Legionella
Aerosols
Cooling towers
Drainage
Cleaning
Disinfection
Victims
Regulations

Grouped cases of legionella

November 2003 – January 2004 (1)

Harnes – [Pas-de-Calais] France

Several cases of legionella (also referred to as legionellosis and legionnaires' disease) were reported in northern France in late November 2003. Despite a variety of technical measures implemented in December 2003, new cases were reported in late January and resulted in several deaths.

THE INSTALLATIONS IN QUESTION

Geographic location

The installations likely to be responsible for releasing aerosols contaminated by legionella are located in the Lens-Harnes region. The investigations thus concentrated on cooling towers, automatic car washes, treatment stations, water jets and fountains, and wells….

Figure 1 - Nord-Pas-de-Calais
http://www.q-net.net.au/~legion/legionnaires.disease.2003.html

CRISIS MANAGEMENT

Governmental services

A variety of governmental departments were involved in managing the crisis, including: the *Prefecture*, the Classified Installations Inspectorate (IIC), the Departmental Health and Social Affairs Department (DDASS), the National Health Monitoring Institute (InVS), the Interregional Epidemiological Centre (CIRE), the French Ministry of Ecology and Sustainable Development (MEDD), and the French Department of Health.

National Legionella Reference Centre

The National Legionella Reference Centre (CNRL) performs a variety of tasks: expert biological assessment, epidemiological monitoring, maintenance of a bacteria collection and serum bank. In terms of the biological assessment, the Centre receives serums, urine samples and pathological products and the relevant information about the cases for diagnosis confirmation or initial diagnosis. The CNRL contributes to epidemiological monitoring by its role in identifying strains having the same genomic profile. It also confirms the grouped nature (same strain) of epidemiologically-linked cases.

[1] Period corresponding to the contamination of the individuals, and thus to the occurrence of the legionella cases (see Investigation report : Community legionella epidemic, Pas-de-Calais France, November 2003 – January / InVS)

Each case of legionella diagnosed at the CNRL is reported to the InVS to complete all available information and to find all undeclared cases. All strains of clinical origin in France must be sent to the CNRL to be registered in a single national collection which, through systematic molecular typing of the legionella strains, enables the extension of the bacterial transmission and the origin of grouped cases to be identified. Parallel typing of strains of environmental origin enables contamination sources to be identified.

Finally, the CNRL participates in the European EWGLI network (European Working Group of Legionellosis Infection) by monitoring travel-associated legionella: exchange and comparison of strains, research work….

Support mission

A support mission was formed at the request of the French Departments of Health and the Environment in order to provide technical support to the Prefect of the Pas-de-Calais, to assist in better identifying the origins of the "epidemic" and to shed light and possible additional orientations.

THE CRISIS, ITS BEHAVIOUR, EFFECTS AND CONSEQUENCES

The "epidemic"

On **11/28/2003**, the DDASS informed the Cire Nord, InVS and the DRIRE Nord Pas de Calais of the appearance of 2 cases of legionella, on November 11 and 15, one of which had resulted in a death. The victims, 2 elderly men suffering from a respiratory ailment, lived in the city of Harnes at a distance of only approximately 400 m from one another and 800 m from the industrial zone. One had been contaminated between November 1 and 11, and the second between November 9 and 29. The report of the 2nd case alerted the authorities as the 1st case had been initially considered sporadic. Health professionals in the sector were informed of the contamination risk for the population in order to be on the look out for any clinical signs that may appear. The IIC, contacted by the DDASS, reported that two industrial facilities (food and petrochemical establishments) located in Harnes were equipped with cooling towers:

- The last measurements taken in the ***food production facility's*** cooling towers showed legionella concentrations less than 50 CFU/l.

- The operator of the ***petrochemical site***, specialised in alcohols and fatty acids, informed the DRIRE in mid-November that an internal check conducted 10/15 showed a legionella concentration of 730,000 CFU/l. After a shock treatment with biocides, new analyses conducted 10/30 indicated a concentration level below 100 CFU/l. The presumptive results of analyses conducted 11/20 indicated a legionella content of 600,000 CFU/l.

The 2 cases of legionella identified and the discovery of contaminated cooling systems led to various measures being undertaken. The DDASS thus conducted environmental studies at the home of the sick individuals and in numerous public buildings…. The existence of **other possible sources of contamination was not excluded**.

On **11/29/03,** after joint efforts with the Prefect and the MEDD, the IIC requested the ***shutdown of petrochemical plant's cooling towers*** based on the results of the analyses. The order was to take effect on the evening of December 2. The petrochemical plant's cooling towers were rapidly identified as a possible source of contamination, and were shut down for draining and cleaning from 12/03 to 12/20/03.

As of **12/03/03, *several other cases*** appeared over time in a dozen or so neighbouring communities (*see Fig. 2*).

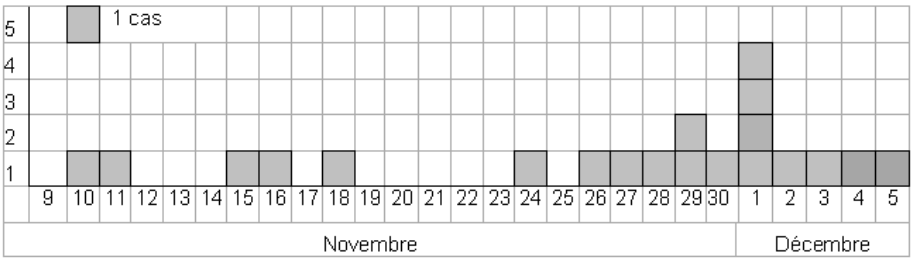


Figure 2 - Distribution of legionella cases according to the dates when the first signs appeared between November and December 2003
http://members.dodo.net.au/~jamgreen/legionellose_france.index.htm

The DDASS and the CIRE conducted an epidemiological survey to confirm the "epidemic" nature of the phenomenon, to measure its extent, and identify the origin and the source of the contamination, then implement adapted control measures.

By **12/19/03**, 29 people living in Pas de Calais had fallen sick; a man living in another department had also contracted legionella after having spent time in Harnes.

The DRIRE proposed that ***all companies subject to ICPE*** (Installation Classified for Environmental Protection) ***regulations*** in the zone concerned, ***search for the possible presence of legionella*** in their cooling water systems and ***implement preventive measures to reduce legionella concentrations*** without waiting for the results of the analyses, as one or two weeks are required to obtain a final result. The Prefect reiterated these proposals in the prefectoral order of 12/30/2003, superseded on 01/09/2004 by a new order expanding the search perimeter to the 45 *communes* concerned.

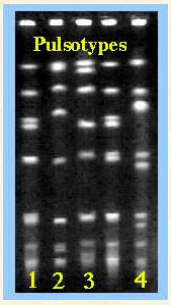
As such, a sample taken 01/05, with the results available 01/14, showed significant legionella development in a cooling tower of ***a refrigerated warehouse*** located in Vendin le Vieil although the previous analyses of December 5, 22 and 29, 2003 had not detected the presence of legionella. The enterprise shutdown, drained and cleaned the circuit concerned.

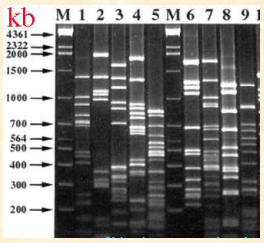
On **01/18/2004**, the Prefect of Pas-de-Calais ordered the shutdown of cooling systems of ***food-industry establishments*** in Harnes. This decision was motivated by the results of the sample taken 12/29/2003 and revealed the same morning. The CNRL of Lyon indicated that the same epidemic strain as that identified among the patients was found in the cooling systems. The concentrations of legionella in these systems was always low (less than 100 CFU/l): the samples of January 5 gave values below the detection thresholds. Based on the detection in the installation of the strain identified among the patients, it became necessary to carefully clean the installations as of a ruling of the health and environment departments and the support mission experts. It should be noted that the presence of legionella in the cooling systems has no impact on the sanitary quality of the food products manufactured by the food-processing plant.

On **01/01/2004**, the pulsotype results established a link between 3 patients and the ***2nd wave of contamination*** by the strain found in the petrochemical plant and the examination of the cleaning methods used by the ***petrochemical plant*** (*see Fig.3*). In application of the precaution principle, the installations were shut down and secured the same day. This decision was based on the order issued by the Prefect of Pas-de-Calais on Jan. 2, 2004. The installation's shutdown was intended to allow the investigations to be fine-tuned to ensure that the risk of contamination was being properly managed and to better understand how this 2nd wave of contamination was able to occur despite the shutdown and cleaning of the cooling tower in question. The experts evoked the possibility that legionella may have been diffused during the cleaning operation which, although highly unlikely, could not be formally excluded in the first days when the plant resumed its activity on 12/22/2003.

Pulsotypes

Pulsed Field Gel Electrophoresis (PFGE) is a technique based on the analysis of bacterial DNA analysis which allows each strain to be assigned a characteristic genetic fingerprint; in this case called a pulsotype. After digestion of the bacterial DNA by restriction enzymes, it can be separated by a specific electrophoresis technique into a number of variable bands characterising a certain profile. The interest in this is being able to compare the DNA amongst themselves and thus the bacterial strains.





http://www.microbes-edu.org/glossaire/glossaire.html
http://www.pasteur-lille.fr/fr/expertises/alimentaire/electrophorese.htm

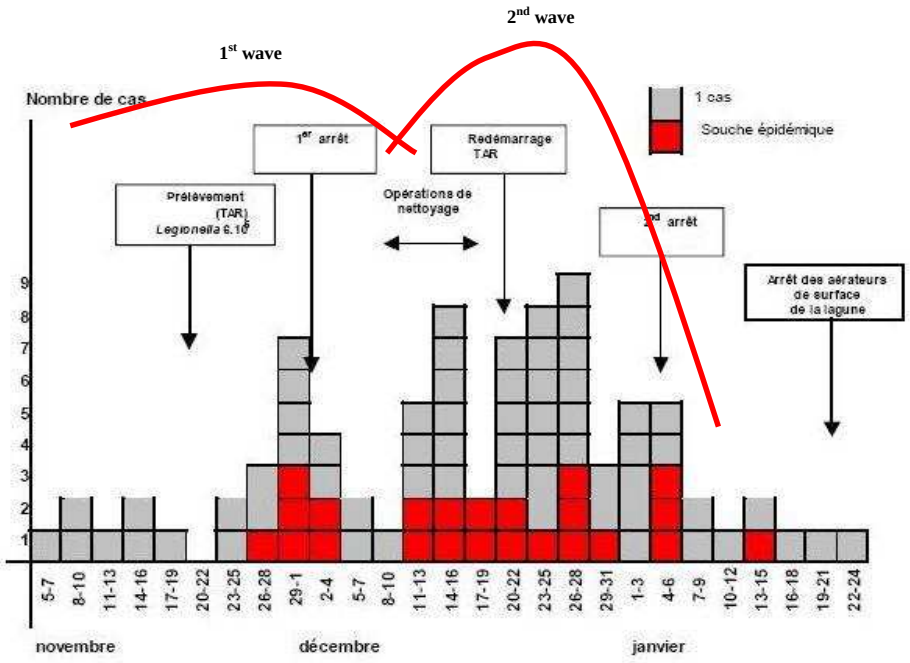


Figure 3 - Distribution of cases and chronology of activities presenting a risk of dispersing aerosols, contaminated by legionella, used at the petrochemical plant (November 2003-January 2004)

While the presence of bacteria in a lagoon is common and desired, a lagoon does not normally generate aerosols. The presence of surface aerators must nevertheless be considered in the possible dispersion of aerosols. Investigations thus showed that a high concentration of legionella was detected in the ***lagoon*** seeded with biological sludge from the petrochemical plant. Analyses revealed this sludge contained very high levels of legionella (> 10^8 CFU/l). Investigations were undertaken to evaluate the contamination risks associated with the operations needed to perform this seeding and lagoon operation.

Following the DRIRE's proposal and after the 2nd shutdown of the installations in early January, the petrochemical company implemented a special action plan to control the legionella risk. A risk analysis on the effluent treatment installations enabled the liquid effluent networks to be broken down into physically identified "zones" on the site presenting different contamination risks. The operations likely to contaminate the cooling towers were done away with or modified (decommissioning of the surface aerators, cleaning without pressurised jets, pumping without the creation of aerosols…). The system's design was modified: elimination of dead zones and zones of low circulation, installation of drains on the remaining low points, installation of branch connections on the inlets and outlets of certain equipment to allow preventive cleaning in a looped circuit and to avoid the possible accumulation of bacteria deposits on the exchangers known to clog up easily. In order to prevent microbiological developments, the preventive and curative treatment implementation conditions were defined to endure their efficiency:

- modification of the injection point of the oxidising biocide used continuously,
- displacement of the sampling location for water specimens for analysis of residual oxidising agent upstream from the injection of chemical products,
- redimensioning of the brominator volume,
- increase of the concentration of residual oxidising agent and the installation of a continuous residual oxidising agent analyser,
- permanent cleaning of all surfaces in contact with water (continuous injection of biodispersant) and suppression of the anti-foaming product which affected the biodispersant's efficiency.

In addition to a series of controlled physio-chemical parameters, biological indicators followed: legionella, total flora and TRA. The samples were taken at different points of the installation to control all water in the system. The frequency of analyses and the standard actions to be implemented in case of a derivation of a control parameter were clearly defined.

The support mission, which became aware of this plan during the meeting of **01/25/2004**, issued a favourable opinion to restart the installation with a few minor reservations (see ruling of March 9, 2004).

Following a ruling of the Departmental Heath Committee on **03/15/2004** based on a report by the DRIRE of 03/12/2004, the Prefect of Pas-de-Calais authorised the petrochemical plant to resume activity by Prefectoral order of 03/19/2004 (*see Fig.4*). However, owing to internal reasons, the establishment decided not to resume activity at its Harnes site.

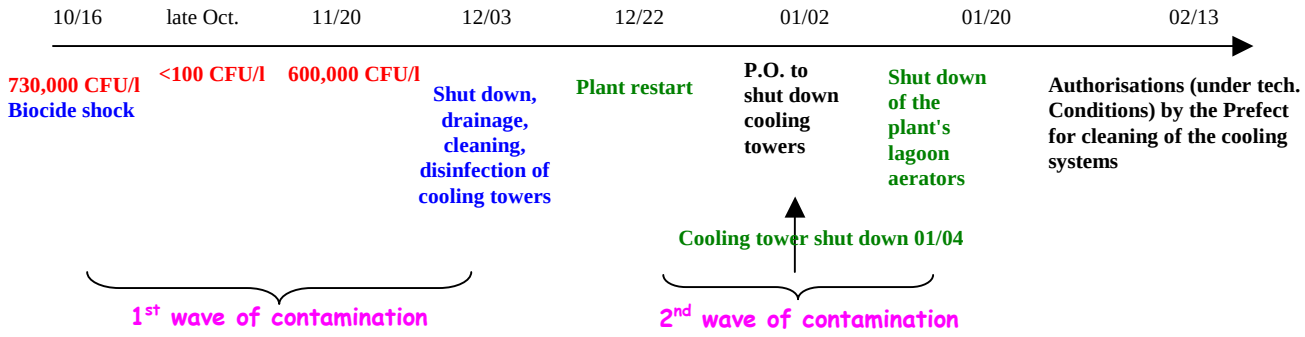


Figure 4 – Chronology of events at the petrochemical plant

Environmental studies on the installations at risk

Additional studies were undertaken at all industrial sites, public buildings, carwashes, public drinking water distribution networks, private and industrial wells, water treatment plants, water jets, decorative fountains, street cleaning machines and canals receiving effluent, located in the perimeter of the 45 *communes* concerned.

Industrial installations

Of the 725 establishments in the perimeter, the IIC identified 33 sites as being likely sources of contamination. These 33 establishments operate 105 cooling towers, of which 93 in service on which more than 700 samples were taken and analyses performed between late November and mid-February 2004.

Public buildings

Within this same perimeter, 28 public buildings equipped with cooling systems were inspected: 25 of these building used a dry system, 2 were shut down, and the last building used a wet type system, although the analyses were negative.

19 supermarkets were inspected to search for possible sources of legionella diffusion: 10 had no air conditioning system, 6 had dry type installations, and the legionella analyses give concentrations less than the detection threshold for the other 3.

LEGIONELLA PNEUMOPHILA

The legionella infection forms a family of 46 species and 64 serogroups. *L. pneumophila* is most frequently found in human pathology, responsible for more than 95% of the cases. *L. pneumophila* serogroup 1 (Lp 1) is responsible for more than 80% of the cases.

http://www.microbes-edu.org/etudiant/Legionella/legion.html
http://dm3.univ-lyon1.fr/legio/LEGIONELLES3.htm

Carwashes

137 carwashes were found in a radius of 12 km around Harnes.

Samples taken 12/15 in the near carwash near a supermarket within the *commune* of Harnes revealed a *Legionella pneumophila* serogroup 1 (Lp1) concentration of 1,600 CFU/l; this strain was identical to that found among the sick. As of 12/24, the installation was closed down, drained, descaled, disinfected for 12 hours non-stop and rinsed, then returned to service on 12/27. A new inspection conducted 48 hours later showed no anomaly.

A disinfection protocol drawn up then validated by national experts had to be followed prior to the reopening of the carwashes.

Public drinking water networks, water table wells

When samples were taken, chlorine concentrations measured in the public drinking water distribution network were between 0.3 and 0.4 mg/l, in compliance with the directives of the *Vigipirate* plan in place at the time of the crisis. As a precautionary measure on 01/12/2004, the distributors increased the active chlorine content to 0.5 mg/l at the reservoir's outlet.

All of the analyses conducted on the 8 of the 16 wells in activity were less than the detection threshold.

Water treatment stations

The high concentrations of legionella measured in the sludge of the petrochemical plant's lagoon led to a check of possible contamination levels of the other water treatment plants in the zone. Between January 12 and 30, 2004, 2 samples were taken in each of the water treatment stations in the zone: one in the clarifier and the other in the aerator. Legionella was not found in these samples, although in many of the installations, a significant amount of interfering flora prevented a conclusive response.

Water jets and decorative fountains

All analysis results were below the detection threshold.

Wastewater system and street cleaning equipment

The results were below the detection threshold, although the services responsible for managing this equipment was required to disinfect their on-board tanks (clean water and dirty water).

Canals

As a result of high concentrations of legionella and the presence of the epidemic strain in the petrochemical plant's pond, samples were taken in the canals receiving effluents from this pond. The presence of interfering flora, however, prevented all detection of Lp1.

Atmosphere

Two experimental devices for measuring legionella in the air were used to complete the research. Beginning 01/14/04, the *Centre Scientifique et Technique du Batiment* (CSTB) took samples at several sites, including the 2 petrochemical and food processing sites. The samples taken near the petrochemical and food processing sites' lagoons, the Fouquières-les-Lens treatment plant and the cooling towers of other industries in Wingles revealed the presence of legionella. The only harvestable samples were taken near the lagoon of the petrochemical plant: 5,400 CFU/m^3 immediately downstream from the lagoon and 330 CFU/m^3 at a distance of 200 m downstream, the epidemic strain being isolated in these samples.

The results of the 2nd series of tests conducted 02/03 near the lagoon of the petrochemical site, surface aerators shut down, showed that the quantity of aerosols measured at the lagoon was two times greater than that measured 200 m downstream from the lagoon (atmospheric background noise). It should be noted that the conditions changed between the 2 series of tests: the concentration of legionella disseminated by the lagoon shifted from 3.10^3 CFU/m^3 to a concentration below the quantification limit of the FISH method[2] and from 5,400 to 62 CFU/m^3 per culture. These results indicated that the lagoon's bottom aerators were probably the generators of legionella aerosols, although their contribution was less than from the main aerators.

Modelling plumes emitted by the petrochemical plant

In the framework of the support mission, operations designed to model the dispersion of legionella in the atmosphere were conducted by an expert third party. The following information was collected:

- The geometric and thermodynamic characteristics of the potential emission source, consisting of the two cooling towers, and the meteorological conditions recorded during his episode allow us to assume that the plumes released could have covered a zone extending roughly ten kilometres around the cooling towers. Furthermore, the model's results indicated that the residences of the cases involved were covered (see figures 5 and 6).

[2] The FISH method (Fluorescence in Situ Hybridization) consists in identifying a specific region of the chromosome, through the use of a complementary oligonucleotidic probe which hybrids with the DNA. Antigens are coupled with certain nucleotides and fix fluorescent antibodies. Using a UV microscope, the ultra violet light highlights colour spots.
http://www.snof.org/maladies/aniridie.html

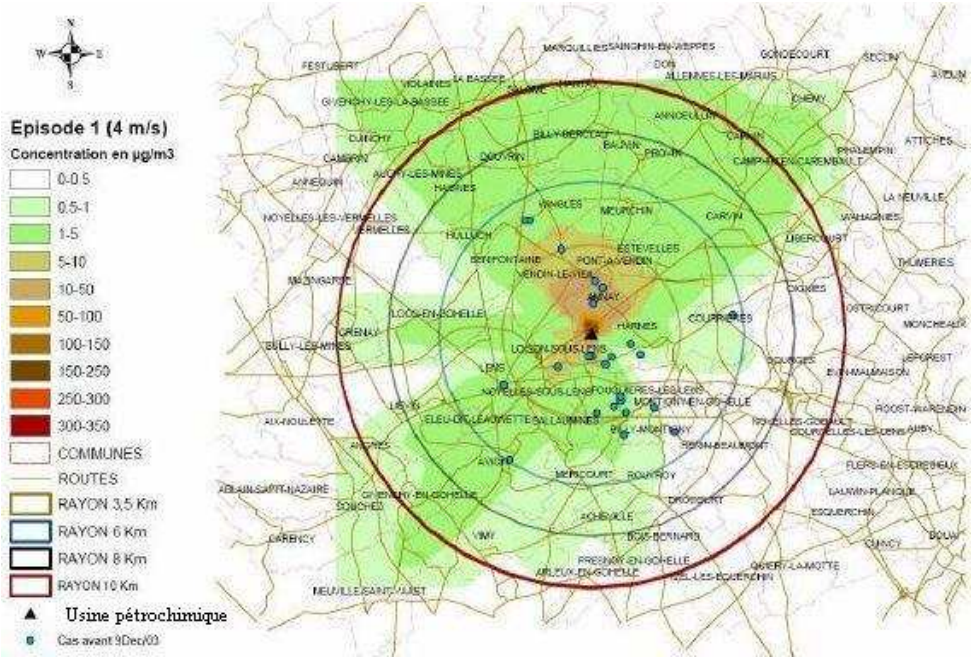


Figure 5 – Modelling of the atmospheric dispersion of the aerosols released by the petrochemical plant's cooling towers during the first wave of the epidemic

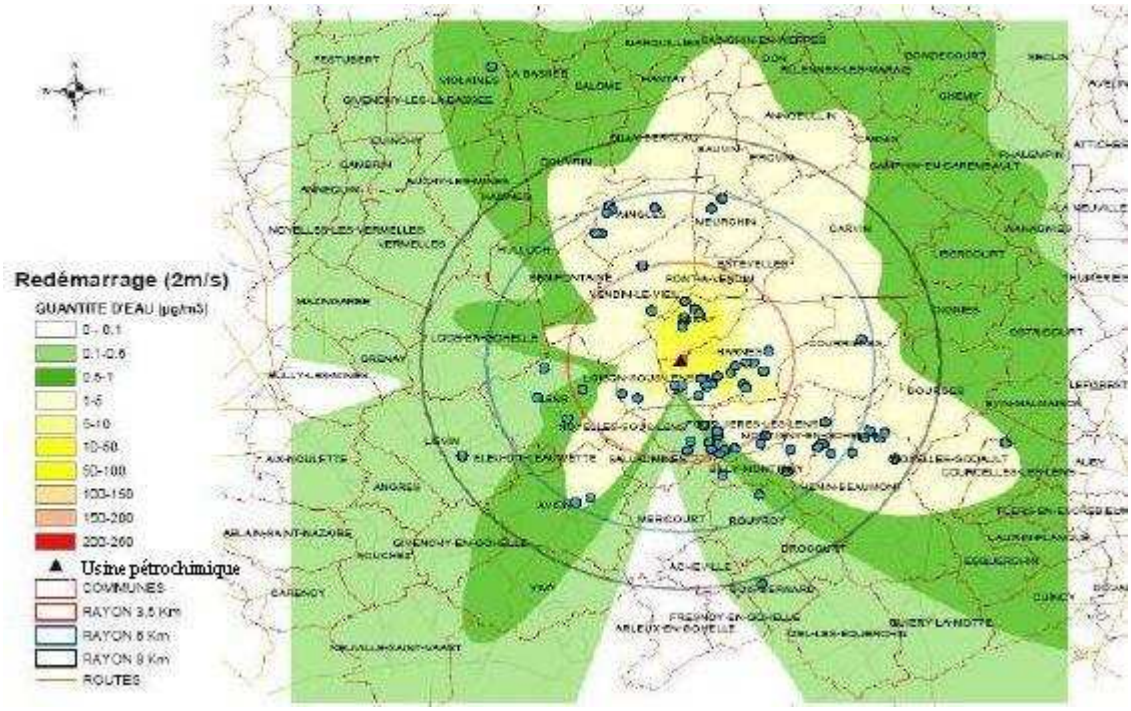


Figure 6 – Modelling of the atmospheric dispersion of the aerosols released by the petrochemical plant's cooling towers when the installations were restarted (12/22/2003 to 01/02/2004)

- The high-pressure jet cleaning of the cooling systems and the truck washing zone generate aerosols that are potentially contaminated with legionella. The study of their dispersion shows that these operations, notably those carried out at high levels, lead to the release of plumes which could have an impact on environment within a radius of 5 to 6 km around the emission source.

- Droplets, generated by the lagoon's aeration process and potentially contaminated by legionella, can be dispersed over a kilometre from the source, which must logically place the cooling towers within range of this source, as well as the commune of Harnes.

Nevertheless, given the uncertainties associated with these calculations, it is important to limit their interpretation as qualitative (the probability of the presence of bacteria a certain distance from the installations). The dispersion models only allow us to confirm or overrule the plausibility of the presence of legionella in a fixed domain and to estimate the probable range of impact.

These conclusions are based on models of five scenarios, corresponding to different processes potentially at risk of disseminating aerosols likely to be contaminated by legionella:

- dissemination of aerosols by cooling towers during the period prior to the first plant shut down,
- dissemination of aerosols during the cooling system cleaning operations,
- dissemination of aerosols during on-site cleaning operations of trucks transporting sludge used to seed the lagoon,
- dissemination of aerosols by the cooling towers while the ventilation of the cooling system was being placed back into service, up to the second shut down of the plant,
- dissemination of aerosols from the lagoon throughout the entire epidemic.

Consequences:

86 people ranging from 32 to 92 years old were **contaminated, resulting in 18 deaths**. The cases appeared in two waves between 11/05/2003 and 01/22/2004:

- 1st wave of cases culminating 12/01, then diminishing to 12/09,
- 2nd wave of 60 cases with a maximum 12/25-26, then falling off progressively until 01/22.

The 83 cases were living in a radius of 12 km around Harnes including 22 communes, 3 other cases living in Béthune or in the *departments* of Seine-Maritime (a truck driver who had delivered to the petrochemical plant on 11/14/2003) and Nord. The 18th death was declared 06/14/2004.

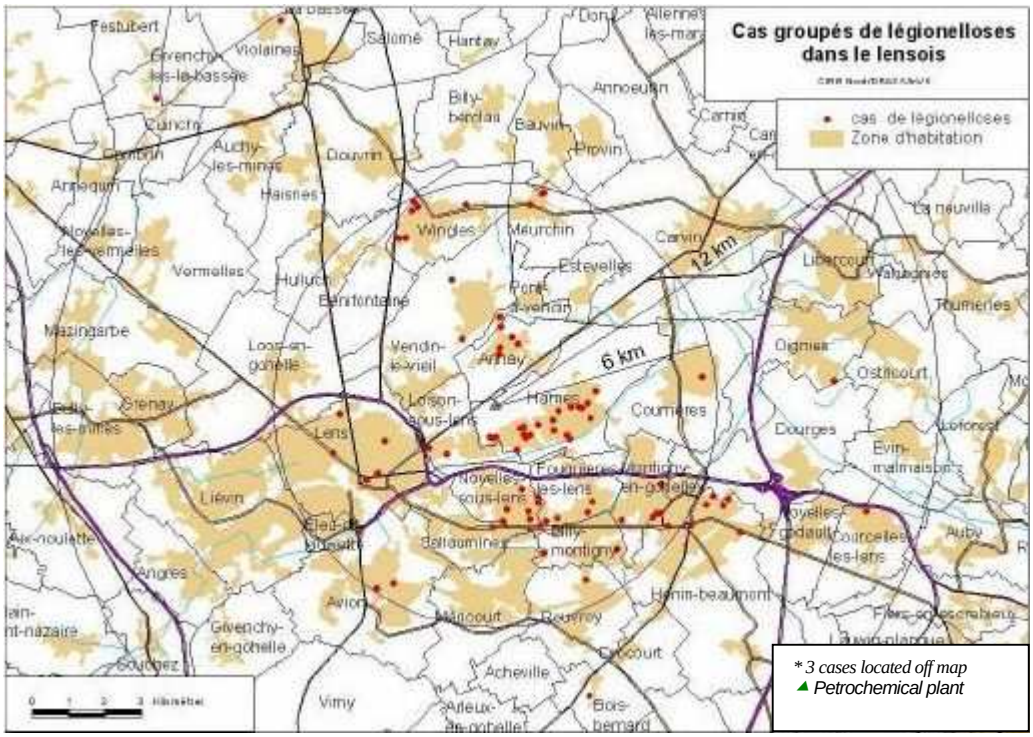


Figure 7 – Geopositioning of cases according to residential addresses (N=83*)

The bacterial strains present in the uncleaned and disinfected cooling systems were sent to the CNRL in Lyon. The petrochemical plant's involvement in the crisis was confirmed by an official statement of 12/23: "*the same macrorestriction profile of the DNA of the Legionella pneumophila serogroup 1 strain was found in two patients with the sickness and in specimens from the samples taken in the hot water pond of the company's cooling tower (…). There is thus an epidemiological link between the environmental and patient strains".*

Losses for the petrochemical plant, associated with a 14-week production shut-down, were in the order of **several million euros**. The shut down of several other companies (carwashes…) can be added to this cost.

European scale of industrial accidents

In order to characterise these cases of legionella, which can be attributed more to a lack of procedural control having serious consequences than to an actual accident, the rating rules of the 18 parameters of the scale made official in February 1994 by the Committee of Competent Authorities of the Member States which overseas the application of the 'SEVESO', directive, can be used as shown below.

The parameters that comprise the four indices and the corresponding rating method are available at the following address: http://www.aria.ecologie.gouv.fr

If the 18 deaths are considered, the H3 parameter of the "human and social consequences" rating must be 6 (H6 ≥ 6 deaths among members of the public). However, there is no absolute link between deaths and the industrial origin of the contamination. Only the 23 patients are considered for which the strains are similar to those present in the petrochemical plant's cooling tower. As a result, the parameter H4 of the "Human and social consequences" is thus rated as 5.

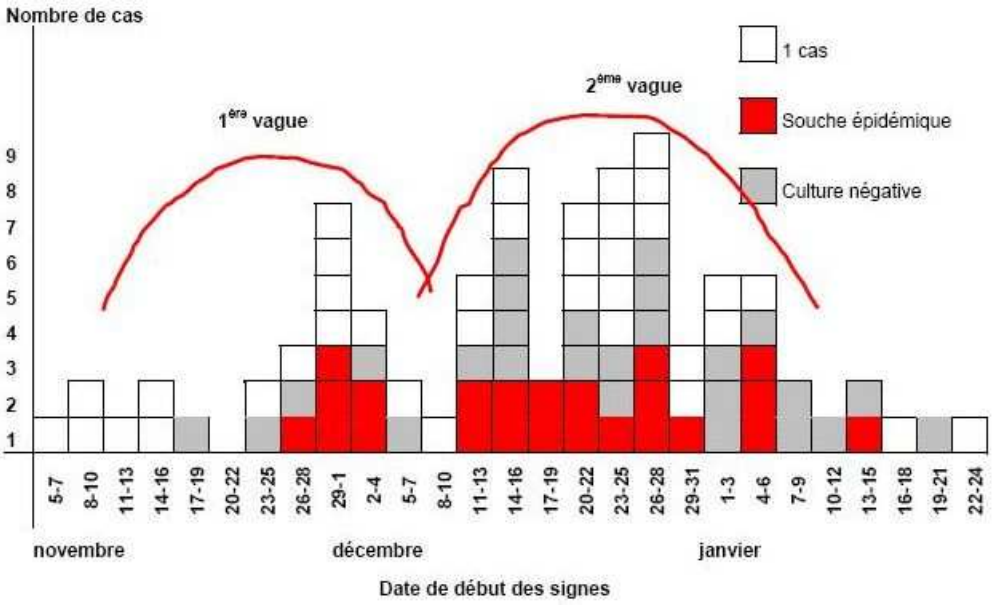


Figure 8 – Epidemic curve per 3-day period according to the date of initial signs and isolation of the epidemic strain

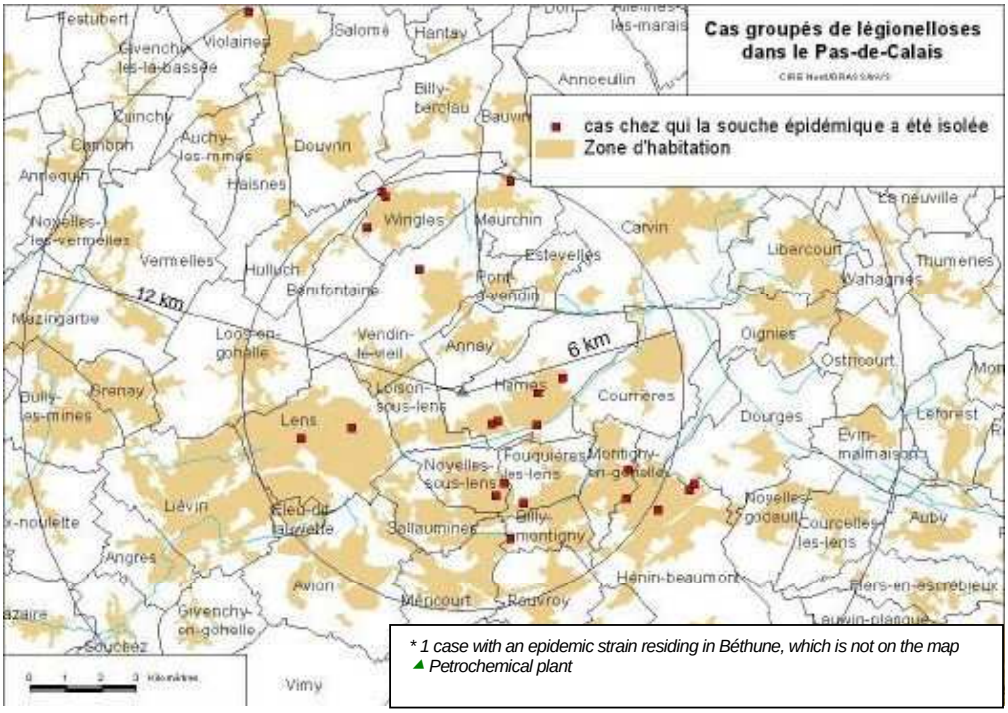


Figure 9 – Geographic distribution of cases according to the commune of residence and the isolation of the epidemic strain

The €16 of the "economic consequences" rating is 4: production losses were estimated at several million euros (€16 between 10 and 50 M€).

CAUSES AND CIRCUMSTANCES OF THE LEGIONALLA PROLIFERATION

The detailed analysis of the "legionella" risk control procedures implemented by the petrochemical company show that the preventive and curative treatments against the proliferation and dissemination of legionella did not reduce the sanitary risk to a minimum level:

- Prior to the shut down in December 2003, system design defects promoted the formation of biofilm: water stagnation, insufficient flow rates in numerous sections of the system, lack of purges to drain deposits from low points, difficulties in performing complete mechanical cleaning of certain parts of the system.

  Cleaning and treatment of the facility's cooling towers not preventing the formation of the biofilm and its elimination. During normal operation, the entire system was not perfectly cleaned. Disinfection operations were efficient only occasionally and the contamination of the water from the persistent biofilm was recurring. In addition, the conditions in which the preventive and curative chemical treatments were performed was not adapted: interaction between biocides, low concentrations of residual oxidising agents, underdimensioned equipment. On a highly-complex circuit with a hydraulic system difficult to control, only the continuous injection of the biodispersant and without the addition of an anti-foaming product would have ensured the progressive elimination of the biofilm and avoided new formations.

- During the 1st shut down in December, mechanical cleaning of part of the system (tower, condensers) was only partially efficient: **the deposit could not be totally eliminated**. The chemical cleaning conditions most certainly fragilised the biological deposits in places (the regular injection of biodispersant coupled with an anti-foaming agent). In addition, aerosols heavily charged with legionella may have been transmitted when the high and low-pressure jets were being used, notably at high levels (10 to 15 m).

- As of 12/22, when the installations resumed operations, **legionella and bits of biofilm**, rendered fragile by successive inefficient chemical treatments, could have been easily **released in the water due to the hydraulic forces exerted on them**.

- The **installations may have been contaminated by the epidemic strain** from contaminated aerosols generated **by the lagoon aerators or operations conducted around this lagoon** (unloading and pumping, truck washing operations).

The study of contamination possibilities of the cooling tower by the epidemic strain precludes those directed at the well water supply question or the rise of wastewater up to the lagoon's purge, although takes other potential sources into account:

- lagoon aeration systems,
- tanker washing station located 300 m from the cooling towers, notably for the trucks delivering seeding sludge,
- degassing of tanker trucks when pumping sludge from various ponds,
- filter press cleaning (sludge pressing),
- unloading of seeding sludge from the Beuvry-la-Forêt chemical plant (59), located 25 km from Harnes.

Direct decontamination of the cooling tower pond by the hose during the sludge pumping operations also appears possible.

ACTIONS TAKEN

Modification of regulations

In keeping with the actions undertaken since 2003, the French Department of Ecology and Sustainable Development created section 2921 dedicated to wet cooling towers in the nomenclature of installations classified for environmental protection (see decree No. 2004-1331 of 12/01/2004 and No. 2004-1479 of 12/23/2004) and published two ministerial orders (see order of 12/13/2004), one for installations subject to authorisation and the other for those subject to declaration.

Since 2004, multiyear action plans implemented for the IIC include the cataloguing of wet cooling towers, information of professional organisations, and the reinforcement of regulatory controls. The action was continued in 2005 by information on cooling tower operators in order to facilitate the new regulations coming into effect May 1st, 2005, with the development and distribution of two methodology and training guides on the risk of legionella. In 2006, the Classified Installations Inspectorate:

- will ensure that the regulatory provisions are respected by conducting unannounced sampling operations: particularly, analysis of the risk of legionella proliferation, installations' maintenance and monitoring plans,
- will verify the transmission of analysis results,
- will inform Departmental Health Councils (CDH) of the results of the actions (presentation of reports).

LESSONS LEARNED

Adopt preventive measures

The petrochemical plant's control of the "legionella" risk was ill-adapted. The contamination of a cooling tower by the addition of wastewater sludge in its immediate environment was highlighted. Certain industrial and wastewater treatment entrepreneurs do not appear to be fully aware of the biological risk facing cooling systems equipped with cooling towers.

The prevention of this risk would include:

- the extensive cataloguing and reinforcement of monitoring operations involving installations at risk (cooling towers…),
- a greater understanding of the biological risk confronting these installations for all parties (potential avenues of contamination…),
- the implementation of adapted management methods in the event of a notable risk: removal of dead branches, selection of appropriate materials avoiding the proliferation of legionella, treatment of

A few sites about legionella

A report entitled "Légionelles : un risque à gérer" (Legionella: a risk to be managed) can be consulted at www.aria.ecologie.gouv.fr.

Various documents are presented on the site of the French Ministry of Ecology and Sustainable Development in the section "Risques et pollutions / Air / Les polluants atmosphériques et la lutte contre la pollution atmosphérique / Légionellose"
http://www.ecologie.gouv.fr/rubrique.php3?id_rubrique=936

make-up water to limit the presence of all elements (scale…) which may contribute to the development of these microorganisms, the implementation of adapted heat, physical or chemical treatments, reduction of scale build-up and corrosion, limitation of the vesicular entrainment to the atmosphere, distancing of building air intakes and ventilation vents, minimisation of the secondary colonisation risk of a cooling tower by aerosols released nearby…,

- the diffusion of good maintenance practices from installations at risk to cooling tower operators and maintenance companies: a better understanding of the recommended products and their efficiency, improvement of conditions in which chemical treatments are employed so that they are efficient and more environmentally conscious…,
- the strict application of official regulations in case the regulatory legionella thresholds are exceeded,
- systematic transmittal of information to the competent authorities (DRIRE…) in the event contamination is found in installations at risk,
- reinforced vigilance of the health authorities (DDASS, InVS, CIRE…) regarding potential sources of community contaminations.

Improvement of diagnostic tools

Becoming aware of the contamination of water samples as soon as possible is a deciding factor in implementing the proper corrective measures as soon as possible. Tests to determine the presence of a high concentration of legionella in the water must be developed as soon as possible and completed by the technique for measuring legionella in the aerosols present in the ambient air which remains to be validated. At the same time, the attention of clinical researchers and biologists must be drawn to the importance of rapid reporting of cases falling under the mandatory reporting framework. These measures contribute to the early identification of grouped cases and the efficient implementation of investigations and control measures.

It would appear necessary to develop tools to model the atmospheric transfer of legionella and to evaluate the extension of zones likely to be contaminated by potential sources (direct modelling) or to search for a source based on the location of cases or samples in the environment (inverse modelling).

Over the last few years, the constant decrease in the proportion of clinical strains isolated among patients can be explained by the performance, ease and rapidity of forming a diagnosis by antigen practices, the search for *Legionella strains* in clinical samples is essential as this method is the only one which is able to characterise and compare the clinical strains amongst themselves to detect group cases. In addition to this epidemiological analysis, the comparison of clinical strains with the environmental strains assists in identifying the source of contamination.

Develop knowledge

The characteristics of the epidemic strain in question in the Harnes region require more in-depth study, and given the current level of understanding, several questions remain without answers:

- Detection of a non-negligible concentration in a cooling water system at relatively low temperature (9 to 15 ℃ in the petrochemical plant's system in early December): Can the strain proliferate at low temperature or did it develop in the exchangers at a more favourable temperature?

- Dissemination over long distances while retaining a virulence potential: Does the strain have greater resistance to environmental conditions? Do its relationships with host organisms (zoomicrobes) explain some sort of protection? Were the meteorological conditions (90% relative humidity) favourable to the survival of the bacterium in the air? Were the physico-chemical conditions of the environments in which they developed favourable to their survival in the air?

- Special virulence of the strain? Does the fragile nature of the population of this mining pond (silicosis…) explain the epidemic's magnitude?

- The strain's culturability from air samples: Why? Is there a link with its virulence?

- The incubation period may be long: Why?

At this time, the experts are unable to indicate with certainty the generation and survival time of the legionella in the processes, in the aerosols present in the air, on the ground and in the water, as well as their resistance to various treatments. Furthermore, the understanding of the contamination parameters of humans (infecting dose) is insufficient.

Finally, it would appear that a better understanding of the risks associated with the wastewater treatment equipment is required, in terms of both the development of legionella and their dissemination. An evaluation of the risks associated with the sludge conversion practices would offer the answers needed.

Nevertheless, it should be noted that despite the exceptional characteristics of this "epidemic", the proper coordination of the investigations, control and communication measures were essential in managing the crisis and most likely contributed to limiting the phenomenon and its consequences on the population.

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