Guide concerning the health monitoring and the management of health risks linked to the presence of radon in water intended for human consumption

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Health monitoring of the radiological quality of water intended for human consumption: the case of radon

National regulations define the nature and frequency of the health monitoring of the quality of water intended for human consumption (WIHC). The monitoring programmes implemented by the Regional Health Agencies (ARS), pursuant to the provisions of European directive 98/83/CE on the quality of WIHC and the Public Health Code, concern microbiological, physico-chemical and radiological parameters. They are a means of ensuring that the waters are in compliance with the regulation quality requirements and represent no health risk for the consumers.

With regard to radioactivity in WIHC, circular DGS/EA4/2007/232 of 3rd June 2007 [1] specifies the methods for monitoring and managing the health risk linked to the presence of radionuclides in the water supplied by a mains distribution network.

Council directive 2013/51/Euratom of 22nd October 2013 [2] introduced new provisions on this subject, transposed into national law at the end of 2015, more particularly with regard to the radon present in WIHC (indicative value, frequency for monitoring).

Radon, an odourless, colourless and inert gas, is naturally present in the atmosphere and in the soil, more so in granitic and volcanic subsoils. For the French population, it is the leading source of exposure to ionising radiation of natural origin. The exposure routes for ionising radiation of natural origin are primarily inhalation (1.43 mSv/year on average, mainly by radon[1]) then ingestion by the consumption of water and foodstuffs (0.55 mSv/year on average, excluding radon) [3].

The first part of this report describes the scope of the above-mentioned Euratom directive and the potential health effects linked to radon. The second part of the report concerns the organisation of health monitoring for measuring radon in WIHC. Finally, the third and fourth parts present methods for managing situations in which the radon quality reference is exceeded in WIHC, as well as for informing the population.

1 Indicator of radiological quality of water for radon

1.1 Scope of the directive 2013/51/Euratom

The Council directive 2013/51/Euratom of 22 October 2013 [2] sets out requirements for the protection of the health of the population with regard to radioactive substances in water intended for human consumption (WIHC). This directive on the one hand concerns the waters supplied by a distribution network and, on the other, bottled spring waters and waters made drinkable by treatment (=table waters).

[1] Annual mean effective dose calculated by the French Institute for Radiological Protection and Nuclear Safety based on the coefficients of the International Commission on Radiological Protection dating from 1993 (publication n°65).

It sets parametric values (indicative values) for radon, tritium and the indicative dose[2] along with an obligation for monitoring of radioactive substances in WIHC. The directive makes provision for the possible adaptation of the frequency of these checks to the actual situations observed (more frequent or less frequent searches for radon as part of the WIHC health monitoring process).

With regard to this directive and the legislative and regulatory provisions already implemented nationally for monitoring the radiological quality of WIHC, **the main change for France concerns the radon parameter, with the definition of a quality reference and methods for checking this parameter**.

For radon, the directive sets a parametric value of 100 Bq/L. The Member States are however granted a degree of flexibility in choosing the level not to be exceeded and below which optimisation of protection should be continued, provided that this remains lower than 1,000 Bq/L.

The French texts transposing the radon provisions of directive 2013/51/Euratom are:

- the order of 9 December 2015 setting out the methods for measuring radon in water intended for human consumption, including in bottled waters, with the exception of natural mineral waters, and in waters used in any food-production undertaking which do not come from a public distribution system, within the framework of the health monitoring system, implemented pursuant to articles R. 1321-10, R. 1321-15 and R. 1321-16 of the Public Health Code [5];
- the order of 9 December 2015 modifying several orders[3] concerning water intended for human consumption implemented pursuant to articles R. 1321-2, R. 1321-3, R. 1321-7, R. 1321-20, R. 1321-21 and R. 1321-38 of the Public Health Code [6];
- the order of 9 December 2015 modifying the order of 14th March 2007 concerning the quality criteria for bottled waters, the specific processing and labelling of bottled natural mineral and spring waters, as well as natural mineral water distributed by a public fountain [7];

1.2 Health effects linked to radon and methods for setting the quality reference

Since 1987, radon-222 (hereinafter referred to as "radon") has been recognised as a certain pulmonary carcinogen for humans by the International Agency for Research on Cancer (IARC – classification group I). This classification is primarily based on epidemiological studies and the monitoring of cohorts of workers exposed to radon *via* inhalation. Radon is the number two known risk factor in lung cancer –

[2] The indicative dose (ID), previously called total indicative dose (TID), is defined in 1 of article 2 of the order of 12th May 2004, amended [4]. The ID corresponds to the committed effective dose received as the result of ingestion, for one year, of all the natural and artificial radionuclides detected in an WIHC, excluding tritium, potassium-40, radon and its short-lived decay products. The dose is calculated for adults on the basis of the consumption of 730 litres of water per year (that is 2 litres of water per day).

[3] Order of 17 September 2003 concerning methods for analysing water samples and their performance characteristics; order of 12 May 2004 setting out the methods for monitoring the radiological quality of water intended for human consumption; order of 11 January 2007 concerning the quality limits and quality references for raw waters and water intended for human consumption mentioned in articles R. 1321-2, R. 1321-3, R. 1321-7 and R. 1321-38 of the Public Health Code and the order of 22 October 2013 concerning health monitoring analyses and surveillance of bottled waters and natural mineral waters used for therapeutic purposes in a spa or distributed by a public fountain.

after tobacco – with an annual number of deaths attributable to domestic exposure to radon in metropolitan France estimated at between 1,200 and 3,000 [8].

The national regulation, implemented as of 2002, therefore first of all focused on managing the risks linked to radon in the atmosphere, in facilities open to the public ("ERP") and in the workplace [9][10]. It was then extended to new areas, such as WIHC. In the field of water, surveys conducted in the Member States of the European Union locally identified high radon activity concentration levels (hereinafter called "concentrations") [11][12]. This related to groundwater resources in areas where high radon activity concentrations had already been identified in buildings as a result of the type of subsoil. This phenomenon can be explained by the passage of radon through the pores in the soil and sub-soil, from the grains of minerals in which it is produced by decay of radium (itself part of the decay chain of uranium-238). When the soil or sub-soil pores are saturated with water, the radon dissolves in the water which then transports it, sometimes over long distances.

In the current state of knowledge, the health risk as a result of ingesting water containing radon is invoked solely on the basis of dosimetry considerations, which rely on theoretical calculations. The dosimetry estimates available indicate that the health risk linked to the ingestion of radon is slight; the corresponding estimated doses remain below or approximately the same as those received from exposure to other sources of naturally occurring ionising radiation [11].

The epidemiological studies available didn't demonstrate conclusive link between the consumption of water containing radon and the increased risk of stomach cancer or any other type of cancer [13][14]. Furthermore, no animal studies have been carried out to examine the risk of cancer linked to exposure to radon through ingestion. Furthermore, there is not as yet any consensus on the part of the scientific community regarding a dose coefficient value and the European regulations set no value for this.

In the absence of any scientific data to justify the adoption of a higher value, as permitted by the European directive, the decision was taken – in accordance with the opinion from the French Institute for Radiological Protection and Nuclear Safety (IRSN) issued on 31st December 2014 [15] and the opinion from the French Nuclear Safety Authority (ASN) issued on 1st March 2016 [16] – to set the quality reference for radon in the national regulations at 100 Bq/L, a value which, if exceeded, can lead to the implementation of corrective measures pursuant to article R. 1321-28 of the Public Health Code (see Chapter 3).

2 Organisation of radon health monitoring in WIHC

The search for radon in WIHC only concerns water of groundwater origin, in accordance with article 1 of the order of 9 December 2015 setting the radon measurement methods [5]. Waters of surface origin covered by article R. 1321-37 of the Public Health Code are not concerned (water courses, rivers, canals, lakes, ponds).

2.1 Notion of "reference radiological analysis"

The radon analysis is now included in the reference radiological analysis defined by the modified order of 12th May 2004 [4].

For new water production and distribution systems, the entire reference radiological analysis must be enclosed with the authorization application file, pursuant to articles L. 1321-6 and R. 1321-7 of the Public Health Code and the order of 20th June 2007 concerning the contents of the application file for authorization of WIHC use [17].

For existing water production and distribution systems authorized under article L.1321-7 of the Public Health Code, **the first radon analysis carried out on the water of the resource or at the source for bottled waters (except mineral waters) shall be considered to be the reference analysis.**

Given the monitoring frequency (see Chapter 2.3), **it is recommended that the first radon measurement be taken:**

- **for production/distribution systems supplying fewer than 500 inhabitants, no later than 31st December 2020;**
- **for production/distribution systems supplying more than 500 inhabitants, no later than 31st December 2019;**
- **for bottled waters, no later than 31st December 2019;**
- **for waters used in a food-production undertaking and which do not come from a public distribution network, no later than 31st December 2019.**

2.2 Radon monitoring strategy within the framework of WIHC health monitoring

In its recommendation of 20th December 2001 [11], the European Commission stressed that within the framework of the system for monitoring radon in WIHC, attention should concentrate on the highest exposures and on those areas where action is most likely to be effective. To date, the order of 22nd July 2004 concerning methods for managing the radon risk in premises open to the public [9] defines the priority *départements* around the country for measuring the radon activity concentration in the air for ERPs and workplaces. These regulatory provisions should move towards the implementation of a classification of *communes* according to their radon potential, on the basis of the IRSN's work [18].

The order of 9th December 2015 [5] sets the water sampling and radon analysis frequencies for WIHC. However, the frequency of water sampling and radon analysis can be increased by the Director General of the ARS in the conditions set out in article R. 1321-16 of the Public Health Code (article 4.I of the order of 9th December 2015 [5]). Conversely, the Director General of the ARS may reduce the frequency, or even eliminate the radon measurement from the health monitoring, when radon is not likely to be present in the water in concentrations which could exceed the quality reference of 100 Bq/L (article 4.II of the order of 9th December 2015 [5]).

Owing to possible measurement uncertainties, linked to the water sampling and analysis conditions (see Chapter 2.4), and the possible variations over time of the radon concentration in water, a reliable check on compliance with the quality reference cannot be based solely on an analytical result. A specific monitoring strategy must therefore be implemented within the framework of WIHC health monitoring, differentiating between two phases:

1/ a preliminary, or investigation phase, which includes the reference radiological analysis;
2/ periodic health monitoring carried out at regulated or appropriate frequencies.

For the waters supplied from a distribution network and for waters used in food-production undertaking which do not come from a distribution network, the monitoring strategy proposed in

Appendix 2 is based notably on the results of the radon analyses carried out during the investigation phase, which then lead either to periodic monitoring of radon in water, or not. During the investigation phase, the search for radon in water may be repeated, at different hydrogeological periods, at the resource and at the point of distribution. When compared with the quality reference, the results of the periodic monitoring are used to determine the resulting preventive and corrective measures.

The results of the IRSN study currently under way on the temporal fluctuations of the radon concentrations (resource and drinking water), as well as feedback from the ARS, could in the future lead to adjustment of the strategy for health monitoring of radon in the water supplied from a distribution network.

For bottled waters (except for natural mineral waters), the monitoring strategy proposed, which is similar to that for water supplied from a distribution network, is given in Appendix 3.

2.3 Procedures for health monitoring of radon

2.3.1 Water supplied from a distribution network

The quality reference of 100 Bq/L must be complied with at the tap(s) normally used by the consumer (point of compliance as defined in article R. 1321-5 of the Public Health Code). However, in accordance with the note in table 1 of appendix 1 to the order of 9th December 2015 [5], water samples can be taken (see Annexe 4):

- from the resource (raw water),
- from the distribution point.

In accordance with the order of 11th January 2007, modified, concerning the programme of health monitoring samples and analyses for waters supplied by a mains distribution network [19]**, the other radioactivity analysis are carried out at the distribution points** (type P2 analyses). **For reasons of sample representativeness and ease of use, it is highly recommended that the periodic radon monitoring be carried out at this same point (for waters originating from groundwater and for mixtures of groundwater and surface waters)**. As the radon concentration in water can only decrease as it passes through the water distribution network, **if the quality reference is met at this point, it will also be met at the point of compliance (that is at the consumer's tap).**

The water sampling and radon analysis frequencies for the WIHC supplied from a distribution network are set out in table 1 of appendix 1 to the order of 9th December 2015 [5] and taken up in table A of Appendix 5 of this report. For the analysis carried out at the distribution point, the water flow rate recommended for setting the health monitoring frequencies (periodic monitoring) is the average daily flow rate. The checks are preferably carried out at different times of year, for example in different quarters, in order to obtain a more representative picture of the radon concentration in water over a period of time.

The water sampling and analysis programmes could be modified in the conditions specified in Chapter 2.2 and Appendix 2.

2.3.2 Waters used in food-production undertaking which do not come from a distribution network

The order of 9th December 2015 [5] sets the methods for organising the health monitoring of radon in water originating from groundwater and which does not come from the distribution network and which is used by food-production undertaking.

The quality reference of 100 Bq/L must be met at those points where the water is used in the undertaking (point of compliance, article R. 1321-5 of the Public Health Code). However, in accordance with the note in table 2 of appendix 1 to the order of 9th December 2015 [5], water samples can be taken from the resource. The distribution of samples between the various points of check is determined by the Director General of the ARS according to the potential dangers identified.

With regard to the periodic checks, the water sampling and radon analysis frequencies are set out in table 2 of Appendix 1 to the order of 9th December 2015 [5] (see table B of Appendix 5 to this report). The frequencies of the radon checks are identical to the check frequencies in the complementary analysis programme (C) set out in the order of 11th January 2007 concerning the programme of health monitoring sampling and analysis for waters used in a food-production undertaking and which do not come from a public distribution network [20].

2.3.3 Bottled waters, excluding natural mineral waters

The order of 22nd October 2013 concerning health monitoring analyses and surveillance of bottled waters and natural mineral waters used for therapeutic purposes in a spa or distributed by a public fountain [52] and part III of appendix 1 to the order of 9th December 2015 [5] make provision for an initial mandatory radon analysis at the sources for spring waters and for groundwaters made drinkable by treatment, followed by a radon search every 5 years.

During the periodic checks, any analysis are performed on the bottled water (article 3 of the order of 9th December 2015 [5]), sampled from the bottling line, in order to take account of any outgassing of radon during the bottling of the water.

The water sampling and analysis programmes could be modified in the conditions specified in Chapter 2.2 and Appendix 3.

2.4 Methods of sampling, transporting, conserving water samples and performance characteristics of radon analysis

2.4.1 Approval of laboratories for health monitoring of radon in water

The order of 5th July 2016 concerning the conditions for approval of laboratories to take samples and carry out health monitoring analysis of water [22] more specifically defines the laboratory approval conditions for radon analysis.

Until 31st December 2019, the laboratories need only demonstrate their technical capability for taking the measurements in accordance with the standards in force and using a method for which there is a validation file drawn up by this laboratory (article 7-II of the order of 5th July 2016 [22]). As of 1st January 2020, the laboratories wishing to be approved for radon analysis health monitoring of water, will need to be accredited and have taken part in inter-laboratory tests.

2.4.2 Sampling, transport and conservation of water samples

Unlike for the physico-chemical parameters, there is no specific approval with regard to the sampling of WIHC for radon analysis, yet sampling and transport can have a significant impact on the integrity of the water sample. However, a standard for radon measurement in water exists and includes general specifications for sampling, packaging and transporting of water samples for radon analysis (standard NF ISO 13164-1).

The ARS will request the following from the approved laboratory(ies) responsible for water sampling and radon measurement in WIHC, for the purposes of health monitoring.

- Sampling

This shall be carried out in accordance with standards NF EN ISO 5667-1 and NF EN ISO 5667-3 [23] (cf. Annexe 6). It shall be performed in such a way as to minimise exchanges with the atmosphere, to maintain the radon in solution in the water sample and limit the risk of the sample being exposed to outside contamination.

- Flasks

The tightness of the flasks used is a major criterion in the quality of sampling. The containers used are made of a material that is not porous to radon. Aluminium flasks are generally used. They shall be equipped with leaktight closure systems, the integrity of which shall be checked prior to sampling of the water and then immediately afterwards. This verification is a means of determining, on the site, whether or not a further water sample needs to be taken.

- Sampling methods

For water samples taken directly from a tap (or from the discharge point for a resource), the sampling flow must not be too high in order to minimise turbulence on leaving the tap and on the walls of the container, which could promote outgassing of the radon. In addition, the water sampled must in general be representative of the water distributed or the water from the resource; flushing may therefore be needed depending on the configuration of the network supplying the sampling tap (the water sampled must not have stagnated).

For samples taken from the water resource, it is also necessary to check that at the moment of sampling, the water pump in the well is functioning and has ideally been functioning for the past 2 hours.

For sampling points with no tap (running water, storage tank), water samples are taken by gradually immersing the flask in the water, so that the water flows gently along the walls without creating turbulence.

Depending on the radon analysis techniques used, double samples may sometimes be taken.

- Conservation

The water samples are kept cool until analysed in the laboratory. The sample transport and conservation temperature shall be lower than that of the water at the time of filling of the flask, while remaining higher than 0°C.

- Transport

The containers shall be protected and packaged such as to avoid any exchange between the sample and the outside atmosphere, in particular any leakage as a result of opening during transport, thus guaranteeing the integrity of the water sample up to the analysis laboratory.

- Beginning of analysis

Given the short radioactive half-life of radon (T = 3.8 days), the samples must be rapidly transmitted to the laboratory so that the activity concentration of the radon at the time of sampling can be accurately quantified: **the time between the end of sampling and the analysis must thus be as short as possible (ideally less than 48 hours), notably for water samples in which the radon activity is liable to be close to the detection limits**.

2.4.3 Methods for analysing radon in water

Standardised analysis methods for the radon activity concentration in the water samples are needed for laboratories carrying out these measurements. There are two categories of analysis methods:

- Gamma-ray spectrometry measurement without preparation of the sample: this method is based on determining the activity of one of the decay products of radon, bismuth-214;
- measurement involving transfer of the radon from the aqueous phase to another phase before taking the measurement (emanometry, liquid scintillation, permeation).

The usual measurement uncertainties are about 25% for a radon concentration in the water of 100 Bq/L.

The order of 19th October 2017 concerning the analysis methods used for the health monitoring of waters [23] sets the radon detection limit for the analysis method used at 10 Bq/L.

For routine measurements requiring no preparation of the sample, the two main analysis techniques used by the analysis laboratories are gamma spectrometry and liquid scintillation (see Appendix 6).

3 Management of situations in which the radon quality reference is exceeded for water supplied from a distribution network

3.1 Background information

Given the current state of knowledge, it is estimated that ingesting water containing radon represents a low risk for human health (see Chapter 1.2). To date, the risk associated with domestic exposure to radon is primarily that of lung cancer through exposure by inhalation, regardless of the route through which radon enters the home: via the building itself or via outgassing[4] from tap water[5].

The increases in radon concentration in the air owing to water being drawn from the tap are occasional and local (bathroom, laundry, kitchen) and often have no effect on the home as a whole. However, even though outgassing of radon from the water to the air can be locally significant (in a shower for example), the exposure times are limited and normally concern spaces that are ventilated naturally or by means of air extraction systems.

Radon can build up in poorly ventilated and enclosed spaces. Simple measures, such as airing-out daily, reduce the radon concentration in buildings.

As underlined by the European Commission in 2001 [11], the management measures taken to deal with the radon risk must be accompanied by adequate information of the population to improve the mitigation of exposure and to raise the awareness of the populations to the health risks associated with radon.

This approach is part of a broader information programme implemented as part of the national radon risk management plans, the national plan 2016-2019 having identified the first priority as being to define a strategy of information and awareness-raising among the public and the stakeholders concerned [25]. Moreover, Council directive 2013/59/Euratom of 5th December 2013 [26] gives a regulatory dimension to the national radon risk management plan. The 3rd national health-environment plan [27] also comprises actions (actions 4 to 7) which aim to ensure that the radon risk in buildings is better taken into account. Finally, radon has also been introduced into the scope of the indoor air quality management system, with it notably being mandatory to inform buyers and tenants of property about the radon-related health risks in homes[6].

3.2 Management principles and approach

With regard to radiation protection, the level of exposure of population to ionising radiation must be kept as low as reasonably achievable, given the current state of technology and economic and social factors (optimisation principle).

In addition *"any decisions to stake steps to (...) prevent or mitigate a risk linked to exposure to a natural source of ionising radiation must be justified, in that they must offer more advantages than drawbacks"* (article L.1333-3 of the Public Health Code) (justification principle).

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[4] Outgassing is the process whereby dissolved radon passes into the air, owing to the pressure difference between the water in the pipes and the atmospheric pressure. The radon thus emitted is added to the radon present in the ambient air emitted by the ground on which the home is built.

[5] There is no simple method for determining the contribution of the radon present in water to the activity concentration of radon in the air. However, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) considers that a value of 10 Bq/L of radon in drinking water would lead to an increase in the radon concentration in the indoor air of a building of about 1 Bq/m^3 [24].

[6] System introduced by Act 2016-41 of 26th January 2016 modernising our health system and Ordinance 2016-128 of 10th February 2016 introducing various measures concerning nuclear activities.

The methods for management of situations in which the radon quality reference is exceeded in WIHC must be based on these two principles. When a remedial action to reduce exposure to radon in water is envisaged, the following must be considered:

- **the expected benefit as opposed to the potential drawbacks (for example: the use of radioactivity treatment is liable to produce waste, risk of exposure of workers, etc.),**
- **the cost and difficulties involved in implementing this action to reduce the radon concentration in water.**

With regard to management of the health risk in the case of the quality references set by the regulations for tritium or the indicative dose or guideline values for gross alpha activity or residual beta activity being exceeded, the ARS base on the circular DGS/EA4/2007/232 of 3rd June 2007 concerning the monitoring and management of the health risk linked to the presence of radionuclides in WIHC [1], itself based on ASN recommendations (deliberation 2007-DL-003 of 7th March 2007 [28]).

Similarly, management measures (ban or restrictions in use) and population information to be disseminated when the radon quality reference is exceeded should be defined.

3.3 Methods for management of situations in which the quality reference is exceeded for water supplied from a distribution network

Two values are adopted for managing situations in which the quality reference for radon dissolved in WIHC is exceeded:

- 100 Bq/L;
- 1,000 Bq/L;

When the concentration of radon in the water is below 100 Bq/L, no specific action is to be taken. Specific information of the population is not needed.

If it is confirmed that the quality reference has been exceeded (several non-compliance analysis), the steps taken by the ARS and the water supplier shall be proportionate, notably according to their technico-economic feasibility and shall be graded according to the radon concentration levels measured. The management methods, defined according to the two levels (radon concentration between 100 and 1,000 Bq/L or greater than 1,000 Bq/L) are based on this graded action.

As previously mentioned, in its recommendation of 20th December 2001 [11], the European Commission underlines that within the framework of radon monitoring in WIHC, attention should concentrate on the highest exposures and on those areas where action is most likely to be effective.

The need to inform the populations varies according to the radon concentrations in WIHC and in relation to the values selected for managing situations in which the quality reference is exceeded (100 Bq/L and 1,000 Bq/L). In the case of information delivered to the consumers, it would appear to be pertinent to position it in the context of the radon health risk as a whole. Recommendations concerning correct ventilation of the premises concerned (bathroom, laundry, kitchen) could be issued. This perspective is all the more important when it is not recommended to drink tap water.

If radon is present in the water, it is inadvisable to treat the WIHC in the home, owing to the possible transfer of the radon from the water to the indoor air through outgassing.

In areas with significant radon potential, people's attention will be drawn to the fact that water from private wells could be contaminated by radon (this information could be distributed in the same way as information about the management of domestic radon in air).

The methods for managing situations in which radon quality reference levels are exceeded are detailed below and summarised in Appendix 7.

3.3.1 Concentration of radon in water between 100 and 1,000 Bq/L

As defined by the regulations, the value of 100 Bq/L is a quality reference and not a quality limit, but it does constitute a target value. Exceeding this value constitutes an alert, albeit with no urgency, provided that the concentration of radon in the water remains below 1,000 Bq/L.

Investigation is required once the concentration of radon in the water exceeds 100 Bq/L, possibly with the implementation of measures with respect to the local context and aspects derived from the optimisation and proportionality principles.

In line with the principle of the graded approach, this examination shall be carried out by the water supplier all the more rapidly as the radon concentration approaches the 1,000 Bq/L level.

If the quality reference is exceeded, but remains below 1,000 Bq/L, there is no urgent need to impose restrictions in use or specific treatment.

However, once the concentration of radon in the water exceeds the reference level of 100 Bq/L, the water supplier shall, on a case by case basis, examine the means available for reducing the concentration of radon in the water (technico-economic study, estimated schedule of performance of the remedial actions proposed if necessary, etc.), with the urgency of these measures increasing the closer the concentration of radon dissolved in the water comes to 1,000 Bq/L.

For drinking water supplies situated in a zone with a significant radon potential [18], the analysis bulletins posted in the town hall and, as applicable, the annual water quality summary report, include information about management of the radon risk as a whole (exposure via water and via air). This information is optional for drinking water supplies located outside these zones. In general, restrictions in use would not appear to be warranted.

3.3.2 Concentration of radon in water in excess of 1,000 Bq/L

If the level of 1,000 Bq/L is exceeded:

- the water supplier initiates urgent and immediate corrective measures in order to obtain a concentration of radon in the water of below 1,000 Bq/L as rapidly as possible and to return to management as described in point 3.3.1; the ARS will ensure that the implementation schedule for the corrective measures to be taken by the water supplier is reasonable and is met;

- it is inadvisable to drink the tap water on a regular basis, in particular if the information provided by the water supplier indicates that this excess level could persist;
- however, there is no need to limit the use of water for bathing and for brushing teeth;
- there is no need to limit the use of water for food preparation (including soups, coffee, tea, etc.) owing to the outgassing that takes place during preparation (cooking, boiling, etc.);
- recommendations concerning the correct ventilation of the premises and regular upkeep of any ventilation systems could be provided (health risk linked to radon in general);
- the attention of private persons will be drawn to the fact that the water in private wells can also be contaminated by radon, especially if located in a zone with a significant radon potential.

The consumers are immediately and systematically informed by the water supplier jointly with the ARS (article R. 1321-30 of the Public Health Code). This information will include information and recommendations to consumers appearing in Appendix 8, as well as information about the remedial actions being envisaged by the water supplier to improve the quality of the water and their implementation schedule.

3.4 Methods for managing levels in excess of the quality reference for waters used in food-production undertaking which do not come from a distribution network

If the quality reference is exceeded but remains below 1,000 Bq/L, there is no need to impose restriction in use or specific treatment.

If the 1,000 Bq/L level is exceeded, there would appear to be no justification for systematic imposition of restrictions in use, given the behaviour of radon in water (outgassing, short half-life). However, pursuant to the European regulations concerning food hygiene (known as the "Hygiene Package"[7]), the food-production undertaking manager is required to conduct a risk assessment to evaluate the consequences for the safety of the food end-product of using this water in the process.

3.5 Technical solutions available

The purpose of the techniques used to reduce the concentration of radon in WIHC is to reduce the exposure of persons through the ingestion of the radon dissolved in the water, on the one hand, and through inhalation of radon outgassed into the indoor air of homes, on the other.

There are various techniques (see Annexe 9, [15]). The most appropriate technique would appear to be ventilation, whether or not forced (radon outgassing).

[7] In particular Regulation 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety; Regulation 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs; Regulation 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin.

When deployed, these technical solutions must be put into place as far upstream as possible on the distribution network, as the consumers should not have to carry out management actions themselves (see Chapter 3.3). These treatments could lead to worker exposure to radon; the evaluation and, as applicable, the monitoring of the occupational exposure of these workers, are the responsibility of their employer.

In addition, the means used to reduce exposure to radon via drinking water shall be proportionate. It should also be recalled that the benefits of any technical solution implemented to reduce the concentration of radon in WIHC must outweigh any risks.

Diluting with water with a lower radon concentration is also a means of reducing the radon concentration in the water supplied from a distribution network.

4 Managing levels in excess of the quality reference for bottled waters, excluding natural mineral waters

The management principles and approaches to be adopted are the same as for waters supplied from a distribution network. However, unlike in this latter case, few radon measurements have already been taken at the sources or in the bottled waters.

When producing the radiological quality report for bottled waters produced in France, IRSN carried out radon analysis of several waters packaged in glass bottles (one spring water and four natural mineral waters) [29]. Radon was only quantified in the spring water, with the radon concentration measured being 5.9 Bq/L. To date, no other specific national data have been identified.

As this information is currently insufficient to establish detailed management measures if the quality reference is exceeded for bottled spring waters and waters made drinkable by treatment, the following approach is adopted:

- performance of a radon analysis at the source for all the waters concerned, no later than 31st December 2019, with implementation of the approach proposed in Appendix 3;
- production of a report by the General Directorate for Health during the course of 2020 in order to define any specific management methods needed.

Appendices

Appendix 1: Reference text and documents

[1] Circular DGS/EA4/2007/232 of 3rd June 2007 on the monitoring and management of the health risk linked to the presence of radionuclides in water intended for human consumption, with the exception of bottled waters and natural mineral waters

[2] Council directive 2013/51/Euratom of 22 October 2013 laying down requirements for the protection of the health of the general public with regard to radioactive substances in water intended for human consumption

[3] IRSN Report 2015-00001 "Exposure of the French population to ionising radiation".

[4] Order of 12th May 2004 as amended, laying down conditions for the monitoring of the radiological quality of water intended for human consumption.

[5] Order of 9th December 2015 laying down methods for measuring radon in water intended for human consumption, including bottled waters, with the exception of natural mineral waters, and in waters used in any food-production undertaking which do not come from a public distribution system, within the framework of the health monitoring system, implemented pursuant to articles R. 1321-10, R. 1321-15 and R. 1321-16 of the Public Health Code

[6] Order of 9th December 2015 modifying several orders concerning water intended for human consumption implemented pursuant to articles R. 1321-2, R. 1321-3, R. 1321-7, R. 1321-20, R. 1321-21 and R. 1321-38 of the Public Health Code

[7] Order of 9th December 2015 modifying the order of 14th March 2007 concerning the quality criteria for bottled waters, the processing and specific labelling of bottled natural mineral and spring waters and natural mineral water distributed by a public fountain

[8] Catelinois O. *et al.*, "Evaluation de l'impact sanitaire de l'exposition domestique au radon en France" *(Assessment of the health impact of domestic exposure to radon in France)* BEH 2007.

[9] Order of 22nd July 2004 concerning management of the risk related to radon in premises open to the public

[10] Order of 7th August 2008 concerning management of the risk related to radon in the workplace

[11] Commission recommendation of 20 December 2001 on the protection of the public against exposure to radon in drinking water supplies (OJ, 28th December 2001, L 344/85)

[12] Results of the 2011-2015 national action plan for management of the radon risk

[13] Laurent O. *et al.*, Conséquences dosimétriques et sanitaires de l'ingestion de radon *via* l'eau de boisson (*Dosimetric and health consequences of ingesting radon via drinking water*), Radioprotection 2010, vol. 45, n°4, pages 551 à 559

[14] IRSN information notice "Radon in water - Dosimetric and health consequences of ingesting radon dissolved in drinking water": http://www.irsn.fr/radon

[15] IRSN opinion 2014-00422 of 31st December 2014

[16] ASN opinion 2016-AV-0260 of 1st March 2016

[17] Order of 20th June 2007 concerning the application file for authorization of water intended for human consumption mentioned in articles R. 1321-6 to R. 1321-12 and R. 1321-42 of the Public Health Code

[18] Map of radon potential available from the following address: www.irsn.fr/carte-radon

[19] Order of 11th January 2007 modified concerning the programme of health monitoring sampling and analysis for waters supplied from a distribution network, implemented pursuant to articles R. 1321-10, R. 1321-15 and R. 1321-16 of the Public Health Code

[20] Order of 11th January 2007 concerning the programme of health monitoring sampling and analysis for waters used in any food-production undertaking and which do not come from a public distribution network, implemented pursuant to articles R. 1321-10, R. 1321-15 and R. 1321-16 of the Public Health Code

[21] Order of 22nd October 2013 modified concerning health monitoring analysis and surveillance of bottled waters and natural mineral waters used for therapeutic purposes in a spa or distributed by a public fountain

[22] Order of 5th July 2016 concerning the conditions for approval of laboratories to take samples and carry out health monitoring analyses of water

[23] Order of 19th October 2017 concerning the analysis methods used for the health monitoring of water

[24] Exposure from natural sources of radiation. UNSCEAR 1993 Report, annex A. United Nations, New York. 1993

[25] 2016-2019 National Radon Action Plan (http://solidarites-sante.gouv.fr/sante-et-environnement/batiments/article/plan-national-d-actions-pour-la-gestion-du-risque-lie-au-radon)

[26] Council directive 2013/59/Euratom of 5th December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom

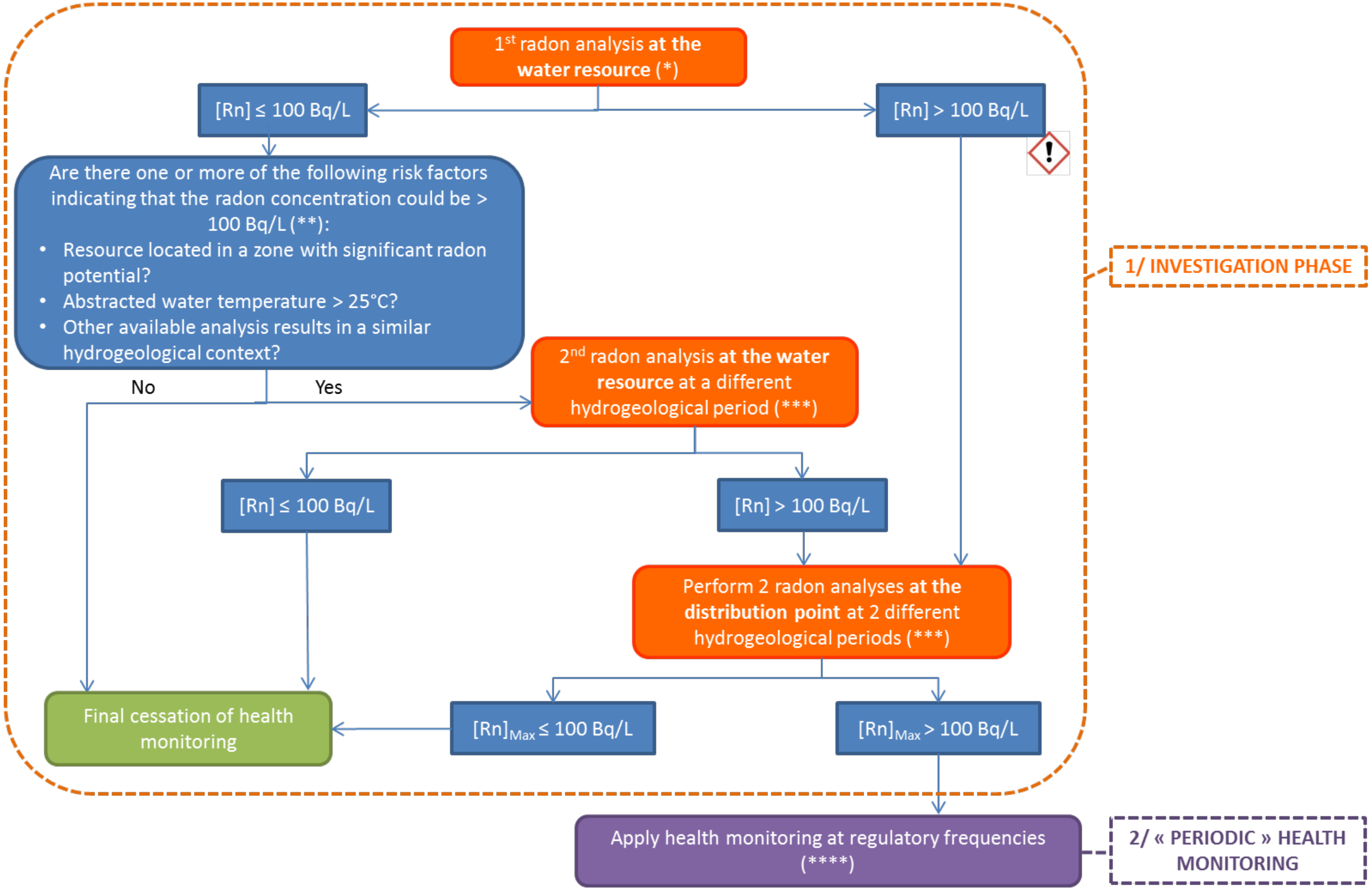
[27] 3rd National Health and Environment Plan 2015-2019 (http://solidarites-sante.gouv.fr/IMG/pdf/pnse3_v_finale.pdf)

[28] ASN Deliberation 2007-DL-003 of 7th March 2007 on the health monitoring of the radiological quality of water intended for human consumption

[29] DGS/ASN/IRSN report on the radiological quality of bottled waters produced in France, September 2013

[30] "The quality of tap water in France, 2013 data", Ministry of Health, 2016 (http://solidarites-sante.gouv.fr/sante-et-environnement/eaux/article/eau-du-robinet)

Appendix 2: Strategy for radon monitoring in water supplied from a distribution network and water not supplied from a distribution network used in a food-production undertaking



<u>(*) First analysis of radon in water:</u>

The 1st analysis is carried out on the resource in order to avoid any effects of treatment and distribution on the radon concentration in the water. In compliance with the regulations, the 1st analysis of the resource may be dispensed with if reliable data on the radon concentration in the water of the resource are available: for example, for a well field (abstraction of water of similar quality), a radon analysis of one of the wells may in certain cases be sufficient for all the wells.

[Rn] > 100 Bq/L

If the radon concentration in the water of the resource is well over 100 Bq/L, the water quality at the distribution point must be rapidly checked and health monitoring must be rapidly implemented on the distribution point at the regulatory frequencies.

<u>(**) Risk factors indicating that the radon concentration in the water could exceed100 Bq/L:</u>

- Resource located in a zone with significant radon potential (zone 3)[18].
- Abstracted water temperature higher than 25°C (except for wells in overseas *départements*); this information gives indirect and partial information on the depth of the well.
- Existence of other analysis results in excess of 100 Bq/L, in a similar hydrogeological context.

<u>(***) Hydrogeological period:</u>

Given the possible variation in the radon concentration in the water as a result of variations in the water table levels, it is recommended that the subsequent analysis (or analyses) be carried out at different hydrogeological periods (high water / low water).

<u>(****) Application of "periodic" health monitoring:</u>

Health monitoring is implemented at the frequencies stipulated in table 1 of appendix 1 to the order of 9th December 2015 [5], at the distribution point. For drinking water supply zones serving more than 5,000 inhabitants, the analyses must be distributed throughout the year; for drinking water supply zones serving fewer than 5,000 inhabitants, the annual analysis shall be performed at an unfavourable period (low water).

In accordance with the legislation, the regulatory health monitoring frequencies can be modified in the following conditions:

- <u>Reduced frequency</u>

The frequency of the water sampling and analysis for health monitoring may be reduced when the radon concentrations of 4 consecutive analyses performed for the purposes of health monitoring are all 100 Bq/L or lower:

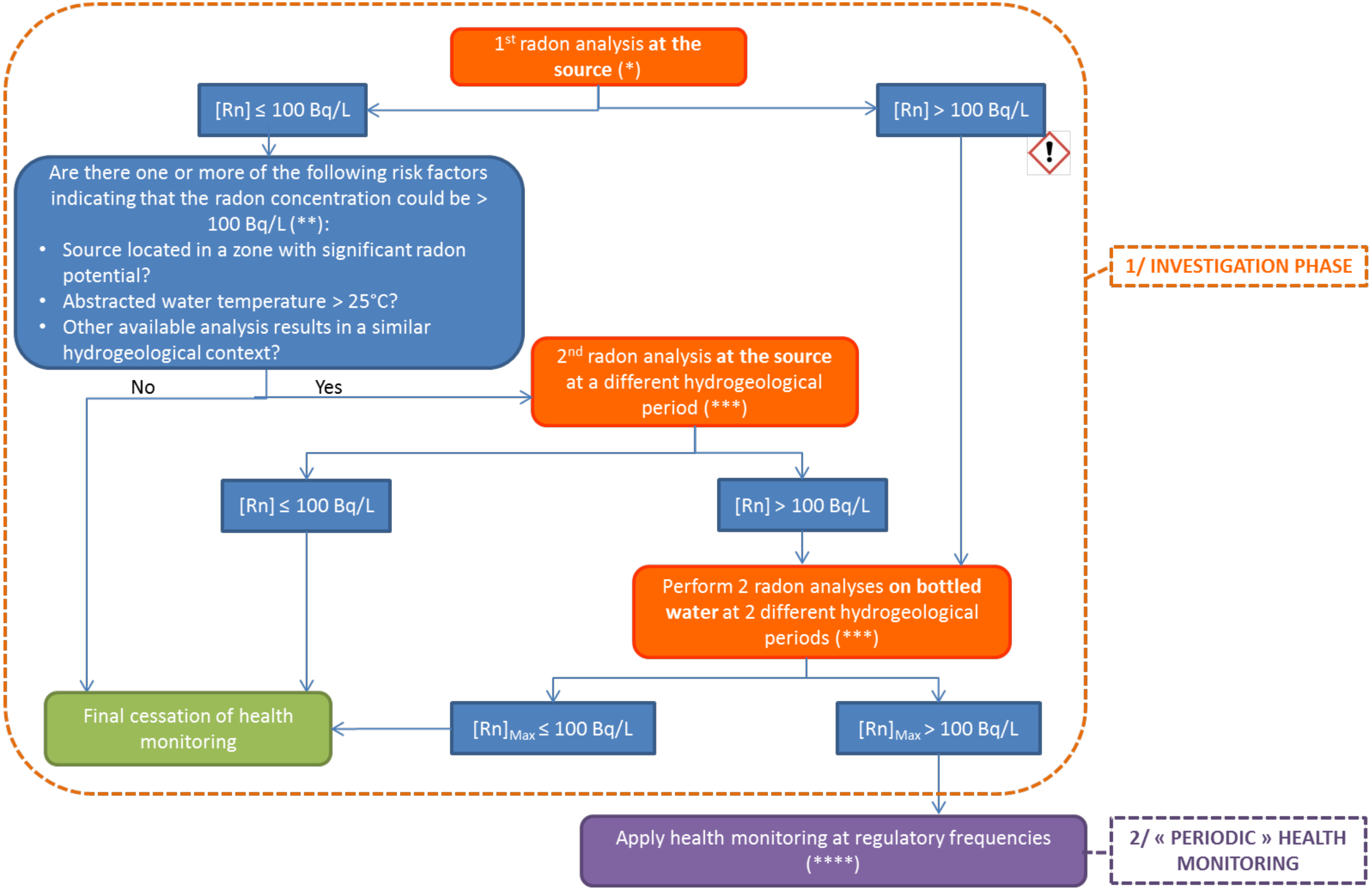
- For drinking water supply zones serving more than 30,000 inhabitants, at least two analyses of radon in water per year should be maintained for “periodic” health monitoring”, to be distributed over two different hydrogeological periods (high water, lower water);
- For drinking water supply zones serving fewer than 30,000 inhabitants, the reduction applied will be assessed by the ARS according to the local situation (scale of past excess levels, management measures implemented, etc.).

If treatment is implemented to reduce the radon concentration in the water, the frequency of water sampling and analysis may be reduced in the above-mentioned conditions. However, health monitoring of radon should at least be maintained to ensure that the treatment is effective.

  - Increased frequency

Any increase in the frequency of water sampling and analysis for health monitoring is at the discretion of the ARS. It may notably be studied when identified groundwater wells are situated in a zone with significant radon potential.

Appendix 3: Monitoring strategy for radon in bottled waters (excluding natural mineral waters)



(*) First analysis of radon in water:

The 1st analysis is carried out at the source in order to avoid any effects of the bottling line on the radon concentration in the water.

[Rn] > 100 Bq/L

If the radon concentration in the water of the source is well over 100 Bq/L, the bottled water quality must be rapidly checked and health monitoring must be rapidly implemented on the bottled water at the regulatory frequencies.

(**) Risk factors indicating that the radon concentration in the water could exceed100 Bq/L:

- Source located in a zone with significant radon potential (zone 3)[18].
- Abstracted water temperature higher than 25°C (except for wells in overseas *départements*); this information gives indirect and partial information on the depth of the well.
- Existence of other analysis results in excess of 100 Bq/L, in a similar hydrogeological context (radon concentration in the bottled water, previous results, results of radon analysis in the water supplied from a public distribution network if of same origin, etc.) ?

(***) Hydrogeological period:

Given the possible variation in the radon concentration in the water as a result of variations in the water table levels, it is recommended that the subsequent analysis (or analyses) be carried out at different hydrogeological periods (high water / low water).

(****) Application of "periodic" health monitoring:

Health monitoring of bottled water is carried out at the frequency stipulated in part III of appendix 1 to the order of 9th December 2015 [5]. The frequency of radon monitoring in bottled water can be increased so that the number of analyses needed can be obtained more rapidly (article 4.II of the order of 9th December 2015 [5]).

In accordance with the legislation, the regulatory health monitoring frequencies can be modified in the following conditions:

- Reduced frequency

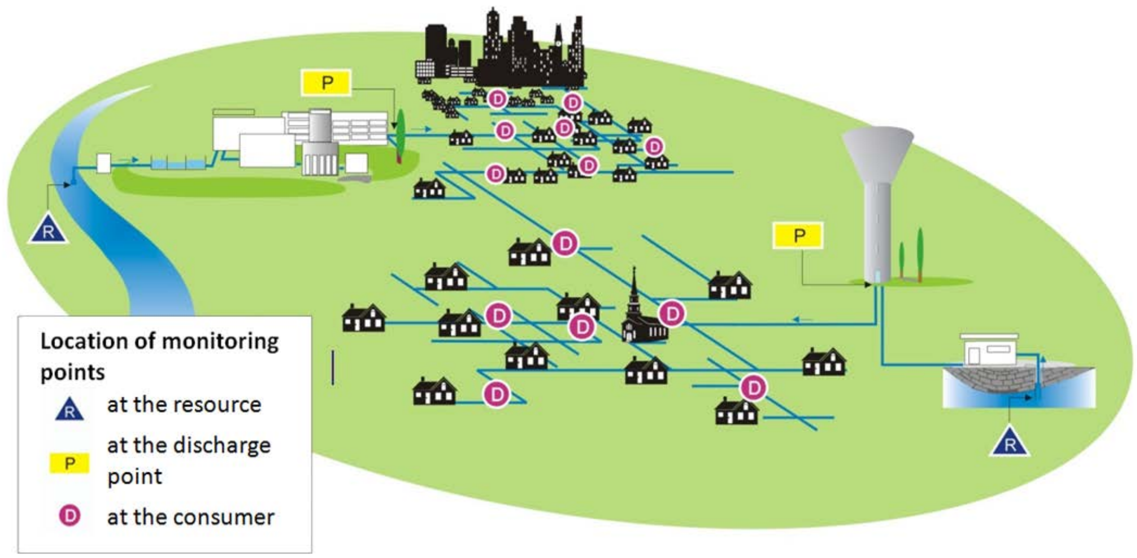
The frequency of the water sampling and analysis for health monitoring may be reduced when the radon concentrations of 4 consecutive analyses performed for the purposes of health monitoring are all strictly below 100 Bq/L. An analysis must be performed at least every 10 years.

- Increased frequency

Any increase in the frequency of water sampling and analysis for health monitoring is at the discretion of the ARS.

Appendix 4: Location of water quality monitoring points

From the "*Quality of tap water in France*" report from the Ministry of Health [29]



▲ At the resource (catchments): monitoring allows evaluation of the quality of the raw water and a check on how it evolves over time. The monitoring frequency depends on the flowrate of the facilities. Certain surface water and ground water may be unusable for the production of drinking water if its quality is too poor.

■ At the distribution point (output from the treatment plant or on the distribution network): monitoring at this level is a means of checking correct management of the treatment facilities and those parameters which do not evolve during distribution or for which the concentration falls during distribution. The frequency of this monitoring depends on the average daily flow rate delivered or on the number of persons supplied.

● At the consumer (consumer's tap): monitoring at this level is a means of verifying compliance with the water quality requirements at the tap and of identifying any deterioration in water quality in the pipes, linked to corrosion phenomena for example. The frequency of this sampling varies according to the population supplied by the distribution network; it should be noted that the parameters analysed at the distribution point are not systematically analysed at the tap, as their concentration does not rise during water transport up to the tap.

Appendix 5: Sampling frequencies of water intended for human consumption

<u>Table A:</u> WIHC supplied from a distribution network (order of 9th December 2015 [5], appendix 1, table 1)

Population served	**Flow rate m^3/day**	**Annual frequency (1)**
0 to 49 inhabitants	0 to 9	0.1
50 to 499 inhabitants	10 to 99	0.2
500 to 1,999 inhabitants	100 to 399	1
2,000 to 4,999 inhabitants	400 to 999	1
5,000 to 14,999 inhabitants	1,000 to 2,999	2
15,000 to 29,999 inhabitants	3,000 to 5,999	2
30,000 to 99,999 inhabitants	6,000 to 19,999	4
100,000 to 149,999 inhabitants	20,000 to 29,999	5
150,000 to 199,999 inhabitants	30,000 to 39,999	6
200,000 to 299,999 inhabitants	40,000 to 59,999	8
300,000 to 499,999 inhabitants	60,000 to 99,999	12
500,000 to 624,999 inhabitants	100,000 to 124,999	12
625,000 inhabitants or more	125,000 or more	12 + 1 for each partial tranche of 25,000 m^3/d of the total volume

(1) Without in any way prejudicing the assessment of compliance with the quality reference at the compliance point mentioned in article R. 1321-5 of the Public Health Code, the water samples may be taken:

- from the resource (raw water);
- at the distribution point: the water quality at this point is considered to be representative of the water quality on the distribution network for a given geographical area, within which water quality may be considered as being uniform, whether the water comes from one or more sources; this network is then called the “drinking water supply zone”;
- from the taps normally used by the consumer.

The water samples shall be taken so that they are representative of the quality of the water (in terms of time throughout the year and geographically).

<u>Table B:</u> Water used in a food-production undertaking which does not come from a distribution network (order of 9th December 2015 [5], appendix 1, table 2)

Flow rate	Annual frequency (1)
≤ 3 m^3/d	0.1
> 3 m^3/d and ≤ 10 m^3/d	0.2
> 10 m^3/d and ≤ 100 m^3/d	0.5
> 100 m^3/d and ≤ 1,000 m^3/d	1
> 1,000 m^3/d and ≤ 1,000 m^3/d	1 + 1 for each partial tranche of 3,300 m^3/d of the total volume
> 10,000 m^3/d and ≤ 100,000 m^3/d	3 + 1 for each partial tranche of 10,000 m^3/d of the total volume
> 100,000 m^3/d	10 + 1 for each partial tranche of 25,000 m^3/d of the total volume

(1) Without in any way prejudicing the assessment of compliance with the quality reference at the compliance point mentioned in article R. 1321-5 of the Public Health Code, the water samples may be taken:

- from the resource;
- at the points where the water is distributed in the company.

The distribution of samples between the various monitoring points is determined by the Director General of the Regional Health Agency according to the dangers identified.

Appendix 6: Normative references

NF ISO 13164-1, Water quality – Radon 222 – Part 1: General principles

NF ISO 13164-2, Water quality – Radon 222 – Part 2: Test method using gamma-ray spectrometry

NF ISO 13164-3, Water quality – Radon 222 – Part 3: Test method using emanometry

NF ISO 13164-4, Water quality – Radon 222 – Part 4: Test method using two-phase liquid scintillation counting

NF EN ISO 5667-1, Water quality – Sampling – Part 1: Guidance on the design of sampling programmes and sampling techniques

NF EN ISO 5667-3, Water quality – Sampling – Part 3: Preservation and handling of water samples

NF EN ISO 10703, Water quality – Determination of the activity concentration of radionuclides – Method by high-resolution gamma-ray spectrometry

NF EN ISO/CEI 17025, General requirements for the competence of testing and calibration laboratories

Appendix 7: The methods for managing situations in which the radon quality reference level is exceeded in water supplied from a distribution network

[Rn] in Bq/L	*Remedial actions*	*Restrictions in use*	*Information*
> 1 000	• Essential and immediate remedial actions	• Advise against drinking tap water regularly (especially if the excess level could persist)	• Immediate information of the population concerning restrictions in use • Specific information about management of the radon risk (health monitoring data sheet with water bill, analysis reports,...) • Reminder of recommendations concerning good ventilation of premises
100 – 1 000	• Investigations needed: case by case examination of means available to reduce the concentration • Implementation based on local context in accordance with the optimisation and proportionality principles (Speed of action: + at 1 000, - at 100)	No	• Information about management of the radon risk as a whole and reminder of recommendations concerning good ventilation of premises (health monitoring data sheet with water bill, analysis reports,...) o for the drinking water supply zones in a zone with significant radon potential o elsewhere: information optional
< 100 = quality reference	No	No	No

Appendix 8: Example of information for the population and recommendations to be given to consumers if the quality reference of 1,000 Bq/L [15] is exceeded

Radon is a radioactive gas of natural origin formed from the radium naturally present in the soil, more so in granitic and volcanic subsoils. Some of the radon formed can accumulate in buildings. As it is soluble, some of the radon that forms in the soil can also dissolve in groundwater.

In the home, radon is therefore a source of exposure to humans through two separate routes:

- inhalation of the radon present in the air (primary route), either originating in the soil, or in the water from which it escapes into the air,
- ingestion of radon present in water.

Radon is a pulmonary carcinogen for humans. To date, the increased risk of lung cancer from radon concentrations in the home is the sole link scientifically proven by epidemiological studies.

Even if the epidemiological studies have not as yet shown any increased risk linked to the ingestion of radon through the consumption of water, it is inadvisable to regularly drink tap water when its concentration of radon dissolved in the water is higher than 1,000 Bq/L, particularly if this situation persists.

Furthermore, a radon concentration in tap water higher than 1,000 Bq/L may indicate the presence of high concentrations of radon in the indoor air of the buildings. Measuring the radon in the indoor air is the only means of determining exposure via the indoor air of the building. Correct ventilation of the premises is also recommended in order to reduce these concentrations and improve the quality of the indoor air as a whole.

Useful link: http://www.irsn.fr/radon

Appendix 9: Technical solutions for treating radon in water

1. Aeration

Aeration consists in "releasing" the radon from the water (outgassing). The radon is then found in the air, which can contribute to an increase in the activity concentration of the radon in the air of water treatment plants or tanks, liable to lead to exposure of the workers. The employer must take account of this phenomenon in its workplace risk assessments. Several options may be possible to reduce this phenomenon, in particular significant ventilation of the premises.

a) Forced aeration or stripping

Stripping consists in passing large quantities of air through columns filled with "Raschig" rings. The flow rate ratio varies from 5 to 40 volumes of air per volume of water (air/water).
This process is used to reduce the carbon dioxide contents (CO_2) in corrosive waters and to reduce the concentrations of volatile compounds (organic micropllutants, H_2S, etc.).

- Advantages
  - Radon is eliminated from water very well.
  - If the oxygen content of the water is not high enough, this technique also enables it to be saturated with oxygen.

- Drawbacks
  - The radon is transferred from the water to the air: Good ventilation of the premises is needed to avoid the radon concentrations in the air from rising, to mitigate worker exposure and guarantee the effectiveness of outgassing.
  - This treatment requires an energy source, which is not always available for the smaller isolated facilities.
  - For air/water volume ratios higher than 5, the carbon dioxide is partially or completely removed from the water, which has the following effects:
    - the pH of the water is 9 or more, which is incompatible with effective disinfection using chlorine or chlorine dioxide. In any case, the pH will have to be corrected.
    - For calcareous bicarbonate waters, the calcium carbonate may precipitate, so the treatment chain must include steps to reduce the risk of scaling (re-acidification of the water for filtration, possible correction of the mineralisation if the water is excessively softened, calcium-carbonate balancing).
    - For waters with low mineralisation, the total elimination of the CO_2 during stripping means that CO_2 must be added to allow remineralisation, so as to ensure good transport of water via the mains distribution network. Remineralisation is either by filtration through a medium consisting of calcium carbonate, or by addition of lime water.
    - A low air temperature can impede this process because the risk of solidification of the water (formation of ice) must not be under-estimated.

b) Weak aeration

This aeration is obtained by cascades at the point where the water reaches the tanks. The loss of CO_2 will be far lower than for stripping (the air/water flow ratios would be about 1).

- Advantages
  - This process can be easily installed. One need simply ensure a sufficient height of water at the first distribution tank.
  - The loss of CO_2 will be small and will not entail any technology change.
  - If the cascade is after the disinfection step, its effectiveness is not compromised.
  - This is a passive treatment involving no risk of human error or mechanical failure.

- Drawbacks
  - Good ventilation of the premises is needed to avoid the radon concentrations in the air from reaching high levels and to mitigate worker exposure.
  - It is essential to run tests to find out the radon elimination rate versus the fall height.
  - It may be necessary to modify the water intakes into the first distribution tanks, in order to create the cascade.
  - Calcareous bicarbonate waters must be slightly corrosive in order to anticipate the slight loss of CO_2 by the cascades (the water distributed must be slightly scaling).
  - The tanks must be ventilated in order to reduce the radon concentration in the ambient air.
  - Treatment may lead to worker exposure to radon. Monitoring the occupational exposure of the workers is the responsibility of the employer.

2. Filtration and adsorption on activated carbon

This process is considered in the literature to be highly effective for the retention of radon in air. The adsorption inhibitors are the organic volatile compounds and the humidity of the air.

This process is nonetheless more costly (purchase and maintenance) than the previous technical solutions and may require worker radiation protection measures. Moreover, it generates some very low level waste (concentration of radon and its decay products on the activated carbon) requiring the use of a specific disposal solution when regenerating the activated carbon.

This treatment also poses a number of problems:

- Adsorption is in fact a balance between adsorption and desorption. As the Henry's constant of radon is high, desorption is extremely fast; the activated carbon could thus reach the adsorption-desorption balance in a very short time (possibly about a month). It is therefore essential to eliminate some of the radon present in water by aeration beforehand.
- As the radon is trapped on the activated carbon, its decay products will also be trapped on the activated carbon (gradual build-up of hydroxides of polonium, lead and bismuth).
- Granulated activated carbon filters are washed by blowing air and a mixture of air/water. The effect of this washing on the elimination of radon is unknown. However, the hydroxides of polonium, lead and bismuth will remain fixed on the activated carbon.
- It is hard to predict the effectiveness of filtration on powdered activated carbon. As the service life of powdered activated carbon is about one month, the utilisation period and effectiveness of the activated carbon will have to be verified.

- The adoption of an inadequately understood filtration treatment could entail problems that are harmful to overall water quality, including in microbiological terms.