

Surveillance of Marine Bauxites residues: The Case of an Alumina plant discharge in the Marine Area of a National Park

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Conference Bauxite Residues June 8-9 2021 DRIIHM OHM-BMP
(* CERGAM-IAE-AIX)



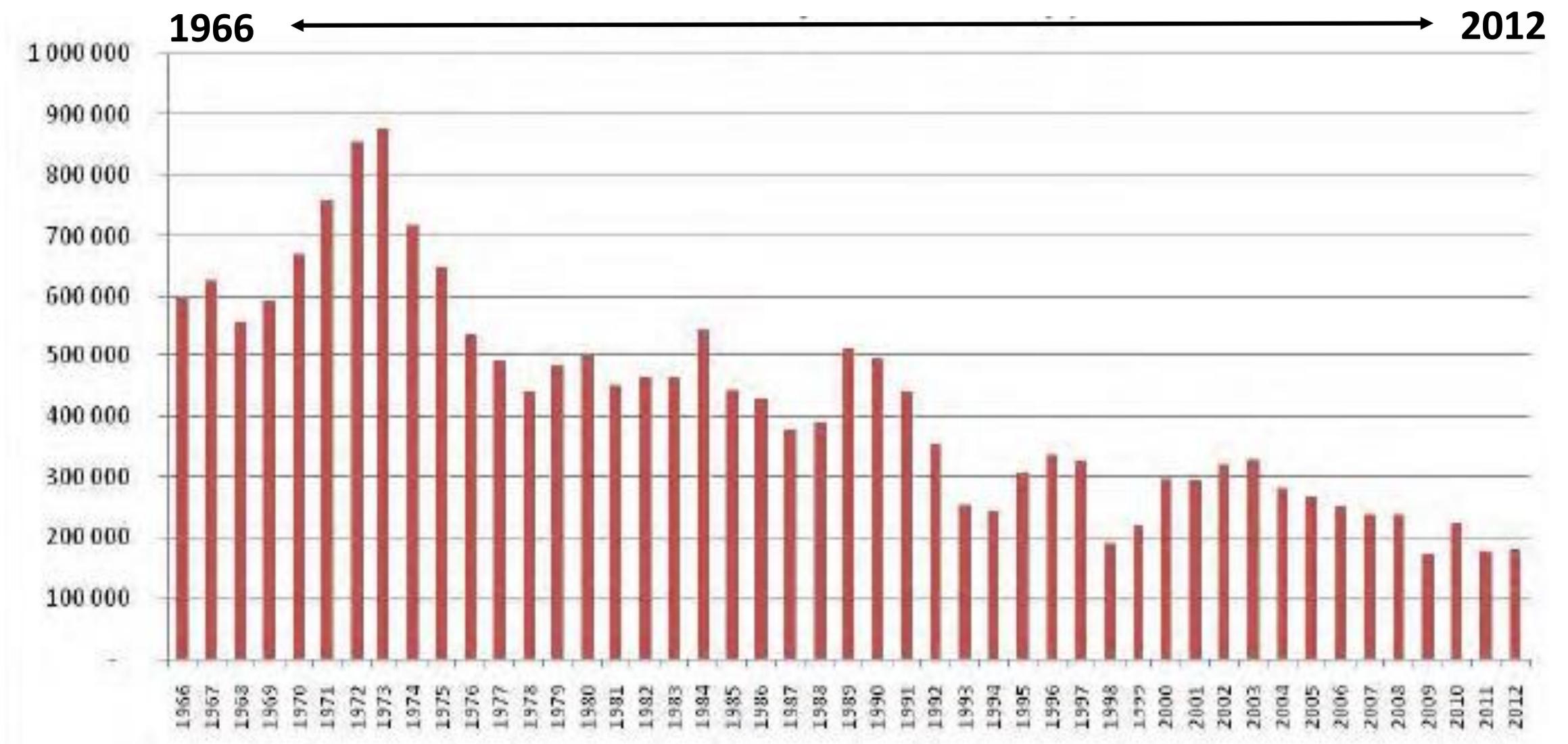
*A thought for **Cédric Garnier** and his family.
Researcher at Marseille Institute of Oceanology, he has conducted the study on hydrotacites, leaving us unexpectedly before the end of the journey.
MIO has created an Award of Excellence to honor his memory.*

The "red muds" files

The "red muds" story is a longstanding dispute that has started in the early 60's and is still not fully settled.

- 1- Brief reminder: major events and time landmarks
- 2 - Focus on surveillance of Gardanne plant *marine residues* beyond 2015 in a conflicting context.
- 3 - Lessons and questions inferred by this environmental conflict

Flow of Discharge over 50 Years



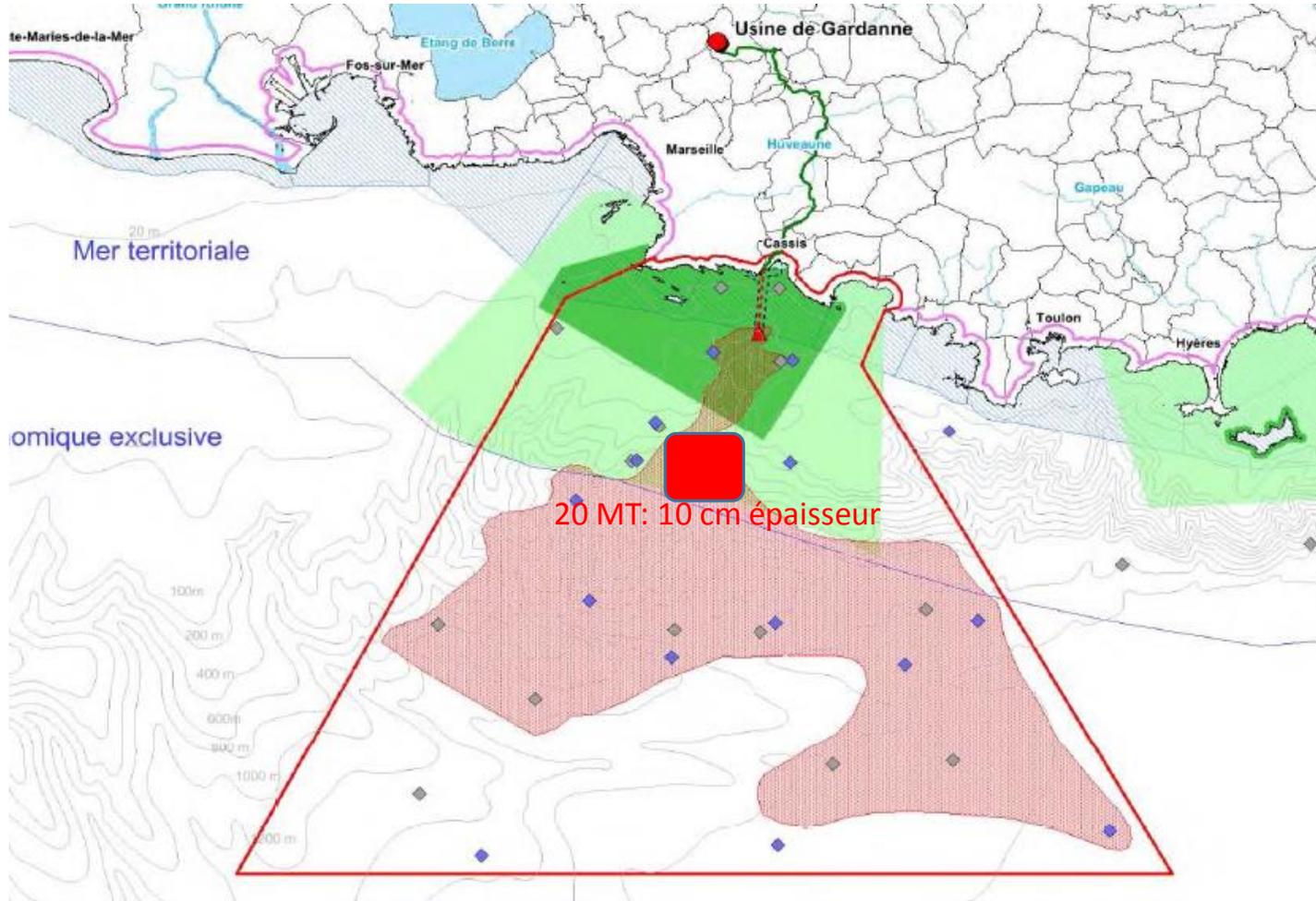
1966 ←

→ 2012

Evolution of solide residues dumped in the sea

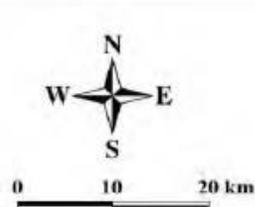
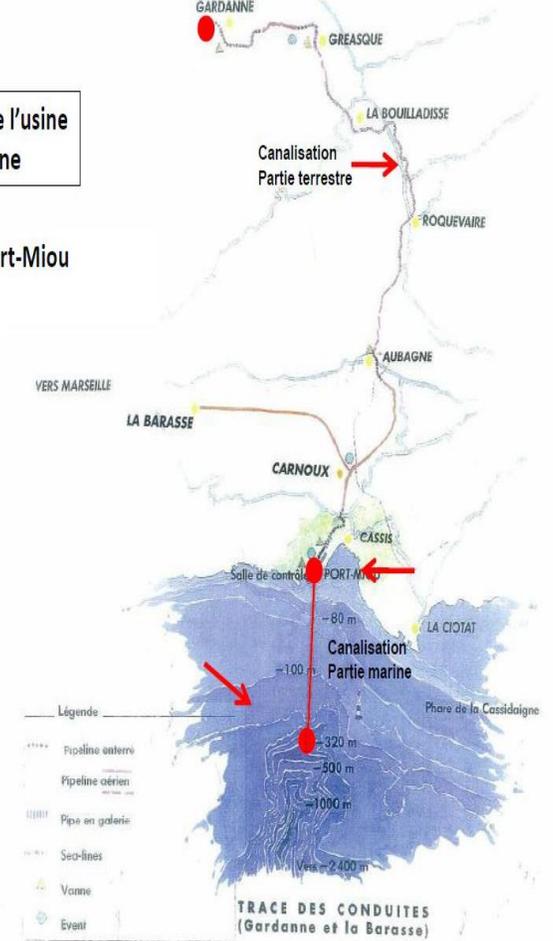
Source : Alteo and Dauvin committee

MAPS



Tracé des conduites de l'usine
ALTEO de Gardanne

47 kms de Gardanne à Port-Miou
7,7 kms en mer



- | | | |
|----------------------|--------------------------------|---|
| — Limites communales | — Canalisations de transfert : | ▲ Point de rejet |
| — Isobathes | — Partie terrestre | ■ Emprise maximale connue des dépôts des résidus de bauxite |
| — Cours d'eau | --- Partie marine | □ Zone d'interdiction de mouillage et de dragage |
| ▨ Masses d'eau (DCE) | | |
- Aires d'étude :
- | |
|---------------------------|
| ▭ Aire d'étude rapprochée |
| ▭ Aire d'étude éloignée |

Stations de suivi des rejets de l'usine de Gardanne :

- ◆ Avant 2012
- ◆ 2012

Parcs nationaux (Calanques et Port-Cros) :

- ▭ Aire marine adjacente
- ▭ Coeur de parc

Gardanne Plant in the Literature

The Plant

Ferreira, 1991 ; Mioche, 1994, Lesclous, 1999 ; 2011, Rychen F., Zimmermann, 2000 ; Daumalin *et al.* 2005); Périères, 1955 ; Savey, 1978 ; Le Roux, 2001): Donze, 2004

Relationship company-environment

- Boulet, 2000 ; Daumas et Mioche, 2004 ; Pezet, 2007 ; Mioche, 2014, Barraqué, 2017

Corporate Social Responsibility

- Loison et Pezet Anne, 2006 ; Olivero, 2013a, 2013b

Sea dumping and pollution

- Vivier, 1978 ; Dauvin, 2010 ; Fontanier *et al.* 2012 ; Fontanier *et al.* 2015

Patrimonial & écologiqcal value of the dumping area

- Bellan-Santini et Perez, 2013

Aerial emissions

- Audurier-Cros, 1982 ; Noack *et al.* 2012 ; Reis *et al.* 2014

Long literature on the Gardanne offshore residus

Between 1965 and 2016, roughly 100 articles and reports specifically on the Bauxite residus and the Cassidaigne Canyon

Recent literature on the "red muds" dispute

- Boutin N., 2018, *Management territorial et conflits environnementaux industriels : à la recherche de la biodiversité*. Thèse Aix-Marseille Université, École doctorale sciences économiques et de gestion.
- Boutin N., Batteau, P., Hernandez S., Gachet S., Raynal J.C., 2019, Conflits environnementaux, milieux naturels, et décisions publiques: étude de deux cas industriels, *Politiques et Management Public*· Vol.36 n°2 (2019). pp.141-167
- Deldrève V. & Metin J. 2019 , Quels cadres d'action collective contre les boues et poussières rouges d'Altéo-Gardanne? Les apports de l'Environmental Justice, *VertigO*, Volume 19, Number 1,
- Deldrève V. 2020, La fabrique des inégalités environnementales en France: Approches sociologiques qualitatives, *Revue de l'OFCE* , 2020/1 165 | pages 117 à 144

Historical landmarks

- **1966**, the Gardanne alumina plant deploys a **54.6 km pipeline** to convey and dump its bauxite residues **offshore (7.7 km)** in the marine canyon of Cassis. **The exit is at - 320 m** and the residues are spread in the canyon and the seabed between **- 1500 and - 2000 m**. The effluent is a **highly alkaline liquid (pH 12)** and, in 2012, it still contains **170 grammes of solid residues per liter**. The rate of flow is then **270 m³ per hour**.
 - **Protests about bauxite residues dumped in the Mediterranean Sea.** The fire is extinguished by pouring compensations over municipalities and fishers. Little concern at that time for biodiversity and marine system functions.
- 1976** The Barcelona convention enjoins the signing parties to take national regulation to stop dumping polluting materials in the Mediterranean Sea. **In 1992**, France commands, by an Order, industrialists to stop sea discharges. **In 1994 and 1996**, first prefectural decrees were issued, requiring the company to gradually comply

Time Landmarks (*continued*)

1995 surveillance of Gardanne plant discharge exerted by **a committee** composed of scientists, and internal and external experts. The committee produced twenty annual rich reports. Controversies were raised about its actual "power" to incite the company to fasten the stopping of the discharge.

The story surges back in 2012 with the creation of National Park of Calanques (PNC).

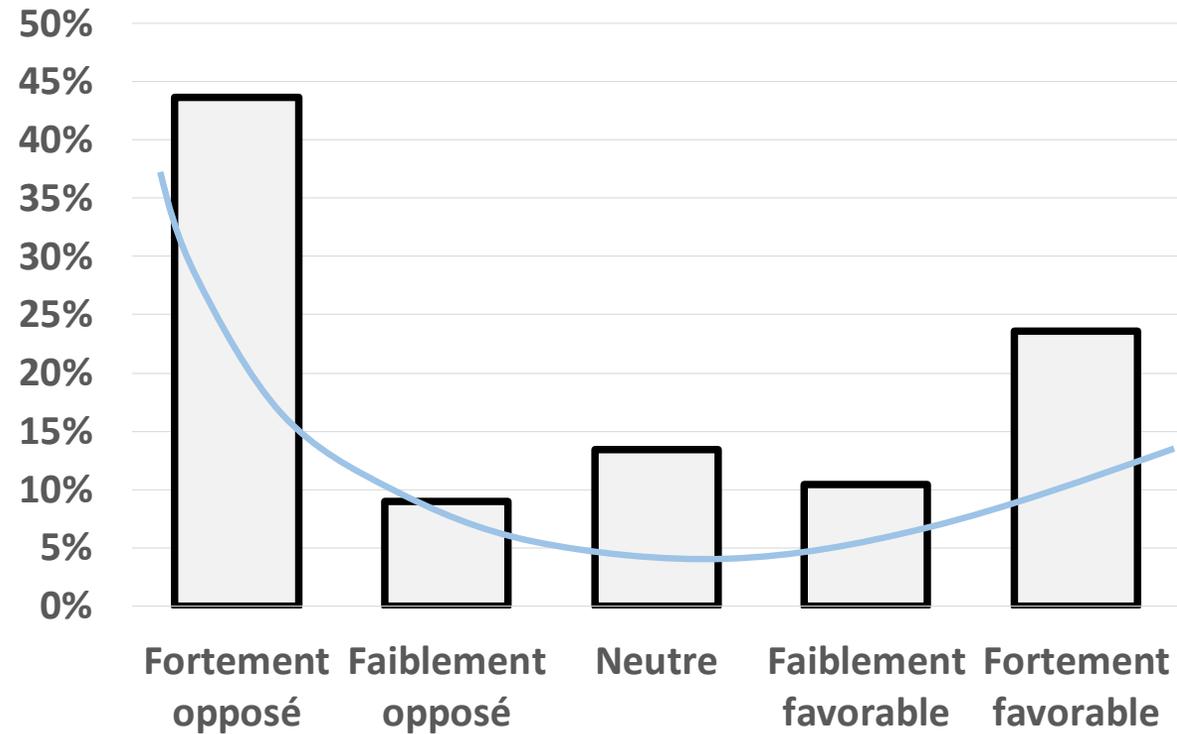
1999 an official public entity (GIS) is established to elaborate the project of a "Parc National des Calanques" on 85 km² on land with hills, high cliffs, *Calanques* (fjords) and islands over 435 km² of marine domain.

2012: the Park is officially created in April. A task force emanating from its Scientific Council is appointed for preparing the official position of the Park about the discharge. The key point is the demand by the industrialist, while stopping pouring "solid" materials, **to continue using the pipe for evacuation of the "operational liquid effluents" of the plant.**

2014-2015 : upsurge, political clash, and social amplification

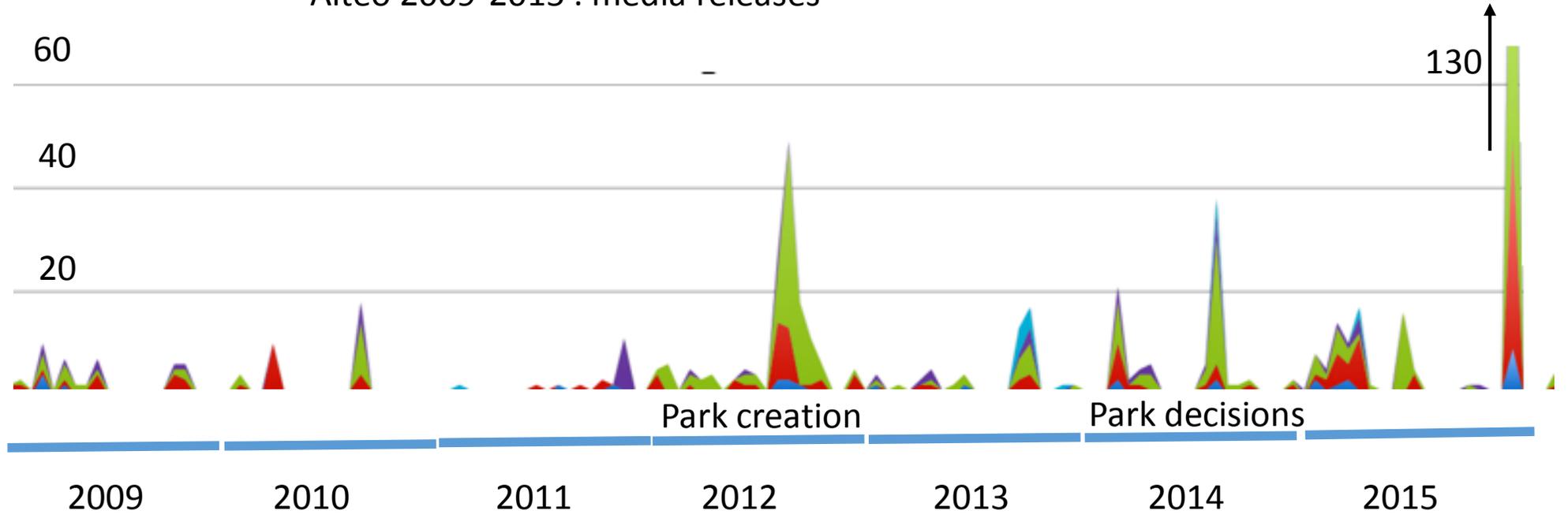
- **In July 2014** Upon the task force report, the **Scientific Board of the Park** (30 people), after a long debate among all the members, issues a unanimous "**reserved statement**", not opposing the project but submitting it to conditions.
- In September 2014, the **Park Board** makes an official statement not opposing the project of the industrialist to continue discharging the liquid effluent, but with conditions.
- At the very end of a consultation procedure, on Dec 22, 2015 the final decision falls upon the **CSPRT "Conseil Supérieur de la Prévention des Risques Technologiques"**. After a long debate (10 hours) four different scenarios are voted. Finally, the most consensual scenario will be chosen to authorize the company's project, but with a grace period of only four years.
- **The PM gives instructions to the Govt regional representative ("Préfet") to issue an order that creates a legal framework for coping with this new situation : end of solid wastes but continuation of the liquid effluent. Order issued on Dec 28, 2015, three days before the deadline.**
- Both Park's decisions, widely amplified in the local and national medias, trigger a violent dispute which **propagates up to the Cabinet in 2016, with a tough clash between the PM and the Minister of environnement, both involved in a sensitive political context (campaign for 2017 presidential election). Many other stakeholders are involved.**

Conflict evidence: the U-curve

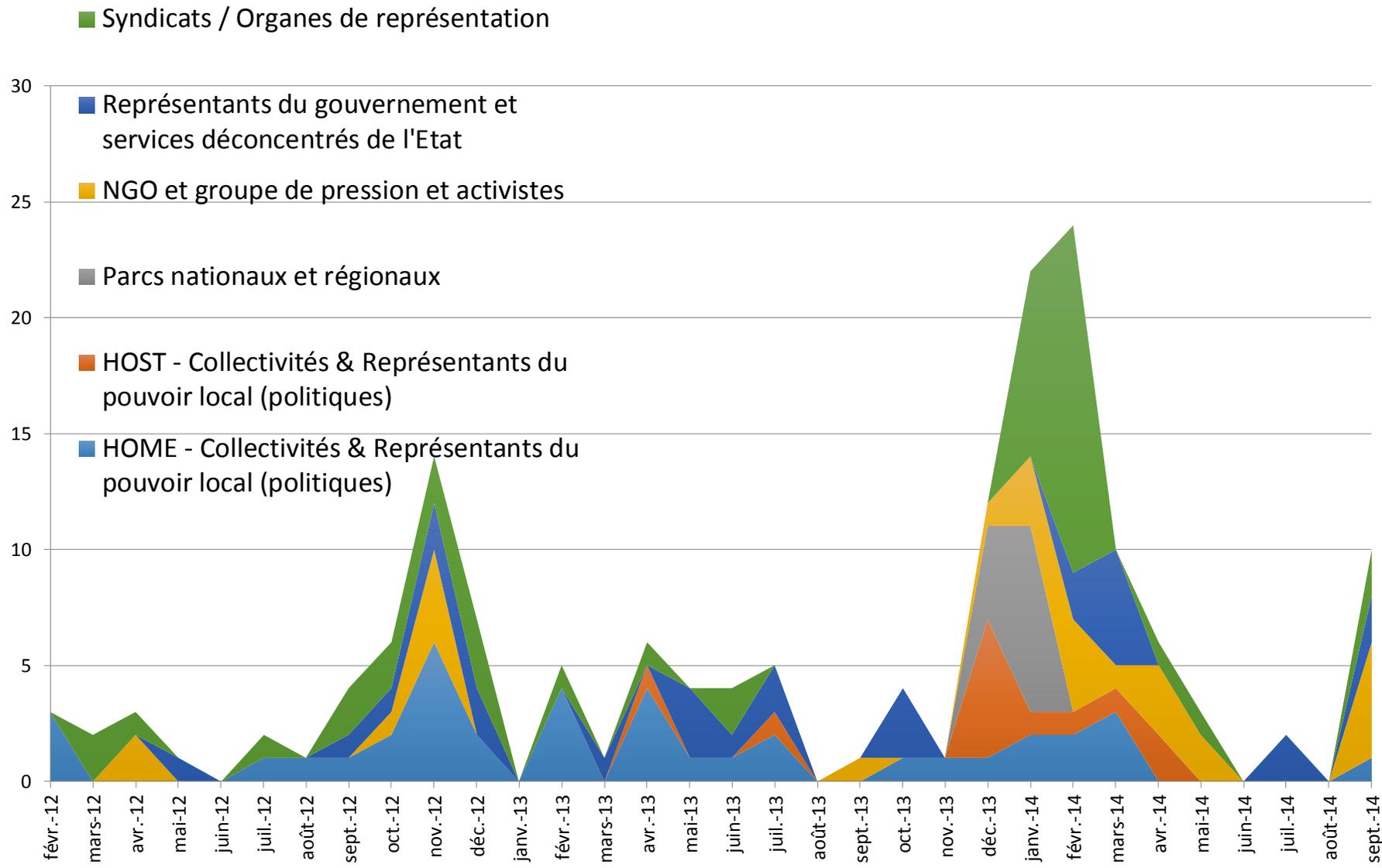


Attitudes before Alteo discharge continuation project (source: Boutin, 2018; Boutin *et al.* 2019, size: 2000 verbatims)

Alteo 2009-2015 : media releases

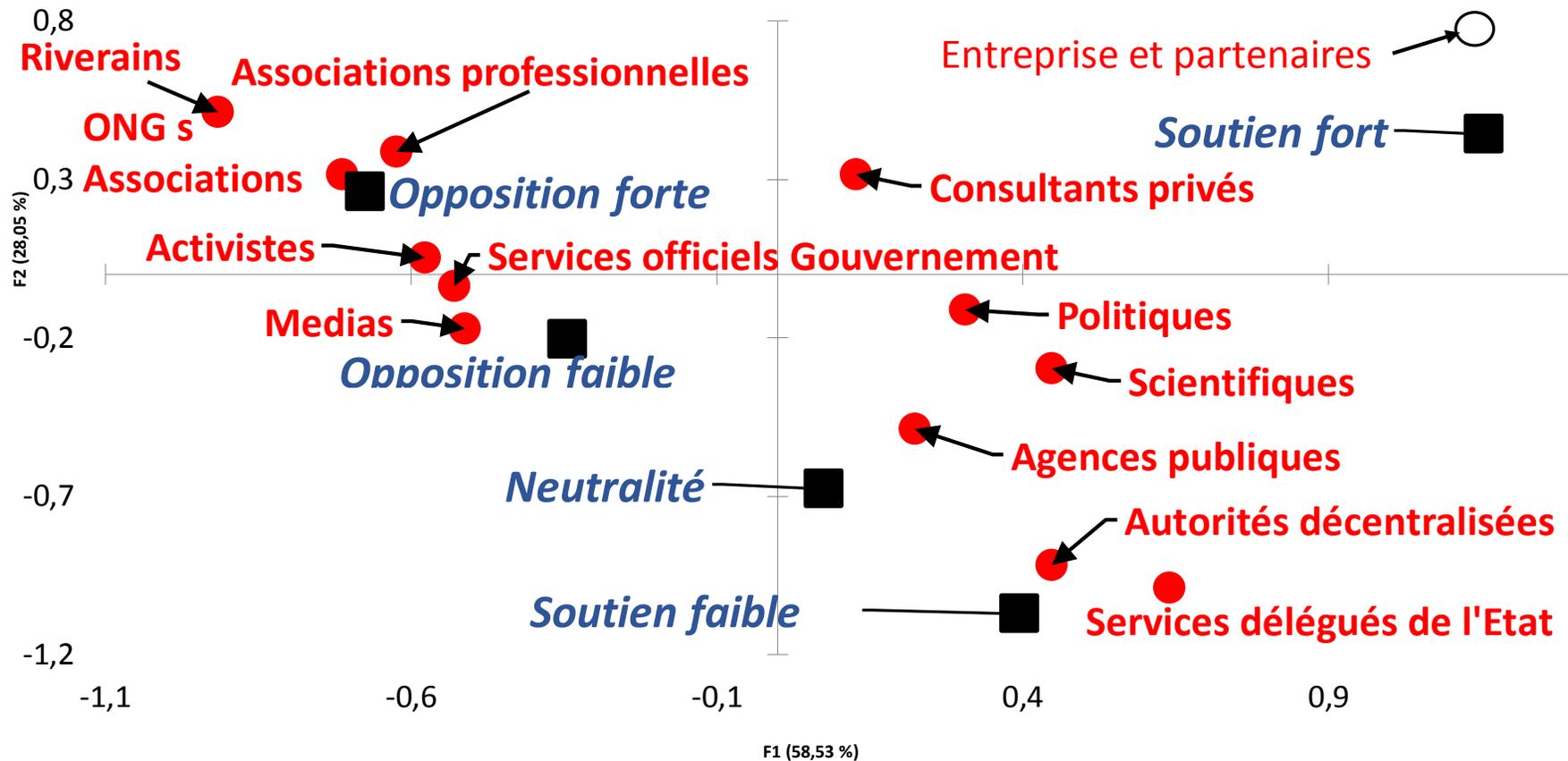


Source: Boutin et al 2018



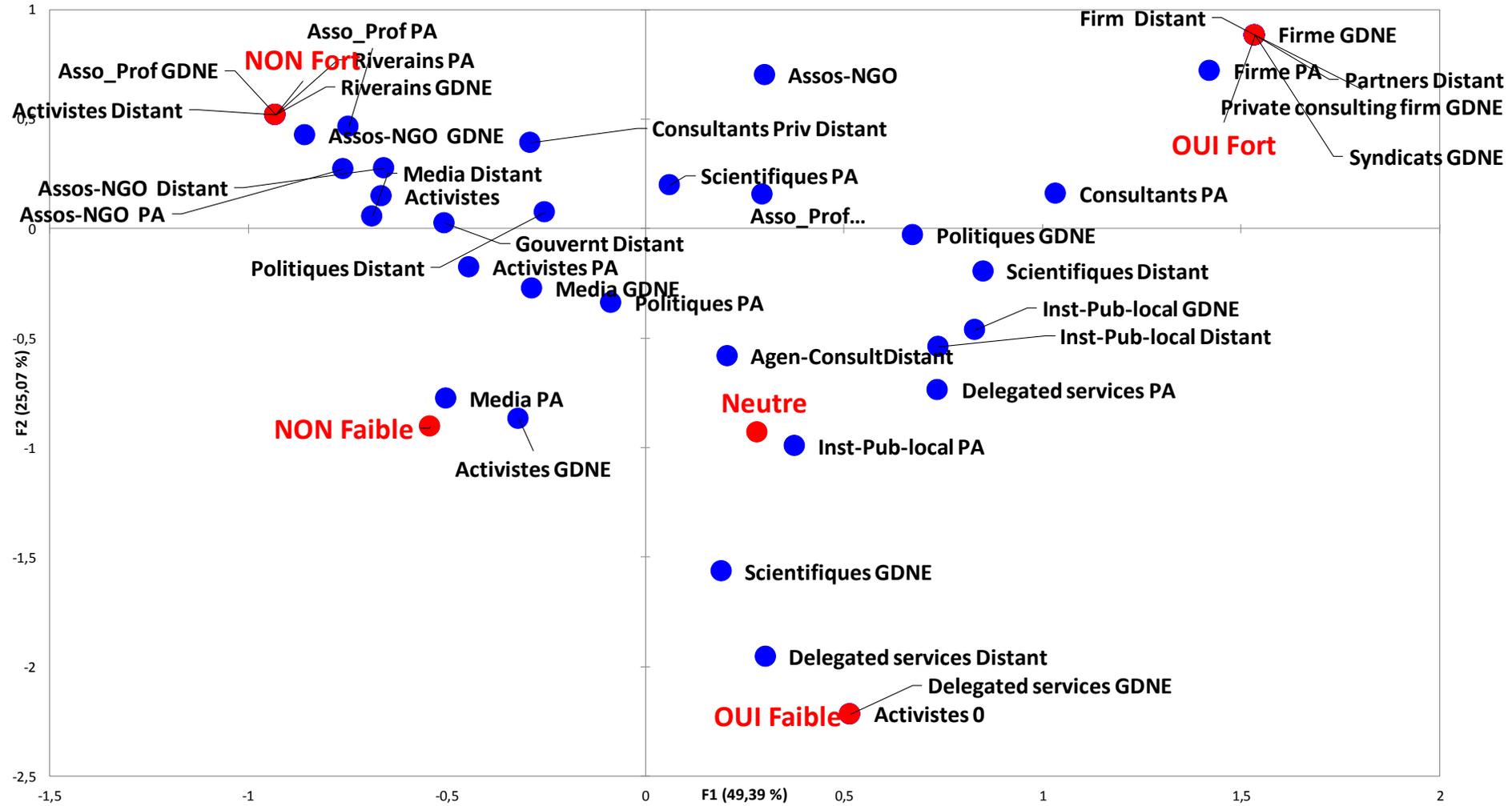
Source: Boutin et al

Stakeholders and Attitudes in the Alteo Discharge Project 2014-2016



Alteo : types de parties prenantes et attitudes Khi^2 (Valeur observée) 644, Khi^2 (valeur critique) 82, DDL 56, p -value < 0,0001, alpha 0,01 (Source, Boutin, 2018)

Attitudes and distance to the site



National Dimension of the Conflict: Evidence

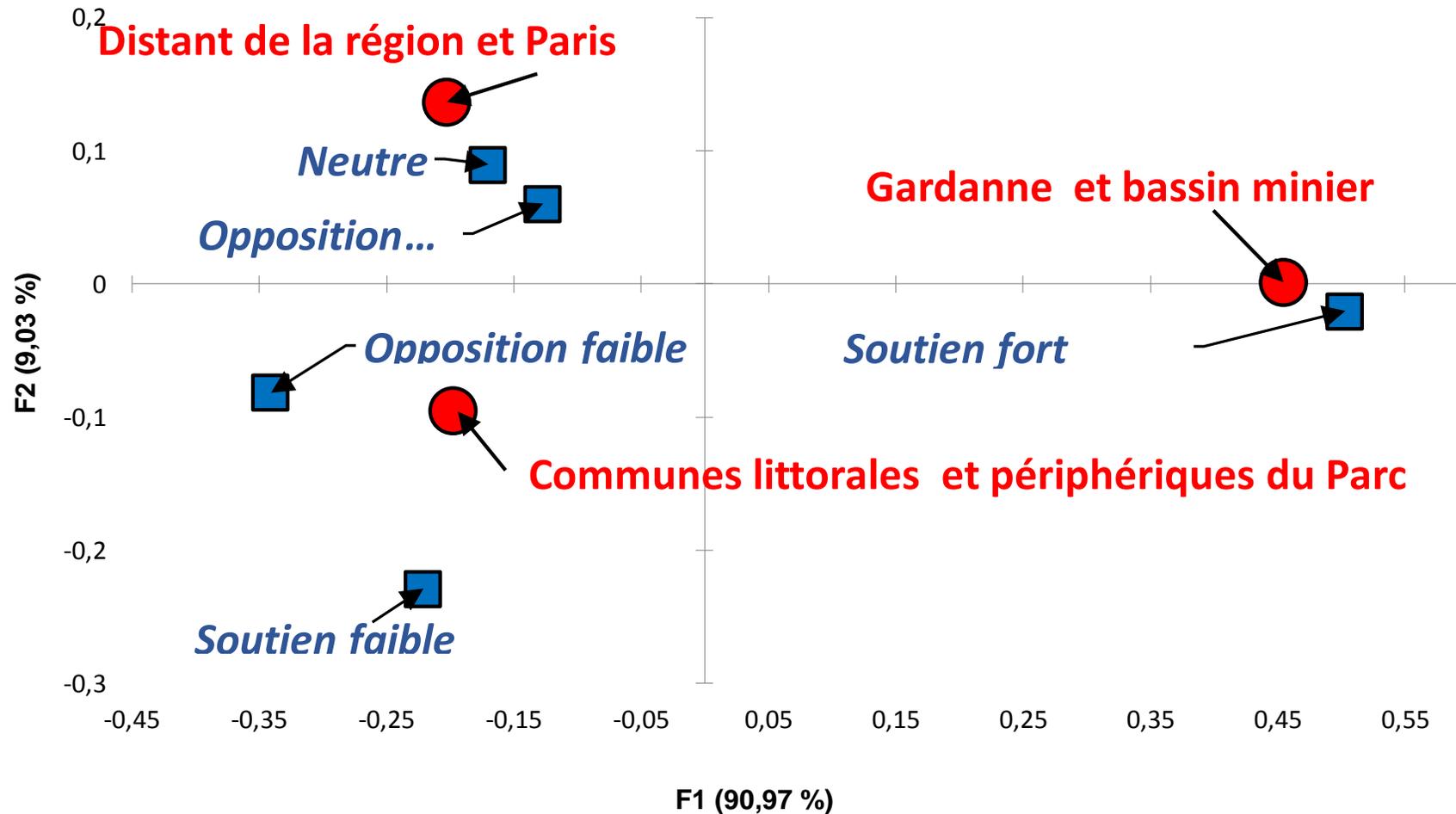
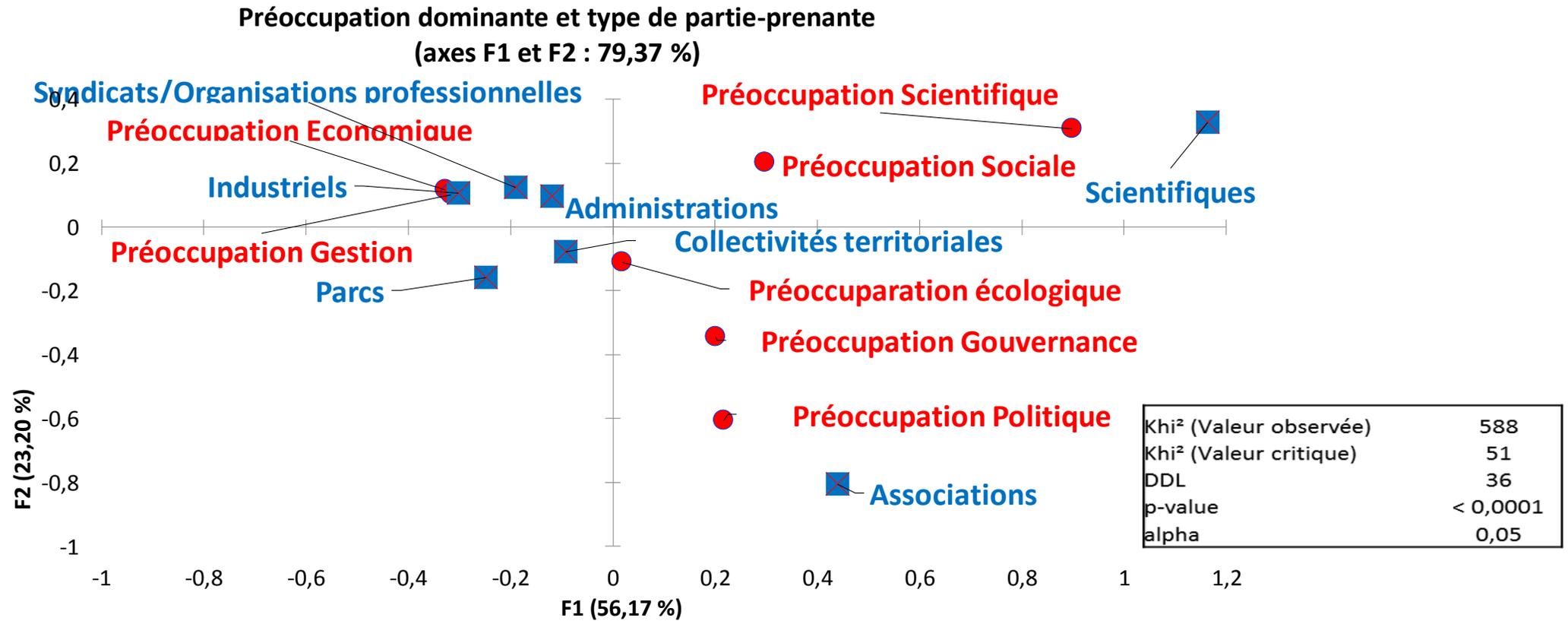


Figure 9 Alteo : attitudes et distance au site

Khi^2 (Valeur observée) 63, Khi^2 (Valeur critique) 20, DDL 8, p -value < 0,0001, alpha 0,01

Source Boutin (2018)

Dominant Concern of Stakeholders



Les variables « parties prenantes » et « préoccupations » exprimées dans les segments de verbatim ont été agrégées en sept catégories dans les deux cas. L'étude est menée sur l'échantillon de 1869 segments de discours après codage. Le khideux élevé (11 fois la valeur critique) exprime la très forte dépendance de ces deux variables. Le résultat est conforme aux attentes résultant de l'étude des cas Alumine

Environmental divergent attitudes : what are their sources?

Noxious or beneficial to direct stakeholder's economic interests			
Noxious or favorable to direct stakeholder's individual welfare			
Stewardship motives (solidarity of the stakeholder with the "losers")			
Ethical motives (approbation/reprobation of specific "practices": nature is valuable <i>per se</i> and should not be disturbed)			
Ideological motives (approbation/reprobation of "systems": industrial system, growth, protectionism, capitalism system...)			
Asymmetry of knowledge and information (e.g. specialized knowledge vs wo.man-of-the-street knowledge)			

NEED OF ARENAS FOR DEBATE AND KNOWLEDGE EXCHANGE

Why is knowledge asymmetrically distributed ? What makes so particular sea dumping of industrial wastes?

Alcaline residues colliding with sea water

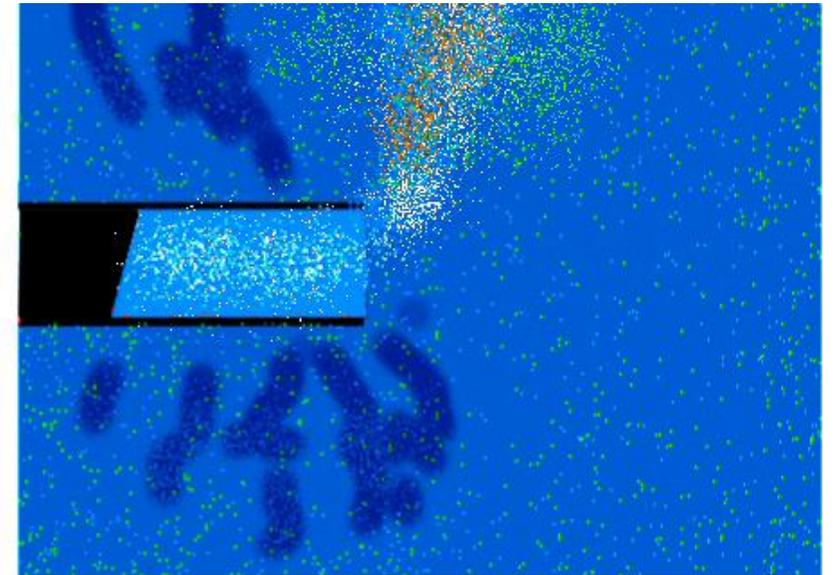
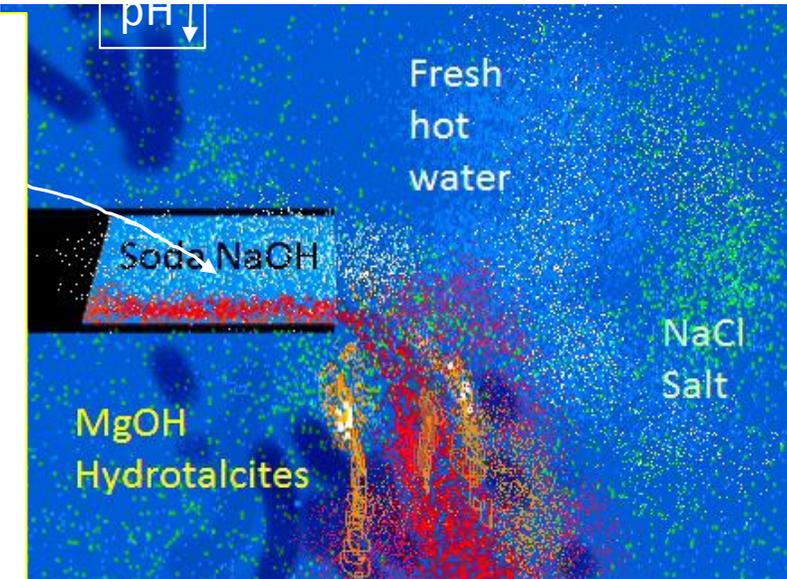
Before 01/01/16

After 01/01/16

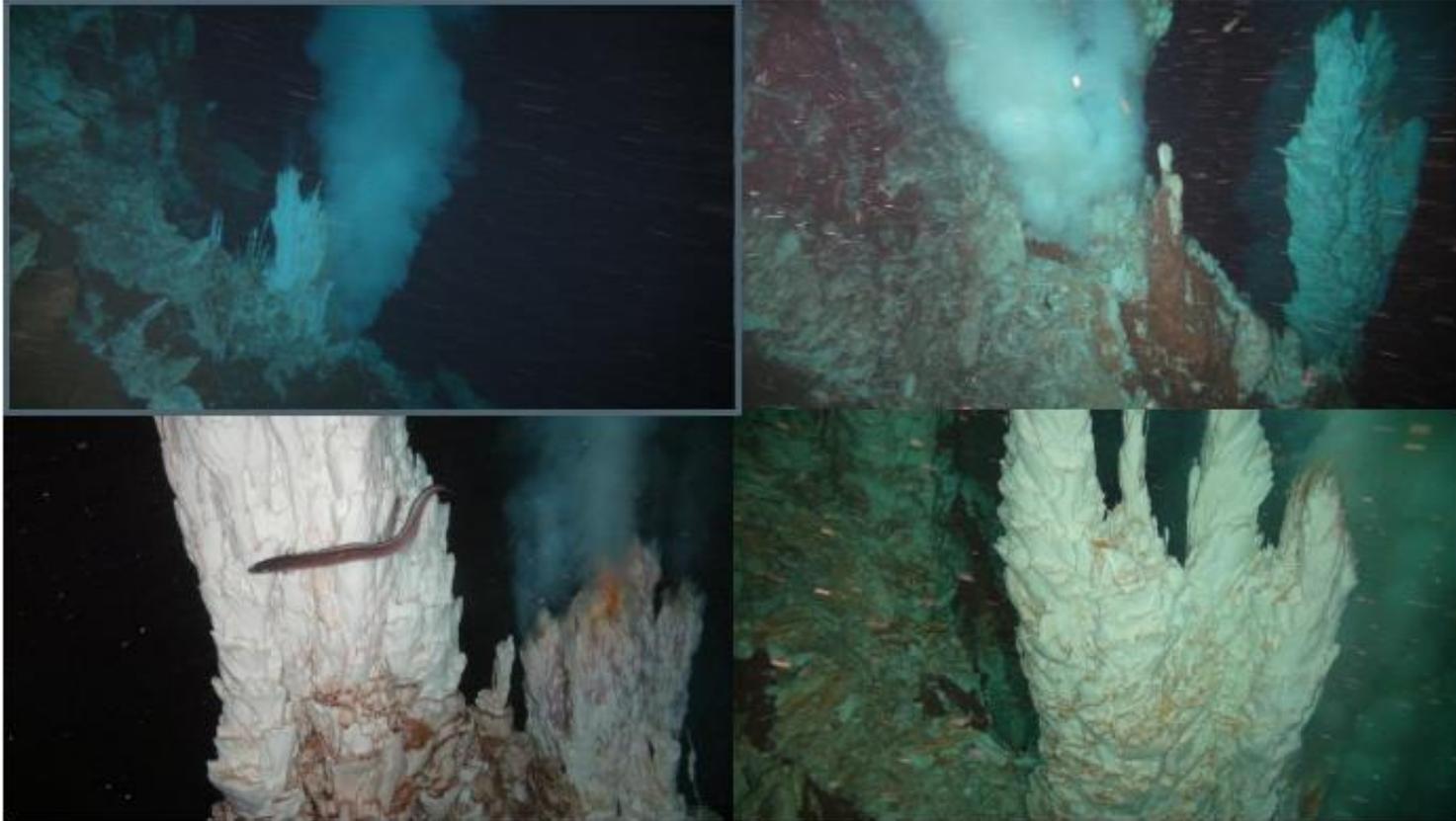
Treating highly alkaline residues dumped in the sea between -320 m and -2000 m is a much more complicated and costly task than on land

After 2016, no more solid residues but still discharge of a lixiviat of Sodium Hydroxide (Soda) $\text{Na} + \text{OH}^-$

- Produces Chemical reactions
- Affects the local hydrodynamics of the plume



Hydrotalcites



Estimated volume of hydrotalcites: 250 m³

Seguin E (2013) Rejets des résidus inertes de l'usine de Gardanne dans le canyon de Cassidaigne -

Evolution of the effluent after 31/12/2015

2012 Effluent composition

270 m³/hour and 24 hour/d \simeq 6500 m³/ liquid composed of;

- Fresh Water (process, opération, rainfalls)
- Alkali : dissolved Soda \Rightarrow pH 12
- **Solid residues: 120 Kg/m³ (120g/l)**
- Average daily flow : 777 T - Average annual flow : 180 000 T (2/3 of time in operation)
- **Hydrotalcites production : precipitate, partly dispersed in the plume partly in concretions**

2016 effluent composition

Solid residues : 35 mg/l instead of 120,000 mg/l

pH 12 \Rightarrow hydrotalcites formation + salinity \uparrow

Parameters before and after 31/12/2015

Parameters	Before derogation	Authorized by derogation	National norm	Authorized max flow (kg/J)
	mg/l	mg/l	mg/l	
Suspended matter in water	120 000	35	35	227
Total Chromium	269	0,3	0,5	2
Mercury	0,01	0,0005	0,05	LQ
Titanium	6 896	3,8		25
Lead		0,01	0,5	0,07
Vanadium	190	11		72
pH	12,4	12,4	5,5 to 9,5	
Al	10 211	1 226	5	7 940
As	6,6	1,7	0,05	11
Fe	43 285	13	2	86
DCO	1 200	800	125	5 180
DBO5	100	80	30	620

New scientific questions with the change of discharge

- Physical and chemical nature of particles?
- Are there excess **trace metals** in the discharge that are **trapped in the solid particles** or are they diluted in seawater and dispersed away by currents?
- How is the plume diffused under different **meteoceanic conditions?**
- Do these particles fall back by gravity or do they dilute distant away with the currents?
- Do metal traces contaminate living organisms?
- How to measure the plume evolution: variations in pH, salinity, turbidity **in vertical and horizontal directions**, metal capture by probes along submerged lines Use of submarine gliders equipped with sensors



Means and equipment for surveillance

High Surveillance costs for marine wastes



ROV (remotely operated underwater vehicle)

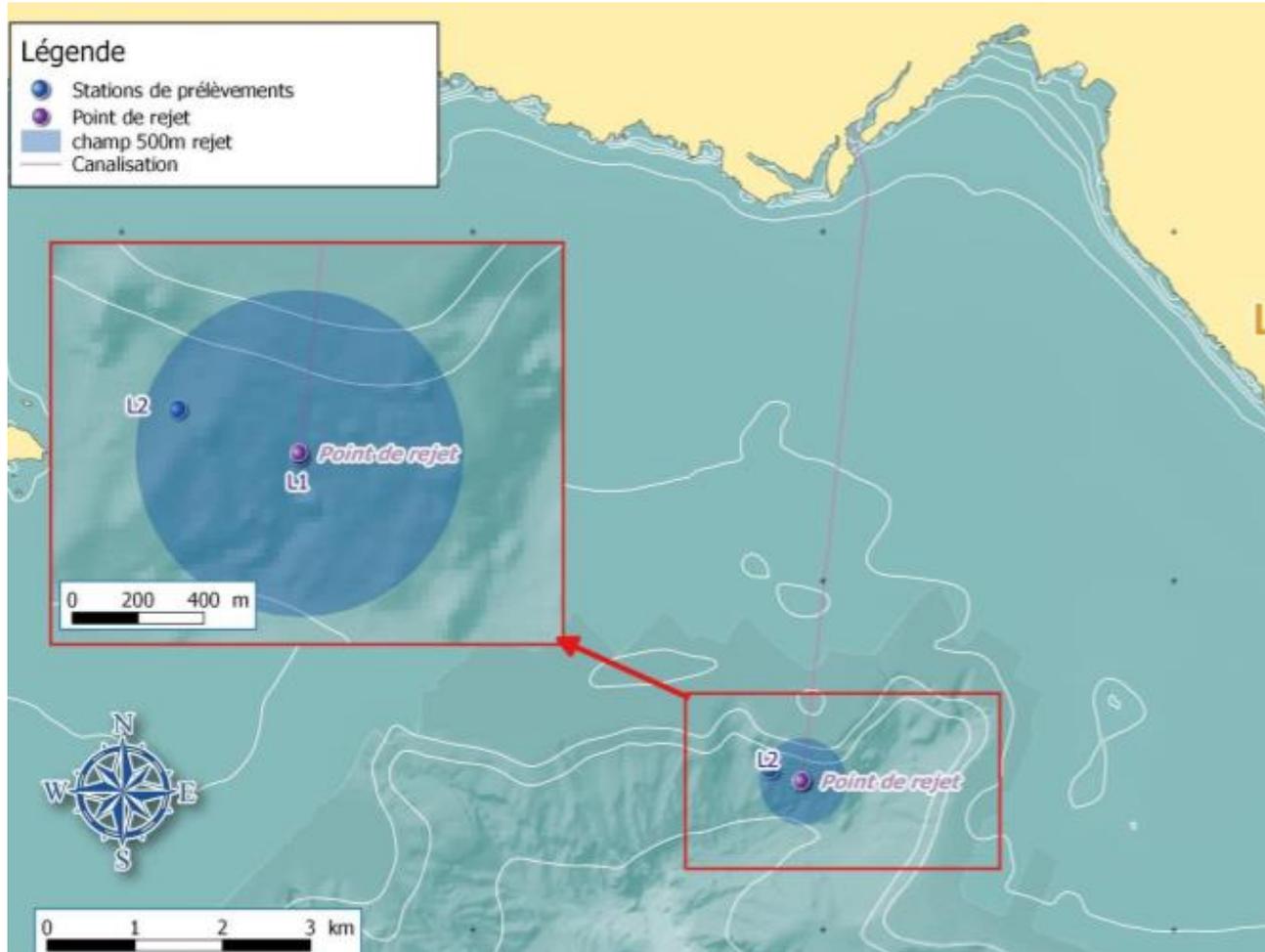


Sources of DATA : Alteo selected operator reports

- ACTIMAR <https://www.actimar.en/fr/>
- CREOCEAN <https://creocean.fr/>
- COMEX <http://comex.fr/en/home/>
- BIO-TOX <http://www.bio-tox.fr/>
- GIS POSIDONIE <https://gisposidonie.osupytheas.fr/?p=3358>
- MIO <https://www.mio.osupytheas.fr/fr>
- La Drome laboratoire <https://www.ladromelaboratoire.fr/>



Using Mooring Lines



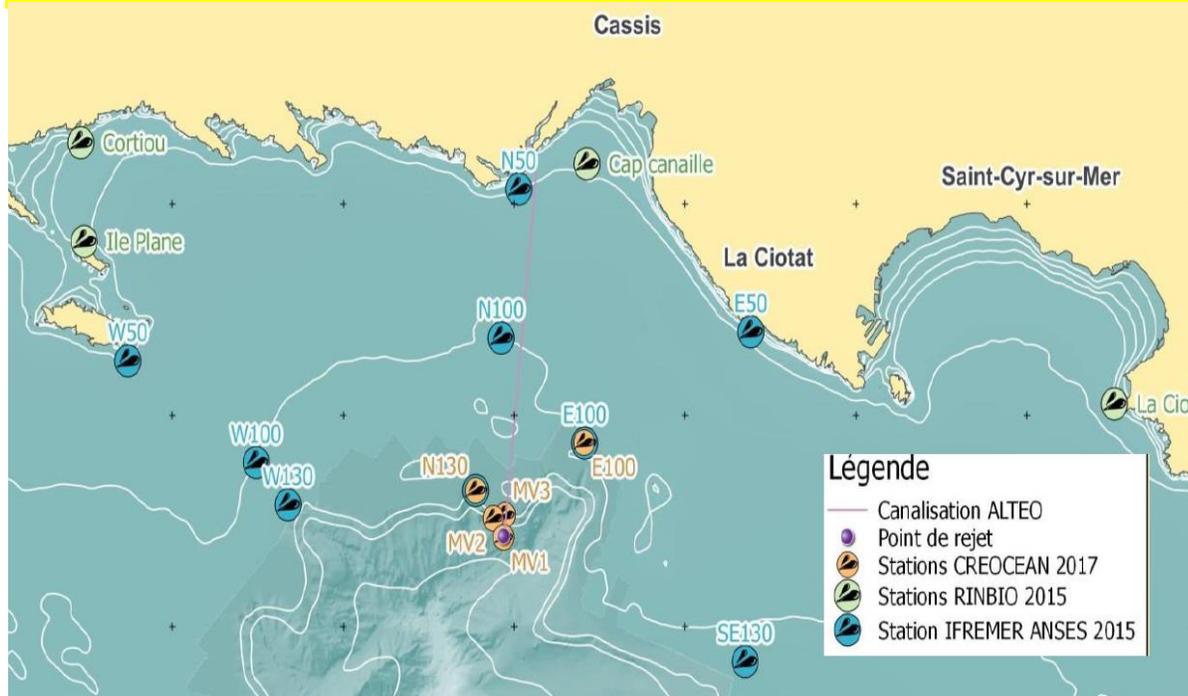
Multiparameter probe
pH, turbidity,
salinity, temperature, O²
pressure

DGT (Diffusive Gradient
in Thin film)

Current flow meter

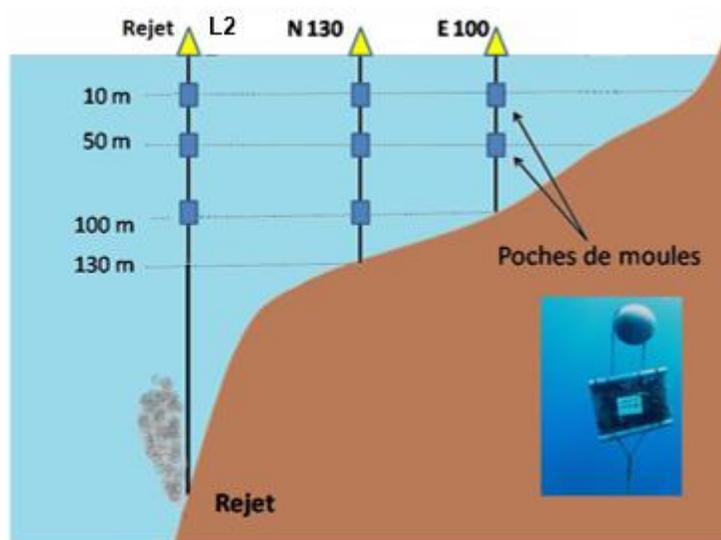
Effect of rejection on mussels: using caging campaign

5 moorin lines and 2 different depths



AOT nécessaire
Autorisation PNC

Période d'immersion
de 2,5 mois entre
Avril et Aout



Public decision: two committees are created by prefectural order

CSS: Committee of Site Surveillance

Selected stakeholders invited to expose their interests and positions about the treatment of residues and receive information from the firm and the authorities (i.e. "Prefet" and various government agencies or services "DREAL" "BRGM", "ANSES"...)

This committee always exists for industrial sites by but includes more stakeholders that usually. **Free expression of stakeholders and information provided by external scientists by law or on request of the CSS.**

CSIRM : Committee of Surveillance and Information on Sea Rejection of Alumina Plant Effluents.

New entity with selected experts providing public scientific information and advising the authorities on the management by the firm of the residues dumped in the sea. Inclusion of "observers"

- **NB : the Scientists' debates take place in the second committee, however defined for marine discharge only. The surveillance of terrestrial wastes, much simpler, is considered as a "routine" task for specialized government services. However after hesitation between designing an equivalent body for terrestrial discharges and integrating scientists of residues in the CSS, the second solution was retained.**

28/12/ 2015 Prefectural order : broad freedom for the scientists in CSRIM

- **Produce critical analyzes on scientific protocols and schedules produced by the industrialist for carrying out study and monitoring programs**
- **Make recommendations on study programs for monitoring discharge into the marine environment and make any proposal for useful additional studies.**
- **Ensure critical monitoring of the implementation of these programs; examine the results obtained, intermediate and final.**
- **Formulate recommendations for reducing pollutant discharges (rejected flows) with regard to the observed effects on the environment**
- **Follow the studies relating to the evolution of the deposit and the physico-chemical behavior of the red mud discharged since the commissioning of the industrial site concerned and their cumulative impact with the authorized discharges.**
- **Encourage monitoring and giving opinion on scientific work contributing to improve knowledge of the marine environment in the zone under the influence of the discharge.**
- **Monitor studies and issue recommendations on the health impacts of discharges at sea**

Principles defined by 2015 Prefect Order

- **Experts collegium: 12 Scientists and experts with signed & published interests declaration (they do not receive any compensation)**
- **Observers collegium : Calanques National Parc, Government services and agencies, ONGs, or association & professional organisations**
- **CSIRM Chairman elected by experts' collegium**
- **A least one meeting per year**
- **Reporting to Prefet, CSS, and Parc National de Calanques Board (CA)**
- **Statements available on dedicated sites**
- **Administrative assistance DDTM (Government service for marine et land territories)**

Surveillance System Relationships

Alteo operators
(contracting
entities)
...

Calanques National Park

Scientists & Experts
CSIRM
Observers

ALTEO

Invitation only

detailed Programs and Protocols
Reports of campaigns

Follow-up and commands

Permissions for
change asked

Préfet
Deconcentrated govt services
DREAL **DDTM**

CSS
Site
Surveillance
Committee

CSIRM
Statements

CSIRM Process

- **Alteo establishes the monitoring programs required by the prefectural order and selects consulting companies or laboratories with expertise to implement these programs. The intervention and measurement protocols are offered by these companies or laboratories in agreement with the company.**
- **The programs and procedures retained are submitted to the CSIRM, which can validate them, invalidate them, propose or require modifications, and issue recommendations. Throughout the implementation, the CSIRM receives information on the implementation of the validated protocols and may request modifications to the operations in progress by formulating "statement" by which it validates or not the results obtained.**
- **The statements are sent to the Prefect who is the only decision-maker *in fine*. The initial so-called "intermediate" program covers 2016 and 2017: throughout this period the CSIRM, its bureau, or its select committees have met on many occasions to carry out the follow-up. During the Covid period several subcommittees have worked with visio-conferencing**

Experts CSIRM

André	MONACO	Sédimentologie et géochimie marines	Directeur de recherche CNRS émérite CEFREM Université de Perpignan
Claude	ESTOURNEL	Modélisation	CNRS Toulouse laboratoire d'aérodynamique et d'océanographie côtière
Pierre	CHEVALDONNE	Benthos et substrat dur	Directeur de recherche CNRS IMBE Université d'Aix-Marseille
Céline	LABRUNE	Substrat meuble	Observatoire Océanologique de Banyuls-sur-mer
Laure	MOUSSEAU	Organismes de la masse d'eau et plancton	Observatoire de Villefranche-sur-mer
Bruno	ZAKARDJIAN	Courantologie	Professeur à l'Institut méditerranéen d'océanologie (IMO, UAM/U Toulon)
Giovanni	PAGANO	Ecotoxicologie	Chercheur associé à la Station zoologique Anton Dohrn de Naples, Italie
Jeanne	GARRIC	Ecotoxicologie	Directeur de recherche IRSTEA Villeurbanne
Pierre	BATTEAU	Economie des milieux naturels et des systèmes industriels	Professeur émérite Université d'Aix-Marseille
Nicolas	ROCHE	Pollutions marines	Professeur Université d'Aix-Marseille
Denise	BELLAN-SANTINI	Biologie marine	Professeur émérite Université Aix-Marseille Présidente du Conseil Scientifique du Parc National des Calanques
Axel	ROMANA	Zones côtières	Vice-Président du Conseil Scientifique du Comité de Bassin

CSIRM Activity 2016-2020

CSIRM Modelling preoccupation

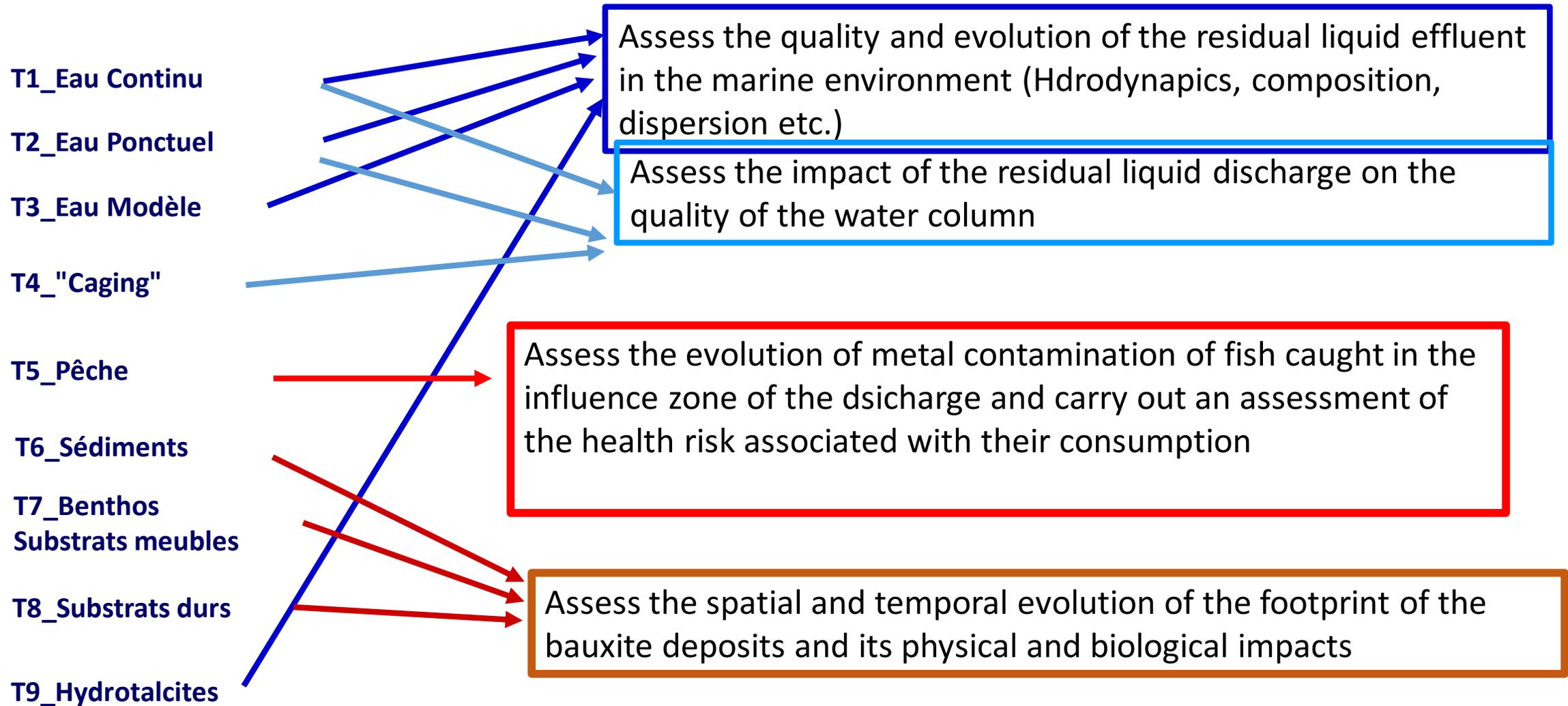
- **A sensitive question is about hydrotalcites, the trapping of metallic trace elements and their fate which depends on the evolution of the plume and the currentology.**
- **Imperative to have a reliable model (i.e. i.e. which was confronted with in situ observations and external data)**
- **Hydrotalcites result from the high pH. ALTEO's new process must bring it back to seawater level to stop their formation. However, the evolution of old hydrotalcites must be monitored beyond the date of a rejection that has returned to standards to assess the evolution of the release.**
- **To do this, the modeling of the plume must be refined and secured to better understand how the dilution of the reported metallic trace elements is carried out.**

**Report form Alteo and missioned operators
10 volumes (*tomes*) (total 1000 pages)**

Different compartments of surveillance

- **Water quality ponctual T1**
- **Water quality continuous T2**
- **Modelling T3**
- **Caged musles T4**
- **Fishing T5**
- **Sediments T6**
- **Benthic communitities on soft substrates T7**
- **Benthic communitities on hard substrates T8**
- **Hydrotalcites T9**
- +
- **Synthetic report**

Consistency with 2015 Prefect Order



(Par Alessandra Accornero Picon pour Conseil Scientifique du Parc National des Calanques juin 2018)

Chapitres des préconisations adressées à Altéo

Qualité des eaux et modélisation

Mesures en continu

Prélèvements ponctuels

Modélisation

Immersion des cages à moules

Utilité des campagnes de pêche

**Communautés benthiques des substrats meubles (Tome 7) et durs
(Tome 8) et sédiments**

Hydrotalcites (rapport final)

Mussels as measure of water quality

- Results of the 2017 monitoring are the first elements about artificial mussel stations *since the end of the discharge of bauxite residues in December 2015*. A previous study was carried out in 2015 by IFREMER before the shutdown solid rejections. **The mussels are used here as biological integrators of water quality**
- . After 2.5 months of immersion, the concentrations of metallic elements present in their flesh reflect the levels present in the water column.
- **The impact of the discharge of the liquid effluent is assessed by observing a decreasing gradient as a function of the distance from the discharge, and by comparison with the reference values resulting from monitoring of the Biological INtegrator Network of Ifremer (Witkowski et al. . 2017) on the area.**
- **The effect of the release is significant on the concentrations of Aluminum, Chromium, and Titanium.** It is however restricted to 100 meters deep. **As in 2015, the area of impact of the discharge remains small since the effect of the effluent is maximum at the level of the discharge and on the stations 500 m around it.** This effect is visible in much smaller proportions in a preferential direction of dispersion going towards the northwest. Compared to the results of 2015 (Bouchoucha & Fabri 2015), the concentrations of Aluminum, Chromium and Titanium are mainly increasing at 100 m depth.
- In the shallower regions, two trends can be observed: concentrations are increasing to 10m and decreasing to 50m at the station closest to the discharge. The iron and manganese concentrations show strong effects on the pockets submerged at a depth of 100 m within a radius of 500 m around the discharge. However, these metals are absent or present at very low concentrations in the liquid effluent leaving the plant. Iron was one of the markers of solid releases, and is currently a marker of historical residues in sediments.
- For Vanadium which is present in the liquid effluent leaving the factory, the concentrations observed do not show a clear effect of the discharge: The levels are up sharply compared to 2015 but only at depths of 50 and 10m, and the maximum values are not encountered at the discharge level, but at more than one kilometer from it. the concentrations in mussels of the other metals do not show clear effects related to the presence of the liquid effluent. The concentrations in the molds of the other metals analyzed do not show clear effects related to the presence of the effluent.

Evolution of abnormal parameters (derogation)

	<u>Valeurs dérogatoires</u>				
Paramètres	<u>pH</u>	<u>Aluminium</u>	<u>Arsenic</u>	<u>DCO</u>	<u>DBO5</u>
Unité		mg/l	mg/l	mg/l	mg/l
AM 02/02/1998	9,5	5	0,05	125	30
AP 28/12/2015 mod par 20/07/2018	12,4	610	0,85	400	80
Janvier 2018	12,4	340	0,22	160	93
Mars 2018	12,7	17	0,042	190	23
Mars 2018	12,5	56	0,056	120	18
Juin 2018	12,5	39	0,073	380	54
Oct 2018	12,5	390	0,44	250	120
Déc 18	12,5	120	0,1	130	<3
06 Mai 2019	7,8	0,3964	0,041	120	54
17 Juin 2019	11,9	0,00125	0,26	161	0,25
08 Juillet 2019	8	1,8	0,038	154	82
19 août 2019	8,2	1,1	0,031	102	57
16 septembre 2019	8,4	2,3	0,021	96	34

Prélèvements réalisés sur 24h



DCO et DBO5 Excess value concerns

The experts consider that, based on the current data, this question is secondary and should not be of concern:

The standards have been defined for releases into environments provided with a limited oxygen reserve in relation to the needs of living organisms and those linked to the degradation of polluting waste (lakes, rivers, ponds, lagoons, etc.).

In the specific environment of the discharge, 7 km from the coast and 320 m deep, sea water is close to oxygen saturation.

However, the CSIRM will formally take up this question for a review of the scientific literature on the subject if the volatility of the values does persist.

Is the story finished ?

- End of the "full" Bayer process in Gardanne. Only white dust now!
- Old residues surveillance : Who is accountable for what lies in the abysses? For how long?
- (nB. Existence of an option value"of stocks in the sea and on land)
-
- Good news and bad news for Gardanne and the metropolitan areas
 - Less pollution NIMBY satisfaction
 - Less industrial jobs, more service jobs : good news or bad news
- Pollution extraded in Africa: who is pleased with that?
 - "solidarity of the poor towards the rich"?=
 - How closely will be surveiyed bauxite resiuues in the Guinea plant reinstated?
 - How will be established the global distribution of wastes in the future ?
- Were there alternatives ? Spreading and/or, move the plant elsewhere?
- Will the tons of hydrotalcite dissolve slowly or quickly?

Lessons and questions

- Was the dispute settlement method appropriate? What else could have been done?
- What would have happened under the former law on national positions or by parcs (before 2006)?
- Balance in the attitudes between ideology, ethics, and defense of vested interests? (Study the CSS minutes)
- When coping with high and extreme risks, whom to listen? The mainstream scientific opinion or the outsiders of deviants? Does the "precaution principle" make sense?
- How is "new" knowledge percolating into Law?
- How to deal with highly "complex knowledge": "*The more we know the more we learn about our ignorance*".
- How is "interdisciplinarity" feasible despite the regular and unavoidable tendency of scientists to erect walls and silos to protect their own discipline and paradigms?
- Is it possible (and desirable) to insulate knowledge production from ideological presuppositions?

Voilà!