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SOMMAIRE **INHOUD**

BVS-ABR History-50 years seminar -april 2013 p.181

- The Belgian Itinerary in the History of Radiation Protection
  Lessons and Prespectives.
  G. EGGERMONT and C. STIEVENART p.183

Dosimetry p.223

- Introduction
  La surveillance de l'exposition des travailleurs aux rayonnements ionisants : bref rappel historique.
  J-P. SAMAIN p.225

- Belgian occupational exposure register: Progress and future steps
  S. LEONARD p.229

- Traçabilité de la surveillance des expositions professionnelles aux rayonnements ionisants en France - Fonctionnement de SISERI p.233
  P. SCANFF

Annales de l'Association Belge de Radioprotection (BVSABR)

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BVS-ABR HISTORY
50 YEARS SEMINAR - APRIL 2013

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50 YEARS BELGIAN SOCIETY FOR RADIATION PROTECTION (BVS-ABR-IRPA) 1963-2013[1]

THE BELGIAN ITINERARY IN THE HISTORY OF RADIATION PROTECTION
Lessons and Perspectives

Gilbert Eggermont and Claire Stiévenart-Godeau

BVS-ABR Board, Brussels, Belgium

Abstract

The Belgian Society for Radiation Protection BVS-ABR was created in 1963. Its early history is strongly associated with the establishment of the EURATOM Community and of IRPA. The paper puts this development also in perspective of the history of the early radium history and the later nuclear industry in Belgium. The authors have scrutinized the rich archives of the Society and interviewed past Presidents in order to reconstruct their impact and that of the Society in emerging issues for the radiation protection profession. The analysis demonstrated how the team spirit of the Executive Board of the Society was the most important guarantee for continuity. The authors further reflected on possible shortcomings of the radiation protection profession and of the Society and on how negative experiences could be transformed into opportunities. Resulting perspectives were presented as input for the 50th anniversary conference.

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1 This paper was presented as introduction to the International Symposium "Challenges for Radiological Protection for the next 50 years", on the occasion of the 50th anniversary of the Belgian Society for Radiological Protection BVS-ABR, member of IRPA, in Hotel Metropole, Brussels, April 8, 2013

1. Introduction

The permanent scientific secretary, the past President and the actual President of BVS-ABR took the initiative to analyse the history of driving forces of this professional scientific society. The aim was to learn lessons from radiation protection history and from 50 y of experience in the professional scientific organisation BVS-ABR. This history is put in perspective to the early developments of radiation protection starting some 70 y earlier. Finally, some perspectives for the future could be drawn, which were presented by the actual President, Frank Hardeman. The Society and the authors congratulate Frank for having made possible this historical analysis, for his input and follow-up and for the successful organisation of the 50th anniversary symposium.

Radiation history started with the discovery of X-rays and radioactivity and got a new dimension with the discovery of fission 45 years later. The early development of protection was spread over 70 years (Eggermont) [1, 2]. The role of ICRP in the development of the radiation protection framework steadily increased [3].

To understand the commitment of the founders of radiation protection in Belgium, it was necessary to look also into the early period of radiation protection worldwide. Consecutively the development processes of BVS-ABR in the sixties, seventies and eighties were looked into through questioning former Presidents on their driving motives.

How were they inspired by this pioneering period?
What was the role of the founders and later Presidents of BVS-ABR at international level?
What was their commitment for IRPA?
Did they think already globally while acting locally?
What were their main challenges and priorities? Why?

2. Historical context of early nuclear developments (1895-1962)

2.1. 1556: Agricola, the first radiation protection expert

The PhD thesis of Hans Vanmarcke[2] on radon [4] started with an historical reflection on exposure prevention "avant la lettre", referring to G. Agricola and his 16th century work "*De Re Metallica*" (Basel, 1556) in the central European region of later uranium mining.
Belgian interest for radium and radon found its origin in the former Belgian Congo colony (RDA) where rich uranium resources were found in 1917, leading to a Belgian radium industry as discussed by Mgr. Gillon [5] and analysed by A.Adams [6]. Uranium industry and radium was crucial for nuclear developments all over radiation protection history.

Did radiation protection already start in the 16th century in mines in Central Europe?

Death toll among miners in Schneeberg in those days was 50 to 75%, and Agricola tried to prevent fatal lung diseases through ventilation measures. The disease could be identified as lung cancer in 1879 by Haerting and Hess. The relation with radon was pointed out in 1924 and confirmed in 1945, Rn having been discovered by Rutherford in 1900. This could be considered the first attempt to reduce an unknown risk of radiation. Agricola was a transdisciplinary scientist, problem oriented, being a mix of an occupational physician an engineer and a researcher. He should nowadays be considered as an RPE or prevention advisor.

Paradoxically, radon was neglected for a long time in radiation protection history. Radon was rediscovered in the seventies, and it was a shock for the coherence of the radiation protection system.

2.2. The pioneer period (1895-1934) without safety standards

Growing risk evidence but in search of a quantity for risk regulation

2 former president of BVS-ABR (1999-2001) and later president of UNSCEAR (2016-)

After the discovery of X-rays by W. C. Röntgen at the end of 1895, the amazing X-ray technology was demonstrated in Belgium already some months later, by H. Van Heurck, director of the Antwerp Botanical Garden, as discussed by R.Van Tiggelen [7]. The X-ray black box, far from scientifically understood those days, created huge medical opportunities and contributed two decennia later to a major objective of medicine, *the reduction of suffering,* not at least in the battle fields of world war I.

The French academy member Henri Poincarré, was very sceptical about X-rays and academy members Henri Becquerel and Pierre Curie were involved in critical evaluations. A brilliant female student who had migrated from Poland for political reasons, Maria Sklodowska, the later Marie Curie, redirected research. It led to the discovery of natural radioactivity in Paris. Double Nobel prize winner and first woman obtaining this honour, she was for decennia the promotor of societal uses of radiation. During the first world war, she promoted the use of X-ray's in the field hospitals at the Belgian front near river Yser. After the war, she came to Belgium again to visit the Union Minière factory in Olen, refining African uranium from Katanga, to apply her expertise in Radium. Radiotherapy with radium could develop.

The other side of the picture however, the radiation risk, remained unknown for decennia for many users. The victims from this pioneering period of development of radiation are engraved in the mid 30's in a monument in Hamburg with 379 names, among them four Belgians.

Marie Curie may have ignored radiation risks as well. She was too much driven by the perspectives of her new discoveries. During her scientific missions in the USA in the early twenties she already suffered from cataract and she died ten years later, in 1934, from the consequences of a lifelong considerable exposure, without serious protection measures. The justified use of radium for cancer therapy survived Marie Curie till other technology became available. Her labs had been contaminated for decennia and remediation took place recently. [3]

3 www.Scienceetavenir.fr/decouvrir/le-mytique-laboratoire-des-curie-rouvre-ses-portes_37283, (part of private communication from BVS-ABR member J-Cl. Zerbib)

It was realised much later that the 16^{th} century problem in the mines in central Europe was a world-wide more general problem. Not only in the mine areas from Katanga to Bohemia and around radium industries such as in Belgium, enhanced exposure to radon was observed. Even in many hospitals, labs and finally in houses, radon had created an enhanced exposure risk.

In the early history of protection from the beginning of X-ray discovery, Nikola Tesla, living in the present-day Croatia, was more aware of risk than Marie Curie. The first risk indication for both was erythema, but Tesla could develop a vision for risk management [2]. He promoted the basic principles of protection as stated by Fucks: time reduction, distance and shielding. Notwithstanding early reporting of cancer risk (10 skin cancers in 1910, 100 cancers of different types in 1920) evidence on detriment arose among radiologists and was overwhelming among radium dial painters in 1924.

The London congress of radiology of 1924 considered risk awareness as a condition *sine qua non* for a commitment to regulate risk. In the international commission for radiological protection (the later ICRP), created by this conference, a Swedish member, Rolf Sievert underlined the need for a unit to express risk. This second requirement for successful risk regulation lead to the development of dosimetry. ICRU was created in 1935 for guiding the use of units and measurements related to radiological risk. Half a century later ICRU was directed by one of the most famous members that BVS-ABR ever had, André Wambersie. He also directed the section *Ionising Radiatio*n of the Belgian Superior Health Council. André is still with us.

Radiation was recognised as a cause of professional disease by Royal Decree in Belgium in 1932 and this was implemented worldwide by UN-ILO. First recommendations for world-wide safer use of X-rays and radium were published by ICRP in 1934 [3].

Nuclear technology was developed during 40 years without regulation. The need arose to quantify risk by units and measurements, a condition *sine qua non* for regulation.

2.3. The pre-and post war period (1934-1963)

30 years with a military shadow on the dream of nuclear development and radiation protection

This period can be characterised as driven by innovation and technological dreams, with growing consciousness of risk evidence at lower dose but overshadowed by the self-censorship on nuclear development during the rise of Nazi Germany. This period spans the discovery of artificial radioactivity over the development of fission technology for military as well as for civil purposes during the war till the cold war A-bomb testing and resulting world-wide pollution. In the same period progress was made in radioactivity measurements and radiation monitoring.

Belgium became the world market leader in radium production during the thirties. Transport of the richest uranium resources in the world was organised by rail from Shinkolobwe in Katanga to the Atlantic coast and then by ship to Antwerp. The refining activities took place in Olen near Mol. Few protection measures were taken [6]. Primary hygiene, such as frequent hand washing, was later considered as having been the most effective protection measure against internal uptake of radium by workers [8]. A huge soil pollution was created in the mine region in Katanga, and as well around the refinery in Olen. These sites have still not been remediated. Uranium waste management was not considered an issue in Belgium and radium bearing soil was used for building foundations. Due to regular flooding of the river Nete in the neighbourhood of the Belgian factory, a rural area was contaminated. This offered interesting research opportunities for radioecology thirty to sixty years later. Few radiation protection measures were taken during the first decennia of exploitation. Risk awareness was only awaking.

World war II changed the picture and strategic considerations took over. Finally, the uranium resources from Katanga, controlled by Belgium, were transferred at the end of the war to the Manhattan project in the USA and used in the bomb on Hiroshima. In the margin of the Manhattan project J.J. Thompson contributed meanwhile to the development of professional radiation protection, starting 1943. On the other hand, cynically said, Hiroshima allowed setting up a huge epidemiological project. This demonstrated evidence of cancer risk and of genetic effects due to ionising radiation.

Sufficient epidemiological evidence was available in 1963, allowing for structured protection measures within a regulatory system addressing a broad spectrum of nuclear activities, supported by units and measurements.

After the war, Belgium was rewarded for the Congolese uranium delivery to the US. Nuclear research in the fifties at SCK·CEN in Mol was co-funded by US support. This was discussed in a book on the nuclear controversies by E. Laes et al [9]. The research centre took up responsibilities in a later phase by studying radium pollution, radon exposure and radium waste management for the company in Olen, now controlled by Umicore. This company gave no permission for an epidemiological study of workers from the period 1922 to the sixties, notwithstanding extensive research planning efforts by SCK·CEN. The rich cohorts of workers in Olen could never been added to the successful international pooling of uranium workers.

With the atomic bomb tests by Russia in 1949 the cold war started and secrecy handicapped the development of radiation protection. In the US, this was part of military research. The cold war lead to an arms race with huge atomic bomb tests in the atmosphere in the late fifties, causing a first demonstration of world-wide measurable dispersion of radioactive products and their transfer in the environment and food chain [10].

In this cold war context, military research with long term secrecy allowed also to perform ionising radiation experiments on human beings (soldiers, prisoners). This was made public in the USA in Science in 1994 and discussed in Health Pysics in 1995 by the late Ken Mossman [11], which lead to ethical guidance by ICRP for biomedical research.

On the other hand, the small-scale development of reactor technology in submarines created opportunities for the worldwide development of compact reactor technology for energy production [9]. The submarine PWR reactor technology of Westinghouse today still dominates the scene of nuclear electricity generation in Belgium and in the world. SCK.CEN invested in a prototype PWR reactor, BR3, which has been dismantled in the nineties.

CERN was created in Geneva with a Belgian serving as first RP Official.

2.4. Early initiatives in radiation protection in Belgium

Our interviews of former BVS-ABR Presidents clearly illustrated the scientific dynamics created in the fifties through collaboration opportunities between Belgium and the USA. Innovative industrial perspectives even created euphoria on cheap and abundant electricity production. Huge starting opportunities were given since 1952 to many Belgian scientists in the US. Post war enthusiasm was the driving force and the sky was the limit.

It is worth mentioning that in this period a precursor of a radiation protection course was already organised in Brussels, by the late Prof. Paul Kipfer (ULB) with the collaboration of Claire Stiévenart-Godeau, the later and honorary permanent secretary of BVS-ABR, together with René Boulenger, the late secretary general [12].

The late Prof. Samuel Halter (ULB) [13], secretary general of the Belgian Public Health administration, together with the late European RP administrator Pierre Recht, both physicians, created in the late fifties an international dynamic in Radiation Protection by preparing a European Association. Halter however also had a global vision and preferred integration with the Health Physics Society (HPS) in the USA. This society had been created in 1955 by the late Karl Morgan from Oak Ridge. He was the first President of Committee 2 of ICRP and was actively involved in the dosimetry in Hiroshima-Nagasaki, where the first epidemiologic evidence on radiation risk became available.

In 1957 EURATOM was set up. This visionary Treaty created industrial opportunities in a more balanced collaboration with the USA and allowed to start the process leading to the Basic Safety Standards.

The same year the first accidents in Europe occurred (Windscale and Kyshtym) with environmental dispersion of radioactivity; they were for a long time covered with secrecy.

In that period, Union Minière and its director the late Gaston André also became concerned by radiation protection [14]. The late Julien Goens [15], had been scientific adviser to the Belgian Embassy in Washington and returned in 1955 to take up the function of general manager of SCK·CEN. He was actively involved in the Belgian fuel cycle developments (Belgonucléaire), expressing another dimension of risk analysis and management

Meanwhile, the innovative dynamics in SCK·CEN created a measurement capacity of radioactivity as well as of dose. This allowed to follow the uptake and impact of global A-bomb pollution in nature as well as in man; this research is continued at present. The occupational physician for the Mol region, the late Maurice Faes [17] and the field radiation protection expert the late René Boulenger (at that time head of the Physical Control at SCK·CEN and later director of CoRaPro [12]) considered the need for a professional organisation.

The director of the Institute for Hygiene and Epidemiology (IHE), the late UCL professor Alphonse Lafontaine [17, 18], actively contributed to develop the Belgian regulation on protection against ionising radiation. This took from 1959 (first Euratom BSS) till publication of the royal decree in 1963, within the frame of the law on ionising radiation of 1957. A.Lafontaine also actively followed up and supported IAEA developments.

3. BVS-ABR History (1963-2013)

3.1. The preparatory phase

Practical national needs in international Radiation Protection dynamics

After almost 70 years of development of ionising radiation technology without radiation protection regulation, it was time to act. A professional, science based society became a necessity.

Pourquoi a-t-il fallu près d'un demi-siècle pour que l'on reconnaisse l'importance vitale de la radioprotection dans l'utilisation en sécurité des rayonnements ionisants? [4]

Belgian administrative authorities and university professors joined the effort to codevelop and implement the regulatory structure just put forward. Different administrations were concerned: Ministry of Social affairs, Public Health, External Affairs and Economy. The Superior Health Council, advisory board of the government was involved with Prof. Jean Van Beneden (ULg, Social medicine), who was chairman of this Health Council and member from 1939 till 1978 [19].

The implementation of the regulation for protection against ionising radiation, the Royal Decree of 1963 was the first incentive for the new organisation. BVS-ABR was founded one year before the creation of the European RP association in 1964 and three years before the launch of IRPA. BVS-ABR affiliated to IRPA during the first IRPA general assembly in 1966.

BVS-ABR was created in 1963 in the context of this international and national dynamic.

3.2. The Founding Fathers

Prof S. Halter was the founding President [13].

L'expert n'est pas celui qui sait tout mais celui qui sait trouver l'information pertinente (S. Halter)

He convened all the above-mentioned experts (Recht, Van Beneden, André, Goens, Lafontaine, Faes) to take up responsibility in the first Board. Gaston André became vice-President or President elect.

Prof. Paul Hublet (ULB), the oldest still living President and honorary speaker to this conference [20] joined the board together with Prof.

4 Alphonse Lafontaine, 4th President BVS-ABR (1969-70) at 25th anniversary meeting of BVS-ABR in Erasmus House, Brussels, 1968 [18] .

Julien Hoste (radiochemistry; research reactor UGent) who would become the third President (1967-68). Some university professors had an impact from the very beginning on the Society without taking up Board responsibilities: André Wambersie (UCL, IRPA) and the late René Kirchman (ULg, SCK·CEN) [21, 22]. They became world leading scientists in the field of radiation quantification and medical applications, respectively radioecology. Paul Hublet was the first treasurer and took up this responsibility till 1972, became later director-general of the Ministry of Labour, Julien Hoste rector of the Ghent University. The logistic support came from Claire Stiévenart-Godeau, Georges Cantillon, pharmaceutical expert and early Board member, who was treasurer from 1973 till 1990 and always welcomed the Society meetings at IHE, and from René Boulenger as secretary general from 1963 till 1976 [12].

Impartiality was guaranteed and no industrial sponsoring was pursued as a guiding principle. The transdisciplinary dimension of the Society was set from the beginning by its first 5 Presidents, together with European support by Pierre Recht. The first, Samuel Halter (1963-64), and fourth President, Alphonse Lafontaine (1969-70), were to represent the Belgian competent authorities for Health. Halter was a national and international authority and chaired the assembly of WHO. The second President, Gaston André (1965-66) from Union Minière, represented the industry and attracted the interest of the CIA for the uranium perspectives. The third President, Julien Hoste (1967-68), and the fifth Maurice Faes (1971-72) [13] represented the universities, research and social medicine. M.Faes became later secretary general of the society from 1977 till 1980. J. Hoste, introduced press communications after the meetings.

A. Lafontaine offered for decennia his auditorium at IHE as the meeting point for BVS-ABR. He took care of the work load of the Board. Dr M. Faes, occupational physician, put the environment and biomedical applications on the agenda. He invited the legendary authority, the late Prof. Mlle Suzanne Simon, in a meeting on radiotoxicity of tritium, expressing her fear for an excessively strict radiation protection. On the other hand, she also put forward in 1971 in a EC document the basics for radiation protection in hospitals using iodine isotopes, based on the dilution of iodine-131 activity. She already called for awareness for hospital waste management [23],[24].

Only one early member of the Board is still alive and even now actively involved in the Society: P. Hublet. He is the living memory of the Society [20], together with Claire Stiévenart-Godeau. He was member of BVS-ABR from the very beginning. Claire joined the Board six years later and only missed one Board meeting in 47 years.

Cheville ouvrière manoeuvrant avec délicatesse…son aide attentive très précieuse, toujours si discrète. Si Claire n'était pas là, c'était une catastrophe vu son role de rassembleur et mère de famille[5]

Some historical events directed the activities of the first Presidents. 1966 was a turning point in the nuclear history in Belgium. In the nuclear research centre of Mol a criticality accident occurred on the Venus rector with one overexposed victim, who survived. The Belgian government decided to install 7 nuclear power plants and the first civil nuclear reprocessing activity started at Eurochemic in Dessel. It remained operational till 1977. In Vienna, the non-proliferation treaty was agreed, launching IAEA.
In 1973 the result of an environmental study was published on the releases of the radium factory in Olen in the local river and its soil contamination through flooding. In 1973 the first oil crisis occurred; it was followed by new ambitions for nuclear reactor developments. At MIT, the PSA study Wash-1400 was published by Norman Rasmussen who received some years later a doctorate honoris causa at KUL in Leuven. The Belgian government ordered in 1975 a commission of "Wise Men" to evaluate nuclear energy development and siting in Belgium, following the first controversies in Belgium on this subject and on siting at the sea coast in particular [9].

3.3. The seventies

A new generation of Presidents (1973- 1979) took over from the founders. The sixth President, Paul De Plaen (1973-74) [25], was no longer a founder of the Society. He was a radiologist from the field, not working at a university. This was considered as an innovation. As editor in chief of the Belgian Journal for Radiology he had made it possible for BVS-ABR to publish the papers presented in the meetings in that Journal. He took

5 Alphonse Lafontaine, 4th President BVS-ABR (1969-70) at 25th anniversary meeting of BVS-ABR in Erasmus House, Brussels, 1968 [18]

care of the “small” users of ionising radiation and argued for avoiding too rigid rules. Dr De Plaen expressed vision on communication as well as on scientific evolution. He invested in good communication with the control organisations. He started with working groups and laboratory visits on scientific meetings and has broadened the scientific programming.

Dans la perspective d’une réponse affirmative à la question - toujours la même – faut-il ou non informer le public dans la clarté, apparait un chapitre nouveau de psychologie et de sociologie de la radioprotection, qui doit trouver ses sources dans l’interrogation des travailleurs et des experts à la lumière des données scientifiques ...

Des perspectives passionnantes à étudier comme la radiobiologie cellulaire, mais nous ignorons trop des processus moléculaires, des phénomènes immunologiques… (P. De Plaen)

He celebrated the tenth anniversary of the Society with an interesting international meeting, attended by André Allissy from BIPM and active in ICRU. His presentation started with:

Il est bon de se féliciter du passé. Il est plus important d’entreprendre l’avenir [6]

It was the first and last time in the BVS-ABR history that a radiologist took the lead. One may wonder why?

The seventh President was Oscar Segaert (1975-76). He is the oldest still living President of BVS-ABR and participated in this 50th anniversary meeting. He was in charge of the RP service at the UGent, in addition to leading a team of scientists in radiation protection within the Nuclear Physics Laboratory He created the Annals of the Society in 1976 together with M.Faes at SCK·CEN as editor. He stopped the week-end meetings of BVS-ABR. He focused on the need for a standard dosimetry lab in Belgium and has clearly put dosimetry on the agenda of BVS-ABR, with attention for film dosimetry. The Radiation Protection Office directed by him at UGent (called RUG in those days) obtained the first certification

6 Paul De Plaen, editor in Chief Belgian Journal of Radiology, on the occasion of 10y BVS-ABR, 1973.

by the competent authorities. The research of his team also paid attention to TLD in its pioneering period and to dental protection considerations. This subject was discussed at a scientific meeting of BVS-ABR as well as the calibration of criticality dosimetry as the Ghent university where a reactor was operational. Oscar Segaert was confronted with the need for quality control (QC) in radiotherapy after an unexpected negative report for Belgian participants on a simple Co-60 dosimetry inter-comparison. This attracted attention of supervising authorities. Representatives of the radiotherapy society objected to publication of these results while accepting inter-comparison follow-up by IAEA. It encouraged him to strive for a Belgian dose calibration facility. [26]. He also encountered the problem of radium contaminations in hospitals and stimulated radon research including ground water sources.

Oscar Segaert and former President Alphonse Lafontaine (P4) involved different BVS-ABR members and later Presidents in reflective work on nuclear energy for the governmental evaluation Committee on nuclear energy in 1976-77, chaired by former BVS-ABR President Julien Hoste (P3) and ULB rector and later President of AVN, the late André Baron Jaumotte. Alphonse Lafontaine chaired the Health subcommittee. The committee discussed nuclear safety and the fuel cycle, the release of radioactivity in accidental as well as in normal operation, noble gasses and radioecology. It has put nuclear waste on the research and political agenda clearly asking for re-evaluation after 10 years of this up to then neglected issue. This was an essential element in the justification process of nuclear energy [9].

The late Alexis Osipenco, eighth President of BVS-ABR (1977-78), was the head of the RP service of the Eurochemic reprocessing plant in Dessel [27] . He multiplied laboratory visits during scientific meetings and invited the late Dan Beninson (ICRP) to discuss ICRP 26 with the Belgian Society. The environmental releases in Dessel, in particularly Kr-85 were considered under his impulse. Subsequently, Kr-85 measurement techniques of high sensitivity were developed by UGent, making it possible to measure this noble gas from reprocessing and accidental releases up to 1000 km distance of the point of release. The programming of Osipenco and his Board paid attention to internal contamination as well. He strengthened collaboration with NVS and other societies. He addressed his personal greetings by mail to the 50th anniversary meeting but could not participate. He passed away a year later.

Raymond Nuyts was the ninth President (1979-80) on the turning point to nuclear controversy after the first accident with a PWR in Harrisburg. He had deployed his activities as civil engineer in the Administration of Work and Employment. For the Society Nuyts prepared over decennia the reporting of parliamentary questions and answers on nuclear matter, making them available for members of our Society in the Newsletter. His Board programmed dose registration of workers, expert certification and training but paid attention as well to non-ionising radiation, a subject which no longer figures among the BVS-ABR missions. R. Nuyts continued to support the Board of BVS-ABR till the preparation of the 50th anniversary. The authors acknowledge his contribution to documenting this presentation.

3.4. The eighties

Institutional changes

The eighties were a period of institutional changes, marked by the creation of the Belgian nuclear waste organisation NIRAS.ONDRAF (1981) and the end of the Belgian reprocessing ambitions (1984) [9]. The restructuring of safety and radiation protection authorities from different departments started after the accident in Harrisburg and progressed after the accident in Chernobyl in 1986 up to the final FANC regrouping in 1994. The interdepartmental Committee on Nuclear Safety and security has supervised this dynamic. The chairman of the Special Commission, ir. G. Bens had a major role in the eighties and co-chaired this committee. Members were Paul Hublet (P10) and A. Lafontaine (P4) but also Ir. Pierre Stallaert and the security authorities at international and national level: Mrs. Simone Herpels and Mr. Jacques Hardy.

The restructuring accelerated after the Transnuklear scandal in Mol (1986-88). Waste management activities from SCK were transferred to Belgoprocess (1989) and SCK·CEN was reorganised to include safety evaluations and to highlight ALARA (1990). Finally, technical support organisations (TSO's) started reshaping with the integration of CoRaPro (SCK·CEN) within AVN [Pierre Govaerts, 28].

Interests of BVS-ABR broadened to a variety of subjects: nuclear transport came on the agenda after the Montlouis accident (UF6) [9]; also, treatment and control of releases, biological and health effects, plutonium and security, X-ray technology, X-ray protection of users, criticality accidents (SL-1 and Venus). Even the use of radioactivity in lightning protection devices, dental X-ray protection and the use of ionising radiation for sterilisation were considered.

In this period a fundamental change in RP occurred with the introduction of an ALARA based stochastic risk management philosophy by ICRP in its recommendation 26. The principles were developed in the BSS, first at IAEA and ILO level in 1982 and later by the EC in 1986. Implementation of the new philosophy took decennia and asked a lot of attention of BVS-ABR. Regulatory implementation and change seemed to be a continuous challenge for a professional Society. The organisation of the RP services, of controlled areas and of emergency response were, and still are today, priority issues.

Several other events marked the eighties: the accident in Goïana in 1987 and the end of ocean dumping of nuclear waste (1982).

The new tendency in BVS-ABR programming was to focus more on the international dimension. The structural collaboration with IRPA needed to be enhanced.

Dosimetry continued to be of interest and calibration extended to contamination measurement (field detectors). The collaboration of radiation protection with social medicine was improved with a meeting on Radiation Protection of hospital staff at UGent.

Presidencies

Paul Hublet took the lead as tenth president (1981-82) [20]. He was the head of the Medical Inspection at work (Ministry of Labour). He had the longest experience in the board from the early beginning as co-founder of the society as well as participant to the Paris meeting for the founding of IRPA. He continued to remind later executives of the founding principles and values such as the importance of independence of the Society from the nuclear companies, research centres and even the Authorities. He advised against sponsoring. He paid a lot of attention to the implementation of BSS, to internal contamination, to waste management and radioactivity in construction materials. He was supported by Jean Delhove as secretary general till 1984.

The eleventh president was the late Ir. Gérard Fieuw (1983-84) [29], the head of the RP service of SCK·CEN, again a civil engineer and former military officer. He focussed field problems with particular attention to practical aspects on the job: surface contamination and monitoring, calibration of radiation protection instrumentation and certification of the use of X-rays.

The 20th anniversary of the society already noticed the shadow of controversy related to the accidents and to the authorised sea dumping those days of low level nuclear waste. It is however noticed that the first years after the TMI accident little attention has been given within the programme of the society itself to the analysis and consequences of this major reactor accident.

Jean-Marie Cordier, occupational physician in the nuclear power plant of Tihange, took over as twelfth president (1985-86) and provided dissemination of public information after the Chernobyl accident. He organised the most successful conference in BVS-ABR history together with the French sister society SFRP on *Radiation Protection of workers of external companies intervening in nuclear installations.* A conference on nuclear war was a bridge too far. He noticed the culture problems within the radiation protection community, shocked by the accidents which had shaped public opinion. He was supported by the late L. de Thibault de Boesinghe as secretary general till 1990 [30]. In 1986 the 25th anniversary was celebrated with as guest speaker the former president and founder Alphonse Lafontaine:

Le mérite essentiel de la RP est d'avoir réussi un compromis acceptable entre le risque réel, le risque perçu et la prise en considération des facteurs sociaux et économiques [7]

But President Dr Cordier warned on communication and ALARA approaches:

On a remplacé la rationalité scientifique par la subjectivité des foules

Prof Paul Schonken, the head of the RP service of KUL became the thirteenth President (1987-88). He started to cope with the post Chernobyl trauma, and so did his three successors. He indicated how crisis situations offer opportunities for culture change. A high-level conference on "Reactor Safety and Emergency" clarified safety and emergency planning as cornerstones. He offered the floor to the late Paul Govaerts [31], a man with vision and with a lot of knowledge and experience in accident management. Paul, the later CEO of SCK·CEN, underlined the need for accident preparedness, since similar problems as those in Russia could happen in future.

Paul Schonken had an outstanding experience on how to reach RP targets in hospitals. He was the pioneer of selective waste management in universities and hospitals. He had a strategy in organising RP at university level in combination with research, education and training.

Jean Delhove took over as 14th President (1989-90) and presented his views to the general assembly in 1990:

Le secteur nucléaire n'est pas à l'abri du séisme, l'imprévisible se produit à Chernobyl, l'impensable se réalise : scandale Transnuklear ...mais que venons-nous faire dans cette galère?
Nous devons sortir de notre tour d'ivoire... et jouer un rôle actif vis-à-vis de la société.

7 Alphonse Lafontaine, 4th President BVS-ABR (1969-70) at 25th anniversary meeting of BVS-ABR in Erasmus House, Brussels, 1998 [18].

He reminded what J. Lakey had said as IRPA President at the 25y BVS-ABR anniversary:

Future requires better balance between risk and economic factors particularly in the production of nuclear power.

Ir. Delhove created a tradition of working groups, which enhanced the effectiveness of the Society. The working groups focussed on communication, regulation of transport, radon and qualification of experts. He was director of Controlatom and was involved in the Society from the early beginning when he started his career at SCK·CEN. He organised another successful conference with SFRP (Société Française de Radioprotection), involved as he had been in the first. The theme now was maintenance of NPP's. He paid attention to the accident in Goïana, to radon exposure and risk, to the related problems in the Olen factory of Union Minière where he had been involved in the first waste management and "decommissioning" operation. Being himself a pioneer in personal dosimetry, this subject was added to the agenda, together with new subjects as Telerad and neutron therapy. He could provide the authors with a lot of documents on the history of the Society.
Under his presidency, the late Raymond Jacobs, head of the RP service of UGent[8] took up the function of general secretary till his death in 2000 [32] when André Polak took over.

3.5. The nineties

The Belgian competent authorities had shown structural problems and a lack of sufficient human resources to confront crisis management and to face controversies. Thus, a new regulatory drive was given to the creation of FANC through the law of 1994. The Chernobyl accident feedback allowed to reconsider the use of promising performant PSA tools for reactor safety analysis and shortcomings. New initiatives developed to start harmonising safety approaches as well, such as the IAEA nuclear safety convention. ICRP 60 had started an implementation process within the EU towards

8 With Oscar Segaert, Raymond Jacobs, Gilbert Eggermont, Augustin Janssens, Hans Vanmarcke and André Poffijn started their career in the so-called *Ghent school* of radiation protection.

a new BSS Directive. Growing development of environmental policies forced ICRP to review slowly its paradigm *"the environment is enough protected if man is*".
Another major development in radiation protection was the re-discovery of natural radiation sources, including cosmic radiation and radon. Radon from soil and radioactivity of building materials was measured systematically from now on. Information campaigns were launched, offering measurements to the public via consumer organisations.
Prof. Dr Léopold de Thibault de Boesinghe, the fifteenth President (1991-92) and occupational physician at the Ghent University, was also radiotherapist [30]. He continued the evaluation of Chernobyl, 5 years after, with attention to the INES scale and to emergency planning, including medical aspects. In addition, he explored nuclear waste management and ALARA. The RP research which had been refocussed at SCK·CEN in Mol was considered as well, and detector innovations were presented at a successful conference at UGent. He passed away after the 50-y conference.
The sixteenth President, the late Prof Julien Garsou (1993-94) [22], was a radiochemist and pioneer of Fricke in medical dosimetry. He focussed Society activities on education and training, and took the initiative for explaining radiation protection in schools. He asked attention for social sciences and for radium in the environment. Subsequently he organised a radon conference in Liège.

The 17th presidency of the Society (1995-96) was taken up by Luc Baekelandt (Federal Administration for Health, Services for protection against ionising radiations (DBIS), integrated subsequently in FANC). He had been secretary general in 1991-92 and paid interest to NIRAS-ONDRAF and waste issues such as nuclear transport and the harmonisation of exemption and clearance in IAEA. He supported the publication of a book on low dose effects by the Belgian Waste Institution, co-edited by André Wambersie. He finalised a school project set-up by BVS-ABR. For the first time, Belgian contributions to IRPA congresses were grouped and published in the Annals.

Christian Thielemans took up the 18th presidency (1997-98). Over a long period, he was occupational physician for the nuclear power plant of Tihange, where he succeeded to a former President (P12) Dr Cordier.

He organised a seminar on doses received by medical staff and a joint conference with SFRP in Lille on low level waste management. He started a website for the Society and prepared reflexions regarding the Royal Decree of 2001 by FANC. He was supported by Mrs J. Czerwiec-Poté as secretary-general.

Hans Vanmarcke (1999-2000), world famous expert on radon from SCK·CEN, took over for the millennia switch. This 19th President paid attention to the new biological challenges related to embryo exposure, genomic instability and genetic predisposition. Under his direction, the radiobiological unit of SCK·CEN till to-day continues research at the frontiers of science. He organised with NVS a conference on nuclear hospital waste. He enforced international collaboration of BVS.ABR and organised together with SFRP a conference on crisis management for large-scale contaminations. Hans was recently nominated chairman of UNSCEAR.

3.6. A new millennium

The 20th President of BVS-ABR, Henri Drymael (2001-02) put communication on the agenda, continuing the initiative of Vanmarcke (P19). Drymael, a civil engineer of AVN and the later BelV, invited Roger Clarke, the President of ICRP to discuss the trends in BSS and organised with FANC a meeting on BSS and R&D implementation. He paid attention to prevention of incidents and accidents in interventional radiology and radiotherapy by stressing the importance of more integration of QC and RP in medical practices. The dose which occur in aviation was considered as well. BVS-ABR considered for the last time issues of non-ionising radiation with analysis of the risk of mobile phones. Henri Drymael also created a working group on certification. The responsibility of secretary-general was taken over in 2001 by J-P. Culot from SCK·CEN.

Pierre Kockerols, a civil engineer at EC JRC Geel after working in the RP service of the MOx industry of Belgonucléaire, took the lead as 21th President (2003-04). He organised an important transdisciplinary conference on risk perception for the 40 years BVS-ABR anniversary. Under his presidency, it was decided to limit the mandate of the Society to ionising radiation, contrary to our Dutch and French sister societies.

ICNIRP had been created and Belgian experts in non-ionising radiation had other professional associations to adhere to. As a European administrator, he paid a lot of attention to international collaboration and started to prepare a conference on 20 years Chernobyl. An ambitious working group was created for preparing consultations by FANC as well as by ICRP. He started the concept of training classes. He was supported by Marc van Eijkeren as secretary-general.

Marc van Eijkeren, a radiotherapist from UZ-Gent took up the 22th presidency (2005-06). He and focussed on IMRT advances in radiotherapy. He also paid attention to the upcoming NORM problem. Dr van Eijkeren realised the Chernobyl conference and established a yearly tradition on training initiatives, a successful response to a need of the members. He made progress in the certification of training events. A remarkable CD-ROM was produced with a compilation of the Annals, which was widely distributed. He was assisted by the late Luc Baeyens, occupational physician at Securitas in Ghent, who became treasurer till 2010. Luc passed away in 2014 [33].

The next presidency (2007-08) had a discontinuous trajectory. The President-elect, Pascal Deboodt (RP service head of SCK·CEN) could not take up his mandate as planned due to an international mission that he took up in IAEA. Antoine Debauche, head of the RP service of IRE took up the responsibility as 23th President, but had to abandon half-way as a result of difficulties within the management of IRE. M. van Eijkeren helped to maintain continuity and again took up the function of secretary-general, while Dr Patrick Smeesters, medical advisor of FANC and Belgian expert in the Art 31 Expert Group of EURATOM accepted to finalise this half mandate (P23bis). He focussed the programming on EC priorities in Radiation Protection and related health risk research "at the frontiers of science" on low dose effects. Following an IRPA initiative, he asked attention for ethical considerations. This lead to an ethical code of conduct for BVS-ABR experts. Patrick Smeesters was reconducted as President-elect in 2013 for the period 2015-16 (P27).

Gilbert Eggermont was the 24th President (2009-10); he was the first of three already retired but still active Presidents. He was the former head of the RP service at VUB, initiator of the PISA programme of SCK·CEN and was section head ionising radiation at the Superior Health Council. He replaced the late Paul Govaerts [31] as member of the Euratom Art31 Expert Group. He was succeeded by another retired member, Jean-Paul Samain (2011-12) (P25) in what was once again a challenging period for radiation protection as a result of the Fukushima accident; he had been the first general manager of FANC and was the President of its scientific board. Claire Stiévenart-Godeau took up the function of treasurer in 2011, while being assisted by Véronique Mertens as permanent secretary.

The next and 26th President, having the honour to organise the 50th anniversary congress of BVS-ABR is Frank Hardeman (2013-14), director of RP research at SCK·CEN, former head of RP service in Mol and member of Art 31 as well. Both last Presidents were actively assisted by Jef Van Cauteren from AIB-Vinçotte-Controlatom as secretary-general.

4. Main findings on half a century of RP evolution and response of BVS-ABR

4.1 Need for a more proactive response on emerging problems in RP

In the last 25 years, nuclear accidents, nuclear waste problems and radiology came on the foreground in radiation protection.

TMI and Chernobyl had questioned safety approaches in depth. Safety culture became a priority and is related to radiation protection culture based on the ALARA principle as well as to security culture. Emergency management had to be reconsidered, with feedback from the major nuclear accidents and from some interesting non-nuclear accidents. Fukushima learned that corrective approaches had been insufficient. The review contributed to face the challenge of terrorism as well [34], as became evident already in the eighties and now receives growing attention.

The occurrence of the Transnuklear waste scandal in Mol in 1986-88 surprised and focussed nuclear waste policy and related RP in depth. The ocean dumping of low level waste including, unlike other, Ra bearing alpha waste as was noticed by the French Castaing Commission [9]. The exposure of mariners to radon on board of the vessels was thereby ignored.

The nuclear transport weaknesses became clear with the Montlouis UF6 coastal accident.

The major doses to the staff and public in interventional radiology were discovered late and the Superior Health Council highlighted the huge collective dose dimension in Belgium of radiology, and CT in particular.

Some problems became embarrassing issues:

- Atmospheric and river pollution problems and a lack of timely waste management can become embarrassing in the long run for the involved companies and for the common good. Authorities had to review provisions and adequate insurances even in case of bankruptcy, requiring more integration of radiation protection in waste management and vice versa, including financial concerns.
- There was a use of unprotected X-ray sources in schools till the seventies.
- In medicine the unacceptable spread of dose accuracy in radiotherapy in the seventies was treated with discretion under international pressure. It was a precursor of more important QA problems with complex technologies that caused even large scale accidental problems 25 years later. The Fund of professional diseases had to treat cases of occurrence of thyroid cancers in nuclear medicine as well with radiation protection and personal dosimetry feedback.
- The Nete river was demonstrated to be an historical tracing instrument for nuclear fuel industry and R&D. Old new problems came up again and proved to be more worrying than first assumed. Radium waste also had a long memory difficult to insert in a traditional waste or site destination policy.
- The refusal of making available epidemiological data of Belgian Radium workers in Olen for international pooling in the nineties.

Upcoming questions

Why was there in the past so little epidemiological research on nuclear risks in Belgium?
Why was nuclear waste disposal, except sea dumping, almost not considered in protection policies up to the end of the cold war?
Why was the study and impact of decommissioning discovered so late?

Why was the capacity for safety evaluation developed so late by the competent RP authorities themselves?
How to define or constrain the public utility function or “commons character” of publicly financed institutions like SCK·CEN, IRE, when they are taking the lead in RP R&D in Belgium?

The Superior Health Council and Art 31 Euratom structurally insisted to focus new challenges like medical RP (Accidental, occupational and patient protection), NORM and to keep focus on new R&D indications at low as well as high doses (ex. Cataract).

From lessons learned to opportunities

One may wonder why the RP community responded very well to some problems, whereas others were not addressed or only very late. One of the reasons may be that each RP expert deals only with those problems for which he has responsibility and on which his views may have an impact. Experts rarely bridge the gap of different compartments (occupational protection, medical uses of ionizing radiation, …). Some of the new issues did not emerge from the operational experience of the experts in the field, but from those in research or in public health administration who strive for coherence of the RP system and who can explore new areas. This applies to the inclusion of natural radiation sources in the system of protection and in the regulations. Finally, for historical reasons RP has focused on protection, when there already is a need for protection, in the sense of reducing current exposures. RP has been less brave in timely addressing broader issues, which may be important in terms of avoiding exposures to occur in future. Experts have their own culture which can be too defensively driven by professional social dynamics (cognitive dissonance)[35]. Conflicts of interest can also affect impartiality. Discomforting information is either ignored or given lower priority. These broader issues are often felt to be beyond the remit of the RP expert when they involve economic, societal or political choices, even more so when these choices are made in a military or security context. Such considerations may provide part of the answer to the above question.

Each crisis that we have met in our profession over the last 50 years also brought new perspectives:

- The Venus accident in 1966 for criticality dosimetry and marrow transplant
- The Chernobyl accident for improvement of dispersion modelling and field measurements
- Accident and incident analysis for safety and ALARA culture development
- Transparency requirements for risk communication development (RISCOM model versus the approach of the nuclear forum)
- Reorganisations and stress tests for establishing confidence after crisis problems
- Participatory experiment in Mol-Dessel after a general refusal of waste disposal siting
- The successful reorganisation of SCK·CEN by Paul Govaerts [31] with its RP priorities and commitments after the waste crisis and the broadening of disciplinary approaches

During the last decennia, (international) R&D progress in most fields was considerable and institutional changes took place, but it took 25 years after Chernobyl.

Institutional problems

The reorganisation of nuclear control authorities was taking too much time to correct perception in public opinion, in particular regarding impartiality, while their capacity and the competence of the *Competent Authorities* was increased considerably in 25 years. The contrast with Finland where there is much more confidence in nuclear can be explained by the fact that capacity building to take up responsibilities was established much earlier, already 30 year ago, in safety, RP and nuclear waste.

4.2 How to improve BVS-ABR response?

Some issues from the past are questioning a professional society. Mainly why and how problem solving was delayed or not paid attention for in due time such as the poor direct attention for the lessons from the TMI accident in the Society in the eighties.

However, the experts charged by the SHC in policy making and advisory work since the mid-eighties, were all active members of the Society. BVS-ABR realised a systematic professional spread of advices and reports of the SHC, as well as communication on parliamentary questions and answers related to ionising radiation. The efforts in communication spent by Hans Vanmarcke, as editor of the Newsletter and as expert in the SHC, cannot be sufficiently underlined.

Perception and Ethics

Perception of public, staff as well as patients was put forward at the BVS-ABR seminar as a real problem for protection experts. Risk perception and communication was considered in depth, with professional support, to be able to organise adequate protection. There are still hurdles to be taken in the further development of radiation protection culture however.

Some content related as well as organisational issues affect radiation protection and the BVS-ABR functioning and independency, such as the revolving doors between regulator, industry and policy makers.

Should BVS-ABR membership be more individual and less taken in charge by companies or agencies? Can we continue to refuse direct or indirect sponsoring? How to find a balance between industrial or licensee interests, political influences and the public interest mission of a regulatory body, a waste agency an advisory body as well as of a professional scientific Society.

Ethical considerations came up as part of the RP job [35] and were integrated both at IRPA level and within BVS-ABR, which has formulated a code of ethics. Practical implementation and the follow-up of ethical conduct and of conflicts of interest is more difficult for the experts. The management of conflicts of interest, where the Belgian Health Council took the lead, is still a challenge for the involved actors, in a still rather closed nuclear culture.

Internal organisational facts, continuity and opportunities

The BVS-ABR network is characterised by a balance of working horses and top scientists and by a balance of disciplines, users, authorities and R&D institutions. The informal dimension of the job remains important.

As the founder and first president S. Halter already pointed out 50 years ago, access to information and a good network is more important than acquired knowledge.

The continuity and success of the society was guaranteed over 50 years not in the first place by all presidents but by their surrounding teams of volunteers and working horses. The board composition and mechanisms proved to be an effective dynamic instrument full of initiative and able to bridge difficult periods. Priorities moved but were framed in biannual strategic reflections steered by president views.

The system of president elect and past presidency supporting the president in daily management proved to be essential for the continuity of activity of the society. The regional and cultural balance was respected over 50 years BVS-ABR history by alternating the presidency every two years between a French and Dutch speaking expert.

We noticed that the disciplines of the presidents alternated rather well: 10 physicians, 8 civil engineers, 5 physicists and 4 chemists were president. Seven of the 27 presidents were from Brussels.

English was used more and more, to complete alternating presentations in the two major Belgian languages or to improve trans-border meetings with sister societies. The board makes no use of translations on the spot. Experience learned that passive knowledge of the languages was sufficient.

No woman ever took up the presidency, notwithstanding the growing part of female members. Even in the board women were a minority, nevertheless controlling the practical functioning of the society. Support and supervision was mostly taken up by women, *a story of man directed by a woman*. These “findings” offer interesting opportunities for future (candidate) presidents. The age and gender distribution in the Board needs to be improved.

European context

Networking over the edges of radiation protection occurs more and more. A broader framing than Euratom, for instance the regulation for prevention at work, interacts with the RP regulation. The exclusive reliance on Euratom legislation may hinder this process.

How do we differ from neighbour societies: NVS, SFRP, BNS, BSR, BSNM, Physicians at work? How to establish collaborating opportunities? Why is there a poor collaboration with UK and German societies and with the hospital physicist association?

Could the society help to improve harmonisation at European level such as for emergency management, a cornerstone of nuclear safety, which will always have a transboundary dimension?

5. Looking forward – present challenges for a professional radiation protection society

Challenge 1: ***People can expect a cumulated life time dose the triple of 100y years ago***

The average dose rate in Belgium has changed from 2.3 mSv/y in 1895 to 4.6 mSv/y at present. Main components of dose are now the medical and natural exposure. The longer life expectancy from about 50 y to 80 y causes a further increase of dose over the life time. The medical exposure has doubled the natural exposure and has added 2.1 mSv/y in a century with as open question:

How to manage digital imaging exposure (2.2 mSv/y), and CT in particular

Risk awareness in medicine will be crucial for managing the dose of the public.

Challenge 2: ***How to prevent the dispersion of man enhanced radioactivity in the environment?***

Accidental atmospheric and aquatic releases of radioactivity happen and will occur again.
A major accident and contamination causes a trans-border impact and broadens the already existing transgenerational ethical problems in geological nuclear waste disposal. Accidents, like the legacies of the past, show the need for proactive integration of waste problems resulting from i.a. decontamination, in nuclear waste management. This enhances long-term financing requirements at least at European level.

Reactor accident preparedness should be reconsidered integrating inherent nuclear waste management as identified in Ukraine and in Fukushima prefecture. Reactor accident management should include a long-term approach in case of an extended long range spread of radioactivity in the environment, and reconsider evacuation approaches.

An ecosystem approach is lacking up to now in ICRP and EU, despite recent advances in ICRP and a non-binding invitation in the new BSS.

(Transgenerational) equity aspects matter in environmental and waste measures.

Challenge 3: ***How to implement and improve BSS – Do we have enough proactive potential? – What is the role of guidelines?***

We noticed an average delay of more than 10 years between new risk indications and risk management corrections. Important scientific indications asking for change in regulations were published in 1950 (first Hiroshima epidemiological data, 1966 (LNT), 1983 (review of Hiroshima data: organ risk data), 1989 (new weighting factors, radon), and 2006 (radon).

The resulting BSS or BSS changes set up by EC occurred in 1959, 1976-1984), 1996 and 2013.The implementation in Belgian regulation occurred subsequently in 1963, 1982, 2001 and (are expected) in 2017.

In case of the lens of the eye, the cataract risk was demonstrated to be radiation specific, requiring a more specific improvement in dose measurement. Protection of the lens of the eye is necessary for children also with consideration of this risk for neonatal exposure as well.

Risk awareness, in particular for children, and new demonstrated health problems require general improvement of practical guidance and less delay in BSS implementation.

Challenge 4: ***The organisation in the field of radiation protection happens in a complex fast evolution of technologies within a new societal perception context and changing regulations***

- A huge technological evolution took place in medical imaging. Innovative dosimetry with new quantities and units came on the foreground.
- Training requirement accelerate, interacting with experience build-up.
- Expertise is submitted more and more to certification while pointing out more and more the limits of a mandate of an expert.
- The role of an RPE should be reconsidered in relation to other professionals.
- The job becomes more attractive for young potentials and women.
- Radiation protection is a transdisciplinary profession, problem solving oriented requiring to manage an interaction of disciplines.
- Communication skill requirements and the need for perception insight complicate this challenge. Moreover, participatory methods with relevant actors will require some sociological skills on the job as well.
- Ethical guidance has been developed while implementation is poor. This requires more guidance and procedures for managing conflicts of interest and more awareness for new scientific data, such as on genetic susceptibility.

➢ Radiation protection overlaps with nuclear safety and safety culture concern. This needs to be extended to delicate security aspects and culture as well.

A strategic approach is needed.

Challenge 5: ***The continuity of a strong BVS-ABR network in an international context, without neglecting new professional networks and internal equilibria***

Radiation protection is driven by an international dynamic, a European framing and a national organisation. Adequate local protection requires global thinking, European strengthening and national independent competency.

The European development of IRPA is too limited, it does not go beyond exchange meetings of national presidencies and the organisation of European IRPA conferences at high level. Bilateral collaboration of national societies was more successful in this weak European IRPA perspective. Representation in IRPA-international essentially remains the business of sister organisations of large countries.

The European dimension should be improved.

Challenge 6: ***A capacity of adaptation in case of a crisis and within a changing context***

The history of radiation protection was determined by unexpected events illustrating a lack of imagination in risk assessment and a lack of proactive thinking. The future will be shaped by the capacity to act in due time. This is enforced by investments in and access to networks, by building a critical sense, by team management of high level expertise.

Regular informal team reflections in the Board can build a balanced integration of ideas and face the challenges in the long-term programming.

6. Conclusions

The Belgian Society for Radiation Protection BVS-ABR was created in 1963. Its early history is strongly associated with the establishment of the EURATOM Community in 1957 and the foundation of IRPA. At that time a Belgian radium industry had operated for 40 years and a prototype

PWR had started production. Belgium's nuclear ambitions extended to the entire fuel cycle and associated R&D was developed. This period was also marked by the atmospheric atomic bomb tests and resulting global pollution. These were also the embryo of later nuclear controversy.

The prominent founders of BVS-ABR faced the challenges for radiation protection, addressed these in a transdisciplinary approach and set up a professional scientific society as the Belgian Section of IRPA. They developed a framework for radiation protection both at national and European level.

Key to the success of the Society, beyond the impulse given by different Presidents, was the team spirit of the Executive Board. It was a guarantee for continuity. The scientific perspective of the Society and the networking that it fostered paved the way for professional creativity. Interesting programs of scientific seminars, international collaboration, a good transdisciplinary balance did the rest. High level research in radiation protection proved to have an impact on international developments in protection and safety, through the efforts of the Society. The analysis of the history also revealed shortcomings in the profession and in the Society. Negative experiences were transformed into opportunities for change. Reflexions were conducted on how to improve transparency, radiation protection culture and communication.

The actual President (F. Hardeman-2013-2014) expressed several challenges and perspectives for setting future priorities for the society. Identified challenges were the increasing life time dose mainly due to medical exposure, the prevention of the spread of man-made enhanced radioactivity in the environment, the proactive implementation of the BSS, the new context of civil society, the interaction with other professionals in a globalised context and crisis management capacities.

Looking forward, risk awareness in medicine and for children in particular, will need our major attention; equity aspects matter in environmental and waste issues, practical guidance should be improved also related to values. The European dimension should be given much more attention and age and gender structure improved.

The Society should act in due time by improving its organisational capacities. More women should participate in the Board and take up responsibility.

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Abbreviations:

BVS-ABR	Belgische Vereniging voor Stralingsbescherming - Association Belge de Radioprotection
BNS	Belgian Nuclear Society
BSR	Belgian Society for Radiology
BSS	Basic Safety Standards
BSNM	Belgian Society for Nuclear Medicine
CT	Computed Tomography
EC	European Commission
FANC	Federal Agency for Nuclear Control
ICRP	International Commission Radiation Protection
ICNIRP	International Commission Non-Ionizing Radiation Protection
IRE	Institut des Radioéléments
NORM	Naturally Occuring Radioactive Material
NPP	Nuclear Power Plant
NVS	Nederlandse Vereniging voor Stralingsbescherming
QC	Quality Control
RP	Radiation Protection
RPE	Radiation Protection Expert

SHC	Superior Health Council
SFRP	Société Française de Radioprotection
TMI	Three Mile Island
UN-ILO	United Nations-International Labour Organisation
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation

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About the authors and the methodology

Claire Stiévenart-Godeau (1931°) is a nuclear physicist from ULB; she worked at SCK·CEN. She is a member of the Society since 1963 and honorary permanent secretary of ABR-BVS. Gilbert Eggermont (1946°) is a nuclear physicist from UGent; he was associated with UGent, SCK·CEN and VUB. He was a member of BVS-ABR since 1969 and president of the Society in 2009-10.

They organised and explored the archives of the society over the past 50 years, and the publications of, and about, former Presidents and their Boards. They interviewed in 2012-13 all still living Presidents of the Society on their objectives, priorities, experiences and the programmes which they realised. Both have known personally all 28 Presidents of the Society and shared a lot of experiences with them. The overview of the BVS-ABR history was considered within the history of nuclear technology and of radiation protection, while referring to scientific developments, IRPA coordination and the regulatory context in the EU.They tried to give an impression of the history of the Society over 50 years. The main conclusions and findings were discussed with the President who organised the 50th anniversary meeting, Frank Hardeman.

Challenges, perspectives and messages for the future of the Society were put forward.

Email

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ANNEXE

Presidents BVS-ABR

1963-1964	Dr.Med. Samuel HALTER
1965-1966	Ir. Gaston ANDRE
1967-1968	Dr.Med. Julien HOSTE
1969-1970	Dr.Med. Alphonse LAFONTAINE
1971-1972	Dr.Med. Maurice FAES
1973-1974	Dr.Med. Paul DE PLAEN
1975-1976	Dr.Sc. Oscar SEGAERT
1977-1978	Ir. Alexis OSIPENCO
1979-1980	Ir. Raymond NUYTS
1981-1982	Dr.Med. Paul HUBLET
1983-1984	Ir. Gérard FIEUW
1985-1986	Dr.Med. Jean-Marie CORDIER
1987-1988	Dr.Med.Sc. Paul SCHONKEN
1989-1990	Ir. Jean DELHOVE
1991-1992	Dr.Med. Léopold de THIBAULT de BOESINGHE
1993-1994	Dr.Med.Sc. Julien GARSOU
1995-1996	Ir. Luc BAEKELANDT
1997-1998	Dr.Med. Christian THIELEMANS
1999-2000	Dr.Med.Sc. Hans VANMARCKE
2001-2002	Ir. Henri DRYMAEL
2003-2004	Ir. Pierre KOCKEROLS
2005-2006	Dr.Med. Marc van EYKEREN
2007-2008	Antoine DEBAUCHE - Patrick SMEESTERS
2009-2010	Dr.Med.Sc. Gilbert EGGERMONT
2011-2012	Ir. Jean-Paul SAMAIN
2013-2014	Dr.Med.Sc. Frank HARDEMAN
2015-2016	Dr.Med. Patrick SMEESTERS
2017-	Dr.Med.Ir. Michel SONCK

General Secretaries BVS-ABR		Treasurers BVS-ABR
1963-1972	René. BOULENGER	Paul HUBLET
1973-1976	René BOULENGER	Georges CANTILLON
1977-1980	Maurice FAES	Georges CANTILLON
1981-1984	Jean DELHOVE	Georges CANTILLON
1985-1988	L. de THIBAULT de BOESINGHE	Georges CANTILLON
1989-1991	Luc BAEKELANDT	Georges CANTILLON
1991-1992	Luc BAEKELANDT	Raymond JACOBS
1993-1996	Henri DRYMAEL	Raymond JACOBS
1997-2000	Jeanne CZERWIEC-POTE	Raymond JACOBS
2001-2002	Jean-Pierre CULOT	Andrzej POLAK
2003-2004	Marc van EIJKEREN	Andrzej POLAK
2005-2006	Jan VAN DAM	Luc BAEYENS
2007-2010	Marc van EIJKEREN	Luc BAEYENS
2011-2012	Marc van EIJKEREN	Claire STIEVENART
2013-2016	Jef VAN CAUTEREN	Claire STIEVENART
2017-	Jef VAN CAUTEREN	Chantal MOMMAERT

Permanent Secretaries

1975-2010 Claire STIEVENART
2011- Véronique MERTENS

Annalen van de Belgische Vereniging voor Stralingsbescherming - Annales de l'Association belge de Radioprotection

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1979-2001 Dr.Med. Maurice FAES
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Associate Editor

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Newsletter

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DOSIMETRY

SCIENTIFIC MEETING 03-06-2016

Annales de l'Association belge de Radioprotection, Vol.41, n° 4, 2016
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LA SURVEILLANCE DE L'EXPOSITION DES TRAVAILLEURS AUX RAYONNEMENTS IONISANTS :

BREF RAPPEL HISTORIQUE

Avertissement

Ce bref document, purement descriptif, n'a d'autres buts que de situer cette problématique dans son cadre règlementaire initial en décrivant les prémices de la situation que nous connaissons aujourd'hui.

L'arrêté royal du 27 février 1963 qui est la première réglementation générale en la matière prévoyait déjà en son article 24 relatif à la surveillance médicale que le contrôle médical des travailleurs exposés est réalisé dans les conditions prévues par le Règlement général pour la protection du travail (ou le règlement minier selon le cas) par des médecins agréés.

Il prévoyait encore que les employeurs intéressés fassent parvenir au Ministre de l'Emploi et du Travail, pour chacun des travailleurs soumis au contrôle médical prescrit par le présent article et en triple exemplaire, le document prévu par les mêmes dispositions règlementaires, portant le relevé des doses individuelles des radiations ionisantes reçues par ce travailleur au cours de l'année précédente. Le Ministre de l'Emploi et du Travail transmet sans délai l'un de ces exemplaires au Ministre de la Santé publique et de la Famille.

La surveillance de ces dispositions incombait, au Ministère du Travail, aux différentes directions décentralisées de l'Inspection technique et de l'Inspection médicale du travail alors que dans l'autre département l’Inspection d’Hygiène, l’Institut d’Hygiène et d’Epidémiologie et puis le service des Nuisances étaient concernés par l’application de l’AR du 28 février 1963.

Notons qu’à cette époque cette mission n’était qu’une parmi bien d’autres et que la quasi absence d’incidents sérieux n’a jamais entraîné d’attention spéciale pour ce secteur. Néanmoins, la Commission spéciale des radiations ionisantes accordait déjà tous ses soins aux processus d’autorisation des établissements de classe I et notamment à la construction des centrales nucléaires dans la seconde moitié des années 70.

A ce moment déjà l’énergie nucléaire retenait l’attention et une Commission d’évaluation en matière d’énergie nucléaire dite Commission des Sages, présidée par le Baron Jaumotte, a été mise en place en 1975.

Les travaux de cette commission conduiront notamment à la création de deux services spécialisés sur le modèle des services équivalents en France : le Service de la Sécurité technique des installations nucléaires au Ministère du travail (SSTIN) et le service de Protection de protection contre les Radiations ionisantes (SPRI) au Ministère de la Santé publique. Dès février 1982, date de sa mise en place, c’est ce service qui a réceptionné les copies des fiches individuelles d’irradiation destinées à ce département.

L’entrée en service de fonctionnaires supplémentaires a permis de faire face à des tâches qui, jusqu’à cette époque, étaient peu ou pas exécutées et à des missions nouvelles comme la première révision périodique de la sûreté des centrales. Il s’est rapidement avéré, notamment lors de la gestion de crises comme la catastrophe de Tchernobyl ou l’affaire Transnuklear, que cette force de travail (une vingtaine de personnes au SPRI et une bonne demi-douzaine au SSTIN) pouvait difficilement faire face à toutes les missions ; en particulier il était pratiquement impossible d’exploiter les fiches individuelles d’exposition arrivant par milliers chaque année, même si l’exposition des travailleurs était un des sujets investigués régulièrement lors des inspections en centrale ou lors des debriefing avec les exploitants (Commission de contact e.a.).

Sur la lancée de la commission parlementaire d'information et d'enquête en matière de sécurité nucléaire du Sénat (dite de Wasseige), et des propositions des services concernés, des discussions au niveau gouvernemental ont conduit au dépôt d'un projet de loi, devenu la loi du 15 avril 1994 créant l'Agence Fédérale de Contrôle Nucléaire. Celle-ci est devenue opérationnelle en septembre 2001 avec l'entrée en vigueur d'une règlementation générale entièrement revisitée, et s'est attelée aux nombreuses missions qui étaient désormais les siennes.

L'exploitation des fiches individuelles d'exposition était déjà une préoccupation mais les moyens matériels, notamment informatiques étaient encore insuffisants. La direction de l'Agence souhaitait évidemment disposer d'un système informatique robuste pour traiter la masse de données en question.

D'autre part, une modification législative était encore nécessaire pour lui conférer explicitement la compétence requise. Ce qui, on le lira dans un autre article n'a été fait que plus tard.

Jean-Paul SAMAIN, conseiller à l'ABR.

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BELGIAN OCCUPATIONAL EXPOSURE REGISTER: PROGRESS AND FUTURE STEPS

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Origin and objectives

In order to guarantee individual dose monitoring for all exposed workers in an efficient way, it is essential to have access to a modern and powerful exposure register. In addition it should also allow to monitor efficiently the critical sub-group of external workers.

In the beginning of the XXIst century it was clear that the system in place always belonging to the Federal Public Service Employment Labour and Social Dialogue, was not particularly functional and did not permit optimal monitoring of external workers. It was thus decided that a new system should be developed. For reasons of efficiency and consistency with the respective tasks of the two parties involved, it was deemed more logical and effective to transfer these tasks to FANC.

Thanks to its statistical and reporting functionalities, the system should provide a powerful tool to help with the following objectives besides its usefulness in verifying compliance with dose limits:

- Identifying critical groups;
- Promoting dose optimization within a particular sector/group;
- Establishing priorities in connection with awareness, training or inspection activities;
- Drawing up and publishing official reports.

By modernizing the exposure register, the underlying intention was also to modernize the dose reporting process to the authorities, i.e. replacing the system of sending paper exposure tables by forwarding electronic files.

The idea was also to ensure that the system was open to stakeholders and used as a central communication tool, specifically between the licensee and external companies with a view to monitoring external workers. Henceforth, parties working in the field should be involved in this project right from the outset and during all key development stages.

Progress

A number of key stages were implemented as part of this project between 2007 and 2010, namely:

- Business and functional analysis of the system in consultation with external users,
- Development of an intermediate version for submission to the sector, to be tested by a group of future external users,
- Implementation of annual electronic dose transfers using a format defined by the Agency via the health physics and dosimetry services.

However, at the end of this initial development and trial period, it was decided to look to a different technological solution to develop the exposure register on the basis of technical and organizational reasons. This led to a standby period until June 2014.

During this standby period, an important stage was still implemented from a legal point of view: the dosimetry law, which provided a legal framework for creation and use of an exposure register by the Agency, was published.

Since June 2014 the development of the system has been restarted. A radiological monitoring data exchange application enabling external parties to upload dose data has been implemented. Basic overview functions have been developed but are now only available for internal use.

The application includes a process for automatic validation of the structure and content of the received files with production of error reports and warnings. The system also contains functions and explanations to help the data suppliers solve errors/warnings.

The upload application was made available in March 2016. Each data supplier uses his/her own username and password to log in to the secure application. The annual dose data transfer for 2015 was made through this application.

Future steps

The future steps of the project are the following:

- Development of detailed overview and analysis functions and gradual availability of external users;
- Implementation of a reviewed data model in the application;
- Gradual opening up of the application to other stakeholders for consultation depending on their rights;
- Implementation of the 'radiation passport' functions for the follow-up of outside workers, and of the 'dose validation by occupational health doctor' function;
- Completion and publication of texts making up the legal framework for exposure register;
- Gradual increase in the transfer frequency with a view to reaching the monitoring cycle frequency;
- Extending the register to include other types of radiological monitoring data like medical fitness or RP training followed by the workers.

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TRAÇABILITÉ DE LA SURVEILLANCE DES EXPOSITIONS PROFESSIONNELLES AUX RAYONNEMENTS IONISANTS EN FRANCE - FONCTIONNEMENT DE SISERI

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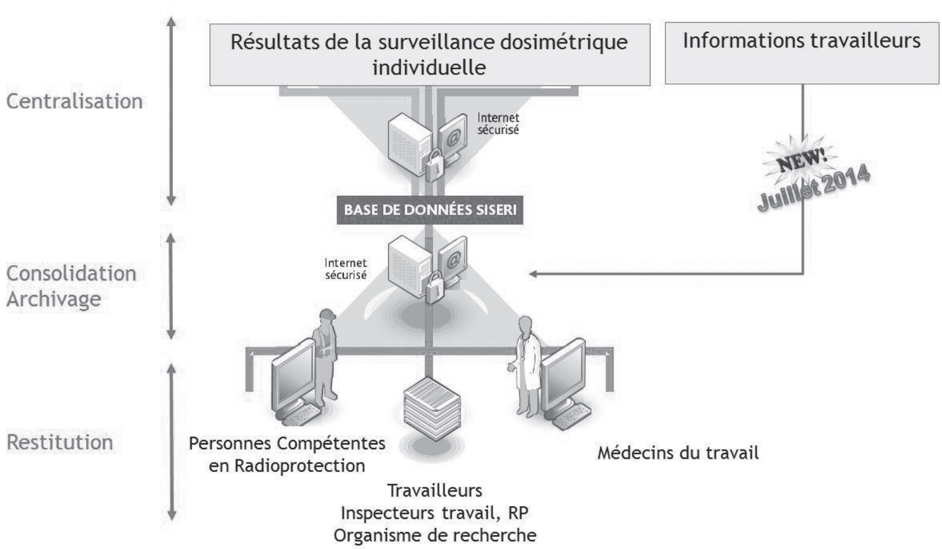
La surveillance de l’exposition professionnelle aux rayonnements ionisants a été réglementairement mise en place en France avec les réglementations de 1967 et 1968. Ces textes réglementaires avaient notamment instauré les principes d’une surveillance dosimétrique individuelle au moyen de dosimètres passifs dont les résultats sont communiqués au médecin du travail et à un organisme centralisateur au niveau national. D’abord sous forme papier, cette centralisation nationale des données de la surveillance dosimétrique des travailleurs a progressivement évolué, avec le développement des technologies numériques vers une centralisation des données sous forme numérisée. Ainsi, à partir de 1996, les résultats de la surveillance dosimétrique des travailleurs ont-ils été centralisés dans une base de données nationale gérée par l’Office de Protection contre les Rayonnements Ionisants (OPRI). Dans la continuité, la France s’est dotée en 2005 d’un Système d’Information de la Surveillance de l’Exposition aux Rayonnements Ionisants, le système SISERI.

Ce système d’information a été développé à la demande et grâce au soutien du Ministère du Travail et sa gestion a été réglementairement confiée à l’Institut de Radioprotection et de Sûreté nucléaire (IRSN). Ainsi, l’article R.4451-125 du code du travail stipule-t-il que pour l’exécution de sa mission de participation à la veille permanente en radioprotection, l’IRSN centralise, vérifie et conserve au moins cinquante ans l’ensemble de résultats des mesures individuelles de l’exposition des travailleurs en vue de les exploiter à des fins statistiques ou épidémiologiques. Un arrêté pris en application du code du travail précise les règles de transmission des résultats du suivi dosimétrique des travailleurs à SISERI ainsi que les règles d'accessibilité à ces données par les différents acteurs de la radioprotection.

Le système SISERI a été mis en service en 2005 mais l'ensemble de ses fonctionnalités n'ont été disponibles qu'à partir de 2010, année à partir de laquelle il a été en mesure de recevoir l'ensemble des résultats dosimétriques devant être centralisées. En 2014, afin de faire évoluer le registre national des doses ainsi constitué, vers un registre national des travailleurs exposés et de disposer des informations nécessaires pour établir des statistiques nationales d'exposition plus précises et plus fiables, le système SISERI a évolué pour recevoir des informations relatives aux activités, métiers et statuts d'emploi de chacun des travailleurs. Pour atteindre cet objectif un nouvel arrêté, entré en vigueur en juillet 2014, a rendu obligatoire le renseignement par l'employeur, dans SISERI, de ces données dites « administratives » selon une nomenclature nationale.

Le schéma général de fonctionnement actuel du système SISERI est présenté ci-après.



Le système SISERI centralise l'ensemble des données de la surveillance de l'exposition des travailleurs aux rayonnements ionisants, à savoir les résultats de :

- La dosimétrie externe passive (corps entier, peau, extrémités, cristallin) transmis par les organismes de dosimétrie agréés pour la surveillance des travailleurs ;
- La surveillance de l'exposition interne, à savoir les résultats des analyses radiotoxicologiques et des examens anthroporadiométriques fournis par les laboratoires de biologie médicale ou les services de santé au travail agréés, et, lorsque les circonstances le nécessitent et le permettent, les doses efficaces engagées et/ou les doses équivalentes engagées calculées par les médecins du travail. Pour rappel, en France, la surveillance individuelle de l'exposition interne se fait selon un programme de surveillance établi par un médecin du travail qui prescrit les analyses radiotoxicologiques et anthroporadiométriques et qui est chargé du calcul de dose engagée, le cas échéant ;
- La surveillance de l'exposition résultant de l'inhalation des descendants à vie courte des isotopes du radon et/ou des émetteurs à vie longue des chaînes de l'uranium et du thorium, transmis par l'organisme agréé pour cette surveillance ;
- La dosimétrie des personnels navigants, calculée à partir de leur activité de vol individuelle, grâce à l'outil SIEVERT-PN développé par l'IRSN.

Le système SISERI centralise également les résultats de la dosimétrie opérationnelle, envoyée par les personnes compétentes en radioprotection des établissements devant la mettre en place du fait du classement de certains de leurs locaux en « zones contrôlées ». L'envoi quotidien de ces mesures par les exploitants nucléaires pour tous les travailleurs intervenant en zone contrôlée permet aux personnes compétentes en radioprotection des entreprises prestataires ou des entreprises intérimaires intervenant sur ces sites de suivre la dosimétrie de leurs travailleurs au jour le jour.

Depuis 2014, SISERI centralise également les informations « administratives » relatives à chaque travailleur exposé : identité, activité, métier, statut d'emploi, quotité de travail… ces informations, qui doivent être déclarées par l'employeur, sont utilisées par SISERI pour mettre à disposition des médecins du travail, la carte de suivi médical pré-remplie. Enfin, lorsqu'un bon niveau de complétude sera atteint, ces données permettront une exploitation à des fins statistiques des données de SISERI plus fine.

L'IRSN assure la consolidation et l'archivage de l'ensemble des informations administratives et dosimétriques afin de les mettre à disposition des différents acteurs de la radioprotection.

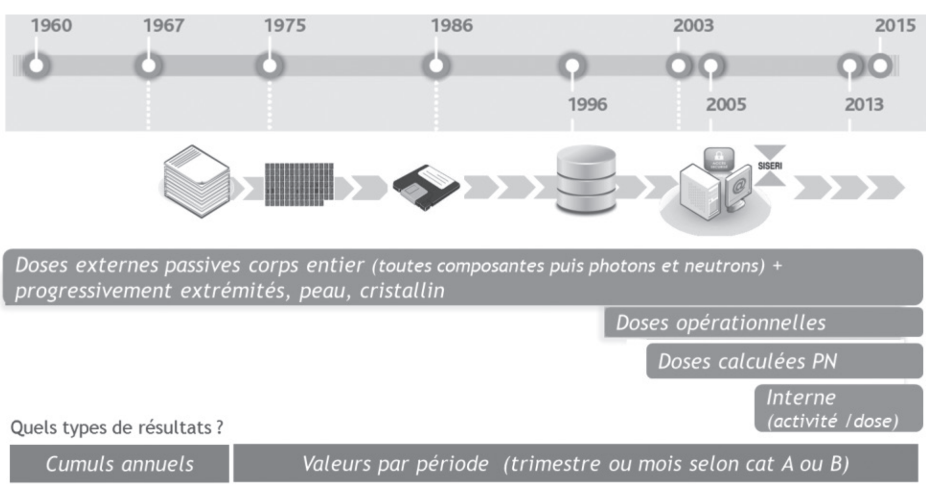
Les personnes compétentes en radioprotection et les médecins du travail accèdent directement par internet aux informations et résultats de la surveillance dosimétrique des travailleurs qu'ils suivent selon leurs droits d'accès définis par la réglementation. En France, selon la réglementation actuellement en vigueur, la personne compétente en radioprotection ne peut avoir connaissance que des doses opérationnelles et de la dose efficace d'un travailleur sur les douze derniers mois. Les médecins du travail peuvent accéder à tous les résultats de la surveillance individuelle des travailleurs sans limitation de durée, même si, pour des raisons pratiques, ils n'accèdent en ligne qu'aux résultats des 24 derniers mois. Les travailleurs, normalement informés des résultats de leur dosimétrie via la personne compétente en radioprotection et le médecin du travail, peuvent faire valoir leur droit d'accès à tous les résultats de leur surveillance enregistrés dans SISERI, en faisant une demande écrite à l'IRSN. Les inspecteurs du travail et les inspecteurs de la radioprotection ont droit d'accès aux résultats individuels de la surveillance de l'exposition externe et à la dose efficace des travailleurs. L'organisation retenue ne prévoit pas d'accès direct en ligne sur SISERI ; ils doivent également faire une demande à l'IRSN. Le fonctionnement détaillé de SISERI est disponible à l'adresse internet www.siseri.irsn.fr.

Parallèlement aux développements fonctionnels de SISERI depuis 2005, la base de données des résultats dosimétriques au cœur de SISERI, constituant le registre national des doses, a été complétée avec tous les résultats dosimétriques qui ont pu être récupérés à partir de l'archivage historique. Il en résulte une capacité à établir des historiques dosimétriques fiables à partir de SISERI.

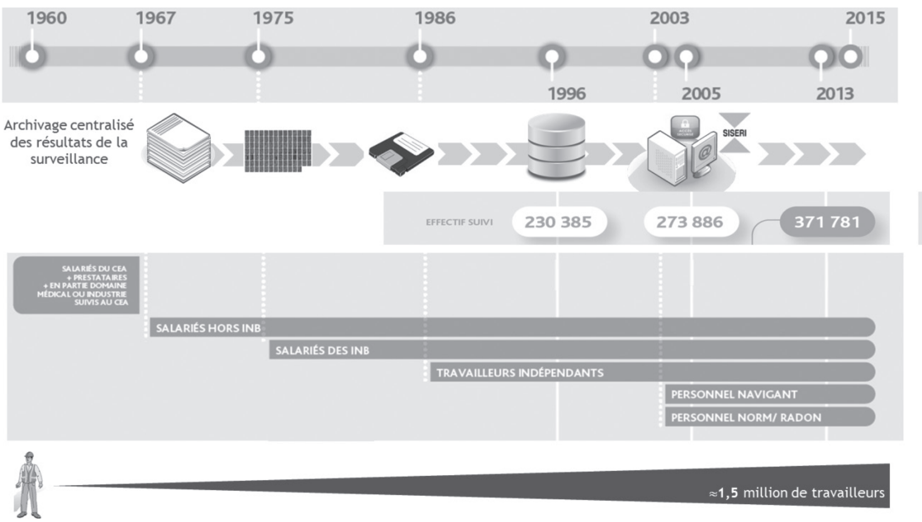
Le schéma ci-dessous résume la nature des informations dosimétriques présentes dans la base données SISERI. Ces informations ont bien évidemment évolué dans le temps avec l'évolution des pratiques de surveillance, lesquelles ont progressivement bénéficié des avancées des techniques dosimétriques. A partir de 1999, après l'utilisation exclusive du dosimètre photographique, la surveillance dosimétrique des travailleurs a bénéficié des évolutions des détecteurs et de leur intégration possible dans des dosimètres. Le développement de ces techniques dosimétriques a permis une surveillance de plus en plus adaptée au poste au poste de travail, tenant compte notamment de la nature des rayonnements. Progressivement s'est mise en place la surveillance dosimétrique « corps entier » pour l'exposition aux neutrons, puis la surveillance de l'exposition des extrémités et tout dernièrement du cristallin.

Les premières doses calculées enregistrées pour les personnels navigants datent de l'année 2000. Les résultats de la surveillance de l'exposition interne ont commencé à être intégrés à partir de 2008 même si, ponctuellement, des résultats plus anciens ont pu être récupérés.

Les résultats des mesures de l'exposition externe les plus anciens récupérés se présentent très majoritairement sous la forme de cumuls annuels de dose. Les résultats par période de port (mensuel ou trimestriel) ont pu être récupérés à partir de l'année 1973.

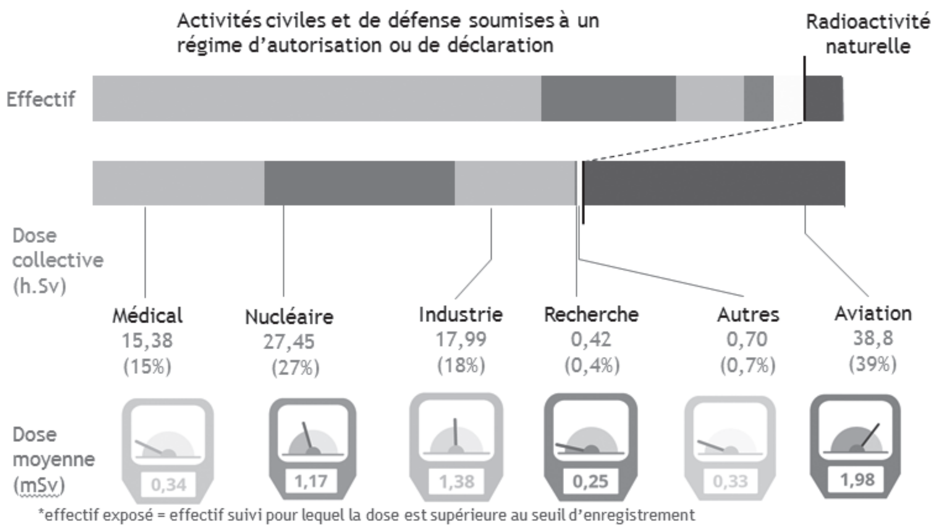


Les populations de travailleurs suivies ont également évolué au cours du temps et des réglementations qui ont successivement considéré en sus les salariés des INB à partir de 1975 puis les travailleurs indépendants à partir de 1986 puis les personnels navigants et enfin depuis 2003 les travailleurs exposés à la radioactivité naturelle dans les industries NORM ou dans les lieux de travail exposant au radon d'origine géologique.



Intégré au dispositif national de radioprotection, le système SISERI est désormais entré dans un régime de fonctionnement stabilisé. L'enjeu sur le court terme est de s'assurer du bon renseignement des données administratives par les employeurs, à la fois en termes de complétude et de fiabilité. Ceci permettra de simplifier le processus d'élaboration des statistiques nationales de l'exposition des travailleurs aux rayonnements ionisants mais surtout d'affiner la connaissance de ces expositions. L'enjeu est, in fine, de mieux caractériser des situations qui peuvent être contrastées dans les différents secteurs d'activité ou pour certaines catégories de travailleurs et où l'optimisation de la radioprotection doit tout particulièrement être renforcée.

En France, en 2015, le nombre des travailleurs qui ont bénéficié d'une surveillance dosimétrique individuelle par dosimétrie externe passive s'est élevé à 386 070. La majeure partie de ces travailleurs (60%) sont dans le domaine médical, 20% travaillent dans l'industrie nucléaire, 10% dans l'industrie non nucléaire, 5% sont des personnels navigants tandis que le domaine de la recherche recouvre 3% de cet effectif. La répartition de la dose collective est présentée dans la figure ci-dessous ainsi que les doses individuelles moyennes calculées sur l'effectif « exposé » c'est-à-dire l'effectif suivi pour lequel au moins une dose supérieure au seuil a été enregistrée. L'intégralité de ces résultats est disponible sur le site internet de l'institut (www.irsn.fr).



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