



**LIFE
BIOREST**

SOIL CONTAMINATION FROM HYDROCARBONS IN ITALY

**A mapping of progress
in the remediation of
Sites of National
and Regional Interest**

Under the patronage of



Soil Contamination from Hydrocarbons in Italy

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in the remediation of
Sites of National and
Regional Interest*

Release Notes

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Glossary and Abbreviations

APPA (Agenzia Provinciale per la Protezione Ambientale) - Provincial Environmental Protection Agency.

ARPA (Agenzia Regionale per la Protezione Ambientale) - Regional Environmental Protection Agency.

Bioremediation - Remediation technology based on living organisms – mainly plants and microorganisms – to decompose and immobilize pollutants.

BTEX (Benzene, Toluene, Ethylbenzene, Xylene) - Class of aromatic, carcinogenic hydrocarbons.

Chlorinates - Chlorine-containing, often toxic molecules. They are used as solvents, insecticides, plasticizers and synthesis intermediates, e.g. chloroform, trichloroethylene, trichloroethane, PCBs and others.

Contaminated site - A site subjected to reclamation treatment, where concentrations of pollutants exceed the legally permitted levels.

Contamination threshold concentrations - Pollutant concentration values (as specified in the annexes to Legislative Decree No 152/2006) above which a risk analysis of a site must be carried out.

EIONet (European Environment Information and Observation Network) - Network created within the European Environment Agency (EEA) with the participation of 39 Member Countries to the purpose of collecting common and comparable indicators, information and data.

FAO (Food and Agriculture Organization) - Participated by 194 member states, the specialized agency of the United Nations leads international efforts to achieve food security for all (<http://fao.org>).

Hydrocarbons - Molecules containing solely carbon (C) and hydrogen (H) atoms. The main sources of hydrocarbons are petroleum, natural gas and their derivatives.

ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale) - The Italian Institute for Environmental Protection and Research is a public research institute with legal personality under public law and technical, scientific and organizational freedom. It performs varied tasks supporting the Italian Ministry for the Environment.

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ISS (Istituto Superiore di Sanità) - Public institution with research, experimentation, control, consulting, documentation and training functions in the field of public health.

LIFE BIOREST (Bioremediation and Revegetation to restore the public use of contaminated land) - Project funded under the LIFE programme of the European Union with the purpose of demonstrating the efficacy and economic sustainability of a biological approach to the remediation of hydrocarbon-contaminated sites and promoting its widespread use in Italy and Europe.

MATTM (Ministero dell'Ambiente e della Tutela del Territorio e del Mare) - The Ministry for the Environment, Land and Sea is an Italian Government statutory authority responsible for environmental policies. It operates in the fields of the conservation and safeguarding of ecosystems, territory and biodiversity. It promotes sustainable development, circular economy, the remediation of contaminated sites and the fight against pollution.

Heavy metals - Inorganic pollutants such as iron, chromium, lead, copper, etc., which are not readily disposable and have harmful health effects.

Microorganisms - Living microscopic organisms such as bacteria, fungi and protozoa.

OECD (Organization for Economic Co-operation and Development) - An international organisation promoting sustainable growth and employment policies for its member States as well as development policies in other countries and the expansion of world trade on a non-discriminatory basis.

PAH's (Polycyclic Aromatic Hydrocarbons) - A class of hydrocarbons containing molecules composed of multiple aromatic rings.

PCBs (polychlorinated biphenyls) - Toxic compounds composed of two aromatic rings having from one to ten chlorine atoms as substituents.

Potentially contaminated site - Site where at least a type of pollutant has contamination threshold concentrations exceeding the legally permitted level, requiring a risk analysis.

Remediated site - A site that, having been subjected to reclamation treatment and assessment, shows concentrations of pollutants that do not exceed the legally permitted levels.

Risk Analysis - Analysis of the health and environmental risks, which procedures are laid down in Italian Legislative Decree No 152/2006 - Annex 1, needed to check the level of danger of a potentially contaminated site based on risk threshold concentrations.

Risk threshold concentrations - Levels of acceptable residual contamination beyond which a site is considered contaminated. They are determined on a case-specific basis through the Risk Analysis procedure according to the principles set out in Annex 1 of Legislative Decree 152/2006.

Site of National Interest (SNI) - A contaminated site identified for the high levels of pollution and included in the remediation procedures managed by MATTM.

Site of Regional Interest (SRI) - A contaminated site which remediation procedures are managed by regional authorities.

Uncontaminated site - A site that, having been subjected to assessment, shows concentrations of pollutants that do not exceed the legally permitted level.

SNPA (Sistema Nazionale per la Protezione dell'Ambiente) - The Italian National Network for the Protection of the Environment was created in 2017 by 21 regional agencies (ARPAs), provincial agencies (APPAs) and ISPRA. Its goal is to monitor the environment, provide technical and scientific support and promote the collaboration among national public institutions.

Abstract

Bioremediation is a reclamation technology that uses living organisms, mainly plants and microorganisms, to degrade and immobilize pollutants such as heavy metals, hydrocarbons and chlorinated solvents.

The advantages of this kind of treatment compared to traditional methods are the minor environmental impact and lower process costs. Indeed, with this approach, microorganisms are used in-situ, thus overcoming the problems connected to off-site and waste disposal practices. Furthermore, it avoids the use of solvents, chemical reagents, high pressures and temperatures, thereby reducing costs.

The selected microbial consortia, usually indigenous, can be applied successfully in the remediation of hydrocarbon-contaminated soil and subsoil. However, the use of biological technologies in Europe accounts for less than 20% of cases.

LIFE BIOREST (www.lifebiorest.com), a European project funded by the LIFE programme "Environment and Resource Efficiency" (<https://ec.europa.eu/easme/en/life>), aims to validate the bioremediation method used at the Site of National Interest of Fidenza (Parma, Emilia-Romagna), which is currently undergoing an intense environmental rehabilitation process and remediation from hydrocarbons and chemical substances derived from crude oil and benzene, which make up for 45% of total contaminants in Europe.

With a total investment of 1.8 million euro, and supported by a European contribution of about 970,000 euro, LIFE BIOREST aims to propose a protocol on the remediation of contaminated soil and subsequent revegetation compatible with public use, supporting local authorities in the safeguarding of land resources. One of the major expected results is the demonstration of the efficacy and reproducibility of the method at other Italian and European sites affected by the same kind of contamination.

Aiming to contribute to the success of LIFE BIOREST, this study gives an overview of the state of hydrocarbon contamination in Italy, with an extended mapping of sites of both national and regional competence, starting from their classification within the register of sites requiring decontamination.

- 6 Through the promotion and dissemination of the results of the project, this study means to inform the public on the advantages of biological bioremediation technologies as an alternative to the traditional practices of contaminated soil disposal at landfill sites.

Introduction

LIFE BIOREST: A Model for Urban Regeneration

The recent FAO “Soil Pollution: A Hidden Reality” study has raised the alarm for the ever greater state of degradation and contamination of the Earth’s surface. A non-renewable resource, soil has always been essential for food production and environmental sustainability and its role often underestimated.

Today 33% of land is moderately to highly degraded, mainly because of erosion, loss of SOC, salinization, compaction, acidification and chemical pollution¹.

The production of chemical substances has grown rapidly in the past decades with a yearly increase of 3.4% within 2030, especially in non OECD-countries. In 2015 the European chemical industry produced 319 million tons of chemicals, of which 117 have been identified as hazardous for the environment. Global production of urban solid waste is growing at solid rates, rising from 1.3 billion tons per year in 2012 to 2.2 billion within 2025.

Soil chemical contamination from heavy metals, chlorinated compounds, hydrocarbons and its derivatives is an environmental emergency which remains to a great extent unresolved². The recent update of the indicators of the state of remediation of European contaminated sites, carried out by the Joint Research Centre[1], [2], shows **650,000 registered sites in the inventories of the 28 EU Member States**, where remediation processes have been completed or are currently in progress. Over 76,000 new sites have been listed since the previous survey in 2014. More than **65,500 sites are presently undergoing corrective measures** or receiving post-intervention support³.

Using living organisms such as microorganisms and plants to degrade and detoxify waste materials and pollutants, among all possible reclamation technologies, **bioremediation** shows important economic and practical advantages compared to excavation and off-site disposal[3]. In the past decades biological techniques have proved effective, however their use is still quite limited: indeed, they are applied in less than 20% of cases in Europe with different rates in the various countries.

Funded by the LIFE programme of the European Union, the LIFE BIOREST (Bioremediation and Revegetation to restore the public use of contaminated land) Project (www.lifebiorest.com), aims to demonstrate the efficacy and economic sustainability of a biological approach to the remediation of hydrocarbon-contaminated sites, promoting its widespread use in Italy and Europe. The method was tested at the Site of National Interest of Fidenza (former Carbochimica plant in Fidenza, Emilia-Romagna, Italy), an area covering over 80.000 sq. m, which was historically contaminated from hydrocarbons and their derivatives, and is meant to be a replicable model for all those sites having comparable contamination conditions.

Consorzio Italbiotec, the first Italian non-profit organization for biotechnology development, leads the Project, in partnership with Actygea Srl, Agenzia regionale dell’Emilia-Romagna per la Prevenzione, l’Ambiente e l’Energia - ARPAE, Università degli Studi di Torino, Università Cattolica del Sacro Cuore, Agencia Estatal Consejo Superior de Investigaciones Cientificas (Spain) and SATT - SAYENS (France).

¹ FAO, Factsheet “Soil is a non-renewable resource” 2015

² Van Liedekerke et al., 2014

³ Joint Research Institute, “Status of local soil contamination in Europe” 2018 [2]

Hydrocarbons in Soil: a Methodological Approach to the Mapping of Sites

This research study is meant to provide a complete **overview of the state of hydrocarbon contamination in Italy** through the comparative data collected at Sites of Regional and National Interest, thanks to an analysis of the remediation sites included in the **regional registers**.

As provided for in Article 251 of Legislative Decree no. 152/2006 and subsequent amendments and integrations, **these registers list the sites undergoing environmental remediation processes**, the implemented measures, the subjects in charge thereof, the public institutions the regional authorities intend to cooperate with and the entities responsible for the reclamation operation.

The structure of these registers was developed and published in its first version in 2001 by ISPRA (Italian Institute for Environmental Protection and Research) in cooperation with the Regions and Regional Agencies for Environmental Protection (ARPA and APPAs)⁴.

The survey on the implementation and update of the registers carried out in 2015 by the Ministry for the Environment has drawn attention to the high degree of fragmentation that characterises the gathering of content and the mapping of progress in the remediation of sites⁵.

The lack of information supported by shared data - as well as the various recent regulatory changes - meant additional work for the regional agencies in charge of data processing, and resulted in the production of indicators that are not easily comparable and do not respond to the assessment criteria set out by OECD.

The creation of the Italian National Network for the Protection of the Environment (SNPA) with Law no. 132 of 28 June 2016⁶, was the first step toward an integrated and synergic institution system that can "ensure consistency and effectiveness in the exercise of actions of public oversight and environmental quality assurance" (Art. 1), and which task concerning sites requiring remediation is to achieve a **common database of the national information system**⁷. This tool will allow the development of a comprehensive picture of the state of soil pollution in Italy, updated according to data exchange standards that can provide information on the management of contaminated and potentially contaminated sites, contaminant effects (according to the EIONet framework), and remediation technologies and rehabilitation costs, both public and private.^[4]

8 In this context, the LIFE BIOREST survey queried **20 regional registers** of the sites requiring remediation on the national territory in order to show – in accordance with the information contained therein - the **impact of hydrocarbon pollution in Italy** and the state of reclamation of contaminated areas.

Over **20,000 Sites of Regional Interest** were surveyed, of which **9,487 still need remediation or further assessment**. Among the latter are **2,119 hydrocarbon-contaminated sites (petroleum and its derivatives)**, accounting for 22% of total contaminated sites in Italy.

The remaining 10,560 areas included in the registers are normally classified as undergoing remediation, uncontaminated after assessment, and potentially contaminated, thus requiring further assessment.

The varying **classification of recorded sites** is partly due to the previously mentioned different application of ministerial provisions in the matter of the registering of contaminated sites and remediation state thereof, which results in various methods for cataloguing, classification and updating data⁸.

The registers of the Abruzzo, Basilicata, Emilia-Romagna, Lombardy, Marche, Piedmont, Tuscany, Trentino-Alto Adige and Valle D'Aosta regions classify Sites of Regional Interest into the four types "potentially contaminated", "contaminated", "remediated" and "uncontaminated after assessment". All other registers, instead, show the total number of contaminated sites, failing to provide the status of remediation administrative procedures. To the purposes of the present study, the total number of sites listed in these registers has been considered as belonging to the "contaminated" type.

⁴ Criteria for the setting up of the Register of sites needing remediation, pursuant Ministerial Decree no. 471 of 25 October 1999
<http://www.isprambiente.gov.it/files/temi/tec-anagrafe-siti-contaminati-criteri.pdf>

⁵ State of implementation the Register of sites needing remediation, pursuant to Article 251 of Legislative Decree 152/2006.
http://www.bonifiche.minambiente.it/contenuti/Anagrafe_07092015.pdf

⁶ Creation of the Italian National Network for the Protection of the Environment (SNPA) e regulations governing the Italian Institute for Environmental Protection and Research (ISPRA). Law no. 132 of 28 June 2016. Official Gazette - General Series no. 166 of 18 July 2016.

⁷ As suggested by Fabio Pascarella (ISPRA) and Barbara Sandri (ARPA), a database providing a comprehensive framework of the state of the Italian soil is necessary. (Workshop Rome 22 February 2017, "Una banca dati sui siti inquinati") [4].

⁸ Emilia-Romagna, Friuli Venezia-Giulia, Lombardy and Tuscany equipped themselves with an alternative system to that set out by Article 251 of Legislative Decree 152/2006 and subsequent amendments and additions.

The fragmentation of the mapping and updating process of registered data, already highlighted by the 2015 ministerial ascertainment, made it particularly difficult to create an accurate picture.

In terms of **data availability** there are differences between the regions. The Basilicata, Friuli Venezia-Giulia, Liguria, Lombardy, Piedmont and Tuscany registers⁹ have been updated as of 2018, while the most recent updating for over half of the other registers dates back to the past three years: Campania, Emilia-Romagna, Marche, Molise, Umbria and Valle D'Aosta (2017), Abruzzo, Lazio and Sicily (2016), Trentino-Alto Adige and Veneto (2015), with Calabria (2013), Puglia (2010) and Sardinia (2003) being the least recently updated.

Regional fragmentation is found even in terms of the **recording of pollutants**.

Indeed, information on contaminant type (e.g. heavy metals, hydrocarbon, chlorinated compounds, asbestos, etc.) is only available in a limited number of registers¹⁰, while most often the mere classification of sites as "contaminated" (e.g. landfill site, industrial area, refinery, fuel points of sale, etc.) can only suggest the kind of polluting substances to be found.

In many cases the extrapolation of collected data included a preliminary digitalization and analytical organization phase¹¹. Such data formed a **digital library** that allowed a full overview of the 20 regional registers, accounting for over 20,000 sites.

A georeferenced reconstruction of **2,119 hydrocarbon-contaminated areas** allows an accurate query function by province, city, and contaminated-site type.

The sites classified in the library as "hydrocarbon-contaminated" correspond to those recorded in the registers on the basis of the "hydrocarbon" pollutant type and to those categorized by site type and source of contamination, e.g. points of sale, deposits, tanks, fuel and oil spills, refineries and petrochemical plants, pipeline spills and accidents.

⁹ The register of the Basilicata Region sites was first published in September 2018 and is currently being implemented. All data used to the purposes of this study cannot therefore be considered as comprehensive.

¹⁰ The register of the Piedmont Region lists the pollutant type for each contaminated site.

¹¹ In most cases data are not available as a library services platform, but rather as .pdf files or digitized versions of paper documents.

Hydrocarbon Pollution and Damage to Health

The definition of legislative approaches and instruments for the treatment of soil contamination is a subject of recent application, as demonstrated by the validation of guidelines for the delimitation of areas and the risk analysis on contaminants. The latter can be different in nature and there is a level of concentration for each one of them beyond which the effects on human health and the environment cannot be ignored. Among the most abundant in soil are heavy metals (lead, iron, copper, chromium, nickel and others), arsenic, asbestos, chlorinated compounds (insecticides, coolants, solvents) and hydrocarbons.

Hydrocarbons are the basic components of petroleum and natural gas and, while being exclusively composed of carbon and hydrogen atoms thus by definition the simplest organic molecules, they are a broad class of compounds. Such characteristic is due to the versatility of the chemistry of carbon, which atoms can create open chains (linear or branched), closed chains (having one or more rings) and hybrid ones.

Hydrocarbons can be classified as saturated, unsaturated and aromatic. The first are the simplest compounds, formed by single-bonded carbon chains saturated by hydrogen; alkanes and cycloalkanes, the main components of fossil fuels, belong to this group. Ordinary gasoline mostly contains saturated hydrocarbons with 4 to 12 carbon atoms, such as butane, heptane, octane and nonane. Among the most renowned saturated hydrocarbons is methane, which is widely used in heating systems and electricity production as it is the main component of natural gas.

Unsaturated hydrocarbons are characterized by the presence of a double (or even triple) bond between two carbon atoms. Those with a double bond $C=C$ are called alkenes: among these is ethylene, one of the most produced organic molecules worldwide, widely used in industrial chemical synthesis. Instead, hydrocarbons with a triple $C\equiv C$ bond are named alkynes - *Figure 1*.

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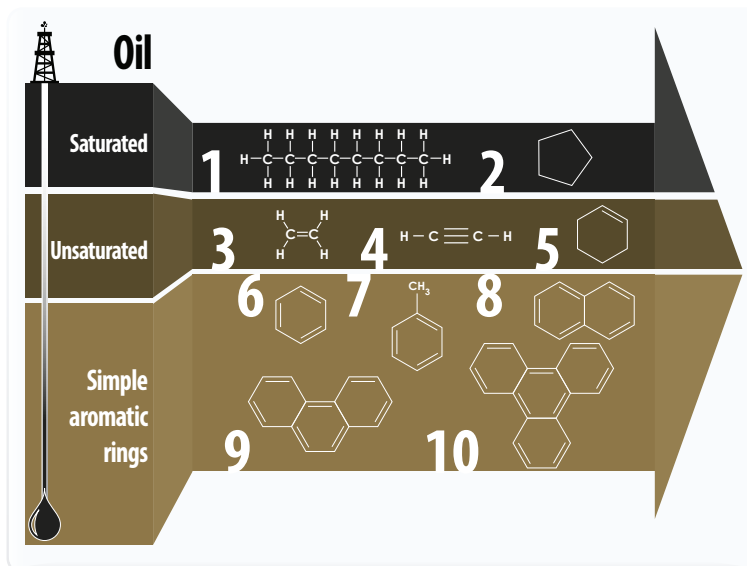


Figure 1 Examples by hydrocarbon type.
Saturated: (1) Octane and Cyclopentane (2). Unsaturated: ethylene (3), acetylene (4) e cyclohexene (5).
Simple aromatic rings: Benzene (6) and Toluene (7); PAH's - Naphthalene (8), phenanthrene (9) and triphenylene (10).

Benzene is a colourless and highly volatile liquid, responsible for the characteristic aroma of gasoline. It is naturally present in petroleum and the refinery processes thereof, and has been used as an additive to improve the quality of gasoline and in the chemical industry as solvent and intermediate in a number of synthesis reactions. With similar characteristics and uses, toluene can be used in the production of benzene. Ethylbenzene and xylene have a very wide range of applications, such as lubricants, colouring agents, antifreeze and starting materials for the synthesis of styrene, which is used in polystyrene.

PAH's are molecules composed of multiple aromatic rings that are found in petroleum and hard coal and are produced as a result of incomplete combustion of gasoline, timber and organic compounds in general [12]. The simplest PAH is naphthalene, formed by two aromatic rings and famously used in mothballs. Other common PAH's are pyrene, anthracene, and phenanthrene [13].

Health issue related to exposure to hydrocarbons vary for each molecule and are still being studied. Generally speaking, PAH's are considered as the most harmful to humans as they are highly toxic and potentially carcinogenic; naphthalene is associated with anaemia, damage to the liver, the nervous system and the larynx, and colon cancer. Pyrene and fluoranthene are irritating for the skin, eyes and respiratory system. Finally, anthracene, one of the main by-products of the fossil fuel combustion, is ubiquitous in the environment, and its effects irritating and possibly carcinogenic.

Beside PAH's, BTEX are extremely toxic and, if inhaled, can lead to severe neurological symptoms, anaemia and damage to the immune system. In particular, exposition to benzene has been associated with a higher risk of developing lymphatic and blood cancer, such as leukemia. High levels of methane lead to suffocating, loss of consciousness, nausea, weakness and vomit. Even other alkanes, such as heptane and nonane, have been associated with irritating and potentially neurotoxic effects. [13]

Legislative Instruments Supporting Soil Remediation

Soil contamination in Italy is a widespread problem mainly attributable to human activities, such as industrial, commercial, landfill and mining operations. In spite of the high incidence and severity and the damage to health documented in numerous epidemiological studies [5]-[7], the problem of soil contamination does not seem to be perceived in the public opinion the same way as air and water pollution, albeit indirectly linked to it. The low public awareness of the environmental emergency is confirmed by the previously mentioned FAO report, which defines soil contamination as a “hidden reality”, as it is more difficult to identify, measure and study in time. The scientific evidence as to the severity of the matter, however, is clear: soil contamination has an impact on human health [8].

The evolution of legislation on contamination reduction and treatment has been affected by this different perception of the problem. The first Italian legislative action against environmental pollution was **Law no. 615 of July 13th 1966** concerning “Measures against air pollution”, aimed to control and reduce smoke, dust, gas and odour emissions by industries and transport, thereby acknowledging the indirect damage caused to citizen health.

With **Law no. 319 of May 10th 1976** the regulation for water protection was defined, a sign of the growing attention to environmental themes which would lead to the creation of a dedicated Ministry.

Introduced by **Law no. 349 of July 8th 1986**, the Ministry for the Environment, Land and Sea (MATTM) has the task “to ensure, within a comprehensive framework, the preservation and restoration of environmental conditions in accordance with the basic public interests and quality of life of the community, as well as the conservation and promotion of the national natural heritage and the safeguarding of natural resources from pollution (Article 1)”. The creation of this government authority coincided with the design of continuous monitoring activities for the state of the environment in the national territory, allowing all Italian environmental associations the right to “intervene in environmental procedures” and “to lodge an appeal against illegitimate actions” (Articles 13 and 18).

Transposing Community directives and policy on waste, **Law no. 22 of 5th February 1997**, introduced the concept of waste as a resource and not anymore as an unnecessary by-product. The first regulation on the theme of environmental remediation was **Legislative Decree no. 471 of 25th October 1999**, containing criteria and procedures for the identification, securing, remediation and restoration of contaminated sites.

The latter was later replaced by **Legislative Decree no. 152 of 3rd April 2006**, concerning “Environmental Regulations” (and subsequent amendments and additions), which redefines administrative procedures pursuing the promotion of human life quality levels, to be attained through the safeguard and the enhancement of environment conditions and an attentive and rational use of natural resources” (Article 2, paragraph 1).

This law defines “contaminated sites” as “a site where the level of risk threshold concentrations, as assessed through the risk analysis procedure [...], are beyond acceptable” [9]. This refers to all areas where, as a consequence of current or terminated human activities, an alteration in the characteristics of the soil, the subsoil or the groundwater has been ascertained, posing a significant risk to human health. Legislative Decree no. 152/2006 and subsequent amendments and additions, also specifies contaminated site types present in the territory and the administrative procedures concerning their identification and management. The whole of contaminated sites is divided into two groups: “**Sites of National Interest (SNI’s)**” and “**Sites of Regional Interest (SRI’s)**”.

The first are defined as follows: “To the purposes of remediation, Sites of National Interest are identified related to the characteristics of the sites, the quantity and harmfulness of pollutants, the importance of the effect on the surrounding environment in terms of health and ecological risk, as well as injury to the cultural and environmental heritage” (Article 252, paragraph 1).

Among contaminated sites, **SNI’s** are identified for their **hazardousness** and **the urgency of immediate intervention**; often these sites lie in areas with a high socio-economic impact, such as densely populated, harbour or industrial areas, or with a high health impact, and have historically been polluted by various kinds of contaminants, at both surface and subsurface levels.

SNI’s thus fall under national law, the remediation procedures thereof being attributed to the Ministry for the Environment, which can rely upon the expertise of the Italian Institute for Environmental Protection and Research (ISPRA), the regional and provincial environmental protection agencies ARPAs and APPAs, and other public or private entities.

Article 36-bis of **Law no. 134 of 7th August 2012** modified the identification criteria and provided a new SNI classification, reducing them from 57 to 39 with the following **Ministerial Decree of 11th January 2013**.

Following the ruling of the Lombardy Regional Administrative Court no. 7586 of 17 July 2014 the area of the Sacco River Basin was once again classified as an SNI. Moreover, the Officina Grandi Riparazioni ETR site in Bologna, which perimeter was recently established, was identified by Law no. 205 of 27 December 2017 as a SNI, bringing the **total number of such Sites** to the current **41** - *Figure 2* [10], [11].

All contaminated sites that are not listed as Sites of National Interest are classified as **Sites of Regional Interest**, and their management is delegated to the respective regions.

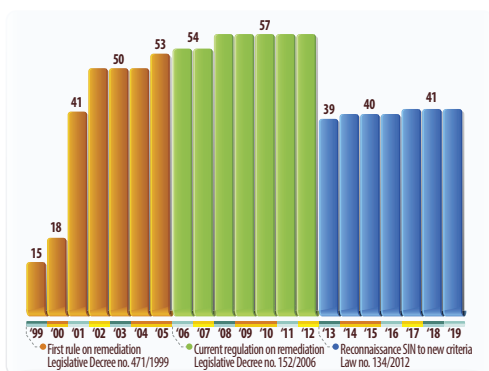


Figure 2 Evolution of the number of SNI's. Current update status of the identification of Sites of National Interest related to the evolution of the regulatory framework (graphics based on ISPRA data).[10]

Article 251 of Legislative Decree no. 152/2006 provided for the creation of a register within the Regions and Autonomous Provinces listing all sites needing remediation. The register content and structure are to be defined by ISPRA in collaboration with the Regions and ARPAs.

The previously mentioned 2015 survey and following updates on the state of implementation of regional registers highlighted a remarkable lack of uniformity, in terms of structures, data update and comprehensiveness of the information on the type of contamination - *Figure 3*.

Created in 2016, the **Italian National Network for the Protection of the Environment (SNPA)** intends to tackle this problem through the adoption of an integrated control system of the sources

of environmental pollution and pressures on the environment deriving from territorial processes and anthropogenic or natural phenomena, even emergency ones, and the impacts thereof, through sampling, analysis and measurement activities on the national territory [10]. In this context the creation of a database providing a picture on the national state of soil contamination is a fundamental tool to combat soil pollution and restore its ecological functions.

The current Italian legislative reference concerning contaminated sites is Title V of Part Four of Legislative Decree no. 152/2006 and subsequent amendments and additions and the related annexes. The Decree changed the tabular approach provided by the previous Ministerial Decree no. 471/1999 and established two levels of threshold concentrations. These must be considered in the environmental compartments and correspond to different intervention techniques:

- **Contamination threshold concentrations:** for the soil, subsoil and groundwater they are defined in Tables 1 and 2 of Annex 5 and represent warning values above which a characterization study of the site must be carried out;
- **Risk threshold concentrations:** they identify the levels of acceptable residual contamination on which to set safety and/or remediation measures and are defined on a case-by-case basis through a specific environmental health risk analysis following the principles set out in Annex 1.

Specifically, a site is considered as:

- **Potentially contaminated**, when one or more limit values for the concentration of pollutants identified in the various environmental compartments exceed the contamination threshold concentration levels, pending a specific environmental health risk analysis that might define a state of contamination on the basis of the risk threshold concentrations;
- **Contaminated**, when the risk threshold concentrations are exceeded, as defined through the risk analysis procedure provided for in Annex 1, Part Four of Legislative Decree no. 152/2006, based on the results of the characterization study;



Figure 3 Register update status. The graphic refers to the most recent update of regional registers.

- **Uncontaminated**, when the contamination identified in the environmental compartments is lower than the contamination threshold concentrations or, if higher, it is lower than the risk threshold concentrations defined following a specific environmental health risk analysis.

The operating procedure for the remediation of a contaminated site, as defined in Article 242 of Legislative Decree no. 152/2006, comprises the following phases:

1. **Communication.** On the occurrence of an event that might contaminate the site or in the case of historical contamination, the person in charge must immediately inform the competent authority, pursuant to Article 304.
2. **Preliminary investigation.** Measurement of pollutant levels above **contamination threshold concentrations** and communication of the results
3. **Notification of contamination and characterization.** If contamination threshold concentrations are exceeded, a characterization study for the risk analysis is executed.
4. **Site-specific risk analysis.** This is carried out to assess the exceedances in **risk threshold concentrations**. If thresholds are within the limits of the law, the procedure is successfully concluded.
5. **Monitoring plan.** This is needed to assess the stabilization of the risk threshold concentrations. If these are exceeded the competent authority will arrange for remediation.
6. **Operational plan of measures for safety and reclamation.** This is called for in the case of exceedances of risk threshold concentrations in order to minimize the risk associated with the state of contamination of the site and restore the limits of acceptability.
7. **Remediation certificate.** It is issued by local authorities in collaboration with ARPA.

The simplified intervention procedures set out in Annex 4, Part Four of Legislative Decree no. 152/2006 and subsequent amendments and additions apply in small contaminated areas.

Sites of National Interest (SNI's)

Launched by the Italian Ministry for the Environment, the National Remediation Plan provides a periodically updated view of the state of pollution of the Sites of National Interest, so classified on the basis of the severity of the environmental contamination, the health risk and the public alarm (Ministerial Decree no. 471/1999).

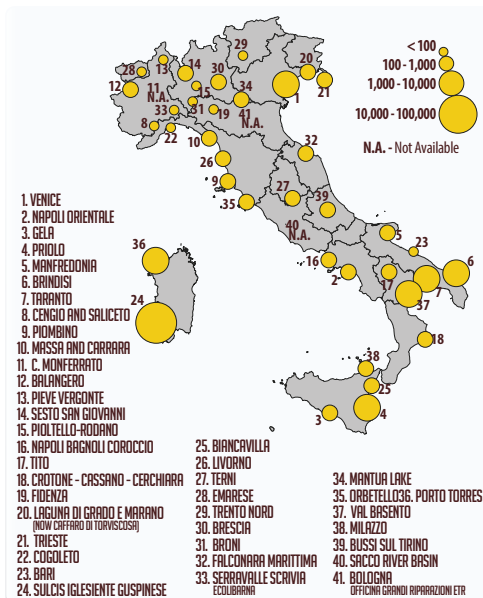


Figure 4 Sites of National Interest.

The dimensions refer to the areas measured in hectares of the perimeters on the ground. (Graphics based on data from the Ministry of the Environment - 2018).

The 41 sites included in the Plan following the 2018 survey currently comprise dismissed industrial areas, industrial areas that are presently undergoing a conversion process, active industrial areas, areas where accidents with chemical spills took place and areas with uncontrolled disposal of waste, including hazardous waste.

All the 20 surveyed Italian regions but Molise host at least a Site of National Interest. The contaminated soil occupies a total of **51,403.5 ha**, equal to about **three times** the surface of the **Milan metropolitan area**.

The highest number of Sites of National Interest is to be found in Northern Italy, specifically in Lombardy (Sesto San Giovanni; Pioltello-Rodano; Brescia; Broni and Mantua Lakes) and Piedmont (Cengio and Saliceto; Serravalle Scrivia, Pieve Vergonte; Casale Monferrato; Balangero), followed by Tuscany (Piombino; Massa and Carrara; Livorno; Orbetello) and Puglia (Manfredonia, Brindisi, Taranto, Bari). On the whole, these 5 regions represent over half of the SNI's on the Italian territory (53.6%, with 22 out of 41 SNI's). The remaining 14 regions host up to 2 sites each, summing up to 19 SNI's (46.4% of contaminated sites) - *Figure 4*.

The State of Remediation

According to the most recent ministerial analysis on the state of remediation of the Italian Sites of National Interest (June 2018), about **13%** of surfaces have undergone **remediation**, for a total of **6,513.1 ha** out of **51,403.5**.

Decontamination interventions have not yet been concluded in 13 SNI's: Cengio and Saliceto, Balangero, Pieve Vergonte, Napoli Bagnoli Coroglio, Cogoletto, Bari, Biancavilla, Livorno, Emarese, Trento Nord, Falconara Marittima, Serravalle Scrivia and Orbetello.

Remediation has been carried out only for 4 hectares of the Site of National Interest in Gela out of the 795 within the perimeter, accounting for 0.5% of its extension, and the same can be said for the sites in Caffaro di Torviscosa, Brescia, Broni and Bussi sul Tirino (about 1%). There follow Mantua (3%) Tito (4%), Massa Carrara (5%), the Napoli Orientale and Brindisi sites (6%), Trieste (7%), Priolo, Taranto and Sulcis Guspinese (8%).

The Fidenza SNI is the first to have reached 10% remediation, followed by Porto Torres (12%), Pioltello and Crotone (13%), Venice (15%), Manfredonia (18%), Milazzo (20%). The Terni SNI has reached 28% of remediated land, Sesto San Giovanni 32%, Piombino 45% and Val Basento positively stands out with 88% of remediated land within the perimeter. In the case of the Val Basento SNI contamination from hydrocarbons is significant and often confined to specific areas, a characteristic that can be found in other regions, such as Valle D'Aosta and Piedmont. Regarding the SNI's of Casal Monferrato (contaminated with asbestos), of the Sacco River Basin (the perimeter of which is currently being defined) and of the Officina Grandi Riparazioni in Bologna, used by the Italian railways (the last one to be listed as a SNI), an update on the state of the remediation of the site is not available.

Characterization plans have been drafted in **57,3%** of the total areas, equal to **29,453.9 ha**, and have been executed in 94.7% of cases. 1,546.5 ha have been undergoing **prevention measures**, about 3% of the total areas, in which solutions have been implemented to reduce the impact of toxic substances on the environment and human health. A **Remediation Project** has been developed covering 7,791.8 ha, equal to **15.2%** of the total SNI surfaces. However, the plan was approved only for 11% of the contaminated areas, equal to 5,478.8 ha.

In short, remediation activities have so far focused only on 12.57% of all SNI areas, totalling 6,513.1 ha overall - *Table 1*.

SNI's	%Remediation 2018	Charact. Submitted	Charact. Completed	Prevention Measures	Remediation Project Submitted	Remediation Project Approved	Remediated Areas	Total Area
1 - Venice	15%	1560	1529	0	1146	1055	241	1618
2 - Napoli Orientale	6%	497	466	89	174	127	50	834
3 - Gela	0%	784	775	0	120	101	4	795
4 - Priolo	8%	2947	2766	11	1000	733	449	5814
5 - Manfredonia	18%	216	216	8	67	42	38	216
6 - Brindisi	6%	5200	5110	0	723	692	378	5851
7 - Taranto	8%	2025	2025	12	341	335	347	4383
8 - Cengio and Saliceto	0%	77	77	0	77	77	0	77
9 - Piombino	45%	928	887	0	239	121	422	931
10 - Massa and Carrara	5%	116	116	0	46	29	5	116
11 - Casal Monferrato	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
12 - Balangero	0%	314	314	305	52	16	0	314
13 - Pieve Vergonte	0%	42	42	0	42	42	0	42
14 - Sesto San Giovanni	32%	255	249	56	215	113	82	255
15 - Pioltello-Rodano	13%	84	84	36	72	28	11	85
16 - Napoli Bagnoli Coroglio	0%	242	242	0	234	234	0	249
17 - Tito	4%	150	45	25	25	25	13	315
18 - Crotone-Cassano- Cerchiara	13%	293	266	7	150	135	69	544
19 - Fidenza	8%	25	25	11	23	23	2	25
20 - Caffaro Torviscosa	0.49%	201	201	0	200	10	1	201
21 - Trieste	7%	365	356	0	162	124	29	435
22 - Cogoletto	0%	45	45	0	33	10	0	45
23 - Bari	0%	14.5	14.5	1	11	11	0	14.5
24 - Sulcis Iglesiente Guspinese	8%	5699	5168	117	1029	922	904	19751
25 - Biancavilla	1%	330	330	25	25	25	0	330
26 - Livorno	0%	206	206	0	206	0	0	206
27 - Terni	28%	655	615	638	6	6	181	655
28 - Emarese	0%	16	16	15	16	16	0	23
29 - Trento Nord	0%	21	21	0	11	11	0	24
30 - Brescia	1%	179	82	0	43	43	4	262
31 - Broni	1%	13.5	9.9	13.5	9.8	9.8	0.1	15
32 - Falconara Marittima	0%	101	98	0	3	3	0	101
33 - Serravalle Scrivia	0%	74	14	0	7	7	0	74
34 - Mantua Lakes	3%	387	369	0	188	63	19	614
35 - Orbetello	0%	62	62	0	0	0	0	204
36 - Porto Torres	12%	1581	1331	0	944	157	226	1874
37 - Val Basento	88%	3330	3224	96	30	23	2925	3330
38 - Milazzo	20%	366	342	59	110	110	111	549
39 - Bussi sul Tirino	1%	171	141	50	12	0	2	232
40 - Sacco River Basin	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
41 - Bologna Officina Grandi Riparazioni ETR	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
TOTAL	13%	29572	27879	1574.5	7791.8	5478.8	6513.1	51403.5

Table 1. State of the art of the areas for the soil compartment concerning the 41 SNI's, the numbers referring to areas measured in hectares (ha), with remediation % calculated on the total perimeters. (data processed from the SNI report of the Ministry for the Environment - 2018).

Hydrocarbon Contamination

The main causes of contamination in **66% of SNI's** are connected to **industrial activities** (46%) and to dismissed industrial areas (20%). **12%** of SNI's are former asbestos **mining areas**: Casal Monferrato, Broni, Emarese and first and foremost the asbestos quarry in Balangero, Piedmont, the biggest in Europe and the cause of a high risk for lung cancer disease [15].

The same health risk is found at the SNI of Biancavilla, Catania, due to the presence of fluoro-edenite [6], [15]. **10%** of SNI's are **harbour areas**, with very well known examples of historical pollution such as Taranto and Venice. Falconara Marittima and Trieste, less renowned, are both contaminated with heavy metals and hydrocarbons. Finally, **landfills (5%)** and **areas with complex industrial and mining activities (7%)** show various sources of pollution (Val Basento; Crotone-Cassano-Cerchiara) - Figure 5.

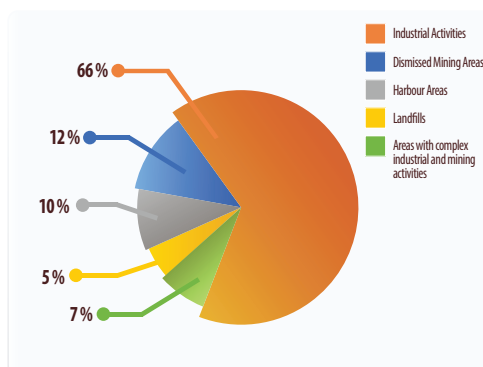


Figure 5 Types of SNI's subdivided by source of contamination

The characterization tests performed at the Sites of National Interest highlighted a predominance of pollution by a combination of **heavy metals, chlorine compounds, hydrocarbons, pesticides and herbicides**, which on the whole account for **61%** of the various contaminants.

Among the most widespread contaminants are **asbestos** in **14,6%** of SNI's, **hydrocarbons and their combination with chlorinates** in **9,8%** of cases, PCB's and mixed heavy metals and hydrocarbons at 4.9% of sites and finally arsenic (2.4%) and fluoro-edenite (2.4%) - Figure 6.

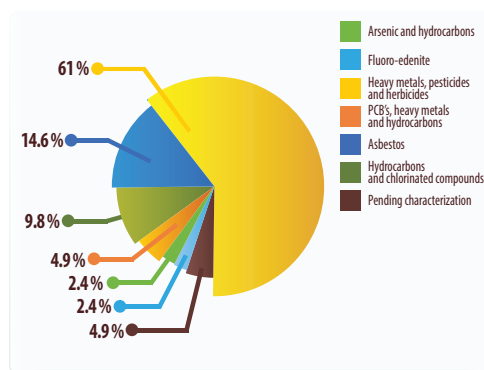


Figure 6 Contamination of SNI's by type of prevalent contamination

At the Sites of National Interest in Bussi sul Tirino and in the Sacco River Basin characterization is still ongoing, therefore data on the type of pollutants are not yet available.

This analysis shows that hydrocarbons are present at 53.7% of SNI's, accounting for 23 sites overall. These data have been processed on the basis of the assessment of pollution sources recorded in the technical reports of the characterization procedures carried out at the SNI's and the information made available through the regional registers.

The sites of Gela, Fidenza, Mantua Lakes, Val Basento and Sulcis Iglesias Guspinese have the highest level of contamination from hydrocarbons - Table 2 e 3.

Contaminants	Number of SNI's	%
Arsenic and hydrocarbons	1	2.4%
Fluoro-edenite	1	2.4%
Heavy metals, pesticides and herbicides	1	2.4%
PCB's	1	2.4%
PCB's, heavy metals and hydrocarbons	1	2.4%
Hydrocarbons and chlorinated compounds	1	2.4%
Pending characterization	2	4.9%
Hydrocarbons	3	7.3%
Heavy metals and chlorinated compounds	3	7.3%
Heavy metals	5	12.2%
Heavy metals, chlorinated compounds and hydrocarbons	5	12.2%
Asbestos	6	14.6%
Heavy metals and hydrocarbons	11	26.8%
Total	41	

Table 2. Type of contaminants detected at SNI's expressed as a percentage. Hydrocarbons are both isolated and mixed with arsenic, PCB's, heavy metals and chlorinated compounds.

SNI	Main contaminants
1 - Venice	Heavy metals, chlorinated compounds and hydrocarbons
3 - Gela	Heavy metals and hydrocarbons
4 - Priolo	Heavy metals and hydrocarbons
5 - Manfredonia	Arsenic and hydrocarbons
6 - Brindisi	Heavy metals and hydrocarbons
7 - Taranto	Heavy metals and hydrocarbons
9 - Piombino	Heavy metals, chlorinated compounds and hydrocarbons
13 - Pieve Vergonte	Heavy metals, chlorinated compounds and hydrocarbons
14 - Sesto San Giovanni	Heavy metals, chlorinated compounds and hydrocarbons
15 - Pioltello-Rodano	Heavy metals, chlorinated compounds and hydrocarbons
19 - Fidenza	Heavy metals and hydrocarbons
20 - Laguna di Grado e Marano (now Caffaro di Torviscosa)	Heavy metals, chlorinated compounds and hydrocarbons
21 - Trieste	Heavy metals and hydrocarbons
24 - Sulcis Iglesiente Guspinese	Hydrocarbons
26 - Livorno	Heavy metals and hydrocarbons
27 - Terni	Heavy metals and hydrocarbons
29 - Trento Nord	Heavy metals and hydrocarbons
32 - Falconara Marittima	Heavy metals and hydrocarbons
33 - Serravalle Scrivia - Ecolibarna	PCB, Heavy metals and hydrocarbons
34 - Mantua Lakes	Hydrocarbons
36 - Porto Torres	Hydrocarbons and chlorinated compounds
37 - Val Basento	IC Hydrocarbons
38 - Milazzo	Heavy metals and hydrocarbons

Table 3. Main contaminants detected at individual SNI's

20

Remediation of Hydrocarbons: the Case History of Fidenza and Other Possible Applications

This study intends to show the extension of the contamination from hydrocarbons in Italy, with the purpose of informing the public authorities on the scale of the problem and encouraging them to develop effective remediation strategies, including biological methods.

The Site of National Interest of Fidenza, where the LIFE BIOREST Project tested its method, is characterized by extensive hydrocarbon contamination resulting from the crude oil refinery activities of petrochemical industries (former Carbochimica and CIP).

Similarly, the SNI's of Val Basento, Gela and Mantua Lakes suffer from hydrocarbon contamination. This section is thus aimed at gaining deeper knowledge on these 4 SNI's, with the purpose of showing potential synergies and benefits of an application of the LIFE BIOREST method.

The Fidenza SNI: a Case of Excellent Urban Regeneration

The Site of National Interest in Fidenza, Emilia-Romagna, comprises 6 areas of 176,000¹² sq.m, including a former productive settlement sprawling over 115,000 sq.m and divided in the two lots of the former Carbochimica and CIP, which name refers to the main companies active in the site between 1888 and 2003.

The production activity here focused on the distillation of coal tar for the production of briquettes and naphthalene (Distilleria di catrame since 1888, followed by Cledca since 1928, and finally by Carbochimica from 1972 to 2003), which were used for the manufacture of explosives during World War I, and replaced by benzene during World War II. After its militarization the site became a target of Anglo-American air attacks, suffering several bombardments, in particular on May 2nd and 13th, 1945.

The Sixties were the time of greatest commercial and occupational growth, with almost 200 workers and 60 products, some of which were packaged for retail sale, such as mothballs. This phase was followed by a virtually unstoppable decline, caused by competition developing oil by-products at a lower cost.

The site of 84,009 sq.m was purchased by the Municipality of Fidenza in 2005.

In the area the production of superphosphates, sulphuric acid produced by the lead chamber process and tetraethyl lead (former Campanini Tito & C. since 1908, then CIP Compagnia Italiana Petroli from 1950 to 1970) sprawled over 30,000 sq.m.

The contamination of the former CIP site concerned the soil, subsoil and surface groundwater and was characterized by heavy metals, very high concentrations of polycyclic aromatic hydrocarbons scattered in the subsoil at two different depths.

Ministerial Decree no. 468 of 18 September 2001 included Fidenza among the Sites of National Interest¹³, and the successive definition of the perimeter (Ministerial Decree of 16 October 2002) described the areas needing characterization, safety and reclamation measures as well as monitoring activities¹⁴.

The City Council of Fidenza identified the sites suitable for reuse after remediation (former CIP and Carbochimica), developing and approving a detailed plan of action called "Loghetto (PPLOG)" between 2001 and 2002 and later including it in the current General Regulatory Plan as an Ecologically Equipped Productive Area (EEPA), with an extension of about 115,310 sq.m, with Resolution no. 19/2008.

The Framework Programme Agreement between the national Government and the Emilia-Romagna Region defined the state of the remediation work and planned activities with a total budget of € 23,627,356.99.

The first phase of the remediation project concerned safety measures (€ 5,618,020.97 funds as per Ministerial Decree no. 468/2001), the removal of contaminated soil and underground equipment with adequate protection for workers, including self-contained breathing apparatus; treatment of hydrocarbon-contaminated groundwater, preparatory activity of organic soil treatment (€ 5,463,083.90 funds as per Ministerial Decree no. 468/2001).

A second remediation project of the CIP area concerned the implementation of a biopile system per the ex situ treatment of hydrocarbons and subsequent processing of unpolluted areas (€ 1,126,984.50 funded by the Ministry for the Environment). The most challenging phase of the former Carbochimica started in the summer of 2013, regarding in the first phase the complete demolition of tanks, equipment and some buildings. The operations concerned first of all the removal of insulation for about 80 tanks, partly still containing about 5,000 tons of chemical substances, of 25,000 sq.m of roofs and 30 km of pipes, largely covered with asbestos, then the recovery of polluting substances and finally the demolition of all plants and equipment and disposal thereof.

The characterization of pollutants pointed out a severe state of contamination, with values exceeding the limits for chlorinated solvents (chloroform, perchlorethylene, carbon tetrachloride), phenols, heavy and light hydrocarbons, PAH's (naphthalene and anthracene) and, in the whole former Carbochimica area, PAH's, BTEX and aliphatic chlorinated solvents in the confined aquifer.

The progress reports on the project concerning ground areas, provided by the Ministry for the Environment and updated to **2018**, state that:

- 44% of areas have been secured;
- 100% have completed characterization;
- 8% have been restored to legitimate use following characterization, which excluded contamination.

The Fidenza Municipality is now committed to finalizing the remediation of the areas with the aim of enhancing their value and recovering them for a quality reindustrialization, compliant to the EEPA parameters set out by the Emilia-Romagna Region pursuant to Act of the Regional Council no. 118/2007.

Ecologically Equipped Productive Areas (EEPA's) are characterized by "the prerequisite system for a modern settlement offer that may respond to the needs of productive companies". Such areas, and the reconditioned pre-existing ones, will guarantee a suitable environment for local enterprises needing new spaces to innovate their production processes, rationalize logistics, improve their image, qualify working conditions and security.

The former CIP and Carbochimica sites, the former Loghetto Farm and the Soprip production unit have been qualified as EEPA's and the urban regeneration project is among the Municipality's objectives to ensure a greater energy efficiency, the promotion of alternative and renewable energy sources, the optimization of the waste cycle, the integrated management of the water cycle and the enhancement of the overall image of the settlements in terms of urban reorganization.

¹² The site includes 6 areas: the former CIP industrial area (purchased by the Fidenza Municipality in 2001), the industrial area of Carbochimica (purchased by the same municipality in 2005), two dismissed municipal solid waste landfills along the Stirone River (in Fornio and Vallicella), the area of the former incinerator of San Nicomede and the area of the former Conforti foundry (which was later found to be uncontaminated).

¹³ Regulation of the "National environmental remediation and reclamation programme"

¹⁴ Beside the industrial sites of the former CIP and Carbochimica, the SNI includes the areas in Vallicella and Fornio, where dismissed municipal and special waste landfills were located in flood plains and were contaminated from organic substances and heavy metals and where erosive phenomena of the Stirone River had partially uncovered waste, and finally the area of San Nicomede, contaminated by ashes from the dismissed incinerator plant, which is also located in the floodlands of the same river.

The Val Basento SNI

ENI President Enrico Mattei, Industry Minister Emilio Colombo and Prime Minister Amintore Fanfani laid the first stone of the Fuel Hydrogenation National Company on 31 July 1961 in Pisticci, Basilicata. A few years later this valley, one of the poorest territories of Southern Italy, with a strong agricultural tradition, was deeply changed, reaching an employment rate of 7,000 workers and turning into one of the main industrial areas of the South of Italy. Such development stopped at the end of the Seventies, with the crisis of the basic chemical industry. Various reindustrialization attempts with a strong social, economic and environmental impact followed since.

Between the end of the Nineties and the start of this century, the site was occupied by the Tecnoparco company with a regional ownership (40% Matera Industrial Development Agency), which provided services for the companies established in Val Basento and managed the wastewater treatment of oil installations. ANIC/Enichem and the Materit factory - a plant for the processing of asbestos - are established in Pisticci and Ferrandina respectively. Today, after the dismantling of chemical plants, there are about 20 chemical and pharmaceutical and manufacturing companies in the area[16].

Law no. 179 of 31 July 2002 provided for the listing of Val Basento as a Site of National Interest. Potentially contaminated areas were included in the perimeter pursuant Ministerial Decree of 26 February 2003, with a total extension of 3,400 ha, and covering the municipal areas of Ferrandina, Pisticci, Grottole, Miglionico, Pomarico and Salandra. This is when dangerous substances in concentrations exceeding the limits imposed by the law were found in the surface water and groundwater, following the tests carried out by both ARPA Basilicata and private entities.

In 2013 the state of contamination registered by the local health board of Matera determined the prohibition of the use of the potentially polluted groundwater in Val Basento and in the neighbouring areas.

On 19 June 2013 the Ministry of Economic Development and the Ministry for the Environment signed the "Remediation of Contaminated Sites of National Interest of Tito and Val Basento (CBMT)" Framework Agreement, funded under CIPE Decision no. 87/2012 and providing for the implementation of a number of remediation and/or characterization operations in the Tito and Val Basento areas with a financial coverage of 46 million euro. The Ministry of Economic Development is responsible for the ultimate supervision and ensures that funding is timely provided, the Ministry for the Environment is the proceeding authority in the SNI's, ensuring that technical procedures are carried out, so as to approve the operations provided for in the Agreement, while the Basilicata Region is the implementing authority, with the task of executing such operations.

22

The progress reports on the project concerning ground areas, provided by the Ministry for the Environment and updated to 2018, state that:

- 3% of areas have been secured;
- 100% have undergone characterization studies;
- 96% have completed characterization;
- 88% have been restored to legitimate use following characterization, which excluded contamination.

The securing and remediation operations as well as the characterization studies were financed with regional and national funds for a total amount of 23 million euro[14].

Characterization allowed local authorities to release and restore uncontaminated agricultural areas to legitimate use, for a total surface of 2,930 ha, while identifying 44 dangerous areas called "hot spots", for a total surface of about 166 ha.

The Gela SNI

During the Fifties an exploratory campaign carried out by Agip led to the discovery of a natural oil field in the plain and gulf of Gela (1956).

ANIC Gela SpA was created in 1959 and the year after Enrico Mattei laid the first stone of the petrochemical plant, which drilling installation first started to function in 1962. The plant was downsized several times in the following twenty years and 1974 was marked by the building of one of the biggest seawater desalination facility in Europe. Air, water and soil pollution from industrial activities with a high environmental impact risk has been recognized since 1990. With Legislative Decree no. 426/1998 Gela was listed in the first 15 Sites of National Interest and with Ministerial Decree of 10 January 2000 the definition of the perimeter and the characterization study of the polluted areas started [18][19].

The 5,955 ha in the perimeter, 795 of which in land and 4,560 in sea, are very closed to the residential area, which developed over the years near the industrial centre. The perimeter includes ENI petrochemical plants and refineries; a petcoke fuelled 262 MW thermoelectric power plant; chemical plants (ISAF and Plomeri Europa). The characterization of pollutants pointed out a severe state of contamination, with values exceeding the contamination threshold concentrations for heavy metals (selenium, mercury, nickel, lead, cadmium, iron and manganese), BTEX, saturated hydrocarbons (C<12 and C>12), PAH's, chlorinated compounds (hexachlorobenzene, PCB's and solvents), asbestos and dioxins [20].

The progress reports on the project concerning ground areas, provided by the Ministry for the Environment and updated to 2018, state that:

- 0% of areas have been secured;
- 97.5% have undergone characterization studies;
- 0.5% have been restored to legitimate use following characterization, which excluded contamination.

The securing and remediation operations as well as the characterization studies were financed with public and private funds for a total amount of over 127 million euro. Epidemiologic studies show an increase in cancer diseases [21], and a study estimated that an investment of 6.6 billion euro for the remediation of Gela would sensibly reducing expenses for the healthcare system in the short and long term. [22]

The Mantua SNI

The industrial site in Mantua first developed with the Carlo Perdomini business for the manufacture, commerce, import and export of petrochemical products.

In 1946 the chemical industries in Mantua were grouped under ICIP (Italian petrochemical industries) and the refinery entered the production phase only after the war, in 1953.

The Sixties were a period of strong economic expansion, with the completion of the oil pipeline from Marghera to Mantua (1963), an infrastructure of 124 km passing through 43 municipalities. Great technological innovations enriched the refinery with new facilities in 1969, bringing the processing capacity of the plant from 900 thousand to 2 million and 600 thousand tons per year. In 1990 the plant was taken over by Cameli Petroli, then, in 1994, by IES Italiana Energia e Servizi SPA, and finally, in 2007, by the multinational MOL group. The refinery was shut down in 2013 and turned into a logistics hub.

The Mantua SNI sprawls across 1,027 ha, 614 of which are on land and 413 are groundwater, and includes the industrial area, Lago di Mezzo, Lago Inferiore, the Vallazza site and some stretches of the Mincio River. Identified with Law no. 179/2002, such area has a great environmental, natural, and social importance and is affected by the industrial waste which petrochemical plants, the IES refinery and other small enterprises discharged in the area since the Fifties.

The SNI areas surround the Mantua city centre on the east and south-east. The refinery soil and subsoil are known to be contaminated from hydrocarbons due to leakage of pollutants from installations, underground process lines, storage tanks and other accidental events. Over the years hydrocarbons reached the groundwater, creating a layer of organic contaminants. The environmental soil investigation pointed out a state of contamination from heavy metals and chlorinated compounds, beside hydrocarbons (low and heavy, BTEX, PAH's). Mostly heavy metals, specifically mercury, are found in the groundwater, with values exceeding contamination threshold concentrations [23].

The progress reports on the project concerning ground areas, provided by the Ministry for the Environment and updated to 2018, state that:

- 0% of areas have been secured;
- 63% have undergone characterization studies;
- 60.1% have completed characterization;
- 3% have been restored to legitimate use following characterization, which excluded contamination.

The securing and remediation operations as well as the characterization studies were financed with public funds for a total amount of over € 15.7 million [23]. Private funds allocated by ENI in September 2018 amount to € 70 million; the company shall allocate further € 150 million for the securing and remediation of the site [24].

Sites of Regional Interest (SRI's)

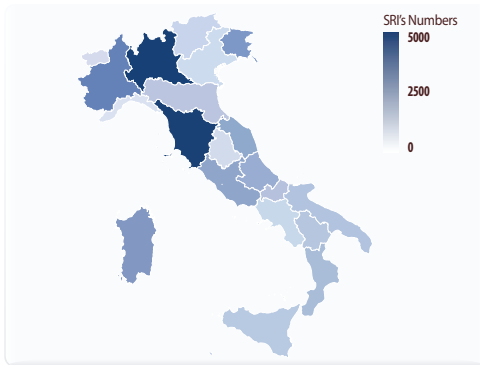


Figure 7 SRI's by Region.

The Regions with the most intense colours have a higher number of SRI's. Lombardy and Tuscany count over 4,000 sites each, while the least polluted regions are Valle D'Aosta and Umbria.

This section of the study is intended to provide an analytical framework of **20 regional registers**, with a specific focus on **pollution from hydrocarbons**. The activity of census and analysis resulted in the mapping of **20,047 Sites of Regional Interest (SRI's)** on the whole national territory. Leaving completed procedures aside (remediated sites and sites found to be uncontaminated after investigation), the number of SRI's needing remediation measures is **9,487**. According to the query results based on regional register data, **2,119** sites are potentially **contaminated from hydrocarbons**. Lombardy has the highest number of contaminated sites, with 4,332 SRI's, followed by Tuscany (4,234) and Piedmont (1,708) while the last in the list are Umbria (142), Veneto (150) and Valle D'Aosta (152) - *Figure 7*.

The percentage ratio of contaminated Sites of Regional Interest on the whole of the sites makes it possible to measure the remediation activity in terms of the areas that still need decontamination interventions. The regions with the best ratio are Valle D'Aosta (18,3%), Lombardy (19,3%), Emilia-Romagna (24,5%) and Tuscany (26,8%), while on the other side Basilicata (79,5%), Veneto (69,3%) and Trentino-Alto Adige (54,9%) show a low ratio between remediated sites and the whole of the registered ones.

An accurate analysis of this ratio suffers from the heterogeneous updating systems of the various regional registers, where in many cases there is no information as to the state of remediation. This is the case of Liguria, Umbria, Campania, Sicily, Puglia, Molise, Calabria, Lazio and Sardinia. - *Figure 8*.

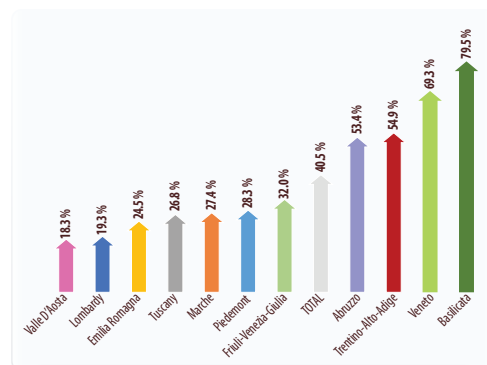


Figure 8 Percentage of contaminated sites on the total registered ones. The regions with their percentage of contaminated sites on the total registered ones are shown in descending order. For the other regions the percentage is 100%

Contamination From Hydrocarbons

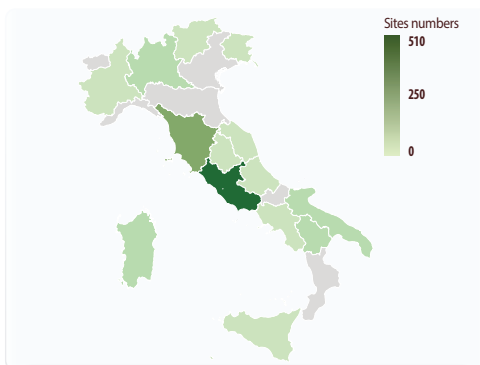


Figure 9 SRI's contaminated from hydrocarbons by Region.

The regions with the greatest number of hydrocarbon-contaminates sites are shown with a darker green colour.

The mapping and analysis of the state of soil contamination recorded by 20 regional registers allowed the identification of **2,119 hydrocarbon-polluted sites**.

Such data are obtained through the querying of the registers that clearly and fully indicate the contamination type (following characterization) and the source of pollution: points of sale, deposits, tanks and fuel spills, oil spills, refineries and petrochemical activities, pipeline spills and accidents.

Considerations on hydrocarbon-polluted sites can be made only for **15 Regions**, while for Emilia-Romagna, Veneto, Liguria, Molise and Calabria the analysis of the type of sites cannot yet be complete and exhaustive.

The regions with a the greater concentration of hydrocarbon-contaminated sites are Lazio (510), Tuscany (338), Sardinia (219) and Lombardy (177), while only a few of them are found in Valle D'Aosta (3), Abruzzo (44) Umbria (50), Campania (60) and Marche (69) - *Figure 9*.

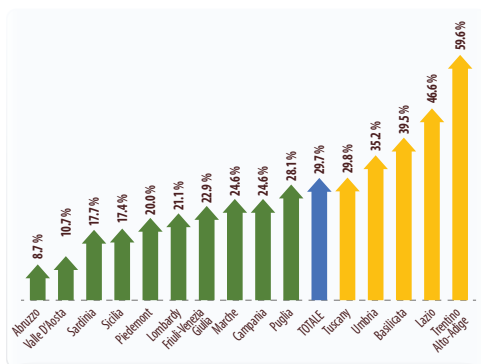


Figure 10 Percentage of hydrocarbon-contaminated SRI's on the whole of polluted SRI's. The percentages are shown for the regions where it was possible to estimate, through the site or pollutant type, the kind of pollution. Data from Emilia-Romagna, Veneto, Liguria, Molise and Calabria are not comprehensive and exhaustive.

The percentage ratio of hydrocarbon-contaminated Sites of Regional Interest on the whole of sites in the 15 investigated regions is 27.1%. The regions with a higher-than-average percentage are Trentino-Alto Adige (59.6%), Lazio (46.6%), Basilicata (39.5%), Umbria (35.2%) and Tuscany (29.8%). Those with the least SRI's from hydrocarbons, on the other hand, are Abruzzo (8.7%) and Valle D'Aosta (10.7%) - Figure 10.

In the list of Provinces with the highest number of hydrocarbon-polluted SRI's Rome is in first position, with 338 potential sites, followed, among the most important ones, by Milan with 94 sites and Trento with 84 sites - Figure 11.

Similarly, the list of Municipalities affected by contamination from hydrocarbons is headed by Rome with 228 SRI's, followed by Milan (37), Trento and Trieste (both 25), Pisticci (21), Cagliari and Ferrandina (both 18), Livorno and Naples (both 16) and Fiumicino (15).

The registers of Abruzzo, Basilicata, Emilia-Romagna, Lombardy, Marche, Piedmont, Tuscany, Trentino-Alto Adige and Valle D'Aosta classify the Sites of Regional Interest into the four types "potentially contaminated", "contaminated", "remediated" and "uncontaminated after assessment", differently from the remaining registers, which provide the total number of contaminates sites, omitting the state of the administrative procedures of remediation.

The vast majority of remediated sites lie in **Lombardy**, which counts **2,194** areas, equal to 50.6% of regional sites, while Tuscany has the leadership in terms of areas that have been ascertained to be "uncontaminated", with 1,703 sites, equal to 40.2% of the region's total sites.

Basilicata stands out for having the greatest percentage of contaminated sites, accounting for 79.4% of the region's total registered areas. **Valle D'Aosta** has the highest number of completed assessment procedures, equal to 81.6% of total areas - Figure 12.

The Mapping of Hydrocarbons Through Regional Registers

The study is based on the data made available by the Regions, regional agencies (ARPA's and APPA's) and by the Ministry for the Environment. Given that such data are sometimes outdated or lacking of information on the type of pollution, the study must be held as preliminary. Indeed, a number of potentially contaminated sites still need characterization. The information on the SRI's has been extracted from the 20 regional registers provided for in the environmental regulations (Article 251 of Legislative Decree no. 152/2006 and subsequent amendments and additions). Data were extrapolated from the official websites of the Italian Regions and Autonomous Provinces of Trento and Bolzano, supplementing them, wherever possible, with information from the Regional Agencies for Environmental Protection (see web references). The sites for which the state of the art of administrative procedures is not specified have been considered as "contaminated". Hydrocarbon-contaminated sites were included among contaminated ones when the register showed the type of contamination. Finally, all sites contaminated by fuel points of sale, fuel deposits, tanks, fuel and oil spills, refineries and petrochemical plants, pipeline spills and accidents have also been included in the latter group.

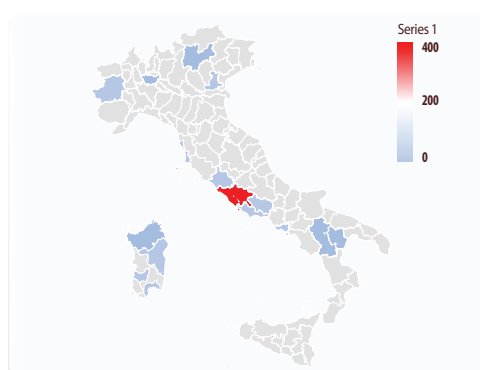


Figure 11 Provinces with the greatest number of hydrocarbon-contaminated SRI's. The 20 provinces with the greatest number of hydrocarbon-contaminated SRI's are shown on the map. Rome stands out negatively, counting as many as 388 alone, followed by

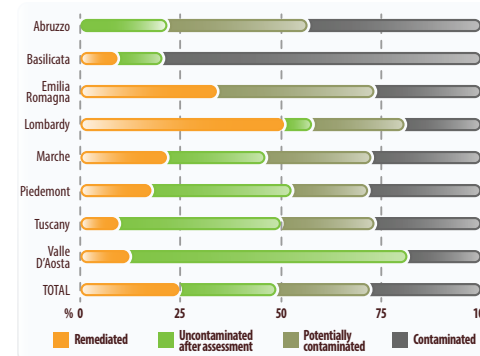
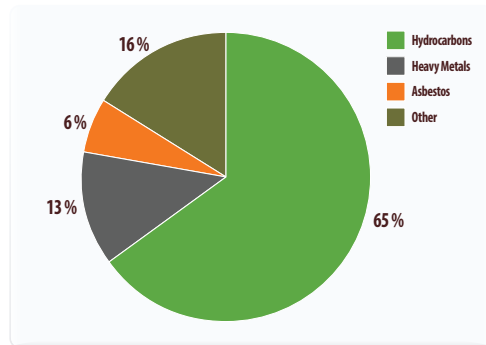


Figure 12 % SRI's by category. The percentage of SRI categories in each region is shown in the chart.

Valle d'Aosta

Total registered sites	152
Potentially contaminated sites	N.A.
Contaminated sites	28
Uncontaminated sites	105
Remediated sites	19
Hydrocarbon-contaminated sites (on the total of identified sites)	3

The regional register of contaminated sites in Valle D'Aosta is updated to 2017 and has listed 152 sites on the whole territory. About 70% of these have started and completed preliminary assessment procedures, which have determined their non-contamination. Remediation and securing measures were applied in 19 sites while 28 of them are currently undergoing treatment, 3 of which for tank spills and subsequent release of hydrocarbons. The most frequent contaminants are hydrocarbons, found in 65% of mapped sites, heavy metals (13%), asbestos (6%) and other contaminants in aggregated form. [11],[12]

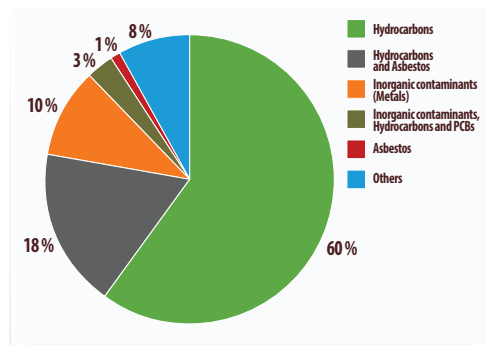


Pollutant types.

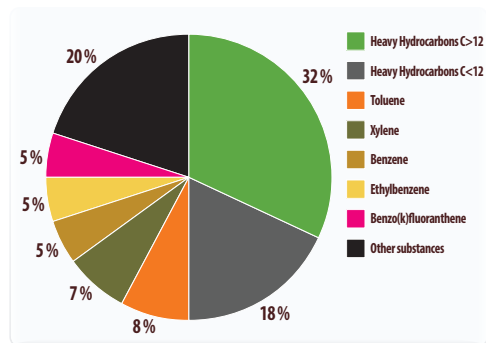
Piedmont

Total registered sites	1,708
Potentially contaminated sites	327
Contaminated sites	484
Uncontaminated sites	592
Remediated sites	305
Hydrocarbon-contaminated sites (on the total of identified sites)	97

Updated to 2018 by ARPA Piedmont, the regional register includes 1,708 sites. 52% of these (897) have completed characterization and securing, 35% (592) do not require decontamination and 18% (305) were remediated. Procedures are ongoing at 811 of sites, equal to 48% of the total, 327 of which are considered as potentially contaminated and 484 have been identified as contaminated following assessment [27]. The Turin Province counts the highest number of contaminated sites in the Region, 46.1% of the total, with 450 ongoing and 337 completed procedures. The Asti Province counts the lowest number of polluted sites (80), 62.5% of which have completed the procedure. There follow Biella (73.7%), Vercelli (37.5%), Alessandria (58%), Verbano-Cusio-Ossola (63.3%), Novara (65.3%) and Cuneo (66.7%) [28]. The regional register gives a full overview of hydrocarbon-contaminated sites. Of the 484 confirmed contaminated sites, 97 have hydrocarbons among the main pollutants. The causes of pollution are, by order of importance, poor plant and waste management and accidental events such as spills and pipeline leakages [29], [30].



Pollutant types.



Hydrocarbons types in the soil.

Lombardy

Total registered sites	4,332
Potentially contaminated sites	1,000
Contaminated sites	838
Uncontaminated sites	300
Remediated sites	2,194
Hydrocarbon-contaminated sites (on the total of identified sites)	177

The Integrated Management Register of Contaminated Sites (AGISCO) includes information on: the environmental relevance of the sites; possible connected sites; cadastral data; the stakeholders who are to various degrees involved in activities based on them; technical and preliminary investigation data; detected pollutants; projects; monitoring activities; ongoing or planned operations.

A new financial section of the register is currently under development, which will allow the management of sites receiving regional funds.

4,332 Sites of Regional Interest are registered in Lombardy.

Of these, 1,000 are classified as potentially contaminated (23.1%), 2,194 as already remediated (50.6%), 300 were assessed and confirmed to be uncontaminated (6.9%) and 838 are listed as contaminated (19.3%).

Data on contamination from **hydrocarbons** in Lombardy, detailed in the regional register and updated to 2018, were integrated with AGISCO sources [31], [32].

Sites defined as potentially contaminated from hydrocarbons in the Open Data Server of the Lombardy Region are identified by site type, mainly "Fuel point of sale", "Deposit" and "Refinery"; sites classified by AGISCO as "Fuel storage or adduction" are added to these.

177 sites, equal to 20% of the total, are contaminated from hydrocarbons, the causes of pollution being fuel storage and adduction activities as well as industrial refineries.

Liguria

Total registered sites	N.A.
Potentially contaminated sites	N.A.
Contaminated sites	N.A.
Uncontaminated sites	N.A.
Remediated sites	N.A.
Hydrocarbon-contaminated sites (on the total of identified sites)	N.A.

About 200 contaminated sites result from a purely visual analysis of the infographic map published by the Region and showing the location of the sites on the territory. Unfortunately it is not possible to access the register, which specifies name, municipality and contaminant type for each site. [33]

Friuli-Venezia-Giulia

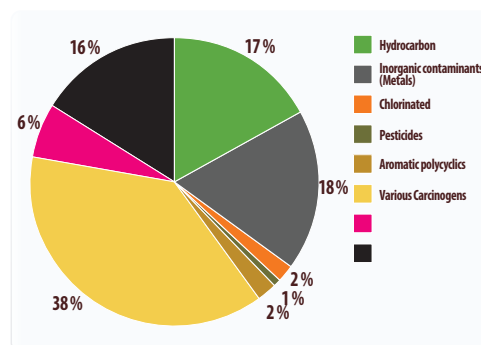
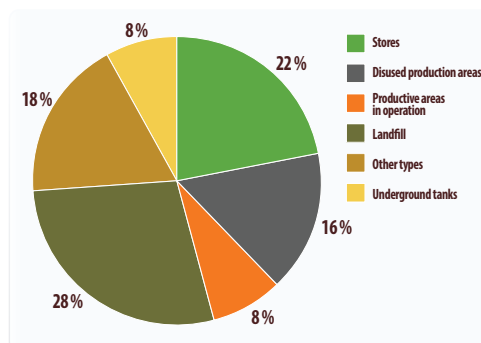
28

Total registered sites	1,297
Potentially contaminated sites*	415
Contaminated sites	N.A.
Uncontaminated sites	N.A.
Remediated sites	N.A.
Hydrocarbon-contaminated sites (on the total of identified sites)	95

* Procedures still ongoing

There are **1,297** listed sites in the Friuli Venezia-Giulia regional register. The information system of polluted sites (SISQUI) shows the environmental knowledge database, capable of supporting specific environmental surveillance tasks on the basis of the compartments affected by a possible contamination. The procedures are currently ongoing at 32% of identified sites (415), while they have been completed at the remaining 68% ones (882).

Hydrocarbon-pollution was confirmed in **95** sites, 45 of which are to be found at fuel points of sale, 12 are due to accidental spills, 7 are former refineries and the remaining have various other sources of pollution [34].



Trentino-Alto-Adige

Total registered sites	524*
Potentially contaminated sites	99
Contaminated sites	59**
Uncontaminated sites	54
Remediated sites	312***
Hydrocarbon-contaminated sites (on the total of identified sites)	84
* 257 Trento, 267 Bolzano	
**48 Trento, 11 Bolzano	
*** 56 Trento, 256 Bolzano	

The mapping of contaminated sites in the Trentino-Alto Adige Region is divided between the Provinces of Trento and Bolzano, each one equipped with its own register.

The Consolidated Text of the Provincial Laws for the Protection of the Environment from Pollution (approved by Decree of the President of the Province no. 1-41/LEG. of 26 January 1987 and subsequent amendments and additions) is the regulatory framework adopted by the Autonomous Province of Trento. Specifically, the remediation of contaminated sites is regulated by Part Three on Waste Management, Articles 76, 77 and 77-bis. With Decision no. 2631 of the Provincial Council dated 17 October 2003 the Trento Province later approved the provincial plan for the remediation of polluted areas, which is still in force and also includes the register of contaminated sites. These are 257 in the Trento Province, 56 of which have been remediated and 54 have been declared as unpolluted after assessment [36].

Found in 84 areas, hydrocarbons are the most common pollutant types, accounting for 57% of contaminated and potentially contaminated sites (147).

As regards the Autonomous Province of Bolzano, the provincial register includes 267 contaminated sites (data updated to 2015), which are divided into three groups: (a) Contaminated sites registered before the entry into force of Ministerial Decree no. 471/1999, therefore lacking remediation certificate; (b) Certified remediated sites; (c) Sites undergoing remediation.

256 sites are listed in the first two groups and 11 are undergoing securing and remediation measures. [11].

Veneto

Total registered sites	150
Potentially contaminated sites	104
Contaminated sites	44
Uncontaminated sites	0
Remediated sites	2
Hydrocarbon-contaminated sites (on the total of identified sites)	N.A.

The regional register, which data are updated to December 2015, provides an analytical framework of the state of contamination on the regional territory. The flexibility of the procedure for data entry in the register makes it possible to obtain information in the various phases of the operations on a site, from the preliminary investigation, to the control assessment and all the following project phases including the final testing.

There are 150 sites in the Provinces of Belluno (4), Padua (38), Rovigo (12), Treviso (16), Venice (34), Verona (16) and Vicenza (30) [37]-[39]

Among these, 104 are considered as **potentially contaminated** due to the start of the investigation procedure (9); risk analysis (21); characterization (47); exceeding of the contamination threshold concentrations (4), while 23 confirmed sites lack of in-depth information. The contaminated sites undergoing remediation procedures are 35, and 9 have started preliminary assessment procedures.

Emilia-Romagna

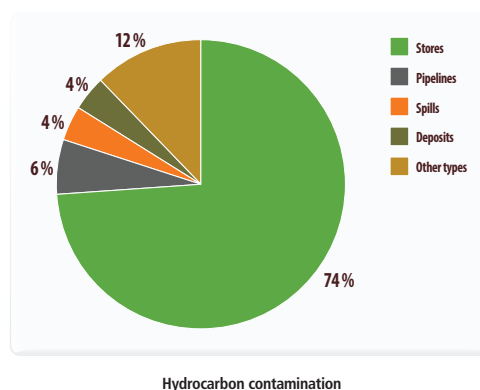
Total registered sites	346
Potentially contaminated sites	135
Contaminated sites	93
Uncontaminated sites	0
Remediated sites	118
Hydrocarbon-contaminated sites (on the total of identified sites)	N.A.

The **346 sites listed** in the regional register (updated to September 2017) are mainly found in the Provinces of Ravenna, Bologna and Ferrara at chemical, mechanical industries and hydrocarbon refining and processing plants. **Two Sites of National Interest** are included in the register, namely Fidenza and Sassuolo-Scandiano, which perimeters have been defined by Decrees of the Ministry for the Environment of 16 October 2002 and 26 February 2003 respectively. Only the Fidenza site is currently listed as a SNI, while Sassuolo-Scandiano was excluded from the list by Ministerial Decree of 11 February 2013, following the amendments to the criteria set to identify SNI's made by the same Ministry.

39% of the sites listed in the register are considered as **potentially contaminated (135)**, 27% are **undergoing remediation (93)**, while the remaining 34% are **remediated** or currently being monitored (**118**). Contamination from hydrocarbons is closely connected to the type of active industrial sites on the territory and to the presence of fuel points of sale. The large majority of contaminated sites are connected to the presence of hydrocarbons, especially heavy ones (C>12), light aromatic hydrocarbons of the BTEX group (mainly benzene) and metals (notably lead). Natural processes also influence the presence of some pollutants, such as metals. An exact quantification of hydrocarbon-contaminated sites is not yet available.

Lazio

Total registered sites	1,094
Potentially contaminated sites	N.A.
Contaminated sites	N.A.
Uncontaminated sites	N.A.
Remediated sites	N.A.
Hydrocarbon-contaminated sites (on the total of identified sites)	510



The Lazio Region, in collaboration with the Regional Environmental Protection Agency (ARPA), has started the development and management of the register of contaminated sites, as provided for in Article 251 of Legislative Decree no. 152/2006. Such register, created pursuant to Decision of the Regional Council no. 310 of 3 October 2013, is currently under development and draws inspiration from the register created by ARPA Tuscany (SISBON).

The register currently lists **1,094 sites** (data updated to 2016) in five provinces: Frosinone (266), Latina (104), Rieti (40), Rome (536) and Viterbo (121). Unfortunately the data do not specify the state of the art of the remediation projects, therefore it is not possible to have a comprehensive framework of those having completed the decontamination procedure.

The sites in the register have been listed by pollution source. Almost 50% (510) of them is contaminated from hydrocarbons, with 379 fuel points of sale; 31 pipelines; 21 accidental spills and 19 fuel deposits, while the remaining have various other causes of pollution.[40]

Marche

Total registered sites	1,025
Potentially contaminated sites	270
Contaminated sites	281
Uncontaminated sites	252
Remediated sites	222
Hydrocarbon-contaminated sites (on the total of identified sites)	69

The register of contaminated sites of the Marche Region includes Sites of Regional and National Interest undergoing remediation procedures and fully redeveloped ones, as provided for in Decree no. 49/CRB of 18 May 2017 [41]. Furthermore, in order to provide a comprehensive framework of the state of pollution, the Marche Region has also included in its register those sites that, though not having reached the remediation phase, have undergone preliminary investigation for the definition of contamination threshold concentrations.

Values exceeding the limits imposed by the law since 1999 have been found at **1,025 sites**, including the former SNI

of “Basso Bacino del fiume Chienti” (lower basin of the Chienti River, BBC) and the SNI of the Falconara Marittima (FM)¹⁵ area. 222 (21%) sites have completed the remediation or securing procedures (Annex B), with a successful resolution of environmental concerns and a restoration to legitimate use¹⁶.

Finally, 281 (27%) sites have been classified as requiring remediation (Annex C), including those where remediation procedures are undergoing, those where the risk analysis showed higher than permitted contamination threshold concentrations, and all sites included within the BBC and FM SNI's which have not yet completed the procedures.

Among these, 281 sites 69 were identified as possibly polluted from hydrocarbons, mostly fuel points of sale and deposits.

Tuscany

Total registered sites	4,234
Potentially contaminated sites	991
Contaminated sites	1,134
Uncontaminated sites	1,703
Remediated sites	406
Hydrocarbon-contaminated sites (on the total of identified sites)	225

The “SISBON” regional register was created by the Tuscan Regional Environmental Protection Agency (ARPAT) on behalf of the Tuscany Region to map and share remediation data with all authorities involved (Municipalities, Provinces, ARPAT, AUSL, Prefecture, Region, Ministry for the Environment)¹⁷.

Through the SISBON system the Tuscany Region has listed 4,234 contaminated and potentially contaminated sites on the whole regional territory. Of these, 991 need assessment, 1,703 have been confirmed as uncontaminated following assessment, 406 have been remediated. The remaining 1,134 have been classified as contaminated, the causes of pollution being fuel distribution activities in 186 of cases and fuel deposits in 37 cases, while 2 sites have been contaminated by oil refineries. [42][43]

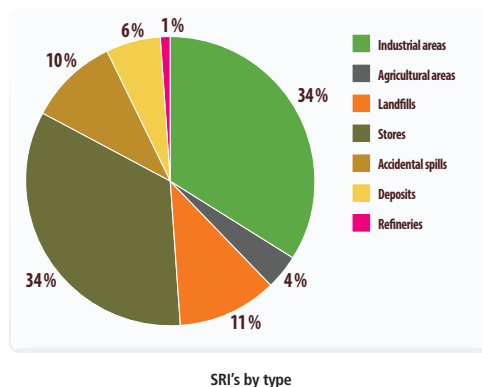
9.6% of all sites have been remediated and 40.2% resulted uncontaminated following assessment.

The open procedures regarding 50% of sites in the register include the assessment of potentially contaminated areas (23.4%) and the treatment of contaminated ones (26.8%). Contamination from hydrocarbons and BTEX was detected in 225 areas at fuel points of sale (186), deposits (37) and oil refineries (2) [43].

31

Umbria

Total registered sites	142
Potentially contaminated sites	N.A.
Contaminated sites	N.A.
Uncontaminated sites	N.A.
Remediated sites	N.A.
Hydrocarbon-contaminated sites (on the total of identified sites)	50



The regional register of polluted sites was implemented pursuant to Article 31 of Regional Law no. 11 of 13 May 2009, and updated to 2018 following Decision no. 1523/2018.

There are 142 registered sites in the region which contamination is connected to industrial activity, accidental spills and fuel supply and adduction [44].

Hydrocarbon contamination has been confirmed at 50 registered sites (35.2%), due to fuel points of sale (33), accidental spills (10), oil and fuel deposits (6), and petrochemical activity (1).

¹⁵ Annex A of Decree no. 49/CRB of 18 May 2017 475

¹⁶ Annex A of Decree no. 49/CRB of 18 May 2017 475

¹⁷ Project implementing the “Operational guidelines and directives concerning the remediation of contaminated sites” set out by Decision of the Tuscan Regional Council 301/2010 and Article 5-bis of Regional Law no. 25/1998. Following the entry into force of the Regional Law no. 15/2016 concerning the reorganization of the administrative functions in environmental matters as of 3 March 2016 the forms provided for by Decision of the Tuscan Regional Council no. 301/2010 and fillable online through the SISBON system are addressed to the Tuscany Region (and not to Provinces or Municipalities).

Abruzzo

Total registered sites	911
Potentially contaminated sites	620
Contaminated sites	40
Uncontaminated sites	251
Remediated sites	0
Hydrocarbon-contaminated sites (on the total of identified sites)	44

Starting from 2002, the Regional Agency for Environmental Protection (ARTA) systematically mapped contaminated sites, completing the first regional listing in 2006, which was incorporated by Decision of the Regional Council no. 1529/2006 and is currently updated pursuant to Decision of the Regional Council no. 794 of 22 November 2016.

On the whole, the **sites on the territory** are **911**, **411** of which are considered as potentially contaminated and needing of further assessment¹⁸.

The Teramo Province counts the greatest number of sites (142), about a third of the total. There follow Chieti (125), Pescara (75) and L'Aquila (69).

97 dismissed sites add to the potentially contaminated ones in the Provinces of Chieti (19), L'Aquila (22), Pescara (18) and Teramo (38) as well as 112 closed landfills [45], 40 of which are currently undergoing remediation. **251** sites have been determined to be uncontaminated following assessment.

The classification of the areas by type of pollutant included in the regional register allows to connect hydrocarbon contamination with fuel points of sale in 7% of cases, equal to 45 sites on the whole of the potentially contaminated ones.

Basilicata

Total registered sites	487
Potentially contaminated sites	387
Contaminated sites	28
Uncontaminated sites	55
Remediated sites	17
Hydrocarbon-contaminated sites (on the total of identified sites)	153

32

The Basilicata Region GeoServer [46] is currently being updated, the last record being September 2019 [47].

Of the 487 registered sites [48]-[51], 17 are remediated and 28 are undergoing remediation, 55 are unpolluted after assessment, while the potentially polluted ones are **387**. Of the latter, 39.5% are potentially contaminated from hydrocarbons, associated to oil extraction activities, crude oil spills from tanks and pipelines, and fuel storage, distribution and sale.

Calabria

Total registered sites	696
Potentially contaminated sites	N.A.
Contaminated sites	N.A.
Uncontaminated sites	N.A.
Remediated sites	N.A.
Hydrocarbon-contaminated sites (on the total of identified sites)	N.A.

In the 409 regional municipalities **696 sites have been listed as polluted by waste** with a volume higher than 250 cu.m, 38.5% of which is to be found in the Province of Cosenza.

About 36% of classified sites are landfills, specifically for the treatment of Urban Solid Waste - USW (240), special hazardous waste (4), bulky waste (5), insert waste and building material (4). At least a potentially contaminated site has been identified in 390 of the regional municipalities. [52] There are no data as to the pollutant types and the list of sites is currently being updated through the "MIAPI Project" for the monitoring and identification of potentially contaminated areas.

¹⁸ Annex 3 of ARTA Abruzzo updated to 22 November 2016.

Campania

Total registered sites	911
Potentially contaminated sites	620
Contaminated sites	40
Uncontaminated sites	251
Remediated sites	0
Hydrocarbon-contaminated sites (on the total of identified sites)	60

The Regional Remediation Plan was published with Decision of the Regional Council no. 129 of 27 May 2013 (Official Regional Gazette no. 30 of 5 June 2013), pursuant to Legislative Decree no. 152/2006. This was first updated following Decision of the Regional Council no. 831 of 28 December 2017 (Official Regional Gazette no. 1 of 2 January 2018), which resulted in the publication of the current Plan (Decision of the Regional Council no. 35 of 29 January 2019 - Official Regional Gazette no. 15 of 22 March 2019).

Many of the contaminated and potentially contaminated sites listed in the Regional Remediation Plan are Sites of National Interest (SNI's), identified through the criteria set out by Article 252 of Legislative Decree no. 152/2006.

Following the entry into force of Ministerial Decree of 11 January 2013 the Domitio Flegreo littoral area and Agro Aversano, the Sarno river basin, the Vesuviano littoral and plain were removed from the list of SNI's, thus only Napoli Orientale and Bagnoli Coroglio are currently classified as SNI's.

Over the years the Regional Agency for Environmental Protection (ARPAC) has developed a number of central and peripheral specialized facilities that enable it to perform its institutional tasks of technical and analytical control of contaminated sites.

The regional register produced by ARPA [53] comprises **60 sites polluted from hydrocarbons**, 28 of which are in the Province of Naples (46.7%), followed by Salerno (20%), Caserta (13.3%), Benevento and Avellino (both 10%).

Molise

Total registered sites	525
Potentially contaminated sites	N.A.
Contaminated sites	N.A.
Uncontaminated sites	N.A.
Remediated sites	N.A.
Hydrocarbon-contaminated sites (on the total of identified sites)	N.A.

Data concerning the Molise Region are included in the yearbook published by the Regional Agency for Environmental Protection ARPA Molise and updated to 2017.

The document provides data on the number of listed sites by municipality, while there is no information as to the state of contamination and remediation or the pollutant type.

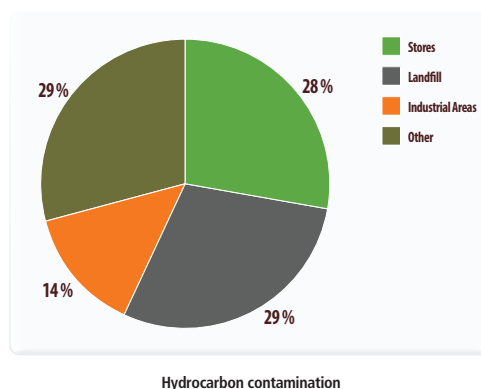
525 sites are listed in the register, 385 of which are to be found in the Province of Campobasso and 140 in the Province of Isernia.

Puglia

Total registered sites	498
Potentially contaminated sites	N.A.
Contaminated sites	N.A.
Uncontaminated sites	N.A.
Remediated sites	N.A.
Hydrocarbon-contaminated sites (on the total of identified sites)	140

The most recent data on the state of contamination and remediation of polluted sites in Puglia refer to a survey carried out by ARPA Puglia in 2010.

The **registered sites** are **498**, 14% of which are industrial areas (70), 29.1% are landfills (145) and the rest cannot be referred to any specific source of contamination.



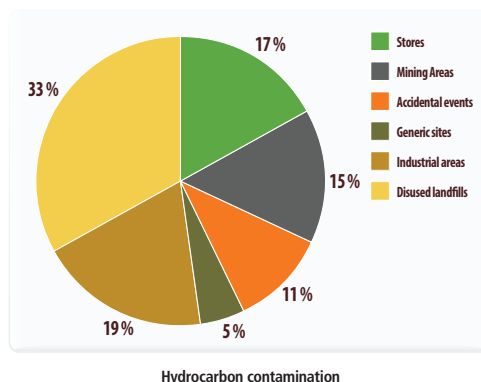
Sardinia

Total registered sites	1,282
Potentially contaminated sites	N.A.
Contaminated sites	N.A.
Uncontaminated sites	N.A.
Remediated sites	N.A.
Hydrocarbon-contaminated sites (on the total of identified sites)	219

Hydrocarbon-contaminated sites (on the total of identified sites): 219
 The Sardinia Region register was last revised in 2003 and is currently being updated [54], [55].

1,282 polluted sites were identified through the search engine available on the "SIRA Sardegna" website and a geo-referenced analysis allows to identify 14% of sites in the Province of Cagliari (180), 10% in Nuoro (135), 10% in Oristano (141) and 17% in Sassari (218) [56]

The register does not provide information on the causes of contamination, however 219 sites are listed as fuel points of sale, equal to 17.1% of the total, where we can assume to find hydrocarbons. The remaining sites in the register comprise 424 dismissed landfills, 240 industrial areas, 198 mining sites, and 142 contaminated areas from accidental events, while 59 are unclassified sites.[56]



Sicily

Total registered sites	529*
Potentially contaminated sites	275
Contaminated sites	114
Uncontaminated sites	N.A.
Remediated sites	82
Hydrocarbon-contaminated sites (on the total of identified sites)	80

* 461 (2016 data) and 68 (2015 data)

34

The Sicily Region in collaboration with ARPA has identified **461 contaminated sites** in 2016, to which the 68 sites found to be polluted in the Province of Palermo in 2015 must be added.

The **potentially contaminated sites** are **275**, which can be grouped as confirmed ones (110), undergoing characterization (89), and undergoing preliminary investigation (57) or risk analysis (19).

114 contaminated sites are involved in a permanent remediation or securing project, while 82 have completed remediation.

17% of total sites (**80**) are contaminated from **hydrocarbons**, the state of remediation thereof being unavailable. That of fuel points of sale is generally a very critical issue, because although each contamination is generally limited, they are extremely widespread in the Region and often located in residential areas.

Conclusions

The study involved **20 regional registers** and analysed the state of remediation of the Sites of National Interest, in order to highlight the **impact of contamination from hydrocarbons** and the state of reclamation of polluted areas. **Over 20,000 Sites of Regional Interest** have been listed, **9,487 of which need remediation procedures** or further assessment, this group including **2,119 hydrocarbon-contaminated sites (petroleum and its derivatives)**, equal to 22% of all contaminated sites in Italy.

The remaining 10,560 areas included in the register are generally classified as undergoing remediation, uncontaminated after assessment and potentially contaminated thus needing further investigation.

Contamination from **hydrocarbons** has been confirmed in 23 **Sites of National Interest**, **53.7%** of the total, and is a severe environmental emergency in Gela, Fidenza, Mantua lakes and Val Basento.

The study is based on data provided by the Regions through their registers, ARPA/APPAs and Ministry for the Environment. These are often non-homogeneous, out of date and unreliable, thus affecting the estimate of sites contaminated from hydrocarbons on the national territory, with various potentially polluted sites still lacking characterization and others where hydrocarbons have been detected but not yet specified (as in many industrial sites).

The creation of the Italian National Network for the Protection of the Environment (SNPA) is the first step towards an integrated system of the state of contamination in Italy. This study is meant as a contribution to this process, with the purpose of enhancing the bioremediation methods and tools tested by the European Project LIFE BIOREST at the Fidenza SNI.

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