European Union Network for the Implementation and Enforcement of Environmental Law

ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale

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A case study of groundwater damage (under ELD)

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ENVIRONMENTAL LIABILITY DIRECTIVE (ELD)
Definitions

Art. 2(1)

- ✓ ***water damage**, is any damage that **significantly adversely affects** the ecological, **chemical or quantitative status** or the ecological potential, **as defined in Directive 2000/60/EC, of the waters concerned**, with the exception of adverse effects where Article 4(7) of that Directive applies; or*

Art. 2(2)

- ✓ *'damage' means **measurable adverse change** in a **natural resource** or **measurable impairment** of a **natural resource service** which may occur **directly or indirectly***

Art. 2(14)

- ✓ *‘**baseline condition**’ means the **condition at the time of the damage** of the **natural resources and services** that would have existed had the environmental damage not occurred, **estimated on the basis of the best information available***

Water Framework Directive (WFD) and GWD Definitions

Art. 2(2), 2(11) and 2(12) WFD

- ✓ *'**groundwater**' means 'all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil*
- ✓ ***'body of groundwater'** means a distinct volume of groundwater within an aquifer or aquifers*
- ✓ ***'aquifer'** means 'a subsurface layer or layers of rock or other geological strata of sufficient porosity and permeability to allow either a significant flow of groundwater or the abstraction of significant quantities of groundwater'.*

Art. 2 (1, 2) GWD

- ✓ ***'groundwater quality standard'** means an environmental quality standard expressed as the concentration of a particular pollutant, group of pollutants or indicator of pollution in groundwater, which should not be exceeded in order to protect human health and the environment*
- ✓ ***'threshold value'** means a groundwater quality standard set by Member States in accordance with Article 3*

Groundwater chemical status classification (WFD)

Table 2.3.2, Annex V
The groundwater good chemical status is that :

General
'The **chemical composition** of the groundwater body is such that the concentrations of **pollutants**:
- ✓ do not exhibit the **effects of saline or other intrusions**
- ✓ do not exceed the **quality standards applicable** under other relevant Community legislation in accordance with Art. 17
- ✓ are not such as would result in **failure to achieve the environmental objectives** specified under Art. 4 **for associated surface waters** nor any significant diminution of the ecological or chemical quality of such bodies nor in any significant damage to **terrestrial ecosystems** which depend directly on the groundwater body'.

Conductivity
- ✓ Changes in **conductivity** are not indicative of saline or other intrusion into the groundwater body

Chemical status:

GOOD

POOR

Assessment of groundwater damage

- ✓ *The availability of data before (baseline) and after the damaging occurrence allows you to **measure the adverse effects** and therefore to **assess the environmental damage***

*An **adverse effect is significant** when…*

- ✓ *It is such as to cause the decay of the chemical or quantitative status of a groundwater body (or of a part of it*)*
- ✓ *It is such as to delay the achievement of the objective of good chemical or quantitative status of a groundwater body (or of a part of it*)*

<u>but also:</u>

- ✓ *produces negative effects such as to affect the quality of drinking water abstracted for human consumption**

**EU COM Notice C(2021) 1860 final*

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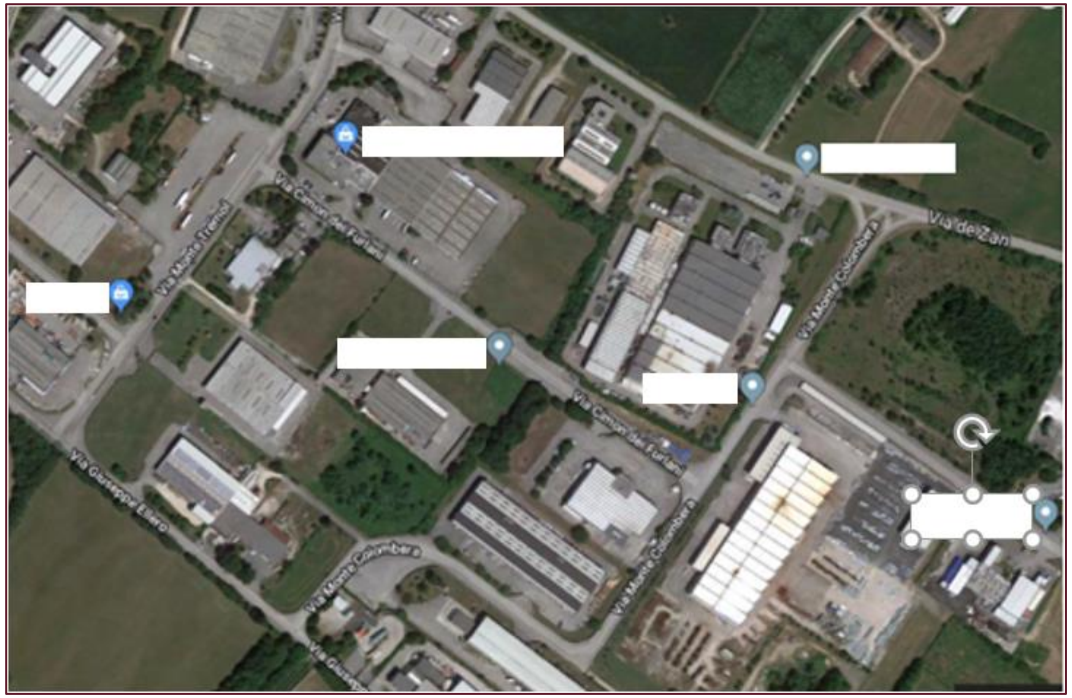
- ***In 1987** it was **ascertained an extensive pollution of the deep aquifer** in some Municipalities due to a strong presence of **chlorinated solvents***
- *As part of the quality controls in groundwater abstraction wells, widely used for water supply, the **presence of tetrachlorethylene (PCE), trichlorethylene (TCE) and 1.1.1 trichloroethane in the aquifer that feeds the aqueduct** of the Municipalities was found in concentrations higher than the limits set for drinking water*
- *The municipalities concerned have issued **ordinances of ban on the use of polluted water for drinking purposes** and provided another source of water supply for the population*



*The **identification of the source site of the contamination went through several stages of investigation.***

*The investigations conducted at that time by the Civil Protection Department have traced the cause of the pollution to **spills of chlorinated solvents, in particular of perchlorethylene (PCE), in the immediate vicinity of a plant for the production of articles in aluminum and other metals***

Diffusion of perchlorethylene in a groundwater body from an industrial site

Investigations - First phase (1987-1990)

Location of the source of impact →

- **Terebration of pilot wells and sampling of existing wells**
- **Study of hydrogeology** of the subsoil
- **Inspections** in installations and establishements in the area

Identification of the characteristics of the source of impact and of the causal link →

- **Results of the analyses** carried out on the groundwater of wells **upstream and downstream of the installation**
- **Installation surface survey** and identification of potential sources
- **Soil and subsoil sampling** (up to 30 m)

Identification of potential targets and impact on natural resources →

- **Soil:** PCE concentrations of the order of tens of g / kgss up to 8 m (approx. 50 cm clay layer)
- **Deep aquifer:** PCE concentrations>> drinking water limits downstream (max PCE values close to 10,000 µg/L)

Investigations - Second phase (1992-1997)

Insights into the extent of contamination and possible ways of repairing it of the damage →

- **Monitoring** of the pollutant diffusion
- **Dynamics** of the phenomena of **migration from the superficial layers towards the deep aquifer** (hydrogeological studies)
- **Plan and design of the interventions** to be put in place, evaluations which were then developed **as part of the remediation procedure**

Diffusion of perchlorethylene in a groundwater body from an industrial site

Cause of the event

Illegal intentional spillage (through the collection sump of rainwater) of **halogenated solvents** and **burying of drums** containing halogenated wastes

Source of impact

Release of a mixture of halogenated solvents (perchlorethylene(PCE), trichlorethylene (TCE), 1.1.1 trichloroethane) used as **degreasers in the aluminum processing industry**

Type of contamination

Continuous and long-term contamination discovered in 1987 and **is still ongoing** nowadays due to the existence of a **secondary source (contaminated soil)** not yet completely eliminated/isolated by the interventions for containment

Magnitude of the contamination

Nowadays the plume of contamination is extended for almost 14 Km^2 of territory and it is constituted of about **42.000.000 m^3** of contaminated groundwater

Natural resources involved

Soil and groundwater body and related surface water bodies

Effects on natural resources

Contamination of the aquifers which led to a **non-compliance with drinking water regulations** and, subsequently, to a **decay of the chemical status** of the groundwater body

Effects on services provided by resources

Loss of the use of the drinking water resource, ban and **interruption of the water supply from the public aqueduct** and **construction of alternative infrastructures to** supply the population with drinking water

Diffusion of perchlorethylene in a groundwater body from an industrial site

Relevant characteristics of Tetrachlorethylene or Perchlorethylene (PCE)

- ✓ The perchlorethylene (PCE) or tetrachlorethylene, it's an **organic halide of the carcinogenic chlorinated aliphatic group**, widely used in the past as **degreaser / stain remover in the metal working industry, in tanneries, in dry cleaning etc.**
- ✓ PCE at room temperature looks like a **colorless liquid with the smell of chlorine, denser than water**. It is a compound, **highly volatile, harmful by inhalation and dangerous for the environment** and how many organic halides it is **poorly biodegradable and poorly soluble in water**. Moreover, in anaerobic deep water the tetrachlorethylene **it can degrade to more toxic compounds, such as vinyl chloride**
- ✓ The IARC (International Agency for Research on Cancer) ranks the perchlorethylene in the 2nd group, **probable human carcinogen**
- ✓ **H phrases are 351** (Suspected of causing cancer) **and 411** (Toxic to aquatic life with long lasting effects)
- ✓ **The higher density of water and the much lower viscosity of water, favor the vertical movement by gravity towards the aquifer** which, in technical literature, is estimated to be three times faster than that of infiltration of water
- ✓ **Once it reaches the water table it settles on the bottom of the aquifer** causing a level of contamination as a function of water solubility. In this way, **even a modest quantity can constitute a sort of reservoir capable of causing constant and widespread pollution**
- ✓ **In groundwater, the absence of light prevents photolytic oxidation and the high pressures drastically reduce its volatility**: **the result is an increase in residence times which compromise the quality of water resources for very long times**

Diffusion of perchlorethylene in a groundwater body from an industrial site

Drinking water limits

Since 1991, for **organo-halogen compounds a Maximum Permissible Concentration (CMA) was equal to 30 µg/L** and a Guide Value (VG) equal to 1µg/l.
With the Legislative Decree 31/2001, the potability limit was changed to **10 µg / l the PCE + TCE parameter**

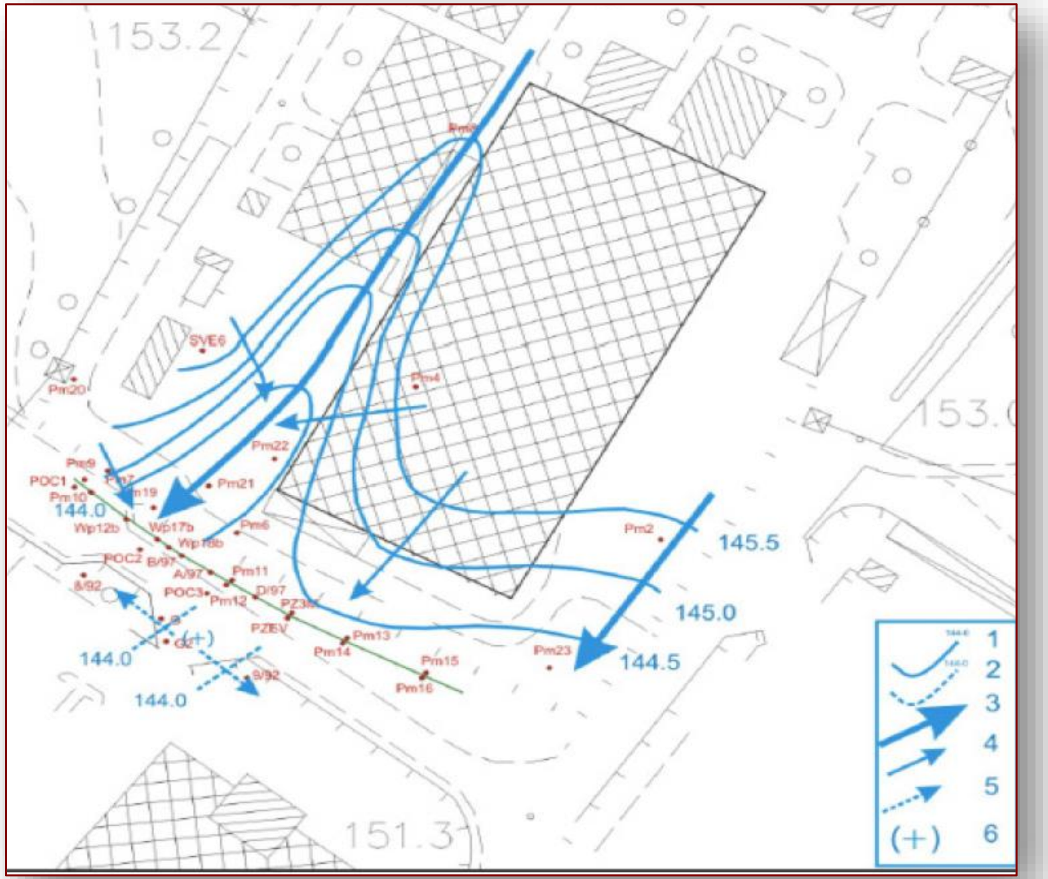
Threshold values for the good chemical status of the groundwater body

To assign a **good chemical status** to groundwater bodies, since 2006, a threshold value of **PCE of 1.1µg/L.**
Since 2016, threshold value became **10 µg/ l referred to the summation parameter PCE + TCE** (thus adapting to the limit for drinking water)

Diffusion of perchlorethylene in a groundwater body from an industrial site

Criticalities of current Operational Containment Measures

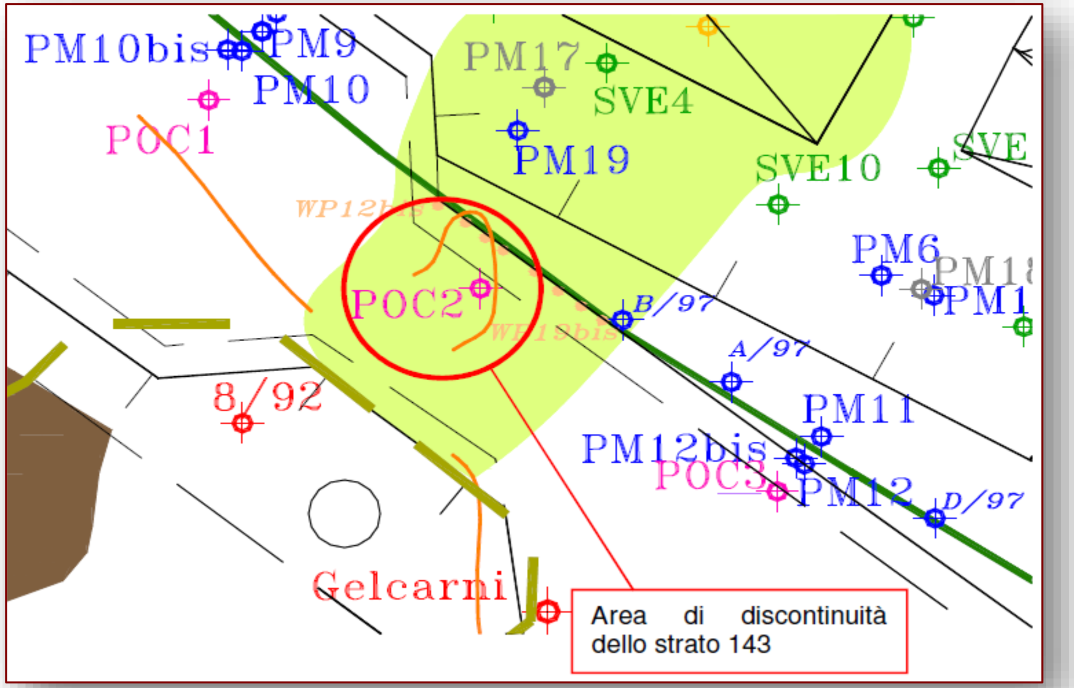
- ✓ **Incorrect initial conceptual model**
- ✓ **Presence of a paleo-channel** which connected the superficial aquifer with the deep aquifer upstream of the hydraulic barrier and, downstream of the hydraulic barrier, the presence of contaminated surface groundwater
- ✓ **Presence of secondary sources** downstream of the hydraulic barrier, shown **both by the presence of PCE as a dissolved phase in groundwater, and by the presence of PCE in the saturated subsoil in free product (DNAPL)**, with the consequent aptitude to release the contaminant in solution in groundwater
- ✓ **Ineffectiveness of the intervention in containing the contamination within the boundaries of the site** and, consequently, **permanence of contamination outside**



Diffusion of perchlorethylene in a groundwater body from an industrial site

Recent Soil Risk Analysis conclusions

- ✓ **Definitive conceptual model achieved only on 2017** which describes the environmental state of contamination of the whole contaminated plume upstream and downstream of the hydraulic barrier and in deep aquifers, due to historical sources of contamination attributable to the site
- ✓ **Permanence of the risk for groundwater due to the overcoming of threshold values in surface and deep aquifers**, even downstream from the plant border, with the presence, in some areas, of free product (DNAPL)
- ✓ **Hydraulic barrier, as currently configured, which does not have the characteristics necessary to guarantee Operational Containment Measures** in accordance with the law, while having a complementary function as a preventive measure



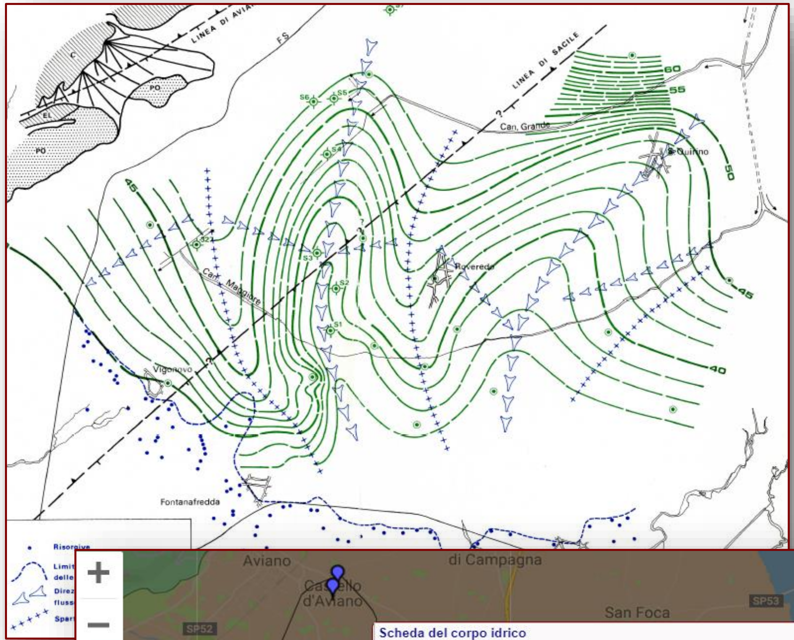
Diffusion of perchlorethylene in a groundwater body from an industrial site

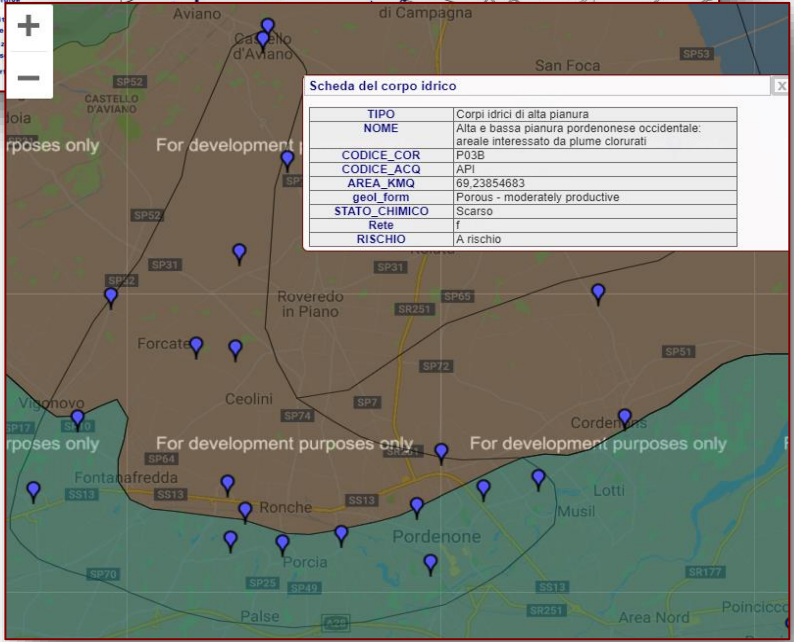
Groundwater body monitoring

The PCE parameter became part of the analytical set selected at the Region **for basic surveillance monitoring** (SET 2) **of the groundwater body**, along with 1,1,1-trichloroethane, trichlorethylene and other substances

On the water body **identified as P03B due to the presence of a plume of contamination by chlorinated organic solvents,** is performed both a **surveillance monitoring**, both a **operational monitoring on the set consisting of chlorinated solvents**, such as in particular **PCE, trichlorethylene and “summation organohalogenates"**.

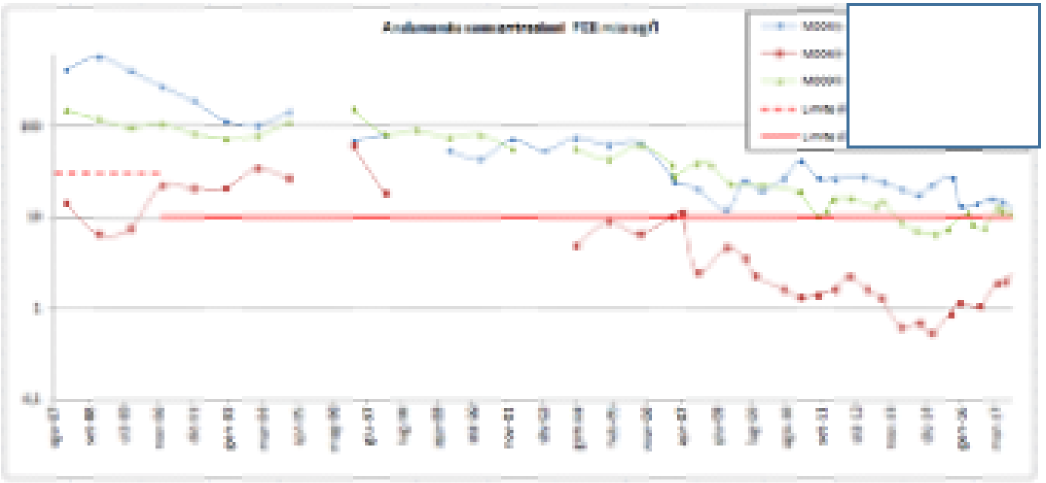
The analytical results that determined the classification of the codified groundwater bodies were acquired in **six-year monitoring period 2009-2014**





Diffusion of perchlorethylene in a groundwater body from an industrial site

Trend in PCE concentrations

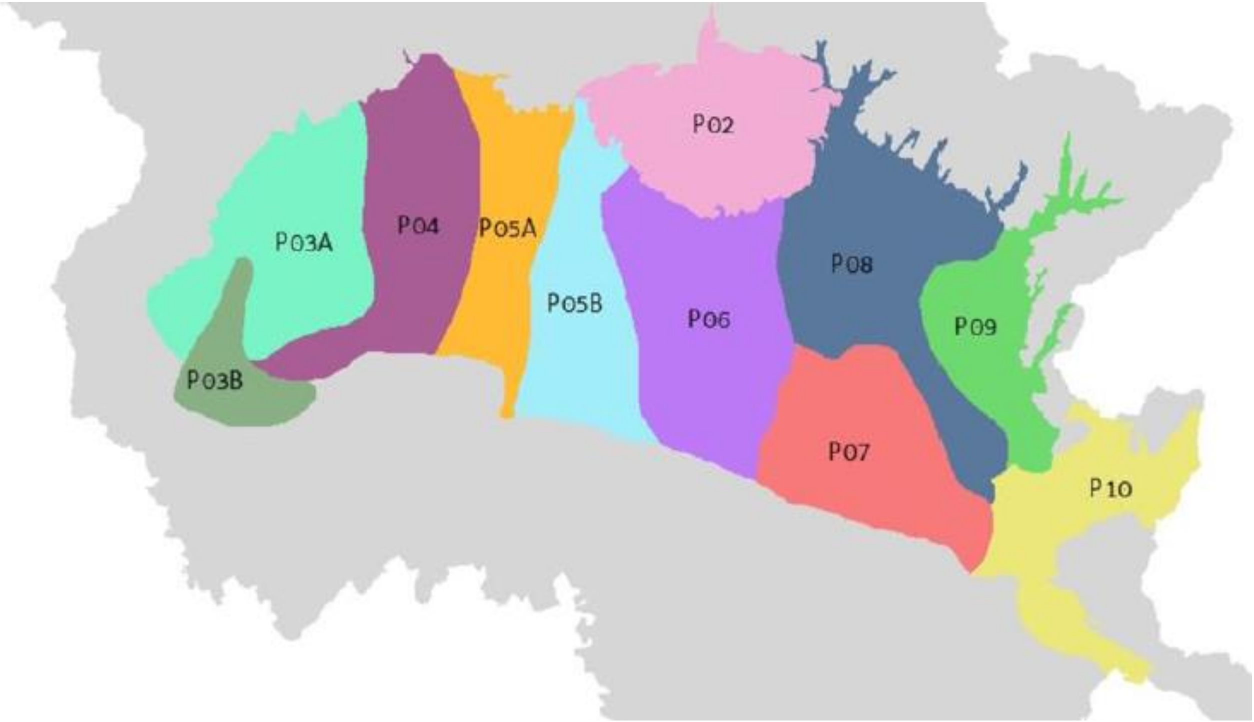


- ✓ As of 2018, in one part of the groundwater body, **PCE concentrations are still higher than the legal limits for drinking water and the threshold values for the attribution of good chemical status**
- ✓ At some points in the site area, the concentrations are even above the solubility limit, due to the **presence of product in separate phase-DNAPL**

Diffusion of perchlorethylene in a groundwater body from an industrial site

Assessment of damage of the groundwater body (1)

The critical situation is confirmed by the Regional Plan of Water Protection (PRTA) reports in 2018: *the area of the plume of the contamination, mostly due to the component of historical spills of tetrachlorethylene in the subsoil, it has reached considerable dimensions reaching the deep aquifer (150 m from the ground level) [...]**determining to date a "poor" quality status for the entire aquifer identified under code P03B** (Area affected by plume of chlorinated solvents)*



For P03B the chemical state, according to the PRTA of 2018, **was prejudiced by tetrachlorethylene (PCE)**, nitrates,metolachlor, bromacil, desethylatrazine, trichloromethane, trichlorethylene and halogenated organic compounds.
Since 2009, the PCE concentrations detected for most of the monitoring points have been above the threshold value of 1.1µg/L expected until 2016
Once the limit a has been changed **10µg/ l for PCE + TCE,** through the latest operational monitoring campaign in 2017, **the area in which the summation PCE + TCE was higher than the threshold value was redefined**

Diffusion of perchlorethylene in a groundwater body from an industrial site

Assessment of damage of the groundwater body (2)

Water Management Plan (PGA) of the hydrographic district, **2010-2015**:

- ✓ **P03B classified as "poor** " and **"at risk" of not reaching the "good" quality target by 2015**
- ✓ **the "good" quality target has been postponed by a planning cycle to 2021 due to persistent contamination**

Water Management Plan (PGA) 2015-2021:

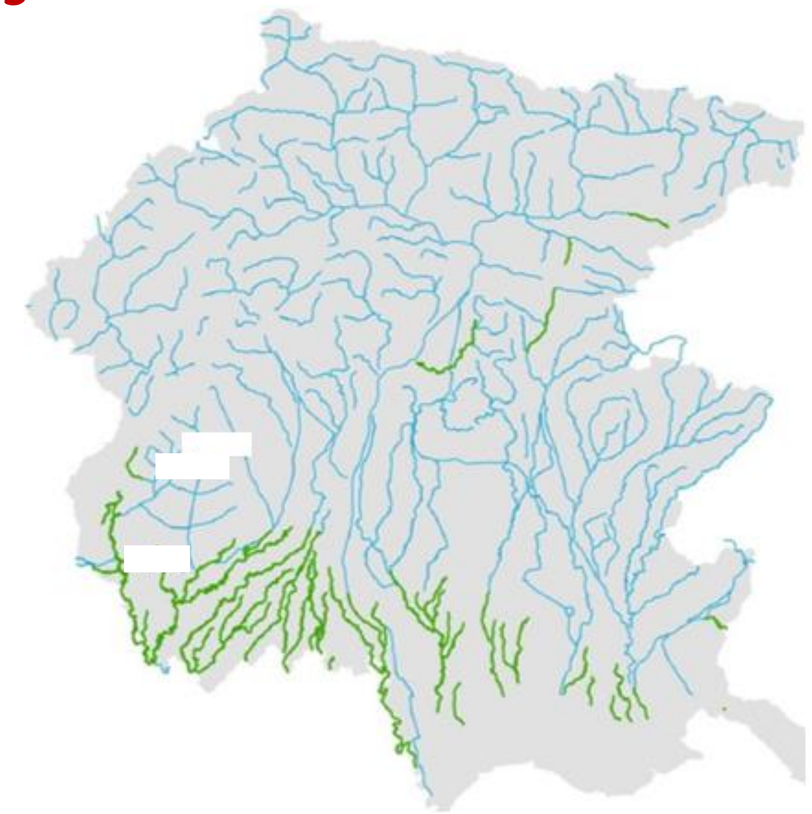
- ✓ **P03B classified as "poor"** and identified as **"at risk" of not reaching the "good" quality target by 2021**
- ✓ **the "good" quality target has been postponed by another planning cycle to 2027**
- ✓ the PGA highlights that **a complete removal of pollutants in the water body was assessed as not technically feasible** and, in any case, their attenuation in time to restore the "good" chemical state by 2027
- ✓ **The identification of limits (possibly less stringent than the threshold values)** on the basis of which classify the "good" chemical status of the water body P03B by 2027, **has been carried out during the 2016-2021 six-year period**

Diffusion of perchlorethylene in a groundwater body from an industrial site

Assessment of damage to the surface water bodies

Water Management Plan (PGA) 2015-2021:

- ✓ **existence of a "dynamic link" between the P03B water body and some surface water bodies**
- ✓ In fact, in the study of May 1999 "Episode of pollution by chlorinated solvents of the groundwater of the medium-high plain of P., phase 2 we read that "(...) **the PCE at least partially abandons the deep circulation and returns to the surface, as demonstrated by the concentrations measured in the waters of the resurgence»**
- ✓ "From this point on, the pollution also affects the surface runoff, the dilution is however greater and a little further south the concentrations cancel out [...] ". This connection is of particular importance considering that the PCE is a substance for which specific quality standards are envisaged for the purpose of classifying the chemical status of surface waters.
- ✓ In all cases, the PRTA shows that the chemical state of some involved rivers is »unknown" in the stretch of interest, while the chemical state of the other involved rivers is "good"



Diffusion of perchlorethylene in a groundwater body from an industrial site

Damage to the groundwater body

- ✓ **Significant and measurable adverse effects of P03B** generating decay of the chemical status ascertained since 2009
- ✓ **Loss of** the use of the aquifer for drinking water purposes (loss of the natural resource service)

Damage to the groundwater body can be distinguished in current and past:

- ✓ **current damage**, identifiable both in terms of **polluted groundwater present nowadays in the plume area where the threshold values are exceeded** generating a decay of the chemical status of the groundwater body, and in terms of **loss of the relative service of usability for drinking purposes**

- ✓ **Interim loss**, identifiable in terms of **loss of the usability service for drinking purposes of the groundwater that passed through the aquifer of the water body in the past** damaged since 2009. The damage, in this case, refers to the **loss of the natural resource service**

Such environmental damage must be the subject to remedial measures in the part that has not been eliminated and cannot be eliminated during the remediation procedure

Diffusion of perchlorethylene in a groundwater body from an industrial site

Imminent threat of damage to the groundwater body

- ✓ **Permanence of active sources of pollution and secondary sources also downstream of the hydraulic barrier**
- ✓ **Permanence of an exposure of the deep aquifer** to further contamination phenomena

Therefore, **the presence of active sources of pollution capable of compromising its chemical status groundwater body represents both a cause of the persistence of current environmental damage, and**
a threat of environmental damage which could cause an extension or aggravation of the damage, for example by preventing compliance with the “good” chemical status in 2027 or by imposing, even afterwards
that date, the persistence of concentrations above the current threshold value

This current threat of environmental damage must be the subject of preventive measures to prevent further damage

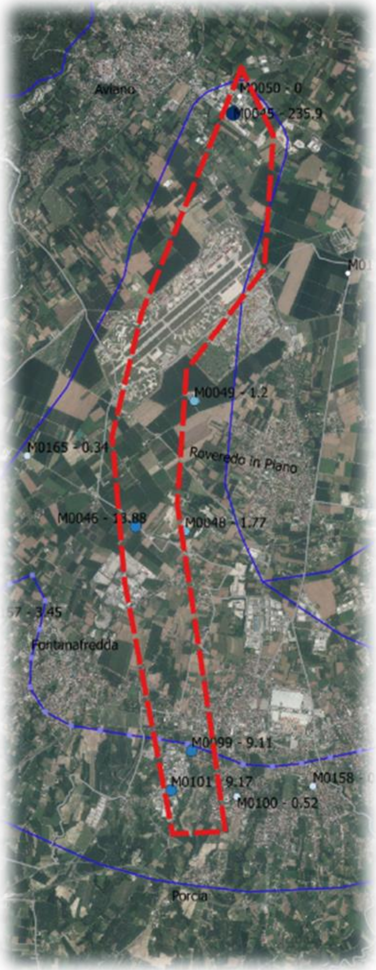
Diffusion of perchlorethylene in a groundwater body from an industrial site

Reparation of current water damage

- ✓ **A complementary remedial measure is required for the current water damage** since this pollution cannot be eliminated with direct interventions; a primary remedial measure is not applicable
- ✓ **Complementary remediation must be carried out at other sites**
- ✓ Such complementary remediation can be identified through a **equivalence between the damaged natural resource and resources of the same type, quality and quantity (equivalent resource).**
- ✓ There **damaged resource** is represented by the quantities of polluted groundwater currently present in the area where the threshold values are exceeded and **the equivalent resource** it can be represented by a corresponding quantity of contaminated groundwater to be subjected to treatment

Quantification of the damaged resource

- ✓ an area of approximately 14 Km^2
- ✓ average thickness of the deep water table of about 20 m on the basis of the hydrogeological section
- ✓ Characteristics of the saturated aquifer, consisting of gravel cemented with conglomerate with an average grain size greater than 3 mm, a "**storage coefficient**» between 0.15 and 0.2
- ✓ We calculate a **instantaneous volume of polluted waters of the deep aquifer equal to 42.000.000 m^3** (0.15 x volume of contaminated saturated aquifer)
- ✓ **The remediation must be aimed at carrying out treatments of a corresponding quantity of contaminated groundwater, also at other sites, for example, where the clean-up intervention would be publicly paid**
- ✓ Such interventions will also ensure the remediation of the current loss of services ecosystems associated with the damaged natural resource

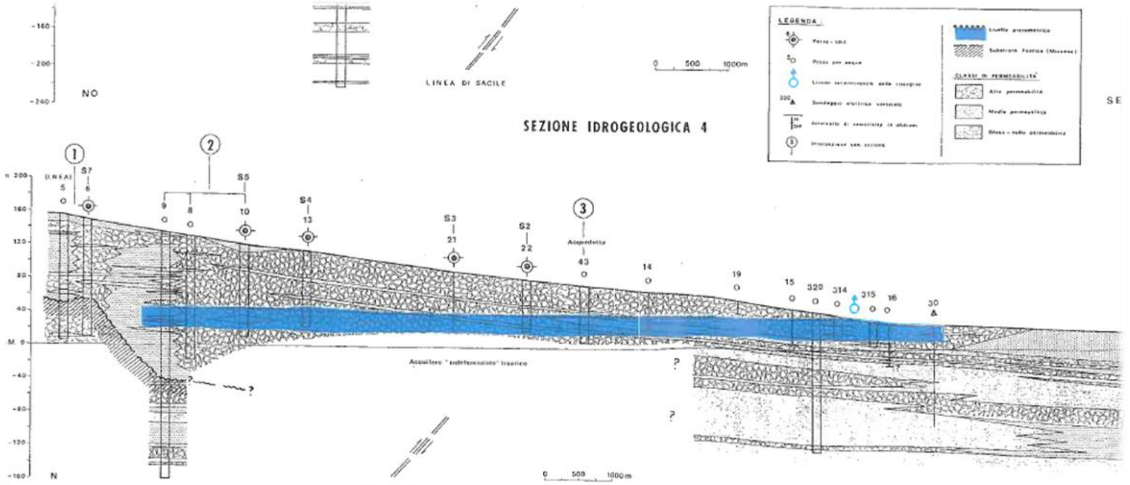


Diffusion of perchlorethylene in a groundwater body from an industrial site

Reparation of the interim loss (1)

- ✓ In addition to the remediation, the current damage must also be remediated by **compensatory measures**, i.e. the loss of the usability service for drinking purposes of the groundwater that passed through the aquifer of the water body in the past due to damage to the natural resource ascertained in accordance with legislation **starting from 2009**, starting from which it was found to be damaged
- ✓ To quantify this form of damage, it is necessary to calculate the quantity of polluted water that has flowed into the aquifer of the water body from 2009 up to now) and **subtract the instantaneous quantity of water present in the aquifer from this value** (associated with current damage)
- ✓ The volume of contaminated water from the deep aquifer diffused by the site along the direction of the aquifer flow, in the period 2009-2018, can be calculated, as a precaution, as a flow having a minimum speed of 5 km / year (estimable aquifer velocity in about 5-14 km / year) passing through the 0.02 km^2 section over the course of 10 years. In these terms, taking into account the effective porosity (the minimum value of which can be set equal to 0.15), the volume is equal to 0.15 km^3 (or **150.000.000 m^3**)

By subtracting from this volume that of the waters present in the aquifer nowadays (to which current damage has been associated) it is possible to obtain the **quantity of water to which the temporary loss must be associated**, equal to **108.000.000 m^3** (150,000,000 - 42,000,000 m^3)



Diffusion of perchlorethylene in a groundwater body from an industrial site

Reparation of interim loss (2)

- Interim loss represented by the loss of service of the deep aquifer relating to the use of water for drinking purposes imposes a **compensatory remedial measure**

- **This compensatory reparation can be identified through an equivalence between the value of the loss, expressed in monetary terms, and the value of the benefit that will derive from the remediation itself, expressed in terms of the cost of carrying out the interventions**

- In particular, the value of the loss can be expressed on the basis of **tariff costs for the supply of drinking water**, applied to the quantity of water for which this ecosystem service has been affected (108.000.000 m^3)

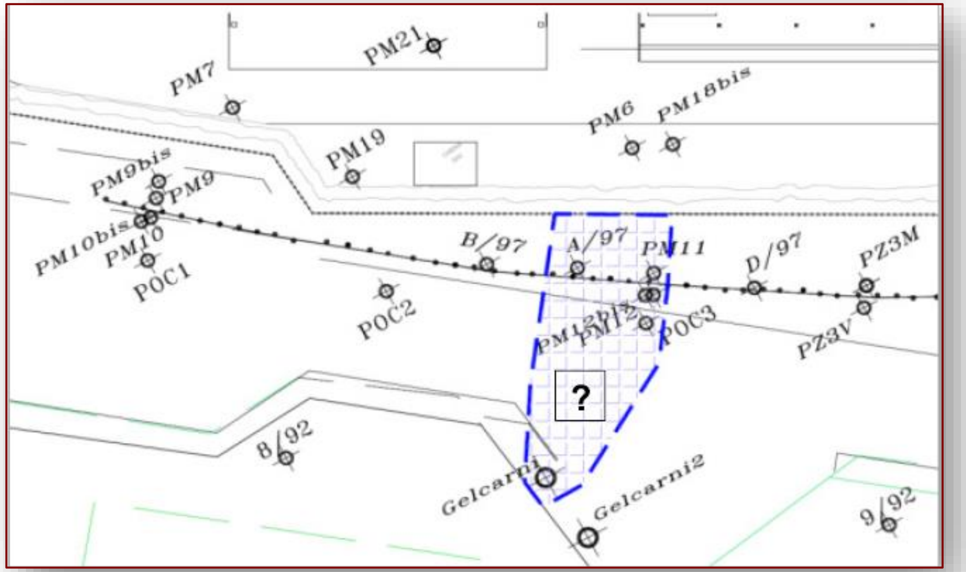
- In this regard, given that the drinking water supply company in the area applies a minimum tariff cost in 2018 of 0.3887 euro / m^3, it is possible to evaluate the loss of natural service equal to **41.979.600,00 euros**

- **In this case, the reparation must be aimed at carrying out interventions to protect the underground water bodies and to optimize the related ecosystem services, also in other areas with respect to the site, having an operation cost equal to this value**

Diffusion of perchlorethylene in a groundwater body from an industrial site

Prevention of the threat of environmental damage

As regards, on the other hand, the elimination of active sources of pollution capable of compromising the chemical status of the groundwater body, sources that represent both a cause of persistence of the current water damage and a threat of further water damage, **interventions on the secondary sources at the site and the surrounding areas must be ensured, by the operator in addition to the purpose of reclamation, to prevent further contributions to the persistence of the current water damage and ensure the prevention of the threat of further water damage to the deep aquifer**



Diffusion of perchlorethylene in a groundwater body from an industrial site

Conclusions

The remediation of the water damage can be ensured by imposing on the operator:

- **as a complementary remediation, the design / execution of clean-up interventions for a volume of 42.000.000 m³** of contaminated groundwater, including at other polluted sites (primarily located in the Region) where the clean-up intervention would be publicly involved
- **as a compensatory remediation**, the design / execution of interventions for the protection of groundwater bodies and for the optimization of related ecosystem services, also in other areas than the site in question, for example through **contributions to depuration treatments, for a cost of € 41.979.600,00**

The preventive measures for water damage, aimed at eliminating active sources of pollution, **instead, they can be carried out by the operator as part of the current remediation procedure** aimed at avoiding the phenomena of diffusion of pollution in the deep aquifer

LESSONS LEARNED

- ✓ *Severity of groundwater damage is mainly due to long-lasting and hidden pollutions, intrinsic environmental hazardousness, persistence, mobility and complicated removal of the substances, vulnerability and use of the acquifer for drinking purposes*
- ✓ *Too much time is needed to investigate and assess groundwater damage, and primary remediation can be too complicated or unfeasible*
- ✓ *To enforce ELD effectively, there is need of coordination of different technical experts (and sometimes competent authorities) for WFD, GWD, IED enforcement, police officers, prosecutors and judges playing a role in the related criminal proceedings*

POSSIBLE SOLUTIONS

- ✓ *Prevention of groundwater damage by reducing the risk of the damaging occurrence to happen plays a fundamental role for the success of groundwater protection*
- ✓ *Risk based assessments of potential groundwater damage must be put in place as obligations for ELD Annex III activities and preventive measures must be established and controls periodically foreseen*

THANKS FOR YOUR KIND ATTENTION!

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