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NORD-COTENTIN RADIOECOLOGY GROUP: AN INNOVATIVE EXPERIMENT IN PLURALIST EXPERTISE

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LIST OF ABBREVIATIONS

ACRO	Association pour le Contrôle de la Radioactivité dans l'Ouest *(Association for Radioactivity Control in Western France)*
IAEA	International Atomic Energy Agency
ANDRA	Agence Nationale pour la gestion des Déchets Radioactifs *(National Agency for the Management of Radioactive Waste)*
BfS	Federal Radiation Protection Office, Germany
CEA	Commissariat à l'Energie Atomique *(Atomic Energy Commission)*
CEPN	Centre d'étude sur l'Evaluation de la Protection dans le domaine Nucléaire *(Nuclear Protection Evaluation Center)*
ICRP	International Commission on Radiological Protection
CNPE	Centre Nucléaire de Production d'Electricité *(Nuclear Power Plant)*
CNRS	Centre National de Recherche Scientifique *(National Scientific Research Center)*
COGEMA	COmpagnie GEnérale des MAtières nucléaires *(General Nuclear Materials Company)*
COMARE	COmmittee on Medical Aspects of Radioactivity in the Environment, United Kingdom
CRII-RAD	Commission de Recherche et d'Information Indépendante sur la Radioactivité *(Independent Commission for Research and Information on Radioactivity)*
CSHPF	Conseil Supérieur d'Hygiène Publique de France *(National Public Health Council of France)*
CSPI	Commission Spéciale et Permanente d'Information près de l'établissement de La Hague *(Special and Permanent Information Committee for the La Hague Plant)*
DCN	Direction des Constructions Navales *(Ship Building Directorate)*
DOE	Department of Energy, United States
DPPR	Direction de la Prévention de la Pollution et des Risques *(Prevention of Pollution and Risks Directorate)*
DSIN	Direction de la Sûreté des Installations Nucléaires *(Nuclear Installations Safety Directorate)*
EDF	Electricité De France

GEA	Groupe d'Etudes Atomiques *(Atomic Studies Group)*
GRNC	Groupe Radioécologie Nord-Cotentin *(Nord-Cotentin Radioecology Group)*
GSIEN	Groupement de Scientifiques pour l'Information sur l'Energie Nucléaire *(Group of Scientists for Information on Nuclear Energy)*
INSERM	Institut National de la Santé et de la Recherche Médicale *(National Institute of Health and Medical Research)*
IPSN	Institut de Protection et de Sûreté Nucléaire *(Nuclear Protection and Safety Institute)*
ISTE	Institut des Sciences et Techniques de l'Environnement - Université de Montbéliard *(Institute of Environment Sciences and Techniques - University of Montbéliard)*
LDA	Laboratoire Départemental d'Analyse de la Manche *(Analysis Laboratory in "Manche")*
NRPB	National Radiological Protection Board, United Kingdom
OFSP	Federal Public Health Office, Switzerland
OPRI	Office de Protection contre les Rayonnements Ionisants *(Office for Protection against Ionising Radiation)*
SCPRI	Service Central de Protection contre les Rayonnements Ionisants *(Central Ionising Radiation Protection Service)*
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation

FOREWORD

At the beginning of July 1999, after two years work, the GRNC "Nord-Cotentin Radioecology Group" publicized the results of its assessment of the exposure levels of children (0-24 years old) to ionising radiation in the Beaumont-Hague canton in the Nord-Cotentin peninsula and the associated risk of leukemia. These results were complementary to the conclusions of previous estimates requested by the public authorities after Professor Jean-François VIEL at the University of Besançon published the results of his epidemiological study in 1997. These results suggested a causal relation between the development of leukemia in children in the region and exposure due to radioactive discharges from the various nuclear installations located in the Cotentin peninsula. They had caused strong local reaction, particularly among mothers of children near the installations, and had created a controversy between the various local and national stakeholders on the nuclear scene. This study followed on from work done by the same team showing a trend towards excess leukemia in children in the Beaumont-Hague canton, where the La Hague reprocessing plant is located.

The experiment carried out by the Nord-Cotentin Radioecology Group is innovative partly because of its methodology that uses a critical approach that is as exhaustive as possible, and also due to its composition and method of working, notably because it incorporates pluralist expertise working in a very sensitive domain, namely the evaluation of the impacts of radioactivity on health. For two years, experts from French and foreign institutes, from associations and from the nuclear industry, all worked in common to build a methodology, collected and analysed a large volume of data and compared their points of view on the best way of estimating the exposure pathways of the populations concerned. Despite the reservations expressed by some members of the Group about evaluation of the results and the refusal by experts in one of the associations to concur with the conclusions of the Group, this experiment produced a summary of data, some of which had never previously been used in impact studies, and made an evaluation of the potential impact on health caused by exposure to ionising radiation due to discharges from nuclear installations.

This report was prepared by an editorial team composed of members of the CEPN (Nuclear Protection Evaluation Center), MUTADIS (a research group on the social risk management), and a representative of the IPSN (Nuclear Protection and Safety Institute) at the request of the President of the Nord-Cotentin Radioecology Group. This document must be distinguished from the final report written by the GRNC itself, under its own responsibility, to report on its work. Therefore this report gives a synthetic overview of the procedure and the main results of the GRNC, and lessons that can be drawn from it. In particular, it is intended to demonstrate the innovativeness of the pluralist approach adopted by summarizing its historic context and differences with the similar experiment carried out in the United Kingdom for the Sellafield nuclear site[1]. It also presents the different steps in the evaluation of exposures and risks associated with ionising radiation. Finally, it emphasizes prospects opened as a result of the Group's experiment on the involvement of stakeholders in the evaluation and management of radiological risk. This final aspect could open up new means of "preventively" dealing with questions related to risks to health and the environment inherent to industrial activities.

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1 The question of a comparison between the approaches used by the GRNC and by the COMARE (Committee on Medical Aspects of Radioactivity in the Environment in the United Kingdom) should be considered in more detail in a new mission addressed to the GRNC by the Ministry of the Country Planning and the Environment, and the Secretary of State for Health.

1. GENERAL PRESENTATION

1.1. GRNC CREATION HISTORY

Many epidemiological studies on mortality by cancer have been carried out around nuclear sites in different Western countries. There are fewer incidence studies on morbidity or "control case" studies for refining these analyses. One of the earliest was done in 1984 in the area around the Sellafield reprocessing plant in the United Kingdom [1].

In 1995, Professor Jean-François VIEL's team at the University of Besançon published the results of research done in the region of the La Hague reprocessing plant suggesting an excess of incidence of leukemia among persons less than 25 years old within the 10 km zone (Beaumont-Hague canton), at the limit of the significance threshold (4 cases observed between 1978 and 1992 compared with 1.4 cases expected) [2]. In January 1997, the same team published the results of a “control case” epidemiological study [3] in the British Medical Journal. This study pointed out the association between some lifestyle habits (presence on local beaches, consumption of seafood, living in a granite house) and the development of cases of leukemia in persons less than 25 years old within a radius of 35 km around COGEMA's La Hague reprocessing plant. The authors assumed a causal relation between this observation and the environmental exposure to ionising radiation.

The publication of the results of this last study in the media caused strong reactions among the local population, and particularly among mothers of children who took this opportunity to organize themselves into a group called "Les Mères en Colère" (Angry Mothers) and published a manifesto asking for "clear and objective information" about discharges from installations in the region and their potential health effects. A nation-wide debate developed around the work done by Professor VIEL involving scientists, experts, operators and associations, and extended beyond our frontiers. In order to contribute to the many questions raised by the conclusions of this work, Mrs. Corinne LEPAGE, Minister of the Environment, and Mr. Hervé GAYMARD, Secretary of State for Health and Social Security, set up a Scientific Committee in the month of February 1997 presided over by Professor Charles SOULEAU, dean of the Chatenay-Malabry Faculty of Pharmacy, to propose a «new epidemiological study in the Nord-Cotentin». The "SOULEAU Committee", the composition of which was defined in the mission letter, included scientists, mainly epidemiologists, including Professor Jean-François VIEL.

Starting at the beginning of its work, the Committee acted upon suggestions made by Ministers and contacted local personalities and particularly the "Mères en Colère", and also felt the need to widen the scope of its initial task to include a radioecological study to retrospectively estimate exposure received by children from discharges from installations and from different medical and natural sources. This extension was motivated essentially by the desire to provide the Nord-Cotentin population with "elements of answers about the past" to reply to questions about the risks to which it had been subjected. Therefore, the approach represented the will to respond to local worries as closely as possible within the framework of a scientific approach.

The Committee set up two working groups, one concentrating on epidemiological aspects and the other on radioecological aspects, the radioecological aspects sub-group being mainly composed of experts appointed by technical advisors to the authorities and operators but also including a non-institutional expert, while the IPSN (Nuclear Protection and Safety Institute) provided the Secretariat. In his final report [4], Professor SOULEAU justified opening up the Committee to operators and non-institutional experts in this way: *"… the Committee is well aware of the complexity of the studies and therefore the difficulty of communication towards a legitimately worried general public. In this respect, it considers that the necessary condition to have confidence in experts is the presence... of institutional and non-institutional experts within the same group … capable of working on common scientific bases with maximum transparency".* In practical terms, all members of the Committee were required to respect a confidentiality agreement, and finally the plenary group validated the results before they were communicated to the public.

In July 1997, after six months of work the Committee President presented the final report to Mrs. Dominique Voynet, the new Minister of the Environment and Mr. Bernard Kouchner, the new Secretary of State for Health of the government formed in June 1997 [4].

Concerning the epidemiological aspect, one of the SOULEAU Committee's conclusions was that the incidence study on persons less than 25 years old in the Beaumont-Hague canton should be completed by data for recent years (1993 - 1996) not included in previous work done by Professor VIEL. Recommendations were also made about the need to improve the epidemiological monitoring system throughout the country and particularly close to sites with risk.

Concerning the radioecological aspect, starting from an evaluation based on models used by operators for the purposes of authorizations procedures for discharges from the COGEMA - La Hague reprocessing plant, the Scientific Committee considered that: "*an additional annual exposure of 300 µSv during 15 years should cause an excess of 0.07 cases for 100,000 children per year, namely less than one case per year for the 0 to 24 year old populations in the Nord-Cotentin*". Furthermore, the Scientific Committee demonstrated the consistency of measurements made in the environment by the different stakeholders (operators, public authorities, associations). In the conclusion to its report, the Scientific Committee recommended that this work should be continued, and in particular that the results of measurements made in the environment should be systematically used to compare them with evaluations made based on real discharges and the model for their transfer through the environment. In fact, only some of the measurements were usable and the database was not exhaustive. Furthermore, a systematic critical analysis of models used by operators had still not been made. For transparency purposes, the contents of these models had to be clarified and their forecasts compared with measurements made in the environment, in order to check that they are valid for local conditions. It was found that a pluralist expertise was necessary to confirm confidence in the results of such a critical evaluation process.

Since Professor SOULEAU did not want to continue his task, in August 1997 the Minister of the Environment and the Secretary of State for Health decided to appoint Professor Alfred SPIRA, Research Director at INSERM, to continue the epidemiological work, and Mrs. Annie SUGIER, Director for the Protection at the IPSN, to continue the radioecological work.

The purpose of the epidemiological work directed by Professor Alfred SPIRA was to set up a reflection on the procedure for monitoring the effects of ionising radiation in France and the continuation of studies in the Nord-Cotentin. The final report was submitted in July 1998 [5]. In particular, this report presented the results of prolonging monitoring of the incidence of cases of leukemia in the Nord-Cotentin during the 1993-1996 period based on the La Manche department cancer register.

The team working on radioecological aspects directed by Mrs. Annie SUGIER was widened once again at her request and with agreement of the Ministers, to include new experts from a number of local and national associations - the ACRO (Association for Radioactivity Control in Western France), the GSIEN (Group of Scientists for Information on Nuclear Energy), the CRII-RAD (Independent Commission for Research and Information on Radioactivity), and European experts from the NRPB (National Radiological Protection Board, United Kingdom), the BfS (Federal Radiation Protection Office, Germany), and the OFSP (Federal Public Health Office, Switzerland). Some of these experts were also members of the CSPI (Special and Permanent Information Committee) for the La Hague Plant, which meant that the CSPI could contribute to this work and thus satisfy the request made by Mr. CAZENEUVE, its President, Member of Parliament. The composition of the team, subsequently referred to as the GRNC "Nord-Cotentin Radioecology Group", was defined to satisfy the objective of creating a tool for in-depth critical analysis of available data about the Nord-Cotentin radioecological situation. The participation of experts from associations and foreign experts was discussed between operators and institutions already represented in the group. It was agreed that the objective of the group was not necessarily to lead to a consensus, but to perform the most exhaustive possible critical analysis emphasizing uncertainties and points of disagreement between experts whenever necessary.

The initial task assigned to the GRNC was to reconstruct doses received from all industrial, medical and natural sources in order to estimate the risk of leukemia associated with ionising radiation for young persons less than 25 years old. This was done assuming as a precautionary measure that a risk exists regardless of the level of the dose i.e. using a linear no-threshold relationship between the dose and the risk (see section 2.1.3). Much of the critical effort was made for sources from the nuclear industry present in the Nord-Cotentin, and particularly the La Hague reprocessing plant. The group developed a retrospective analysis to estimate the risk associated with ionising radiation, based on an inventory of discharges from Nord-Cotentin nuclear installations, and radioactivity measurements made essentially to satisfy the requirements of the regulatory environmental monitoring.

Furthermore, in November 1997, the Minister of the Environment, and the Secretary of State for Health, asked the GRNC to provide authorities with elements of its work that could be helpful for the current revision procedure to texts governing operation of the COGEMA La Hague plant.

The GRNC submitted two progress reports during 1997 and 1998, and a methodological note in July 1998 [6, 7, 8]. The conclusions of the GRNC's work were sent to the Ministry of the Environment and to the Secretary of State for Health on July 7 1999 and were made available to the public on Internet (www.ipsn.fr/nord-cotentin) at the same time. The final report, comprising four volumes and a summary report, was distributed in

October 1999 [9].

1.2. Presentation elements of the Nord-Cotentin region

The Nord-Cotentin peninsula located at the extreme north-west tip of Normandy is an essentially rural region, and together with the city of Cherbourg (100,000 inhabitants) forms one of the major economic areas of the La Manche department (about 470,000 inhabitants). The nuclear energy industry makes an overriding contribution to its industrial activities. The Beaumont-Hague canton, about which the study was particularly concerned, is composed of 19 villages with about 11,000 inhabitants (see Figure 1).

Figure 1. The Beaumont-Hague canton

1.2.1. Nuclear activities

Except for Alcatel Télécom (400 jobs), most large companies working in the region are associated with the civil and military use of nuclear energy. These large companies are the Cherbourg Arsenal, the La Hague reprocessing plant, the La Manche low and medium activity radioactive waste storage centre and Flamanville nuclear power plant.

The DCN (Shipbuilding Directorate)

The development of the nuclear industry in the Nord-Cotentin began with the construction of submarines in the Cherbourg Arsenal in 1958. The DCN (Shipbuilding Directorate) now has a large shipbuilding activity for building new ships, fleet maintenance and dismantling decommissioned ships, in the military port of Cherbourg.

COGEMA spent fuel reprocessing plants

The Atomic Energy Commission (CEA) decided to build a second reprocessing plant to reprocess spent fuel from "Natural Uranium - Graphite - Gas" (UNGG) type reactors, in 1959; the first plant (UP1) was built in Marcoule (in the Rhone Valley). The La Hague plant (UP2) started operation in 1966 for the reprocessing of UNGG fuel, and then in 1976 started reprocessing of fuel from light water reactors (UP2-400). The responsibility for operation was transferred to COGEMA in 1978. Two new plants were built during the 1980s; the UP3-A plant for reprocessing foreign light water fuels that was commissioned in 1989 and the UP2-800 plant for reprocessing light water fuels that started in 1994. COGEMA's spent fuel reprocessing plants are located in La Hague 20 km west of Cherbourg at the far north-west of the Cotentin peninsula. They cover an area of 290 hectares (220 hectares, plus a 70-hectare area between the plant and the sea). About 6000 persons work on the site permanently, including 3000 persons working for COGEMA, 2000 persons working for subcontracting companies doing maintenance and 1000 persons working on construction of the latest projects. These three plants had reprocessed a total of 1680 tonnes of spent fuel by 1996.

The ANDRA La Manche low and medium activity radioactive waste storage centre

The construction of the first French centre for shallow-land storage of low level and intermediate level radioactive waste was authorized in 1969. This centre was operated firstly by the INFRATOME company under the responsibility of CEA, and then since 1979 by the ANDRA. It is located at the tip of the Cotentin peninsula (Beaumont-Hague canton) over an area of about 15 hectares. Its operations were shut down after the last parcel was put into storage in July 1994, making its total volume of stored waste equal to 527,214 m^3. Placement of the cover started in 1991 while material was still being put into storage, and was completed in 1997. Therefore, the Centre has begun a monitoring phase that is intended to last for 300 years. During this phase, ANDRA's essential objective will be to estimate changes to the properties of the cover, verify the behaviour of the storage facility and carry out whatever maintenance operations are necessary.

Electricité de France's Flamanville nuclear power plant

Flamanville Nuclear Power Plant comprises two pressurized water type reactors with a unit power of 1300 MWe. The first unit was commissioned in December 1985, and the second unit was commissioned in June 1986. The power plant is located within the boundaries of the village of Flamanville, in the Pieux canton in the La Manche department 21 km to the south-west of the Port of Cherbourg on the west coast of the Cotentin. The site employs almost 600 persons.

1.2.2. Other activities

Traditional port activities such as building warships (DCN, the Arsenal) and merchant ships (Constructions Mécaniques de Normandie) – employ 4750 persons. An entire local fabric of subcontractors has been built up around the port industry, similar to that around the nuclear industry. Thus the Cherbourg employment basin includes 200,000 persons.

There is also a major food processing activity specializing in breeding and dairy production in the Nord-Cotentin. The La Manche department is one of the leading milk producing departments in France. More than two thirds of the farm area in the Beaumont-Hague canton consists of meadows, 20% of the area is set aside for fodder crops and 10% for cereals. There is also a market gardening activity around Cherbourg. Fishing activities (including sea trout farming, oyster farming and mussel breeding) contribute a non-negligible part towards the local economy. Finally, tourism occupies an increasingly important position in the economy of the region, and in particular Cherbourg is the leading stopover port in France for cruise ships.

1.3. The environmental monitoring system around nuclear installations in France

In order to complete its evaluation procedure, the GRNC relied largely on available data about radioactive discharges from the nuclear installations presented above and radioactivity measurements made in the environment near these installations. Most of these data were produced to satisfy the regulations for discharges of radioactive gaseous and liquid effluents from Nuclear Installations (INB) [10]. The following sections describe the main regulatory requirements that have progressively been set up in France for monitoring the environment.

1.3.1. General principles for environmental monitoring

In general, the operator and the authorities determine a radioecological «point zero» before the construction of a nuclear installation. This point zero is used to determine the ambient radioactivity level resulting from the presence of natural radioactivity and radioactivity caused by prior habits or events that affected the planned site (for example fallout from atmospheric testing of nuclear weapons). A radioecological impact study carried out before the installation is commissioned predicts exposures that will be received by the various population groups who live close to the installation, considering discharges authorized by authorities.

This estimate is made starting from general models frequently based on national and international comparisons of operating experience with similar installations, applied to the site configuration. These evaluations are essentially theoretical and are based on very conservative assumptions building in large safety factors for precautionary reasons.

Radioactivity controls after the installation has been commissioned are made by the operator in the installations themselves and at release points, before the discharges are made and during the discharges. The authorities also make controls in the environment around the installations. Monitoring points are chosen in agreement with the authorities, to satisfy several criteria:

- points at which maximum radioactivity levels would be expected: plants on the down wind side of atmospheric discharges, points at the installation boundary or where the plume drops to the ground …,
- optimum dilution points chosen to check that dilution in aquatic and atmospheric media is taking place under good conditions.

All these measures are set up to confirm that the released radioactivity has been dispersed or diluted in accordance with forecasts, and that there is no abnormal increase in the levels of environmental radioactivity with time.

Radioecological studies on nuclear installations in operation are carried out at ten-year or possibly annual intervals. The purpose of the ten-year study is to compare measurements on various samples with the values found during the previous ten-year study and with the initial "point zero". The annual study is less extensive but its purpose is the same as the ten-year study, namely to confirm that there has been no unexpected increase in radioactivity levels around the site.

1.3.2. Progressive setting up of regulatory controls in the Nord-Cotentin

The first controls of the marine environment in the Nord-Cotentin region were made in the middle of the 1960s by operators of the La Hague reprocessing plant and the Cherbourg arsenal and by the Ministry of Health. They were made on sea water, sediments, shellfish, molluscs and seaweed. The La Hague reprocessing plant also started its first systematic controls of drinking water and dairy milk starting in 1966. The La Manche storage centre started making controls on small streams in the immediate vicinity of its site (Roteures, Sainte Hélène) in 1970.

At the time, atmospheric emissions and discharges into the aquatic environment by industrial plants were governed by the regulatory requirements set down in the 1961 law for the reduction of atmospheric pollution and smells (law No. 61-842 August 2 1961) and the 1964 law about water flow characteristics and distribution and the control of water pollution (law No. 64-1245, December 16, 1964). Furthermore, a 1963 decree stipulated that prior authorization was necessary before the construction or modification of a nuclear installation (decree No. 63-1228, December 11, 1963).

Later, radioactivity in the environment was monitored systematically when the first regulatory texts appeared governing gaseous and liquid radioactive discharges from nuclear installations (decrees No. 74-945, November 6, 1974 and No. 74-1181, December 31, 1974). These general texts were replaced by decree No. 95-540, May 4, 1995. The decrees governing discharges of liquid and gaseous radioactive effluents obliged operators to make pollution controls of the immediate environment.

Orders for the authorization of discharges specific to each site define annual limits of released activities and the conditions under which these discharges are made. These orders were adopted in 1980 and were set in 1984 for the La Hague reprocessing plant, in 1985 for Flamanville Nuclear Power Plant and in 1969 for the La Manche storage centre.

1.3.3. Efficiency of environmental monitoring

There are several reasons for regularly questioning the relevance of initial regulatory requirements for monitoring the environment around nuclear power plants. Investments made throughout the life of an installation result in improvements that gradually change priorities and needs for environmental measurements.

A particular type of priority problem in the years after an installation is commissioned will justify a particular monitoring system, and will then become less important as a result of investments made by the operator at the request of the authorities, or because the operator's facilities are modernized. Therefore, resources dedicated to monitoring must take account of changes to operating conditions over time. For example, this is the case for COGEMA's La Hague installations for which surveillance and controls were concentrated mainly on liquid discharges in the early stages of operation. Later, gaseous radioactive discharges became predominant in population exposure, taking account of progress made in the treatment of radioactive liquid effluents that made it possible to significantly reduce released quantities.

Furthermore, additional controls complementary to those initially planned were introduced over the years to take account of changes to the installation. Thus, COGEMA modifies its plant environment monitoring plan every year after receiving the opinion of the OPRI, to take best account of studies and operating experience during the previous year.

Finally, starting in the nineteen eighties, nuclear power plant operators implemented the approach to optimise radiation protection for the public which led to adopt an increasingly realistic evaluation of transfers of radionuclides through the environment and population exposures, taking account of local lifestyle habits. Realistic and accurate measurements contribute to identifying rooms for manœuvre and the most effective measures with regard to protection of the public. In the context of optimisation, it is also important to note that these rooms for manœuvre must be examined firstly considering protection of the public, and also taking account of risks of exposure transfers to personnel responsible for the management of radioactive effluents, and in order to achieve efficient use of protection resources.

Recent changes to European regulations require even greater realism in the evaluation of the impact of discharges from nuclear installations [11], particularly in order to increase the relevance of international comparison studies of discharges from installations, that can only be valid if they are made on a comparable basis. A comparison based on conservative data, without knowing the relative magnitude of the safety factors used, is of limited use. Realism is an achievable objective considering that there are many available environmental measurements made after installations have been commissioned, that can be used to calibrate models used to estimate radioactivity transfers through the environment, by substituting real data for conservative assumptions made in the first place. From a regulatory point of view, the Ministerial Order in application of the May 4, 1995 decree dated November 26, 1999 fixes general technical requirements about methods of taking water samples and discharges of liquid and gaseous effluents subject to authorization.

1.3.4. Monitoring the environment and health impacts

Due to changes to the regulations mentioned above, environmental monitoring systems are increasingly faced with the necessity to produce realistic evaluations of the health impact of industrial discharges. In this context, environmental monitoring measurements make an essential contribution towards estimating the impact of discharges in terms of doses and risks.

It was found necessary to use increasingly efficient sampling and measurement techniques to determine the real impact of discharges on the environment and on man, in order to satisfy this need for realism. It is now possible to detect extremely low radioactivity levels as a result of progress made in this field during recent decades. However, a distinction has to be made between two objectives of making measurements:

- measurements made to check that no operating incident has occurred, practically in real time; in this context there is no real need to attempt to lower detection limits, and the measurements (usually automatic) are made on a tight network of sampling points;

- measurements made so that the impact of radioactive discharges on health and the environment can be estimated retrospectively. In this case, significant values can only be obtained if a large number of samples is collected and if the measurement techniques used are capable of detecting very low radioactivity levels. These measurements are obviously more difficult and take longer to make and require much more sophisticated technical means. They are the only measurements that can be used to create and validate dispersion models and estimate the real impact of the installation.

In general, the increasing involvement of stakeholders and particularly associations in the process for assessing and controling nuclear installations is the reason for an increasing number of debates firstly about the representativeness of measurements made in the environment around installations, and secondly the reliability of estimates of exposures of the public resulting from discharges into the environment according to radionuclide transfers specific to these discharges. For this type of debate, it is increasingly important to be able to monitor the future of each type of discharged radionuclide within the environment and its contribution to exposure of persons, as precisely as possible.

1.4. Prior experiment: the COMARE committee

The specific context in which the GRNC was created was described in the introduction to this report. The characteristics of this group concerning the nature of its participants and its method of operation, are significantly different from the characteristics of a similar experiment carried out previously in the United Kingdom with the COMARE Committee.

In November 1983, a television program mentioned an abnormally high number of cases of leukemia in children under 10 years old in the village of Seascale, 3 km from the Sellafield spent nuclear fuel reprocessing plant. Following this announcement, the British Ministry of Health set up an Independent Advisory Group chaired by Sir Douglas Black with the objective of verifying the incidence of leukemia and the theory of a possible relationship between these cases of leukemia and radioactive discharges from the Sellafield installation. The NRPB (National Radiological Protection Board), the national institute with expertise in radiological protection, made the calculations on the exposure of the population and the associated risk for the purposes of this task. In its final report (1984) [1], the group confirmed that there was an excess number of cases of leukemia but concluded that, based on the estimates that it had made, it was impossible to identify a cause to effect relationship with discharges from the Sellafield installation. However, considering uncertainties about several parts of its evaluation, the group recommended additional studies.

In reply to the recommendations made in the Black report, the COMARE (Committee on Medical Aspects of Radiation in the Environment) was set up in November 1985 to advise the British Government about effects on health of natural and artificial radioactivity in the environment, to estimate the relevance of available data and finally to identify the needs for further researches in this subject.

The COMARE Committee is a permanent committee composed of about fifteen scientists and professors from university, mostly working in the fields of radiobiology and cancerology. The Government regularly asks the Committee to examine specific questions as a function of events or new knowledge about the effects of radioactivity in the environment. The Committee uses a secretariat and *ad hoc* working groups composed of members of the Committee, the secretariat and outside experts whenever necessary, in performing its duties. All members of the Committee and the various working groups agree to respect a "Code of good conduct" that guarantees that they remain independent from the nuclear operators. The Ministry of Health was initially responsible for the Secretariat. The NRPB has been responsible since 1996.

The COMARE Committee has published six reports since it was created. The first report in 1986 related to uranium oxide discharges from the Sellafield plant that had not been included in the Black report [12], and concluded that this further information did not change the previous conclusions. The second report was published in 1988 and dealt with risks of leukemia for children living close to the Dounreay nuclear installation in Scotland [13]. It concluded that there was a significantly higher incidence than the average, but there was no causal relationship between discharges from the installation and leukemia, based on scientific data available at the time. The third report applied to the Aldermaston and Burghfield sites [14], and presented the results of the evaluation of exposure caused by the installations, and put them into perspective with exposure due to natural radiation. Its conclusions included the need for precise information about the geographic distribution of the incidence of leukemia throughout the United Kingdom, in order to get a better understanding about the question of the higher number of cases of leukemia around nuclear installations. The fourth report published in 1996 was intended mainly to re-estimate the initial study around Sellafield taking account of all new data and knowledge accumulated in the meantime [15], and concluded that the estimate of the risk due to discharges from the installations was too low to explain the observed excess risk. The fifth report examined the situation around the Greenham site and the sixth report updated the study for the Dounreay site.

It is interesting to note that the composition of the COMARE Committee gave priority to scientific expertise in order to remain as independent as possible from operators of nuclear installations. This independence is considered to be an important element towards instilling confidence in the published results. However, operators may participate in the working groups, essentially to provide industrial data essential to make the necessary evaluations. The role of the secretariat is to coordinate experts and to provide technical control over the evaluation work. The fact that the NRPB is responsible for this secretariat confirms the importance of being able to base the work done on a technical organization with expertise in radiological protection. No local stakeholders or foreign experts are invited to participate in the work. The Committee alone validates the work after it has been completed, and is therefore responsible for the scientific quality of the results.

1.5. The composition and operation of the GRNC

1.5.1. A pluralist experts group

The GRNC continued the work initiated by the SOULEAU Scientific Committee in the radioecological field, and used the same principle of pluralist participation including not only public expertise organizations, but also experts representing different group of stakeholders concerned by this evaluation process, and particularly nuclear operators in the Nord-Cotentin region, experts from the Special and Permanent Information Committee for the La Hague plant, non-institutional laboratories and organizations and foreign organizations (Table 1).

This GRNC's policy of including pluralist expertise is significantly different from the approach adopted by the COMARE Committee. It reflects the changes that have been made during the last decade concerning what is generally and maybe improperly referred to as communication about risk. In the 1980s, it was generally accepted that the attitude of the public with regard to activities creating risks was largely based on the perception of the public towards the people who provided information about this risk. Consequently, confidence was seen to depend on the scientific nature of information and also the integrity of the persons who gave it.

Table 1. Origin of experts participating in the GRNC

Public expertise and inspection organizations	
Office for Protection against Ionising Radiation	**OPRI**
Nuclear Protection and Safety Institute	**IPSN**
Ecotoxicology Service – Phrama-Nantes - EP 61	**CNRS**
Nord-Cotentin nuclear operators	
General Nuclear Materials Company	**COGEMA**
National Agency for the Management of Radioactive Waste	**ANDRA**
Electricité de France	**EDF**
Atomic Studies Group	**GEA**
The Special and Permanent Information Committee for the La Hague Plant	**CSPI**
Non-institutional and university expertise organizations and laboratories	
Association for Radioactivity Controls in Western France	**ACRO**
Independent Commission for Research and Information on Radioactivity	**CRII-RAD**
Group of Scientists for Information on Nuclear Energy	**GSIEN**
Department Analysis Laboratory	**LDA**
Nuclear Protection Evaluation Center	**CEPN**
University of Montbéliard - Institute of Environment Sciences and Techniques	**ISTE**
Foreign expertise organizations	
National Radiological Protection Board (United Kingdom)	**NRPB.**
Federal Radiation Protection Office (Germany)	**BfS**
Federal Public Health Office (Switzerland)	**OFSP**

It is also useful to emphasize that in the GRNC, the pluralist expertise is exercised through the plenary group and not only within the framework of working groups as it was in previous committees (COMARE and the SOULEAU Scientific Committee). Thus, the critical evaluation approach is based more on a principle of genuine cooperation between the different interests represented in the expertise than simply on including more participants. This pluralist aspect combined with the principle of collegial operation is an important factor in the quality and credibility of the work done.

1.5.2. Cooperation rules

The GRNC adopted a two-fold structure to perform the various aspects of its task. There was the Plenary Group that met regularly (20 meetings total) and was responsible for the management of the work, and four specialized working groups including members of the plenary group and other experts, each working group being assigned to one of the following subjects:

- a critical examination of discharges declared by operators of Nord-Cotentin nuclear installations,
- collection and interpretation of environmental measurements made by the various participants,
- comparison of models representing transfers of radioactive discharges through the environment and used to estimate resulting exposures of populations in the region and to compare the results predicted by models with measurements made in the environment,
- estimate of doses received by the public and of the risk of leukemia to the public.

Members of the GRNC quickly realized that traceability of its activities and availability of information were the first prerequisites for a transparent debate and credibility of the group's work. Therefore it was decided that a progress report would be written following each session of the working groups. Meetings of the plenary group were typed in full and detailed minutes were written for each meeting. Summary conclusions were published within 48 hours and helped to identify points of agreement and disagreement during the sessions. These documents could be used by any member of the group for any external communication.

As soon as the GRNC was created, it was agreed that any member of the group would be free to provide any information about the state of progress of the studies provided that she or he did not give any conclusions about the work being done before they had been scientifically validated. It was decided that members of the GRNC would not be governed by any type of confidentiality obligation. Finally, all mail addressed to the members of the group or to its President were put in common within the group.

The operation in working groups required the active participation of members of the GRNC in production and verification of data. Several verification operations were made in each working group to achieve high quality results. Furthermore, as an Institute, the IPSN contributed to these verifications by proof reading and making consistency tests, particularly for orders of magnitude. Finally, the participants in the process agreed to make all their data available to the GRNC: measurements of discharges and measurements in the environment. The approach was financed partly by a subsidy from the DSIN (Nuclear Installations Safety Directorate) and the DPPR (Pollution and Risk Prevention Directorate) of the Ministry of the Environment. An agreement was signed on this subject between the IPSN and these two directorates. During the two years in which the group was in operation, the time spent by its members in order to carry out the evaluation was paid by the institutions employing each member. Thus, the total cost of the Group's work is difficult to estimate precisely, but there is no doubt that it is several millions French Francs.

1.5.3. Openness towards concertation organisms and associations

The GRNC has been in regular contact with local organizations concerned by its task. The GRNC presented a progress report on the group's work to the CSPI (Special and Permanent Information Committee for the La Hague Plant) on several occasions. The presence of observers and the press at CSPI meetings provided an opportunity to broadly distribute information about progress of GRNC work to the public.

Local groups such as the "Mères en Colère" and national associations such as Greenpeace involved in the debate that followed the publication of Professor Jean-François VIEL's study, and that attended CSPI meetings as observers, were informed about the GRNC's intermediate results and progress as it was made. Some of their questions helped to contribute to enriching the critical work done by experts. The President herself provided direct and regular information to the "Mères en Colère".

2. THE GRNC'S METHODOLOGICAL APPROACH

2.1. The doses and risks evaluation process

2.1.1. Exposures

Persons are exposed to radioactive sources from a wide variety of sources, apart from the radioactivity naturally present in the human body. The resulting exposure can be classified into three main categories, namely exposure related to the presence of radioactivity in the environment, exposure caused by medical practice and occupational exposure.

Environmental exposure

In our daily lives, we are all exposed to ionising radiation originating from natural radioactivity in our environment, and from various human activities. Thus, radioactive elements are present in all media (air, water, soil and the food chain). The radioactivity present in the environment can be measured. This measurement can be made for each radioactive element (radionuclide) and the technical equipment necessary for the measurement is more or less easy to use depending on the medium and the radionuclide concerned, and in particular depends on the detection threshold of the measurement instruments used. The most frequently used measurement units are becquerel per litre (Bq/L) for a liquid medium, becquerel per kilogram (Bq/kg) for food products, becquerel per cubic meter (Bq/m^3) for air and water, and finally becquerel per square meter (Bq/m^2) on the ground. The presence of radioactivity in the environment causes external radiation, or internal radiation by inhalation of air or ingestion of food or water that contains radioactive products.

Natural radiation sources include:

- radiation originating from the cosmos and particularly the sun (cosmic radiation) that varies with the altitude and latitude,
- radiation from the earth (terrestrial radiations) that varies depending on the nature of the ground,
- radon that is a radioactive gas and is found in some homes or some work places, in quantities that vary depending on the nature of the materials,
- natural radionuclides present in the environment (water, plants, animals).

The following radiation sources originate from human activities:

- fallout from atmospheric testing of nuclear weapons distributed mainly around the entire northern hemisphere and fallout from the Chernobyl accident that mainly affected the European continent,
- residues from former activities that contain radioactive products and that may be local (former industrial sites) or diluted in the medium (immersed radioactive waste),
- liquid or gaseous radioactive discharges from nuclear and industrial installations during normal or accident operation.

For radioactive fallout, residues or discharges, the activity level corresponding to the radionuclides released into the atmosphere in a given year gradually reduces due to the radioactive decay phenomenon. Thus, for example, the radioactivity due to the presence of cesium 137 (^{137}Cs) measured in a given year is divided in half after about 30 years, whereas the radioactivity of ruthenium 106 (^{106}Ru) is halved after only one year.

All radionuclides released into the environment can migrate from one compartment in the environment to another depending on more or less complex physicochemical phenomena. The compartments of the environment concerned are different for discharges into the atmosphere and for discharges into the aquatic medium (rivers or seas). Therefore released radionuclides may be located in the ambient air, on the ground or in the water in rivers or seas. Radionuclides released into the atmosphere will be more or less concentrated in different crops (cereals, leaf vegetables, etc.), depending on the environment and the nature of the radionuclides (and particularly their physicochemical form). Similarly, radionuclides released into an aquatic environment will be found in fish, seaweed, molluscs, crustaceans and marine sediments. Radionuclides can eventually reach human populations through successive transfers, and these populations will be more or less exposed as a function of their lifestyle habits and particularly their dietary habits. The main exposure pathways for man are:

- ingestion of products containing radionuclides. The magnitude of the exposure then depends on the nature and amount of the products consumed,
- inhalation of radioactivity in the ambient air that can vary depending on the breathing rate of each person,
- external exposure caused by radionuclides present in the direct environment of persons. In this case, exposure depends mainly on the time spent in the same location as the radioactivity.

Figure 2 shows pathways from the environment to man for different exposure types.

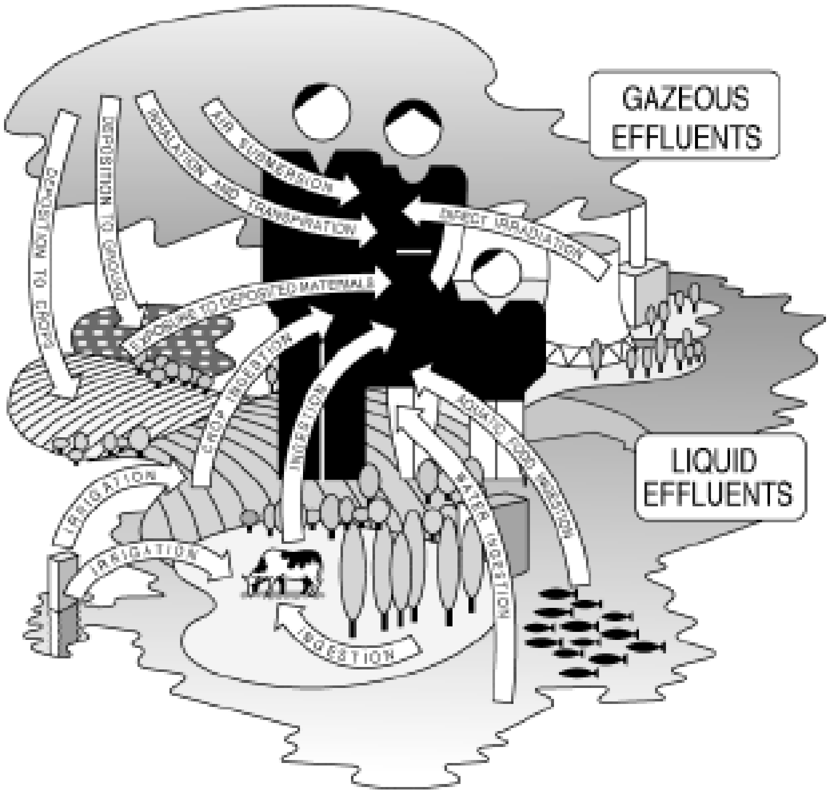

Figure 2. Modes of transferring radioactivity through the environment and exposure pathways

Man can exert some control over his exposure, depending on the source of the radioactivity, for example, in the case of exposure to radon in homes, simple actions such as opening windows to renew ambient air or installing ventilation or isolation systems to reduce concentrations.

Therefore every member of the public receives an annual exposure that depends on his lifestyle habits, his job, his leisure and the degree to which radioactivity is present in the environment. Although natural radioactivity varies little with the time, significant changes can be observed for radioactivity caused by various human activities, and particularly resulting from discharges from nuclear installations into the environment. Thus, the radioactive fallout from the Chernobyl accident significantly contaminated large areas and to a lesser degree most countries in Western Europe. It is also worth mentioning the significant reduction in discharges from most nuclear installations during recent decades due to progress made in terms of processing and management of these discharges. Thus, to manage environmental exposure can be managed, it is necessary to know the contribution of the different exposure sources and the means available for reducing exposure.

Medical exposure

The use of ionising radiation in medicine is by far the most significant source of public exposure, among the different types of exposure induced by human activities. The different exposure categories are related to the use of radiation for diagnosis (radiology and nuclear medicine), operational radiology or radiotherapy. However, it should be noted that the purpose of using radiation in the medical field is to produce a direct benefit for exposed patients, both for diagnosis and therapy.

Furthermore, there is a very wide range of levels of exposure according the individuals depending on the type of examinations made and the procedures and equipment used. In France, the distribution of medical exposure is not well known, and in particular it is not really known how to estimate the consequences on doses received by patients as a result of recent technical change such as the increased use of scanners and image digitalisation.

Occupational exposure

The number of persons concerned by occupational exposure is limited and known. This exposure is measured and checked in work environments and individually for each worker for whom individual dosimetric monitoring is carried out. Furthermore, specific individual medical monitoring is carried out for these persons. This applies to workers exposed as part of their work in nuclear installations and in the medical and industrial field. The total number of persons in France exposed to ionising radiation at their work is now about 230,000, including about 60,000 in the nuclear industry.

2.1.2 From exposure to dose

The total exposure of man to ionising radiation is due to:

- either radiation emitted by a radioactive source outside the human body, which is referred to as external irradiation,
- or the presence of radioactivity in the human body (for example subsequent to ingestion or inhalation of radioactive particles), which is referred to as internal irradiation.

Very schematically, the interaction of ionising radiation with the human body causes cellular damage, or damage to organs and tissues in the human body through which radiation passes. This damage depends on the quantity of energy deposited in the cells in each organ or tissue by radiation. The magnitude used to measure the quantity of energy absorbed is the gray (denoted Gy). This unit is defined as an energy of 1 joule deposited per kilogram of living matter. The resulting biological effects vary for a particular organ (or tissue) and for the same absorbed dose, depending on the type of radiation applied to the organ (or tissue). Thus, a distinction is made between X rays, γ rays, α and β particles and neutrons and protons. An "equivalent dose" (expressed in sievert (Sv)) is then calculated for each organ (or tissue) as a function of the radiation type considered. Finally, the different organs (or tissues) have a different radiation sensitivity, in other words the probability of the occurrence of long term damage will be different for the same equivalent dose depending on the organ (or tissue) considered. Modes of exposure (on several occasions or all at the same time) also have to be considered.

External irradiation usually causes quasi-uniform exposure of organs and tissues. For internal intake, the accumulation of radionuclides incorporated by ingestion or inhalation is not uniform, and is different according to organs and tissues concerned. Some organs or tissues have a particular affinity for some elements, for example the thyroid for iodine, and the bone marrow and foetus for strontium.

The ICRP (International Commission on Radiological Protection) has introduced an indicator called the «effective dose» measured in sievert, so that the risk associated with all possible exposure situations can be expressed using a single unit (see Figure 3). This magnitude takes account of the dose in grays, the type of radiation considered, and the sensitivity of the organs to the damage. Thus, regardless of the source (natural or artificial), the nature of the radiation (alpha, beta, gamma, X rays or neutrons), the modes of exposure (external or internal), the tissues or organs affected, the effective dose expressed in sievert or a sub-multiple of sievert (millisievert (mSv - 1/1000 sievert) or microsievert (µSv - 1/1,000,000 sievert)) can be used to estimate the risk and to compare different exposures with each other.

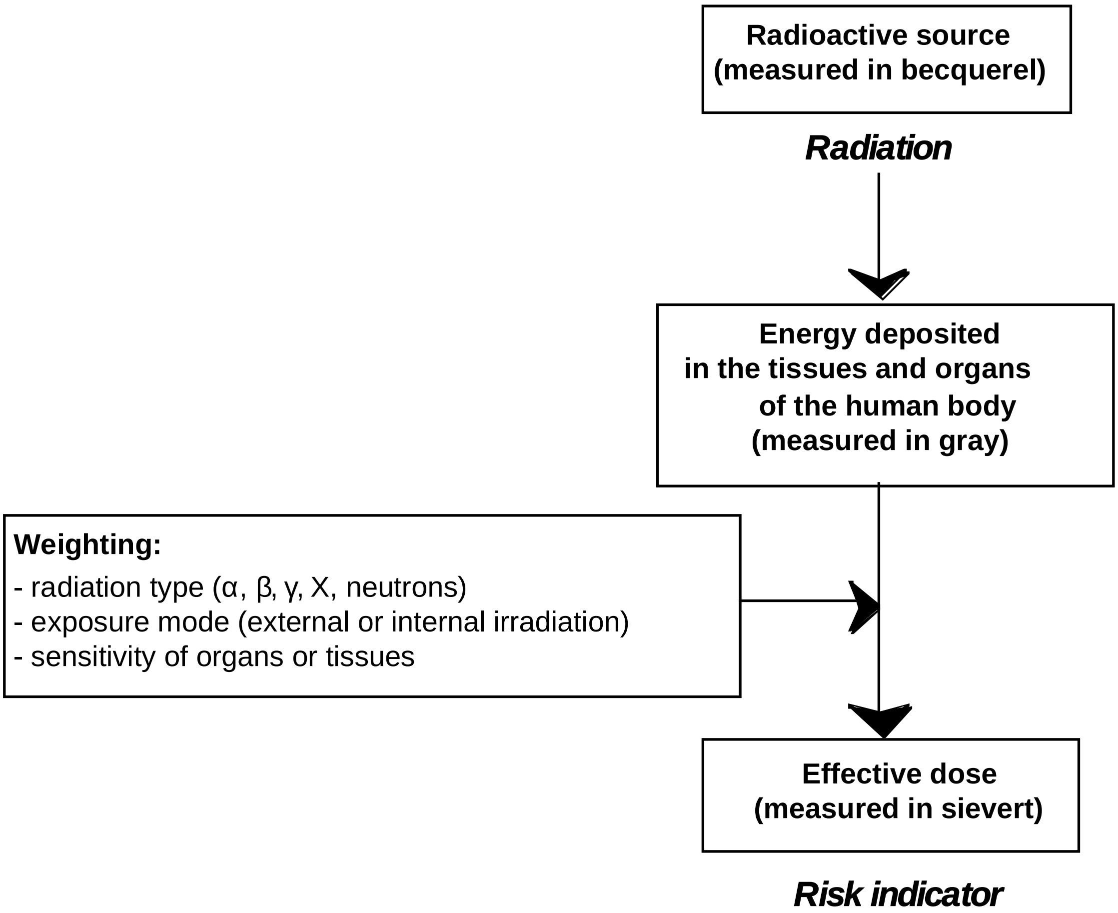

Figure 3. From source to dose

It is not always possible to measure directly the effective dose received by persons exposed to ionising radiation. Exposure levels at work are sometimes high enough so that the dose can be measured directly using dosimeters worn by workers. Thus, for example, the annual average occupational dose to persons exposed in the nuclear industry is of the order of 1.5 mSv.

It is not easy to measure medical doses to patients directly, and indirect measurements of the radiation field and simulation models are used to reconstruct doses received by patients as a function of the different types of examinations made. According to the UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation), the average individual dose due to radiation diagnosis in France is of the order of 1.1 mSv/year. For example, whole body doses associated with examinations made with scanners are of the order of:

- 4 mSv on average per examination, with values of up to 10 for the lung,
- 8 mSv on average per examination, with values of up to 20 for the abdomen,
- about 1 mSv on average per examination, with values of up to 3 for the skull,
- about 3 mSv on average per examination, with values of up to 6 or 7 mSv for the spinal chord.

It is inconceivable (except in case of accidents) to measure directly doses caused by environmental exposures of persons, considering the very low exposure levels and the number of persons involved. Therefore, models will systematically have to be used to estimate the dose received by each person due to all sources to which he is exposed. Radioactivity released into the environment of exposed persons is determined by measurements or calculations, and transfer models characterizing the environment of these persons and incorporated products are used to estimate internal and external exposure levels. The corresponding doses (equivalent or effective) are calculated using models that simulate modes of transfers and fixing in the various human organs and tissues, in a fairly detailed manner. Table 2 provides information about average individual doses received in France from the various environmental exposure sources.

Table 2. Average individual doses associated with environmental exposures in France (effective doses)

EXPOSURE SOURCE	AVERAGE INDIVIDUAL DOSE (millisievert per year)
Cosmic radiation	0.4
Terrestrial radiation	0.5
Radon indoors	1.3
Ingestion of natural radioelements in food	0.2
Fallout from atomic tests	0.02
Fallout from the Chernobyl accident	0.01
Impacts of discharges from nuclear installations	of the order of 0.00001
TOTAL	2.43

2.1.3. From dose to risk

The effects on health caused by exposure to ionising radiation depend on the energy deposited in the human body and the duration of exposure. Deposited energy causes cellular damage that may kill the cell, or may be reparable. However, this repair in itself may be correct or incorrect. Therefore, two types of effects can be observed depending on the severity of cellular damage, namely deterministic effects and stochastic effects also called random effects.

Deterministic effects

When the energy deposited in organs or tissues goes above certain thresholds (of the order of several grays), ionising radiation can cause the death of many cells in the exposed organs or tissues and can affect health more or less quickly depending on the cellular mortality rate. The severity of these effects depends on the received dose. For example, the symptoms of an irradiation of this type that can occur within days or weeks can include skin burns after irradiation of the skin, and medullar aplasia due to destruction of tissues fabricating blood cells, if the entire body was exposed. Furthermore, very high exposure of a large part of the body (of the order of a few grays) can cause death within a few weeks after exposure. Other symptoms are only seen later, for example a cataract in an irradiated eye, or fibrosis in an irradiated tissue. These effects occur within dose ranges (expressed in terms of deposited energy) of the order of 0.5 to a few grays (to organs or the whole body) for a short-term exposure.

Stochastic effects

When lesions induced by ionising radiation at cellular level are not repaired correctly, the genetic material of the cell will remain modified and cause cellular mutation as the damaged cells multiply. These mutations can cause the appearance of hereditary effects (if the mutation affects a reproduction cell or a germinal cell) or can induce cell transformations that can cause cancers several years after exposure, and occur at random in the exposed population. These effects are called stochastic, or probabilistic or random effects. The only way to demonstrate them is to observe populations that have been exposed to ionising radiation and comparing them with populations that have not been exposed. Thus, epidemiological investigations have demonstrated excesses of different types of cancers among populations exposed to doses higher than one tenth of a sievert and for whole body irradiation applied over a very short period. In particular, this is true for leukemia and cancers of the lung, breast, digestive tract and the thyroid. The largest epidemiological study of this type concerns the follow-up of the survivors of the Hiroshima and Nagasaki atomic bombs. For estimating the risk due to in-utero exposure, it is also important to note that epidemiological studies have demonstrated that there is a radiation-induced risk of leukemia for foetal doses equal to as little as 0.01 sievert.

Effects caused by low doses spread over time and within the range of a few thousandths of a sievert (mSv), or even millionths of a sievert (μSv), are so small (if they exist at all) that it is difficult or even impossible to demonstrate them by epidemiological studies. In particular, these studies cannot come to any conclusion about whether or not there is a dose threshold below which there is no longer any effect related to exposure to ionising radiation. Consequently, as a precautionary approach and in order to go into the side of protection, an international consensus has been reached by which it is considered that any exposure to ionising radiation could induce an effect over an entire population, regardless of the level of this radiation.

The BEIR (Committee on Biological Effect of Ionizing Radiation from the United States Sciences Academy) and UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) have developed exposure-risk relationships that extrapolate to lower rates observations made in epidemiological studies, assuming a relationship without a threshold for conservative reasons. The ICRP (International Commission on Radiological Protection) used the same relationships to create its system of recommendations for protection of the population.

Exposure-risk relationships are used to convert doses received by a person or a population into a risk of health effects appearing for this person or this population. The results of these relationships are expressed in terms of average values that are difficult to interpret since they express a phenomenon that is actually a random process that can be well defined only by the use of statistical methods. Thus, a risk expressed for a person is actually an average risk for a population of persons with the same characteristics. This is why it is sometimes preferable to present the statistical distribution of the risk rather than the average risk, expressed as a number of cases within a population.

2.2. The GRNC's objectives

2.2.1. The GRNC's first objective

The first objective of the GRNC was to reconstruct environmental exposures (i.e. from natural sources and related to human activities) and medical exposures for the population that could be affected by Nord-Cotentin nuclear installations and to estimate the risks of leukemia associated with these exposures. Considering the previous description of the modes of exposure and evaluation of doses, it was impossible for the group to make a complete and exhaustive evaluation for all exposures.

Thus, although the group's objective was to reconstruct doses for all exposure sources, the question raised by Professor J.F. VIEL's epidemiological study brought particular attention to the contribution of nuclear installations in the Nord-Cotentin, and particularly the COGEMA La Hague installation. Consequently, from the point of view of reconstructing exposures, much of the group's work was related to discharges from Nord-Cotentin nuclear installations and their consequences on the environment, with the objective of being exhaustive and realistic. Furthermore, since industrial discharges have changed significantly over time, doses caused by discharges from these installations needed to be reconstructed over the entire period considered, and in particular the variations of these discharges with time needed to be analysed.

Since epidemiological studies for the population of young people from 0 to 24 years in the Beaumont-Hague canton covered the 1978-1996 period, the group performed a retrospective exercise to reconstruct all doses (environmental and medical) received by this population over this period. The objective was to estimate the risk of radiation-induced leukemia, and therefore doses to the bone marrow were considered because the bone marrow is a target organ for the development of leukemia. Thus, estimates of doses to the bone marrow for this population (called the cohort in the study) considered exposure received by children, and also by foetuses (*in utero* exposure). Table 3 contains the various exposure categories considered.

Table 3. Exposure categories considered depending on the source

Exposure source	Exposure categories considered
Medical	- Radiodiagnosis only
Environmental	
- Natural radioactivity	- Radon indoor - Cosmic and terrestrial irradiation - Ingestion of natural radionuclides
- Fallout from the Chernobyl accident and atmospheric testing of nuclear weapons	- Exposures (inhalation, ingestion, external irradiation) related to concentrations in the various compartments of the environment
- Releases from nuclear installations (in normal operation and related to incidents)	- Exposures (inhalation, ingestion, external irradiation) related to liquid and gaseous radioactive discharges including the four Nord-Cotentin nuclear installations.

Table 4 shows the exposure pathways considered for different media taking account of data for environmental radioactivity.

Table 4. Exposure pathways considered depending on the medium

Medium	Exposure pathway
Air and soil	- Inhalation: activity in the air and soil activity put back into suspension - External exposure: activity in the soil and the release plume - Accidental ingestion: soil activity
Sea spray, sea water and sand	- Inhalation: activity in sea spray - External exposure: activity in beach sand and sea water when bathing - Accidental ingestion: activity in beach sand and sea water when bathing
Sea and land food	- Ingestion: activity in food (including pathways from seaweed manuring)

Figure 4 diagrammatically shows the evaluation method used to calculate the risk for the 0-24 year old cohort in the Beaumont-Hague canton.

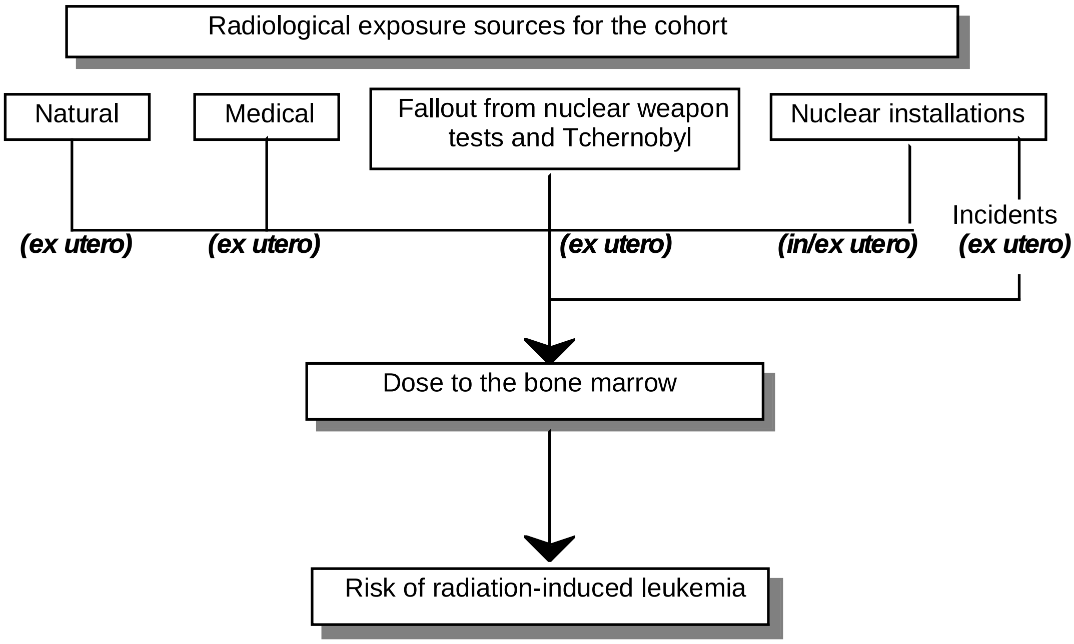

Figure 4. Block diagram showing the method of estimating exposures and risks adopted for the 0-24 year old cohort in the Beaumont-Hague canton

2.2.2. The GRNC's second objective

The second objective of the GRNC was to respond to the Ministerial question about the procedure to revise texts governing operation of the COGEMA La Hague plant, and particularly concerning release authorizations. The GRNC made a number of complementary evaluations for population groups that could be particularly exposed, to help provide useful information for this purpose. The GRNC estimated annual whole body doses (effective dose) for a set of exposure scenarios for adult persons that could be among the most significantly exposed around the COGEMA La Hague installation, based on data and models developed to estimate exposure of the cohort. It should be noted that this estimate was restricted to exposure due to discharges from installations, and it was not followed by an associated risk calculation.

2.3. Work procedure

Four specialized working groups were formed, each being made responsible for a specific step in the general procedure adopted for the evaluation of exposures and risks, to achieve the objectives of the GRNC's task and to encourage experts to participate as much as possible in the critical analysis work. All work carried out in these working groups was presented and discussed within a plenary group. The four groups worked in parallel using an iterative approach for their questioning, so that the available data or models could be explored exhaustively, or possibly new measurements could be made. Coordination actions were necessary to achieve logical chaining between the groups so that the most precise possible estimate of exposures and risks could be made. This type of approach involving pluralist expertise took a relatively long time, but the result was that the analysis could be made systematically and new questions could be raised. Furthermore, it should be emphasized that one result of this joint effort was a calculation tool specific to the Nord-Cotentin region.

2.3.1. Reconstruction and critical analysis of radioactive discharges from installations

The first working group critically examined liquid and gaseous radioactive discharges declared by operators of nuclear installations of the Nord-Cotentin since the installations were first built, and reconstructed missing data whenever necessary [16]. Thus, discharges from each of the various installations since they were commissioned were examined, namely since 1966 for the COGEMA La Hague installation, 1969 for the Manche Storage Centre, 1980 for the French Navy's Arsenal in the Port of Cherbourg, and 1986 for Flamanville nuclear power plant.

This reconstruction was made deliberately ignoring the relative influence that a specific radionuclide would be expected to have on the dosimetric impact, in other words without referring to prior studies. In particular, this analysis provided a cross check of the results of measurements of released activities provided by operators, so that they could be modified if they were inconsistent (for example for krypton 85 discharges), added to if measurements were missing for several years, or other radionuclides could be added if the corresponding discharges were not considered to be significant after an impact calculation made by the operators, or due to limitations in analysis techniques.

Essentially, the steps of the critical analysis were applied satisfactorily to COGEMA's La Hague plants for which it was possible to determine annual quantities and characteristics of the main radionuclides present in the spent fuel at the time of its reprocessing, and which could therefore be released into the environment, making use of standard calculation programs based on the annual reprocessed tonnage and the characteristics of the spent fuel (nature, irradiation rate and average cooling time). The group successfully reconstructed a theoretical inventory for about twelve radionuclides for which no measurements had been made, considering similarities in the physicochemical behaviour of different elements and taking account of available information about impurities present in the fuel. When the discharges, concentrations in the environment and finally the dosimetric impact estimated according to this approximation were obviously overestimated, the results were corrected based on measurements.

For example for chlorine 36, the first calculations of concentrations in the environment and the effective dose to persons exposed on particular scenarios gave relatively high impacts that were absolutely unrealistic based on prior knowledge in this subject. After verification by further environmental measurements around La Hague carried out by the OPRI, IPSN and ACRO at the request of the GRNC, the plenary group considered that the inventory of chlorine 36 was overestimated by a factor of at least 400, and divided it accordingly. This example gives an excellent illustration of the iterative work necessary between groups and the desire for realism searched for in the final evaluation of doses.

In all, 39 out of the 75 radionuclides considered for discharges from the COGEMA installation (52% of the total) were added to the list of radionuclides supplied by COGEMA to the working group. In terms of total activity, these complements did not modify the orders of magnitude of the results supplied by the operator; however, they did help to define the composition of these discharges in more detail and to give more exhaustive information about their composition which is necessary for a detailed dosimetric reconstruction.

The input for the reconstruction for the two reactors in EDF's Flamanville power plant was more limited. For these two reactors, and for nuclear reactors in general, the nature and activity of radionuclides present in the liquid and gaseous effluents depend on a large number of parameters such as the reactor operating mode, the rate of release of radionuclides from fuel assemblies (micro-cracks, failure rate, etc.), the release of activation products from structural materials in cooling circuits and especially the treatment and management of liquid effluents before they are released into the sea, which have changed with time. Nevertheless, liquid and gaseous discharges supplied by EDF since the power plant was commissioned were completed firstly by an evaluation of carbon 14 activities (making use of data in foreign literature), and of nickel 63 in liquid discharges (making use of recent measurements made by the OPRI).

For ANDRA's Manche Storage Centre, there is no simple relation between the radiological inventory of stored waste and activity discharges measured in the environment (particularly the Grand Bel and Sainte Hélène streams). This relation cannot be determined unless the history of the packages and the rates at which radioactive substances are transported in the subsoil (related to their solubility) are known. Therefore, the reconstruction work consisted of specifying the different phases in the management of water in the rainfall drainage network and in the separation network, by analysing and explaining the origin of activities measured in the water in Sainte-Hélène stream.

For discharges from installations in the Port of Cherbourg Arsenal, the Ministry of Defence provided the total summary of activities released in liquid and gaseous effluents since 1980, which had never previously been presented in the public domain. Cross controls means for these installations are even more limited. Releases into the marine environment are much lower than discharges from COGEMA's reprocessing plants and their contribution to the added activity in the environment is very low.

The working group also attempted to re-examine incidents that occurred in Nord-Cotentin nuclear installations during the last three decades and that caused discharges of activity into the environment, in greater detail. In particular, a critical analysis and a reconstruction of discharges or a re-estimate of discharges estimated at the time that incidents occurred, were made for three events. These events are:

- the tritium contamination to Sainte-Hélène stream through the water table under storage facilities (October 1976), at the La Manche storage centre,
- the perforation in the liquid discharges sea pipe from COGEMA's La Hague plant (December 1979) that contaminated Moulinets beach[2],
- the fire in the UNGG fuel reprocessing waste silo (January 1981) in the COGEMA La Hague plant that caused a radioactive atmospheric release.

For example, this search for exhaustiveness that consisted of not deciding that any event was minor unless an evaluation showed it to be minor, helped to estimate the significant

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2 A complementary report of the GRNC was published in June 2000 concerning the analysis of the perforation of the pipe. This report has not been considered in the analysis presented hereafter.

contribution of strontium 90 during the silo incident, although impact evaluations at the time were limited to considering the impacts of cesium 137.

Releases of more than 80 radionuclides were reconstructed over a period of about thirty years, considering all installations combined. The results obtained do not cast doubt on data supplied by operators in terms of released activity, however, they did help to clarify the composition of discharges necessary to make dosimetric impact calculations.

2.3.2. Inventory, appraisal and analysis of environmental measurements

The second working group collected and interpreted environmental measurements performed by different organizations (operators, institutional and non-institutional measurement laboratories) [17].

In doing this, it was not enough simply to collect information. The variability of measurements within the same laboratory and in different laboratories had to be analysed. It was then necessary to define factors that had an influence on radioactivity levels in the environment and that could explain the observed differences, particularly considering the objectives assigned to the measurements made. Samples, processing and radioactivity measurements of samples are adapted to the objectives specific to each laboratory (surveillance, expertise or research). This may make it difficult to compare results, particularly because detection thresholds are different depending on the objectives.

The working group spared no effort to be exhaustive for its inventory of samples and measurement types. On the other hand for the measurement results, it was decided to give priority to the information that is most relevant for the comparison with model results and for estimates of doses to populations, considering the large amount of data to be collected and verified within a limited time. In the end, only the results of measurements made after 1978 were used, since these measurements were usually computerized and their quality was significantly better due to the use of higher performance detectors, particularly for gamma spectrometry. Therefore, the study includes data available from 1978 to 1997.

This work, which had never previously been done in France, helped to collect and analyse about 500,000 “determinations of radionuclide or total activity concentrations”. Most of the measurements used had been made by the operator or inspection organizations (see figure 5). However, even though the numbers of samples taken by non-institutional laboratories and research organizations were fewer, they were very useful because they provided complementary information about radioactivity levels at release points, and particularly for bio-indicators or specific radionuclides.

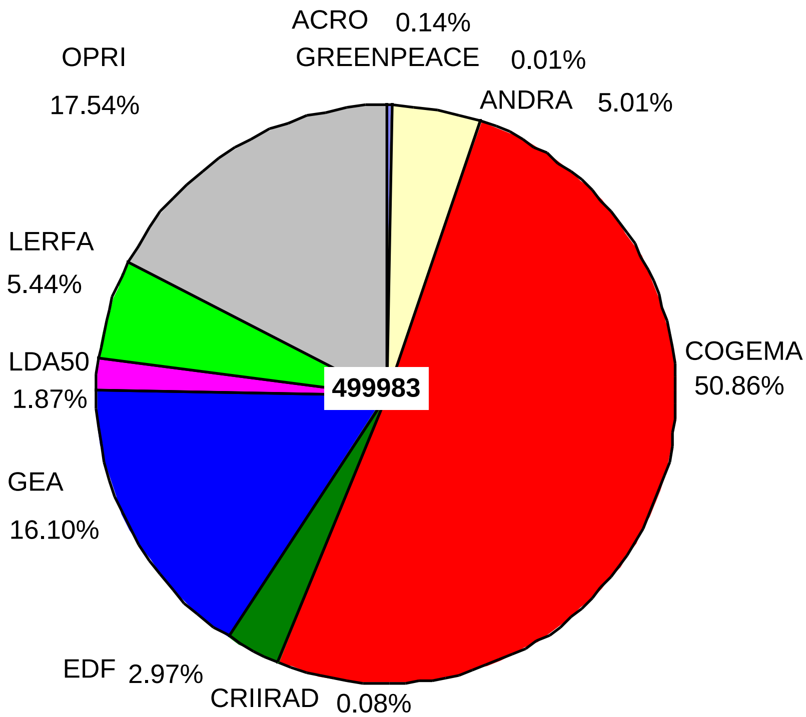


Figure 5. Source of measurements used

In summary, despite the diversity in procedures, all the work done on environmental measurements has demonstrated that all results are generally consistent when all evaluation elements are considered, and participants have reached a consensus about the analysis of the variation of radioactivity levels detected in the environment. Therefore, these results were collectively validated so that they could be compared with the results predicted by models for transfers through the environment, or could be used directly for dosimetric reconstruction when there are no suitable models.

This large scale review required a great amount of work. The collected data and the analysis results are now available on a CD Rom. This data bank may be enlarged in the future when new data become available.

2.3.3. Comparison between model results and measurements

The general objective of the third working group was to propose the most suitable models for estimating the concentrations of radionuclides released into the environment by nuclear installations in the Nord-Cotentin [18]. The group's activities took place in three steps.

The first step consisted of making a comparison between available models for dispersion of discharges into the atmosphere and into the sea, and identifying which were the best adapted to the objective which was a detail dosimetric evaluation taking the best account of the characteristics of the local context. This investigation procedure included an examination of models used by the IPSN, the European PC-CREAM model and models used by different French operators (COGEMA, ANDRA, EDF) in regulatory release authorization procedures. Since the observed differences between the models for atmospheric and sea discharges were rarely greater than 10, the group considered that this type of difference was normal. They are partly due to the inherent nature of the models and the representativeness of the chosen parameters, and partly due to the inevitable fluctuation of the environmental measurements used to build these models.

The second step, in which the results of the models used were compared with measurements, included an adjustment of model parameters to suit local reality whenever possible (very exceptional for this type of work). There is no doubt about the benefit of these comparisons in the marine environment, where sufficient numbers of sufficiently sensitive environmental measurements are available for many radionuclides. However in the terrestrial domain, the fewer number of measurements above detection limits and the relative magnitude of the background radioactivity made it impossible to carry out an equally extensive comparison between models and measurements.

The third step consisted of calculating environmental concentrations over the entire period as a function of the discharges from installations based on the finally selected models. Thus, the working group supplied atmosphere-to-ground transfer coefficients for the nineteen communes in the Beaumont-Hague canton. These coefficients were estimated based on average weather conditions for the years 1992 to 1997, and in particular take account of different wind classes and speeds in dry weather and in wet weather. Activity transfer coefficients for air-to-animal transfers and air-to-plant transfers for plant species in the food chain were also supplied.

Although IPSN speciality departments prepared the model, the results were presented, discussed and criticized within the working group, and then in the plenary group. The role of local associations and laboratories was fundamental for making the selected models as realistic as possible taking local features into account as accurately as possible. A systematic comparison between model forecasts and environmental measurements actually made enabled an adjustment of model parameters to local reality.

2.3.4. Dose and risk calculations

The activity of the fourth group consisted firstly of estimating the average dose to the bone marrow received by the «cohort» considered (children and young adults from 0 to 24 years old in the Beaumont-Hague canton) due to nuclear industrial installations in the region and due to other exposure sources, and then estimating the corresponding risk of leukemia [19]. This evaluation was made in three steps: reconstruction of the exposed population (the cohort), evaluation of individual doses to the bone marrow and calculation of a number of cases of leukemia that could theoretically be assigned to exposure to ionising radiation.

Reconstruction of the cohort

This work was done based on the compilation and extrapolation of demographic data derived from censuses and birth registers based on the assumption that any person born in the study area (Beaumont-Hague canton) lived in the same canton until her or his 25th birthday (or until 1996). Since the risk calculation covered the 1978-1996 period, it was necessary to use data starting in the year 1954 in order to reconstruct the cohort. Consequently, all generations from 1954 to 1996 were considered. The number of school-children was also used to take better account of the increase in the population of children during the “major construction” period during which the second COGEMA La Hague plant was built between 1982 and 1989. The number of young people (0 - 24 years) who lived in the Beaumont-Hague canton during the period considered (1978-1996) was 6,656 persons (see Table 5).

Table 5. Size of the reconstructed 0-24 year old cohort in the Beaumont-Hague canton between 1978 and 1996

	Persons born in the canton (1954 to 1996 generations)	Influx during "Major construction"	Total
Number of persons (reconstructed cohort)	5,506	1,150	6,656
Person.years	55,437	13,871	**69,308**

Estimate of exposure of the cohort

The values of parameters characterizing dose-relevant habits of persons in the cohort were discussed and then validated, giving priority to realism. The objective was to determine average exposure situations based on the following parameters:

- food rations for different age classes and for each food category;
- auto-consumption rates;
- time spent inside homes, bathing, on the beach, in the sea;
- quantities of sand, soil or sea water accidentally swallowed;
- resuspension rates;
- protection factors in homes (walls and roofs);
- average breathing rates (as a function of the age of persons);
- fishing locations.

The values used for these parameters were adjusted to suit the local habits in the Nord-Cotentin region whenever necessary. For example, spreading seaweed on vegetable gardens, greater cider or jam consumption than the average in France, all of which were identified following local enquiries and due to the presence of experts familiar with local habits and customs among the GRNC members.

Doses (individual and collective) to the bone marrow (a target organ for the risk of leukemia) were calculated for the entire cohort based on data for the concentrations of the various radionuclides in different compartments of the environment. Doses related to discharges from nuclear installations were calculated since 1966, both for routine discharges and for discharges due to accidents and incidents. The evaluation of other sources of exposure to ionising radiation (medical, natural, fallout from atmospheric testing of nuclear weapons and the Chernobyl accident) was mainly based on a bibliographic study. Finally, doses to the foetal bone marrow during pregnancy (*in utero* exposure) were considered only for routine discharges from nuclear installations.

Furthermore, since doses to the bone marrow had been calculated for "average persons" in the cohort, the group considered different scenarios to estimate the variability of results as a function of possible particular habits: "cohort scenarios" were thus defined to quantify, in terms of dose to the bone marrow, the four particular habits identified in the 1997 study by Professor Jean-François VIEL as being statistically significant factors contributing to the risk of leukemia. These are:

- prolonged presence on local beaches by children,
- prolonged presence on local beaches by mothers during pregnancy,
- the higher consumption than average of local seafood,
- living in a granite house or a house with a large concentration of radon.

This was done by applying a factor of 2 or 5 to the value selected for the corresponding parameters (time spent on the beach, food ration, radon concentration and exposure to terrestrial radiation) to the average estimate made for the cohort. The individual dose to the bone marrow (associated with exposure during childhood) was also calculated for these scenarios.

Estimating the risk of the leukemia

The last step in the calculation consisted of estimating the number of cases of leukemia that could theoretically be assigned to exposure to ionising radiation (radiation-induced risk) considering doses made to the bone marrow. As mentioned above, the estimate was based on the dose-effect relationship without any threshold. This radiation-induced risk was calculated for the period during which epidemiological data were available elsewhere (1978-1996). The risk models selected to estimate the risk due to exposure during childhood *(ex utero)* were the model proposed by the United Nations Scientific Committee for the effects of Atomic Radiation (UNSCEAR) [20] in 1994 and the model proposed by the United States Academy of Science (BEIR) [21], for which the risk coefficients are derived from the study of survivors of the Hiroshima and Nagasaki atomic explosions. The models selected for *in utero* exposure were those developed by the NRPB and derived from the Oxford Study on Childhood Cancers (OSCC) in 1989 [22]. The collective leukemia risk was calculated mainly using the European ASQRAD program for the assessment of the radiological risk, developed by the CEPN and the NRPB [23].

It should be emphasized that the group used these internationally recognized models to calculate the risk of leukemia without carrying out their own critical analysis, although in this case they are used within a dose range very far from the range in which they are normally used. Dose levels for which the program is valid are between 50 and 200 mSv for the different radiation-induced cancers in the study of Hiroshima and Nagasaki survivors, and starting from 10 mSv for foetal doses in the English study.

2.3.5. Evaluation of effective individual doses for particular scenarios

The fourth group also estimated the effective dose (whole-body dose) for population groups or persons likely to be most exposed to discharges from the COGEMA La Hague plant due to their geographic location or lifestyle habits. This evaluation was made to provide background information for decisions necessary for the revision being made to texts governing operation of the reprocessing plant. In doing this, the GRNC has set up a series of scenarios taking account of local features concerning lifestyle habits. Thus, individual doses (effective whole-body doses) have been estimated firstly for chronic exposures expressed as an annual dose, and secondly for occasional exposures expressed as a dose for an action or a situation with a limited duration.

The GRNC made a distinction between the following chronic exposures:

- critical scenarios used by COGEMA in its impact studies (fisherman of Goury, inhabitant of Digulleville);
- three additional particular scenarios taking account of lifestyle habits or particular locations of homes (fisherman of Huquets, 1500 m zone around the COGEMA La Hague installation, farmer of Pont Durand).

Furthermore, taking account of information collected for the analysis of exposures of the cohort, the GRNC made effective dose calculations for an "average adult" assuming lifestyle habit parameters for an adult representative of the cohort and average concentrations in the terrestrial and marine environment provided for the cohort. Exposure pathways considered in this average scenario correspond to exposure pathways selected for the cohort for routine discharges from nuclear installations.

About ten occasional exposures scenarios were selected, most of which model local and usually fairly infrequent habits (or habits that could be observed exceptionally) known by local participants in the GRNC, for example fishing in Sainte-Hélène stream, the footpath close to the sea discharge of the radioactive effluents pipe from the COGEMA plant, eating a crab caught close to this discharge pipe, and bathing near the mouth of the Sainte-Hélène.

3. RESULTS

This chapter describes the main results and conclusions of the GRNC firstly about exposures and risks of leukemia for the cohort of 0-24 year old children and young people in the Beaumont-Hague canton, and secondly exposures associated with specific scenarios for the most exposed persons around the COGEMA La Hague plant. These results are also discussed and compared with the results of the COMARE study carried out in the United Kingdom.

3.1. Exposures and risks of leukemia for the cohort

3.1.1. Individual exposures

The annual individual *ex utero* dose to the bone marrow due to all exposure sources (nuclear installations, and medical, natural, atmospheric testing of nuclear weapons and the Chernobyl accident) for the cohort was estimated at between 2720 µSv and in the range of 5000 µSv per year. Among these exposures, *ex utero* doses related to discharges from nuclear installations during the period are between less than 1 and 11 µSv per year. The observed variations reflect differences in exposure depending on the age of persons and differences in the amount of radioactivity in the environment depending on the period considered. Individual doses to the bone marrow due to *in utero* exposure associated with routine discharges from nuclear installations should also be added to this estimate. These doses vary between 0.3 µSv for the generation of children born in 1967 and 10 µSv for the generation born in 1972.

In detail, it can be noted that *ex utero* doses due to routine discharges from installations varied with time as a function of discharges (see Figure 6 for nursing infants). The highest doses were in 1985, the year in which liquid discharges from the COGEMA La Hague plant were maximum. In that year, the *ex utero* dose to the bone marrow was estimated at:

- 11 µSv for nursing infants (mainly due to accidental ingestion of sand),
- 4 µSv for children,
- and of the order of 6 µSv for young adults (the food ration of seafood for young adults being greater than for children).

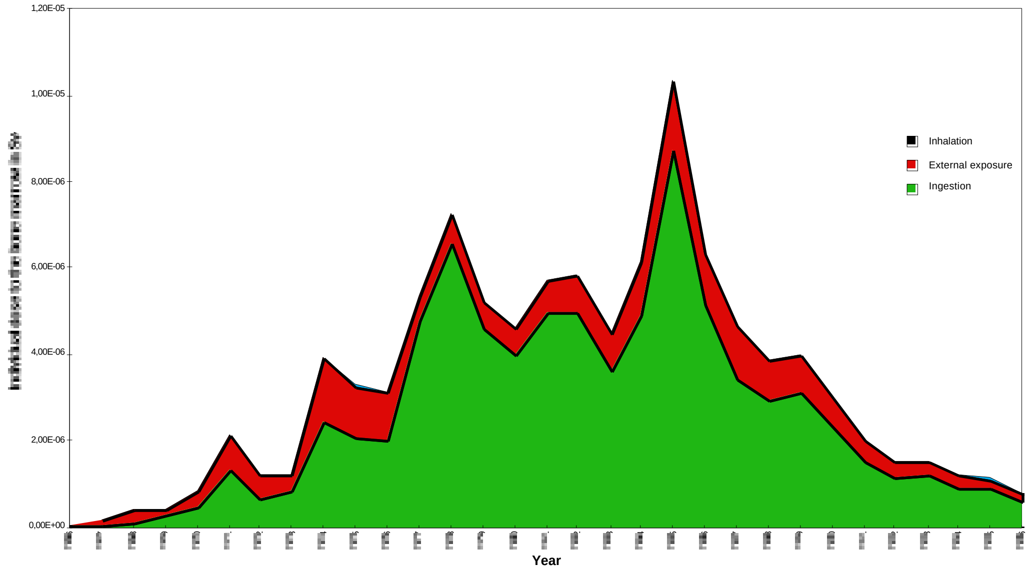


Figure 6. Individual ex utero doses to the bone marrow (1 year old nursing infant)

A large variation in the exposure to natural sources is observed, related to the differences in dietary habits depending on the age of persons. The dose is maximum for nursing infants and is minimum for 13-14 year old children. Table 6 shows the breakdown of these doses as a function of the exposure sources considered.

Table 6. Annual individual doses to the bone marrow due to natural exposure sources

Exposure type	Dose to the bone marrow (µSv per year)
Natural	1950 - 3460
- *radon*	*330*
- *cosmic*	*270*
- *terrestrial*	*410*
- *intake of natural radionuclides*	*940 - 2450*

The maximum value for atmospheric testing of nuclear weapons was estimated for the year 1963 (namely 270 µSv). Estimates for recent years are 30 µSv per year, includithe contribution of the Chernobyl accident that was estimated at less than 10 µSv per year. (This contribution concerns the years 1986 and 1987).

Note also that the two most significant release accidents (the perforation of the sea discharge pipe from the COGEMA installation in December 1979 and the silo fire in January 1981) only caused exposure for a small fraction of the cohort. As an illustration, the maximum individual doses for a single person assumed to have been exposed, born in 1971 and living in the village of Herqueville (the closest village on the down wind side from the silo fire) were observed in the twelve months following the accident considered, and were equal to 61 µSv for the perforation of the sea discharge pipe and 700 µSv for the silo fire. Figure 7 illustrates the variation with time of the annual *ex utero* dose to the bone marrow for this person due to the silo fire compared with the estimated dose due to routine discharges from installations. For the year 1995, the *ex utero* dose to the bone marrow associated with the two accidents for the same person was estimated at 3 µSv and was therefore additional to the dose to the bone marrow related to routine discharges from nuclear installations estimated at about 5 µSv for 1995.

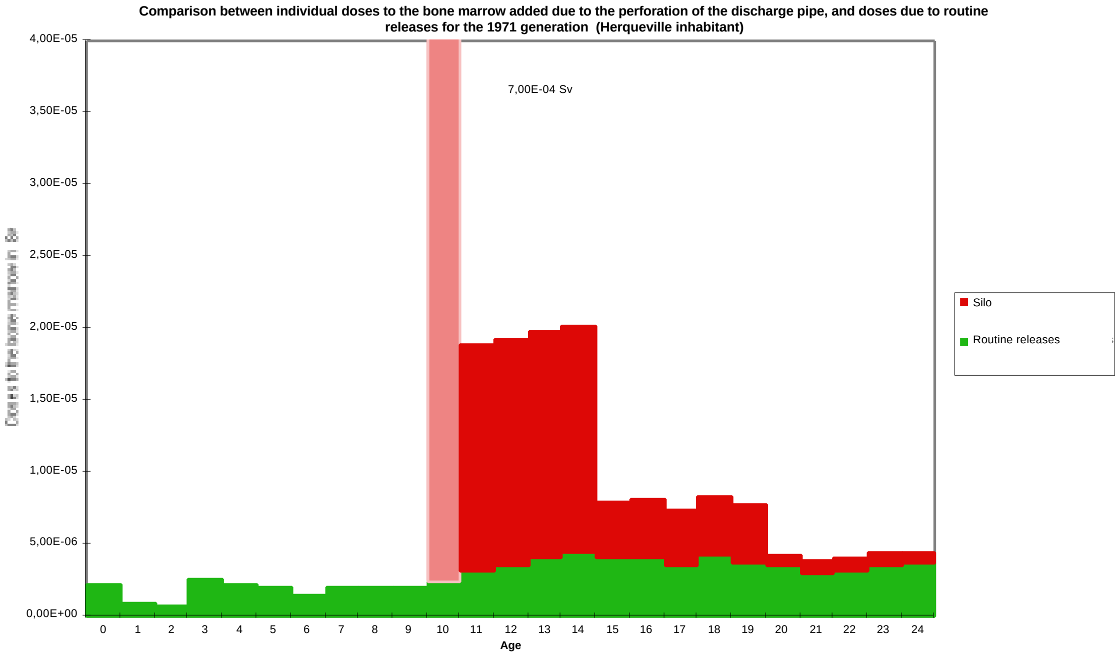


Figure 7. Additional individual ex utero doses to the bone marrow related to the silo fire for a person from the 1971 generation assumed to be exposed (Sv per year)

Table 7 contains a summary of estimated individual doses for the cohort taking account of variations according to the age of persons and the variation of exposure during the analysis period.

Table 7. Individual annual *ex utero* doses to the bone marrow

Exposure type	**Dose to the bone marrow (µSv per year)**
Nuclear installations	
Routine discharges*	< 1 - 11
Incidents	0 - 700
Medical	740
Natural	1950 - 3460
Atmospheric testing of nuclear weapons and the Chernobyl accident	30 - 270
Total	2721 - ≃ 5000**

* *Not including the individual in utero dose to the bone marrow related to routine discharges that vary from 0.3 to 10 µSv depending on the generation considered.*

** *This is an indicative value, as far as the maximum values for the different exposure types correspond to different reference years for routine releases, incidents and atmospheric testing.*

3.1.2. Collective exposures

Based on all the individual doses presented above, the total collective dose to the bone marrow for the cohort of young people in the Beaumont-Hague canton for the 1954-1996 period is 322 person.sievert. The preponderant exposure source is natural exposure with a contribution of about 74%, namely 241 person.Sv. The main natural exposure pathway is ingestion of Polonium 210 (21% of the total collective dose), mainly through the ingestion of seafood. Medical exposure is a non-negligible source of exposure (24% of the total collective dose, namely 76 person.Sv). Exposure due to fallout from atmospheric testing of nuclear weapons and the Chernobyl accident contribute about 2% (5 person.Sv). Finally, routine discharges from nuclear installations in the Nord-Cotentin contribute less than 0.1% (0.30 person.Sv). Out of the contribution from nuclear installations, marine discharges contribute about 78% of the collective dose, the preponderant exposure pathways being ingestion of seafood (42%) and external exposure by beach sand (22%). The exposure pathway consisting of the accidental ingestion of sand (representing 9%) is particularly applicable to young children.

When the sea discharge pipe from the COGEMA installation was perforated (1979-1980), the collective added dose to the bone marrow for the exposed cohort (estimated at 24% of the total cohort) was estimated at about 0.04 person.Sv (to be compared with 0.30 person.Sv due to normal operation). During the 1981 silo fire, the collective added dose for the exposed population (estimated at 20% of the total cohort) was estimated at about 0.14 person.Sv.

Finally, the collective dose to the bone marrow resulting from *in utero* exposure due to routine discharges from local nuclear installations was estimated at 0.02 person.Sv, which is about 6% of the collective dose (*ex utero* and *in utero*) due to routine discharges from local nuclear installations. Table 8 summarizes the various contributions to the collective exposure.

Table 8. Contribution of various sources of exposure to the collective *ex utero* dose for the 1966-1996 period

Exposure source	Collective dose for the 1966-1996 period (person.sievert)
Nuclear installations	
Routine discharges*	0.3
Incidents	0.18
Natural sources	241
Medical sources	76
Nuclear tests and the Chernobyl accident	5
Total	322.5

* *Not including the collective dose to the bone marrow due to in utero exposure associated with routine discharges from local nuclear installations. This is estimated at 0.02 person.Sv.*

3.1.3. Risks of radiation-induced leukemia for the cohort

Based on the selected dose-effect relationships for the entire cohort and for the 1978-1996 period corresponding to the period covered by the epidemiological studies, the total number of leukemia cases within the cohort that could theoretically be assigned to *ex utero* exposure to ionising radiation in the Nord-Cotentin, is 0.835. The total number of cases of leukemia associated with *in utero* exposure due to routine discharges (namely 0.0003) should be added, which increases the estimated number of cases by the order of 33% compared with cases that can be assigned to *ex utero* exposure due to routine discharges alone. Figure 8 shows the proportion associated with each exposure source. Natural exposure and medical exposure are the main contributors to the risk (74% and 24% respectively). Nuclear installations in the Nord-Cotentin contribute 0.0014 case (for *ex utero* exposure) namely 0.1% of the total, corresponding to 0.0009 case due to routine discharges and 0.0005 case due to incidents (0.0001 case for the perforation of the COGEMA sea discharge pipe and 0.0004 case for the COGEMA silo fire).

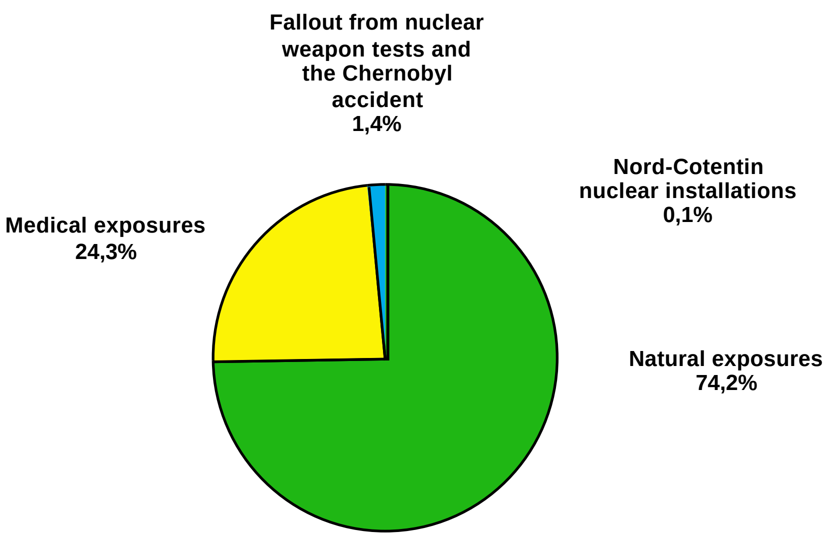


Figure 8. Proportion of the number of *ex utero* cases of leukemia as a function of exposure sources

There are several different exposure pathways for routine discharges from installations. Exposure pathways corresponding to marine discharges contribute almost 87% of the total risk of leukemia that can be assigned to local installations, the predominant pathway being ingestion of seafood (fish, molluscs and crustaceans). In terms of individual risk, the 1970 to 1980 generations have the highest risk of leukemia over the observation period considered (between 1978 and 1996). Thus for these persons, the estimated risk of the incidence of leukemia that can be assigned to exposure caused by local nuclear installations accumulated between the ages of 0 and 24 years is between about 0.2 and 0.3 per million. Figure 9 shows the distribution of the number of cases of leukemia as a function of the different *ex utero* exposure pathways considered.

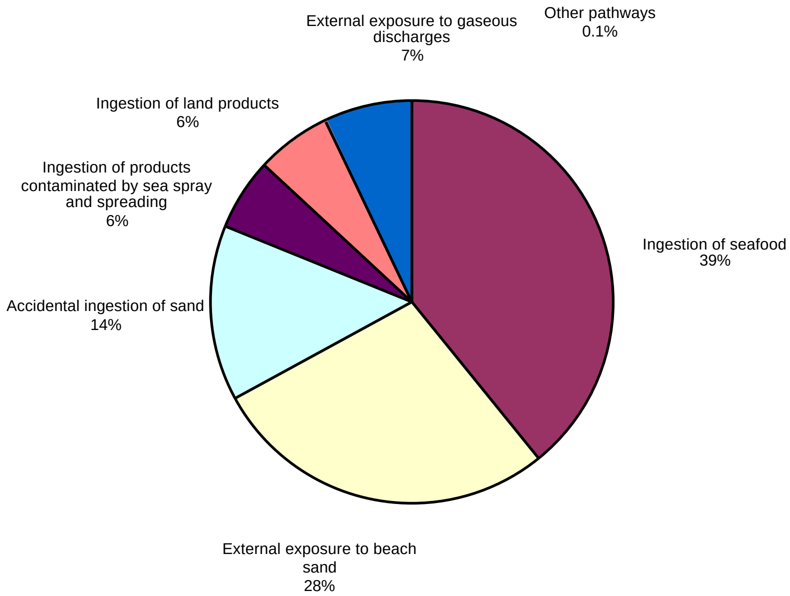


Figure 9. Distribution of the number of ex utero cases of leukemia that can be theoretically assigned to routine discharges from nuclear installations in the Nord-Cotentin as a function of exposure pathways

Table 9 summarizes the estimated numbers of leukemia cases that can theoretically be assigned to different sources of exposure to ionising radiation in 6656 young people between 0 and 24 years old for the Beaumont-Hague canton during the 1978-1996 period.

Table 9. Summary of estimated numbers of cases of radiation-induced leukemia for the cohort

Exposure source	Number of cases of radiation-induced leukemia for the cohort
Nuclear installations	0.0014
*Routine discharges**	*0.0009*
Incidents	*0.0005*
Natural sources	0.62
Medical sources	0.2
Atmospheric testing of nuclear weapons and the Chernobyl accident	0.01
Total (rounded)	**0.835**

* *The in utero contribution to the exposure risk should be added which is equal to 0.0003 cases, this value being calculated only for routine discharges from nuclear installations.*

Thus, the proportion of cases that can theoretically be assigned to exposure related to nuclear installations (*ex utero* and *in utero*) represents less than 0.2% of all cases that can be assigned to all ionising radiation exposure sources. Based on this estimate, the probability that a case of leukemia can be assigned to discharges from local nuclear installations is of the order of 1 to 2 per thousand (apart from in utero exposure) for all members of the cohort for the 1978-1996 period. Exposure to natural and medical sources contributes more than 99.8% of the total risk.

3.1.4. Sensitivity analysis

An analysis of four particular cohort exposure situations can be considered as a sensitivity analysis of average risk estimates calculated for the cohort. This analysis leads to the following conclusions:

- "Prolonged presence on the beach of children during their childhood" and " prolonged presence on the beach of mothers during pregnancy" exposure situations show that increasing presence on beaches by a factor of 5 (namely 1h20 per day for 24 years) does not significantly increase the risk of radiation-induced leukemia.

- In the "consumption of local fish and seafood" exposure situation, a person who consumes a large quantity of local seafood (up to 590 g per day) will have her or his radiation-induced risk from all exposure sources increased by about 73%, mainly due to the ingestion of radionuclides from natural sources (polonium 210 contributing almost the entire dose).
- The "living in a granite house" exposure situation shows a risk that increases with the concentration of radon. An increase in the radon concentration by a factor of 5 above the average concentration (74 $Bq.m^{-3}$) will increase the risk by almost 100%.

3.2. Exposure due to particular scenarios

The objective is to calculate annual doses (expressed as doses to the whole body (effective dose) and not simply to the bone marrow) for persons likely to be more exposed than the average of inhabitants in the canton. Thus, the GRNC analysis of these particular exposure situations compared exposure levels corresponding to situations leading to the highest effective doses with exposure levels corresponding to the critical group situations selected by COGEMA in its impact studies. The years included in Table 10 are the years for which the impacts on marine and terrestrial pathways were greatest.

Table 10. Comparison of particular scenarios and COGEMA critical groups

	Individual effective dose (µSv/y)	
	1985	1996
COGEMA "critical groups"		
- Fishermen of Goury	41	5
- Inhabitants of Digulleville	14	6
GRNC particular scenarios		
- Fishermen of Huquets	226	26
- Farmers of Pont-Durand	53	59

The results obtained for fishermen of Huquets and inhabitants of the hamlet of Pont-Durand particular scenarios give values for 1996 about 5 to 10 times higher than values obtained with the critical groups used by COGEMA in its regulatory estimates of the impact of its discharges using the same methodology as was used by the GRNC. These differences are due to choices made about lifestyle habits and locations with the worst exposure. The results may be considered as being a sensitivity study for these two factors.

Concerning the "average scenario" for an average adult in the canton whose lifestyle habits and exposure pathways are derived from the analysis of the 0-24 year old cohort, the values obtained for individual effective doses are: 18 µSv/y for the year 1985 and 4 µSv/y for the year 1996.

Furthermore, individual effective doses corresponding to about twelve occasional scenarios (in other words that might be observed a few times a year in the Nord-Cotentin region) are given for an occurrence in Table 11. The results show that taking account of particular habits results in increases in the effective dose that are less than, or as a maximum are of the same order of magnitude as the effective dose associated with the "average scenario". The only way that an effective dose of several hundred µSv could have been received would be to have eaten a crab caught close to discharge point during the year 1985.

Table 11. Individual doses associated with occasional scenarios

Scenario description	Effective whole-body dose (µSv/occurrence)
Fishing close to the COGEMA plant discharge pipe	20 µSv
Walking close to the pipe	7.5 µSv
Fishing at the bottom of the concrete block and posts	2.75 µSv
Walking in the Anse des Moulinets	< 1 µSv
Diving near the pipe	2.5 µSv
Eating a crab (250 g) caught less than 300 m from the discharge point in 1985	313 µSv (7-12 years old)
Using Sainte-Hélène water in 1979	10 µSv
Using Sainte-Hélène water in 1986	3 µSv
Fishing in Sainte-Hélène in 1979	0.015 µSv
Fishing in Sainte-Hélène in 1986	2 µSv
Playing at the mouth of the Sainte-Hélène in 1987	10 µSv
Playing at the mouth of the Sainte-Hélène in 1991	0.5 µSv
Walking close to the Manche Centre	0.5 µSv

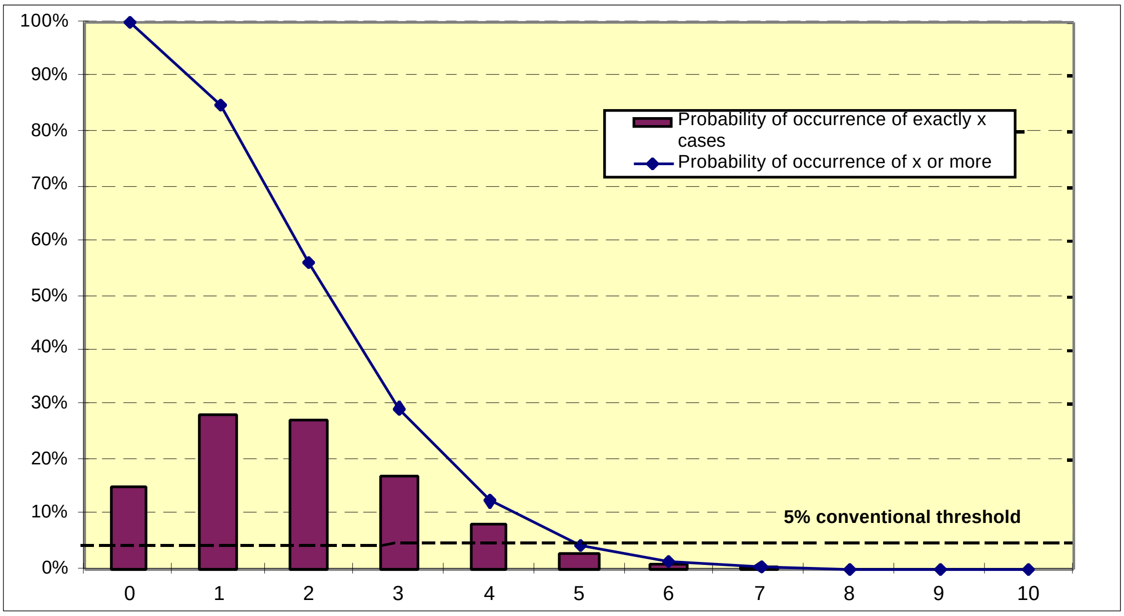
3.3. Interpretation of the results in terms of risk

The results given above concerning the estimate of the risk of leukemia for the cohort are expressed in terms of average risk value for an exposed population during a determined period, comparable to the period for epidemiological studies. The result is 0.835 case of leukemia that can be assigned to ionising radiation from all exposure sources. In reality, either zero, one or several cases of leukemia are observed, but never a fraction. A statistical type of interpretation is necessary to better estimate the significance of the estimated risk to the cohort, in other words a probabilistic law has to be used. A "Poisson"' distribution is applicable for this statistical phenomenon. We are dealing with rare events; about 70,000 person.years of exposure creating a risk per person per year of exposure of the order of 1 in 100,000 of developing leukemia that can be assigned to all sources of exposure to ionising radiation. The statistical analysis suggested to interpret the results considers three separate probabilities of occurrence of leukemia:

- as a function of the basic incidence of leukemia for the general population (independently of estimated risks of radiation-induced leukemia);
- leukemia cases that could potentially be assigned to *ex utero* exposure to discharges from nuclear installations;
- leukemia cases that could potentially be assigned to all *ex utero* exposures to ionising radiation.

The basic incidence of leukemia

Firstly, considering a cohort with the same risk of leukemia as the French population in general (estimated using results taken from the FRANCIM French cancer registers network applied to the Nord-Cotentin cohort), the number of cases expected for the entire cohort over the observation period considered is equal to an average of 1.9 cases. This value should be compared with four cases actually observed in the same population during the 1978-1996 period. Application of a Poisson distribution to this average value (see Figure 10) gives an estimated probability of observing at least four cases related to the basic incidence of leukemia during the same period equal to 12%. Since this probability is greater than the 5% confidence threshold usually used in epidemiological studies, the possibility that this excess number of cases could be due to chance cannot be ignored. However, it should be noted that the incidence of leukemia during the 1978-1996 period in the Beaumont-Hague canton remains high compared with what would be expected according to the reference rates, although this difference remains very limited.



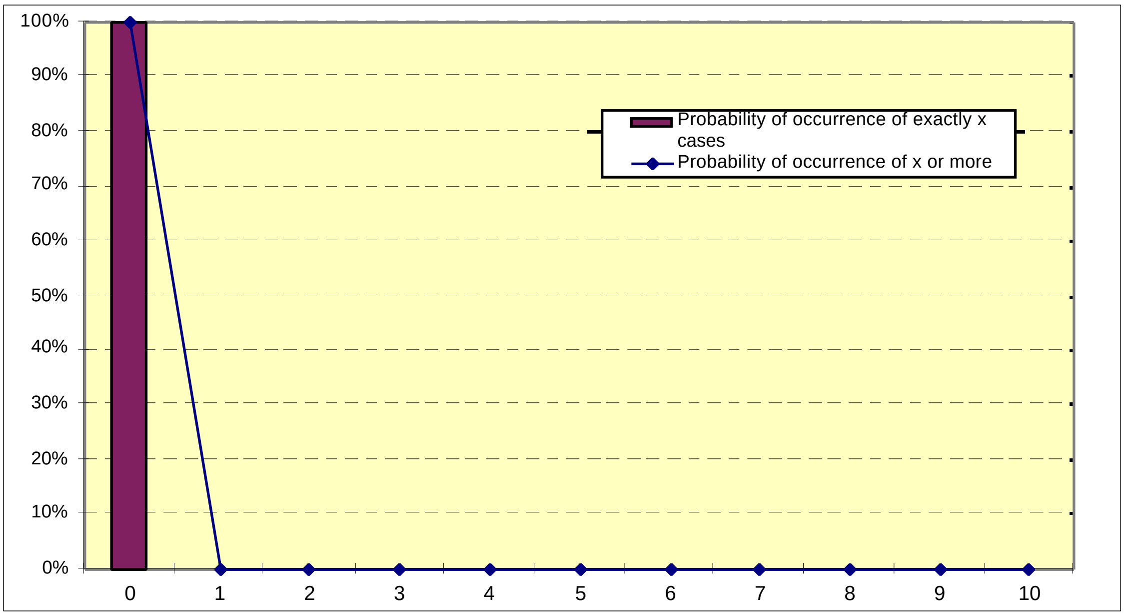
Number of cases x	Probability of observing exactly x cases	Probability of observing x or more cases
0	14.957%	100%
1	28.418%	85.043%
2	26.997%	56.625%
3	17.098%	29.628%
4	8.122%	12.529%
5	3.086%	4.408%
6	0.977%	1.321%
7	0.265%	0.344%
8	0.063%	0.079%
9	0.013%	0.016%
10	0.003%	0.003%

Figure 10. Probability of observing leukemia according to a Poisson distribution with average 1.9

(corresponding to the basic incidence derived from the French average applied to the Beaumont-Hague canton for the 1978-1996 period, for persons between 0 and 24 years old)

The risk associated with nuclear installations

The evaluation of the number of cases of leukemia that can be assigned to *ex utero* exposure during childhood due to discharges from Nord-Cotentin nuclear installations is an average of 0.0014 cases for the entire cohort over the observation period, that can be compared with the four observed cases. Application of a Poisson distribution to this average value (see Figure 11) results in an estimate of the probability of observing at least one case during this period that can be said to be caused by Nord-Cotentin nuclear installations of 1.4 per thousand (0.14%) (the probability of observing at least two cases is of the order of one per million). Furthermore, the average risk of leukemia for each person in the cohort during this period that can be assigned to *ex utero* exposure related to routine discharges from local nuclear installations is extremely low, since it is equal to about 1 per 100 million per year of exposure. This value is equal to the risk of occurrence of leukemia, related to the number of person-years.



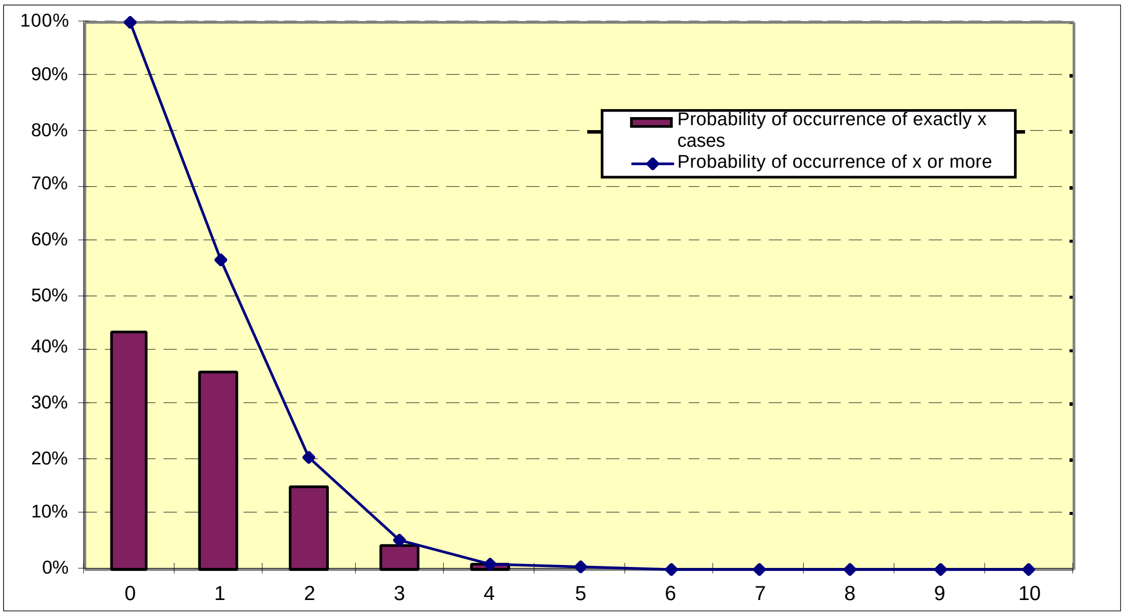
Number of cases x	Probability of occurrence of exactly x cases	Probability of occurrence of x or more cases
0	$9.99\ 10^{-1}$	1
1	$1.40\ 10^{-3}$	$1.40\ 10^{-3}$
2	$9.79\ 10^{-7}$	$9.79\ 10^{-7}$
3	$4.57\ 10^{-10}$	$4.57\ 10^{-10}$
4	$1.60\ 10^{-13}$	$1.60\ 10^{-13}$
5	$4.48\ 10^{-17}$	$4.48\ 10^{-17}$

Figure 11. Probability of occurrence of leukemia according to a Poisson distribution with average 0.0014

(corresponding to the estimated number of cases of leukemia that can be assigned to ex utero exposure to discharges from nuclear installations in the Beaumont-Hague canton during the 1978-1996 period for persons aged from 0 to 24 years)

The risk associated with all exposures

The evaluation of the number of cases of leukemia that can be assigned to all *ex utero* exposure to ionising radiation during childhood (natural irradiation, medical exposure, fallout from atmospheric testing of nuclear weapons and the Chernobyl accident, discharges from nuclear installations) is of the order of 0.835 case, namely about one quarter of the number of cases observed. 99% of this risk can be assigned to sources other than discharges from nuclear installations, including almost 75% due to natural radioactivity, 24% due to medical exposure and of the order of 1% for fallout from atmospheric testing of nuclear weapons and the Chernobyl accident. The use of a Poisson distribution applied to the number of leukemia cases that can be assigned to all *ex utero* exposures to ionising radiation gives results of 57%, 20% and 5% as estimates of the probability of observing at least 1, 2 and 3 cases respectively that can be assigned to all sources during the same period (see Figure 12). Therefore on this basis, it is impossible to reject the assumption that some of the four observed cases of leukemia could be due to natural irradiation and medical exposure. The average individual risk within the cohort corresponding to these exposure sources is of the order of one per 100,000 per person and per year.



Number of cases x	Probability of occurrence of exactly x cases	Probability of occurrence of x or more cases
0	4.34E-01	1
1	3.62E-01	5.66E-01
2	1.51E-01	2.04E-01
3	4.21E-02	5.26E-02
4	8.79E-03	1.05E-02
5	1.47E-03	1.70E-03
6	2.04E-04	2.31E-04
7	2.44E-05	2.72E-05
8	2.54E-06	2.80E-06
9	2.36E-07	2.56E-07
10	1.97E-08	1.98E-08

Figure 12. Probability of occurrence of leukemia according to a Poisson distribution with average 0.835

(corresponding to the estimate of the number of cases of leukemia that can be assigned to ex utero exposure to ionising radiation in the Beaumont-Hague canton during the 1978-1996 for persons aged from 0 to 24 years)

3.4. Conclusions and recommendations of the GRNC

Considering all the results presented above, the GRNC final main conclusions [9] are:

"Epidemiological studies have shown that the total number of cases of leukemia expected in the Beaumont-Hague canton from 1978 to 1996 would be of the order of 2 if the occurrence rate of this disease was the same as the value observed nationally. Four cases were observed. Nevertheless, this difference is not statistically significant.

The reconstruction of exposures from nuclear installations, as was done by the Nord-Cotentin Radioecology group, has led to a calculated number of 0.0014 case of radiation-induced leukemia[3] during the 1978-1996 period. This number is low considering the incidence of leukemia observed by recent epidemiological studies.

However, this result is an average estimate and at this stage it should be emphasized that margins of uncertainty have not been quantified. Due to these reservations, some members of the group are of the opinion that it is impossible at this stage to conclude that it is unlikely that discharges from nuclear installations contribute to the incidence of leukemia observed in the Beaumont-Hague canton.

The results obtained can be compared with the results of similar studies carried out in the United Kingdom around the Dounreay and Sellafield reprocessing plants. The conclusion of the British studies was that the observed number of cases of leukemia cannot be explained by discharges from nuclear installations".

More generally, the GRNC concluded that *"the work done (epidemiological and radio-ecological) cannot explain the relatively high observed number of cases of leukemia, but does not disprove the basic working assumption that there is no threshold in the dose/effect relationship, in other words low doses are related to a low risk rather than a zero risk. However as a result of this work, it is recommended that priority should be given to carrying out a more detailed study of exposures due to medical and natural sources in the Nord-Cotentin, and that in any case, exposures of the public to all sources should be minimized (as required by the regulations)".*

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[3] The contribution to the risk of in utero exposure associated with routine releases of nuclear installations has to be added and corresponds to 0.0003 case.

Based on its work, the GRNC suggested a series of recommendations in order to study some aspects of the evaluation of exposures and risks for the population of the Beaumont-Hague canton in more detail, and also more generally to draw information from this experiment for monitoring exposure of various populations to ionising radiation. The main recommendations are presented briefly below.

Exposure sources other than nuclear installations

"More detailed retrospective studies should be carried out locally on medical analyses on young people and pregnant women as a result of these exposure sources. It would also be important to widen the scope of the expertise to include other pollution sources (chemical pollution, etc.) and their synergy (if any) with the effects of ionising radiation".

Uncertainty analysis

"Uncertainty analysis on the effect of the variability of all data used, and particularly the variability of the measurements, were carried out in the marine environment but were not used for the dose calculation. It should be emphasized that a global uncertainty analysis was not carried out for similar work done in the United Kingdom. A study of this type could be made later (for the Beaumont-Hague canton - editor's note)".

Surveillance

"The group has made extensive use of the results of environment monitoring measurements, but also observed the need for more specific measurements for some radionuclides and lower detection limits in order to better estimate population exposure levels in the future...
Finally, a framework needs to be defined for cooperation between the various laboratories that contributed to building up the environmental measurements database in order to continue updating this base and widening it to include indicators that are not included at the present time".

Pluralist expertise

"Considering the reactions of these various stakeholders (members of the GRNC - editor's note), it will be necessary to consider the contribution of this type of expertise to the process for analysing impact files in other situations later".

3.5. Comparison of the GRNC results with the COMARE results

For the purpose of a comparative analysis, although a lot of differences have to be quoted, it is interesting to summarize the results obtained in the COMARE study on the population of young people from 0 to 24 years old living close to Sellafield installations in the United Kingdom (BNFL Seascale plant in the West Cumbria region), for which the last re-estimate was published in 1996.

This estimate applies to populations exposed between 1945 and 1992 and includes a population of 1348 persons. The main results obtained in terms of *ex utero* and *in utero* doses to the bone marrow and the risk of leukemia that can be assigned to exposure to ionising radiation are given in Table 12.

Table 12. Results of the COMARE study for populations living close to the Sellafield installation

Exposure source	Collective dose to the bone marrow (person.sievert)	Number of cases of radiation-induced leukemia
Nuclear installations*	4.1	0.04
Natural sources	39	0.36
Medical sources	3.1	0.02
Atmospheric testing of nuclear weapons and the Chernobyl accident	2.2	0.03
Total (rounded)	**48.5**	**0.45**

* *The reprocessing plant contributes 2.39 person.sieverts, and the Windscale fire contributes 0.917 man-sieverts to the total discharges from nuclear installations.*

On this basis, the COMARE committee concluded that the estimated exposure of the Seascale population to ionising radiation was much too low to explain the number of cases of leukemia observed among young people during the period considered for the study. Considering the number of cases of leukemia observed (12 cases) and estimated doses for this population, the committee estimated that the received doses were about 25 times too low to explain the observed cases.

A direct comparison with the results obtained by the GRNC is difficult, particularly considering differences in terms of the population size and the time during which exposures were monitored, differences in the models used, lifestyle habits and the amounts of discharges into the marine environment (more in the past for Sellafield than for the COGEMA La Hague reprocessing plant). However, exposures and risks for routine discharges were expressed per 100,000 person-years in order to make the GRNC results comparable with the COMARE results (see Table 13). This analysis shows that the estimated risks for the Seascale cohort are about 40 times higher than for the cohort in the Beaumont-Hague canton.

Table 13. Comparison of COMARE and GRNC studies (only for routine releases)

	Seascale (Sellafield) [15]	**Beaumont-Hague [9]**
Period	1945-92	1966-96
Number of persons	1348	6656
Person-years	≈ 25300	94296
Collective dose (in utero and ex utero) due to routine discharges	2.39 person.Sv	0.32 person.Sv
Collective dose per 100,000 person-years (in utero and ex utero) due to routine discharges	9.45 person.Sv	0.34 person.Sv
Estimated number of radiation-induced cases in the cohort	0.020	0.0012
Risk of leukemia for 100,000 person-years	0.079	0.002

Keeping these differences in mind, it is interesting to compare the contributions of the different exposure sources to the risk of leukemia that can be assigned to ionising radiation, according to the two studies (see Table 14).

Table 14. Contribution as a percentage of the risk of leukemia that can be assigned to ionising radiation (rounded values)

Exposure source	Seascale COMARE[1]	Beaumont-Hague GRNC[2]
Nuclear installations	9%	0.2%
Natural sources	80%	74.5%
Medical sources	6%	24.1%
Atmospheric testing of nuclear weapons and the Chernobyl accident	5%	1.2%

[1] Including *ex utero* and *in utero* exposures

[2] Including *ex utero* exposures only

These two evaluations (COMARE and GRNC) do not cover exactly the same types of exposure, and the figures presented in this table have to be used with caution, nevertheless some significant differences between these two evaluations can be identified:

- differences in the modes of exposure for discharges from installations due to differences in terms of discharges, lifestyle habits and models;
- differences concerning medical exposure for which the contribution is much lower in the GRNC study than in the COMARE study.

However, it can be noted that there is relatively good agreement about the magnitude of natural exposure sources.

4. PROSPECTS ARISING FROM THE GRNC'S EXPERIENCE

4.1. The point of view of experts from associations

Before starting to discuss conclusions that can be drawn from the process set up by the GRNC, it appeared important to question experts from associations who participated in the group's work, after the work had been completed, in order to get a good understanding of what they thought about the procedure and the lessons that they had learned from it for the future. The fact that these experts wanted to explicitly express reservations about the final conclusions clearly demonstrated differences in the interpretation of the results, and also the method adopted by the group. The first step was to organize individual meetings with Mrs. SENE from GSIEN and Mr. BARBEY from ACRO, who directly participated in the GRNC work. A meeting was then held with Mr. DESBORDES, President of the CRII-RAD in order to find out this association's position, which participated in the work done by the GRNC but did not want to be associated with its conclusions.

4.1.1. Mrs. SENE's point of view

Mrs. Monique SENE from GSIEN considered that the widened composition of the Nord-Cotentin Radioecology Group was beneficial in that it increased the range of the debates and that this type of method should be extended to other nuclear related contexts, and also to other fields of expertise concerning risks to health and the environment. However, she emphasized that it is impossible to do the work necessary to improve the efficiency of the "independent" expertise (i.e. without depending on operators or inspection authorities), unless sufficient human and financial resources are available for them. In other words, experts or associations participating in similar experiments in the future will require direct financial support.

Having said this, Mrs. SENE considered that the GRNC's results still include many uncertainties about many calculations carried out by the working groups. She mentioned the following examples of these uncertainties:

- the validity of models selected for the dispersion of radionuclides in the environment. In this respect, she would be interested to know if there are other possible models than those that were used, and also if the selected models are the most appropriate for the situation. Are there any ongoing developments related to modelling of environmental dispersion that could be used to produce more suitable new models in the future? In this case, she considers that it would be useful to continue scientific monitoring and making a new estimate as soon as possible. She considers that this form of vigilance is essential in any rigorous and responsible scientific procedure.

- Identification of different causes of leukemia. Although the study does provide elements of answers to the question raised by Professor VIEL about ionising radiation, it completely ignores other possible causes. Therefore now that this first investigation has been completed, all other possible causes of leukemia observed in the region should be investigated.

Considering these limitations, Mrs. SENE emphasized the advantages of continuing scientific research in order to better understand firstly the risks associated with exposure to ionising radiation, and secondly the contribution (if any) of other risk factors. Therefore for these various reasons, the GRNC results should be considered with caution and presented specifying that they only reflect the state of current knowledge, and that this knowledge can change quickly. She also emphasized that the work done by the GRNC included drawing up a relatively exhaustive inventory of the situation in the Nord-Cotentin (including cancers) that should now be used and kept up to date to provide genuine health monitoring for the public and for workers.

Furthermore, in her opinion, the GRNC experience demonstrated the advantage of setting up a new regulation mechanism for monitoring discharges from nuclear installations into the environment. This regulatory control around nuclear installations should enable increased, credible and sustainable participation of the public, particularly by getting a pluralist expertise involved in the process of estimating and inspecting these installations. The nature of this approach should encourage confidence in the entire evaluation and control process, which up to now has mainly been based on confidence in the public authorities through its control organizations. In her opinion, if this type of process is to operate correctly, it must initiate a genuine dialogue between the various stakeholders, accepting that all questions of all natures can be asked and that answers should be given to them. In this respect, she considered it essential that operators and the public authorities should make all information available to independent experts so that they can exert their role of making critical examinations and thus supporting their questions. Mrs. SENE found it very unfortunate that even now, frequently in processes in which independent experts are involved, information is not provided until these experts ask for it, rather than as a prerequisite before the process is started. The pluralist evaluation process must also make it possible to reconsider existing evaluations regularly by adopting clear rules, for example such as intervals defined as a function of the main steps in the life of installations or at time of particular events. In this approach, she considered it important to be particularly vigilant with regard to future discharges.

Finally, Mrs. SENE mentioned the difficulties caused by the participation of independent experts in experiments like the GRNC, within the associations that employ these experts. She considered that it is important to bear in mind, and to make members of associations realize that:

- Participating in the work done by a group does not mean agreeing with everything done by the group, and in particular that it is always possible to be able to express her or his point of view at the end of the participation process. In any case, that is what she did within the GRNC.

- Critically questioning the evaluations made and the results obtained in a pluralist evaluation process does not necessarily mean disagreeing with the group and disqualifying the work done.

In her opinion, she considered that it is important for independent experts to be able to participate in GRNC type work to be able to ask questions, even if they are disturbing, and obtain all available information. This is the price to be paid to have confidence in the control process. She also believed that participation of a pluralist expertise in evaluation work like that done in the GRNC is the means of gradually transforming the nuclear installation control and monitoring system to make it more open.

4.1.2. Mr. BARBEY's point of view

Mr. BARBEY from ACRO believed that the composition of the GRNC resulted in partial recognition of the associations and their role in the estimate of risks and controls of discharges from nuclear installations. However, he emphasized that in the case of the GRNC, this participation was limited to the expertise of members who were invited to participate in the process, and that in this respect the associations did not have an official role. This situation created some difficulties for participating experts with regard to association members who were not directly involved.

Globally, Mr. BARBEY considered that the first objective of his participation in the GRNC work, namely « opening black boxes » was achieved. His participation as a scientific expert from an association was justified in his opinion, essentially by the desire to know and understand all dispersion and exposure models used by operators and the public authorities in the evaluation and authorization procedures related to radioactive discharges from nuclear installations. Considering the objectives of the ACRO, it is essential that these procedures should be well controlled. When he joined the GRNC, he was interested in « black boxes » but he was also interested in finding information about discharges. In this respect, he considered that he was satisfied and he mentioned that operators and institutional experts had made unquestionable progress during the GRNC procedure in terms of sharing information and expertise.

In terms of his personal involvement in the GRNC working groups, Mr. BARBEY had the impression that his opinions were considered to a certain extent, but he regretted that a number of points that he raised and considered to be very important did not receive the attention that they deserved from other group members. Nevertheless, he considered that in particular, his participation contributed to a better definition of critical groups that were likely to be the most highly exposed, taking account of local habits that could have a significant influence on exposure. He also appreciated the fact that the President of the group always took special care to ensure that everyone understood that the objective was not to reach a unanimous position or even a consensus, but simply to pool all information and questions from the different participants and to write texts in which any differences and reasons for these differences would be clearly set down. In his opinion, this approach was the necessary guarantee for real involvement of associations in this type of approach.

However, Mr. BARBEY emphasized that the presence of associations in the GRNC should not conceal the important unbalance that was prevalent throughout the process between the different stakeholders in terms of equipment resources, human potential, evaluation tools and even experience in a field traditionally reserved for operators and institutional organizations. In this respect, he considered that voluntary work characterized by the associative approach is reaching its limits and that reflections should be considered on how the expertise from associations can be involved in similar procedures in the future. In his opinion, the lack of resources and support is one of the reasons for the reserved attitude that the associations must maintain with regard to GRNC type experiments.

Regarding the evaluation procedure, Mr. BARBEY considered that in terms of the radiological risk and considering the uncertainties that remain about the real health impact of radiation, particularly at low exposure levels, an “envelope” (conservative) approach should be adopted in all evaluations of the health impact, since this is the only way of guaranteeing that the final results surround the genuine value of the impact if it is impossible to obtain a precise measurement of the uncertainty related to so-called “realistic” calculations. In his opinion, it is important to express these reservations to emphasize remaining uncertainties about the risk calculation, and therefore the limits of the work done by the GRNC, in order to prevent any premature final conclusions. However the difficulty in establishing a cause to effect relationship in the case of leukemia cases in the Nord-Cotentin does not prove that this causal relationship does not exist. Mr. BARBEY also mentioned that attempting to understand the calculations and reaching an agreement about the models used does not necessarily mean that the results that they produce should be accepted, if the uncertainties have not been estimated. Mr. BARBEY also considered that it is quite possible that the group could have missed some important input data that could significantly modify the results of the study.

More generally, it is by no means certain that a pluralist expertise will necessarily contribute to social confidence. The fact that associations are present in the process for evaluation of the impact of discharges from nuclear installations does not mean that they accept these discharges. The term "social confidence" that has been fashionable recently, should not conceal the reality of antagonisms and should not be understood as a pure and simple acceptance of the situations concerned. He considered that this point is very important and to demonstrate it he referred to the example of the difficulty that he himself encountered within the ACRO due to his participation as an expert in the work done by the GRNC. Participating in no way means cooperating and certainly not accepting discharges. Nor does active involvement in the work done by the GRNC mean participation in co-management of risk. It is intended more specifically to set up concerted action on the impacts of discharges from nuclear installations, including public disagreement about the risk evaluation. The associations' essential objective is to remain vigilant regarding discharges from installations.

4.1.3. Mr. DESBORDES's point of view

Unlike the other experts in the associations, the CRII-RAD expert did not want to be associated with the GRNC's conclusions[4]. Nevertheless, Mr. DESBORDES, the

[4] See synthesis note 99-26: “Summary of the CRII-RAD's participation to the GRNC's work”, published in January 2000 (Responsible of the study: Bruno Chareyron).

President of the CRII-RAD, did agree to an interview in which he was invited to give his opinion about the procedure. He did not participate directly in all the GRNC's work, but closely monitored the various developments, consequently most of his comments were related to general information that can be drawn from this experience.

Firstly, Mr. DESBORDES explained that the CRII-RAD considered that the conclusions of the GRNC were written very hastily, so that it was impossible to find solutions to fundamental differences. As a result, the CRII-RAD had no choice but to dissociate itself from the synthesis document. Due to events beyond their control and considering the deadlines imposed by the President of the GRNC, experts in this association considered that they did not have enough time to analyse and discuss the conclusions of the GRNC. Therefore under these conditions they preferred to abstain from making any contribution to the conclusions. In this respect, Mr. DESBORDES considered that the GRNC experiment should be qualified as plural rather than pluralist, because the means made available to the various participants were not of the same nature and in any case were very disproportionate, so that in his opinion the expertise could not be considered as being pluralist. He emphasized that the available means were distributed unequally between the various stakeholders and furthermore that only a few experts from associations were able to participate in the GRNC which consequently was not genuinely representative of these associations as a whole.

Having said this, Mr. DESBORDES considered that despite the conclusions made by the GRNC, globally the results were not really reassuring for the populations concerned to the extent that the uncertainties associated with the different calculation steps were not estimated. He considered that the evaluation is far from being complete and he would like communications of GRNC members to include a clearer statement of limitations on the results, until a more detailed analysis of the uncertainties about which he is concerned is available.

Mr. DESBORDES also mentioned that restricting the study to the dose to the bone marrow and the associated risk of leukemia made it impossible to make a complete investigation of questions about the potential health effects of exposure to ionising radiation. Similarly, he found it unfortunate that the question of synergy with other toxic products could not be considered. In his opinion, the approach was only partial and did not provide very convincing answers to the initial questions. He considered it essential that the analysis should be broadened and particularly other potential causes of the occurrence of leukemia should be explored for before coming to any conclusion about the innocuousness of discharges from installations. In this respect, he believed that further evaluations must be carried out with the involvement of expert medical doctors in the plenary group.

Mr. DESBORDES believed that the conclusions adopted by the plenary group are too affirmative, considering the remaining uncertainties. Furthermore, he regrets that the results of the study were not followed by a debate on the "zero discharges" option with the prospect of implementing the OSPAR Convention to which France has made an international agreement. He made it clear that this is a medium term objective that should be discussed now in order to determine the best way of achieving it in the not too distant future. In this respect, he thought that a study should be carried out on the legitimacy of discharges into the environment. Even if current discharges are legal to the extent that they do not exceed authorized discharges for operation of the installations concerned, he believed that the legitimacy of these discharges should be questioned in the longer term. He believed that considering firstly accumulation and transfer phenomena that are far from being genuinely controlled even in terms of understanding, and secondly the fact that it is impossible to predict how future generations will use the environment, we should be cautious and therefore minimize as much as possible any form of radioactive or other discharges. Releases into the environment will become increasingly unacceptable in future years, and therefore we should set ourselves the objective of moving towards zero discharges starting from now, and fixing a realistic deadline.

Mr. DESBORDES considered that the GRNC's task has remained too restricted so far, to the extent that the approach concentrated on man exposures « here and now ». The environment as such was not really considered, in other words the future of this environment and how it will be used in the future were not considered. In particular, there was no study about the various compartments of the environment that man does not use at the moment, but that could be used in the more or less distant future. In this respect, he specified that the CRII-RAD would like its future actions within the associations to consist of taking a precautionary attitude and maintaining extreme vigilance about discharges from nuclear installations, rather than taking a position for or against the use of nuclear energy.

4.2. The point of view of the "Mères en Colère"

The "Mères en Colère" group was created in February 1997, shortly after the second study by Professor VIEL was published, and played an important role in the procedure that resulted in setting up the SOULEAU Committee, and then the GRNC. Although the "Mères en Colère" did not participate in the GRNC directly, fairly regular contacts were held with the President, Annie SUGIER, who was careful to inform the "Mères en Colère" group about developments in the work throughout the process. A meeting with representatives of this group was organized at the request of Annie SUGIER, in order to collect their feelings following publication of the results in July 1999.

For the "Mères en Colère", setting up the GRNC was an important step in the process to obtain information about discharges from Nord-Cotentin nuclear installations according to their objectives at the time that the group was created. The work done by the GRNC provided the first elements of an answer to this worry, and the results about the risk of leukemia were received with some relief, since there had been real anxiety among the population and particularly families with young children. However, the GRNC's evaluation does not nearly answer all questions raised by the "Mères en Colère" as the GRNC work progressed, and the work in general was followed with a great deal of attention. The group considered that although at the moment it is possible to state that there is no direct relation between the four cases of leukemia observed in the canton and discharges from installations, the work done by the GRNC provided no new information about possible health effects other than leukemia caused by radiation. Furthermore, the "Mères en Colère" considered that doubts remain, that uncertainties were not estimated and therefore that investigations should be continued for other potential risk factors and particularly chemical discharges that were not considered by the GRNC.

Beyond an interpretation of the results, the "Mères en Colère" emphasized that the GRNC's approach helped to unblock a situation that was halted due to lack of information, since available information was intended only for experts and could only be interpreted by experts. Members of the "Mères en Colère" group had the feeling that they have been taken seriously in their desire to understand and be able to obtain independent, credible and clear information, which had never been the case in the past. The fact that the President of the GRNC came to visit them personally to present the results before making them public was seen by the "Mères en Colère" as a mark of respect that was appreciated. It was the first time that a scientist had agreed to spend the time necessary to explain the results and answer all questions. The "Mères en Colère" would like to see this method repeated in the future and is considering taking actions in the future to enable it to maintain contacts and dialogue with scientists. The group would also like to see this type of approach developed within the GRNC applied to other industrial activities.

The presence of independent experts in the GRNC, and particularly experts in local associations, was a factor contributing towards reassurance about the quality and credibility of work done by the GRNC. The GRNC's approach in this respect provides hope about the openness and independence of information processes on risks associated with discharges from nuclear installations in the region. Nevertheless, the "Mères en Colère" considered that the involvement of local associations is not a substitute for action of the group, which does not have the same nature. The presence of experts thoroughly familiar with the region does not automatically guarantee that the results will be credible, and in this respect the "Mères en Colère" would like total independence from operators and from associations and politicians, and would like to maintain complete freedom of action in the future.

The GRNC experiment « opened up a process » locally that should be continued in the future. This is the logic within which the "Mères en Colère" would like to continue its existence so that it can be regularly informed about the life of nuclear installations in the region and particularly the COGEMA La Hague plant. The "Mères en Colère" considered that doubts and reservations expressed by the associations should be borne in mind and that vigilance should not be relaxed.

Specifically, members of the "Mères en Colère" decided to continue the GRNC's work « in their own way » to understand what is happening in their direct and daily environment. This is the price that these mothers have to pay for a certain degree of tranquillity. This is why the "Mères en Colère" have started the organization of an international assembly of mobile radiological laboratories for Autumn 2000. This meeting was organized to « *add to information about routine discharges from nuclear installations in the Cotentin, and the natural radioactivity of granite by making measurements on sites identified by inhabitants interested in this approach. The "Mères en Colère" consider this as prolonging and enriching the work done by GRNC, by inciting direct involvement of the public »*.

4.3. What lessons can be learnt from the GRNC?

Before discussing conclusions that could be drawn from the process set up by the GRNC, it is worthwhile emphasizing its specific features.

Firstly, it should be remembered that the group started its work in a context of strong anxiety caused by the publication of Professor VIEL's study. The controversy about the existence of excess leukemia and its possible relation to the operation of nuclear installations quickly became a national question.

In the subsequent discussions, technical arguments made by the different groups of epidemiological experts were mainly related to the methodology adopted by Professor VIEL and on how he reached his conclusions in his study about the possible cause-to-effect relationship between radioactivity and the development of leukemia in the population of young people less than 25 years old. The result was a serious crisis of confidence and genuine anxiety both on the health risk and the regional socio-economic incidence of this situation. The fact that the controversy is inherently related to health risks made irrelevant the attempts to reassure populations based on references to the system that had existed since the installations were commissioned to check that discharges were conform with the authorized limits.

This system, based on measurements of discharges and related environmental measurements, could not provide convincing proof that doses related to discharges could not have caused an excess number of leukemia cases demonstrated by Professor VIEL's epidemiological study. Therefore, the GRNC experiment is unusual considering the nature of the context in which this group was set up, which justified the use of exceptional means.

Furthermore, the fact that there are four nuclear sites in the Nord-Cotentin that could contribute to exposure of the populations, added a dimension of complexity which obviously affected the work done by the group. The process to broaden the expertise, considering the importance of the stakes (in particular the debate concerned the French nuclear plant that produces the largest amount of radioactive discharges and is frequently criticized by opponents to nuclear energy), thus brought in both local and national associations.

Note also that some technical difficulties encountered by the group were due to the fact that not all data necessary for the reconstruction of doses and the health evaluation were available: there were not enough release data to satisfy the requirements for exhaustiveness, environment data were dispersed and sometimes imperfect, some comparisons between models still needed to be made, and knowledge of doses related to natural and medical irradiation were incomplete.

Having identified the specific nature of this experience, it is also important to emphasize the information and lessons that can be drawn from it in the future and the tools to be used, both in the Nord-Cotentin context and in other contexts. This operating experience concerns the large number of technical tools that were produced and also the concertation process of a pluralistic and transparent nature that made an important contribution to the efficiency of the evaluation work.

The conditions under which some of the mechanisms were set up at the time of this experiment also need to be examined and could be adopted in the future, considering their impact on the quality and credibility of the environmental monitoring mechanism. In particular, this concerns the principle of exchanging data between the different categories of experts and maintaining the pluralistic expertise network built up (under conditions to be defined).

Some aspects of the GRNC experiment were suggested in recent studies or legal and regulatory policies. Therefore, this experiment should be examined in the light of these studies. In particular, it is worth mentioning the November 26, 1999 order that obliges operators to write annual reports for distribution to the public. These reports include the summary of environmental measurements and measurements made to monitor discharges and a realistic estimate of doses received by the most highly exposed population groups due to the operation of nuclear installations.

In general, the dosimetric impact of nuclear installations is estimated in the context of the release authorization request. The predictive assessment of the impact is made with the objective of estimating total discharges from a given installation and is based on generic models developed at the international level. At this stage, evaluations made by the operator are necessarily based on conservative assumptions to avoid underestimating the impact. However during revision procedures, the operator has operating experience with real marking of the environment and therefore can refine his evaluations to make them more realistic. The evaluation of the impact also allows for the detection of incidents, if any. In principle, the existence of other installations or other habits causing exposure to ionising radiation (non-medical) must be considered in estimating doses received by reference groups, but in practice the evaluation of the impact is restricted to the installation concerned by the authorization.

In this respect, the approach adopted by the GRNC introduces a significant change, in that the dosimetric impact is estimated from the point of view of populations actually exposed to a set of installations and activities (including medical irradiation), and to natural irradiation sources. Therefore the approach implies putting different risks into perspective. In this respect, it is consistent with the approach adopted in regional plans produced to comply with the December 1996 law on air quality that is based partly on an inventory of emissions and partly on an assessment of effects on public health [24].

As we have seen, the dosimetric reconstruction is based largely on correctly calibrating models by making environmental measurements. In order to be realistic, this reconstruction requires good knowledge of the “source term”. In this respect, the GRNC experiment has made a significant contribution to improving this knowledge, particularly in the case of the COGEMA La Hague plant. Radionuclides in the environment can only be counted as exhaustively as possible if measurement methods are modified so that they have the sensitivity necessary to detect low concentration levels. This type of count is not necessarily justified in routine operations provided that it has been demonstrated that radionuclides with a dominant influence on dosimetry have been considered. However, a new analysis should be carried out every time that the industrial process is changed, and this analysis should be as exhaustive as possible.

4.3.1. Tending towards a pluralist form of expertise

The GRNC, an innovative pluralist expertise process

Broadening of the GRNC beyond the traditional framework of discussions between operators and representatives of expertise organizations has contributed to improving the quality of the work, and undoubtedly its credibility. The presence of representatives of non-institutional organizations and foreign experts has enriched the work by adding complementary skills and sensitivities essential for a critical analysis. In return, the joint work over the long term and a comparison of sometimes very different points of views has undoubtedly assisted the stakeholders in reaching a better understanding of each other's logic and values, and eventually contributed to a better mutual understanding, without necessarily arguing against frequently very firm convictions.

From the point of view of the public, setting up a pluralist expertise is undoubtedly a guarantee of high quality results, requiring more than ever before a clear statement of the issues and debates to which the different parties can contribute. It is now accepted that an expertise, although founded on known scientific facts, inevitably involves more or less implicit choices made particularly to get around scientific uncertainties and gaps in our knowledge. Bringing together experts representing different interests of the public, and experts in different disciplines, helps to highlight these implicit choices and therefore make a better distinction between what actually depends on science and engineering and what depends on values and firm convictions.

It is obvious that the presence of experts within associations who can hardly be suspected of concessions to operators, authorities and institutional experts, can only help to ensure that nothing is swept “under the carpet” and avoid what some considered to be dead ends harmful to the credibility of the entire evaluation process. Thus for example, the exhaustiveness approach adopted by the group helped to identify chlorine 36 as being a radionuclide that could make a significant contribution to the dose resulting from gaseous discharges from the La Hague reprocessing plant. The group concluded that the dosimetric impact of chlorine 36 really was very low, after specific measurements have been made on this radionuclide that it had not considered would be useful in the past.

Setting up a forum enabled the different groups of experts involved firstly to estimate their mutual credibility, which is a prior requisite for debate. Thus, a consensus was gradually set up about the quality of measurements made by the various participants. The existence of a structure including experts from different social backgrounds allowed the group to deal with points of disagreement or even controversies, without the use of invective. This provides a setting for a common search for solutions.

By incorporating local components and interests, a pluralist expertise is a means of enriching evaluation models based on better knowledge of local habits.

Thus, for example, concerning the question of fishing areas, as requested by ACRO experts and that reflected questions asked by the public, the GRNC decided to study a particular "Fishermen of Huquets" scenario in which fishing was done in an area (Les Huquets de Jobourg) located 1 km from the release point and where contamination levels were 4 to 5 times higher than contamination levels used for the reference "fishermen" group initially put forward by the operator and located in the Goury area at a distance of 7 km from the pipe.

Similarly, the pluralist expertise added further information about local habits and lifestyle habits particularly with regard to a retrospective evaluation. This is the context in which dietary habits were modified in some scenarios at the request of experts from associations.

Other similar experiments

Although quite separate in some respects, an experiment carried out by the Department of Energy (DOE) in the United States deserves mentioning. In this case, inhabitants of areas contaminated by nuclear installations (particularly Rocky Flats, Hanford and Los Alamos) were involved in decisions related to decontamination of residential areas [25]. Studies carried out by the DOE and the Atlanta Center for Disease Control were submitted to a commission composed of local citizens and researchers chosen by these citizens, in order to estimate the health impact of these sites. A citizen environmental sampling committee was set up to help reconstruct doses around the site, and this committee called in its own consultants. The fact that the conclusions reached by this committee were similar to the conclusions reached by the official organization significantly contributed to improving the credibility of these organizations.

In France, there is much in common between the evaluation of the exposure of the public living around the Salsigne site north of Carcassonne, coordinated by the National Public Health Network in 1997 [26], and the GNRC approach. The purpose of this evaluation was to estimate recent exposure to the main pollutants identified in the Salsigne Region as precisely as possible, particularly including lead, cadmium, arsenic and cyanides from the la Combe du Saut mining and industrial facility, in order to identify risk groups (if any) and study the morbidity declared by the resident population. This evaluation experiment originally started with the active participation of the population concerned since it included biological samples (urine and hair) and a questionnaire about the various risk factors related to the personal characteristics of the persons involved, their place of residence, their food and drinking habits and their work, and a questionnaire about the various symptoms experienced and the medically treated pathology. This approach demonstrated that residents of the region are overexposed to arsenic, but the amplitude of this exposure remains small and is not likely to cause any health problems in the future. Obviously, this result in no way prejudges the health impact of previous exposures that were greater and could only be identified by epidemiological studies. The Salsigne experience demonstrates firstly that the procedure to reconstruct exposures is common to several risk factors, and secondly that it is possible for exposed persons to participate directly in this reconstruction. Specifically, the Salsigne evaluation identified the main risk factors, for example such as the consumption of garden products when the garden is subject to flooding, or drinking well water or locally made wine. Based on these results, the public authorities were able to make recommendations and the public modified some of its habits in order to reduce exposure.

4.3.2. Tending towards a complementary approach to monitoring discharges

One of the important questions that emerges from the GRNC work is to identify the objectives of environmental monitoring. The vast majority of the 500,000 “concentration determinations” handled by the group are routine measurements made to ensure that there is no malfunction in the installations.

However, there are far fewer measurements that can be used to give as much as possible a realistic and an exhaustive reconstruction of doses received by the public. Furthermore, these measurements concern not only radionuclides released by the installations, but also radionuclides present in the environment (natural radioactivity, fallout from tests and the Chernobyl accident, etc.). Therefore, in order to get an idea about the future of radionuclides in the environment and their contribution to exposure of the public, measurements other than routine measurements have to be envisaged. This type of measurement would also participate towards the effort made to monitor the global quality of the environment, in the same way as measurements made on non-radioactive pollutants and health monitoring of the public. These two types of measurements are undoubtedly justified and complementary. We need to think about the equilibrium to be found between different measurement types in the future, based on the work done.

A radioecological reference database needs to be built up in order to reconstruct doses received by the public originating from environmental sources. There are technical problems in setting up such a base, not least due to the difficulty of measuring very low activity levels.

Two types of data are used in this respect: measurements on locally consumed products, and measurements on “ bio-indicators” used to adjust transfer models. These models are essential for two reasons. Firstly, they can provide guidelines in advance about the choice of sampling and measurement points, and secondly they enable the calculation of doses that would be impossible to determine from environmental measurements alone.

This measurement effort should be made in priority for radionuclides shown to be important in terms of the contribution to the dose received by the public, in the work done by the GRNC. Sampling and measurement points should take account of local lifestyle habits and the dietary habits of various population groups, in an attempt to be realistic.

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APPENDIX:

INSTITUTIONS AND ORGANIZATIONS REPRESENTED IN THE GRNC

PUBLIC EXPERTISE AND INSPECTION ORGANIZATIONS

The OPRI (Office de Protection contre les Rayonnements Ionisants - Office for Protection against Ionising Radiation) is a public establishment under the control of the Ministries of Labour and Health. The main guidelines for its task are set down in its July 19 1994 creation decree:

- to participate in the application of laws and regulations on radiation protection, by carrying out all controls necessary due to the use of ionising radiation,
- to advise the public authorities about medical and health measures to be taken in the case of an incident or accident, to perform continuous monitoring for this purpose and to take action in a radiological emergency,
- to contribute towards training and information of persons exposed at work and the general public,
- to organize and coordinate studies on revisions to radiation protection standards and radiation measurement techniques.

In particular, the OPRI regularly monitors radioactivity emitted by Nord-Cotentin nuclear installations in application of the regulations, including the COGEMA La Hague plant, the La Manche storage centre, and Flamanville nuclear power plant. The military part of the Port of Cherbourg is controlled through an agreement signed with the French Navy Headquarters.

The IPSN (Institut de Protection et de Sûreté Nucléaire - Nuclear Protection and Safety Institute) carries out research and expertises on the control of nuclear risks and their consequences on man and the environment. Its task is to assist the authorities and everyone involved in safety and radiation protection in normal and accident situations, particularly by contributing radioecological and dosimetric expertise.

The IPSN has played a significant technical support role within the framework of the

Nord-Cotentin Radioecology Group. The Institute's experts have been asked to carry out the necessary calculations to facilitate the group's analysis work. Furthermore, IPSN representatives in the GRNC have been very strongly involved in the organization and technical and administrative secretariat for working groups. They made important contributions to the work necessary to proof read analysis documents. The IPSN facilitated the process by taking control of the physical organization of group sessions.

THE OPERATORS

COGEMA is an industrial group with activities covering the entire fuel cycle (ore extraction, conversion, enrichment, fuel fabrication, reprocessing, transport). COGEMA's spent fuel reprocessing plants are located in La Hague 20 km west of Cherbourg at the far north-west of the Cotentin peninsula. They cover an area of 290 hectares (220 hectares plus a 70 hectare strip connecting the site to the sea). About 6000 persons work on the site. Half of them are employed by companies external to COGEMA.

There are several reprocessing plants in the La Hague complex. The UP2-800 and UP3-A plants are each technically capable of reprocessing 800 tonnes of spent fuel/year. The UP2-400 plant is capable of reprocessing 400 tonnes of spent fuel per year.

The ANDRA (Agence Nationale pour la gestion des Déchets RAdioactifs - National Agency for the Management of Radioactive Waste) is responsible for long term management operations for radioactive waste. The December 30 1991 law transformed the ANDRA, that was formally a single service created within the CEA in 1979, into a Public Industrial and Commercial Institution (EPIC), independent of waste producers, and made it responsible for:

- a research task: to study storage solutions,
- an industrial task: the construction, operation and monitoring of storage facilities,
- an inventory task: which in particular includes the annual publication of the inventory of radioactive waste in France.

Electricité De France (EDF) is the world's leading electricity producer. It has almost 30 million customers in France and 15 million customers in other countries, and generates more than 400 billion kWh for sales of more than 180 billion Francs. Power plants used to generate electricity include hydroelectric power plants (15% of production), thermal combustion power plants (5%) and 58 nuclear reactors (80%).

The GEA (Groupe d'Etudes Atomiques - Atomic Studies Group) is a Radioecology studies and research organization reporting to the "'environment - nuclear safety - health, safety and working conditions" unit of the French Navy Headquarters. The GEA is set up in Cherbourg and is particularly concerned with radiological monitoring in the English Channel; radioecology studies about the diffusion of liquid and gaseous effluents and determination of the activity of radionuclides (particularly the definition of determination methods); monitoring of all equipment used by radiological monitoring services in the Navy and the Navy's analysis, monitoring and expertise laboratories; the analysis and archiving of data related to monitoring of radiological monitoring of the Navy's nuclear sites that are provided to it by the responsible authorities.

THE CSPI

The La Hague CSPI (Commission Spéciale et Permanente d'Information - Special and Permanent Information Commission) was created in 1981 to inform the public about operation of the COGEMA La Hague plant and any effects it may have on the environment. It is chaired by the Member of Parliament for the Cherbourg constituency and is composed of 36 members in colleges (18 elected, 6 representatives of local unions, 6 scientists and 6 representatives of associations and environment defence movements). Ordinary meetings are held every quarter in the presence of the local press. They are open on request to associations and union or professional associations not represented in the colleges.

Members of the CSPI participating in the Nord-Cotentin Radioecology Group also participated as independent experts representing local and/or national associations.

NON-INSTITUTIONAL LABORATORIES AND EXPERTISE ORGANIZATIONS

The ACRO (Association pour le Contrôle de la Radioactivité dans l'Ouest - Association for Control of Radioactivity in Western France) is an association set up to provide information and expertise. It is provided with an analysis laboratory and its task is to provide everyone (communities, companies, persons) with inspection tools for monitoring the environment and food and industrial products. Its independence is assured by the fact that it has a large number of members and the diversity of its financial resources. The ACRO is based in the City of Caen and has three regional branches so that it can participate in several local information organizations located close to nuclear installations. In the Nord-Cotentin, the ACRO participates in the CSPI close to the La Hague plant and in the Manche Storage Center Monitoring Commission, where it is the only association.

The CRII-RAD (Commission de Recherche et d'Information Indépendante sur la Radioactivité - Independent Research and Information Commission on Radioactivity) is an approved non-profit making association (1901 law) for protection of the environment. It was created in 1986 as a reaction to information provided by official authorities about the impact of the Chernobyl catastrophe in France. The principles that it is designed to defend are: the right to information about all questions related to radiation and the right to protection against the effects of radiation. The CRII-RAD has acquired a radioactivity analysis laboratory, equipped in particular with a gamma spectrometry measurement system and liquid scintillator so that it is capable of performing counter-expertises in the field and preparing information independent of the State and operators. Its scientific team has worked around the La Hague site several times since 1994. It has made controls on the radiological state of the environment, radiametric measurements on the sea discharge pipe for liquid effluents from treatment installations, and independent analyses, sometimes with its own funds, and sometimes at the request of Greenpeace or on behalf of the Cherbourg County Court.

The GSIEN (Groupement de Scientifiques pour l'Information sur l'Energie Nucléaire - Group of Scientists for Information on Nuclear Energy) was founded 25 years ago in France, and distributes information about many questions that arise related to the development of the nuclear industry in France, including safety and radiation protection. The GSIEN has demonstrated that a fraction of the French scientific community would like evaluation structures independent of one of the largest nuclear programs in the world, by requesting access to documentation, and carrying out very many analyses in order to oblige official authorities to provide sincere information. The GSIEN has contributed to the emergence of an independent expertise that it considers as being essential to the participation of everyone in important decisions affecting the future of the country. This is why members of the GSIEN agree to participate in pluralist groups such as the Nord-Cotentin radioecology group.

The LDA 50 (Laboratoire Départemental d'Analyse de la Manche - La Manche Departmental Analysis Laboratory) is a service provided by the La Manche Department General Council, created in 1947. It employs 56 persons. The LDA 50 performs analysis in veterinary biology, food safety and the environment, and is also a genuine public health laboratory. It has been making analyses of radioactivity measurements in food and the environment since 1972. The General Council has been distributing a pedagogic brochure to all inhabitants of the La Manche department three times a year since the beginning of 1999 (210,000 copies) presenting the results of its radioactivity measurements in the La Manche department.

The CEPN (Centre d'étude sur l'Evaluation de la Protection dans le domaine Nucléaire - Nuclear Protection Evaluation Center) is a non-profit making association created in 1976 by Electricité de France and the French Atomic Energy Commission to act as a research and study centre for the optimisation of radiation protection and the comparison of health and environmental risks associated with energy systems.

There have been three members of the association since 1993: EDF (Electricité de France), the CEA-IPSN (Atomic Energy Commission represented by the Nuclear Protection and Safety Institute), and COGEMA (Compagnie Générale des Matières Nucléaires - General Nuclear Materials Company). As a research group, the CEPN benefits from the recommendations of a Scientific Council that includes professors from University, operators and representatives of expertise organizations, and French and European Authorities. The CEPN's program is organized around five themes: methods of evaluation and management of radiological risk; radiological protection of workers in the nuclear and medical fields; health and environmental impacts of nuclear installations; economic and social stakes in the management of radioactive waste; involvement of stakeholders in decentralized management of the radiological risk.

The ISTE (Institut des Sciences et Techniques de l'Environnement - Institute of Environmental Sciences and Techniques) is a component of the University of Franche Comté. It includes about fifty Lecturers - Researchers who belong to different University laboratories and work together within the ISTE to carry out environmental research. The various themes studied are the study of atmospheric pollutants, the search for bio-indicators or bio-accumulators, and knowledge of the consequences of stress on the different links in the environment. All these themes include natural and artificial radioactive elements, and also heavy metals, pesticides, etc.

In the radioactivity field, the ISTE has long experience in the metrology of radon, and gamma, beta and alpha emitters in general. Furthermore, the pluralist approach enables chemical, ecophysiological and environmental analysis of the results. Some of the studies that have been done or are still ongoing include: setting up of a radon measurement network in the Kouzbass region in Russia and studies of cesium transfers through forest environments in Bulgaria, Russia, Switzerland and France.

FOREIGN EXPERTISE ORGANIZATIONS

The NRPB (National Radiological Protection Board) is an independent British organization that carries out research into the protection of man against ionising radiation, and provides information and expertise about radiation protection to Ministries and other government organizations, and technical assistance to the stakeholders concerned by risks related to ionising radiation. It is financed partly by the Ministry of Health and partly by its own services. Now at the IAEA, Dr. A D Wrixon, supported by a British team has helped the GRNC to benefit from experience acquired by the NRPB in similar studies and in particular has provided a critical review of the evaluation methodology built up by the group.

The BfS (Federal Radiation Protection Office) in Germany is an independent Federal Authority controlled by the Ministry of Environment, Protection of Nature and Nuclear Safety (BMU). The BfS performs scientific and administrative activities on behalf of the Government in the field of radiation protection, nuclear safety, transport of radioactive materials, and construction and operation of federal installations for the interim and ultimate storage of radioactive waste. Within the BfS, the Radiological Health Institute is responsible particularly for expertise, research and development on biology, nuclear medicine, radioecology and protection in an emergency situation.

The OFSP (Office Fédéral de la Santé Publique - Federal Public Health Office) in Switzerland is an independent national organization responsible for protection of the population against nuisances that could endanger health. In the field of ionising radiation, the OFSP Radiation Protection division is the authority competent to issue authorizations for the use of ionising radiation in medicine, industry and research and for monitoring radioactivity in the environment. Key actions performed by this division were preparation of a modern legislation consistent with international concepts, its application in practice and actions designed to reduce the highest radiation doses to the Swiss population. This approach includes the strategy adopted in the national Radon program and central recording of doses accumulated by persons exposed to radiation at work. Coordination of the program for monitoring radioactivity in the environment, publication of compiled results and an evaluation of the health implication of these results form an integral part of the OFSP's tasks.