CHEMICAL ENGINEERING TRANSACTIONS
VOL. 115, 2025
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it
Guest Editors: Carlo Pirola, Antonio Espuña, Sabrina Copelli

ISBN 979-12-81206-16-8; **ISSN** 2283-9216
DOI: 10.3303/CET25115009

A Reference Model to Assess the Underground Environment in National IED Plants

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Industrial pollution has been accounted to produce several impacts on the environment, thus stimulating a complex environmental governance all over the world. At a European level, the directive 2010/75/EU (so called IED Directive) promoted the adoption of the Best Available Techniques (BAT) to address and reduce environmental impacts related to industrial plants. The focus of this paper is to show the model elaborated by Italian Institute for Environmental Protection and Research (ISPRA) to assess some “baseline reports”, with reference to soil and groundwaters monitoring. More in detail, the study starts from the analysis of technical documents sent by Italian operators to the national competent authority (MASE) for the implementation of the IED Directive. The proposed model was developed starting from the data investigation related to 15 installations, in compliance with national and European guidelines on the theme. Further research perspectives could rise from using such a model to identify critical and open points in the field.

1. Introduction

In scientific literature, producing electricity, treating and managing chemicals to yield new substances (e.g. refineries, chemical plants etc.) as well as intensive farming are reported as common examples of those human activities emitting great amounts of contaminants in the air, water and, in general, in the natural environment (Hou et al., 2022).
While all over the world different approaches to industrial pollution have been promoted, in the European Union a unique legislative framework has been established since 1996. However, the complete maturity of such a framework has been reached with the Directive 2010/75/EU (so called Industrial Emission Directive - IED), aimed at making the processes more efficient and reducing the use of resources, preventing the emission of pollutants in the air, water and land. Moreover, other purposes concern establishing efficient waste management among industrial plants and promoting an integrated and harmonized approach to tackle industrial pollution across the EU countries, through the Best Available Techniques (BAT).
In such a context, while several BATs and European laws have been published to tackle air and surface water pollution (Daddi et al., 2013), a few references have been named to address soil protection (Heuser, 2022). Currently, the soil protection governance is split in policies, strategies, communications etc.
However, even though this fragmented context, IED Directive has required since 2010 the production of a baseline report on soil and ground waters in all installations applying for a new integrated environmental permit (Panagiotakis et al.,2018). The baseline report has been introduced with the aim to provide a reference state of the soil and groundwater, in case of the installation’s decommissioning and the site restoration.
The focus of our study is to illustrate the model elaborated by ISPRA to assess such “baseline reports”, starting with the data available from the national competent authority for the Integrated Pollution Prevention and Control (IPPC) in Italy.
Accordingly, the article is organized as follows. In the next section a description of the reference materials and methods is reported. In section 3 the final checklist to assess IED baseline reports is outlined, while section 4 concludes the paper addressing further research works.

Paper Received: 02 October 2024; Revised: 15 November 2024; Accepted: 14 January 2025
Please cite this article as: Mauro F., Stracqualursi A., Zanellato M., Zampetti F., Borghesi R., 2025, A Reference Model to Assess the Underground Environment in National IED Plants, Chemical Engineering Transactions, 115, 49-54 DOI:10.3303/CET25115009

2. Materials and methods

As stated above, this study started from the selection of some relevant cases at a national level. We considered the technical documentation provided by operators, whose activities are required to be in compliance with an integrated environmental permit, released by the Italian Ministry of Environment and Energy Security (MASE). Data are available in Italian on MASE website (MASE, 2025).

2.1 The national dataset on the IED installations

More than 6300 installations have been authorized according to the framework of IED Directive. Among them, about 130 installations have applied for an integrated environmental permit in Italy at a national level. They are listed in the Annex XII to the Second Part of the Legislative Decree 152/2006 and include, for instance, refineries (IPPC code 1.2), large chemical plants (IPPC codes 4.1 and 4.2), large combustion installations (IPPC code 1.1), iron and steel production (IPPC codes 1.3, 2.1 and 2.2).
According to the mentioned Decree, the integrated environmental permit's procedure starts when the operator sends the information to the Competent Authority with a specific goal in mind (for example, changing some conditions included in the permit, updating the production cycle to reduce the environmental impacts etc.). All the data are organized according to a specific format, which requires information related to the context, the production cycle, the consumption of raw materials, the emissions in water, air and soil, as well as the waste production and disposal (Borghesi et al., 2024). Generally, operators are requested to send a non-technical report too, to promote public participation in the final decision. According to European provisions, environmental authorizations for construction and industrial activities are expected to be participated processes (Mauro et al., 2024), where the final decision results from the balance among all the interested parties.

2.2 The reference data

Among the installations subjected to IED framework at a national level, we selected a reference sample of 15 industrial sites. They were chosen due to the following reasons:

a) Availability of the baseline report for soil and groundwater quality on the Competent Authority's website.
b) Need to consider different production cycles and hazardous substances in the whole process of assessment.
c) Need to consider complex and hazardous production cycles, as performed in such installations.

In figure 1 and table 1 the features of the reference sample are well defined.

Table 1: Information on the 15 industrial sites with specifics of the installation and relative procedure in which the baseline report is submitted. The Installation ID is assigned by authors, while the Procedure code is given by MASE. The abbreviations in Installation type column stand for: Thermo-Electric Power Plant (TEP) and Chemical Plant (CHE).

Installation ID	Region	Installation Type	IPPC code	Procedure code
01	Piedmont	CHE	4.1(h)	12831
02	Piedmont	CHE	4.2	12398
03	Lombardy	TEP	1.1	12413
04	Friuli Venezia Giulia	TEP	1.1	12288
05	Lombardy	TEP	1.1	12550
06	Lombardy	CHE	4.1; 4.1(h); 5.1	14767
07	Emilia-Romagna	CHE	4.1(i)	12375
08	Emilia-Romagna	CHE	1.1; 4.2; 4.3	1035
09	Emilia-Romagna	CHE	4.2(b); 4.3	12385
10	Emilia-Romagna	CHE	4.1(b)	1172
11	Tuscany	CHE	4.1(b); 4.1(f); 4.2(a); 4.2(b); 4.2(c); 4.2(d)	12838
12	Tuscany	CHE	1.1; 4.2(b)	12419
13	Apulia	TEP	1.1	12411
14	Sicily	TEP	1.1	12388
15	Sicily	CHE	4.1(a); 4.1(b)	12387

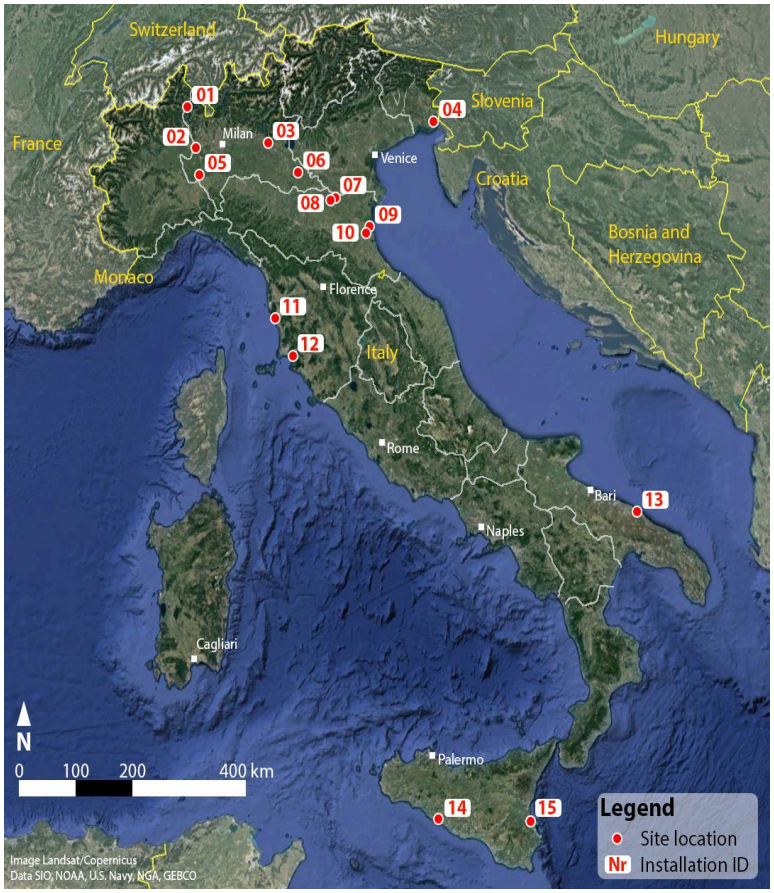

Figure 1: Geographical location of the 15 industrial sites considered. Elaboration of the authors.

The installations are mainly located in northern Italy, in line with the high concentration of industrial activities. Among the 15 industrial sites, 4 are in the region Emilia Romagna, 3 in Lombardy, 2 in Piedmont, 2 in Tuscany, 2 in Sicily, 1 in Friuli-Venezia Giulia, and 1 in Puglia.
Two types of installations are detected: TEP (n.5 installations) and CHE (n.10 installations), identified with the IPPC codes 1.1 and 4.1, 4.2, 4.3, respectively. In ID 06, the IPPC code 5.1 refers to the secondary activity of disposal or recovery of hazardous waste.
Information was derived from technical documents written in Italian, provided by operators without following a standard.

2.3 The research approach

As stated in the introduction, a few references have been released at a European level to address soil protection and monitoring in industrial sites. Among them, we could cite the European guidelines on baseline reports for IED installations (2014/C 136/03), the Joint Research Centre's Report on environmental monitoring (JRC, ROM-2018), the Ministerial Decree 95/2019 and the SNPA Guidelines n.48/2023, as relevant for the topic.
Hence, considering the previous references and the free structure of initial data (par.2.2), the research approach consisted in the implementation of the following phases:

1. Selection of the case studies from the national IED dataset;
2. Analysis of the baseline reports submitted by the operators in compliance with the IED provisions;
3. Clustering the information from texts into two areas:
   a. Data related to the installation and its production cycle;
   b. data aimed at describing the reference state of soil and groundwaters;
4. Identification of evaluation criteria, to assess the overall quality of the baseline reports;
5. elaboration of a reference checklist.

Figure 2 illustrates the overall research approach.

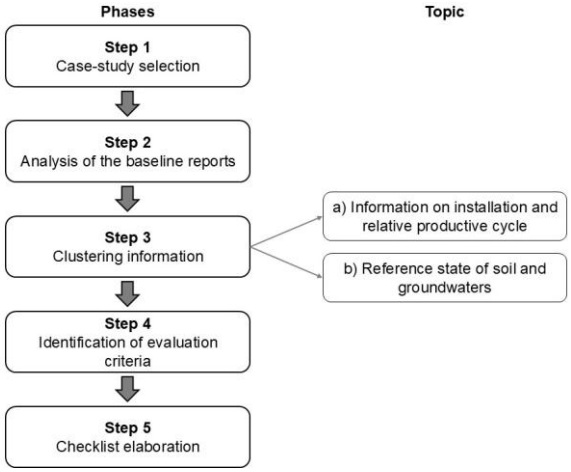

Figure 2: Research methodology flowchart.

3. Assessing the "baseline reports": a reference checklist

After grouping the initial text information, we stated two groups of criteria: group A, named "industrial cycle and related hazardous substances" and group B called "the underground environment".
For each group of criteria, a set of minimum requirements has been individuated (7 in group A, 9 in group B). All criteria were rated through closed-ended questions (yes/no).
Criteria in group A are aimed at describing the installation, in terms of production cycle, hazardous pertinent substances, accident and maintenance history.
Criteria in group B are intended to assess the underground environment from both a qualitative and quantitative point of view. For example, we focused the attention on present and past land uses, investigation of soil and groundwater quality, geological and hydrogeological context, as well as past remediation activities carried out on site.
In Table 2 a synthetic overview of the proposed model is provided.

Table 2: The reference checklist to assess the IED baseline reports.

Group of criteria	n.	Criteria	Result
A	1	All the hazardous substances, which are produced/used or storage on site, are identified in terms of quantity, chemical and physical properties	Yes ☐ No ☐
A	2	For each of the following groups, the operator evaluated the total amount (kg/year) of substances and compared the related value with thresholds. More in detail, the operator assessed that the quantity of each substance and/or group of substances overcomes/do not overcome the related threshold. The classification includes[1]: 1. Carcinogenic substances or mutagenic (confirmed or suspected) – threshold equal to 10 (kg/year); 2. Lethal substances, substances dangerous for fertility or for fetus, toxic substances for the environment - threshold equal to 100 (kg/year); 3. toxic substances for the human-kind - threshold equal to 1000 (kg/year); 4. substances dangerous for the human-kind and the environment - threshold equal to 10 000 (kg/year).	Yes ☐ No ☐
A	3	Information about intermediate products is provided by the operator	Yes ☐ No ☐

Group of criteria	n.	Criteria	Result
A	4	For all the substances' groups some reference chemical parameters are identified by the operator to assess the quality of soil and groundwaters.	Yes ☐ No ☐
A	5	Information about places and strategies to storage hazardous substances are provided by the operator, with reference to each substance.	Yes ☐ No ☐
A	6	Information about past industrial accidents (e.g. substances' leakages and faults) is provided by the operator. Lessons learnt are discussed by the operator.	Yes ☐ No ☐
A	7	Information about the ordinary/extraordinary industrial maintenance is provided by the operator.	Yes ☐ No ☐
B	8	The operator describes the past land uses of the site	Yes ☐ No ☐
B	9	The operator describes the present land use (industrial, service, commercial etc.) and the main objectives of the industrial process	Yes ☐ No ☐
B	10	The geological context is correctly described (also through geological map at local scale, stratigraphic logs, grain-size curve, permeability data)	Yes ☐ No ☐
B	11	The hydrogeological context is correctly described, providing information on depth-to-water, flow direction, hydraulic gradient of the aquifer(s) underlying the site	Yes ☐ No ☐
B	12	The operator individuates the "areas of potential concern", which are areas of the site where a potential for soil and groundwater contamination can be inferred based on the installation layout. They are identified through an alphanumeric code and geo-localized in a map.	Yes ☐ No ☐
B	13	The operator includes information about: • The location, number and depth of soil samples; • The sampling pattern and the analytical method; • The analytical parameters investigated to assess the contamination of soil by hazardous pertinent substances • Which parameters exceed the legal thresholds for soil The operator specifies whether the information is related to the last two years.	Yes ☐ No ☐
B	14	The operator includes information about: • The location, number and depth of groundwater samples; • The sampling and analytical methods; • The analytical parameters investigated to assess the contamination of groundwater from hazardous pertinent substances • Which parameters exceed the legal thresholds for groundwater The operator specifies whether the information is related to the last two years	Yes ☐ No ☐
B	15	The operator provides data about potential remediation activities carried out/to be carried out in the site (e.g. risk analysis, remediation of soil/groundwaters etc.)	Yes ☐ No ☐
B	16	The operator provides information about the past documents delivered to assess the quality of soil and groundwater.	Yes ☐ No ☐

[1] The classification and the thresholds reported in this checklist are derived from the Italian Ministerial Decree n.95/2019 (MASE, 2019).

To sum up, in compliance with the IED Directive provisions and the contents of D.M. 95/2019, we created a systematic assessment checklist to support (a) The Competent Authorities in the administrative procedure, aimed at the validation of documents provided by the operators; (b) The operators themselves, to identify potential omissions and self-assess the overall quality of their elaborations; (c) Research entities, to cluster potential gaps and identify solutions to improve the overall approach to the topic.

3.1 Advantages and limitations of the study

We believe that our model can efficiently address the requirement of technical homogeneity in assessing baseline reports. Moreover, it can promote further studies to identify potential gaps in this field, if applied to many installations. More research results (e.g. critical points in soil/groundwaters monitoring) are likely to rise from the investigation of such data with artificial intelligence technology.
The main limits of the study concern the reference to the legislative framework of IED Directive. We created a model to address the lack of homogeneity in the assessment of baseline reports, which is a specific requirement in EU States. So, potential applications of our model to installations located all over the world should consider the differences in policies addressing the pollution prevention and control.
Moreover, the model was developed starting from a national sample of installations. Hence, applying it to other European installations could require further discussion, in case of differences among soil protection national policies.
Finally, the availability of data on such a topic limited our study. In fact, as reported by the European Commission in the Report n.793/2021 (European Commission, 2021), the implementation of the baseline reports assessment is still a matter of concern in several EU countries.

4. Conclusions

In the framework of IED Directive, we proposed a national reference model to evaluate baseline reports, delivered by operators of 15 installations selected from the national IED dataset. The model resulted in a checklist to assess the overall quality of data submitted by the operators in response to European and Italian provisions, regarding the “baseline report” about soil and groundwaters conditions.
However, further research works could be appreciated to test our model on other European installations and to produce comparable and F.A.I.R. data to depict the state of soil and groundwaters in European industrial sites.

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