Dilution or containment: controlling radioactive liquid effluents from the 1950s to the 1980s on Marcoule plant, France

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Abstract. Nuclear facilities constantly produce radioactive liquid effluents, as a part of their ordinary operation. However, controlling a circulating fluid is problematic. This paper focuses on Marcoule plant in Southern France, on the Rhône River, to document how radioactive effluent containment evolved from the 1950s to the early 1980s. The 1950s and 1960s were a time of experimentation: engineers intended to find a way to dilute radioactive wastes into the river, following a traditional conception inherited from the 19th century. However, due to multiple factors (scientific research and a better understanding of radiation effects, raising protests against nuclear wastes, first legislation on radioactive effluents), both guiding concepts and technical solutions evolved to a stricter containment and control of radioactive effluents.

1 Introduction

Steel-reinforced enclosure, radiation shielding for workers, waste barrels… These are the first images that come to mind when we mention radioactive containment. It also implies a solid matter (uranium, plutonium) with invisible radiation in the air. In this paper, we chose to focus on a different type of nuclear waste: the radioactive liquid effluents and their management, through the example of Marcoule plant in Southern France. How do you contain a radioactive fluid? By asking this simple question, we will analyze several aspects of nuclear containment from the early years of nuclear industry in the 1950s to the beginning of the 1980s.

Like many industries, the nuclear industry uses a great amount of "industrial water[1]", which is a major part of its industrial metabolism. [1] Depending on the technology, water can be used as a coolant, to produce electricity (steam), to clean the facilities… Every nuclear site has miles of pipes[2], upstream pumps, effluent treatments plants, and downstream discharge lines. By circulating into the pipes, a part of this water receives different amounts of radioactivity. Part of it doesn't. It implies the use of separate conduits for radioactive and non-radioactive effluents and ranging the former from least to most radioactive, separating the effluents according to different radionuclides, etc. This also leads to a strict legal

[1] This term is often used in documents to refer to water of sufficient quality, but also to differentiate it from drinking water, water used for irrigation, and to trivialize its nuclear use.
[2] A single reactor as G2 in Marcoule contains 1672m of pipes within the building.

distinction between radioactive and non-radioactive effluents, implying separate controls, separate authorizations, different administrations, and distinct legal processes. It is important to underline that these radioactive effluents are constantly produced and discharged into the river, as a part of the normal operation of the facility.

We intend to analyze the management of these effluents from a microscale (the pipes network on the site) to a local and regional scale, and we will underline three main results. First, we suggest that containment conception evolved from a containment *by* the river to a containment protective *of* the river. During the 1950s and the early 1960s, the river water was conceived as a natural barrier used to contain radioactivity by diluting it, following a traditional "dilution paradigm" that emerged during the 19th century. We suggest that the later technical solutions developed during the 1960s and 1970s, designed to concentrate and to contain radioactivity on site, were partly inspired by the natural dilution into the flow, though we can observe the emergence of a new "containment paradigm" (containing solid matter on site) finally established during the 1990s for most nuclear wastes. [2]

Secondly, the technical solutions (pipes, drainage system) materialize this conceptual evolution. After years of experiments to evacuate and dilute the effluents with a single pipe, these effluents are being separated from each other to limit radioactive hazards. This containment transforms a unique river water into multiple "industrial waters" with their own distinct treatment, timeframe, storage, and space.

Thirdly, we want to stress the geographical aspect of containment, showing how the spatial impact of the radioactive effluents evolved from the 1950s to the 1980s, due to a combination of scientific, social, and legal factors. Conceived as a local problem during the 1950s, the radioactive effluents were first controlled to contain antinuclear fear, and to avoid any radioactive concentration downstream, until the waste reached its final destination: the Mediterranean. With the joint development of national and European legislation during the 1970s, the massive nuclear equipment and the raise of environmental concerns, radioactive effluents became a problem for the entire river and the basin itself.

We chose to focus on this specific period (1950s-1980s) for several reasons. During the 1950s, nuclear safety measures were directly negotiated between safety experts and engineers (the so-called "French-cooking", as described by M. Mangeon and F. Pallez) [3], in a time of experiment and quick development of the nuclear industry. We intend to lead a long-term study, from this period of experiment to the raise of a national legislation: a 1963 decree set out the first legal definition of a nuclear facility; the *Société de Contrôle et de SOUDURE Industrielle*-SCSIN, a national authority in charge of radiological control, was established in 1973; above all, the first legal frame for radioactive effluents was fixed in 1974 [4] and 1976 [5]. It was also a crucial time for water legislation, with the Water Act (1964), meant to reduce pollution and establishing the so-called Basin Authorities. At that time, the Rhône was deeply modified by the activities of the *Compagnie Nationale du Rhône*-CNR, the national company in charge of building dams along the river.

We will investigate this period by focusing on a single site, the nuclear plant of Marcoule, in Southern France, on the Rhône River. Established in 1953 by the *Commissariat à l'Énergie Atomique*-CEA (Atomic Energy Commission) and birthplace of the military plutonium used in the first French atomic bomb in 1960, this facility represents the renewed French *grandeur* after World War II, as analyzed by Gabrielle Hecht. [6] It was also a "hybrid site", where *Électricité de France*-EDF (the French nationalized electric utility company) produced nuclear-generated electricity for the first time in 1956, by placing a turbine on one of CEA's plutonium production reactors. In 1977, there were two plutonium production reactors in operation (G2-G3), two tritium production reactors (*Célestin* 1-2), a fast-breeder reactor prototype (*Phenix*), a plutonium extraction factory, laboratories, one of the reactors being decommissioned (G1). A total of 100.000 m^3 of radioactive effluents were being evacuated into the river every year. [7]

This paper relies on several local archives, especially on those of the administration in charge of water regulation along the Rhône (*Service Navigation Rhône*), the administration in charge of agriculture and fisheries resources, and the *Préfet* (regional representative of the State), as well as constructors archives. Every new application to use and to discharge waste leads to an official report, debates among local and national health experts (Hygiene Committees). The *Service Navigation* centralizes all these documents and is also in charge of supervising the construction of pipes into the water. We will focus on these official reports and administrative discussions, and especially on the first *Application for the disposal of liquid radioactive effluents* (1976), resulting from the new legislation of 1974.

2 Containing radioactive hazard by diluting radioactive waste into the river (1953-1974)

During the 1950s and the 1960s, radioactive effluents were managed on each nuclear site separately, negotiated between the radioprotection service and the local administration. Starting with a single plutonium production reactor in 1956, Marcoule counted with over 14 buildings producing radioactive effluents in 1975. Due to its central role in the development of both nuclear energy and the atomic bomb, the site was allowed to be built up in a very short time, and the effluents were deemed inevitable. The safety rules to limit their effect were being invented and experimented at the same time.

We want to underline three aspects: a) the river was considered as a useful barrier to contain radioactivity, through the old traditional industrial paradigm of dilution; b) the amount of radioactive waste diluted into the stream did not matter as much as its dispersion; c) to reconcile the quick development with safety rules, the CEA and local authorities conducted live experiments on the river, to find out the perfect dilution into the "natural radioactivity" of the water. But containing the radioactive hazard was not the main concern: it was more a way to contain people's fear and protect local agriculture rather than a proper containment.

2.1 The river as a barrier for containing radioactive hazards: the dilution paradigm

On December 21, 1955, a meeting of the Higher Council of Public Hygiene of France took place, gathering state officials, medical experts and CEA officials, to examine "the problem of disposal of radioactive effluents from the Saclay and Marcoule plants", both CEA sites. M. Berger, Professor of Medicine in Lyon University, presented a report on the possibility to "accept the principle of dumping radioactive waste into the river". He said:

> "The disposal of radioactive spills is only permissible if their instantaneous dilution is compatible with safety standards. In addition, account must be taken of the evolution of the waste from its point of discharge to the sea, the possible contamination of aquifers by the infiltration of radioactive water into underground deposits and the possible concentration of radioelements in living beings (animals and plants)". [8]

At this point, radioactive spills were still theoretical: the first reactor G1 was started one month later. However, the amount of water needed was expected to increase in the following years, and so it did: 18m3/s pumped for G2 and G3, 8.6m3/s for Celestin in 1964, etc. In the 1950s, the discharged water was separated in two types: non-radioactive (rain, sewage water, hot water after being used as a coolant) and radioactive (mostly a by-product of the decontamination after extraction of the plutonium, but also water used to clean the facilities, or that from the workers showers). These effluents were being discharged continuously by way of two separated sewer systems built on site[3]. [9] These effluents were not traditional industrial effluents, so the situation was new and also urgent:

> "The documentation is still insufficient as far as Marcoule is concerned and the various aspects of the situation need to be studied very closely, in particular the supply of drinking water of the various communities bordering the Rhône downstream of Marcoule, the problems of irrigation and the processes used abroad to annihilate radioactive waste". [8]

This radioactive fluid was composed of multiple radionuclides, but their nature and effects were not well-known yet. The solution adopted was a compromise: the Higher Council chose the dilution solution, with a "high safety coefficient". The radioactivity limits were those adopted by Great Britain in Oakridge and by the USA in Hanford, following the International Commission on Radiological Protection-ICRP recommendations. [10] However, considering the importance of the river flow, it was decided to divide the admitted radioactivity limits by 30. This "safety coefficient" was very unclear and different for the Saclay plant on the Seine River (100). Another letter from a senior engineer in charge of water quality mentioned a coefficient of 18.5.

These effluents required a chemical treatment and could be stored on site when the river flow was not sufficient. On the August 5, 1957, the CEA was authorized to discharge 86.400m3/day of radioactive spills, within a limit of 20 curies[4] a day. This radioactive waste must reach its final destination, the Mediterranean, where it was supposed to disappear into the "natural ambient radioactivity".

2.2 The river as a protection and as a field of experimentation

The river was seen as a way to convey waste and to "annihilate it". Several factors were necessary to this end: sufficient flow speed to avoid concentration, long enough distance, homogeneity of the dilution, and water depth. Since the first spill was "authorized on an essentially provisional and experimental basis" [11], the river acted in fact as a field of experimentation. The local health administration even called for a "permanent experimentation".

The CEA appointed the *Société Grenobloise d'Études et d'Applications. Hydrauliques*-SOGREAH, a company specialized in hydraulic studies, to conduct experiments into the river and find the better way to disperse radioactivity into the flow. In 1957, 135kg of fluorescein were discharged into the river[5]. This experiment showed that the pipes must be installed deep into the water, in the middle of the Rhône, and adapted to the river flow to create an adequate dilution factor. But this dispersion was paradoxically conceived as a way to contain this inevitable radioactivity. The radioactive waste must stay into the river until it reaches the sea, constantly moving to avoid concentration, especially along the riverbanks or on its bottom.

What could happen if radioactivity concentrates in vegetation, wildlife, or groundwater that serves as a drinking water reservoir for downstream cities? In case of a flood, could the sediments contaminate the fields? Such concerns emerged among the health and river experts meeting at the *Préfecture du Gard* in June 1957. Some physicians were concerned about the possibility that the chain of contamination reached humans, either directly through drinking water (downstream cities such as Arles, Nimes, Villeneuve-lès-Avignon used the river or groundwater as a drinking water supply), or via agricultural products (such as *Camargue* rice

[3] *Les Forges d'Audincourt* was the company in charge of the construction of this sewage system for the plutonium extraction facility. Their documents show the pipes and the two systems.
[4] A curie is an old unit of radioactivity, defined as the quantity or mass of radium emanation in equilibrium with one gram of radium. It is equal to 37 GBq (gigabecquerels).
[5] SOGREAH first wanted to use radioactive cesium for the experiment, but changed plans due to "technical complications".

cultivated downstream), plants, animals, or sediments. However, the report analyzed during this meeting was comforting. According to a study conducted on a hydropower dam (Donzère-Mondragon on the Rhône),

> "there is reason to hope [the emphasis is ours] that at certain spots the alluviums contain elements that may delay the passage or even absorb certain radioactive elements. […] It was indeed indicated to us that when the Donzère-Mondragon canal was put into service, significant leaks in the sand of the banks were very quickly and spontaneously clogged by the deposits left by the mud in suspension". [8]

A "natural" containment was supposed to protect the local population, but all these expectations relied on theory, on foreign experiments which could not be reproduced ("the American observations are not necessarily transposable since fishes are not the same, they are not necessarily the same active ingredients, nor the same contaminating feeds"), and on obscure safety coefficients. These uncertainties of safety measures, being established and experimented at the same time, were materialized into the separated pipe networks being built during this period.

2.3 Building the perfect pipes to contain radioactive hazard: the "*Clarinette*" (clarinet, in English)

According to the experiments conducted during the summer of 1957, and as the amount of water pumped and discharged into the river increased, CEA engineers and their "comrades[6]" of the river administration design a network of underwater pipes that extend the site's right-of-way well beyond its terrestrial boundaries.

To avoid any interference between radioactive and non-radioactive effluents, the radioactive conduit was extended to discharge the waste downstream. Given the fact that non-radioactive effluents were discharged more than 200 m upstream, engineers considered that the interactions with radioactive effluents could be limited. A 262 m steel pipe was installed, that crossed a dam to reach the so-called "living Rhône" at sufficient depth, implying a 180 m extension of the existing EDF pipe. A specific piece of equipment was also installed, the so-called *Clarinette*. It was a 54.5m long end piece "fitted with ten conical diffusers oriented towards the channel, resting on a platform established at 6.5 m below the low water level and with a 1% slope downstream". [8] This *Clarinette,* designed by the SOGREAH for this particular situation, was supposed to split the effluents and facilitate its dilution into the water.

However, the CEA and the EDF were not the only industries using the river flow: established in 1933 and entrusted by the State to develop and operate the Rhone, the CNR had three goals: power generation, navigation, irrigation. The company had been granted a concession over the river. Since 1956, the CNR was planning a new dam at *Caderousse*, only 2 km downstream of Marcoule plant. This new dam, finally built in 1971, changed the river flow and altered its dilution capacity, creating tensions between the CEA and the CNR. Despite the State concession [12], CNR officials often complained about the lack of information on water use by the CEA and the EDF, and especially on radioactive effluents. For instance, the CNR director complained he was not aware of the CEA's applications for radioactive effluents. [13]

2.4 Containing information and fear while increasing the amount of radioactive effluents

[6] Officials from the CEA and the *Service de Navigation* often used this term and showed a strong sense of community, for they had graduated in the same schools and received the same education.

This lack of information was part of a culture of secrecy, partly connected to the military side of Marcoule plant, but also to a usual nuclear secrecy developed in France since the beginning of the nuclear planning. For instance, in 1952, the head of the CEA Pierre Guillaumat wrote an official letter to the local officer in charge of agriculture in the *Département du Gard*, explaining that the CEA was looking for a site to build "industrial facilities" close enough to the river to use the water as a coolant; Marcoule seemed to be a suitable location. In the same archive file, we have found a copy of this letter, but slightly different. Dated from the same day, written by P. Guillaumat but sent without stamps, this second letter explained the nuclear aspect of the planned facility, but the tone was reassuring: the water used would only be slightly heated then rejected into the river without any chemical alteration. [14]

Information on radioactive effluents was always strictly confidential: applications to discharge radioactive water and non-radioactive water were separated, involving different administrations, which were not supposed to object nor to express any opinion on the other aspect they were not in charge of. Some officials even confessed their incapacity to criticize any radioactive limit, or any technical aspect; this could be a real incapacity, due to the technicality of the reports, or a kind of self-censorship. Others complained about the lack of precision on the composition of the effluents in the information given by the CEA or the EDF. However, both local officers and CEA/EDF officials agreed on the necessity to reassure the local population, by highlighting concrete containment and control measures[7], to hold back antinuclear opinions[8]. The effluents worried mostly to the local agriculture and the population downstream.

After years of experimentation, both scientific recommendations and technical solutions based on dilution evolved. According to studies by Garcier and Boudia, multiple factors combined to lead to a new regulation of radioactive effluents. First, scientists gained a better understanding of the different radionuclides and developed expertise on radioactive waste. Secondly, a distinct national nuclear legislation was established during the 1960s and the 1970s, leading to the 1974 decree "relating to radioactive liquid effluent discharges from nuclear installations". The development of this legislation was connected to the mounting criticism of nuclear energy, as antinuclear protests boomed with the massive nuclear planning announced in 1974 (Plan Messmer). More broadly, the development of environmentalism played a significant role. Simultaneously, a specific legislation appeared to limit water pollution (Water Act 1964). The debate over ocean disposal of radioactive waste also played a significant role in the evolution of waste management, with international treaties (London Convention 1972). The CEA abandoned ocean disposal projects in 1969. Finally, regarding the Marcoule plant, the modification of the Rhône itself due to CNR fittings, and the increase of radioactive effluents (plutonium generation facilities, tritium production reactors, laboratories) involved new technical solutions to contain their effects. This switchover can be observed through the officials reports and the debates over Marcoule radioactive effluents during the 1970s.

[7] In 1957, the *Préfet du Gard* was "alluding to the emotion aroused at the beginning of the year at the *Conseil Général de la Seine* by the dangers of radioactivity. It is therefore necessary, particularly with a view to creating favorable psychological conditions for the development of nuclear energy in France, to take precautions to reassure the population through concerted action between the various departments of the Ministries concerned".

[8] We can also mention the political and ideological containment taking place during the 1950s and 1960s within the CEA to avoid hiring Communists (mentioned by Gabrielle Hecht), which we will analyze in a future publication based on Intelligence Service Archives.

3 Keeping radioactive effluents on site, protecting the river: from dilution to a stricter containment (1970s)

As a result of the 1974 legislation, the CEA (and, after 1976, its new subsidiary company, the *Compagnie Générale des Matières Nucléaires*-COGEMA, in charge of a large part of Marcoule) had to submit a new application for the disposal of radioactive effluents. This 400-page request allows us to observe the evolution of the site since the 1950s. It was divided into 8 chapters (description of the site, radioactive effluents, nature of these effluents, other installations producing effluents in the river Basin, environment, population, intermediation between environment and population, and radionuclides). It was sent to the *Service Central de Sûreté des Installations Nucléaires*-SCSIN, the new radioactive control authority established in 1973.

By analyzing this request and the debates over Marcoule radioactive effluents during the 1970s, we would like to underline three main aspects.

First of all, the guiding concept of radioactive containment evolved: the river was now conceived as an environment to protect, and not only as a barrier; national and European legislations compelling the CEA to consider every potential contamination, every water use, also became a threat to local populations. Both factors lead to reduce radioactive effluents effects as much as possible.

Secondly, this movement towards a stricter containment was materialized in new technical solutions. The precise description of the plant and of the radioactive effluents makes it possible to examine the material organization of fluids on the site itself. These effluents were organized, prioritized, and separated into five categories to avoid interference. The *Clarinette* system itself, as a symbol of this technical twist, was out of order due to siltation caused by the *Caderousse* dam. The river silt was not a protection anymore: it must now be contained to protect the pipes and the plant itself.

Thirdly, reactions from local officials to the request challenged its weaknesses and its lack of information, by calling for a more transparent regulation of radioactive effluents. They also suggested a redefinition of the “concerned area”, conceived on a larger scale than direct vicinity or downstream cities.

3.1 Containing on site to protect the river: the guiding conceptions of containment evolve

As we mentioned, the social and scientific context of the 1970s led to new containment conceptions, concerning every kind of radioactive waste (solid, liquid, gaseous). The idea of dilution was now being challenged by research over concentration and vitrification. Radioactivity must be trapped, by treating radioactive effluents to obtain solid waste being stored and contained on site, rather than diluted and discharged into the river. A hierarchy appeared, ranging from gaseous effluents to solid waste, easier to control. In between, the water was used as a “biological protection [that] strongly reduces irradiation and prevents contamination from dispersing into the atmosphere”, but also as a waste carrier to obtain a solid form (sludge). At the same time, research was being conducted on waste in the Vitrification Facility in Marcoule.

Decontaminating effluents became a major concern. It was controlled on each effluent, but also as a whole, to limit the impact of Marcoule plant: "the effectiveness of the treatments is given by the decontamination factor (DF) which is the ratio between the activity received and the activity discharged into the Rhône". [15]

European legislation compelled the CEA to strengthen the containment of radioactive effluents, by defining higher safety standards in order to protect population health. [16] The 1974 decree required a study of the environmental impact of the radioactive effluents. It led to the construction of a complex “initial state” of the environment (animals, plants, population, agriculture etc.) with a very detailed description of the agricultural products, of local irrigation or fish consumption. By depicting every type of contamination through intermediation (by eating a fruit or a fish, by drinking water, etc.), this study made it impossible to consider dilution as a reasonable solution anymore. The drainage system materialized this evolution towards a stricter containment.

3.2 New technical solutions to contain radioactive effluents effects

As a symbol of this transformation, the *Clarinette* installed to dilute the radioactive effluents produced by two military tritium producing reactors (*Célestin* 1-2), fell out of order in 1975. Due to the canalization of the Rhône as a part of the *Caderousse* dam, the flow had slowed down, causing siltation. The dilution system became a problem: tons of sediments were pumped and released each week, clogging the pipes.

Besides this technical problem, this situation also illustrates the struggle over water use on the Rhône. After a first maintenance work at the expense of the CNR, the same problem occurred again in 1979, leading to six years of tensions. The CNR refused to pay for any new repair work; CNR officials argued that the radioactive spill was illegal, the COGEMA having never submitted any application for these pipes.

Inside the plant, the complex drainage system described in the 1976 report materialized in the evolution of containment measures. Fourteen buildings produced radioactive effluents: plutonium producing reactors, laboratories, tritium producing reactors, industrial laundry, etc. All of them were connected to a non-radioactive sewer network, but also to at least on the five radioactive drainage system, depending on their function and on the radionuclides they released. Five different types of effluents were separated into these systems, ranging from "suspect" (low level waste)," tritiated", "intermediate-level waste", "high-level waste" and "carbonated". This was very different from the situation of the 1950s, where all the radioactive effluents were homogeneously considered. The report underlined that

> "the guiding idea in the design and construction of this sewer system is to have two permanent barriers between the effluents and the natural environment in order to preserve the integrity of the soil and the water table".

These two permanent barriers were the pipe itself, and a concrete trough, divided into 58 sections, in order to facilitate an intervention in case of contamination. Fluids were conducted to a buffer storage area (5 m^3 to 50 m^3 tanks) to measure the quantity received and to check that there had been no "shunting error". Then each effluent was dispatched and retreated with different chemicals, at different temperatures and for a different duration. For instance, "suspect effluents" were discharged after a settling time and sand filtering. "Intermediate-level effluents" were conducted through three successive settling pools for "sludge maturation". "Carbonated effluents" were concentrated and stored 10 years before being mixed with other effluents and finally discharged into the river.

It is interesting to observe that this organization of the radioactive effluents management was a reproduction on a micro scale of the "natural" conditions of the river as they were conceived during the 1950s, with sediments and sand supposed to be a barrier by concentrating radioactivity.

3.2 Local administration reaction to the lack of radioactive effluents containment: where does the "impacted environment" stop?

The CEA request was forwarded to the local administration for approval. This caused administrative problems: which *départements* were to be consulted? Considering the fact that the Rhône is an administrative limit, both sides (*Ardèche* and *Gard* versus *Drôme*, *Vaucluse* and *Bouches du Rhône* departments) must give their opinion because both were concerned by the radioactive effluents.

The definition of the "impacted environment" also met considerable difficulties, given the fact that it did not match any administrative district. The environmental study we mentioned relied on approximate figures: how could you give a precise description of nutritional habits for a population defined as "more or less directly related to the water of the Rhône River"? In short, what was the effective spatial impact of radioactive effluents?

The upstream region was also a problem, due to the suggested synergies between all the nuclear powerplants along the river. As numerous nuclear power plants were being built along the Rhône, especially after the massive plan for nuclear energy announced in 1974 (Plan Messmer), the Rhône became a "nuclear valley" that demanded a control on the whole river scale. Chapter 4 of the report listed the "other nuclear installations along the river", and the possible cumulative effects implied.

For many local officers (*Service de Navigation* engineers, health experts, agriculture officers), both the information and the control over radioactive effluents were insufficient. Some criticized the report details and what they identified as a conscious retention of information. For instance, the CEA seemed to ignore the amount of radioactivity produced upstream, even though *Pierrelatte* was one of its own uranium enrichment facilities. The Chief engineer of the Regional Water Development Department complained in February 1979 that he was not able to give an opinion because of the degree of technicality of the report ("I will simply express the wish that the files should be compiled in a clearer and more directly usable way for the uninitiated"). The Chief engineer of the *Service de Navigation* identified substantial differences between the upper limit of authorized radioactivity asked by the CEA and the amounts described for each type of effluents. Why was the requested amount so high[9]? According to CEA experts, the reprocessing of new nuclear materials from old reactors (Vandellos in Spain; Chinon, Saint-Laurent-des-Eaux in France) explained this situation. However, local officials were not satisfied by this response.

Three of them pointed out the failures of the report: why was there no chapter on accidental releases? Why was the chapter on the effects on human bodies so thin? We even found critics on the legislation itself: why apply for separate authorizations (gaseous, solid, liquid effluents) when all these wastes could interact and have an amplified impact on population? CEA and COGEMA experts replied that they followed the plan established by the 1974 legislation scrupulously.

Behind all these critics, we can observe the tensions between a containment traditionally regulated by the nuclear industry itself, and the new pressures to build a more transparent regulation.

4 Conclusion

By analyzing the containment of radioactive fluid on Marcoule plant, we can observe a profound change of containment conceptions and technical solutions designed to materialize them. Even though we can identify various factors explaining this shift, their respective impact needs further investigation.

However, this evolution documents two aspects of nuclear wastes control. First, despite being experimental and insufficient, technical solutions to dilute effluents during the 1950s were adopted because something had to be done to reassure the local population and to control a constantly developing industry. Secondly, safety measures and knowledge were established and experimented at the same time: facing new problems raised by radioactivity, nuclear and water experts had to adapt the control of liquid effluents inherited from "classic" industry to this new hazard.

[9] There was a difference of 2500 curies.

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