Advantages and Limitations of Dose Assessments to the Members of the Public Based on Environmental Monitoring

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INTRODUCTION

Annual doses received by members of the public due to routine releases from nuclear installations are usually assessed by means of models calculating the dispersion of radionuclides in air and water, and concentrations in the different compartments of the environment.

Such assessments need to use a large number of parameters, some of them being associated with large uncertainties. Consequently, the objective of such evaluations is to estimate an upper bound of the doses received rather than a realistic value. This approach is relevant to verify the compliance with dose limits, but is not sufficient to satisfy to the optimisation principle. That is why recommendations from international competent organisations or authorities now request for more realistic dose assessments. To comply with these recommendations, two ways should be investigated : the improvement of existing assessment methods and models, and the research on other methods.

This paper presents the results of the methodological approach used to assess doses received by the public on the basis of environmental measurements, with a particular emphasis on :

- the methodological difficulties raised by the assessment of the dose to the most exposed group of population (the reference group) due to plant discharges, when the environmental measurements are used ;
- the exhaustiveness of the impact evaluated according to this approach, by comparing the results obtained with the results of an assessment based on the modelling of environmental transfers ;
- the improvements required to perform more realistic public dose assessments.

This methodology was applied to the discharges of the Marcoule reprocessing plant, and conducted under an agreement with the site licensee (COGEMA). Results are extensively described in a report (1), from which the main results are given here.

AVAILABLE DATA

Two kinds of measurements are performed in the vicinity of the Marcoule reprocessing plant :

- routine measurements, which are priorly devoted to the environmental survey, in view to demonstrate compliance with regulations, and to detect any unexpected event. These objectives are not always consistent with a dosimetric assessment. These measurements, for which the reaction time must be short, are performed on a systematic way by the licensee, and they provide activity concentrations in many compartment of the environment (food products, water, soils,...) ;
- periodic measurements, which are used to determine the impact of discharges on the environment and to detect temporal evolutions. This kind of measurements are usually performed on an annual basis ; it needs more precise measuring devices and methods (lower thresholds) and the reaction time is longer. For these goals, radioecologists often focuse on parameters that are not relevant for a dosimetric assessment (concentrations in bio-indicators by example).

Most of the measurements are not performed continuously and then they reflect only the radiological situation at a given time or for a limited period of the year. Nevertheless, these measurements are supposed representative of mean annual values.

METHODOLOGICAL DIFFICULTIES

Localisation and characterisation of the reference group

Former studies have shown that the reference group of populations, both for the liquid and gaseous discharges, is the population of Codolet, a small village (450 inhabitants) located along (downstream) the Rhone river, 3.4 km South of the plant, downwind 50% of the time. Moreover, there are no recent local data allowing the characterisation of this group in terms of time spent outside, dietary habits and origin of consumed foodstuffs. Values used in this study are issued from statistics of extended region where the village is located.

It must be noted that this difficulty is not specific to a given assessment method and is encountered whatever the method may be.

Need for reference concentration values

Concentrations measured in the environment include the consequences of discharges from the plant of interest, but also the contributions of the natural radioactivity, of the fallout from nuclear weapon tests in the atmosphere and of the Chernobyl accident, of discharges from other plants,... Then, it is necessary to deduce the radiological background to the measurements performed in the vicinity of the plant. To this end, it is necessary to dispose of reference values, that means concentrations out of the plant influence. For this purpose, measurements are usually performed before the plant operates but, in the case of the Marcoule plant, which is in operation since 1956, the radiological background has been substantially modified by the nuclear weapon tests and by the Chernobyl accident, so that measurements performed prior to the starting of the plant cannot further be considered as reference values for this study.

To overcome this difficulty, reference sampling places were identified, sufficiently close from the site to suppose that observed concentrations were representatives from the radiological background on the site, but located so that the influence of plant discharges was negligible. Regarding liquid discharges, sampling performed upstream can be considered as giving reference values, but in the terrestrial environment, the choice is more complex and only areas can be identified, for which the probability to be downwind is the smallest.

Detection limits

Concentrations observed in the environment due to plant discharges are often very low, below the detection limits. Significant measurements are few with regard to the total number of performed measurements. In addition, some measuring devices count only the total sample activity, without any differentiation between radionuclides. This also reduces the number of usable data.

Attribution of the assessed doses to the discharges of the plant

To decide on whether the difference in the doses calculated for the Codolet reference group and for the population living in unexposed places can be attributed to the plant discharges or not, it was necessary to establish some rules :

- When there is an overlap between the confidence margins of the doses, the difference is noted " not significant " : the case occurs for the global external dose : $0.73 \pm 0,15$ mSv.a^{-1} in Codolet and $0,60 \pm 0,12$ mSv.a^{-1} in non exposed places ;
- For a given compartment or a given radionuclide, when a concentration measured in Codolet is not reproduced in an unexposed area, this concentration is attributed to the plant discharges ;

Other considerations are also introduced to judge if it is relevant to attribute the difference in concentration at Codolet and at non exposed place to the plant discharges of the plant : by example, the regional variability of caesium concentrations in soils due to the Chernobyl accident is taken into account.

PATHWAYS OF CONCERN

External exposure due to the direct radiation from the plant

Dose rates along the plant fences are significantly higher than in more distant places. To account for this dose rate, a scenario was elaborated, considering the farmers of Codolet who spend time in the close vicinity of the plant.

External exposure due to the plume

The daily average activity (global α and global β,γ activity) of the particles in the atmosphere is measured by the licensee at Codolet and at several other places. The global γ activity has been attributed to ^{137m}Ba, the ^{137}Cs daughter. This assumption is accepted because most of the γ emitters have external dose factors of the same order of magnitude.

Air concentrations of gases discharged by the plant are not monitored in the environment on a routine

basis. Therefore, the dose contribution of these radionuclides cannot be assessed by using measurements.

External exposure due to ground deposition

Dose rate is measured in several locations, inside and outside the plant. The main contributor to the dose rate is the natural radiation, for which the terrestrial variability is too high to allow the attribution of the difference between two differently located measurements to the plant discharges. Then, the dose due to ground deposition was calculated on the basis of soil concentrations and taking into account an average duration of exposure over the year.

Inhalation

Doses received by inhalation are calculated on the basis of weekly measured air concentrations.

Ingestion

Concentration measurements are usually done on the edible part of the foodstuffs and, for vegetables, after peeling and washing, so that it was not considered necessary to apply correction factors to take into account the decontamination of foodstuffs due to culinary preparation and cooking. Dietary habits considered in this study are issued from a food consumption survey at the regional scale performed in 1987.

The consumption rates are not known with accuracy at the local scale. In particular, the part of local products in the diet is unknown. Assumption was made that the totality of the diet come from local products, excepted for fish for which it was supposed that only 10% of the annual consumption was from fish catched in the Rhone river, close to the discharge pipe.

Drinking water at Codolet is pumped in the water table. Global α, global β,γ and tritium concentrations are measured on a routine basis after filtration and treatments.

EFFECTIVE DOSE ASSESSED ON THE BASIS OF ENVIRONMENTAL MEASUREMENTS

Dose assessed according to this methodology, and received by the Codolet reference group, are comprised between 0.89 $mSv.a^{-1}$ (if concentrations below the detection limit are taken equal to zero) and 0.93 $mSv.a^{-1}$ (if concentrations below the detection limit are set to that limit). The contribution of the plant discharges is assessed between 0.005 $mSv.a^{-1}$ and 0.023 $mSv.a^{-1}$. Table 1 below shows the contribution of each pathway :

Table 1 : Annual exposure of the Codolet reference group (adults), and contribution of plant discharges to this dose ($mSv.a^{-1}$), as deduced from environmental measurements

	Total effective dose received at Codolet	Contribution of plant discharges
global external exposure	0.73 ± 0.15	0
including :		
direct radiation	3.4 E-03	3.4 E-03
air concentrations	8.8 E-07	1.7 E-07
ground concentrations	3.2 E-02	0
inhalation	2.2 E-02 to 2.9 E-02	0 to 7.9 E-03
ingestion		
vegetables	6.1 E-02 to 9.4 E-02	1.6 E-03 to 5.3 E-03
wine	2.1 E-02	2.2 E-04 to 2.4 E-03
water (underground)	4.7 E-03	0 to 4.0 E-03
milk (goat's)	1.1 E-02	1.7 E-05 to 2.8 E-04
fishes	1.0 E-03	2.0 E-05
total	**0.89 to 0.93**	**5.0 E-03 to 2.3 E-02**

EFFECTIVE DOSE ASSESSED ON THE BASIS OF ENVIRONMENTAL TRANSFER MODELLING

As discussed above, it is obvious that the impact as calculated on the basis of environmental measurements must be completed by using an other approach :

- Some radionuclides, which are declared in the annual discharges, are not measured in all the compartments of the environment : the most important example is ^{85}Kr in the atmosphere ;
- Measurements are representative of concentrations at a given time and even if these measurements are periodically repeated, it cannot be ensured that the arithmetic mean of concentration of a given radionuclide in a given environmental compartment at a given place is representative of an annual mean : by example, tritium concentrations at a given place in a given compartment can vary widely from one day to another.

In order to appreciate the degree of confidence in the dose assessment based on environmental measurements, public exposure has been assessed by modelling the environmental transfer of radionuclides discharged by the plant in 1993. Two computer codes were used (FOCON96 for atmospheric discharges (2) and AQUAREJ.2 for liquid discharges (3)), that were developed in our Institute on the basis of the European methodology (4) to assess the dosimetric consequences of routine discharges.

Results of this assessment are given in table 2.

Table 2 : Total effective dose received by the Codolet reference group, as deduced from transfer modelling ($mSv.a^{-1}$)

	Total effective dose received at Codolet ($mSv.a^{-1}$)
external dose	
air concentrations	1,2 E-02
ground concentrations	5.0 E-05
inhalation	1.4 E-02
ingestion	
vegetables	1.5 E-02
water (river)	5.1 E-03
fishes	5.1 E-05
total	**4.6 E-02**

The computer codes used do not allow to calculate transfer to the geosphere and then contamination of underground waters. In the same way, dose due to direct radiation from the plant is usually not taken into account.

Main radionuclides are ^{85}Kr, which is responsible of the totality of the external dose due to the plume (26% of the total dose) ; ^{129}I generates a dose of 1.5 E-02 $mSv.a^{-1}$ (one third of the total dose) due to ingestion of contaminated foodstuffs and water ; tritium contributes in the same proportion (1.5 E-02 $mSv.a^{-1}$), mainly due to inhalation ; ^{90}Sr in foodstuffs is the fourth main component (3.4 E-03 $mSv.a^{-1}$ that is to say about 7% of the total dose).

COMPARISON OF RESULTS OBTAINED BY THE TWO APPROACHES

Such comparison is difficult, due to several factors : ^{129}I, which is a main contributor in the modelisation, does not appear in the assessment based on environmental measurements because its detection limit is usually too high. The same occurs for ^{85}Kr, for reason discussed above.

Nevertheless, and despite the uncertainties inherent in models, the comparison of the two approaches suggests the following comments :

- When concentrations are measurable, they are generally in good agreement with the calculated ones, the main exception being for tritium in vegetables and wine ;
- Considering detection limits and expected concentrations, it is clear that a large number of radionuclides noted by the licensee in the list of radionuclides released by the plant are not accessible to the measure (^{125}I, ^{133}I, ^{60}Co, ^{103}Ru, ^{54}Mn,...), whatever sample is taken ;
- inversely, some radionuclides (^{129}I, ^{90}Sr, ^{125}Sb, ^{106}Ru-Rh) are expected at concentrations close to the detection limits in most of environmental compartments, and a reasonable improvement of these detection limits could allow to measure them regularly.

CONCLUSIONS AND PERSPECTIVES

Dose assessment based on results of environmental monitoring and on transfer modelling are different, but not really in contradiction. In both cases, the contribution of the plant onto the surrounding populations is at maximum a few percent of the mean individual dose in France.

In the present context of the search for the most realistic assessment, modelling and monitoring are both useful : some contributions are more accessible by modelling (for instance the contribution of ^{85}Kr to the external exposure), others by monitoring (water table pathway or direct radiation from the plant). In any case, a more realistic assessment needs a better knowledge of local parameters (dietary habits, origin of consumed foodstuffs).

It clearly appears that the objective of a dosimetric assessment must be considered when defining the environmental monitoring system : this objective largely influences the choice of samples (nature, location and frequency) and the presentation of the results.

REFERENCES

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