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Opportunities and critical issues related to the use of amendments as remediation techniques

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RESULTS

OBJECTIVE

During the last 5 years, the choice of amendments as best remediation technologies has been steadily growing. With this study we would like to analyze the opportunities and criticalities related to the use of amendments.

MATERIALS & METHODS

Based on a dataset of 100 contaminated sites, the performance of the following amendments:

- aerobic bioremediation;
- ISCO;
- surfactants

was compared with the performance of other groundwater remediation technologies such as:

- Air Sparging (AS);
- Monitoring Natural Attenuation (MNA)
- Multi-Phase Extraction (MPE);
- Pump&Reinjection (P&R);
- Pump&Treat (P&T).

The considered factors were:

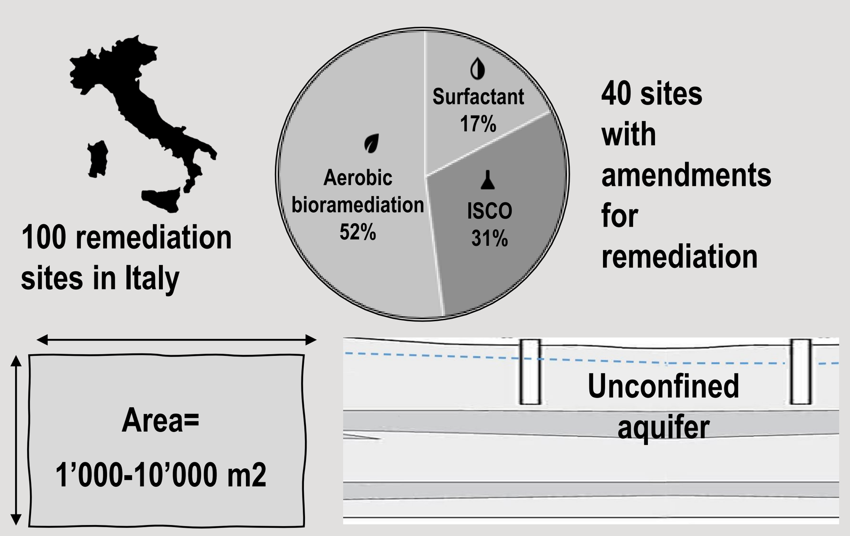
- cost to remediate;
- time to remediate;
- sustainability;
- effectiveness of the remediation carried out by amendments;
- critical issues occurring using amendments.

The sustainability analysis was carried out by analyzing the following parameters:

- energy consumption;
- waste production;
- emission to air;
- water use;
- raw materials use.

and assigning a value from 1 to 5, where 5 represents the maximum environmental impact.The occurrence and types of amendments-related issues were studied on 40 sites where the amendments had been applied. For each issue, a detailed investigation was carried out in order to understand the related processes.

Figure 1: data description



Parameter	Italian Threshold Limits (µg/l) – CSC Acque Sotterranee
Benzene	1
Ethylbenzene	50
Styrene	25
Toluene	15
p-Xylene	10
Total hydrocarbon (n-hexane)	350
MTBE	40
ETBE	40

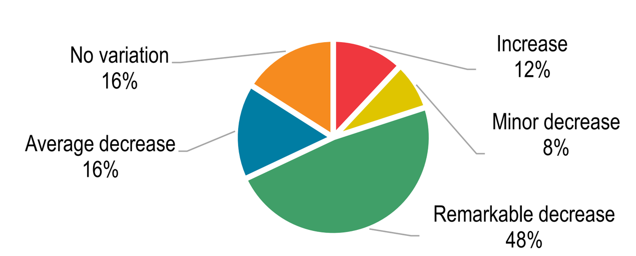
1 - 100 times the limits

OPPORTUNITIES

Effectiveness of remediation by amendments

64% of the analyzed cases led to a reduction in contaminant concentrations within one year. 48% of the sites had a remarkable decrease of contamination and are near to the closure of the environmental case

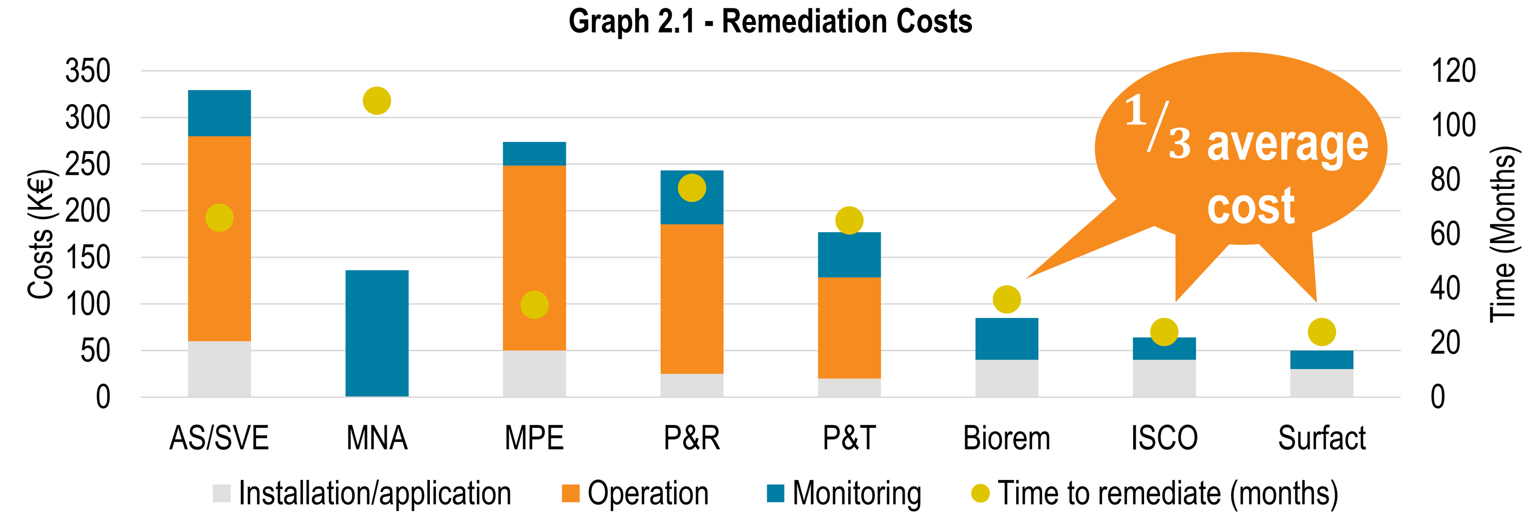
Graph 1 - Effectiveness



Comparison between remediation technologies Remediation Costs

The Graph 2.1 shows the cost for each remediation technology from the plant start-up/application to the operation and monitoring. When using amendments the cost is about one third in comparison to the other technologies.

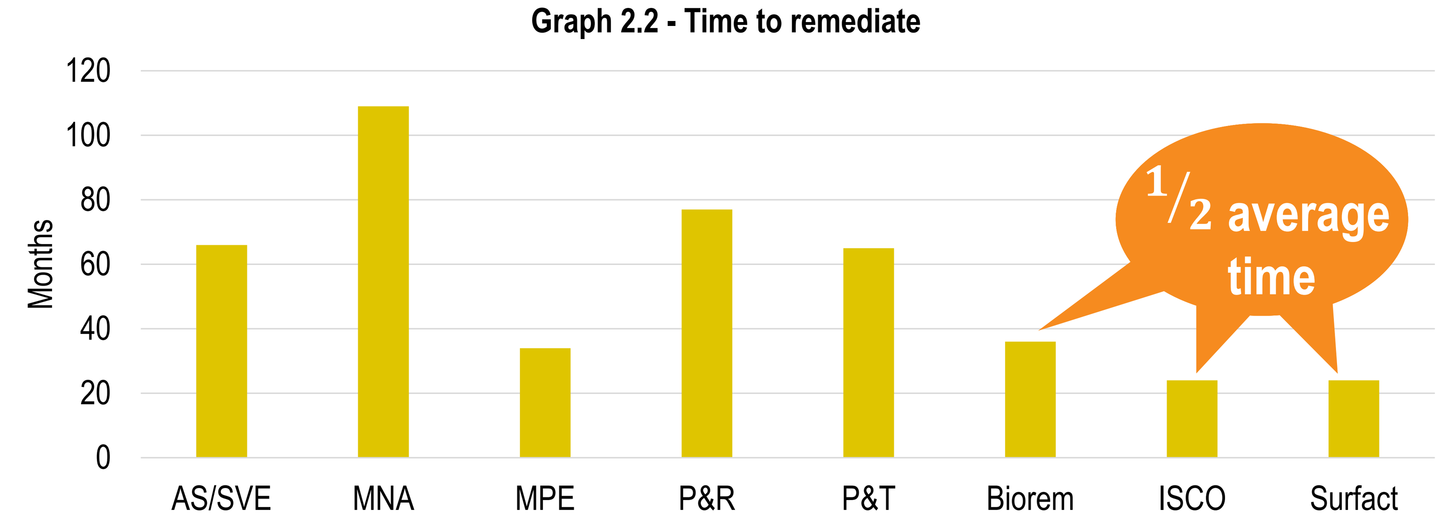
Graph 2.1 - Remediation Costs



Time to remediate

The Graph 2.2 shows the time needed to remediate for each remediation technology from the plant start-up/application. When using amendments the time needed for remediation is around one half.

Graph 2.2 - Time to remediate



Sustainability

MNA is the most sustainable choice in term of environmental impact. The use of amendments reduce all the factors in comparison with a plant solution. Considering the plant solutions, the recirculation of groundwater into the wells (P&R technology) allows to significantly reduce the water use.

	Energy	Waste	Emissions to air	Water use	Raw materials	Total Impact	Total sustainability
AS/SVE	3	3	3	0	3	12	13
MNA	0	0	0	0	0	0	25
MPE	4	5	4	4	4	21	4
P&R	4	4	0	0	3	11	14
P&T	4	4	0	5	3	16	9
Biorem	1	1	0	1	2	5	20
ISCO	1	1	0	1	2	5	20
Surfact	1	3	0	2	1	7	18

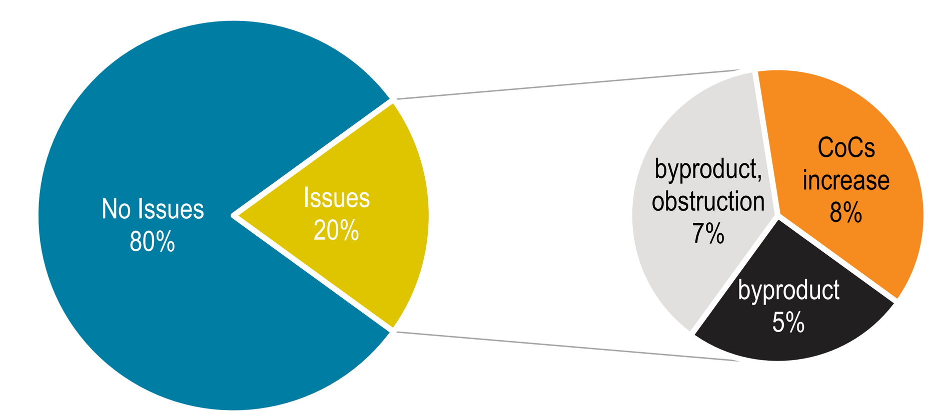
To make the technologies by amendments even more sustainable, it is very important to carry out a careful design of the remediation to minimize the amount of amendments to be applied. The use of products from circular economy (for example biosurfactants deriving from production residues) could increase the sustainability.

CRITICAL ISSUES

Amendments-related issues occurred in 20% of the 40 analyzed cases and consisted of:

1. partial or total occlusion of the monitoring wells and by-product formation, for example heavy metals;
2. by-product formation without well obstruction;
3. increase in contaminant concentrations and potential downstream migration

Graph 3 – Critical Issues Occurrence



Detailed investigation of the processes

The processes related to the critical issues are:

pH-Eh variations

pH and Eh variations modify the chemical equilibria and result in the solubilization of pH and Eh-sensitive compounds such as heavy metals [2]. The aquifer is usually able to generate a buffering effect due to, for example, iron minerals and organic matter.

In an unbuffered system, high pH values up to 13 and high redox potential values (100 mV) were measured , promoting the speciation of Chromium VI.

Hydraulic conductivity reduction

The change in pH can lead to a reduction in hydraulic conductivity if clay minerals are present in the aquifer [3]. The swelling of clays significantly changes the grain structure of the entire aquifer, reducing the hydraulic conductivity. The aquifer may no longer be suitable for injection or other technologies that require good hydraulic conductivity.

Contaminant desorption

In some cases, during the post injection monitoring, an increase in CoCs concentrations were detected in particular where the surfactants had been applied. The surfactant remediation technology is based on this process, it is the desired effect. Therefore, the contaminant desorbed must be totally and promptly removed to avoid downgradient migration. The injection not only of surfactants but in general of the amendments could also cause the physical mobilization of the contamination.

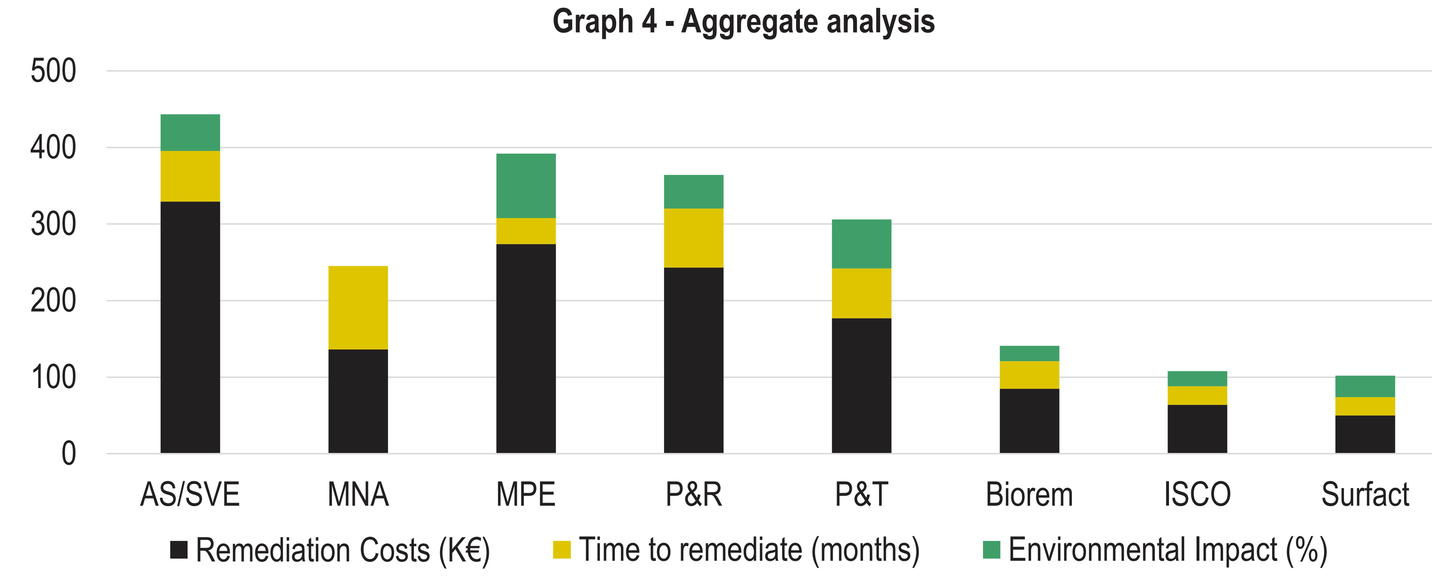
Design and procedural gaps

The occurrence of critical issues during the use of amendments can highlight design flaws and procedural gaps.

- Surplus of amendment. The excess of amendment could lead to issues related to the shifting of pH-Eh equilibrium and could cause well obstruction.
- Application method selection. The use of an injection network not coinciding with the monitoring network will preserve the monitoring wells from damaging.
- Contaminant removal by purge. In case of surfactant use, the desorbed contaminant must be totally and promptly removed in order to avoid its migration down gradient at the boundary of the site.

AGGREGATE ANALYSIS

Graph 4 - Aggregate analysis



CONCLUSIONS

The use of amendments turns out to be an effective solution: in 64% of the analyzed sites it led to a significative reduction of the contamination within one year from the application.

The cost is about one third compared to other technologies, the operational time is about half compared to other technologies.

Based on the results of the environmental sustainability analysis, the amendments technologies reduce the production of waste, the energy, water and raw material use and have no emissions to air.

The observed critical issues can be avoided or mitigated with an accurate design; the execution of pilot tests; the application of delivery and monitoring protocols; and at least with a prompt response adopting a corrective action plan, if necessary.

Based on the aggregate analysis of the time to remediate, the cost to remediate and the environmental impact, the remediation using amendments turn out to be the better solutions, minimizing all these factors.

Considering the sustainability in its broadest sense it is possible to state that the remediation by amendments are the most sustainable.

In fact, in a balance of the benefits, not only environmental, but also economic and time-related sustainability can be considered. Short-term remediation means to return the land to the community more quickly. A remediation technology that ensures this kind of sustainability would meet the interest of all the stakeholders.

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