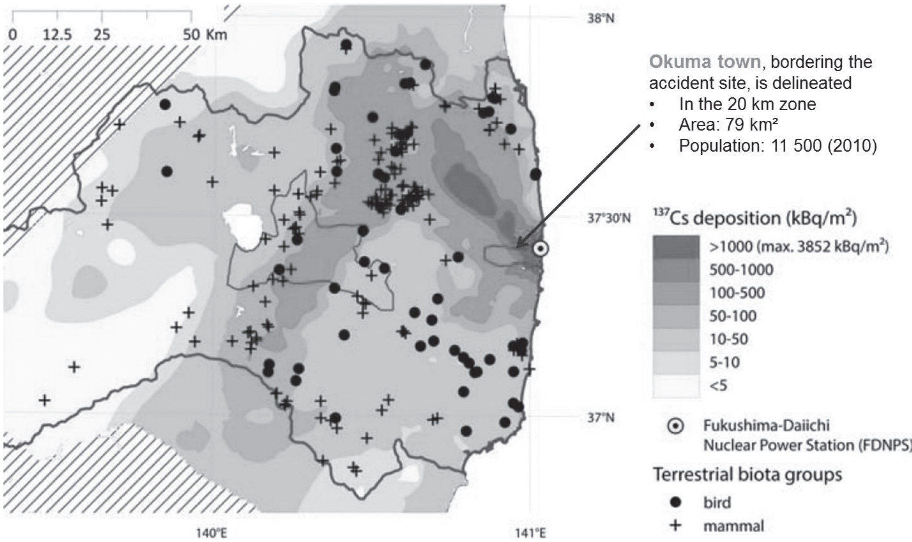

Figure 2. The radioactive contamination of the soil with ^{137}Cs in the Fukushima prefecture after the accident in 2011. The sampling locations of mammals and birds used in the UNSCEAR assessment of the environment are indicated on the map [4].

The estimated dose rates for the ICRP reference organisms in Okuma in June 2011, which is three months after the accident, are given in table 4 and compared to the ICRP benchmarks. The benchmark taken is the lower bound of the ICRP DCRL band (Derived Consideration Reference Level). It is used by the ICRP to identify where there is likely to be some chance of deleterious effects on individual reference animals and plants.

Table 4. Dose rates for ICRP reference organisms in Okuma – a town bordering the accident site – in June 2011, three months after the accident [4]

Reference organism	Dose-rate estimate (µGy/h)	Dose-rate benchmark (µGy/h)	Ratio of estimate to benchmark
Bee	18	400	0.04
Deer	71	4	17.8
Duck	21	4	5.3
Earthworm	46	400	0.11
Frog	18	40	0.45
Pine Tree	17	4	4.3
Rat	46	4	11.5
Wild grass	26	40	0.65

The exposure rates of plants and animals in Okuma are below 100 µSv/h, the reference level UNSCEAR derived in its 1996 and 2008 reports for population effects on the ecosystem. The reference level is used by UNSCEAR to evaluate whether the exposure to ionizing radiation could have changed the presence of certain plant or animal species. From this UNSCEAR concludes that beyond a geographically very restricted area the potential for effects on biota may be considered insignificant [4].

The atmospheric aerosol release of the Doel nuclear power station is a few MBq/year, about nine orders of magnitude lower than atmospheric release of cesium-137 from the Fukushima accident (8.8 PBq). This brings me to a personal observation: why are we dealing with the protection of the environment during normal operation if the potential effects of the Fukushima accident on plants and animals may be considered insignificant?

6. Summary

I have given in my presentation a few examples, all based on UNSCEAR data, to illustrate how the perception of the public can be considerably influenced by the way we treat a particular subject, the data we select to present and the comparisons we make. The three examples that were developed:

- The collective dose from the Chernobyl and Fukushima accidents corresponds to respectively 1800 years and 240 years of exposure from the nuclear fuel cycle during normal operation.

- The population exposure in the most contaminated areas during the first 10 years after the Chernobyl accident is on average less than the difference in exposure between the Campine region in Belgium and the Ardennes. On the other hand how many of the 49 000 inhabitants of Pripyat city would have survived the initial dose rate of 1 Gy/h if the wind blew in their direction and not in the direction of the red forest?
- UNSCEAR estimates the atmospheric release of cesium-137 from the Fukushima accident at 8.8 PBq, resulting in deposition densities up to a few MBq/m². The atmospheric aerosol release of the Doel nuclear power station is a few MBq/year, about nine orders of magnitude lower than the release from the Fukushima accident. This brings me to a personal observation: why are we dealing with the protection of the environment during normal operation if the potential effects of the Fukushima accident on plants and animals may be considered insignificant?

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ETHICAL ISSUES IN RISK EVALUATION: LESSONS FROM FUKUSHIMA[1]

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1. Introduction

Since the Fukushima accident, a lot of meetings and workshops have been conducted throughout the world, international organizations dealing with nuclear safety have been working intensively and numerous papers have been published. Remarkably, all of them nearly constantly highlighted one or another aspect of this accident having an ethical component.

One of the most frequently highlighted issues was the need of a global approach, not limited to radiological protection but enlarged to all public health aspects and to societal aspects. Among others, the attention has been drawn on the negative side effects of some countermeasures and on the psychological and social consequences of the accident, as for example the risk of stigmatization of the victims in specific cultural contexts.

The need for taking better into account long term issues, including return to « normality », has also been frequently underlined.

While many of the above-mentioned issues have been largely recognized, other more challenging ethical issues have been mainly highlighted by

1 This text has also been presented during an EU scientific seminar in November 2014 (Fukushima: lessons learned and issues) and will be part of the Proceedings published in the EC Radiation Protection series under the title "Ethical issues debated after Fukushima" (publication in progress).

people “outside” the nuclear and radiological world, as the media and non-governmental organizations (although some of these issues have been taken into account by national and international authorities and organizations). Among these challenging issues, appear the lack of independency of safety agencies, collusions between authorities and companies and the frequent reluctance of authorities to disclose information, as for example on doses or contaminations or one dose distributions. More touchy issues were also sometimes underlined, such as potential conflicts of interest of some involved experts and international organizations working in the field (due to their explicit mandates or to conventions).

May be the most touchy ethical issue concerned the fairness, quality and adequacy of risk communication to the affected populations and to people in general. Downplaying of the risk of health effects or even denying such risks by some experts or national authorities as well by some international organizations has been frequently denounced, not only by the media but also by other experts and organizations. On the other hand, experts asking for more fair risk communication were sometimes accused to be “ anxiety-provoking experts “, while as well “ reassuring “ experts or organizations as these “ anxiety-provoking “ experts all claimed being following only ”science” .
The question is then: “Who “tells the “scientific truth “? And what is “science-based information”?
This is an insidious issue. Political reasons that can explain these discrepancies regarding judgment and evaluation of risks exist and play almost certainly a role, but there are also deep and somewhat hidden epistemological issues.

2. Epistemological and ethical questions at stake in risk evaluation and communication

There exist some fundamental epistemological and ethical issues that are at stake in risk evaluation and communication. The lack of recognition of the existence and of the consequences of these issues and the resulting expert quarrels threatens the social credibility of all the experts in (among others) radiological questions. These fundamental issues are the existence of non-recognized conflicts of interest, the misuses of the evidence-based approach and the questioning of the adequacy and legitimacy of the precautionary attitude within the scientific work.

2.1. Non-recognized conflicts of interest: danger for credibility

In the nuclear field, potential conflicts of interest are unavoidable for many countries – as they are or have been in the past responsible of major radioactive contaminations (or could be in the future…) - and for many international institutions whose official mandate is to promote some practices (as the pacific use of nuclear energy).

Other conflicts of interest are linked with the potential socio-political consequences of nuclear accidents.

The risk is serious that such conflicts of interest may interfere with risk evaluation and communication.

After the Fukushima accident, a clear goal for several influent national and international players was to "reassure" the Japanese population, particularly about the health of their children. A right (and then not necessarily reassuring) risk evaluation and communication was then jeopardized by the socio-political perceived need to reassure and then to relativize or minimize as much as possible the possible radiation effects from exposure. Such mixing of the roles creates a danger for the credibility.

2.2. Use and misuse of the evidence-based approach

Evidence-based approach is currently become a dominant scientific paradigm, particularly in the medical field, where it is the condition of agreement of any new drug and even of any treatment.

The basic concern is to avoid concluding that a causal relationship exists before it is strongly proved (hard evidence is required).

In other words, the main concern is avoiding the "false positives".

Current dominant pressure of this paradigm leads some experts or groups to consider that this way to proceed (to avoid carefully false positives) is the only way compatible with science, which is based on the possibility of testing and falsifying any hypothesis.

They use as an argument that the scientific method is based on the principle that there is an underlying order to the nature of things, and that by following certain rules and guidelines this nature can often be revealed. Ideas (hypotheses) are generated from observations and then tested by controlled experiments or observational studies, leading to better understanding (empirical science). Yet the problem is that, particularly in the current world, new things (or situations) are introduced rapidly but have possibly long term consequences, unknown by definition, asking for vigilance and responsiveness for early indications of health effects. Potential observations may be only possible after a long time, generating hypotheses at a late stage, whose testing (if feasible) may again take a long time. But decisions most frequently are to be made about these new introduced things (or situations), while strong evidence or certainty is lacking. Such decisions must be based on available “evidence” (evidence, here not in the sense of “certainty”, but in the sense of “indications” or “corpus of knowledge”), even if there persists uncertainties. Decision-makers need then a sound basis for informed decision-making and are asking scientific experts (groups, committees …) for science-based *balanced* information, including science-based inferences about the risks in the future.

These science-based inferences have to stick to scientific observations and are part of the scientific work. They are not “external to science” while decisions based on these inferences are “external to science”.

This very fundamental conceptual issue lies at the root of the discussions at the level of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), that, as a committee, tends these last years to give overwhelming importance to the avoidance of false positives, by highlighting all possible bias for an association between effect and exposure, in comparison with the avoidance of false negatives, while possible dismissal of real health effect of radiation is a major concern for responsible decision-makers. This attitude is good illustrated by the exclusively critical reactions about recent low dose reports on effects at low dose (Pearce 2012, Kendall 2013) in the UNSCEAR Report on Effects of radiation exposure of children (UNSCEAR, 2013). This attitude lies also at the basis of the minimized risk estimates of UNSCEAR regarding the health effects of Chernobyl and, recently, of Fukushima (UNSCEAR, 2014): there is indeed no “100 % certainty” for many of these effects.

Finally, and more importantly, this attitude of giving overwhelming importance to the avoidance of false positives was at the origin of the comeback of the 100 mSv “magic number”.

In recent discussions within UNSCEAR, several experts stated indeed that “attribution” (meaning for them “unequivocal attribution”, i.e. with 100 % certainty) of health effects to ionizing radiation is impossible under 100 mSv. They justified this statement by the fact that 100 mSv is currently the first statistically significant point in the dose-effect relation for all solid cancers together in the gender- and age-mixed population of the Japanese survivors to the atomic bombing (LSS) and that there are no other individual epidemiological study where the evidence is strong enough to draw 100% certain conclusions. As a consequence no effect could be « attributed » to radiation under 100 mSv and even inference of risk for the future under this dose would be « non-scientific ». Such an approach is at the basis of the health evaluations in (and communications about) the last UNSCEAR report regarding Fukushima (UNSCEAR, 2014).

This is an unbalanced use of the evidence-based approach, looking only to the avoidance of false positives (100% certainty necessary before concluding anything), and by doing so ignoring the risk of dismissing real health effects. In fact, these statements give overwhelming importance only to epidemiology (and within this only to "strong epidemiological evidence"), while consistency of the corpus of knowledge coming from all epidemiological studies and from all concerned disciplines (including radiobiology) is an important part of a balanced scientific assessment. Another characteristic of these statements is that the epidemiological evidence concerning radiation-induced solid cancers in a mixed population is generalized to all types of health effects and populations (such as radiosensitive populations as young children, embryos or fetus or cancer-prone subgroups with genetic predispositions). In reality there *are* evidences below 100 mSv (or "about" 100 mSv), the population is not homogeneous regarding the risk and our knowledge is not uniform throughout the range from some mSv to 100 mSv. The issue of combined exposures is also ignored.

Yet there were recently some important changes. The UNSCEAR's strategic objective for the period 2009-2013, endorsed by the General Assembly, in its resolution 63/89, is "to increase awareness and deepen understanding among authorities, the scientific community and civil society with regard to levels of ionizing radiation and the related health and environmental effects as a sound basis for informed decision-making on radiation related issues". Now, UNSCEAR underlined in a recent report to the General Assembly (General Assembly, 2012), that "this strategic objective highlighted the need for the Committee to provide information on the strengths and limitations of its evaluations, which are often not

fully appreciated. This *involves avoiding unjustified causal associations (false positives) as well as unjustified dismissal of real health effects (false negatives*)." Formally it was an important step forward.
Unfortunately the culture is far to have changed in a large part of this committee and the use of the 100 mSv figure as a kind of pseudo-scientific general threshold is far from having disappeared and is implicitly used as well in the Fukushima report (UNSCEAR, 2014) as in the Children report (UNSCEAR, 2013).

The recently published UNSCEAR report on Attributing health effects to ionizing radiation exposure and inferring risks (UNSCEAR 2015) tries to clarify these concepts and the approach of UNSCEAR. After years of discussions, debates and amendments, the final text offers much more nuances than initially, particularly regarding inferences of risks for the future. Nevertheless, there is still a tendency towards black or white statements or approaches, particularly regarding attribution of observed health effects to ionizing radiation exposure, considered as necessarily unequivocal (100% certain), while the reality is that the vast majority of scientific evaluations are requested and necessary in situations where there is no 100% certainty and no 100% expert agreement. There are often "degrees" of attributability, with different levels of confidence.

2.3. Misunderstanding of the precautionary principle: Precaution in Science is relevant!

Precaution is relatively largely accepted regarding decision-making processes in situations of uncertainty (although the definition of this concept may be very different).
The point here is that the precautionary approach is also relevant and appropriate *within* science. This is frequently misunderstood.

As underlined in the COMEST report from UNESCO, the precaution approach in science includes:

- a focus on risk plausibility rather than on hard evidence
- a responsiveness to the first signals ("early warnings")
- a systematic search for surprises ("thinking the unthinkable"), particularly for possible long term effects

The first point is linked with the previous discussions concerning misuses of the evidence-based approach.

For society the main concern of the experts is expected to be the protection of health. When there is scientific plausibility ("enough" evidence) of the existence of a risk of serious harm, action is needed. Even if there is still uncertainty and no 100% evidence!
In other words, a main societal concern is also avoiding the false negatives. Precaution in science means in fact focusing on (or at least giving attention to) risk plausibility and not only to hard evidence.

The corollary is the need of being vigilant and responsive to the first signals of potential health problems ("early warnings"), as for example is the rule for vigilance about drugs.
Recent developments regarding the late recognized radiation effects of low to moderate doses on the lens of the eye and on the circulatory system are good illustrations of a lack of vigilance and responsiveness regarding early warnings that were described many years ago.

The third point is the need of a systematic search for surprises ("thinking the unthinkable"), particularly for possible long term effects. In this respect, it is worth remembering the EC report on "Recent scientific findings and publications on the health effects of Chernobyl" (EC, 2011).
This EC report opens the discussion on the issue of the controverted reasons of children's morbidity in the most affected areas around Chernobyl. There are many claims concerning the health of children in the contaminated territories around Chernobyl, which seem to suffer from multiple diseases and co-morbidities with repeated manifestations. The reports from international organizations did not give until now much interest in the multiple publications by Ukrainian, Russian and Byelorussian researchers on children's morbidity. According to the EC report, this is partly due to the fact that many of these studies were not available in English but also to the fact that they often did not meet the scientific and editorial criteria generally required in the Western peer reviewed literature.

Anyway, all these health problems were generally collectively qualified as "psycho-social" side effects in the reports from international organizations. More or less recent studies brought again this issue into light, including the debated publications of Bandazhevsky, linking 137Caesium body loads with ECG alterations and cardiovascular symptoms in children, and the studies on neurobehavioral and cognitive performances in children of the contaminated areas.

The EC report drew the attention on IRSN conducted series of animal studies. Rats were exposed to 137Caesium contamination during several months (generally 3 months, sometimes 9) through drinking water containing 6500 Bq/L. Intake of 137Caesium was estimated to be 150 Bq/day/animal (500 Bq/kg of body weight), a figure that is considered by the authors to be comparable with a typical intake in the contaminated territories (based on Handl's evaluation in Ukraine: 100 Bq/day with variations, according to geographical location and diet, from 20 up to 2000 Bq/day as in the case of special dietary habits like excess consumption of mushrooms) .

Although the animals tested in these studies did not show induced clinical diseases, a number of important biological effects were observed on various systems: increase of CK and CK-MG, decrease of mean blood pressure and disappearance of its circadian rhythm; EEG modifications, perturbations of the sleep-wake cycle, neuro-inflammatory response, particularly in the hippocampus, etc. The report underlined that these somewhat unexpected results are obtained after relatively modest intakes of 137Caesium and that a fraction of the population in the contaminated territories has been shown to incorporate ten times more 137Caesium with their food.

Again according to the same EC report, on the ground of the fact that there is currently a lack of analytical studies in which dose and risks on non-cancer diseases in children were estimated on an individual level, a series of longitudinal studies have also been initiated in Ukraine in conjunction with the US University of South Carolina and were devoted to children's health, making use of the fact that all children in the studied territory had been obliged to participate in a yearly medical examination.

A first study investigated, for the years 1993 to 1998, the association between residential soil density of 137Caesium (used as exposure indicator) and blood cell concentrations in 1251 children. The data showed a statically significant reduction in red and white blood cell counts, platelet counts and haemoglobin with increasing residential soil contamination. Over the six-year observation period, hematologic markers did improve. The authors draw the attention on the fact that similar effects and evolution were reported after the Techa River accident in 1957.

A second study investigated, for the same years 1993 to 1998, the association between residential soil density of 137Caesium and spirometry measures in 415 children. They found statistically significant evidence of both airway obstruction and restriction with increasing soil 137Caesium. The authors advance as possible explanation a radiation-induced modulation of the immune system leading to recurrent infections and finally to detrimental functional effects.
The authors of these studies conclude by saying that the current "optimism of the UN reports may be based on too few studies published in English, conducted too soon after the event to be conclusive").

Fundamentally, looking to such studies, the questions which should be considered are:

- whether the observed morbidity in children after the Chernobyl accident is only explained by psycho-social factors or whether it is at least partly due to currently not recognized *non-cancer* effects of chronic internal exposure
- whether there is always equivalence of risk for external and (chronic) internal exposures
- and whether the currently used concept of equivalent/effective dose is a right risk indicator for *all* types of effects (including all types of non-cancer effects).

This issue is a major societal concern after large-scale contaminations and asks for adequate research.
Unfortunately the above-mentioned references were even not quoted in the UNSCEAR Fukushima report (although asked for) and there were practically no research published to try to verify the above-mentioned observations and experiments and to check the possible dose-dependence of the biological perturbations observed in the IRSN study.

Systematic search for surprises ("thinking the unthinkable") is a difficult challenge, because it means often challenging dominant paradigms or at least refusing to "follow fashion". It may seem strange or incredible but there are fashions in the scientific world. Example in the current radiation specialists' field is the lack of interest about hereditary effects, judged frequently as being practically inexistent or negligible just because nothing was seen until now (some tens of years …) in the survivors of the atomic bombing. Bad surprises may arrive in this field in the future.

The same is true concerning non-cancer effects after in utero irradiation, where the dominant concept is currently that there is nothing to fear under 100 mGy, while the domain of long term Nervous Central System (NCS) effects, of effects of internal exposures and of potential long term effects linked to epigenetic effects, as perturbations of gene expression, is largely unexplored, with a few recent exceptions such as the CEREBRAD project (Cognitive and Cerebrovascular Effects Induced by Low Dose Ionizing Radiation), a collaborative European project funded in 2011 within the 7th EU framework programme, Nuclear Fission and Radiation Protection.

UNSCEAR reports (Fukushima, children) are based quasi exclusively on the "hard" evidence approach and generally fail to consider and discuss epistemic uncertainties. Science-based balanced information after Fukushima should have included at least mentioning and discussion of the above-mentioned studies and uncertainties, common to all nuclear accidental situations and frequently brought up by the media and the NGO's.

3. Fairness of risk communication: a fundamental ethical issue in accidental situations

As explained above, decisions are most frequently to be made about situations, where strong evidence or certainty is lacking. Such decisions must be based on available "evidence" (evidence, here not in the sense of "certainty", but in the sense of "indications" or "corpus of knowledge"), even if there persists uncertainties. Decision-makers need then a sound basis for informed decision-making and are asking scientific experts (groups, committees …) for science-based balanced information, including science-based inferences about the risks in the future and science-based information about uncertainties and their potential consequences.
The same is true for affected populations (or patients in medical exposures) which have to take autonomous informed decisions regarding their health and the health of their children.

To take the right decision and take their responsibilities, societal as well as individual decision-makers must be *aware* of "*potential*" harm ("are you sure it is safe?" and, if not, "what may happen?", "what is at stake?"), and of the way uncertainties, including epistemic ones and research needs linked, are *assessed* ("how do you evaluate and balance the available

evidence?”, “what is the degree of confidence that we avoid false positives and false negatives?”, “what is the degree of consensus?”, and particularly, “what are the reasons for divergent views?”).
Fair communication and information should allow for responsible and autonomous decision-making (as well for decision-makers as for population). In this respect, the uncertainties and assumptions have to communicated, together with their level of confidence.

Communication heard after Fukushima such as “no detectable (or discernible) effect is expected” is misleading as it is understood as indicating an absence of risk while it in fact just means that there are statistical limitations that would not allow to show a statistically significant effect, ….even if this effect is 100% certain!
The same misleading character is true for statements as “it is safe under 100 mSv”. Everybody understands that there is no risk under 100 mSv or that there is a risk threshold at this level, while this statement is just the result of an unbalanced use of the evidence-based approach, looking only to the avoidance of false positives (100% certainty should be necessary before concluding anything). In reality there are a lot of evidences below 100 mSv (or “about” 100 mSv), particularly for radiosensitive sub-populations as young children, embryos or foetus or cancer-prone subgroups with genetic predispositions, and there are solid radiobiological reasons for asking for prudence in the low dose field.

Unbalanced reassuring information is not only misleading but is also counterproductive as it provokes contesting reactions in specialized people, leading to general distrust in all experts and causing finally more anxiety within the population.

The right way to communicate about risks and associated uncertainties should be discussed with human science specialists (not only in communication) but also with the stakeholders, including representatives of the affected population and of NGO’s.

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