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DIRECTORATE GENERAL FOR
ENVIRONMENTAL QUALITY AND ASSESSMENT

GUIDANCE DOCUMENT
FOR THE DEVELOPMENT OF
ENVIRONMENTAL RISK ANALYSES

TECHNICAL COMMISSION FOR THE PREVENTION AND REMEDIATION
OF ENVIRONMENTAL DAMAGES

CONTENTS

This document is a summary in English of the original version of the document published on the section on Environmental Liability of the website of the Ministry for the Ecological Transition and the Demographic Challenge

1. INTRODUCTION

1.1. Legal framework

Article 24 of Law 26/2007, of 23 October, on Environmental Liability establishes that certain operators of the activities included in its Annex III must provide a financial security which allows them to cover the inherent environmental liability of the activity or activities which they intend to carry out. This provision is established notwithstanding the exemptions foreseen in Article 28, including the flexibility mechanism whereby the limit for the value of the damage from which the financial security is mandatory is set at €300,000, or €2,000,000 for operators who are permanent and continuous participants in the EMAS Community eco-management and audit scheme and/or the UNE-EN ISO 14001 environmental management system in force.

Chapter 3 of the Regulation of partial development of the law, approved by Royal Decree 2090/2008, of 22 December, implements the essential provisions on the mandatory financial security. These provisions cover both the procedure for determining the amount of the financial security and its form –bank guarantee, technical reserve or insurance policy– and the identification of the categories of occupational activities which are either exempt from providing or required to provide the financial security and, therefore, which must carry out the environmental risk analysis foreseen in the law for its determination.

Law 11/2014, of 3 July, amending Law 26/2007, of 23 October, introduced a new Section d) in Article 28 of the law, which establishes the criteria for determining the activities which are exempt from providing the mandatory financial security, with the aim of limiting this obligation to the activities with the greatest environmental impact. Royal Decree 183/2015, of 13 March, amending the partially implementing Regulation, amended Article 37 of the Regulation for determining the activities exempt from the obligation to provide a financial security. As such, the occupational activities required to provide the financial security are those included in Section 2.a) of Article 37, which are also required to carry out environmental risk analyses, based on which the amount of the financial security is determined. The occupational activities **subject to the obligation to provide the financial security** are the following:

- Operators subject to the scope of application of Royal Decree 840/2015, of 21 September, approving measures to control risks inherent to serious accidents involving hazardous substances (SEVESO operators).
- Categories of industrial activities included in Annex I of the recast text of the law on integrated pollution prevention and control approved by Royal Legislative Decree 1/2016, of 16 December.
- Operators with mining waste facilities classified as category A in accordance with the provisions of Royal Decree 975/2009, of 12 June, on the management of waste from extractive industries and the protection and rehabilitation of spaces affected by mining activities.

In accordance with the above, the operators exempt from the obligation to provide the mandatory financial security and from carrying out environmental risk analyses are the following:

- The occupational activities of Annex III of Law 26/2007, of 23 October, which do not fall under any of the cases of Section 2.a) of Article 37 set out above and which establish the scope of operators subject to the mandatory financial security.
- The use of the plant health products and biocides referred to in points 8.c) and 9 of Annex III for agricultural and forestry purposes.

Finally, the following operators are required to carry out the environmental risk assessment, but are exempt from providing the financial security:

- Operators of activities likely to cause damage, remediation of which is valued at an amount of less than €300,000.
- Operators of activities likely to cause damage, remediation of which is valued at an amount between €300,000 and €2,000,000 and who demonstrate, through certificates issued by independent bodies, that they are permanent and continuous participants in the Community's Eco-Management and Audit Scheme (EMAS) or the UNE-EN ISO 14001environmental management system in force.

The environmental risk analysis required to determine the amount of the financial security is a standardised and efficient calculation method which allows the cover or economic value of the environmental risk associated with each of the economic and occupational activities to be defined. To facilitate the assessment of risk scenarios as well as to reduce the cost of carrying them out, the Regulation permits operators subject to the obligation to provide the financial security, and who belong to the same occupational activity, to create voluntary sector-specific instruments such as sectoral environmental risk analyses and rate tables. The sector-specific instruments, which must be carried out specifically for each case, can consist of Model Environmental Risk Report Templates –referred to as MIRAT (*Modelos de informe de riesgos ambientales tipo*) in Spanish– or methodological guides, when the heterogeneous nature of the activities included in a single sector so requires.

On the other hand, the Regulation also gives the option of creating rate tables which allow operators to determine the amount of the financial security without having to carry out an individual environmental risk assessment.

In all cases, a favourable report will be required from the Technical Commission on the Prevention and Remediation of Environmental Damage so that these instruments can be used by operators from the sectors which created them, and it will be down to the Ministry for the Ecological Transition and the Demographic Challenge to publicise the instruments with favourable reports on its website.

The date from which the provision of the mandatory financial security is required for each of the occupational activities of Annex III subject to this obligation was to be established by ministerial order in accordance with the provisions of the fourth final provision of Law 26/2007, of 23 October.

Order ARM/1783/2011, of 22 June, established the order of priority and the calendar for the approval of the ministerial orders based on which the provision of the financial security is required for all activities obliged to provide the financial security and classified with a priority level between 1 and 3.

Subsequently, and in accordance with the new Article 37 of the Regulation of partial development of Law 26/2007, of 23 October, reducing the scope of activities subject to the obligation to provide a financial security, Order APM/1040/2017, of 23 October, amended the Annex of Order ARM/1783/2011, of 22 June, and established the date from which the provision of the financial security was required for the economic activities classified with priority levels 1 and 2.

As such, the activities classified with priority level 1 in Order ARM/1783/2011, of 22 June, must provide the mandatory financial security from 31 October 2018; and the activities classified with priority level 2 from 31 October 2019.

Finally, Order TEC/1023/2019, of 10 October, establishes the date from which the provision of the mandatory financial security will be required for activities classified as priority level 3. This

Order establishes that priority 3 activities must provide the financial security for environmental liability from 16 October 2021, except for intensive rearing of poultry or pigs, which must provide the financial security from 16 October 2022.

1.2. Objective

The General Directorate for Environmental Quality and Assessment of the Ministry for the Ecological Transition and the Demographic Challenge has had a support service in operation since 2010 for providing technical advice to occupational activities for preparing environmental risk analyses carried out within the context of environmental liability regulations. This service has the following specific objectives:

- Answering questions about specific methodological aspects for planning and carrying out sector-specific and individual environmental risk analyses.
- Technical guidance for applying the methodology for preparing environmental risk analyses, including quantifying and monetising the damage associated with the reference accident scenario.
- Answering questions on the use of the ARM-IDM-MORA computer program, available to the public via the Ministry for the Ecological Transition and the Demographic Challenge website[1]. This application integrates the three ARM, IDM, and MORA computer modules into a single tool in order to help the user prepare the event trees on which the risk analysis is based, calculating the Environmental Damage Index (IDM) and the economic valuation of the environmental damage associated with the specific reference scenario based on which the financial security is calculated.

This service has so far dealt with and resolved more than 600 technical queries relating to drafting environmental risk analyses and the procedure for estimating the amount of the financial security.

Following the analysis of the types of queries or technical concerns posed by operators and occupational sectors in the context of this support service, those aspects which demand further development in order to offer a common technical solution framework have been identified for all of the occupational activities subject to the obligation to provide a financial security. In this context, and to continue responding to the demand expressed by the occupational activities to help them to resolve the more complex technical aspects of the risk analyses, this guide has been prepared.

The guide brings together the more complex technical aspects of environmental risk analyses referred to by Articles 33 and 34 of the Regulation partially implementing Law 16/2007, of 23 October. Its objective is to offer a common framework to all operators subject to the obligation to provide a financial security for environmental liability, which facilitates technical decision-making and the resolution of the most common problems identified during the preparation of environmental risk analyses.

To this end, the guide is structured in two parts:

- A first part answering the most frequent questions identified in the context of the activity of the support service for occupational activities subject to the obligation to provide a financial security for environmental liability (Section 2).

[1] https://servicio.mapama.gob.es/mora/login.action

- A second part where the specific technical aspects involving greater complexity are identified and where the technical guidance in this regard demands that they be dealt with independently (Sections 3 and 4).

The technical aspects examined and for which specific work has been done refer to the consideration of biological agents and transgenic materials in environmental risk analyses, and the selection and practical use of dispersion criteria and models for quantifying environmental damage. These dispersion models are aimed at explaining the behaviour of damaging agents once released into the receiving environment.

It is important to remember that the competent authority establishes the type and scope of the corresponding control systems which allow it to confirm that the operator complies with the corresponding technical requirements, such as having to report in the liability declaration that they have carried out the environmental risk analysis and have provided, where applicable, the financial security in accordance with the provisions of Article 33 of the Regulation, and in accordance with the information included in its Annex IV.

Finally, it is essential to bear in mind that the guidance presented in this guide must be understood exclusively as recommendations, and that the analyst must at all times appropriately justify and document all technical decisions made when preparing environmental risk analyses.

2. *FREQUENTLY ASKED QUESTIONS ON ENVIRONMENTAL RISK ANALYSES*

This section sets out a range of questions on performing risk analyses which have been frequently posed to the General Directorate for Environmental Quality and Assessment by operators. These questions are related to the most complex technical aspects which arise during the preparation of environmental risk analyses, and which are deemed likely to be of interest to a large number of operators, given that they consist of cross-cutting aspects when carrying out these assessments.

2.1. Consultation on the scope of environmental risk analyses and the inclusion of subcontracted activities.

Environmental liability applies to operators of the economic or occupational activities performed by any natural or legal person as part of an economic activity, business or undertaking, whether private or public, profit or non-profit.

Article 2.10 of Law 26/2007, of 23 October, identifies an operator as any natural or legal, private or public person who operates an occupational or economic activity or who, in any capacity, controls the activity or has decisive economic power over the technical functioning of any such activity. In identifying the operator, account will be taken of the provisions in sectoral and regional legislation for each activity governing holders of permits or authorisations, as well as registrations with and notifications to government agencies.

In keeping with this, Law 26/2007 identifies, in the first instance, the holder of the corresponding permit, authorisation or registration as the operator. Nevertheless, in accordance with the aforementioned definition, those who perform, control or have decisive economic power over the technical functioning of a certain activity may also be considered operators. As a result, a single party could be considered an operator due to “controlling the activity or having decisive economic power over the technical functioning of any such activity” and, at the same time, be included in some other category of parties to which Law 26/2007, of 23 October, also attributes liabilities in addition to the operator, as is the case of a parent company (Article 10), or the jointly or subsidiarily liable parties to which Article 13 refers. As such, a *de facto* administrator, in principle, is subsidiarily liable and, in turn, could fit within the broad concept of operator due to “controlling the activity or having decisive economic power over the technical functioning of any such activity”, as set out in the definition of an operator in Law 26/2007, of 23 October.

Article 27 of Law 26/2007, of 23 October, establishes that subcontractors and professionals who collaborate with operators may be included as covered persons in the financial securities which must be provided by operators. As a result, it seems reasonable that the environmental risk analysis on which the calculation for determining the amount of the financial security is based must cover the activity performed by these subcontractors or collaborators when they can be held environmentally liable due to controlling the activity which is subcontracted, while also maintaining a functional and operational relationship with the main activity under study, or are covered by one of the situations of joint or subsidiary liability to which Law 26/2007, of 23 October, refers in its Article 13.

As a general rule, the recommendation is to take account of all of the hazards which may be related to the environmental risk inherent to the occupational activity under study, including in said spectrum all of the activities of the collaborators and subcontractors which may fall within the definition of an operator established by Law 26/2007, of 23 October, due to having operational control over the subcontracted activity, as well as persons to whom, where applicable, environmental liability may be attributed in line with the provisions of the aforementioned Article 13 of Law 26/2007, of 23 October.

2.2. Consultation on the option of using the probability calculation method from a Sector-specific Environmental Risk Analysis belonging to another sector.

The use of probability calculation methods of a MIRAT or Methodological Guide for a sector other than the one to which the operator belongs may be used if it consists of a method for quantitatively estimating probability. If failure rates are linked to specific types of components or industrial equipment referring to initiating events or determining factors of the event tree (and not to a specific profile of activity), the operator may use these data as a basis provided that it is duly justified that the component in the event tree of the sector-specific analysis has characteristics equivalent to those of the event tree under analysis.

Meanwhile, if it consists of a qualitative probability method which does not refer to its sector of activity, it is highly unlikely that the calculation method established by the sector-specific risk analysis can be adopted as is in the individual risk analysis because it does not comply with all of the elements and criteria which have been established specifically and with a greater level of subjectivity for calculating the probability in the context of another occupational sector.

2.3. Consultations on the preparation of consequence trees

2.3.1. Can accident scenarios which are similar be eliminated if there are many of them? Does the aggregation of scenarios affect the calculation of the financial security amount?

It is not possible to eliminate relevant scenarios from the environmental risk analysis despite them being similar in terms of the substance spilled and/or the resources affected. This is because, as indicated by Article 33.2 of the Regulation of partial development of Law 26/2007, to calculate the financial security, it is necessary to:

a) Identify the accident scenarios and establish the probability of occurrence of each scenario.
b) Establish the value of the environmental damage index associated with each accident scenario by following the steps established in Annex III [of the Regulation].
c) Calculate the risk associated with each accident scenario as the product of the probability of occurrence of the scenario and the environmental damage index.
d) Select the scenarios with the lowest environmental damage indices which comprise 95% of the total risk.
e) Establish the amount of the financial security as the value of the environmental damage of the scenario with the highest environmental damage index of the selected accident scenarios.

If some relevant scenarios are eliminated from the assessment, it may occur that the reference scenario used to calculate the amount of the financial security [Section e)] is different to the one which would be selected using all of the scenarios. Another issue would be that some scenarios were categorised as not relevant, either due to the improbability of occurrence or due to a null value of the IDM, and their risk was zero. As a result, these non-relevant scenarios would not count towards the identification of the reference scenario and in the determination of the financial security.

In any event, there are two situations in which it is considered feasible to limit the selection of relevant scenarios in an environmental risk assessment. Firstly, it is common and reasonable to assume that each and every one of the possible hazards is not considered in a facility from the outset when there are many of them. For example, low-toxicity substances in small-volume containers which are adequately managed, such as a bottle of bleach, can be disregarded. This decision allows for a reduction of the number of scenarios from one source. However, it would be debateable where the toxicity of the substance and/or the volume stored were greater.

Another situation would be where, among the selection of relevant scenarios, a group of scenarios exist which share the same IDM value but where each scenario is caused by a different hazard. In these cases, the scenarios which share the same IDM value can be integrated into a single scenario which maintains this IDM value and which shows the total probability of the scenarios which are grouped together. This solution does not affect the calculation of the financial security because this amount is independent of the probability value. In this way, if one of the scenarios comprising the total were selected as a reference scenario, the scenario which now aggregates the other one would be selected, the value of whose financial security remains the same (given that once the reference scenario is selected, this value is independent of the probability of the reference scenario). This is a situation which can occur where there are different groups of containers of the same type and capacity, where the probability of a spill occurring in one of them is proportional to the number of containers of each type.

Without prejudice to the above, the identification of relevant scenarios will depend on the decision to declare hazards relevant based on those which cause these scenarios, where the precautionary principle must prevail in the decision-making process.

2.3.2. When applying event trees, can a single accident scenario be identified in the risk analysis?

In exceptional cases and in the case of very simple facilities, where the natural resources or receptors established by Law 26/2007, of 23 October, (land, bodies of surface water, bodies of groundwater, shorelines and tidal inlets, and protected wild species and habitats) are not potentially exposed to environmental damage, the possibility may arise that only one relevant accident scenario is identified in the facility. The corresponding financial security will be calculated based on this sole accident scenario.

In any event, and even in facilities which have a very low environmental risk associated with them, it will always be necessary to identify at least one accident scenario in order to establish the cover of the financial security in accordance with Article 33 of the Regulation of partial development of Law 26/2007, of 23 October. This identification must be performed based on the event trees described in the UNE 150008 standard.

2.3.3. How to proceed when the primary remediation of all the relevant accident scenarios is based on natural recovery?

In accordance with the provisions of Article 33 of the Regulation of Law 26/2007, of 23 October, remediation of the damage caused in the reference accident scenario cannot be based on primary remediation which, in turn, consists entirely of natural recovery. This is because the cover of the financial security for environmental liability only covers, mandatorily, the primary remediation of the damage, a situation which requires scenarios whose primary remediation is based on natural recovery to be discarded as the reference scenario, given that there is no cost associated with primary remediation and, as a result, it cannot serve as a reference for the calculation of the financial security.

Taking into account the aforementioned rules, it would not be acceptable for each and every one of the accident scenarios identified in the context of a risk analysis to have an associated primary remedy based exclusively on natural recovery.

In this context, a feasible solution could be based on at least one of the accident scenarios which have been deemed relevant requiring primary remediation based on partial natural recovery, combined with other specific primary remediation measures aimed at the specific type of damage. In other words, it is essential that, in the situations and under the hypotheses which may be established in the risk assessment, it is foreseen that the damage caused in at least one of the identified scenarios is not remedied entirely through natural recovery.

An example of how to proceed could be a spill of chemical substances on land, where the analyst proposes the natural recovery of the affected areas with a lower concentration of the pollutant and the performance of other specific primary remediation techniques in the most polluted areas.

The Environmental Liability Supply Model (MORA) is especially useful for consulting different remediation techniques, the computer program and associated documentation for which are available on the Environmental Liability website of the Ministry for the Ecological Transition and the Demographic Challenge[2].

Additionally, from a practical point of view, some considerations could help to simplify decision-making aimed at identifying possible primary remediation techniques in cases of damage to bodies of surface water and land.

- For the "body of water" resource, if the analyst deems that the techniques suggested by MORA do not adequately fit the scenario under assessment, it might be useful to consult other references such as the *Federal Remediation Technologies Roundtable* (FRTR) of the United States Government (https://frtr.gov/scrntools.htm) or other specific official sources. In these scenarios where potential environmental damage is caused to a body or bodies of water, possible damage which may be caused to species which inhabit the potentially damaged body of water should also be considered, thereby allowing the application of primary remediation techniques (introduction of fish, etc.), which can be combined, where applicable, with a form of natural recovery.
- For land, whether it is the initial or final receptor of the pollution, the procedure would be similar, in the sense that it would be possible to consider the possibility of relevant or significant environmental damage when the concentrations reached by the damaging agent exceed the permissible levels in the receiving environment. The MORA database also offers different primary remediation techniques which can be applied in isolation, in combination or partially associated, as applicable, with a process of natural recovery of the natural resource.

All these recommendations determine the need for the remediation of at least one of the accident scenarios not to be based entirely on natural recovery, as well as the importance of all of the decisions made in the context of a risk analysis being duly justified.

2.3.4. How is the probability assigned to the accident scenarios?

The UNE 150008 Standard on Environmental Risk Analysis and Assessment establishes the possibility of the analyst deciding on the technique for assigning the probability to the event trees, and for this the probability must first be assigned to the initiating events and the determining factors, based on the combination of which a specific accident scenario will be generated.

Two different methods are proposed for assigning the probabilities: quantitative and semi-quantitative. The choice of one method over the other will fundamentally depend on the complexity which the event trees have acquired and the information available, and it must always

[2]https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/responsabilidad-mediambiental/modelo-de-oferta-de-responsabilidad-ambiental/

be in keeping with the reliability criteria required to satisfy the object of the analysis. Table 1 shows the main differences between quantitative and semi-quantitative methods for assigning probabilities to the accident scenarios.

Quantitative method	Semi-quantitative method
Its use requires referring to bibliographical sources or a historical record of accidents considered valid.	Its use requires constituting a group of experts who establish a set of probability indicators.
It consists of a more objective method.	It consists of a less objective method.
The method offers fewer options for the introduction of preventive measures and risk management into the model.	The method offers more options for the introduction of preventive measures and risk management into the model given that the variables it uses are often related to maintenance of facilities, staff training and, in short, environmental risk management.
There is generally a weaker link between the data used and the reality of the facility or of the sector under study (international bibliographical references are normally used). Therefore, generic values for the industry or for the sector are used, without being able to go into detail on the specific characteristics of a facility.	There is generally a stronger link between the data used and the reality of the facility or of the sector under study (the indicators are normally determined *ad hoc* by a panel of experts): Possibility of establishing specific indices for the sector or for the facility.
There is a greater risk of data obsolescence, and special attention must be paid to the year of publication of the databases which are to be used.	There is a lower risk of data obsolescence, given that the panel of experts can establish a set of indicators adapted to the current situation.
There is a greater probability of not finding specific data for one of the components identified in the model (zones, activities, initiating events, determining factors, etc.)	They offer the possibility of designing specific indicators of the probability of occurrence for each component of the model.

Table 1. Most important differences between quantitative and semi-quantitative methods for assigning probabilities in event trees. Source: by the authors.

The application of a quantitative method involves the bibliographical review of databases which provide information on the probabilities of failure of different equipment and operations which have been recorded in recent decades. Generally, this quantitative probability is expressed in units such as events/year or failures/demand when it refers to an initiating event, and in terms of probabilities of, in addition to failure/demand, success/failure or, where applicable, presence/absence when referring to a determining factor. Some of the most extensive bibliographical references so far include the *Purple Book*, *Failure Rate Event Data for Use within Risk Assessments* and *Handbook Failure Frequencies.* In any event, the analyst must review the bibliographical references, which apply to their case study and understand the respective limitations of each of them.

A semi-quantitative method involves the transformation of a series of indicators into numerical values by assigning an ordinal scale. This permits a criterion for comparison to be established between some indicators and others for each initiating event and determining factor whose respective probability of failure, frequency or presence is to be assessed. The inherent subjectivity of the semi-quantitative method must be minimised by constituting a group of experts who establish, in a technically consistent and justified manner, the type of indicators and the ordinal scale which explain the probability of each variable.

The analyst can opt to apply a quantitative or semi-quantitative method to assign the probability to the initiating events and to the determining factors which make up the event tree. Next, the probability of each accident scenario is always calculated in the same way: by multiplying the probability of the initiating event by the probability of the determining factor. In other words, the probability of occurrence of each accident scenario is calculated by applying the logical “AND” operator or intersection of the probabilities of the initiating event and of the determining factors which make up the accident scenario. Mathematically, the calculation of the probability of occurrence of the accident scenario is expressed as follows:

$$P_S = prob\_I.E. \times P_1 \times P_2 \times \ldots \times P_n \qquad \text{[Eq.2]}$$

Where:

P_S, is the probability of occurrence associated with the scenario “S”, which is defined as being the result of the joint occurrence of the initiating event “I.E.” and the determining factors “1, 2, … and n”.

prob_I.E., is the probability of occurrence of the initiating event leading to the accident scenario “S”.

P_i, is the probability of success (or failure) of the determining factors which, based on a specific initiating event, affect the definition of the accident scenario “S”. The probability of success plus the probability of failure of each determining factor add up to one, given that they are alternative events (the factor acts or does not act).

The explanatory report of the “Methodological guide for certain hazardous and non-hazardous waste management activities”, available to the public via the Environmental Liability website of the Ministry for the Ecological Transition and the Demographic Challenge[3], describes the specific characteristics and sources of information for each quantitative and semi-quantitative method, as well as an illustrative example of each method for assigning probabilities to event trees.

2.3.5. In the event of applying one or more preventive measures, should the consequence tree and the identification of accident scenarios be adapted to the new conditions? What consequences could it have on the event trees and the determination of the financial security?

Any modification which can affect the makeup of the relevant accident scenarios of the facility which have previously been identified in the risk analysis requires the consequence trees to be adapted and the reselection of the reference accident scenario established in Article 33 of the Regulation partially implementing Law 26/2007, of 23 October. In other words, once the consequence scenarios considered relevant have been identified and the reference scenario based on which the amount of the financial security will be estimated has been selected, the environmental risk analysis cannot be immutable and must be modified to adapt to any possible future change to the facility which may affect the pattern of consequence scenarios specified in said risk assessment.

In this regard, Article 34.3 of the Regulation of partial development of Law 26/2007, of 23 October, states that “*the operator shall adjust the environmental risk analysis whenever it deems fit and, in any event, whenever substantial modifications occur in the activity, facility or substantive*

[3] https://www.miteco.gob.es/en/calidad-y-evaluacion-ambiental/temas/responsabilidad-mediambiental/Memoria_GM_tcm38-194022.pdf

authorisation". Therefore, criteria such as the timeliness of the change and substantiality of the modifications are used which provide a certain leeway in the interpretation of the need to modify the risk analysis or not when changes occur in the facility or the activity assessed.

Meanwhile, it is worth remembering that the elimination of one of more relevant accident scenarios resulting from the application of one or more preventive measures which may have been deduced from the risk analysis does not always represent a reduction in the cover of the financial security (although in most cases this is the most likely outcome). The reduction of this amount will depend on how the elimination of the corresponding scenario(s) affects the selection of the reference scenario based on which the cover of the financial security is calculated. An isolated but possible case would be where the elimination of an accident scenario displaces the reference scenario (the one with the highest environmental damage index among those accounting for 95% of the total risk) towards a different scenario, exceeding the selection range of the less damaging and more likely scenarios, and thereby favouring the selection of a reference scenario with a value associated with the financial security which turns out to be higher (more damaging and less likely) than the scenario which would have been selected without having applied the corresponding prevention measure(s). In these specific cases, the value of the damage on which the cover of the financial security is calculated would increase.

All of these issues relating to the change which the amount of the financial security may undergo in response to a modification of the facility affecting the makeup of the event trees, i.e., the environmental risk of the facility, highlight the utility of risk analysis as a tool for managing environmental risk, providing information of great value to the operator on the hazards, the determining factors and/or the consequence scenarios on which it is most advisable to act to reduce both the environmental risk and the cover of the financial security.

2.3.6. Starting at what stored amount of a polluting substance is it recommended or necessary to take into account a specific hazard?

There is no predetermined amount starting at which a substance must be considered in an environmental risk assessment. It will always be the analyst who will determine, based on the hazards present in the facility, if a certain polluting agent is stored in a quantity which, in the event of its release, could produce damage or a threat of damage to the natural resources protected by Law 26/2007. The hazard level of the polluting agent may equally be an argument for considering or discarding a specific hazard.

By way of guidance and in a facility with multiple hazards, the amount of 1 m^3 can be adopted as a reference for taking into account a container of a dangerous substance as a hazard in the risk assessment. In any case, and based on the precautionary principle, it is important to bear in mind some situations which, in the context of an accident, can lead to the amplification of the damage and, as a result, to finally consider a substance which was initially disregarded as a hazard due to the limited volume stored (and not because it is a substance which is associated with a high level of danger). This would apply to a substance which could be carried by another one which acts as the pollution vector, as often occurs with fire water.

2.3.7. What examples can serve as a reference for the application of Article 3.4.b of Law 26/2007, of 23 October, on Environmental Liability?

Paragraph 4.b of Article 3 of Law 26/2007 establishes that exceptional, inevitable and irresistible natural phenomena fall outside of the scope of application of the law. As a result, it is not necessary to consider these phenomena as an initiating event in environmental risk analyses. Earthquakes and seaquakes, extraordinary flooding, volcanic eruptions, atypical cyclonic storms, falling astral bodies and meteorites can be considered examples of these natural phenomena.

<u>*2.4 Consultation on quantifying damage and the use of dispersion models*</u>

2.4.1. How are chemical agents quantified when they consist of a mixture of substances?

It is common for operators not to handle a pure substance which can be unequivocally classified into one of the categories specified in the scheme of Box 1, included in the IDM Calculation Module User Guide which allows for the simple classification of the different damaging agents based on their characteristics, with mixtures of substances being more common. In these cases, it shall be the operator who decides on the most appropriate way to adapt these scenarios to the schema of Box 1, although the chosen option must be adequately justified.

<table>
<tr><td rowspan="16">Damaging agent</td><td rowspan="8">The chemical (agent) has an associated toxicity threshold</td><td rowspan="7">Not explosive substance</td><td rowspan="6">Organic chemical agent</td><td rowspan="4">BP < 325ºC</td><td rowspan="2">BP<100ºC</td><td>The chemical contains halogen elements</td><td>Damage from halogenated VOCs</td></tr>
<tr><td>The chemical does not contain halogen elements.</td><td>Damage from non-halogenated VOCs</td></tr>
<tr><td rowspan="2">BP>100ºC</td><td>The chemical contains halogen elements</td><td>Damage from halogenated COSVs</td></tr>
<tr><td>The chemical does not contain halogen elements.</td><td>Damage from non-halogenated COSVs</td></tr>
<tr><td rowspan="2">BP >325º</td><td>Fuel</td><td colspan="2">Damage from fuel oils</td></tr>
<tr><td>Other substances</td><td colspan="2">Damage from non-volatile organic compounds (NOCs)</td></tr>
<tr><td>Inorganic chemical agent</td><td colspan="4">Damage by inorganic substances</td></tr>
<tr><td>It is an explosive substance</td><td colspan="5">Damage due to explosive substances</td></tr>
<tr><td rowspan="8">The chemical (agent) has not an associated toxicity threshold</td><td rowspan="3">Physical agents</td><td colspan="5">Damage due to extraction or disappearance of the natural resource</td></tr>
<tr><td colspan="5">Damage due to dumping of inert waste</td></tr>
<tr><td colspan="5">Damage due to temperature increase</td></tr>
<tr><td>Fire</td><td colspan="5">Fore damage</td></tr>
<tr><td rowspan="4">Biological agents</td><td colspan="5">Damage from Genetically Modified Organisms (GMOs)</td></tr>
<tr><td colspan="5">Damage by invasive alien species</td></tr>
<tr><td colspan="5">Damage by viruses and bacteria</td></tr>
<tr><td colspan="5">Fungal and insect damage</td></tr>
</table>

Box 1. Schema to assist in selecting the damaging agent. BP = Boiling point. Source: IDM calculation module user guide

Some of the criteria commonly proposed in environmental risk analyses are listed below:

a. Selection of a similar substance as a reference:

The proposal is to take the substance from the above scheme which is most similar to the mixture analysed. Aspects such as the behaviour of the mixture, its toxicity, the cost of possible damage which it could cause, etc. will be considered.

b. Selection of the most toxic substance as a reference

   This is one of the most conservative options, assuming that the mixture has the properties of the most toxic substance present in it.

c. Selection of the substance which could cause environmental damage with the highest remediation cost as a reference

   As with the previous proposal, this is a conservative approach in which it is assumed that the mixture behaves entirely like the substance which can cause the greatest environmental damage of all of those which it comprises. To justify this choice, the MORA tool can be used to calculate the remediation costs linked to each type of substance.

d. Selection of the toxic substance which represents the greatest volume in the mixture as a reference.

   A less conservative choice, but equally justifiable, is where the mixture is assumed to be the majority toxic substance in its formulation.

These guidelines must also be taken into account by the analyst when estimating the IDM and its corresponding coefficients related to the damaging agent linked to a specific accident scenario, a point at which it is necessary to determine various parameters related to the properties of the mixture of chemical substances (biodegradability, solubility, toxicity, etc.). Specifically, the 'Vvert' parameter of the IDM represents the amount of the agent involved in the damage, which is equivalent to the volume spilled which enters into contact with the natural resource.

Note that different considerations may come into play when the damaging agent is composed of a mixture of substances. In any case, the analyst must justify their decision based on the type and quantity of the damaging agent considered when a mixture of substances is involved in the quantification of an accident scenario.

2.4.2. What decision can be taken when the toxicity threshold of a certain chemical substance is not included in the safety data sheet and this figure cannot be used to apply it in the pollutant dispersion model of the potentially affected receptor?

The toxicity threshold is used to determine the intensity of the damage in accordance with Articles 11 and 13 of the Regulation of partial development of Law 26/2007, an indicator which contributes to characterising the damaging agent. Additionally, Section III of Annex I of the regulation on technical aspects of determining environmental damage establishes a series of criteria for calculating the intensity of the damage; specifically, point 1 of said Section III of Annex I focuses on the intensity of the damage caused by a chemical agent. This section indicates that the intensity level shall be measured in relation to the concentration or limit dose, comparing in one way or another the concentration which the spilled substance reaches in the receiving environment with the toxicity threshold of said receptor and the relationship between the exposure time and this toxicity threshold.

Article 2.e) of the partially implementing Regulation establishes three damage intensity levels:

> 1 "Severe": A level of intensity that represents clear, short-term adverse effects on the receptor, with evident consequences on the eco-systems and their habitats and species.

Severe effects have an impact on at least 50% of the population exposed to the damaging agent.

2 “Chronic”: A level of intensity that indicates possible long-term adverse effects on a percentage of the population exposed to the damaging agent ranging from 10% to 50%.

3 “Potential”: A level of intensity that corresponds to effects that exceed the eco-toxicological threshold and affect at least 1% of the population exposed to the damage, but do not reach chronic or severe levels. The term “admissible concentration level” refers to the eco-toxicological threshold.

Each damage intensity corresponds to a toxicity threshold —called CTDs, chemical toxicity distributions— in accordance with the following categories:

- Median Lethal Concentration (LC50) or Median Effect Concentration (EC50): these are normally taken as a reference for evaluating severe effects, i.e., those which affect at least 50% of the population.
- No Observed Effect Concentration (NOEC) or No Observed Adverse Effects Level (NOAEL): these are used as a reference to evaluate chronic effects, which affect between 10% and 50 % of the population.
- Predicted No Effects Concentration (PNEC): it is assumed that this threshold does not guarantee the absence of potential damage, i.e., it affects at least 1% of the population.

In addition to these three levels, for practical reasons, in risk analyses a fourth damage intensity level tends to be differentiated, lethal intensity, which corresponds to the loss of 100% of the population.

This way, the determination of the intensity of the environmental damage of a chemical agent is constructed by comparing the predicted concentration of the toxic substance in the receiving environment (a value termed Predicted Environmental Concentration or PEC, which can be obtained from the models and criteria mentioned in the section on calculating the extent of the damage) with the above toxicity thresholds. This way, if the PEC exceeds the LC50 value of the released substance, the appearance of severe damage can be affirmed and, with it, over 50% of the population being affected.

To carry out this exercise, it is necessary to have the information on the PEC —the pollutant dispersion model used must provide this expected concentration of the substance in the receiving environment— and on the toxicity levels —potentially available in bibliographical references on toxicology or, occasionally, in the safety data sheets of the substances, although for a limited list of species.

Nevertheless, in the scope of environmental risk analyses, in which hypothetical environmental damage is assessed, one or both of the above-mentioned components may not be available, either because the dispersion models and criteria used do not provide the expected concentration of the polluting substance and/or because there is no toxicological information on the polluting substance(s) released in the reference scenario. Faced with this potential impossibility of assessing the damage intensity according to severe, chronic or potential levels, the recommendation is to adopt a prudent judgement and consider that the hypothetical damage would be considered lethal damage and, therefore, the environmental damage would affect 100% of the population. In any case, other impact levels on the population can be selected if duly justified.

In relation to the evaluation of the intensity of damage from a chemical substance spill polluting inland surface watercourses, the Technical Guidance Document (TGD) of the European Commission (ECB, 2003) provides a free model publicly accessible on the internet for obtaining the expected concentration of the substance in the environment (PEC). On the other hand, in the present day there is a large amount of data on the toxicity thresholds of numerous substances in water, meaning that assessing the intensity of the damage in the case of spills of chemical substances in this receiving environment may turn out to be more feasible than performing the same operation for damage to other receptors.

2.4.3. In the case of a spill on land which reaches groundwater, how is the amount spilled distributed between the land and the body of groundwater?

A general-scope pollutant dispersion model which allows for the simple estimation of the distribution of the damaging agent between land and groundwater has not been identified. It is therefore recommended to carry out a case-by-case estimate in order to make the decision which best fits each specific situation. In this regard, the precautionary principle must be followed such that the calculations performed obtain conservative results whenever a high level of uncertainty is associated with the estimate.

A series of relatively simple practical proposals are listed below which the operator can follow in order to quantify this type of damage, although the advisability of it being the operator who applies, in a justified manner, the criterion which best fits the circumstances is stressed. These proposals are made due to the lack of a dispersion model which permits this type of estimation with greater efficiency and precision within environmental risk analyses, and may be subject to modifications if a more appropriate model is identified or developed.

The first possibility which is recommended is based on the model developed in Grimaz et al*.* (2007) and Grimaz et al*.* (2008). Specifically, this model provides a relatively simple procedure for estimating the area and depth which a hypothetical spill on land would reach. The model is applicable to the area of land not saturated with water; i.e., it will cease to provide results starting from the level at which the depth reached by the spill equals the groundwater level of the body of groundwater. Nevertheless, given the *a priori* nature of environmental risk analyses, for practical and cost-efficiency purposes of the calculation processes, the option of using the results of Grimaz et al*.* (2007) and Grimaz et al*.* (2008) for estimating the distribution of the damaging agent between unsaturated land and the saturated zone is considered.

In this regard, this proposal consists of calculating the depth which the spill would reach with the equations published in Grimaz et al*.* (2007) and Grimaz et al*.* (2008). If this depth (total reach of the spill) exceeds the depth at which the groundwater level is found, the damaged area could be assumed to be a cylinder whose surface matches the expansion surface of the spill and with a height (depth) equal to the total depth which the spill reaches. By means of this procedure, the amount of damaged land would be given by multiplying the affected area by the depth at which the groundwater level is found. The amount of damaged groundwater is given by multiplying this area by the difference between the total depth which the spill would reach and the depth at which the groundwater level is found, with the option of taking the land porosity into account to estimate the volume of groundwater affected.

The Grimaz (ibid*.*) model, on the basis of experience acquired by the Ministry for the Ecological Transition and the Demographic Challenge in the development of sector-specific instruments for environmental risk analysis, turns out to be suitable for estimating the amount of the damaging agent which would reach the groundwater level at which the body of groundwater is found and the amount of water polluted.

In any event, regardless of the quantification criterion followed, it is worth indicating that in the case of damage from chemical agents to bodies of groundwater, the assessment of the environmental damage using the Environmental Liability Supply Model (MORA) presents high fixed costs and relatively low unit costs (per unit of resource affected). The high fixed costs, especially those associated with the review and control procedures required to test and evaluate the success of the remedy, mean that the cost of primary remediation of groundwater polluted by chemical agents has a very limited dependence on the amount of groundwater to be remedied, making the precision of the quantification procedure less significant.

In other words, monetizing the damage to groundwater using MORA means that the cost of primary remediation of groundwater fundamentally depends on the fixed costs of the remediation technique, and therefore it is not very sensitive to the amount of water affected. This characteristic means that the effect on the value of the damage from the volume spilled (and the consequent amount of the body of groundwater polluted) is less than in other combinations of damaging agents and affected natural resources. Therefore, the analyst will have a degree of flexibility when deciding and justifying the criterion finally applied. In this regard, if significant uncertainty is considered to exist about the decision, it could be advisable to carry out a sustainability analysis which can assess the effect which each possible option would have on the predicted value of the environmental damage, in order to make the most appropriate decision in a justified manner.

2.4.4. How is a spill which ends up at a treatment plant external to the operator assessed in an environmental risk assessment?

The uncertainly about the functioning of a treatment plant external to the operator faced with the arrival of a spill of polluted water makes it impossible to predict whether the plant will be able to retain or treat, at least partially, a possible spill, which leads to the assumption that the least favourable situation possible from an environmental risk perspective will occur. In other words, the inaction or lack of effectiveness of the treatment plant is assumed in the face of a possible spill of toxic water and, under this hypothesis, the precautionary principle is adopted. In accordance with this precautionary principle, the environmental risk is assessed in the absence of the treatment plant and the river and/or watercourse into which the treatment plant outputs are identified as potentially affected receptors.

2.4.5. How is the environmental risk analysis of a toxic spill of soluble substances into a body of surface water approached?

The high variability of the circumstances which can surround this resource (watercourses or static water bodies, different flow rates, etc.) mean that the criteria for quantifying the damage caused by chemical substances of varying solubilities need to be qualified. In the configuration of an accident scenario where the initiating event consists of the release of a chemical agent into a body of surface water, the analyst can take account of the solubility of the substance and its density compared to water in order to identify the fraction of the spill which could be deposited on the bed and the fraction which could remain in the water.

As a general rule, the greater the solubility and the lower the density of the substance spilled into inland (or marine) surface water, it can be assumed that the greater the probability will be that the substance dissolves in the water. Given that solubility is a property which can manifest to differing degrees (some substances dissolve totally in water, others only partially, as a certain percentage, and others do not dissolve in water at all), the analyst could determine what quantity of the substance spilled (provided that it is denser than water and insoluble or partially soluble in water) would mostly end up dissolved, floating or deposited on the bed. As such, assuming a simplified criterion, when the substance is denser than water, the quantity deposited on the bed will be the quantity spilled minus the amount which was capable of dissolving in the water.

The quantification will also have to take into consideration whether the spill takes place in a moving body of water (rivers, streams, etc.) or a relatively static body of water (lake, reservoir, etc.). Likewise, the possibility of a containment structure existing which limits the spill downstream will also be a factor to be considered when assessing and quantifying the damage caused by a chemical spill, regardless of its solubility, into a body of surface water. In these cases, the analyst may deem that the pollution could be retained downstream and, thereby, treat (in terms of quantifying and remedying the damage) a spill into a moving body of water as a spill into a static body of water.

The determining factors which come into play once the initiating event occurs in the form of a discharge or spill (generally, preventive measures and/or measures to avoid new damage implemented by the operator) can range from reducing (or even nullifying) the quantity of damaging agent which finally comes into contact with the natural resources (for example, the installation of a bunding which, if it functions correctly, fully confines the spill) to increasing the quantity of the spill (the fire water generated when putting out a fire can come into contact with soluble substances present in the area or in the facility and thereby considerably increase the quantity of a damaging agent). Extinguishing media (such as water) used to put out a fire which could occur in a facility are considered either a damaging agent (if they mix with soluble substances) or a vehicle for the spread of pollution (in the case of insoluble substances).

As a result, the fact that the damaging agent consists of a soluble chemical substance has a greater effect when determining the amount of surface water exposed to damage which ends up being polluted and which is associated with an accident scenario. In these cases, the amount of the water body which ends up being affected in the possible accident scenario is different to the amount of the chemical substance released in the initiating event as a result of the dilution of this substance in the receiving environment.

In cases where the watercourse does not have containment structures or they are at such a distance that their consideration as a containment element is not considered prudent, the analyst may estimate the volume of water polluted by multiplying the flow rate of the river by the time during which the pollutant remains in the water. Subsequently, the remediation techniques would be scaled based on this volume (cost of treating the water, etc.). Following the same logic, if the spill of a soluble chemical substance takes place in a relatively static water body or if the spill into the watercourse has managed to be contained in some way, the entire body of water would be affected by the spill. In any case, the analyst must use the pollution dispersion model which, in the case of the course of a river, allows them to understand the evolution of the concentration of the pollutant in order to identify the point of the watercourse where its dilution means that damage no longer exists, and in the case of a static water body (lakes, reservoirs, etc.), lets them evaluate whether the concentration of the soluble agent in the receiving environment would cause damage.

The analyst must take into consideration the possibility of considering the natural recovery of the resource, especially (but not exclusively) in the event of a spill of a soluble substance into a surface water body. Nevertheless, this natural recovery, in addition to not necessarily implying a zero damage value (there are costs relating to the decision to opt for natural recovery and, subsequently, evaluate its success), does not allow damage caused to other resources related to inland surface water bodies (fauna and flora linked to this environment) to be ignored. In this context, the analyst must also consider the possibility of the damage caused being such that the baseline condition of the natural resource cannot be recovered, and therefore primary remediation measures cannot be performed. In this case, the damage would be declared irreversible and the amount of the financial security could not be calculated using this reference scenario (given that a complementary remediation measure would have to be applied and the cover of the financial security does not mandatorily cover either this remediation or compensatory remediation measures). The dispersion of the pollution which could be caused by fast-flowing water and/or more mobile substances would extend the sphere of action of the remediation technique and would require the decontamination of a greater volume and, therefore, a greater remediation cost.

On the other hand, if the water body affected by the pollution episode is relatively static, this would allow any remediation technique to be proposed and, therefore, the re-establishment of the baseline condition. In any case, the analyst must never reject the possibility that the damage can be remedied by natural recovery or that the damage can be considered irreversible, in which cases the selected scenario would not be valid for establishing the amount of the financial security.

2.4.6. How do we approach the environmental risk analysis of a toxic spill due to the polluting substance being carried by fire water?

Fires can act on the event tree as an initiating event, when they can trigger chemical damage due to the pollution of land and/or water bodies due to firefighting water carrying polluting substances (in which case the damaging agents are the substances which pollute the land and/or waters), or as an accident scenario, when a scenario occurs which gives rise to the burning of a habitat or wild species (in which cases the fire is also considered a damaging agent).

In cases where it has not been possible to extinguish the fire swiftly (or if the operator deems it necessary even in the case of swift extinguishment due to the characteristics of the facility), it is assumed that firefighting water can be generated in sufficient quantities to cause environmental damage, either by diluting soluble substances present in the facility and/or by carrying non-soluble substances in the water. Occasionally, the existence of a drainage network could prevent firefighting water from coming into contact with natural resources and thereby causing environmental damage.

A high solubility of the damaging agent significantly affects the calculation of the amount of the pollutant which comes into contact with the natural resources in the case of a fire, due to this soluble substance being carried by the fire water. This amount of water used in extinguishing the fire can act as a determining factor in the event tree, given that, on mixing with the soluble substance which is associated with the initiating event, the total quantity of the damaging agent which comes into contact with the receiving environment will depend on it.

In this situation, when the substance involved in the incident is water-soluble, the quantity of the damaging agent will depend on the amount of water used to extinguish the fire, which will be equal to the sum of the extinguishing media of the facility (firefighting fixtures installed, hydrants, etc.) and, if they act, external media (fire services). Some general guidelines are given below for the context where a body of surface water is affected by polluting substances being carried by the fire water. The procedure for calculating the extinguishing media, which act as a mixture of damaging agents, can depend on the characteristics of the facility (open-air or covered, essentially) and the available information (capacity of the extinguishing media available at the facility).

If the facility has buildings or warehouses which allow the industrial plant to be treated independently (open-air or open-plan facility), two scenarios can be proposed to estimate the extinguishing media for interior firefighting:

i. The operator possesses data on the stock of water required to extinguish a possible fire in each of the areas of the facility (deluge system flow rate, capacity of fire-fighting tank, etc.).

ii. The operator does not possess these data and nor can they be identified, in which case the analyst may resort to alternative bibliographical sources which must be used following a conservative criterion, i.e., using the maximums of the ranges obtained.

If the analyst does not have data on the flow rates and capacities of the extinguishing media present in a facility which does not have warehouses or buildings, the calculation of the fire water can by supported by the Technical Prevention Notes (NTP) published by the Spanish National Institute for Safety and Hygiene at Work (INSHT). *NTP 420: Installations for supplying firefighting water* provides some criteria for estimating the amount of fire water generated in a fire:

1. Firstly, it should be indicated that guidance manuals propose a minimum extinguishing flow rate of between 4 and 20 litres/min/m^2 (expressed per m^2 of the planned area). Following the criterion of prudence which must govern the preparation of an environmental risk assessment, the recommendation is to use a flow rate of 20 litres/min/m^2.

2. The NTP estimates the duration of the fire based on the type of fire, as indicated in Table 2.

Duration of fire (minutes)	
Category I	< 10
Category II	15 - 60
Category III	>60

Table 2. Categories of fires based on their duration. Source: By the authors based on NTP 420 (INSHT)

Assuming that the most common fires in facilities are fires in tanks or liquid leaks (pool fires), the NTP includes these fires in category III, meaning they can be considered as fires with a duration of over 60 minutes.

As a result, the volume of firefighting water generated can be estimated as the product of the following three parameters:

- Reference flow rate (20 l/minute/m^2 or 0.02 m^3/minute/m^2)
- Average estimated duration of the fire (minutes)
- Area of the facility of each risk zone (m^2)

Finally, the analyst will consider, on the one hand, the volume of polluting substances involved in the fire which can end up polluting the fire water or be carried by it and, secondly, they will estimate the volume of fire water affected by the pollution. To do so, the following hypotheses can be assumed:

- To estimate the quantity of the polluting substance present in the zone which ends up polluting the fire water, 20% of the volume of the reference polluting substance (of greatest volume, most hazardous, etc.) present in the zone where the fire occurs can be assumed, in accordance with the provisions of the Institut National d'Etudes de la Sécurité Civile (2001).
- The volume of fire water can be estimated by means of the following calculation procedure:

$$V_I = \left(\left((V_{EF} + V_{IF}) \times Fm \right) + (0.2 \times V_{sust}) \right) \qquad \text{[Eq.3]}$$

Where:

V_I, is the total volume of fire water (m^3)

V_{EF}, is the value of the volume of water calculated for exterior fighting (m^3)

V_{IF}, is the value of the volume of water calculated for interior fighting (m^3)

Fm, coefficient that introduces into the model the possibility that not all of the water used for extinguishing is contaminated. As a general rule, this coefficient can be considered to be the miscibility of the substance which could potentially pollute the water, a figure which can generally be obtained from the safety data sheet of the substance; this percentage is the result of the quotient between the solubility of the substance and its density. If these data are not available, a default value of 30% is proposed, following the “Methodological guide for certain hazardous and non-hazardous waste management activities” published by the Directorate-General for Environmental Quality and Assessment.

V_{subst}, is the volume of the reference chemical substance (of greatest volume, hazard level, etc.) present in the zone affected by the fire (m^3)

The factor *Fm* shows the effect of the solubility of the substance on the calculation of fire water. For substances insoluble in water, this factor will be equal to 0, excluding the fire water as a damaging agent; in this case, the fire water is limited to acting as a vehicle for the pollution, by carrying the polluting substance to natural resources.

A more detailed description of the technical guidelines which the analyst may take into consideration in the case of scenarios of damage to bodies of water where soluble chemical substances are involved can be found in the “Methodological guide for certain hazardous and non-hazardous waste management activities” and the Model Environmental Risk Report Templates (MIRAT) for the foundry sector on the Environmental Liability website of the Ministry for the Ecological Transition and the Demographic Challenge[4].

2.4.7. When quantifying damage caused to animal species, where can data be gathered on population density?

The determination of damage caused to animal species is one of the greatest challenges which currently exists in damage quantification. The main difficulty lies, on the one hand, in that it consists of a mobile resource –it travels freely– and, on the other hand, in the absence of fauna inventories for the entirety of the natural environment. Specifically, the information which should ideally be used in the quantification would be a map featuring the density of the individuals of each species existing in each area –expressed as the number of individuals per unit area or per unit volume of water. This way, once the amount of damaged resource is known, the number of affected individuals could be directly estimated.

An initial reference for identifying wild species which can potentially be affected by possible damage is the Environmental Liability Supply Model –MORA– computer program. For this, the analyst must select the point at which the natural resource which comes into contact with the damaging agent and the program will produce a list of wild species which could potentially be damaged.

The source of information which the MORA computer tool draws on is the National Biodiversity Inventory[5], where the list of species in the entire national territory can also be consulted directly in 10 by 10 km grids. This inventory also indicates the threat level which each species is under, although it has the limitation that it does not provide the population density present in each grid of the territory. In any case, given the extent and characteristics of a supposed chemical spill which is being assessed and the threat category of each species, the analyst can rule out a significant impact on certain species. By way of example, a spill with limited dimensions and low level of toxicity in an area where only generalist species exist will have a small probability of causing significant adverse effects on the populations.

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[4]https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/responsabilidad-mediambiental/

[5]https://www.miteco.gob.es/es/biodiversidad/temas/inventarios-nacionales/inventario-espanol-patrimonio-natural-biodiv/default.aspx

To obtain information on wild species population densities, the Red Natura 2000 viewer[6] can be used, where a file can be downloaded for each zone with an associated dialogue box with the species inventory and a variety of information referring to Sites of Community Importance (SCI) and Special Protection Areas for Birds (SPA). Along these lines, when damage does not take place in a Red Natura 2000 zone, the analyst could also use the damage from the nearest Red Natura site as a tentative reference.

It is worth remembering that, in additional to information available nationally, each Autonomous Region or even the operator can find more detailed information specifically referring to the territory where the facility under study is located.

Note that, if the analyst does not have any wildlife inventories –whether prepared by the facility or supplied by the government agencies– it should adopt a justified criterion for quantifying the damage to the corresponding natural resource.

In the case of damage which could be caused to inland surface water and, with it, could affect aquatic wildlife, a notable resource is the ID-TAX database, available on the Ministry for the Ecological Transition and the Demographic Challenge website[7], which provides annual reports on the presence of certain fish species at a national network of sampling points, also indicating the fish densities which can be found at those points. It is also worth noting the existence of fish densities taken by some catchment area organisations for several of the reservoirs, and these data may be directly applied by the operator in its risk analyses.

Finally, in the case of hypothetical damage located in a body of water not covered by any database, the extrapolation or transfer of results, always in a justified manner, from other bodies of water with similar characteristics to the object of the study, is a legitimate method which allows the analyst to obtain an approximate number of aquatic wildlife individuals potentially affected by a possible spill. In any case, it will always be more desirable for precise data on fish density to be available to the analyst.

In light of these technical provisions, the type of damaging agent –whether chemical, physical, thermal or a fire– does not substantially determine the manner of quantifying the damage potentially caused to terrestrial and/or aquatic wildlife. That is, once the volume of the body of water or the vegetation area affected by spill or a fire, as applicable, has been calculated the analyst must assess the significance of the damage to the species and estimate its extent in terms of the number of individuals affected, and its intensity – the quantity of individuals with respect to the population exposed to the damage of these same individuals, for which they can use the above-mentioned criteria and guidelines.

Nevertheless, the inherent mobility of terrestrial species (with respect to the affected area) will often prevent large-scale contact with the damaging agent, and as a result, the magnitude of the damage in the terrestrial environment may be judged to be many times lower than the damage which could be caused where a body of water is affected and, as a result, the immense majority of individuals of the aquatic species present in it. For this reason, in general terms, the damage to wildlife only tends to be considered when fires in habitats or spills into inland waters occur. For spills on land, unless they are large or they occur in especially sensitive habitats or species, it can be considered that the animal species would not make significant contact with the damaging agent

[6] http://sig.mapama.es/bdn/

[7] https://www.miteco.gob.es/es/agua/temas/estado-y-calidad-de-las-aguas/aguas-superficiales/programas-seguimiento/ID-TAX.aspx

fundamentally due to the limited extent of the spill and the aforementioned capacity for movement of terrestrial species.

In water bodies, for example, their maximum temperature or the maximum concentration of a soluble chemical substance at which aquatic species can survive and reproduce constitutes a reference indicator based on which the analyst, if they know the population density and dynamics of the species present in the body of water, could find the damage intensity level by extrapolating the proportion of individuals affected on surpassing the threshold (of temperature or concentration, as applicable) with respect to the total. Likewise, in situations where there is a lack of data for aquatic environments, the suggestion is that the analyst assume a lethal impact (of 100% of the population) when it is suspected that the pollution thresholds could be exceeded, thereby ensuring the analysis errs on the side of safety.

In light of these rules, a reasonable solution to the lack of information which can be adopted during the quantification process consists of assigning each of the species identified in the list from the National Biodiversity Inventory a specific population density, or directly, a certain number of affected individuals given the hypothetical extent of the spill or fire. This value could be justified based on the threat category and the type of animal based on bibliographical references, by applying an expert judgement, consulting with the competent government agencies, etc., but always in a justified manner, on the basis of available information and applying the precautionary principle, ensuring that these estimates are prudent. In short, the analyst must justify and document all technical decisions taken during the preparation of environmental risk analyses and the competent authority will subsequently be the one, where applicable, to accept these decisions.

2.4.8 How is the extent of damage caused to wild species by a fire determined?

In the context of the environmental liability regulations, damage from fire should only be considered when it significantly affects one of the natural resources they cover.

The estimate of the extent of the damage on plant species caused by a fire will be decisively influenced by the dominant direction of the fire. There are different models of forest fire spread, among which is the Behave model, which involves relatively high documentation requirements, and the model developed by Julio et al*.* (1995)[8], which is less demanding in terms of the information required for its application but has a sufficient level of reliability in the context of a risk analysis where uncertainty inherent to the study inevitably exists and is assumed.

The Behave model is a good option for estimating this type of damage given that it is an internationally recognised tool which is free and easily accessed on the internet[9].

Behave simulates and analyses the development of a hypothetical forest fire by estimating its extent based on the calculation of an ellipse whose shape and extension will be a function of variables such as the slope of the terrain, and the dominant wind speed and direction in the area where the fire occurs. In addition to these external components, which influence the development of the fire and the direction that it will take, with a view to determining the extent or affected area, the recommendation is to incorporate the response time for emergency services to extinguish the fire in the model. If the extinguishing media are close by, they will act early and, as a result, the

[8] JULIO, G., PEDERNERA, P. and CASTILLO, E. (1995) Diseño funcional de simulador de incendios forestales [Functional design of a forest fire simulator]. Laboratorio de Incendios Forestales. Universidad de Chile.

[9] https://www.firelab.org/project/behaveplus; http://www.firemodels.org/index.php/behaveplussoftware/behaveplus-downloads

affected area will be reduced. Consulting the websites of the corresponding Autonomous Regions and their corresponding plans against forest fires can provide information on the proximity of extinguishing media to the place where a fire could potentially be declared.

The model developed by Julio et al. (1995) is constructed based on easily obtained data (vegetation type, slope of the terrain, wind speed, temperature and relative humidity of the air), thereby allowing a diagram of the area affected by the fire and an estimate of the area burned to be produced. A description and practical application of this model is included in the Rate Table for the porcine industry.

There is a more conservative option which hugely simplifies the task of determining the extent of the fire in terms of the area of vegetation burned. This consists of proposing the possibility that all of the grid squares with vegetation or the area potentially exposed to the fire will burn until the fire reaches a non-combustible element (firebreak, communication routes, areas with limited or no vegetation, bodies of water of a certain width or size, etc.). This way, the area affected by the hypothetical fire could be determined by studying maps and/or aerial photographs, locating these non-combustible elements of the landscape where the hypothetical fire would potentially be stopped to determine the affected area.

The estimate of the extent of the damage caused by a fire to animal species can be constructed, insofar as the availability of information permits, by following the guidelines and sources of information in Section 2.4.7: once the area of vegetation affected by the fire has been estimated, along with the presence and population density of animal species in the territory affected by it, it is possible to estimate the number of individuals of the animal species affected by the hypothetical fire.

Another aspect to be taken into account is the intensity of the fire. In the context of the regulations on environmental liability, fire can be treated as a combination of physical and chemical damage. The intensity of the damage caused by a fire can be established by calculating the quotient between the area burned and the total area which would have been exposed to the fire, such that: for values of this quotient below 0.03, the damage will be considered potential; values between 0.03 and 0.25 would represent chronic damage; and values greater than 0.25 would involve severe damage.

Nevertheless, as stated, in the event of uncertainty about this assessment, a declaration of lethal damage could be made, taking a precautionary stance.

2.4.9 How should fine particles of heavy metals in suspension be dealt with in an environmental risk assessment? If these reach a body of surface water, what part would remain in suspension and what part would settle as sediment?

Estimating the proportion of fine particles (heavy metals) which could remain in suspension or settle as sediment in an *a priori* context entails a high level of uncertainty. It is therefore suggested that a reasonable and transparent decision and one in keeping with the precautionary principle always be made, and that it be justified. It is also recommended that this decision be accompanied by the input values which have been used to calculate the IDM, and to quantify and cost the damage if it consists of the reference accident scenario.

Several options are given below for approaching the treatment of fine materials in the context of environmental risk analyses:

- One possibility would be to estimate the IDM of the two most extreme cases —where all of the particles enter the sediment or all of the particles remain in suspension— and use the highest IDM value in order to make the most conservative decision possible.

- A simpler option would be to argue, under the hypothesis that they consist of particularly fine particles, that a lower proportion of heavy metals would enter the sediment (with over 50% remaining in suspension).

Any decision will be considered appropriate if it is reasonable and transparently justified.

3. DAMAGE CAUSED BY BIOLOGICAL AGENTS AND TRANSGENIC MATERIAL

3.1. Regulatory framework

Law 26/2007, of 23 October, on Environmental Liability explicitly considers pathogenic micro-organisms, invasive alien species and genetically modified organisms as damaging agents. For their assessment, the Regulation of partial development of Law 26/2007, of 23 October, refers to the technical criteria of sectoral legislation in order to establish an equivalence between these and how damage is characterised and assessed in the context of environmental liability regulations (e.g., use of the containment level of the transgenic material referred to by Law 9/2003, of 25 April, to determine the intensity of the damage on the basis of the Regulation).

Likewise, the regulations establish that the significance of the damage caused by biological agents must be characterised and assessed on a *case-by-case* basis by means of a study accredited by a duly recognised body.

Annex III of Law 26/2007, of 23 October, includes the occupational activities which are subject to an objective environmental liability regime, including in the following sections those relating to damage caused by genetically modified organisms:

> *"11. Any contained use, including transport, involving genetically modified micro-organisms as defined by Law 9/2003, of 25 April, establishing the legal regime for the contained use, voluntary release and placing on the market of genetically modified micro-organisms.*
>
> *12. Any deliberate release into the environment, transport and placing on the market of genetically modified organisms as defined by Law 9/2003, of 25 April. […]"*

Meanwhile, the partially implementing Regulation establishes a series of technical provisions in relation to the consideration and assessment of damage caused by biological agents which operators subject to the obligation to provide a mandatory financial security must fulfil in their risk analyses. An extract of these technical provisions is included below:

Article 8. Identification of the damaging agent.

The operator shall identify the damaging agent and shall classify it into one of the following types: chemical, physical or biological. The latter is composed, inter alia, of genetically modified organisms, invasive alien species and pathogenic micro-organisms.

Article 9. Characterisation of the damaging agent.

"If the agent is a biological agent, the damaging organism and its taxonomic definition or specific nomenclature shall be considered, as the case may be, as well as any other parameters, pursuant to the legislation in force and the technical recommendations issued, where applicable, by the qualified entities or official authorities. Some of the parameters to consider, depending on the type of biological agent, are:

1. Genetically modified organism: the genetic modification of the organism, how this was effected and its specific nomenclature, survival capacity, manner of dispersal, dominance and genetic evolution when interacting with other living organisms shall be studied on a case-by-case basis.

2. Invasive alien species: among other aspects, the species introduced, the quantity and capacity to threaten the native biological diversity due to interference in the dynamics of the population, including, where applicable, the capacity to contaminate chemically or genetically, compete, prey on or transmit diseases to native species shall be considered.

3. Pathogenic micro-organisms: among other features, the species, hazard level, genetic stability and capacity to interact with native fauna and flora species shall be analysed.

Article 17. Significance of the damage in reference to the agent type.

The significance of the damage caused by a genetically modified organism shall be determined through case-by-case analysis, verified by an officially recognised agency.

Annex I. Extent of the damage, Section II; Intensity of the damage, Section III. 2.2. Determination of the environmental damage

II. Extent of the damage

If the damaging agent is a genetically modified organism, the extent of the damage shall be determined pursuant to the terms set forth in Law 9/2003, of 25 April, establishing the legal system for contained use, voluntary release and placing on the market of genetically modified organisms, and in Royal Decree 178/2004, of 30 January, approving the general Regulation for implementation of the aforementioned law, through case-by-case analysis to such end, accredited by an officially recognised agency.

In determining the extent of damage caused by genetically modified organisms, both direct exposure to the damaging agent and indirect exposure through mechanisms such as interaction with other organisms, the transfer of genetic material or changes in use or management shall be considered. Likewise, the long-term accumulated effects shall be considered under the terms described in Annex IV of Royal Decree 178/2004, of 30 January.

III. Intensity of the damage

2.2. If the damaging agent is a genetically modified organism, the damage intensity shall be defined on the basis of its hazard level, according to the following criteria and the terms set forth in Law 9/2003, of 25 April, and in Royal Decree 178/2004, of 30 January:

In the case of contained use:

a) High intensity level: When the genetically altered organism is type 3 or 4, meaning those that must be used with a high or moderate containment level.

b) Medium intensity level: When the genetically altered organism is type 2, meaning that it is associated with a medium containment level.

c) Low intensity level: When the genetically altered organism is type 1, meaning that it is associated with a low containment level.

In the event of voluntary release, the damage intensity shall be determined through case-by-case analysis, accredited by an officially recognised agency.

With this wording, Law 26/2007, of 23 October, and its partially implementing Regulation provide various technical criteria on some of the key aspects for applying the environmental liability framework to the damage caused by biological agents. In any case, some guidelines are given below aimed specifically at each biological agent (genetically modified organisms, pathogenic micro-organisms, and invasive alien species) including some of the legal precepts of the respective sectoral regulations which may be of use to the operator with a view to preparing environmental risk analyses.

3.2. State of scientific and technical knowledge on damage caused by biological agents

The high uncertainly associated with the assessment of damage caused by any type of biological agent requires that this type of damage be approached more from the perspective of environmental risk, rather than from the practice of approach in the context of damage which has already occurred. Proof of this is the lack of experience relating to quantifying, assessing and remedying damage caused by genetically modified organisms, invasive alien species or pathogenic micro-organisms. This paucity of knowledge, together with the high uncertainty about the scope of the potential effects which these biological agents could cause in native animal and plant species and their habitats, is the most decisive reason why environmental liability regulations refer to sectoral legislation to deal with damage caused by biological agents and, more specifically, by genetically modified organisms.

The Regulation of partial development of Law 26/2007, of 23 October, specifies three types of biological agents among the elements which the operator must identify in the assessment of damage: genetically modified organisms, invasive alien species and pathogenic micro-organisms, while Directive 2004/35/CE, of 21 April 2004, only explicitly mentions damage caused by genetically modified organisms. On this matter, the European Commission carried out a regulatory analysis in 2013 on the transposition of the Environmental Liability Directive into their respective legal frameworks by 11 Member States[10]. From this analysis, it can be confirmed that the vast majority of Member States have incorporated the provisions on genetically modified organisms as they appear in the Directive and without broadening the spectrum of damage to other biological agents such as invasive species or other pathogenic agents. For this reason, although there is no harmonised technical basis which has permitted substantial progress by Member States in the assessment of damage caused by the different types of biological agents which our legal system introduces to the subject of environmental liability, there are more analyses referring to genetically modified organisms than to biological agents such as invasive species and pathogenic micro-organisms.

Another interesting aspect to be considered is related to the identification of the occupational activities in Annex III of Law 26/2007, of 23 October, which can potentially cause damage produced by biological agents. While Sections 11 and 12 of said Annex III already explicitly mention the occupational activities linked to the use, transport and/or release of genetically modified organisms, the other biological agents (invasive alien species and pathogenic agents) are not explicitly mentioned in the list of operators subject to an objective liability system by means of this annex. This is why the identification of the occupational activities with an associated environmental risk due to the presence of or exposure to risks caused by pathogenic micro-organisms or the presence of genetic contamination caused by invasive alien species can only be performed on a case-by-case basis and not systematically. It is sufficient to consider any occupational activity which has a warehouse with pallets whose wood could have become contaminated with the introduction of an invasive alien species during the transport of goods. Likewise, the uncertainty associated with the origin of the source of contamination with pathogenic agents in livestock activity makes it difficult to establish the causality of the damage and its relation to the possible wild species affected.

One characteristic which all three types of biological agents have in common is the irreversibility of the damage which would be caused to the animal and/or plant species exposed both to

[10] European Commission (2013) “Study on Analysis of integrating the ELD into 11 national legal frameworks. Final Report 16”. Steven and Bolton LLP. December 2013

genetically modified organisms and to invasive species and pathogenic micro-organisms. Another aspect which complicates the assessment of damage caused by biological agents is the broad time horizon in which the effects on the affected natural resources can manifest and, therefore, be detected and their chances of expansion mitigated. For example, GMOs exist with the capacity to combine with wild plants through cross-pollination, providing these modified species with a competitive advantage over natural or native plants over the years, so they eventually colonise the habitat by behaving like invasive species. This condition, together with the uncertainty surrounding the assessment of the characteristics of the biological agent, its persistence in the environment and its effects on the dynamics of the potentially affected species, unavoidably leads to the application of the precautionary principle in decision-making relating to the treatment of damage caused by biological agents.

3.3. Application of the precautionary principle in the specific context of risks posed by biological agents

The "precautionary principle" constitutes an essential part of European policy, the grounds for which are developed in the Communication from the Commission on the precautionary principle (2000). The European Commission argues that this precautionary principle chiefly concerns risk management and that, more than a guide, it is a criterion to be adopted by Member States in the decision-making process, which includes regulatory development. This is confirmed by this extract from the Communication which largely summarises the spirit of the precautionary principle: "*Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation*."

Along these same lines, the European Commission REFIT working paper[11] establishes that the obligation to carry out preventive measures in the application of Directive 2004/35/CE is only triggered when it is likely that the failure to take measures can result in significant environmental damage, as would foreseeably be the case in a scenario where damage by a biological agent is involved. However, in application of the precautionary principle, scientific certainty that the potential damage will exceed the threshold of significance is not required, and a reasonable belief would be sufficient to apply Law 26/2007, of 23 October, as well as the possibility of applying sectoral regulations if their application ensures that the prevention, avoidance and remedying of environmental damage is achieved at reasonable cost.

In line with the above and in application of the precautionary principle, when faced with an accident scenario where a biological agent poses an imminent threat of causing significant damage, the application of environmental liability regulations would also apply. On the other hand, when it is deemed that the imminent threat of environmental damage could give rise to non-significant damage, the competent authority could refer to sectoral legislation to resolve the threat of damage.

In the context of the environmental risk analyses which operators must carry out to determine their mandatory financial security, if an accident scenario caused by a biological agent could lead to a risk which poses an imminent threat of damage which could give rise to significant damage, this scenario must be included. Note that this technical premise –consideration of which *a priori* is systematic– is made flexible, as argued in Section 3.6, in the case of the occupational activities of the intensive rearing of poultry and pigs, where the Directorate-General for Environmental

[11] COMMISSION STAFF WORKING DOCUMENT REFIT Evaluation of the Environmental Liability Directive Accompanying the document Report from the Commission to the European Parliament and to the Council pursuant to Article 18(2) of Directive 2004/35/EC on environmental liability with regard to the prevention and remedying of environmental damage.

Quality and Assessment has carried out the respective sector-specific analyses. These works have concluded, on this technical basis and unless proven otherwise, that the risk scenarios associated with damage which may be caused by pathogenic micro-organisms can be disregarded.

Another technical provision which arises from the review of the state of technical and scientific knowledge on the subject is that the characterisation and assessment of damage associated with a scenario involving a biological agent must always be performed on a case-*by-case* basis in light of the uncertainty and the specific nature of the magnitude and of the effects linked to this type of damage.

3.4. Guidance for the assessment of damage caused by genetically modified organisms

As has been stated, Annex III of Law 26/2007, of 23 October, separates aspects relating to the contained use and transport of genetically modified organisms (GMOs) and aspects related to voluntary release, transport and placing on the market of GMOs into independent sections, although both refer to operators subject to the same sectoral regulation: Law 9/2003, of 25 April, establishing the legal system for the contained use, voluntary release and placing on the market of genetically modified organisms and Royal Decree 178/2004, of 30 January, approving the general regulation for the implementation and execution of Law 9/2003, of 25 April.

Since the amendment of the Regulation of partial development of Law 26/2007 reducing the mandatory financial security for the occupational activities of Annex III of the law, the activities referring to genetically modified organisms are excluded from the obligation to carry out an environmental risk analysis and to provide a mandatory financial security. However, these activities are subject to objective and unlimited environmental liability; i.e., they have the obligation to bear the totality of the costs for prevention, avoidance and remediation (primary, compensatory and complementary) associated with environmental damage caused by a GMO, if this damage takes place and is significant, and regardless of the existence of bad faith, fault or negligence.

The technical criteria for preparing environmental risk analyses set out below are aimed at clarifying the provisions established by the Regulation of partial development of Law 26/2007, of 23 October; the provisions linked to the sectoral legislation; and to the definition of the figure of the operator and the safety requirements for handling transgenic material which are used to quantify the damage caused by GMOs.

Royal Decree 178/2004, of 30 January, defines an operator as "*any natural or legal person who places a product on the market or receives a product marketed in the European Union, whether from a Member State or a third country, in any stage of production or distribution, except for the end consumer, who is understood to be the final consumer who will not use the product as part of a commercial operation*."

Combining this definition with the one provided by Law 26/2007, of 23 October, an operator can be understood to be any natural or legal person who finds themselves directly or indirectly in charge or in operational control of the activity at the time when the incident causing the environmental damage occurs. Promotors, producers, notifiers, exporters, importers, transporters or suppliers of the GMO would fall within this context. Likewise, it is worth reflecting on the possibility of equating the term "owner of the activity", referred to in Law 9/2003, of 25 April, to the concept of operator established in the environmental liability system. In this regard, the operator could refer to the owner of the operation which is responsible for or controls any activity which could be defined within the category of "*contained use of GMOs*" (Section 11 of Annex III of Law

26/2007, of 23 October) or "*any deliberate release into the environment, transport and placing on the market*" (Section 12 of Annex III of Law 26/2007, of 23 October).

In relation to the contained use and transport of GMOs to which Section 11 of Law 26/2007, of 23 October, refers, the sectoral legislation understands contained use to be any activity by which the genetic material of an organism is modified or by which, having been modified, it is grown, stored, used, transported, destroyed or eliminated, provided that containment measures are used in the performance of such activities in order to limit its contact with the population and the environment[12]. As for the deliberate release of GMOs referred to in Section 12 of Annex III of the law, Royal Decree 178/2004, of 30 January, defines voluntary release as the deliberate introduction into the environment of a genetically modified organism or combination of genetically modified organisms (GMOs) without adopting specific containment measures, to limit their contact with and provide a high level of safety for the population and the environment.

All of these activities are required by sectoral legislation to carry out a prior assessment of the possible risks to human health and the environment. This risk analysis is a key and necessary element for the competent authority to authorise the activities and different operations to which the sectoral legislation applies. The requirements for this assessment of risks to human health and the environment which Royal Decree 178/2004, of 30 January, establishes both in its Annex I (for activities of contained uses of GMOs) and in its Annex IV (for voluntary release operations), make up the technical basis of reference for this sector of activity, given that all operators must meet the technical requirements established therein to carry out the aforementioned risk analysis and comply with the conditions for marketing authorisation.

In light of the fact that the risk analysis established by the sectoral regulations is required for authorisation and placing on the market, it is not surprising that the risk inherent to these activities is assessed from this sectoral perspective taking advantage of the efforts and knowledge acquired in that risk assessment.

More specifically and in the case of the voluntary release of GMOs, Royal Decree 178/2004, of 30 January, establishes that the risk analysis must properly take into account GMOs which contain genes which express resistance to the antibiotics used in medical or veterinary treatments, in order to detect and progressively eliminate the markers of resistance to antibiotics in GMOs which can have adverse effects on human health and wild species, in accordance with the first additional provision of Law 9/2003, of 25 April. In any case, assessment of the risk must take into account the potential adverse effects which genetic transfers from genetically modified organisms to other organisms can directly or indirectly exert on human health or the environment. Furthermore, any genetic transfer from GMOs to other organisms must be subject to a case-by-case assessment of the potential adverse effects which they might directly or indirectly exert on human health and the environment.

As can be confirmed in the text of the regulatory development of the partially implementing Regulation which accompanies Section 3.1 of this report, the environmental liability regulations are based on the technical provisions of the sectoral regulations in accordance with the provisions

[12] Genetic modifications obtained by self-cloning and cell fusion, including that of protoplasts, both of prokaryotic species with the exchange of genetic material by known physiological processes, and cells of any eukaryotic species, including the production of hybridomas, are excluded from this category and, therefore, from damage by GMOs which may also be approached based on the environmental liability framework, provided that such techniques and methods do not involve the use of recombinant nucleic acid or GMOs obtained by means of techniques or methods other than those which are excluded from the scope of application of the law (first paragraph of Article 1, Section 2).

of Royal Decree 178/2004, of 30 January, for carrying out risk analyses. Proof of this is the reference to the types of containment referenced in Royal Decree 2090/2008, of 22 December, to establish the intensity of possible damage resulting from the contained use of GMOs, given that the danger which might be associated with the GMO is directly related to the containment level and, therefore, to the adverse effects which it may have on receptors in the event of its release. For these purposes, the hazard level of the activity can be inferred from the type of containment required to carry out the use of GMOs.

To determine the extent of damage caused by a GMO during its contained use, as established by Royal Decree 2090/2008, of 22 December, a *case-by-case* study must be carried out which considers both direct exposure of the receptor to the damaging agent and its indirect exposure through mechanisms such as interaction with other organisms, transfer of genetic material, or changes in use or management. This task will also consider the long-term accumulated effects under the terms described in Annex IV of Royal Decree 178/2004, of 30 January.

Likewise, for the transport of GMOs, an assessment of the risk to human health and the environment is required, and the specific occupational health and safety rules must be followed in accordance with the provisions of Annex I of Royal Decree 178/2004, of 30 January.

In the case of voluntary release, the intensity of the damage, in accordance with the Regulation of partial development of Law 26/2007 of 23 October, shall be determined through case-by-case analysis, accredited by an officially recognised agency. The criteria of hazard level associated with the deliberate release of GMOs, which could have been given by the regulation, can be inferred from the risk analysis requirements included in Annex IV of Royal Decree 178/2004, of 30 January.

Chapter III of Royal Decree 178/2004, of 30 January, establishes all of the technical criteria and requirements for placing GMOs on the market as products or components of products. According to the regulation, "*placing on the market is understood as any action which involves delivering to third parties, for valuable consideration or for free, of genetically modified organisms or products which contain them*." This term does not include either operations of the supply of GMOs which are regulated as part of the activities of contained use or the supply of GMOs exclusively for voluntary release which comply with the requirements established in Chapter II of this Title.

Operators who intend to place GMOs or a combination of them on the market for the first time as products or subcomponents of products must request express authorisation from the competent authority. Among the conditions specified by the regulation, this authorisation must also include an assessment of the risk to human health and the environment and the conclusions demanded in Section D of Annex IV. The risk analysis must be carried out in accordance with the principles established in Annex IV of Royal Decree, the supplementary guidance notes contained in the Annex to Commission Decision 2002/623/EC, of 24 July 2002, and taking account of the information provided in accordance with Annexes V and VII of the aforementioned regulation. In any case, assessment of the risk must consider the potential adverse effects which genetic transfers from GMOs to other organisms can directly or indirectly exert on human health or the environment.

Meanwhile, in the context of the risk analyses established by environmental liability regulations, the unique nature of GMOs adds some particularities with respect to other chemical and physical agents and, of course, compared to fires. These particularities entail assessing the possible adverse effects associated with the different levels of biological complexity in greater detail: at the level of the genome (short-term effects on the expression of the gene introduced and its stability in the face of different environmental conditions), population (medium-term effects on the dynamics of populations) and ecosystem (long-term effects on the structure and function of ecosystems).

In line with the importance of analysing the interaction of the modified gene and the environment which it is in contact with, Box 2 provides a series of tasks which could be of use to the operator when assessing the relevance of each of the scenarios involving GMOs which have been identified in the environmental risk analyses established by the environmental liability regulations.

- Assess whether there is a probability of at least one GMO escaping and surviving outside the facility where it is contained or of its being released, and thus potentially intervening in the dynamic of wild populations.
- Analyse whether the GMO can reproduce, assessing the probability of that individual reproducing outside its usual containment area.
- It is also advisable to assess the probability of the GMO hybridising with wild individuals of the same species in the surrounding area, and producing viable, fertile hybrid descendants, or which might hybridise with other species and produce fertile interspecies hybrids.
- Assess whether there are enough fertile GMOs to become established in the receiving environments as new wild populations (the probability of this happening).
- Assess the probability of at least one GMO or its hybrid descendants could colonise and survive in new receiving environments not occupied by wild organisms.

Box 2. Tentative identification of some tasks which the analyst could carry out to assess the relevance of environmental risk scenarios involving GMOs. Source: By the authors, based on the EFSA GMO Panel (2013)

In conclusion, and in accordance with the state of scientific and technical knowledge on the subject, the approach which is being adopted to assess the risk associated with damage caused by GMOs by applying the provisions of the environmental liability regulations has the following characteristics:

- The expectation that GMOs can cause direct and indirect effects on human health and the environment, the uncertainty surrounding their effects on ecological structure and function, their persistence and the way this transgenic material interacts with wild species, and the fact that these effects can be irreversible once detected are reasons which make it possible to state with full confidence that the probability of significant damage from an accident involving transgenic material is very high. For this reason it is necessary to follow the precautionary principle both in the prevention and management of the risk of activities relating to this type of biological agent during normal operating conditions, and in establishing the most conservative avoidance and remediation measures possible in order to minimise the effects which could result from an accident with these characteristics, as well as to establish all remediation measures necessary to prevent their spread. For its part, the European Commission argues that the precautionary principle chiefly concerns risk management and that it is a criterion to be adopted by Member States in the decision-making process, which includes regulatory development.
- The lack of experience in assessing this type of damage in accordance with environmental liability regulations and the obligation established by the sectoral legislation to carry out an assessment of the risks to human health and the environment for the authorisation and placing on the market of the activities included in Sections 11

and 12 of Annex III of Law 26/2007, of 23 October, incentivise approaching this type of damage from the perspective of sectoral legislation.

- The uncertainty and specificity associated with the damage caused by GMOs explain why the partially implementing Regulation establishes that the assessment and quantification associated with this type of damage according to the provisions of the environmental liability regulations should be determined by a case-by-case analysis, accredited by an officially recognised body.

3.5. Consideration of invasive alien species in environmental risk analyses

Among the activities of Annex III of Law 26/2007, of 23 October, it is not possible to carry out a systematic identification of those which may be associated with an environmental risk of damage from invasive alien species, given the breadth and randomness of the circumstances which could lead to damage with these characteristics. For example, an occupational activity may store substances on pallets which could have been contaminated with an alien insect species during transport. From the above it is deduced that it is not possible to know if this type of scenario would be one of those inherent to an occupational activity which is currently subject to the obligation to provide a financial security. In any case, given the lack of information on the treatment of this type of damage in the context of environmental liability regulations, it is deemed worthwhile to provide some technical guidance for the consideration of invasive alien species in environmental risk analyses.

The consideration of invasive alien species in the environmental liability regulations is established in Article 8 of the Regulation of partial development of Law 26/2007, of 23 October, on referring to invasive alien species among the possible damaging agents of a biological nature. Notably, the regulations in force for this damaging agent differentiate between invasive alien species and other alien species (not considered invasive). Specifically, in accordance with Article 2 of Royal Decree 630/2013, of 2 August, regulating the Spanish catalogue of invasive alien species, an alien or non-native species would be any species or subspecies (including parts, gametes, seeds, eggs or propagules which could survive or reproduce) introduced outside the area of its natural distribution and of its potential dispersal areas, which it would not have been able to occupy without its direct or indirect introduction, or without human care. Meanwhile, only those alien species which are introduced or established in an ecosystem or natural or semi-natural habitat, and which are an agent of change and threat to the native biological diversity, whether due to their invasive behaviour or due to the risk of genetic contamination, shall be considered invasive. There is an intermediate category in the regulation, potentially invasive alien species, which is reserved for alien species which could become invasive in Spain and which is especially focused on those which have demonstrated this nature in other countries or regions with ecological conditions similar to those of Spain.

The Annex to Royal Decree 630/2013, of 2 August, regulating the Spanish catalogue of invasive alien species, includes the catalogue with alien species for which there is scientific and technical information indicating that they pose a serious threat to native species, habitats or ecosystems, agriculture, or economic resources associated with the use of natural heritage, in accordance with Article 61.1 of Law 42/2007, of 13 December, on Natural Heritage and Biodiversity.

In any case, it must be stressed that this catalogue established by the regulation is not static, but is expected to be modified, both to include new species and to remove those which cease to be considered invasive.

When a species is included in the Spanish catalogue of invasive alien species, a series of conditions are imposed on its handling. These are, in accordance with Article 7 of Royal Decree 630/2013, of 2 August, regulating the Spanish catalogue of invasive alien species, as follows:

a) The general prohibition of their possession, transport, trafficking and trade in live specimens, in their remains or propagules, which could survive or reproduce, including foreign trade. This prohibition can be set aside, following administrative authorisation from the competent authority, when necessary for reasons of research, the health and safety of people, or for the purposes of control or eradication, in the context of strategies, plans and campaigns approved for this purpose.

b) The prohibition on introducing them to the natural environment within the scope of the national territory determined by the Spanish catalogue of invasive alien species.

c) Specimens of animal and plant species included in the catalogue which are extracted from nature by any procedure may not be returned to the natural environment. This prohibition can be set aside in situations of research and the health and safety of people, when previously authorised by the competent authority for the environment of the General State Administration or the autonomous regions and cities of Ceuta and Melilla.

d) Under no circumstances can actions or behaviours destined to promote the species included in the catalogue be permitted.

Up to September 2019, the Spanish catalogue of invasive alien species has been modified just once, by Royal Decree 216/2019, of 29 March, approving the list of invasive alien species of concern for the outer peripheral region of the Canary Islands and amending Royal Decree 630/2013, of 2 August, regulating the Spanish catalogue of invasive alien species. In any case, to know what the latest list of species is at any time, the official information supplied by the Ministry for the Ecological Transition and the Demographic Challenge should be accessed via its website[13]. On this website, and within the Catalogue, each of the species designated as invasive alien species is accompanied by a descriptive file (in PDF format) including basic information about it for its characterisation.

In light of the above, it would be recommended for operators liable to cause this type of damage to consult the Spanish catalogue of invasive alien species in order to determine if they could cause an accidental episode involving them as part of their activity, with special attention to the actions specifically prohibited by Article 7 of Royal Decree 630/2013, of 2 August, regulating the Spanish catalogue of invasive alien species.

Among the entry routes of invasive alien species, Capdevila et al. (2006) distinguish between intentional and unintentional introductions:

a) Intentional introductions with different purposes such as food production, timber production, soil improvement, halting erosion, stabilising dunes, aesthetic improvements in gardening and landscaping, tourism, recreational hunting and fishing, livestock feed, biological control, improving industrial processes, increasing the number of species present in a certain area, species recovery, pet abandonment, the presence of stray pets and deliberate release through vandalism.
b) Unintentional introductions, citing as examples: shipments of agricultural products, timber, flowers and seeds, species incrusted on ship hulls, discharge of ballast water, discharge of ballast solids (earth and stones), breakdown of geographical barriers by engineering work, the use of other organisms as vectors, the existence of stowaways in

13 https://www.miteco.gob.es/es/biodiversidad/temas/conservacion-de-especies/especies-exoticas-invasoras/ce-eei-catalogo.aspx

the interior of planes and boats, dispersal in vehicles, equipment, clothing, footwear, etc., the transport of goods and packaging materials.

As such, there are multiple possible entry routes for invasive alien species in a certain area and, at least *a priori*, they could appear in a wide variety of economic activities addressed by Law 26/2007, of 23 October, on Environmental Liability. In this regard, any action involving the transport of materials from one region to another nationally and, above all, internationally may be especially relevant. Nevertheless, the difficulty and uncertainty when taking these types of episodes into consideration in environmental risk analyses is generally very high. Specifically, there are different stages which would be especially complicated to comply with, including: identifying the source of the environmental hazard, specifying the damaging agent, estimating the probability of occurrence, and estimating the possible environmental consequences. For this reason, it may be advisable to reserve this type of agent, “invasive alien species”, for economic activities which can identify this risk with sufficient certainty, at least in light of the above aspects (hazard causing the emission, specific species causing the damage, probability of an accident occurring and possibility of estimating the consequences). When these circumstances occur, it can be especially useful for the operator to consult the competent authorities regarding the existence of a risk analysis on the invasive alien species which it wishes to assess.

Royal Decree 630/2013, of 2 August, regulating the Spanish catalogue of invasive alien species establishes the possibly of there being a risk analysis for alien species in which the probability and consequences of the introduction and establishment of an alien species in the natural environment, as well as the measures which can be applied to reduce or control these risks, are studied from a scientific-technical perspective. These risk analyses provided for in the regulations on invasive alien species take on particular importance when modifying the Spanish catalogue of invasive alien species as foreseen in Article 5 of Royal Decree 630/2013 of 2 August regulating the Spanish catalogue of invasive alien species; when applying for authorisation for the release of non-native species, in accordance with the provisions in its Article 8; when preparing and applying strategies for the management, control and possible eradication of invasive species, Article 16 of the same Royal Decree; and when applying to open new facilities which handle these species, in accordance with its sixth additional provision.

The information included in these risk analyses can be of great utility if considered in environmental risk analyses, given that it can assist operators in several of the stages which they must include. Capdevila et al*.* (2006) provide a more detailed description of these tools.

One aspect of note is that the seventh additional provision of Royal Decree 630/2013, of 2 August, regulating the Spanish catalogue of invasive alien species determines that the environmental damage which can be caused by invasive alien species must be prevented, avoided and remedied in accordance with the terms established in the basic legislation on the subject of environmental liability. Therefore, this stage of the assessment of environmental risks and the management of accidents which could be caused must take account of the provisions of Law 26/2007, of 23 October, on Environmental Liability and Royal Decree 2090/2008, of 22 December, approving the Regulation of partial development of Law 26/2007, of 23 October, on Environmental Liability.

As stated in Capdevila et al*.* (2006) the possible consequences of the introduction of invasive alien species are wide-ranging, and the following can be identified: depredation of animals and plants, competition, hybridisation, facilitating of invasion by other species, erosion due to degradation of vegetation, and the introduction of disease and parasites. The multiplicity and complexity of the effects which can arise, as well as the possible appearance of synergies among them, lead to the recommendation that the environmental consequences foreseen by each operator be assessed on a case-by-case basis, taking account of the operator’s specific characteristics, both with respect to the environment in which it operates (with special attention to the potentially affected habitats and species) and with respect to its own characteristics (with special attention to the characteristics and the specific agent which would be released). In any case, whenever it is deemed necessary, the precautionary principle is recommended in the assessment of risks, adopting the most conservative decision.

The Environmental Liability Supply Model (MORA) opts for a simplification which permits the assessment of possible damage caused by invasive alien species with a reasonable amount of resources and is suitable for the deductive nature and associated uncertainty of environmental risk analyses. Specifically, the remediation proposed in MORA for this type of damage is as follows:

- For damage caused by plant species, it is assumed that the damage only affects plant species of the same type as the invasive alien species introduced. The technique proposed in MORA would consist of removing the invasive species and subsequently repopulating the affected territory with similar but native species.
- Similarly, for damage caused by animal species, it is assumed that only animal species of the same type as the invasive alien species introduced are affected. In this regard, MORA includes the capture of the invasive alien individuals and the subsequent reintroduction of similar but native species.

In this case, the MORA methodology assumes that the damage would only be reversible when: (1) it can be assumed that the capture or removal of the invasive alien individuals can be carried out, and (2) when this capture or removal is performed in a short timeperiod, such that the spread or reproduction of the individuals is prevented. Otherwise, it would be advisable to consider another type of irreversible damage and/or equivalent approaches to remediation other than those established in MORA (of the service-service, value-value, value-cost types). In these cases, it would not be possible to take them into account for the calculation of the mandatory financial security given that they are not compatible with the provisions of Article 33 of the Regulation, which relates the calculation of the guarantee to the cost of primary remediation.

While the approach and hypotheses of MORA can be considered manageable for many cases and fit the requirements of environmental risk analyses, in complex situations or where there is more precise information available and in accidents which occur in reality, it could be advisable to modify the data and principles proposed by MORA such that the assessment of the damage fits the situation under assessment as closely as possible. In other words, the economic valuation of the damage must be the truest possible reflection of the case under study, regardless of the data proposed for it by MORA by default.

In this regard, it may be advisable for the analyst to investigate the existence of strategies, plans, programmes, campaigns, etc. specifically aimed at the eradication of the invasive alien species under assessment, given that they may identify specific measures described and valued in economic terms. By way of example, the "Management, control and eradication strategy of the American mink (*Neovison vison*) in Spain"[14] can be downloaded from the Ministry for the

[14] https://www.miteco.gob.es/es/biodiversidad/publicaciones/pbl_exo_inva_vison_americano_tcm30-69978.pdf

Ecological Transition and the Demographic Challenge website, and the “Manual for the control and eradication of invasive freshwater turtles”[15] from the European Commission website.

3.6 Specific indications for the assessment of damage caused by pathogenic agents in the livestock sector

This section exclusively refers to the pathogenic micro-organisms referred to by the Regulation of partial development of Law 26/2007, of 23 October, among the different types of biological agents considered by the regulatory framework.

Experience acquired when preparing the sector-specific risk analyses for livestock activities, more specifically, the MIRAT and the Rate Table addressing the egg-producing poultry and poultry meat sector and the MIRAT and Rate Table for the pig sector, has allowed for the assessment of the importance of considering risk scenarios associated with the treatment of the environmental risk associated with possible viruses, bacteria or other pathogenic agents which originate and/or spread in livestock facilities and which can affect wild animal species near a facility. Based on this analysis, the reasons why the consideration of this type of risk could be disregarded are set out in the specific case of the intensive rearing of poultry or pigs; activities which must carry out the environmental risk analysis given that they are required to provide the corresponding financial security.

- The difficulty of establishing causality between the effects detected and the source of the damage, causality which the environmental liability system deems necessary for its application. By way of example, the appearance of sick or dead individuals of wild species in the vicinity of the facility could be due to an outbreak originating on the farm, or not. It is considered that significant difficulty can exist when establishing a relationship between infected wild species and the declaration of an outbreak in a certain facility. If, furthermore, they consist of currently widespread diseases, it is considered more difficult to precisely determine the origin of the biological agents which affect wild populations.
- The consideration of the irreversibility of the damage caused and, therefore, the provision of a complementary remediation measure, a measure outside of the scope of the mandatory financial security. The damage caused to wild animal species if they are affected, at least in the scope of the livestock sector, can already be significant by the time it is detected. In essence, it could be considered that a realistic and manageable plan in the scope of the livestock sector is that, once the disease originates in or is transmitted from a facility to nearby wild species, it is difficult to perform an effective primary remediation measure which controls the disease in a short space of time. In other words, once the damage has been caused, it could be considered to be irreversible and not taken into account for the calculation of the mandatory financial security as it must be remedied by means of complementary remediation techniques (in accordance with the provisions of Article 33 of the Regulation).
- The handling of biological damaging agents, such as viruses and bacteria, does not form part of the specific or characteristic production process of the livestock sector, in contrast to what might occur in other sectors where the main activity centres on handling these types of agents. In that case, the consideration of this type of scenario could be justified, given the characteristics of the sector itself. Likewise, the measures established by sectoral legislation on livestock and animal health are mainly aimed at preventing contagion by pathogenic agents from outside the farms to the inside. This leads to a lack of legal provisions and

15 http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.showFile&rep=file&fil=TRACHEMYS_Manual_Control_Erradicion_GalapagosInvasores.pdf

technical instructions for the operator to incorporate this type of accident scenario in the risk analysis in order to manage and prevent their appearance.

- The existence of a high level of uncertainty when determining the probability of occurrence of these scenarios and quantifying the damage associated with them. No literature has been found on the probability of occurrence of these episodes, nor are there any references which could serve to support the sector in the procedure for quantifying the environmental damage, and therefore the estimation of the associated risk would lead to a high level of uncertainty in these scenarios.

It is important to remember that all economic operators who work in rearing domestic animals as well as zoological institutions, which can end up being a source or vector of biological contamination by pathogenic micro-organisms to wild species, must always adopt both the preventive measures deemed appropriate against an imminent threat of damage and the measures to avoid new damage if damage of this nature occurs, in keeping with Article 17 of Law 26/2007, of 23 October. The above is without prejudice to the objective and unlimited liability system which the occupational activities in its Annex III are subject to, under which, in the event of damage, they must adopt the remediation measures (primary, compensatory and/or complementary) deemed necessary to return the affected natural resources to their baseline condition.

4. SELECTION AND PRACTICAL USE OF DISPERSION MODELS AND CRITERIA FOR QUANTIFYING ENVIRONMENTAL DAMAGE

This section identifies a series of useful models and criteria for quantifying environmental damage as part of environmental risk analyses. In this regard, it is worth noting that the utility of these models is reduced in environmental damage which has already occurred, given that, on the one hand, they are accompanied by a high level of uncertainty and, on the other hand, in these cases real data on the extent, intensity and time scale of the damage would be available. In fact, Article 34 of the Regulation of partial development of Law 26/2007, of 23 October, on Environmental Liability, allows operators to cover the estimated extent, intensity and time scale of the damage in an adequate level of detail given the hypothetical nature of the damage, providing a degree of flexibility when studying these aspects.

While the procedure for quantifying environmental damage includes the extent, intensity and time scale of the damage (broken down, in turn, into duration, frequency and reversibility), this section mainly focuses on the extent parameter for two reasons:

- Firstly, it consists of a parameter for which references or simple decision-making rules have not been found which can be applied directly by operators in their environmental risk analyses, and therefore it is advisable to at least offer them certain guidelines.
- Secondly, extent is a key input parameter for operators who wish to produce an economic valuation of their environmental damage using the Environmental Liability Supply Model (MORA) prepared by the Technical Commission for the Prevention and Remediation of Environmental Damage.

In order to estimate the intensity and time scale of the damage, the operator may carry out a specific study for its specific case or take into account a series of guidelines which may be acceptable exclusively in the context of environmental risk analyses. These guidelines are specified below and may be consulted in greater detail in the environmental risk analyses made available publicly via the Ministry for the Ecological Transition and the Demographic Challenge website[16].

4.1. Guidelines relating to determining the intensity of environmental damage

The intensity of the damage is defined in the environmental liability regulations as the severity of the effects caused by the damaging agent. Specifically, the level of intensity consists of the classification of the severity of the damage, considering parameters such as mortality, immobility, growth inhibition, mutagenicity, teratogenicity and carcinogenicity, to name a few.

In the Regulation of partial development of Law 26/2007, of 23 October, three levels of intensity are distinguished, as follows:

1. “Severe”: A level of intensity that represents clear, short-term adverse effects on the receptor, with evident consequences on the eco-systems and their habitats and species. Severe effects have an impact on at least 50% of the population exposed to the damaging agent.

[16] https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/responsabilidad-mediambiental/analisis-de-riesgos-sectoriales/herramientas.aspx

2. “Chronic” A level of intensity that indicates possible long-term adverse effects on a percentage of the population exposed to the damaging agent ranging from 10% to 50%.

3. “Potential”: A level of intensity that corresponds to effects that exceed the eco-toxicological threshold and affect at least 1% of the population exposed to the damage, but do not reach chronic or severe levels. The term “admissible concentration level” refers to the eco-toxicological threshold.’

For practical reasons, and with particular utility in environmental risk analyses, a fourth intensity level of lethal type can be differentiated which assumes the loss of 100% of the individuals of a population.

The determination of the intensity of the damage as part of environmental risk analyses can be performed by means of a specific process carried out by the operator, but always complying with the provisions of the regulations. The main references which must be taken into account are found in Article 13 of the Regulation of partial development of Law 26/2007, of 23 October, and in Section III of Annex I to the aforementioned Regulation.

As an acceptable alternative in the context of environmental risk analyses, the operator could follow the precautionary principle and assume the worst possible consequences associated with its accident scenarios. In the scope of intensity, these consequences will result in the assumption of a lethal type of damage and, therefore, all calculations to quantify and value the damage would posit the total loss of the populations which have come into contact with the damaging agent.

4.2. Guidelines relating to determining the time scale of environmental damage

Article 14 of the Regulation of partial development of Law 26/2007, of 23 October, indicates that the time scale of environmental damage comprises the study of the duration, frequency and reversibility of the damage. Once again, to determine these aspects the operator could establish specific criteria for the specific case, while always complying with the provisions in the regulations.

Alternatively, in order to establish the duration, frequency and reversibility of the damage, the operator could follow the following guidelines.

Firstly, in terms of the duration of the damage, one possibility accepted in the context of environmental risk analyses consists of using the Environmental Liability Supply Model (MORA) and entering the data of the accident scenario under analysis. As part of its results, MORA will provide the operator with an estimate of the predicted duration of the damage, stated in months or years. The operator could therefore take that result as a reference for inclusion in its environmental risk assessment.

Figure 1 shows, through an example, the MORA screen providing the recommended values for the duration of the damage. Specifically, duration is broken down into two factors: waiting time and recovery time, where the total duration estimated for the damage is the sum of the two figures (15 months in the case illustrated in Figure 1).

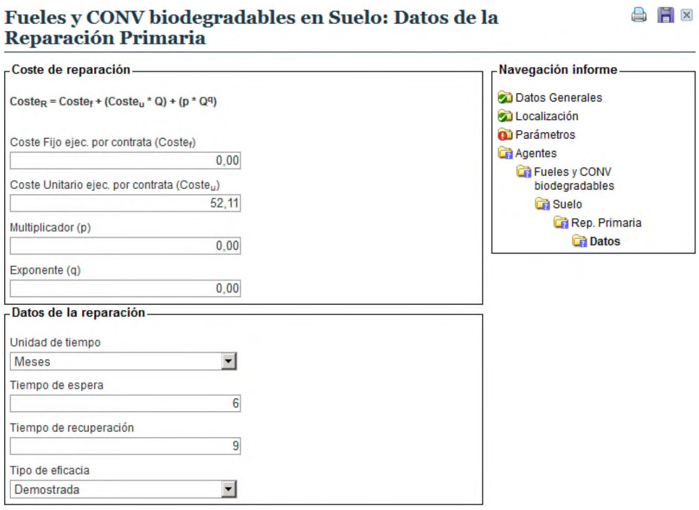

Figure 1. Consulting the estimated duration of the damage in the MORA computer program. Source: MORA

The next attribute to be considered is how often the environmental damage occurs. In the case of environmental risk analyses, the predicted frequency can correspond to the probability of occurrence assigned to the scenario being quantified. By way of example, in the practical case which accompanies the MIRAT for the foundry sector carried out by the Spanish Federation of Foundry Associations (FEAF), the reference scenario is assigned a probability of 2.55 x 10^{-8} times/year, and therefore in this case it can be assumed that the expected frequency of the damage being assessed is 2.55 x 10^{-8} times/year. Alternatively, given that the regulations do not impose restrictions in this regard, analysts basing their environmental risk analyses on semi-quantitative probabilities could determine frequency categories of this type (high-medium-low or similar scales).

Finally, the reversibility of the damage is a crucial aspect, given that, among other things, it determines when primary remediation must be designed (for reversible damage) and when complementary measures must be applied (for irreversible damage). Additionally, it must be considered that the Environmental Damage Index (IDM) foreseen in the Regulation of partial development of Law 26/2007, of 23 October, is only applicable to damage considered reversible.

Article 2 of the Regulation of partial development of Law 26/2007, of 23 October, defines reversibility as "the capacity of a receptor to recover its baseline condition, regarding its life cycle or prospects for use, within a certain time scale".

The regulations do not establish guidelines or categorical criteria for considering damage reversible or irreversible, so this determination is ultimately left up to the justification of the operator. Nevertheless, the MORA Methodology Document, available on the Ministry for the Ecological Transition and the Demographic Challenge website[17], offers a series of guidelines based on Article 22 of the Regulation of partial development of Law 26/2007, of 23 October, which the analyst can take into account when determining whether the damage assessed is reversible or not.

[17]https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/responsabilidad-mediambiental/Documento%20metodolog%C3%ADa_tcm30-177400.pdf

Specifically, this document recommends examining the following aspects:

(i) The geographical location of the damage. Taking into account the geographical location of the damage, MORA determines that damage is irreversible if it occurs in an inaccessible area and is due to a damaging agent which cannot be degraded by natural processes, i.e., without human intervention.

(ii) The damaging agent and the amount of the resource affected. Based on the damaging agent and the extent of the damage, the effects can be considered irreversible. For this, the viability of effectively treating certain amounts of the agent must be evaluated, given that for large quantities of affected resource —whether because a large volume of the agent is released or because it is spread over a large quantity of resource— remediation could turn out to be inviable and therefore the damage irreversible. In short, remediation would require the existence of available techniques.

(iii) Disproportionate cost of primary remediation. If the cost of primary remediation is disproportionate to the environmental benefits which would be attained, the damage caused could be declared irreversible. In this case, the operator must accredit the disproportionate cost by means of an economic report.

(iv) Time required for primary remediation. Finally, if the time required for primary remediation is disproportionate, the damage could be considered irreversible.

4.3 Guidelines for determining the extent of environmental damage

The dispersion models and criteria detailed below focus on determining the extent of environmental damage. Nevertheless, some of them could serve as the basis for operators to estimate the rest of the components of the quantification (intensity and time scale of the damage).

The extent of the damage refers to the quantity of the resource or service damaged and must be calculated in accordance with Article 12 and Section II of Annex I of the Regulation of partial development of Law 26/2007, of 23 October.

Table 3 includes the combinations of damaging agents and affected natural resources shown in Table 1 of Annex III of the Regulation of partial development of Law 26/2007, of 23 October, for calculating the Environmental Damage Index, which essentially matches the one used in the Environmental Liability Supply Model (MORA).

Table 3 is considered to include the combinations which most commonly appear in environmental risk analyses. For each combination, specific models or criteria are provided for estimating the extent of the environmental damage in the following sections of the document. Nevertheless, it is important to stress that the provisions of these criteria are not binding, meaning that operators can choose to adopt them or not, or even modify them within their environmental risk analyses. In any case, the recommendation is that the decisions be duly justified and, if significant uncertainty is identified, the most conservative values available be used in keeping with the precautionary principle.

Table 3 does not include the damage caused by biological agents, given that their high specificity prevents general indications being provided to quantify them for all operators. As such, operators that need to select this type of agent must consider them by taking account of their specific characteristics within their corresponding environmental risk analyses.

In contrast, the combination of the emission of chemical agents into the atmosphere has been included in the table, solely taking into account the atmosphere as the pollution vector, given that it is not found within the resources defined by the environmental liability regulations. Therefore, this type of damage would only be considered if the agent ultimately causes significant damage to one of the natural resources covered by the law.

<table>
<tr><td colspan="3" rowspan="4"></td><th colspan="8">Natural resource</th><th>Vector</th></tr>
<tr><th colspan="3">Waters</th><th rowspan="3">seabed and inland waters' bed</th><th rowspan="3">Soil</th><th rowspan="3">shoreline and coastal inlets</th><th colspan="2">Species</th><th rowspan="3">Atmosphere</th></tr>
<tr><th rowspan="2">Marine</th><th colspan="2">Inland</th><th rowspan="2">Plants</th><th rowspan="2">Animals</th></tr>
<tr><th>Surface</th><th>Groundwater</th></tr>
<tr><th rowspan="11">Damaging agent</th><th rowspan="7">Chemical</th><td>Halogenated VOCs</td><td rowspan="5">C1</td><td rowspan="7">C2</td><td rowspan="7">C3</td><td rowspan="4"></td><td rowspan="7">C5</td><td rowspan="5">C6</td><td rowspan="7">C7</td><td rowspan="7">C8</td><td rowspan="7">V1</td></tr>
<tr><td>Non-halogenated VOCs</td></tr>
<tr><td>Halogenated COSVs</td></tr>
<tr><td>Non-halogenated COSVs</td></tr>
<tr><td>Fuels and CONVs</td><td rowspan="3">C4</td></tr>
<tr><td>Inorganic substances</td><td></td><td></td></tr>
<tr><td>Explosives</td><td></td><td></td></tr>
<tr><th rowspan="3">Physical</th><td>Extraction/Disappearance</td><td></td><td>C9</td><td>C10</td><td></td><td>C11</td><td></td><td>C12</td><td>C13</td><td></td></tr>
<tr><td>Dumping of inerts</td><td></td><td></td><td></td><td>C14</td><td>C15</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Temperature</td><td></td><td>C16</td><td></td><td></td><td>C17</td><td></td><td>C18</td><td>C19</td><td></td></tr>
<tr><td colspan="2">Fire</td><td></td><td></td><td></td><td></td><td></td><td></td><td>C20</td><td>C21</td><td></td></tr>
</table>

VOCs volatile organic compounds (boiling point <100ºC)
VOCs semi-volatile organic compounds (boiling point between 100-325ºC)
VOCs non-volatile organic compounds (boiling point >325ºC)

Table 3. Combinations of damaging agents and affected natural resources. Source: by the authors, based on the Regulation of partial development of Law 26/2007, of 23 October.

The following sections deal specifically with each of the different combinations, indicating where applicable the input data required, the results obtained and the data which must be entered in MORA in order to assess the cost of environmental damage if this model is used.

4.3.1. Modelling of pollution of seawater by chemical agents (C1)

In the MIRAT for the foundry sector produced by the Spanish Federation of Foundry Associations (FEAF) and available on the Ministry for the Ecological Transition and the Demographic Challenge website[18], the proposal is to make decisions on quantifying this type of damage by first observing the solubility of the damaging agent.

When the agent is soluble in seawater, in general, it may be assumed that the volume of water of the affected resource (in this case the ocean or sea) will permit the dilution of the agent in a short space of time, not generating significant damage or, in the case that it is generated, it can be remedied by means of natural recovery. If the operator justifies the adoption of natural recovery, it must be taken into account that this remediation technique (permitted by the environmental liability regulations) does not necessarily imply zero remediation costs. In fact, in accordance with MORA, it is necessary to include at least the costs associated with the consulting work and the work to review and monitor the pollution caused in order to confirm that the seawater effectively recovers its baseline condition. In any case, the analyst must also analyse the damage which could be caused to other natural resources, such as animal and plant species.

[18]https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/responsabilidad-mediambiental/memoriamirat_tcm30-378584.pdf

When the substance spilled is not soluble in seawater, its density or its tendency to precipitate on the seabed can be taken into account in order to design the procedure to quantify the damage, given that, at least *a priori* and in a certain proportion, the possibility could exist that the spill would be deposited on the seabed or remain floating on the surface. Given that the safety data sheets of chemical substances provide data on their physicochemical properties, these can be used as a reference to justify the decisions made.

The proportion of the spill which ends up deposited on the seabed can be quantified by taking account of criterion C4 set out below.

As for the fraction of the spill which is estimated to remain floating on the surface, the analyst could rely on bibliographical sources or dispersion models of pollution considered valid and adequate for the case in question. By way of example, USEPA (2010) includes different average thicknesses of spills in seawater. Therefore, by dividing the volume of the spill by the average thickness of the spill, a measure of the extent of the slick expressed in square metres of seawater affected would be obtained.

Mean equilibrium thickness	Value (cm)	Value (m)
Temperate waters	0,00254	0,0000254
Cold waters	0,25400	0,0025400

Table 4. Reference thickness values for spills in seawater. Source: by the authors, based on USEPA (2010).

For damage by chemical agents in seawater, MORA requires the quantity of the damaging agent which would be spilled into the resource (expressed in tonnes) and the quantity of seawater damaged (expressed in cubic metres) to be entered.

The quantity of damaging agent which is released should be determined directly by the operator once it has its environmental risk assessment, given that guidelines for estimating this figure should be provided by these documents.

As for the quantity of seawater damaged, expressed in cubic metres, the operator can establish an average depth of seawater that would be affected under the slick which has been determined based on USEPA (2010), among other possible references. If this process is associated with significant uncertainty, the recommendation is to adapt it as far as possible to each specific case and use a value considered conservative, in keeping with the precautionary principle.

Table 5 summarises the input and output data relating to the proposed quantification criterion. Meanwhile, Table 6 shows an example of applying this criterion using hypothetical input data.

Data Type	Datum	Unit	Source
Input	Amount spilled to seawater	m^3	Operator
	Thickness of discharge slick	m	USEPA (2010)
	Depth of seawater affected	m	Operator
Output	Surface area affected	m^2	-
	Volume affected	m^3	-
Enter in MORA	Amount spilled to seawater	m^3	Operator
	Volume affected	m^3	-

Table 5. Input and output data for the proposed quantification criterion. Source: by the authors.

Data Type	Datum	Value	Unit	Source
Input	Amount spilled to seawater	10	m^3	Operator
	Thickness of discharge slick	0,00254	m	USEPA (2010)
	Depth of seawater affected	5	m	Operator
Output	Surface area affected	3.937	m^2	-
	Volume affected	19.685	m^3	-
Enter in MORA	Amount spilled to seawater	10	m^3	Operator
	Volume affected	19.685	m^3	-

Table 6. Application of the proposed quantification criterion to a hypothetical example. Source: by the authors, based on USEPA (2010).

4.3.2. Modelling of pollution of inland surface water by chemical agents (C2)

In the MIRAT for the foundry sector produced by the Spanish Federation of Foundry Associations (FEAF) the proposal is to follow a similar quantification procedure to the one designed for quantifying damage caused by chemical agents to seawater. However, in this case, a series of additional specifications are drawn up based on whether the damage occurs to a watercourse (river, stream, etc.) or a relatively static body of water (lakes, reservoirs, etc.).

As such, first the analyst would determine whether the spill dissolves in the water or not, being able use the water solubility data included in the corresponding safety data sheets of the chemical substances, among other factors. In the case of insoluble substances, the analyst must estimate the fraction of the spill which would precipitate to the bed and the fraction which would remain on the surface of the body of water. The damage caused by the first fraction would be subject to quantification in accordance with a specific procedure, for which the indications given in Section C4 can be consulted. For the second fraction and water-soluble substances, the following indications are given based on the type of body of water affected by the accident:

- Quantification criteria for damage by chemical substances to watercourses
  If the watercourse which receives the spill has a containment structure downstream (dam, weir, etc.), the analyst can determine that the damage remains contained by this structure and that, therefore, the quantification of the damage can follow the quantification criteria given for static bodies of water provided in subsequent paragraphs.

  If, on the contrary, the watercourse does not have any containment structures or they are located at a distance at which it is not deemed prudent to consider them as containment structures, the analyst must resort to other criteria to quantify the damage. By way of example, the volume of water polluted could be estimated by multiplying the flow rate of the river by the time that the pollutant remains in the water, or the volume of water required to dilute the spill to concentrations not considered significant could be calculated, etc.

  In order to implement these criteria, parameters inherent to the environment are useful, such as the flow rate of the river, the quality of the body of water prior to receiving the spill, maps of containment structures, etc. In any case, the analyst must seek to obtain an estimate of the volume of water which would be significantly affected as a result. Subsequently, the remediation techniques would be scaled based on this volume, enabling a justified natural recovery of this resource.

  In the case of opting for natural recovery, it must be remembered that it is not necessarily associated with zero remediation costs, given that, by way of example, in accordance with the MORA methodology, the costs associated with the consulting work and the work to review and control the recovery of the baseline condition must be allocated. Additionally, opting for natural recovery of the water does not exempt the operator from considering and evaluating, where applicable, the techniques which it should apply to other natural resources which could be affected, such as animal and plant species.

Furthermore, the analyst can study the possibility of determining that it is impossible to recover the baseline condition of the area affected by the damage in a justified manner. In this case, the damage would be declared irreversible, and the design of complementary rather than primary remediation measures would follow.

- Quantification criteria for damage by chemical substances to static water bodies
  In this case, the spill would occur in a static water body (such as a reservoir, a weir, a lake, etc.) or a watercourse which has such an element in close proximity. Within this same category, the analyst can also include the possibility of deploying or building a containment barrier in a short space of time which makes it possible to stop the expansion of the spill (construction of emergency dikes, deployment of floating barriers, etc.).

  Given that under these circumstances the analyst considers the containment of the damaging agent within certain limits, one option would be to assess the adoption of water remediation measures, such as the proposals in MORA or from any other reference source in the field of water decontamination. Likewise, the analyst could assess in a justified manner the natural recovery of the damaged resource or the declaration of the damage as irreversible, based on the specific circumstances.

  The volume of water subject to remediation would be evaluated in relation to the volume of water present in the static body of water.

Taking account of the above, it can be concluded that the procedure for quantifying the damage caused to inland waters largely depends on the specific characteristics of each operator, given that a wide variety of options exist which, at least *a priori*, could be considered manageable. Nevertheless, by way of example, a procedure for quantifying damage based on the reduction of the concentration of the damaging agent to levels not considered significant is set out below. Specifically, the case used as an illustration is based on the one set out in the practical case accompanying the MIRAT for the foundry sector produced by the Spanish Federation of Foundry Associations (FEAF). Among other operations, this practical case calculates the volume of inland water which would be polluted by the spill of a certain substance with a 0.073 mg/l PNEC (concentration of a substance which causes damage to 1% of the population and which is usually included in the safety data sheet of chemical substance).

Table 7 lists the input parameters used for this practical example, which are: the amount spilled into the body of surface water (which must generally be expressed in kilograms and which must be obtained from the operator's environmental risk assessment) and the toxicity threshold selected for use as a reference (in this example it is the PNEC taken from the safety data sheet of the substance). In order to simplify the simulation, assuming that it consists of a valid approximation in keeping with the uncertainty associated with the assessment of environmental risks, the complete and uniform dilution of the substance is assumed.

Data Type	Datum	Unit	Source
Input	Amount spilled	kg	Operator
	PNEC	mg/l	Safety data sheet
Output	Amount of damaged water	m^3	-
Enter in MORA	Amount of damaged water	m^3	-

Table 7. Sample input and output data for the proposed quantification criterion. Source: by the authors, based on the MIRAT for the foundry sector produced by the Spanish Federation of Foundry Associations (FEAF).

Table 8 illustrates the calculation with data taken from the practical case accompanying the MIRAT for the foundry sector produced by the Spanish Federation of Foundry Associations (FEAF). Specifically, as input data the amount spilled has been taken to be 11.9 m^3, converted to kg using the density figure for the substance included in the corresponding safety data sheet and subsequently to milligrams by multiplying by 10^6. Subsequently, the PNEC taken from the safety data sheet (0.073 mg/l) is considered and the volume of water potentially affected is calculated by dividing the amount spilled (in mg) by the PNEC (in mg/l). Finally, the amount damaged was expressed in m^3, as these are the units required by MORA.

Data type	Datum	Value	Unit	Source
Input	Amount spilled	11,9	m^3	Operator
	Amount spilled	16.006	kg	Safety data sheet
	Amount spilled	1,601E+10	mg	Operator
	PNEC	0,073	mg/l	Safety data sheet
Output	Amount of damaged water	2,193E+11	l	-
	Amount of damaged water	219.253.425	m^3	-
Enter in MORA	Amount of damaged water	219.253.425	m^3	-

Table 8. Application of the proposed quantification criterion to a hypothetical example. Source: by the authors, based on the MIRAT for the foundry sector produced by the Spanish Federation of Foundry Associations (FEAF).

It is worth reiterating once again that, as with other quantification processes, the procedure for quantifying damage to surface water depends to a large degree on the particular circumstances and characteristics of each operator. Specifically in the case illustrated, it was determined that from the point of the spill to the river mouth there was not enough water to reduce the concentration to non-toxic values. For this reason, a severe damage zone was specified (using the LC50 toxicity threshold included in the safety data sheet for this purpose) and it was determined that the rest of the river (to the outlet to the sea) would suffer chronic effects (affecting 10% of the fish population). Taking account of these characteristics of the accident, it was decided to justify natural recovery of the surface water on assuming that the spill could not be contained before reaching the sea in light of the flow-rate data and the speed of the river, sourced from the gauging stations managed by the corresponding Hydrographic Confederation. In any event, it is important to reiterate once again that adopting natural recovery as a remediation measure for surface water, on the one hand, does not necessarily imply zero remediation costs for the resource and, on the other, does not exempt the additional assessment of the possibility of the other natural resources which could have been damaged being affected, mainly fish (animal species) and riverside vegetation (plant species). In order to quantify both natural resources, the operator can take the quantification criteria proposed in the following sections as a reference.

4.3.3. Modelling pollution due to damage to land and groundwater (C3 and C5)

Land and groundwater are natural resources included in the regulations on environmental liability. Therefore, an operator that damages these resources (or threatens to do so) must take the necessary preventive, avoidance and/remediation measures, as the case may be. Likewise, operators confirming that these natural resources are susceptible to damage as a result of their activity will have to include this possible damage in their risk analyses and, if the reference scenario for calculating the financial security includes damage to these resources, they must be able to quantify and cost the damage and to differentiate to what degree each resource will be affected. Solutions must be found which facilitate the task of operators quantifying damage to land and/or groundwater, as well as the distribution between the two resources.

The Technical Commission for the Prevention and Remediation of Environmental Damages (CTPRDM) has published the document *Analysis of tools for evaluating the spread and behaviour* *of chemical agents in the context of environmental liability regulations*[19], as well as a range of rate tables and risk analyses which illustrate the quantification of damage to these resources.

The document offers a number of alternatives for modelling damage to land and/or groundwater. The following table shows the main characteristics of the models included in it, which are:

- Model name.
- Model type. Two types of models are identified: analytical and numerical.
- Cost. Free models are differentiated from those where users must pay for a licence.
- Resource. Refers to the resource(s) which the model is appropriate for, distinguishing between land, groundwater, and land + groundwater.
- Some of the models can also be used for other resources ("Groundwater + land + others") such as the atmosphere -not included in environmental liability law as a natural resource, but as a pollution vector- or surface water. Nevertheless, given that this section solely deals with damage to land and to groundwater, the other resources have not been included in the table.
- Substances. The different substances for which the model is appropriate are indicated, distinguishing between metals, chlorinated solvents, SVOCs, insecticides/PCBs, hydrocarbons and radionuclides.

Model	Model type	Cost	Resource	Substances
BIOSCREEN	Analytical	Free	Groundwater	Multiple substances[20]
BIOCHLOR	Analytical	Free	Groundwater	Chlorinated solvents
BIOPLUME III	Numerical	Free	Groundwater	Hydrocarbons
CONSIM	Analytical	Licence	Groundwater + land	Multiple substances[21]
HSSM	Analytical	Free	Groundwater + land	Hydrocarbons and SVOCs
RBCA TOOL KIT	Analytical	Licence	Groundwater + land + others	Multiple substances[22]
RISC Workbench	Analytical	Licence	Groundwater + land + others	Multiple substances[23]
Modflow/MT3DMS	Numerical	Licence	Groundwater + land	Multiple substances[24]

Table 9. Types of dispersion models for analysing damage to land and groundwater. Source: By the authors, based on the document "Analysis of tools for evaluating the spread and behaviour of chemical agents in the context of environmental liability regulations".

[19]https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/responsabilidad-mediambiental/herramientasdeevaluaciondifusionycomportamientoagentesquimicos_251019_tcm30-177407.pdf

[20] Metals, chlorinated solvents, SVOCs, insecticides/PCBs, hydrocarbons and radionuclides.

[21] Metals, chlorinated solvents, SVOCs, insecticides/PCBs, hydrocarbons and radionuclides.

[22] Metals, chlorinated solvents, SVOCs, insecticides/PCBs and hydrocarbons.

[23] Metals, chlorinated solvents, SVOCs, insecticides/PCBs and hydrocarbons.

[24] Metals, chlorinated solvents, SVOCs, insecticides/PCBs, hydrocarbons and radionuclides.

Out of the models indicated in the table above, only four are free, and only the HSSM model can be used to analyse damage to both resources. Nevertheless, the document prepared by the CTPRDM indicates that "*the use of this model requires a high degree of knowledge about pollution transport models, including multiphase transport models*" and "*the model requires expert knowledge of hydrogeology and LNAPL migration to ensure that it is used correctly and its limitations are interpreted appropriately*".

Meanwhile, the rate tables and risk analyses by the CTPRDM which illustrate the quantification of this damage to these resources have generally been based on the model developed by Grimaz et al*.* (2007 and 2008) given that it is simple (requiring few input parameters) and free of charge.

Additionally, there are other models such as *GreenAmpt* which, while very robust, require a large amount of information to be provided (and with great precision), which can be difficult for operators to obtain.

As a result of the above analysis of the possible tools available to operators for assessing damage to land and/or groundwater, it has been decided to focus this section on looking at the model proposed by Grimaz et al*.* (2007 and 2008) in greater depth, given that it combines the following characteristics:

- Free.
- It requires few input parameters.
- It permits the quantification of damage to both land and groundwater.
- There are sector-specific risk analyses from different sectors carried out by the Directorate-General of Environmental Quality and Assessment, which illustrate its application.
- It permits certain simplifications which make it even easier to use

Grimaz et al*.* (2007) develops a model for impermeable soils, and based on this, performs a series of simplifications which allow the area of the spill (A_{pool}) to be estimated on permeable soils as well.

On the other hand, the equations of these models vary based on whether the terrain in the spill location is flat or sloped. As such, the model establishes an equation for the area of the spill (A_{pool}), which varies based on whether the land is flat (circular area) or sloping (elliptical area). Additionally, the model determines an equation for establishing the depth reached by the spill; this depth can be calculated under the soil saturation hypothesis (h) or without the saturation hypothesis (D_{MP}).

4.2.4. Modelling pollution by chemical agents of the bed of inland surface waters and marine waters (C4)

In the MIRAT for the foundry sector produced by the Spanish Federation of Foundry Associations (FEAF) it is assumed that, for a certain damaging agent to reach the bed of the water, it must first have passed through it. Therefore, at least in principle, a fraction of the agent could remain floating on the surface and/or dissolved in the body of water, and only a certain proportion would precipitate to the bottom. In this regard, the recommendation is that the analyst jointly consider the criteria included in Sections C1, C2 and C4. As such, the analyst must determine the amount of the damaging agent which reaches the bed, considering, among other aspects, parameters such as the solubility of the substance in water, its relative density, etc.

Once the quantity of the damaging agent which will end up deposited on the seabed or the bed of the inland waters has been calculated, the analyst must determine the extent of the damage expressed in units of the resource.

In order to estimate the quantity of the bed damaged, the analyst can consider aspects such as the carrying capacity of the current and the degree of mobility of the substance (taking account of, by way of example, its density and solubility), with the final objective being to determine the area or volume of the bed affected. By way of guidance, it could be determined that the spill of a substance with limited mobility in calm waters would result in a reduced extent. In contrast, spills of highly mobile substances in fast-flowing waters could result in greater dispersion of the pollution on the bed.

In the case of spills into watercourses and the existence of containment structures across them downstream (dikes, dams, etc.), one option to consider would consist of assuming that the spill will expand until retained by the containment structure. This way, the extent could be estimated more simply as the area defined by the length travelled by the spill and the average width of the watercourse, conservatively estimating an average depth of the polluted bed to be removed.

In any case, whenever it is deemed that a relevant degree of uncertainty exists associated with the calculation process, the recommendation is to follow the precautionary principle by adopting the most unfavourable values.

It is important to stress, once again, that the application of the guidelines included in this section is largely based on each specific case, meaning that the analyst must adapt them if they wish to include them in their risk analyses and always justify their decisions. Nevertheless, by way of illustration, Table 10 includes certain input and output parameters which the operator could assess to determine the damage to the bed. Subsequently, Table 11 assigns specific values in order to provide an example of the procedure, which are not based on a real case.

Data type	Datum	Unit	Source
Input	Amount Spilled	t	Operator
	Solubility in water	-	Safety data sheet
	Density of the substance	-	Safety data sheet
	Distance to nearest dyke	m	Operator
	Average width of watercourse	m	Operator
	Surface area affected	m^2	Operator
	Depth of affected bed	m	Operator
	Volume of affected bed	m^3	Operator
	Density of bed material	t/m^3	Operator
	Amount of bed damaged	t	Operator
Output	Total amount of bed damaged	t	Operator
Entre in MORA	Total amount of bed damaged	t	Operator

Table 10. Sample input and output data for the proposed quantification criterion. Source: by the authors.

The numerical example proposed below simulates an operator's calculation, based on the data on the safety data sheet of the substance (insoluble and high density), determining the total amount of the spill which is deposited on the bed. In order to provide a conservative estimate of the quantity of the bed affected, the operator determines the impact from the point of the spill to the nearest dike located downstream. This way, the potentially affected area is determined by estimating the average width of the watercourse. Subsequently, an average depth of the bed affected by the spill must be established. It is important to stress that, in the event of identifying a high degree of uncertainty in the estimate, conservative values should be selected to ensure the study errs on the side of caution. Finally, the analyst must enter the estimated density for the bed in order to convert the volume units to mass units. The final step consists of adding the amount of the agent spilled (given that the remedial measure must remove it) and the amount of the bed affected, obtaining the total amount of the bed as the result, and this is the value which should be entered into MORA.

Data type	Datum	Value	Unit	Source
Input	Amount Spilled	10	t	Operator
	Solubility in water	Insoluble	-	Safety data sheet
	Density of the substance	High	-	Safety data sheet
	Distance to nearest dyke	1.000	m	Operator
	Average width of watercourse	3	m	Operator
	Surface area affected	3.000	m^2	Operator
	Depth of affected bed	0,30	m	Operator
	Volume of affected bed	900	m^3	Operator
	Density of bed material	1,5	t/m^3	Operator
	Amount of bed damaged	1.350	t	Operator
Output	Total amount of bed damaged	1.360	t	Operator
Enter in MORA	Total amount of bed damaged	1.360	t	Operator

Table 11. Application of the proposed quantification criterion to a hypothetical example. Source: by the authors.

4.2.5. Modelling the pollution of the shoreline and coastal inlets by chemical agents (C6)

The shoreline and coastal inlets are natural resources which, for the purposes of quantifying environmental damage, could be considered a combination of the other natural resources covered by the environmental liability regulations. Therefore, when estimating the extent of the damage caused, the analyst can use the criteria and guidelines provided for land, surface water, groundwater and marine water, and for plant and animal species.

For all of these calculations performed by the analyst, the MORA computer program requires three data points to be entered:

- The amount of shoreline damaged (t). This data point could generally be considered equivalent to the one obtained through the quantification of damage caused by chemical agents to land, as set out in the corresponding section.
- The amount spilled on the shoreline and coastal inlets (t), which is a data point the operator should have based on the corresponding environmental risk assessment.
- The type of effect (partial/total). In accordance with the MORA User Guide, available on the Ministry for the Ecological Transition and the Demographic Challenge website[25], the expected formation of pools, films or layers of polluting agent with a continuous or discontinuous distribution and with a thickness greater than one millimetre is considered totally affected, and the expected formation of slicks or films of polluting agent with a patchy or sporadic distribution with a thickness of less than one millimetre is considered partially affected.

[25]https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/responsabilidad-mediambiental/guiausuarioarm_idm_mora_tcm30-519984.pdf

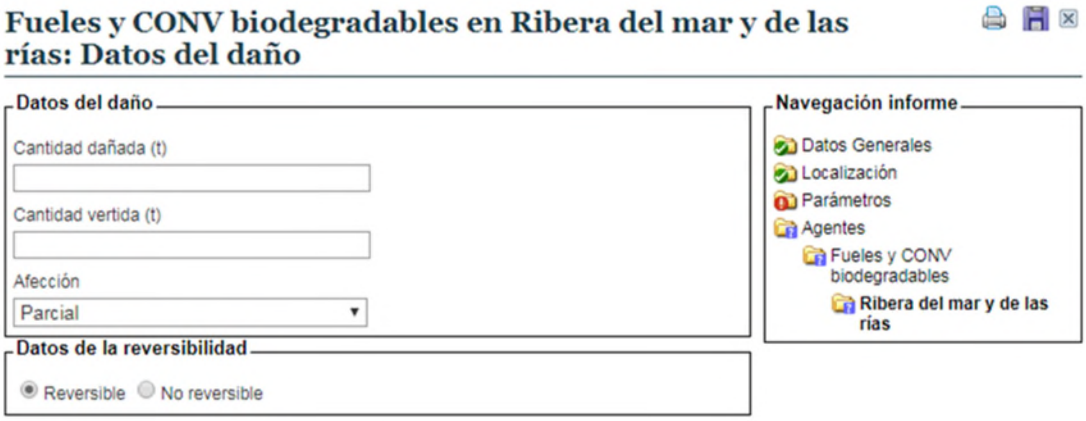

Figure 2. Input data for damage by chemical agents to the shoreline and coastal inlets in the MORA computer program. Source: MORA.

4.2.6. Modelling of the pollution of plant species by chemical agents (C7)

The MIRAT for the foundry sector produced by the Spanish Federation of Foundry Associations (FEAF) proposes quantifying the damage caused by chemical agents to plant species based on the data obtained from quantifying the damage caused by chemical agents to land and/or to surface water, as applicable. Specifically, this MIRAT focuses on the case of spills on land. In this case, the proposal is to take the area affected by the spill obtained in the quantification of damage to land by chemical agents as a reference.

Along these lines, in the case of vegetation adjacent to surface water bodies, the analyst can use the results of the corresponding quantification procedure to estimate the area potentially affected by chemical agents.

Once the potentially affected area has been defined, it is possible to access MORA to find out which plant species are present in the area. Specifically, the map viewer provided by MORA provides the latest Forestry Map of Spain (MFE) created by the Ministry for the Ecological Transition and the Demographic Challenge. This map provides, for each point in the territory, the type of vegetation present (grassland, shrubland, forested land, etc.), the fraction of total canopy cover, the fraction covered by forest and, for the forest species, the relative occupancy of each of the three main species in the selected area. Therefore, once the area affected by the damage is known, the analyst can estimate the fraction of that area which corresponds to each species and/or type of vegetation. In this regard, it may be especially useful to compare the data supplied by the map with those directly observed in the territory in order to ensure the data used match the real situation to the greatest possible degree.

It is worth noting that if the operator, whether by consulting the MFE or by direct observation of the territory, determines a significant effect on grassland and/or shrubland, these natural resources must be expressly selected in MORA, given that the application does not predetermine effects on these natural resources. However, if forest species exist at the point selected, the MORA application does show them and preselect them on the screen, thereby proposing an effect on these resources.

By way of example, Figure 3 shows the plant species (trees) selected by default in MORA for the point X: 414,109.62 and Y: 4,524,216.96. It is therefore stressed that MORA does not select damage to grassland and shrubland by default, so if the analyst determines significant damage to these resources, they must select them manually.

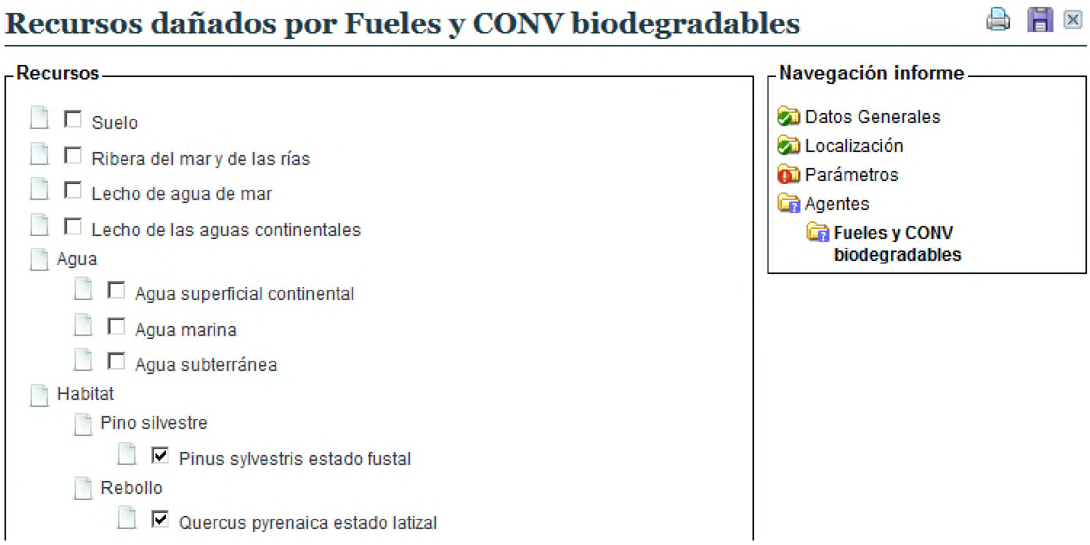

Figure 3. Identification of tree species present at a point. Source: MORA.

Having reached this point, the analyst could express the extent of the damage in terms of the area of each species affected (hectares of grassland, hectares of shrubland and/or hectares of each tree species). Additionally, the analyst could proceed to estimate the extent of the damage in terms of trees or individuals affected.

In order to determine the number of trees or individuals affected, it is necessary to know the density per hectare. Note that, in the case of grassland, this measurement can be of limited utility, and providing the results in terms of the area and qualitative density (high, medium, low, etc.) may therefore be more appropriate.

In the case of woody vegetation, the MORA program proposes density data (trees/ha) for each species taken from the Third National Forest Inventory (IFN3) prepared by the Ministry for the Ecological Transition and the Demographic Challenge. Given that the IFN3 does not include density data for shrubland, a general density of 863 shrubs/ha is proposed for this natural resource in the MORA program. In this regard, once again it is important to remember that the analyst must adopt or modify the data and the quantification process in a justified manner in order to ensure that it reflects their specific case to the greatest possible degree.

Figure 4 shows the data proposed in MORA for the tree species *Pinus sylvestris* at the location X: 414,109.62 and Y: 4,524,216.96; where it can be seen that the density of this species and the fraction of total canopy cover in the area are both reported. The other characteristics of the area, as indicated, can be consulted in the MORA map viewer.

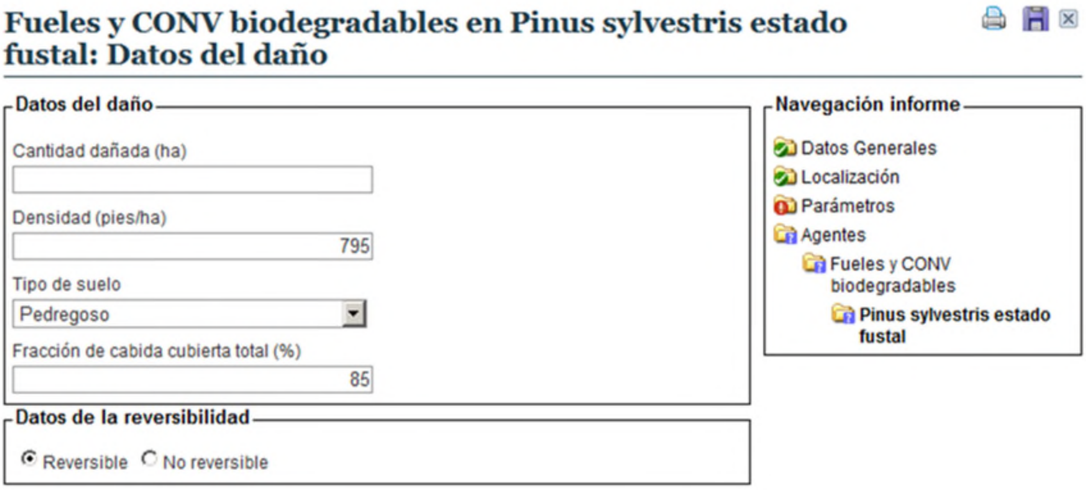

Figure 4. Identification of tree species present at a point. Source: MORA.

Table 12 lists the input data proposed for estimating the area affected corresponding to each plant species. In this regard, the process would start with the total area affected by the damage (calculated by means of other processes, methods or quantification criteria). This area would be assigned to the different plant species which the analyst deems potentially affected, relying, by way of example, on the data on the species present, the fraction of canopy cover, and occupancy of each species as shown in the table.

Data type	Datum	Unit	Source
Input	Affected area by the damaging agent	ha	Operator
	Species present (1…n)	-	Operator-MFE
	Total fractional canopy cover	%	Operator-MFE
	Fractional canopy cover of shrubland	%	Operator
	Fractional canopy cover of trees	%	Operator-MFE
	Occupation of tree species	%	Operator-MFE
Output	Affected area of each species (1...n)	-	-
Enter in MORA	Affected area of each species (1...n)	-	-

Table 12. Sample input and output data for the proposed quantification criterion. Source: by the authors.

In Table 13 some specific numerical values are entered, which do not pertain to a real case, in order to illustrate the calculation process. In this example, damage of an area occupied by two tree species (Scots pine and maritime pine) and shrubland has been assumed. The total affected area (100 ha) has been divided between these three components using the data on fractional canopy cover (total and forested) and the occupancy data in the case of the tree species.

Data type	Datum	Value	Unit	Source
Input	Affected area by the damaging agent	100	ha	Operator
	Species 1: Pinus sylvestris	-	-	Operator-MFE
	Species 2: Pinus Pinaster	-	-	Operator-MFE
	Species 3: Matorral	-	-	Operator-MFE
	Total fractional canopy cover	90	%	Operator-MFE
	Fractional canopy cover of shrubland	10	%	Operator
	Fractional canopy cover of trees	80	%	Operator-MFE
	Occupation of species 1: Pinus sylvestris	90	%	Operator-MFE
	Occupation of species 2: Pinus Pinaster	10	%	Operator-MFE
Output	Area occupied by species 1: Pinus sylvestris	72	ha	-
	Area occupied by species 2: Pinus Pinaster	8	ha	-
	Area occupied by species 3: Shrubland	10	ha	-
Enter in MORA	Area occupied by species 1: Pinus sylvestris	72	ha	-
	Area occupied by species 2: Pinus Pinaster	8	ha	-
	Area occupied by species 3: Shrubland	10	ha	-

Table 13. Application of the proposed quantification criterion to a hypothetical example. Source: by the authors.

4.2.7. Modelling of the pollution of animal species by chemical agents (C8)

The MIRAT for the foundry sector produced by the Spanish Federation of Foundry Associations (FEAF) reflects the mobile nature of fauna (to a greater or lesser degree depending on the taxon or species) and the relative scarcity of quantitative inventories and/or maps on the populations and their densities which hinders the precise estimation of the number of individuals affected by a spill of chemical substances. As such, in general, significant uncertainty can be foreseen when determining both the populations which exist in a certain territory and the specific number of individuals which could be present at the time of an environmental accident. It is therefore worth stressing once again the recommendation that in such cases operators should align their studies with the precautionary principle by selecting the most conservative values available.

The estimate of the species and the number of individuals affected can be based on data on the extent of the damage calculated for the other natural resources where animal species are found: land, water, plant species, etc.Once the area of a river affected by damage has been determined, it would be possible to start assessing the species which exist in that area. To this end, it is especially useful to be able to rely on fauna inventories referring to specific territories and which include data on both the species present and the number of individuals in each population.

Nationally, it is possible to cite the Spanish Inventory of Land Species (IEET)[26] provided by the Ministry for the Ecological Transition and the Demographic Challenge, which can be consulted via its website, and which identifies the species in each 10 by 10 km grid square into which the territory is divided. The disadvantage of this source is that it only provides qualitative data, meaning that the final estimate of the extent of the damage would be the responsibility of the operator.

[26] https://www.miteco.gob.es/es/biodiversidad/temas/inventarios-nacionales/inventario-especies-terrestres/inventario-nacional-de-biodiversidad/bdn-ieet-default.aspx

On the other hand, the forms of each Natura 2000 protected area, also available on the Ministry for the Ecological Transition and the Demographic Challenge website[27] can be particularly useful, given that they provide quantitative estimates of the existing populations. These data can be taken as a reference in a justified manner within environmental risk analyses. By way of example, the operator could begin with the data of a Natura 2000 protected area close to its area or one which has similar characteristics to the area potentially affected by the damage in question.

In any case, whenever possible it is preferable to perform a bibliographic search aimed at locating specific inventories of the area under study or, in their absence, areas which can be considered similar.

The intermediate results which must be available to the operator are the species and the number of individuals present in the area affected by the damage, usually based on a specific population density figure.

On the other hand, given that the damaging agent is a chemical, if sufficient data are available, the operator could take into account the concentration reached by the agent in the environment and the toxicity thresholds of the substance released. The data required to carry out this operation would be the predicted environmental concentration (PEC) and the threshold starting at which certain toxic effects occur (PNEC, LC50, NOEC, etc.).

The Regulation of partial development of Law 26/2007, of 23 October, on Environmental Liability, differentiates between the toxicity thresholds included in Table 14, without prejudice to the operator being able to use different ones where justified. For each toxicity threshold in this table, there is also a percentage loss of individuals of the population which must be adopted in environmental risk analyses in accordance with Article 34 of the Regulation for partial development of Law 26/2007, of 23 October.

For practical reasons, the lethal category has been added to the levels of damage intensity in the regulations (severe, chronic and potential), which, by applying the precautionary principle, assumes the loss of the entire population.

The use of Table 14 would start with the predicted environmental concentration (PEC), with the possibility of establishing different impact zones based on this concentration. The PEC value should be calculated by the operator taking account of the pollution dispersion models considered most appropriate, with the possibility of considering the criteria set out in this document (for land, water, etc.) or others considered appropriate, where justified.

The PEC obtained would be compared with the toxicity threshold selected in a justified manner as the most appropriate from among those included on the substance's safety data sheet. It should be noted that, in general, safety data sheets provide different thresholds based on exposure time, the receiving organism, the receiving environment, etc. By comparing the PEC with the toxicity threshold, the percentage of individuals of the population which would be lost would be determined in each zone assessed.

Alternatively, following the precautionary principle, the operator could assume the loss of 100% of the individuals of the population (lethal damage). In this case, it would not be necessary to calculate the PEC and compare it with the toxicity threshold, given that the extent would coincide with the total number of individuals exposed to the agent.

[27] https://www.miteco.gob.es/es/biodiversidad/temas/espacios-protegidos/red-natura-2000/rn_espana_espacios.aspx

Expected concentration	Toxicity threshold	Criterion	Type of effect (intensity)	Loss of individuals (%)
PEC	PNEC	PEC>PNEC	Potential	5
	NOEC	PEC>NOEC	Chronic	30
	NOAEL	PEC>NOAEL		
	LC50	PEC>LC50	Acute	75
	LD50	PEC>LD50		
	EC50	PEC>EC50		
-	-	-	Lethal	100

Table 14. Sample toxicity thresholds, decision criteria for each type of effect, and the percentage loss of individuals. Source: by the authors.

In order to provide a specific example of the above proposals, Table 15 summarises a series of possible input data and the output data which could be obtained in the quantification of damage to animal species by chemical agents.

Data type	Datum	Unit	Source
Input	Amount of affected resource	ha, m^2, m^3…	Operator
	Species present (1...n)	-	Operator-inventories
	Species density (1...n)	Ind/resource unit	Operator-inventories
	Population exposed to the damaging agent	Individuals	Operator
	PEC	mg/l	Operator
	Toxicity threshold	mg/l	Safety data sheet
	Damage intensity	-	Operator
	Percentage of population lost	%	Operator
Output	Number of individuals	Individuals	-
Enter in MORA	Number of individuals	Individuals	-

Table 15. Sample of possible input data for quantifying damage to animal species by chemical agents. Source: by the authors.

Table 16 provides a hypothetical numerical example to illustrate a procedure for quantifying damage to fish present in a river. Specifically, in the example, damage of 2 ha (area measurement) of the river has been entered in which a fish density of 5,940 individuals/ha has been estimated, and therefore the population exposed to the agent is 11,880 individuals. The concentration of the toxic substance estimated by the operator, referring to the dispersion models and criteria considered most appropriate, in the affected area is estimated at 100 mg/l. Assuming that the substance's safety data sheet includes an LC50 value of 90 mg/l, the operator could assume chronic damage. Specifically, in this example, the loss of 75% of the exposed population is established, which is 8,910 individuals. Alternatively, the operator, following the precautionary principle or in the absence of PEC data and/or toxicity thresholds, could have declared the damage as being of lethal intensity and assumed the loss of all of the exposed individuals (11,880).

Data type	Datum	Value	Unit	Source
Input	Amount of affected resource	2	ha	Operator
	Inland fish	-	-	Inventories
	Inland fish density	5.940	ind/ha	Operator-inventories
	Population exposed to the damaging agent	11.880	individuals	Operator
	PEC	100	mg/l	Operator
	LC50	90	mg/l	Safety data sheet
	Damage intensity	Acute	-	-
	Percentage of population lost	75	%	Operator
Output	Number of individuals	8.910	individuals	-
Enter in MORA	Number of individuals	8.910	individuals	-

Table 16. Application of the proposed quantification criterion to a hypothetical example. Source: by the authors.

4.2.8. Modelling of the damage from the extraction/disappearance of natural resources (C9-C13)

The "extraction or disappearance of natural resources" agent can cover a wide variety of accidental episodes which result in the natural resource in question disappearing or ceasing to be in the place where it was originally found. Therefore, it can encompass different scenarios, such as explosions, the extraction of resources above certain limits or outside certain established geographical boundaries, the carrying of resources due to the release of large volumes of non-toxic substances (such as water or inert materials), etc.

Given the heterogeneity of these episodes, it is difficult to offer guidelines or criteria which are valid for the different situations encountered by operators during their corresponding environmental risk analyses. For this reason, the recommendation is that the quantification procedure be designed specifically and in a justified manner as part of the environmental risk analyses.

In any case, the result obtained must be the quantity of the resource which would be extracted or which would disappear due to the effect of the accident under consideration. To this end, it is stressed that if significant uncertainty exists, conservative criteria should be adopted to ensure the study errs on the side of caution.

4.2.9. Modelling of the damage from spills of inert natural resources (C14-C15)

Inert waste is defined in Royal Decree 1481/2001, of 27 December, regulating the elimination of waste through landfill, as "*non-hazardous waste that does not undergo any significant physical, chemical or biological transformations. Inert waste will not dissolve, burn or otherwise physically or chemically react, biodegrade or adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm human health. The total leachability and pollutant content of the waste and the ecotoxicity of the leachate must be insignificant, and in particular not endanger the quality of surface water and/or groundwater*". Therefore, the analyst could assume that the area affected by the damage is limited to the area receiving the accidental spill of inert waste. Generally, it is considered that the area must be established by each operator taking account of its specific characteristics and the indications in this regard provided by its environmental risk assessment.

The input data required in MORA to assess damage by inert agents depend on the natural resource affected, as shown in Table 17.

Affected natural resource	Input data	Unit
Soil	Amount spilled	t
	Amount damaged	t
Bed of inland waters	Amount damaged	t
Seabed	Amount damaged	t

Table 17. Data required in MORA for assessing damage caused by inert agents. Source: by the authors.

In the case of spills on land, the analyst must estimate the amount spilled and the quantity of land damaged. The first parameter should come directly from hypotheses stated in the corresponding environmental risk assessment. The quantity of land damaged must be estimated on a case-by-case basis taking account of the specific characteristics of each operator and the accidental episode under assessment.

Meanwhile, where applicable, the analyst must calculate the amount of the bed damage (inland and/or marine) in a justified manner and state the results in tonnes.

It is worth noting that the amount of the resource damaged should comprise, as a minimum, the amount of inert material spilled in the environment in order for the MORA calculations to assess, at least, the removal of the damaging agent. This minimum value could be increased by each operator taking account of the criteria deemed most appropriate for the case in question.

4.2.10. Modelling damage from temperature changes to inland surface water (C16)

In the MIRAT for the foundry sector produced by the Spanish Federation of Foundry Associations (FEAF), a method is proposed for estimating the volume of water which could undergo a certain change in temperature due to a water spill.

This method proposes starting with thermodynamics equations, specifically the equation relating heat to the specific heat capacity, system mass and the temperature variation experienced.

The heat associated with the spill would be defined by the following expression:

$$Q_s = m_s \times C_p \times (T_s - T_f) \qquad \text{[Eq.21]}$$

Where:

Q_s, is the heat transferred by the water spilled (kcal)

m_s, is the volume of the the hot water spilled [flow rate at which the spill occurs (m^3/s) if the receiving water body is a river or stream and amount of hot water spilled (m^3) if the receiving water body is a lake or reservoir]

C_p, is the specific heat capacity of the water (1 kcal/kg·°C)

T_s, is the temperature at which the spill occurs (°C)

T_f, is the temperature to which the spill would fall on mixing with the water of the receiving water body(°C)

On the other hand, as for the receiving body of water, the heat absorbed is evaluated by the same expression but adapted to this medium:

$$Q_{body} = m_{body} \times C_p \times (T_f - T_{body}) \qquad \text{[Eq. 22]}$$

Where:

Q_{body}, is the heat absorbed by the receiving body of water (kcal)

m_{body}, is the volume of the receiving water bdoy [flow rate of the water body (m^3/s) if the receiving water body is a river or stream, and volume of the receiving water body (m^3) if the receiving water body is a lake or reservoir]

C_p, is the specific heat capacity of the water (1 kcal/kg·°C)

T_{body}, is the temperature at which the receiving surface water body is found (°C)

T_f, is the temperature to which the water of receiving water body would rise on mixing with the water spilled (°C)

In accordance with the laws of thermodynamics, if two masses at different temperatures come into contact, they will exchange heat until their temperatures are equal. Therefore, at the point of equilibrium $Q_s = Q_{body}$ will be true.

As such, assuming the flow rate or the volume of the spill (m_s) is known, along with the temperature of the water spilled (T_s), as well as the flow rate or volume and the temperature of the water body into which the spill occurs (m_{body} and T_{body}), it is possible to estimate the temperature which the surface water body will rise to when the spill occurs:

$$T_f = \frac{m_s \times T_s + m_{body} \times T_{body}}{m_s + m_{body}} \qquad \text{[Eq. 23]}$$

Where:

T_f, is the temperature to which the receiving water body rises (°C)

m_s, is the volume of the mass of the hot water spilled [flow rate at which the spill occurs (m^3/s) if the receiving water body is a river or stream and amount of hot water spilled (m^3) if the receiving water body is a lake or reservoir]

T_s, is the temperature at which the spill occurs (°C)

m_{body}, is the volume of the receiving water body [flow rate of the body of water (m^3/s) if the receiving water body is a river or stream and volume of the receiving water body (m^3) if the receiving water body is a lake or reservoir]

T_{body}, is the water temperature of the water body (°C)

In the above expression, the figures for the flow rate or the total volume of water spilled and the temperature at which the spill occurs should be provided directly by the operator's environmental risk assessment.

On the other hand, the flow rate (for rivers, streams, etc.) or receptor volume (for lakes, reservoirs, etc.) and temperature data of the media must be consulted by the operator with reference sources such as Hydrographic Confederations. In any case, the values selected must be duly justified.

The end result of this process is the estimation of the temperature reached by the body of water receiving the spill (T_f). Based on this figure, the analyst can adopt the following decisions:

- If the value of T_f reached is deemed to involve significant damage to fish species, the analyst must consider remediation of this damage. In this regard, the indications provided in Section C8 could be used as a basis for identifying the species and quantifying them.
- If, on the contrary, the value of T_f reached would not cause significant damage to the species, it could be assumed, always providing justification, that no significant damage would be caused to them and the assessment of the damage could be focused on remedying the surface water.

By way of illustration, Table 18 reproduces the information published in the MIRAT for the foundry sector produced by the Spanish Federation of Foundry Associations (FEAF) relating to the temperature at which physiological damage begins to appear in a sample of fish species based on their life cycle. In any case, the analyst must identify the species present in the specific situation and assess the possibility of damage to them with the data which best fit their characteristics.

Scientific name	Common name	Upper limit (ºC)				
		Embryos	Larvae	Juvenile ind.	Adults	Spawning
Barbus barbus	Common barbel	-	24	32	32	20
Telestes souffia	-	-	-	-	27	15
Leuciscus cephalus	-	30	-	30	30	30
Gobio gobio	Goby	-	-	-	36	17
Gymnocephalus cemuus	Ruffe	24	-	30	31	18
Chondostroma nasus	-	20	28	-	-	14
Albumoides bipunctatus	Chub	-	-	-	27	21
Chondostroma toxostoma	Nase	-	-	-	-	14
Leuciscus leuciscus	Common dace	25	-	-	32	12

Table 18. Temperature starting at which physiological damage appears in a series of fish species based on their state. Source: by the authors, based on Souchon and Tissot (2012) cited in the MIRAT for the foundry sector produced by the Spanish Federation of Foundry Associations (FEAF).

If the analyst deems that the temperature reached by the water body (T_f) receiving the spill of hot water exceeds the damage threshold, the quantification of the environmental damage caused to the surface water (i.e., the volume of water of the body of water receiving the spill which has reached the temperature T_f) will be the value of the variable m_{body}, which is calculated with the following equation:

$$m_{body} = \frac{m_s \times (T_s - T_f)}{(T_f - T_{body})} \quad \text{[Eq.24]}$$

Where:

m_{body}, volume of the receiving body of water that reached the temperature T_f (m^3)

m_s, volume of hot water spilled (m^3) (where applicable, it can be estimated as the flow rate of the spill times the response time)

T_s, is the temperature at which the spill occurs (°C)

T_{body}, is the temperature at which the receiving surface water body is found before the spill (°C)

T_f, is the temperature to which the receiving water body rises (°C)

As such, a simplified and conservative procedure to proceed to quantify this type of damage would consist of defining the temperature at which damage would be produced in the receiving receiving environment (T_f), providing justification, and calculating the volume of the receiving receiving environment (m_{body}) which would reach that temperature and which, therefore, would be subject to remediation. As has been indicated, the possible damage to species must be quantified expressly, and the indications offered in Section C8, among other references, can be followed. Table 19 illustrates this calculation procedure through a series of input and output data, and Table 20 provides a hypothetical numerical example.

Data type	Datum	Unit	Source
Input	Volume of spilled hot water (mv)	m^3	Operator
	Temperature at which the spill occurs (tv)	ºC	Operator
	Temperature of the surface water body prior to spill (Tmasa)	ºC	Operator
	Temperature to which the water in the receiving body rises (tf)	ºC	Operator
Output	Amount damaged	m^3	-
Enter in MORA	Amount damaged	m^3	-

Table 19. Sample of possible input data for quantifying damage to animal species by changes in the temperature of surface water. Source: by the authors.

The hypothetical example included in Table 20 simulates a spill of 100 m^3 of water at high temperature (a temperature of 50 °C is estimated) into a body of surface water which, under natural conditions, is at 20 °C. It is assumed that the operator estimates (providing justification, and taking into account the source considered most appropriate) that the temperature starting at which environmental damage occurs is 30 °C. Entering these data into the calculation equation Eq.24 would give a volume of damaged water of 200 m^3. Note that, in addition to this calculation, the operator must, where applicable, estimate the damage caused to the species which could be affected by the spill. To this end, as indicated, the criteria set out in Section C8 or other criteria considered adequate could be followed.

Data type	Datum	Value	Unit	Source
Input	Volume of spilled hot water (mv)	100	m^3	Operator
	Temperature at which the spill occurs (tv)	50	ºC	Operator
	Temperature of the surface water body prior to spill (Tmasa)	20	ºC	Operator
	Temperature to which the water in the receiving body rises (tf)	30	ºC	Operator
Output	Amount damaged	200	m^3	-
Enter in MORA	Amount damaged	200	m^3	-

Table 20. Application of the proposed quantification criterion to a hypothetical example. Source: by the authors.

4.2.11. Modelling damage due to a temperature change to land and to plant and animal species (C17-C19)

In prior experience garnered through the environmental risk analyses made available to the public by the Ministry for the Ecological Transition and the Demographic Challenge, models or criteria specifically for quantifying damage due to spills of high-temperature water to land and to plant and animal species have not been found. Nevertheless, with due caution, the operator could use as a basis for calculation the criteria for spills of chemical agents on land and on species, but always providing justification and taking account of the limitations of each model. In this case, the operator must give special consideration to the fact that the criteria provided for chemical agents are focused on substances associated with a certain toxicity threshold. Meanwhile, in the case of physical agents, there is no such toxicity threshold, given that the damage would result from other characteristics of the agents, such as is the case with temperature. Therefore, the decisions adopted must be justified, and if significant uncertainty exists the recommendation is that the most unfavourable values be adopted, thereby ensuring the study errs on the side of caution.

4.2.12. Modelling of damage to plant species by fire (C20)

In order to calculate the extent of the damage in the combination of fire and plant species, two methodological approaches are proposed: first, the use of fire spread models and the estimation of the area affected, defining an area by natural or artificial barriers where the fire could stop by itself or with extinguishing media deployed to the area, such as firebreaks, areas of limited or no vegetation, bodies of water of a certain width or size, communication routes, etc.

In the second methodological alternative, the area affected by the hypothetical fire could be determined with maps and/or aerial photographs which make it possible to see the areas located between the source of the fire and the aforementioned barriers. This provides, at least in principle, the most conservative results. As for the first alternative mentioned, there are different models of forest fire spread in the literature, which although demanding in terms of the information required for their correct application, guarantee results which can subsequently be compared with the real environment in each case. Notable among these models is the BEHAVE System produced by the United States Forest Service.

A third possibility consists of combining the BEHAVE model with the criterion of estimating the affected areas by means of the aforementioned natural or artificial barriers which would stop the fire. In other words, once the area affected by the hypothetical fire has been estimated with the BEHAVE model, the operator would limit it by taking into account the natural or artificial barriers surrounding the facility which would impede the spread of the fire.

It is important to note that the estimate of the extent of the damage on plant species caused by a fire will be decisively influenced by the dominant direction of the fire. The BEHAVE model, which is a publicly available, free tool easily accessed on the internet, can be used as a model to estimate this type of damage.

This model estimates the direction which a fire would take, along with its extent for a given period of time. It is an internationally recognised model, allowing for the simulation and analysis of the development of the hypothetical forest fire by estimating its extent based on the calculation of an ellipse whose shape and extension is a function of variables such as the slope of the terrain and the dominant wind speed and direction in the area where the fire occurs.

The BEHAVE system allows the user to select from a wide range of input and output data as required in each specific case.

4.2.13. Modelling of damage to animal species by fire (C21)

The quantification of damage caused to animal species by fire could take as its starting point the result of the quantification of the damage caused by fire to plant species. Specifically, having calculated the hypothetical extent of the fire (by way of example, by using one of the methods set out in Section C20), the operator could follow the indications given in Section C8 to define the species potentially affected by the fire and the number of individuals. Nevertheless, in contrast to the proposals in Section C8, with this type of damage the agent is not associated with a toxicity threshold, meaning that the analyst must estimate the percentage of the population affected in the absence of this figure. To this end, and following the precautionary principle, the recommendation is to assume damage involving the entire loss of the populations reached by the fire, thereby providing a conservative result.

4.2.14. Modelling atmospheric pollution caused by chemical agents in the form of toxic clouds and particles in suspension (V1)

Law 26/2007, of 23 October, does not consider air as a natural resource which is a potential receptor of environmental damage. However, as stated in its Article 2.2., "*The definition of damage includes environmental damage caused by airborne elements*." In other words, the regulations on environmental liability consider air to be a vehicle of agents (chemical substances, heat, pressure, etc.) which could cause damage to the natural resources covered by the regulation (water, land, shorelines and coastal inlets, species and habitats).

To assess potential damage to the natural resources covered by environmental liability regulations due to damaging agents transported through the air, it is necessary to model this transport. In the case of chemical agents, toxicity mechanisms can appear as two different forms of atmospheric pollution:

(i) Damage from inhalation and/or skin contact produced by toxic gas clouds
(ii) Damage from wet and/or dry deposition of atmospheric particles

From the above, it is possible to deduce the need to model the transport of the chemical agent when this occurs in the form of a toxic gas cloud and if deposited in the form of particles on natural resources which the toxic cloud passes. The effects of atmospheric pollution on natural resources (water, land, seashores and coastal inlets, species and habitats) will be a consequence of the exposure of these natural resources to the toxic cloud and the wet and/or dry deposition of particles in suspension, as the case may be.

General limitations and hypotheses assumed for modelling atmospheric pollution

Before discussing the mechanism through which the transport of atmospheric pollution (by means of a toxic gas cloud or particles in suspension) may be significant in the context of environmental liability regulations, it is worth considering the difficulties which analysts may encounter when assessing the damage quantitatively (extent, intensity and time scale) and, by extension, assessing its significance. These difficulties, while not exclusive to environmental damage resulting from an atmospheric pollution episode, are enough to necessitate some hypotheses or specific assumptions which help to overcome the inherent difficulties of assessing this type of damage.

On the one hand, modelling the behaviour of a pollutant in the atmosphere is particularly complex. Currently, there are numerous atmospheric dispersion models with varying degrees of complexity and precision, some of which are accessible to non-specialist professionals, but in many cases they provide partial results (they might not consider the pollution associated with a certain substance or not include processes such as wet and/or dry deposition in their equations).

On the other hand, where atmospheric pollution can be modelled, the analyst can face a lack of information on toxicity thresholds. Note that, in this case, information must be available on toxicity through inhalation (in the case of toxic clouds) or through contact, ingestion, mixing, dilution, among others (in the case of the deposition of particles from toxic clouds). This information is not always available to the analyst for the specific substance being modelled, and so they must resort to alternatives such as those in Annex I, Section III, point 1.3 of the Regulation of partial development of Law 26/2007, of 23 October.

In this context, two key reports, both available on the environmental liability website of the Ministry for the Ecological Transition and the Demographic Challenge, simplify the quantification and assessment of the damage in accordance with the provisions of the environmental liability regulations:

(i) The document "Analysis of tools for evaluating the spread and behaviour of chemical agents in the context of environmental liability regulations"[28], created by the Technical Commission for the Prevention and Remediation of Environmental Damage (CTPRDM), provides a description and brief comparative analysis of a selection of different atmospheric dispersion models available on the web.

[28]https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/responsabilidad-mediambiental/herramientasdeevaluaciondifusionycomportamientoagentesquimicos_251019_tcm30-177407.pdf

(ii) The document "Determination of the significance of environmental damage in the context of Law 26/2007, of 23 October, on environmental liability"[29], approved by the Technical Commission for the Prevention and Remediation of Environmental Damage, includes the guidelines for assessing the significance of the damage established in Law 26/2007, of 23 October, and the partially implementing Regulation. Additionally, a more specific annex has been created for determining the significance of environmental damage to water.

According to the document "Analysis of tools for evaluating the spread and behaviour of chemical agents in the context of environmental liability regulations" by the CTPRDM, AERMOD is the reference model proposed by the United States Environmental Protection Agency (USEPA)[30] for modelling atmospheric pollution. Nevertheless, it is a model designed for assessing continuous emissions rather than specific short-duration emissions. The latter are more in keeping with the environmental risk analyse s established by the environmental liability regulations for determining the mandatory financial security for the occupational activities subject to this obligation.

As a result, this model may not be appropriate for simulating the behaviour of a toxic cloud in the context of an accident as part of environmental risk analyses.

The ALOHA Model (*Areal Locations of Hazardous Atmospheres*) is freely available software[31] which appears to be the best option for simulating the behaviour of a chemical pollutant in a toxic cloud in the context of environmental liability regulations. It is a model designed by the USEPA (United States Environmental Protection Agency) and NOAA (National Oceanic and Atmospheric Administration) to provide a simple response to emergency situations and estimate the threat zones associated with the emission of both neutral and dense gases. Its outcome predicts the dispersion and dimensions of a gas cloud, based on the physical characteristics and reference levels of the compound, the atmospheric conditions, and the circumstances in which the emission takes place (maintaining input variables related to weather factors, the source of the pollution and constant toxicity thresholds).

By default, the ALOHA model provides toxicity thresholds referring to the human population, consistent with the purpose of aiding in the management of chemical emergencies for which this atmospheric dispersion tool was conceived. In any event, the tool also offers the possibility of the user manually entering any toxicity limit (CTD or AEGL denominated by ALOHA). This solution turns out to be particularly useful when there is information available on the eco-toxicological thresholds of the natural resources covered by the environmental liability regulations for a specific substance.

In general, plant species are considered the natural resource most exposed to the risk of undergoing significant damage due to an atmospheric pollution episode, taking account of the inherent mobility of terrestrial animal species (at least, those of greater size) and their ability to evade the effects of exposure to a possible toxic cloud which may or may not be accompanied by particles in suspension. However, it is precisely the lack of information on toxicity thresholds for natural resources covered by Law 26/2007, of 23 October –particularly the absence of eco-toxicological thresholds or CTDs for plant species– which has led to the adoption of some of the most decisive hypotheses for modelling atmospheric pollution in the context of preparing a risk

[29] https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/responsabilidad-mediambiental/procedimiento_exigencia_responsabilidad/determinacion-signficatividad.aspx

[30] https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models

[31] https://www.epa.gov/cameo/aloha-software

assessment. The solution to this lack of information is proposed based on the type of information available and its consistency with the provisions established by the regulatory framework of Law 26/2007, of 23 October. In this context, the proposal is to adopt the following rules which simplify the quantification of the damage associated with an accident scenario based on an atmospheric pollution episode:

- Priority will be given to assessing potential damage experienced by plant species over other natural resources covered by the environmental liability regulations as a result of a toxic cloud and/or wet or dry deposition of particles in suspension. In any case, the analyst must appropriately justify that there is no significant risk to animal species, land and/or surface water in the specific case of the toxic cloud being accompanied by particles in suspension.

- It is possible to forgo the use of a specific computer tool for modelling the behaviour of particles in suspension from a toxic cloud. This simplification is because the technical effort which these dispersion models involve is not worthwhile if the result cannot be combined with sufficient information on the eco-toxicological thresholds of plant species for a specific substance and exposure time. In other words, the lack of these toxicity thresholds referring to plant species means that it is not possible to rigorously assess whether a certain concentration of gases and/or particles in suspension can cause potential damage to plant species. Faced with this situation, a series of assumptions may be adopted regarding the toxicity values entered into the ALOHA Model and the results of its graphical output (see Section 5.2.1.3), which result in a practical solution (based on a model which is freely available and easy to operate) for assessing the scope of an atmospheric pollution episode. The ALOHA model is finally proposed as the appropriate tool for modelling toxic gas clouds, the result of which could equally be used to assess possible damage caused by wet and/or dry deposition of particles in suspension if this situation were to arise.

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