



**ASN opinion 2018-AV-0306 of 4th May 2018  
concerning the identification of research subjects to be taken further  
in various fields of nuclear safety and radiation protection**

The French nuclear safety authority - ASN (Autorité de sûreté nucléaire),

Having regard to the Environment Code, more specifically its Article L. 592-31-1;

Having regard to the order of 7th February 2012, amended, setting out the general rules relative to basic nuclear installations;

Having regard to ASN opinion 2012-AV-0147 of 10th April 2012 concerning the importance of research for ASN and the identification of initial research topics to be taken further in the fields of nuclear safety and radiation protection;

Having regard to ASN opinion 2015-AV-0226 of 8th January 2015 concerning the identification of research subjects to be taken further in various fields of nuclear safety and radiation protection;

Having regard to the recommendations of the ASN Scientific Committee of 4th July 2014, 10th December 2014, 6th July 2015, 10th December 2015, 26th August 2016, 30th January 2017 and 1st September 2017;

Whereas the proposals and recommendations of the abovementioned opinions of 2012 and 2015 remain relevant and should be supplemented,

**Issues the following opinion** on the research topics to be taken further in the following fields of nuclear safety and radiation protection:

- natural external hazards;
- fire risk in basic nuclear installations (BNI);
- nuclear fuel cladding materials for pressurised water reactors;
- health effects of ionising radiation;
- socio-economic consequences of a nuclear accident.

**1 - With regard to external natural hazards, ASN:**

**Points out that:**

- the external hazards to be considered in the nuclear safety case of the basic nuclear installations are defined in article 3.6 of the abovementioned order of 7th February 2012;
- research into external natural hazards is in progress or scheduled by various organisations in France and, in certain cases, is carried out in cooperation with OECD/NEA and under bilateral agreements;

- greater priority is granted to research into earthquakes, flooding and the impacts of climate change, which is appropriate;
- other natural risks (frazil ice, high temperatures, etc.) requiring less research are also addressed;
- progress has been made in the knowledge of earthquakes, particularly through the SIGMA and SINAPS@ programmes, to improve the prediction of ground movements and of the behaviour of structures, systems and components (SSC) and thereby reduce the uncertainties in the assessment of the associated risks;
- historical data on floods and the development of statistical methods for analysing the data are essential;
- the Fukushima accident highlighted the need to better characterise the external hazards, and the tornado risk in particular, and that the most widespread international approaches for characterising this risk, including the American approach, are probabilistic, which does not correspond to the deterministic approach required in France;

**Considers that:**

- divergences subsist between experts in the determination of earthquakes of very low probability, less than  $10^{-4}$ /year, given more specifically the lack of data on severe earthquakes in France;
- increased efforts should be made to develop the seismic fragility curves of the SSCs, taking advantage of the international work such as that carried out by the United States and Japan;
- the assessment of the risks associated with external flooding on the installations is particularly complex;
- the impact of climate change on the frequency of extreme natural hazards must be taken into account despite the difficulty in determining this;
- the tornado risk must receive particular attention in order to be better integrated in the safety case of the BNIs, and that the frequency of occurrence of this phenomenon in France does not allow optimum utilisation of the probabilistic approach which is suitable for countries where this phenomenon is frequent;

**Recommends that research be taken further concerning:**

- earthquakes, particularly to further knowledge of seismic sources in regions with geological and seismic characteristics similar to those of France, and research into site effects;
- method of assessing the risks associated with external flooding of the installations, including flooding induced by earthquakes;
- the potential impact of climate change on natural hazards, such as heat waves, hurricanes, tornadoes and storm surges;
- the models adopted for the deterministic characterisation of the tornado risk in France;

and that any initiative that fosters cooperation between organisations conducting research into natural risks in France should be encouraged.

**2 – With regard to the fire risk in BNIs, ASN:**

**Points out that:**

- fire is one of the main risks for nuclear power plants and fuel cycle and waste disposal facilities, which can lead to malfunctions of equipment fulfilling safety functions, or even severe accidents with release of radioactive materials, therefore fire must be prevented and its consequences mitigated;
- in the last twenty years, significant progress has been made in the understanding and modelling of the development of fire, its propagation in confined and ventilated spaces and its consequences in terms of radioactive releases;

**Considers that:**

- the characterisation of the combustion of certain complex fires (cables or electrical cabinets, glove boxes, waste in drums, etc.) must be improved to better guarantee the conservative nature of the hazards considered in the safety case of the BNIs;
- the risks of fire propagating along electric cable raceways can call into question fire sectorisation in the BNIs;
- under-ventilated fires can, through the production of soot, jeopardise the functioning of certain items of equipment, and deteriorate containment through the igniting of unburned gases;
- insufficient experimental data are available today to characterise the releases and transfer of plutonium from solution fires and glove box fires involving this radionuclide;
- the effects of pressure resulting from a fire, particularly pressure oscillation phenomena, are insufficiently understood and modelled, even though they can call into question the pressure cascades between premises, or even compromise the effectiveness of sectorisation;
- having a better understanding of the risk of radioactive material dispersion in the event of fire would be useful for assessing the containment provisions;
- fires induced by earthquakes and fires that could affect radioactive waste in Cigéo, the deep geological repository, must be better characterised;

**Recommends that research be taken further concerning:**

- the propagation of fires in electric cable raceways;
- under-ventilated fires, concentrating on the characterisation of combustion and its effects, particularly in terms of soot production and ignition of unburned gases;
- the effects of such fires on the behaviour of the sectorisation components and safety equipment, particularly the conditions of failure of electrical and electronic equipment exposed to fumes and soot;
- the releases and transfer of plutonium from solution fires and glove box fires involving this radionuclide;
- the pressure oscillations in case of fire, observed in certain ventilation configurations and which could be detrimental to the functioning of the sectorisation components and other nuclear installation fire protection systems;
- the modelling and control of fire in underground facilities;
- the performance of the specific fire protection systems, particularly sprinkler systems and thermal protection devices;
- the methods of assessing the risks of fire caused by earthquakes.

**3 - With regard to nuclear fuel cladding materials for pressurised water reactors, ASN;****Points out that:**

- maintaining the containment of the first barrier (provided by the cladding) and maintaining a geometry that allows cooling of the reactor core are of major importance for safety;
- ballooning of the cladding caused by the pressure and temperature conditions inside the fuel rods is prejudicial to their cooling;
- oxidation by water in normal operating conditions or by air and steam in accident conditions plays a major role in the behaviour of the zirconium-based cladding materials used in pressurised water reactors with respect to loss-of-cooling accidents affecting the reactor or spent fuel pool, and severe accidents;
- the development of new cladding materials less sensitive to these phenomena is a key factor in improving the safety of current and future reactors;

**Considers that:**

- the work to understand and model the physical phenomena coming into play during accidents affecting fuel cladding must be continued;

**Recommends that research be taken further concerning:**

- the behaviour of the fuel in the event of loss of cooling, particularly the possible fragmentation of the fuel and its potential repositioning inside the ballooned cladding in an accident situation;
- new improved cladding materials, particularly with respect to the risks of ballooning and oxidation in loss-of-cooling and severe accident situations.

**4 – With regard to the health effects of ionising radiation, ASN:****Points out that:**

- people living near nuclear installations regularly ask questions on a possible increased cancer risk due to radioactive discharges;
- to detect such an increase would require extremely large quantities of data of high quality, and studies conducted with too small sample size are not conclusive;
- a latency of 10 to 30 years after exposure to radiation is necessary to reveal a risk if there is one.
- studies on the incidence of cancer in various populations exposed to ionising radiation have shown that the risk of radiation-induced cancer is higher in persons exposed when young (high doses: survivors of the Hiroshima and Nagasaki bombings, radiotherapy treatments; low doses: computed tomography scanner examinations);
- the majority of studies conducted in France and internationally have not revealed an increased risk of childhood leukaemia near nuclear sites under normal conditions of operation. However, an excess risk has been observed in the young child of under 5 years of age in several studies (German KiKK study and GEOCAP programme, living a short distance from the nuclear site over the period 2002-2007), but without establishing a causal relationship;
- the studies conducted on the basis of the registries of cancers in children and adolescents (solid tumours and leukaemias) enable the incidence of these cancers in populations living a short distance (less than 5 or 10 km) from nuclear sites to be compared with those living 20 km or more from them. Even though the most recent French studies have taken into account the levels of radioactive discharges in the atmosphere, these studies do not enable a causal relationship to be established because they do not take other specific risk factors into account.
- the last seminar organised by ASN that brought together French and foreign experts pointed out that radiation can induce leukaemias, but that other factors interact and can create a predisposition for or be involved in the development of these diseases, and it is still difficult to determine the part played by each one. The various histological forms of leukaemia are sometimes governed by different underlying risk factors, and one can ponder on the respective contributions of genetics, epigenetics and *in utero* exposure;
- epidemiological studies on occupational exposure are important because if an excess of cancers is observed in a population living close to nuclear sites, they would make it possible to distinguish a risk associated with an environmental factor (such as discharges) from an occupational risk, knowing that nuclear industry employees often live close to their place of work. Moreover, studies of cohorts of workers enable all the factors that could be involved in the development of an occupational disease to be analysed, and therefore dose-effect relationships to be established for relatively low levels of cumulative exposure;
- France does not have a national registry of cancers in the adult, and although it does have a number of regional registries, the majority of them do not cover areas close to nuclear sites and monitoring of the cancer risk in adults is today limited to studying the causes of death.

**Considers that:**

- a study of leukaemias and solid tumours around nuclear sites should be carried out at least once every 10 years using the national registry which exists for children and adolescents;
- the studies initiated recently on the monitoring - during childhood and then in adulthood - of children who have been exposed for medical purposes (computed tomography scans or radiotherapy), must be sustained over the long term because they should allow the low-dose risk to be estimated;
- having reliable figures for the incidence of cancers by age bracket and sex, which can serve as a reference for a regional population, would be extremely useful as much for public information purposes as for long-term epidemiological monitoring, particular following a significant discharge into the environment from a BNI;

**Recommends that research be taken further concerning:**

- the long-term effects of exposure to ionising radiation during early childhood, in order to clarify this risk and study the relationship between the dose received and the effect observed. These studies must be carried out following an internationally recognised protocol so that studies published in several different countries can be compared;
- the knowledge of other cancer risk factors in order to better identify the effects due to radiation;
- the role of genetics, epigenetics and *in utero* exposure in radiation-induced cancers;

**and over and beyond the research subjects to be taken further, recommends:**

- supporting the existing registries and encouraging collaboration between the persons responsible for the registries and the persons involved in the epidemiological studies.
- encouraging syntheses that allow the acquired knowledge to be regularly assessed;
- examining the appropriateness and feasibility of putting in place a national registry of adult cancers.

**5 – With regard to the socio-economic consequences of a nuclear accident, ASN:****Points out that:**

- the prospective socio-economic assessment of the consequences of a nuclear accident provides decision-makers with useful information for managing the post-accident phase;
- multidisciplinary research into the socio-economic consequences of a nuclear accident is in progress;

**Considers that:**

- questions still remain on the hypotheses and models to take into consideration to estimate the socio-economic consequences of a nuclear accident, particularly regarding the remediation strategies and the consideration of risk aversion;
- strong cooperation is required between the BNI licensees, the nuclear risk assessment experts, the emergency situation preparedness and management and post-accident management teams and the economy and insurance experts in order to pool their knowledge to assess the socio-economic consequences of a nuclear accident;
- the international work must continue and it would be worthwhile organising a seminar in four or five years' time to review the progress made in this area;

**Recommends that research be taken further concerning:**

- the medium- and long-term socio-economic consequences of past nuclear accidents by collecting and analysing the necessary data;
- the methodology for assessing the socio-economic consequences of a nuclear accident through, for example, a call for research project proposals;
- consideration of the individual or collective perception of and aversion to risks, in addition to the deterministic and probabilistic approaches used in the safety case;

- the nuclear risk insurance mechanisms and the associated indemnification, more specifically how risk aversion is taken into account in the economic evaluation of the cost of an accident, and the distribution of insurance cover between the licensee, the State concerned and the international community in the event of a nuclear accident.

Done in Montrouge, 4th May 2018.

The ASN Commission,

Signed by

Pierre-Franck CHEVET

Sylvie CADET-MERCIER   Philippe CHAUMET-RIFFAUD   Lydie EVRARD   Margot TIRMARCHE