SYNTHESIS NOTE

Ecological Index of Concern (EIoC) Management tool for identifying soil qualified for ecological upgrade

January 2025

In response to the target of "zero net land take" set by the French government in its Biodiversity Plan, technical and research institutions, municipalities and consultancy firms are stepping up initiatives to identify industrial or urban brownfield that are suitable for ecological restoration, with the goal of incorporating more green spaces into our cities.

Some of these polluted and abandoned lands are home to evolving ecosystems of ecological interest (due to the presence of heritage species, for example). This raises the question of whether to leave the pollution in place to preserve the ecosystems there or to undertake decontamination operations, the implementation of which could lead to the sacrifice of these ecosystems. Since pollutant concentration levels that are higher than background and other management values do not necessarily play a part in any impact on an ecosystem, it is possible to upgrade this category of brownfield to one which has a potential for ecological use - providing that an absence of risk can be demonstrated. The ecosystem risk assessment (ERA) process as described, for example, in the Ineris document referenced in the footnote[1], can be used to help make such decisions. However, the ERA methodologies prescribed are rarely implemented because they are often regarded as technically and financially too costly.

An "Ecological Index of Concern" (EIoC) has therefore been developed to characterize polluted soil in terms of the risk it poses to ecosystems. It is based on the principles of the TRIAD method (NF ISO 19240) and, in particular, on the combination of the three-pronged (ecological, chemical and eco-toxicological) approach. The EIoC defines three categories of polluted sites: those whose state raises "no concern", meaning that the site might be readily upgraded to a site for ecological use, those whose state raises "medium concern", meaning that the site can be reclassified as either of the other two states once the bioavailable character of the pollution has been established and those whose state raises "concern" and require more extensive investigation, such as an ERA.

The Ecological of Concern Index (EIoC) is a tool designed to guide the management or remediation methods of polluted sites. In case studies developed as part of Ademe's Tipomo project, the EIoC demonstrated its workability and utility for brownfields with higher pollutant levels that the background values but where the soil had potential environmental benefit for ecosystems already present (carbon storage, recreational zones, reducing heat islands and flooding, etc.).

Context and issues at stake: urban and peri-urban soil contamination

A large number of environmental, social and economic debates are focusing on the future of urban or peri-urban brownfields and all the more keenly given the goals to reduce urban sprawl and requalify abandoned sites. Such lands play an essential role for achieving the "zero net land take" target set out in France's Biodiversity Plan. Some of these spaces do indeed lend themselves to a change of land use, to one of ecological restoration (see box below). When degraded lands are offered a new lease of life, the rewards are many: people gain a pleasant environment, a heat sink is created for a local community and a source of biodiversity within an urban enclave can be maintained.

When requalification projects concern contaminated lands with identified health or ecological issues, the national methodology for managing polluted sites and soils is to prescribe a health and environmental risk assessment. The "risk" approach enables the ecological quality of the environment to be examined. An ERA (ecosystem risk assessment) (InerisS, 2022) is based, for example, on the calculation of a risk characterisation ratio that is essentially equivalent to the risk quotient used to estimate the health risk. It corresponds to the ratio between the exposure concentration (predicted from measured or modelled concentration levels) (the PEC) and the predicted no-effect concentration (PNEC). The ERA can also be conducted by applying the standardised TRIAD[2] approach which uses the tools from various fields of risk assessment science to reduce the uncertainties of the assessment and to obtain the most relevant result possible. However, such studies are long and expensive and are only carried out on a limited number of contaminated wastelands. Even when they are used, uncertainties may remain about the need to remediate the brownfield if the process results in the destruction of an evolving ecosystem on the site.

Restoring contaminated lands to their natural state

The "Climate and resilience" act is the driving force behind Article L.556-1 A which was added to the Environment Code in 2021 to simplify rehabilitation operations of polluted sites and soils. The Code defines "use" as "the function or activity or activities being carried out or contemplated on a defined piece or pieces of land, the soil covering that land or the buildings and facilities on it." It defines rehabilitation, such as of contaminated lands, as "measures that ensure that the quality of the soil safeguards, on the one hand, the interests stipulated in Article L. 511-1 of the Environment Code and, if relevant, those stipulated in Article 211 and, on the other hand, measures that are appropriate for the intended use of the land." Decree No. 2022-1588 of 19 December 2022 lists and defines the eight different types of land use in the management of polluted sites and soils. The decree came into effect on the first of January 2023. Ecological restoration implies the operations to preserve or to restore or improve the functionality of the land, mainly by means of reversing soil sealing, in order to develop habitats for the ecosystems.

Goals

A new methodological approach to characterising the quality of the soils has been developed called the Ecological Index of Concern (EIoC). Its aim is to simplify the management and ultimately the upgrading of contaminated lands and, in particular, the management of abandoned sites where evolving ecosystems with an ecological value are present (e.g. where protected or heritage species are found).
The method can be employed prior to risk assessment procedures, in order to screen for situations where land contamination is liable to have an adverse effect on terrestrial ecosystems. The results of the Ecological Index of Concern should therefore enable us to identify contaminated lands with evolving ecosystems that qualify for simplified upgrading to ecologically restored land (as part of a green belt or a biodiversity reserve, etc.) and those where such an upgrade might be possible but which require the go-ahead provided by an ERA, using the methods described above.

The Tipomo project

The Ecological Index of Concern (EIoC) was developed as part of an ADEME study, the "Étude du Transfert, Indice de Préoccupation : Outil pour la valorisation des friches MOyennement contaminées" (report in French) ("Study of Translocation, Ecological Index of Concern: Tool for upgrading moderately contaminated lands"), otherwise known as the "Tipomo project". The project partners — the French national institute for industrial environment and risks (Ineris), the Saint-Étienne engineering school (École des mines) and the EODD engineering consultancy — worked together to test the new management tool through its use on eight urban brownfields selected from the database of ADEME's "RESOLU" programme.

Details of the Tipomo project are presented in the research report (in French): "Étude TIPOMO[3], Étude des Transferts, Indices de Préoccupation : Outils pour la valorisation des friches urbaines MOyennement contaminées" ("TIPOMO study, Study of translocation, Ecological Index of Concern: Tool for upgrading moderately contaminated lands") available in Ademe's online library. The report contains, for example, the detailed method used to calculate the Index and the correlation between the interpretation of the Index and the results of a battery of bioassays carried out on soil organisms.

The Ecological Index of Concern

Context of use

The Ecological Index of Concern (EIoC) is a management tool that can be used before performing an ecosystem risk assessment. Its purpose is to classify contaminated land intended for ecological use based on the level of concern it presents for the health of terrestrial ecosystems.

The EIoC applies to urban or peri-urban industrial brownfields that are contaminated with 5 PTEs (potentially toxic elements), in this case, arsenic, cadmium, copper, lead and zinc, and with the PAHs listed in the US Environmental Protection Agency's list of priority PAHs. A prerequisite for carrying out an Ecological Index procedure is that the contaminated land in question must sustain an evolving ecosystem (significant ground cover and one or several soil functions[4]).

The Ecological Index of Concern (EIoC) provides managers with sufficient information to be able to promote a site from being a polluted land to one that supports a functional biodiversity, while dispensing with the need for an ERA whose cost/benefit ratio is not justified.

Method principles

The iterative method is based, firstly, on the total contaminant concentrations measured in the soil. To start with, the total PTE and PAH concentrations are combined to form an Index comparable to a calculation of toxic pressure: one Index for the PTEs ($EIoC_{metals}$) and one Index for the PAHs ($EIoC_{PAH}$). The indices are compared with a lower threshold value of 5 and an upper threshold value of 15 (Figure 1). If the indices $EIoC_{metals}$ and $EIoC_{PAH}$ are below the lower threshold value, the contaminated land is classified as being of "no concern" and can be requalified as land of ecological use without the need to carry out an ecosystem risk assessment. If either the $EIoC_{metals}$ or $EIoC_{PAH}$ indices is greater than the upper threshold value, the state of the contaminated land gives cause for concern and an ecosystem risk assessment must be done to see whether the level of pollution in situ would allow for ecological restoration to proceed (ecological continuity, green space, natural area, etc.). The data obtained by the Ecological Index of Concern calculation provides a good starting point from which to conduct the risk assessment. In other cases (where one or both indices are between the lower and the upper threshold value and neither are greater than the upper threshold value), a bioavailability characterisation of the substances can be performed to determine the quality of the brownfield more accurately.

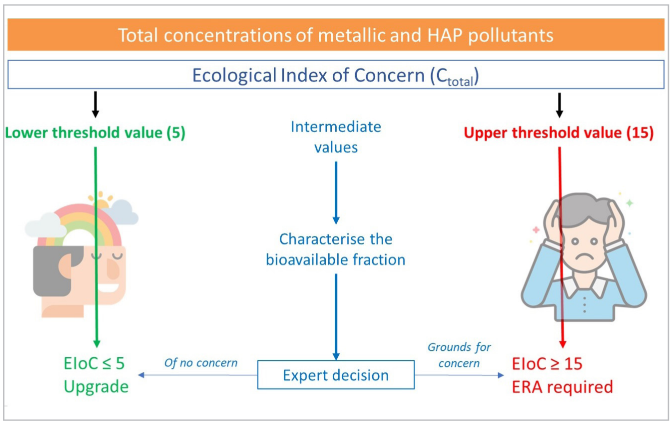

Figure 1 /
How the Index of Concern is used

The Ecological Index of Concern calculation is a management tool used to differentiate three types of contaminated lands that sustain an evolving ecosystem:

- Contaminated lands where the residual pollution poses no risk for the ecosystems (no cause for concern);
- Contaminated lands where the residual pollution might be a cause of concern for its ecosystems (moderate concern). A characterisation of the bioavailability of the pollutants is required to provide a more accurate assessment of the state of the land;
- Contaminated lands where residual pollution is worrying for the in-situ ecosystems (cause for concern). No impact has been demonstrated but an ecosystem risk assessment must be conducted.

Bioavailability in the context of ecosystem risk assessment

The French standard EN ISO 17 402 (2011) defines environmental availability as the «fraction of the contaminant potentially available to an organism as the result of the physical-chemical process of desorption». It is directly related to the environmental conditions[5] (soil properties, humidity, temperature, nature of the contaminants, etc.). It is this fraction, capable of being absorbed by organisms, that may cause adverse effects. Total concentration includes both the bioavailable fraction and the fraction fixed to the "soil" substrate that cannot be taken up by organisms.

Calculating the EIoC

First, the total PTE and PAH concentrations are aggregated in the form of two indices: one Index for the PTEs ($EIoC_{metals}$) and one for the PAHs ($EIoC_{PAH}$). The Ecological Indices are calculated by taking into account, on the one hand, the concentrations of the substances and, on the one hand, their toxicity in the form of the ecotoxicity potential (EcotoxPot) of each substance. The EcotoxPots are relative values based on the concentrations that have no effect on the environment (PNEC) of the substances. The equation proposed is derived from the METOX index calculation method: a management tool used by water agencies to measure aquatic pollution and to calculate any tax that certain polluters must pay the area water boards.

As with the METOX calculation method, the total concentration of the substance measured is multiplied by a factor indexed to its degree of toxicity, where it is the toxicity for terrestrial rather than aquatic organisms that is of interest in this case. It is then divided by 100 to express it on a more practical scale.

$$EIoC = \frac{Total\ concentration\ substance \times \mathrm{EcotoxPot}\ substance}{100}$$

The EcotoxPots established when this document was written are shown in appendices 1 and 2. The $EIoC_{metals}$ and the $EIoC_{PAH}$ are then differentiated by calculating them as follows:

$$\mathrm{EIoC_{metals}} = 5 \times \sum \frac{\mathrm{EIoC}\ _{substance\ metals}}{n_{MTE}}$$

(where n_{ETP} represents the number of metals considered).

$$\mathrm{EIoC}\ _{\mathrm{PAH}} = 5 \times \sum \frac{\mathrm{EIoC}_{substance\ \mathrm{PAH}}}{n_{PAH}}$$

(where n_{PAH} represents the number of PAHs considered).

Note : The factor of 5 used in the calculation is a scaling factor designed to adjust the range of result interpretation, shifting it from 1-3 to a range of 5-15. This modification makes the communication of results easier, particularly when they approach the threshold values, making their interpretation more intuitive and accessible.
Appendix 3 gives an example of an EIoC calculation.

Interpreting the Ecological Index of Concern

The calculated Ecological Indices of Concern are interpreted with reference to a lower and an upper threshold value (Figure 1). They allow the user to distinguish lands that are not concern and which can be upgraded to "suitable for ecological use" from those where the level of contamination is too great for immediate upgrading without more extensive analysis in the form of an ecosystem risk assessment.

- The lower threshold value (5)
  The EIoC value (PTEs and PAHs) below which a state of a land is considered no concern is 5. The value 5 is chosen because this is the value that would be obtained if the EIoC were applied to a land where an ecosystem risk assessment demonstrated acceptable total concentration levels. The limit enables us to readily identify lands that are of no concern for the environment.

- The upper threshold value (15)
  The EIoC value (PTEs and PAHs) above which a contaminated land is considered concern is 15. This is the value that would be obtained for a land whose total concentrations are too high for a decision to be made about its future without performing an ecosystem risk assessment. The limit enables us to distinguish vegetated lands where an ERA is required from those whose bioavailable concentration suggests they could be upgraded for more rapid ecological use.

The interpretation of the index according to the threshold values is shown in Figure 1. There are three conditions of industrial wasteland on which an evolving ecosystem exists:

- $EIoC_{metals}$ and $EIoC_{PAH} \leq 5$: (no concern) the brownfield causes no concern for the ecosystems. The site is suitable for ecological restoration or ecological upgrading;

- $5 \leq EIoC_{metals}$ and $EIoC_{PAH} \leq 15$: (moderate concern) the brownfield is likely to cause concern for the ecosystems there. The pollutant bioavailability must be measured to provide a more precise assessment of the state of the land;

- $EIoC_{metals}$ and $EIoC_{PAH} > 15$: (cause for concern) the state of the land gives cause for concern and an ecosystem risk assessment must be done to evaluate compatibility between soil pollution and the ecological use. The document referred to in the footnote provides guidance on assessing the chemical risk for ecosystems (in French)[6].

The results of a bioavailability measurement can advance the change in status of a wasteland "of medium concern" to that of "no concern". Neither the guidance document nor the Tipomo[7] project report, which describes how the index is constructed, determines the tools to be used for measuring the bioavailability of pollutants in the soil. However, the Tipomo project report offers a number of potential approaches; four of the techniques, from chemical extraction (CaCl2-extractable trace elements and non-exhaustive extraction techniques - Tenax extraction) to measuring the fraction accumulated in the tissues of exposed organisms (TML index[8] - plants and measuring bioaccumulation in earthworms) have already been used, as well as observing the effects of the bioavailable fraction on living models (battery of laboratory bioassays). The cases studies in the report also provide examples of interpretations of anticipated results for "medium concern" brownfields. Appendix 4 provides a non-exhaustive list of standardised bioavailability measurement.

Possible developments

The Ecological Index of Concern calculation is relatively easy to apply and is based on the scientific principles used in the field of ERA. The two-step procedure can be used to differentiate lands with pollution levels that cause concern (EIoC greater than 15) from those that cause no concern (EIoC less than 5). A third group, lands with EIoC values causing medium concern, can be classified using the criterion of contaminant bioavailability. Nonetheless, certain areas for improvement have already been identified.

Firstly, it is essential to refer Ecological Index of Concern "medium concern" values for expert opinion and when bioavailability data have been generated. The method has not yet been sufficiently tested to propose threshold values for bioavailable concentrations. An ERA expert's report has been requested in order to select the tools most suited to the context and to interpret their results. For now, this is viewed as possibly hampering the efficiency of the method.

Another improvement would be to increase the number of substances covered (only 5 PTEs and 16 PAHs are currently considered). A first step might be to identify the groups of substances that are most relevant to the specific context of contaminated soils where there is a local evolving ecosystem, or to construct a method to adapt the Ecological Index of Concern to other pollution contexts.

Appendices

Appendix 1: Ecotoxic potential of metallic pollutants

Substance	Ecotoxicological potential
Arsenic	10
Cadmium	150
Copper	2
Lead	1
Zinc	1

Table 1 /
Ecotoxicological potential of the metallic pollutants considered

Appendix 2: Ecotoxic potential of PAHs

Substance	Ecotoxicological potential
Acenaphthene	200
Acenaphthylene	1000
Anthracene	500
Benzo[a]anthracene	900
Benzo[a]pyrene	1000
Benzo[b]fluoranthene	200
Benzo[k]fluoranthene	200
Benzo[ghi]perylene	300
Chrysene	100
Dibenzo[ah]anthracene	900
Fluoranthene	30
Fluorene	100
Indeno[1,2,3-cd]pyrene	400
Naphthalene	200
Phenanthrene	50
Pyrene	100

Table 2 /
Ecotoxicological potential of the PAHs considered

Appendix 3: Calculating and interpretating the Index of Concern

The following table shows an example of the total concentrations that can be measured in a contaminated land with significant ground cover and the Ecological Index that can be calculated.

Substance	PTE or PAH	Total concentration in mg/kg (DW)	Index of Concern
Arsenic	PTE	130	13,00
Cadmium	PTE	1,4	2,10
Copper	PTE	130	2,60
Lead	PTE	230	2,30
Zinc	PTE	620	6,20
Index of Concern — PTEs			**26,20**
Acenaphthene	PAH	0,05	0,10
Acenaphthylene	PAH	0,05	0,50
Anthracene	PAH	0,05	0,25
Benzo[a]anthracene	PAH	0,05	0,48
Benzo[a]pyrene	PAH	0,05	0,50
Benzo[b]fluoranthene	PAH	0,06	0,12
Benzo[k]fluoranthene	PAH	0,05	0,10
Benzo[ghi]perylene	PAH	0,05	0,15
Chrysene	PAH	0,06	0,06
Dibenzo[ah]anthracene	PAH	0,05	0,45
Fluoranthene	PAH	0,08	0,02
Fluorene	PAH	0,05	0,05
Indeno[1,2,3-cd]pyrene	PAH	0,05	0,20
Naphthalene	PAH	0,05	0,10
Phenanthrene	PAH	0,06	0,03
Pyrene	PAH	0,07	0,07
Index of Concern — PAHs			**0,99**

Table 3 /
Demonstration of the Ecological Index calculation

The Ecological Index for the five metals is 26.2, a value substantially higher than the upper threshold value (15). The soil on this wasteland has a worrying level of metal contamination. On the basis of this Ecological index, the evaluator will not therefore recommend it for simplified upgrading, such as for ecological restoration. A classic ecosystem risk assessment is required to address the situation appropriately. At 0.99, the index of concern for PAHs is well below the lower threshold value of 5. Based on the PAH criterion alone, it would have been possible to recommend the brownfield towards a use that ensures the land's biodiversity can be adequately managed. The interpretation of both scores shows us that the level of pollution on the wasteland in question is worrying and that it is not possible to pronounce on the risk the land represents for ecosystems without an ecosystem risk assessment. The tool also highlights the fact that if pollution management solutions are to be implemented, particular attention should be paid to the contamination by arsenic and zinc, as these were the highest contributors to the Ecological Index score.

Appendix 4: Tools for characterising the bioavailable fraction of pollution in the soil

Tool category	Tool type or name	Standard
Extraction by solvents (PTEs and organometallics)	Extraction of trace elements (DTPA)	NF ISO 14870
	Extraction of trace elements (EDTA)	NF X31-120
	Extraction of trace elements (HNO3)	NF ISO 17586
	Extraction of trace elements (CaCl2)	NEN 5704 (Dutch standard)
	Extraction of trace elements (NaNO3)	VSBo (Swiss standard)
	Extraction of trace elements (NH4NO3)	NF ISO 19730
Extraction by adsorbent agent (organic pollutants)	**Non-exhaustive extraction techniques (Tenax extraction)**	XP ISO/TS 16751
	Non-exhaustive extraction techniques (cyclodextrin)	XP ISO/TS 16751
Leaching	Liquid/solid leaching ratio 2L/kg	NF EN ISO 21268-1
	Liquid/solid leaching ratio 10L/kg	NF EN ISO 21268-2
	Leaching by percolation	NF EN ISO 21268-3
Passive samplers	DMT (Donnan Membrane Technique)	-
	DGT (Diffusive Gradient in Thin film)	-
	SPMD (Semi Permeable Membrane Device)	-
Bioindicators of accumulation	SET Index - Snails (Sum of Excess Transfers)	ISO/DIS 24032
	TML Index - plants (Total Metal Load)	-
	Bioaccumulation in earthworms	Test No. 317 OECD Guideline 207

The techniques in bold were used in the Tipomo[9] project.

[1] Ineris (2022). Document d'orientation pour l'évaluation du risque chimique pour les écosystèmes - Impact local des activités humaines sur les milieux naturels et la biodiversité (document in French) ("Guidance document on the assessment of chemical risk for ecosystems - Local impact of human activity on natural habitats and biodiversity").

[2] Standard NF ISO 19 204: Procedure for assessing specific ecological risks at the contamination site (Triad approach).

[3] Nicolas PUCHEUX (Ineris), Nicolas MANIER (Ineris), Olivier FAURE (Ecole des Mines de Saint-Etienne, research unit UMR 5600 EVS) - 2021 – "Identification de friches polluées éligibles à une reconversion écologique - étude TIPOMO, Étude des Transferts, Indices de Préoccupation : Outils pour la valorisation des friches urbaines MOyennement contaminées" ("Identification of polluted wastelands that qualify for ecological upgrade - TIPOMO study, Study of Translocation, Indices of Concern: Tools for upgrading moderately contaminated urban wastelands") 103p.

[4] Ecological functions of soil: Phenomena specific to the ecosystem arising from the combination of the state of the ecosystems and of the ecological structures and processes, and that occur with or without the presence of humans. Essentially, this includes the basic functions and the maintenance of the ecosystems' ability to function (nutrient cycling, soil formation, primary production, etc.).

[5] Bioavailability and Bioaccessibility of Pollutants in Contaminated Soils: State of Present Knowledge and Research Avenues, RECORD, 2012, 259 pages.

[6] Ineris (2022). Document d'orientation pour l'évaluation du risque chimique pour les écosystèmes - Impact local des activités humaines sur les milieux naturels et la biodiversité (document in French) ("Guidance document on the assessment of chemical risk for ecosystems - Local impact of human activity on natural habitats and biodiversity.

[7] Nicolas PUCHEUX (Ineris), Nicolas MANIER (Ineris), Olivier FAURE (École des Mines de Saint-Etienne, research unit UMR 5600 EVS) - 2021 – "Identification de friches polluées éligibles à une reconversion écologique - étude TIPOMO, Étude des Transferts, Indices de Préoccupation: Outils pour la valorisation des friches urbaines MOyennement contaminées" (in French only) ("Identification of polluted wastelands that qualify for ecological upgrade - TIPOMO study, Study of Translocation, Indices of Concern: Tools for upgrading moderately contaminated urban wastelands"). 103p.

[8] The CMT index is a bio-indicator of accumulation in plants that characterizes soil-to-plant transfers into three categories: «no abnormal transfer,» «low to moderate transfer,» and «high transfer.»

[9] Nicolas PUCHEUX (Ineris), Nicolas MANIER (Ineris), Olivier FAURE (École des Mines de Saint-Etienne, research unit UMR 5600 EVS) - 2021 – "Identification de friches polluées éligibles à une reconversion écologique - étude TIPOMO, Étude des Transferts, Indices de Préoccupation : Outils pour la valorisation des friches urbaines MOyennement contaminées" (Report in French): ("Identification of polluted wastelands that qualify for ecological upgrade - TIPOMO study, Study of Translocation, Indices of Concern: Tools for upgrading moderately contaminated urban wastelands") . 103p.

Institut national de l'environnement industriel et des risques
Parc technologique Alata • BP 2 • F-60550 Verneuil-en-Halatte
03 44 55 66 77 • ineris@ineris.fr • www.ineris.fr

Réf. : Ineris-206988-2749425-v1.0