TECHNICAL-SCIENTIFIC INDEX FOR THE CLARIFICATION OF ILLICIT ACTIONS ON WATER RESOURCES

apa agência portuguesa do ambiente

MINISTÉRIO PÚBLICO
PORTUGAL
EM DEFESA DA LEGALIDADE DEMOCRÁTICA

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Inspeção-Geral da Agricultura, do Mar, do Ambiente e do Ordenamento do Território

POLÍCIA JUDICIÁRIA

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European Union Network for the Implementation and Enforcement of Environmental Law

IMPEL National Network

Aprovado

Nuno Lacasta — Assinado de forma digital por Nuno Lacasta Dados: 2023.04.05 10:35:26 +01'00'

Pimenta Machado — Assinado de forma digital por Pimenta Machado Dados: 2023.04.05 10:24:27 +01'00'

Ana Teresa Perez — Assinado de forma digital por Ana Teresa Perez Dados: 2023.04.05 13:05:35 +01'00'

Ana Cristina Chora e Martins Carrola da Silva — Assinado de forma digital por Ana Cristina Chora e Martins Carrola da Silva Dados: 2023.04.05 13:12:01 +01'00'

Paula Cristina Duarte Matias — Assinado de forma digital por Paula Cristina Duarte Matias Dados: 2023.04.14 10:14:40 Z

José Manuel Brito e Silva

ÍNDICE TÉCNICO-CIENTÍFICO: ESCLARECIMENTO DO ILÍCITO SOBRE OS RECURSOS HÍDRICOS

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REDE NACIONAL IMPEL

TECHNICAL DATA

Portuguese Environment Agency, I.P.
Anabela Rebelo
Andreia Franco
Bruno Simplício
Maria Felisbina Quadrado
Sofia Batista
Vanda Reis

Inspectorate-General for Agriculture, Sea, Environment and Spatial Planning
Ana Isabel Garcia
Rodrigo Ferreira

Public Prosecutor's Office
Elisabete Matos
Filipe Preces
Joaquim Morgado
Magician Pacheco

Judiciary Police
João Ferreira

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Institute for Nature Conservation and Forests
João Loureiro, Nuno Saavedra and Frederico Lobo

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Foreword

As part of the work of the IMPEL National Network, the Portuguese Environment Agency, I.P. (APA), as the National Water Authority, was asked to draw up a technical guidance document that would make it possible to deepen the concept of *substantial damage* to water resources.

The document has a multiple purpose. The main one is to define, from a technical-scientific point of view, the intolerable offence for the relevant resource and thus to provide the sanctioning system with a benchmark that makes it possible to distinguish the administrative infringement from the criminal offence and, at this level of the criminal offence, to identify the factors that, if present, constitute, from a technical-scientific point of view, a *substantial damage* to water resources. The document also provides frameworks for the intervention of supervisory, inspection and investigation bodies, providing guidelines to support the effective detection of traces of water pollution and the collection of evidence.

Being a technical-scientific document on the negative impact for water resources, it assumes the inherent complexity, based on methodologies of mathematics and physicochemical and environmental sciences. But in broad terms, it is considered *i)* the *intrinsic potential of* the substance or situation (*v.g.* is there a rejection of a chemical product, of what nature, in what quantity; is there faecal matter; is there ionizing radiation, etc.); *ii)* the typology of the *occurrence* (*v.g.* was it exceptional, unusual, or on the contrary, is it regular *occurrence*, etc.); *iii)* the *severity of* the observed impact (v.g. territorial extension of the negative factors observed, number of cadavers, etc.); *iv*) the characteristics or vulnerability of the *exposed water resources* (v.*g. it* is a protected area, has an agricultural use, is an infiltration zone, etc.). These factors are weighted (on a scale of 3, 5, 7 and 9) in such a way that, from a technical and scientific point of view, and according to the metric achieved (≥4), an intolerable impact on the aquatic environment can be established, which allows the assertion of significant damage to water. All factors take into account surface water and groundwater.

The Public Prosecution Service, as a member of the IMPEL National Network led by the General Inspection of Agriculture, Sea, Environment and Spatial Planning (IGAMAOT), has associated with the work of APA, with contributions from public prosecutors for discussion, in partnership with other entities that are part of the network. We have the privilege of presenting the document in this foreword, which is in line with the recognition that Directive No. 1/2021 of 4 January of the PGO[1] has given to environmental concerns, especially those related to the protection of that vital and scarce resource that is water.

Elisabete Matos
Central Department for State Litigation and Collective and Diffuse Interests of the PGO

[1] TN: Prosecutor General's Office

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List of Chemical Acronyms and Symbols

APA	Portuguese Environment Agency, IP
BOD_5	Biochemical oxygen demand at 5 days
cfu	Colony forming units
COD	Chemical oxygen demand
ECHA	European Chemicals Agency
ELV	Emission Limit Value
I_{tc}	Technical-scientific index for the clarification of illicit actions on water resources
MPN	Most probable number
NH_4	Ammonium
NO_3	Nitrates
N_{total}	Total nitrogen
pH	Potential Hydrogen
Pt-Co	Platinum-Cobalt
P_{total}	Total phosphorus
RBMP	River Basin Management Plan
VOC	Volatile organic compounds
WRUP	Water Resources Use Permit
WWTP	Wastewater treatment plant

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1 Introduction

1.1 Aim

The present work develops a technical-scientific index for the clarification of illicit actions on water resources (henceforth, I_{tc}) that develops a methodology, supported by classical risk characterisation methods, to assess the extent of a given adverse effect on water bodies resulting from a specific occurrence or hazardous event.

The I_{tc} will therefore make it possible to determine whether a given hazardous event or occurrence has caused significant adverse effects on water resources and, if so, whether these effects have caused significant damage to water resources.

1.2 Background

The risk assessment on water resources is the exercise of forecasting the occurrence of adverse effects on water, in a given spatial and temporal reference, which includes a risk characterisation process that depends on:

- the potential to cause such effects, i.e. the specificities inherent to the hazardous event or occurrence, such as the intrinsic characteristics of the pollutants;
- the consequence of the hazardous event, which, in turn, depends on the vulnerability of the water body, i.e., the potential for water bodies being affected due to its inherent characteristics (physical, hydrogeological and morphological characteristics, uses and services of the water body) and the negative impacts likely to occur due to the specific characteristics of the hazardous event (e.g. toxicity of the pollutants).

In a classic process of risk characterisation, the adverse effect associated to a given scenario is obtained by the mathematical product between the likelihood of the scenario and the severity of the adverse effect itself.

In a real-world scenario of pollutant emissions to the aquatic environment (i.e., as a result of direct discharges of substances, chemicals, raw or inadequately treated effluents, or improper disposal or handling of waste likely to contain pollutants) there may be adverse effects on water quality, aquatic ecosystems and/or water uses or services, with impacts on water resources ranging from insignificant to significant. Therefore, in real situations, rather than considering probabilities and possible scenarios, the focus is on actual adverse effects, which can range from insignificant (minor effects) to significant (major effects).

Accordingly, the present I_{tc} defines a technical-scientific methodology, supported by classical mathematical methods of risk characterisation, to clarify potential illicit actions on water resources. In a predictive analysis, the result of the probability of occurrence of an event is assessed (i.e., the moment in time when a given adverse event has not yet happened and consequently, the respective "likelihood of occurrence" is less than or equal to 100%, i.e., an absolute value equal to or less than one). However, if the assessment is carried out in a period of time in which a given adverse occurrence has already occurred or is in progress, ”its likelihood of occurrence" is 100% (absolute value equal to one), thus allowing the use of this methodology to determine, under these conditions, the effective result of the occurrence on water resources for real situations.

Therefore, this working tool defines the methodology for determining the result of a given adverse event that has occurred in a given space and time reference, allowing, in each specific case, to measure the effective result of the event on the receiving environment and, in situations where the result found is unacceptable for water resources, to conclude that there is a significant adverse effect in order to assess whether there has been significant damage to these resources.

In this way, by applying the methods of risk characterisation to water resources, the I_{TC} will be able to assess whether or not a specific incident of pollutant emission into the aquatic environment has caused significant adverse effects on water resources and to conclude whether or not they represent significant damage to these resources.

The on-site investigation process of any occurrence or hazardous event involving discharges or spills of pollutants to water resources shall follow nationally and internationally recognised best practices.

1.3 Definitions

In order to facilitate the interpretation of this document, there is a list of terms and definitions which should be taken into account when reading this document.

Adverse effect: impairment of the quality of water resources, aquatic ecosystems or the current uses or services provided by water bodies.

Chemical: Mixture or solutions composed of two or more substances, consisting of chemical elements and their compounds, in the natural state or obtained by any manufacturing process, including any additive necessary to preserve its stability and any impurity deriving from the process used.

Mortality: Death of specimens of a population under given environmental conditions as a result of a given occurrence or hazardous event. This definition excludes losses of specimens under ideal or non-limiting conditions corresponding to the normal mortality rate of the species.

Occurrence or hazardous event: an abnormal act of limited duration, which may occur once or periodically and has an adverse effect on water resources. The occurrence or hazardous event can be of three types, namely accidental, discontinuous or continuous, as described in section 2.5.1.

Pollutant: any physical, chemical or biological substance that may be emitted into water resources by direct release or through any runoff, leaching, percolation, wastewater discharge or waste disposal and which is likely to adversely affect water resources.

Result of the occurrence in the receiving environment: the effective result on water resources of a given occurrence or hazardous event that has arisen in a given space and time reference, as measured by the methodology described in this document.

Risk assessment on water resources: prediction of the occurrence of adverse effects on water in a given space and time reference.

Risk: the possibility of the appearance of adverse effects, resulting from a certain occurrence or hazardous event, in a given space and time reference or under certain circumstances.

Severity: the degree to which the water resources are affected by the occurrence or hazardous event in question, i.e., the characteristics of the event that may potentiate such adverse effects.

Significant adverse effect: adverse effect resulting from an unacceptable outcome for surface water and/or groundwater resources, which may/should result in significant damage to them.

Waste: any substance or object which the holder discards or intends or is required to discard.

Wastewater[2] : waters resulting from domestic, urban, industrial or service activities, surface runoff (including contaminated rainwater), stormwater from unitary or pseudo-separative drainage systems, or from any accidental inflow or infiltration into wastewater drainage systems. The wastewater term is divided into the following:

i. **domestic wastewater**: wastewater from residential settlements and services which originates predominantly from the human metabolism and from household activities;

ii. **urban wastewater**: domestic wastewater or the mixture of domestic wastewater with industrial wastewater and/or runoff rainwater;

iii. **industrial wastewater**: wastewater which is discharged from premises used for carrying on any trade or industry, other than domestic wastewater and runoff rainwater;

iv. **contaminated runoff rainwater**: runoff rainwater which, in contact with impermeable surfaces, is likely to carry suspended materials or other pollutants and contaminants, and whose load requires treatment prior to reuse or direct discharge into the receiving water bodies.

Water quality deterioration: exceedance (or non-compliance[3]) of at least one of the applicable parameters in terms of emission limit values, maximum recommended or admissible values, quality standards, environmental quality standards, environmental objectives or threshold values set in national legislation or in a Water Resources Use Permit (WRUP[4]), and in accordance with the specific features described in the text of the current document.

Deterioration of water quality is also defined as an increase in the concentration of at least one pollutant in the receiving waters, compared to the characterisation of the status of the water body[5], according provisions of the Water Framework Directive (WFD)[6], even if the respective threshold (expressed in the form of maximum recommended or admissible values, quality standards, environmental quality standards, environmental objectives or threshold values established in national legislation, in accordance with the specific features described in the text of the current document) has already been exceeded. The values measured at each monitoring point shall be taken into account individually.

[2] Definition from the Decree-Law No. 119/2019, of 21st August (TN: that establishes the Portuguese water reuse framework).

[3] For certain quality parameters, non-compliance with the standard may not be due to an exceedance, but rather to the presence of values below the standard (e.g. dissolved oxygen) or values outside the stipulated range (e.g. pH).

[4] TN: In Portuguese legislation, the acronym TURH is used to refer to permits for the use of water resources, such as, water abstraction, wastewater discharge or use of public areas of water resources.

[5] Characterisation of water bodies defined in the territorially applicable River Basin Management Plan (RBMP).

[6] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, usually known as Water Framework Directive (WFD).

2 Methodology for the definition of a technical-scientific index for the clarification of illicit actions on water resources

2.1 Methodology development

In this section, the methodology used to determine the effective result for the water resources is presented as follows.

The purpose of this study is to quantify, clarify and classify the magnitude of the decurrent adverse effects of a particular occurrence or hazardous event. The study is based on a conceptual methodology, supported by the classical methods of risk characterization, for the evaluation of a certain historical event marked in time and space.

In order to quantify the magnitude of the adverse effects, the present I_{TC} even allows the effective result of the occurrence or hazardous event to be obtained separately for the two types of water body, i.e., surface water and groundwater.

Accordingly, the conceptual model is adopted that allows the quantification of the various elements identified and the prioritisation of results on the basis of the following factors:

- the potential adverse effect inherent to the occurrence or hazardous event ($P_{occurrence}$);
- the consequences of the adverse effects resulting from the occurrence or hazardous event ($Consequence_{adv}$).

Thus, the technical-scientific index for the clarification of illicit actions on water resources (I_{tc}) can be obtained from the equation 1:

$$I_{tc}=P_{occurrence}\times Consequence_{adv} \quad (1)$$

The potential of the occurrence ($P_{occurrence}$) represents the potential to cause adverse effects on water resources inherent to the intrinsic properties of the chemical, biological or ionising content of the rejection or emission. However, the consequence of these effects on the water bodies also depends on the physical, hydrogeological, morphological characteristics and uses of the water resources in question, i.e., the respective potential for these to be affected by a given occurrence or hazardous event. In other words, a hazardous event may have an adverse effect on the water body due to the intrinsic properties of its content (e.g., toxicity of a chemical substance). On the other hand, depending on their characteristics (e.g., special protection areas for the protection of aquatic birds), water resources may be more susceptible to these adverse effects. Combining these two situations translates the global consequence of the adverse decurrent effect of a given occurrence or hazardous event. This consequence can be determined by equation 2, where $P_{impair\ WR\ (SW\ or\ GW)}$ is the potential to affect surface water or groundwater and $Effect_{adv}$ is the adverse effect:

$$Consequence_{adv}=Effect_{adv}\times P_{impair\ WR\ (SW\ or\ GW)} \quad (2)$$

As mentioned above, the adverse effect is directly linked to the characteristics of the occurrence or hazardous event and, consequently, to its severity, i.e., the magnitude of the impairment and the temporal variation of the occurrence or hazardous event. This variation constitutes the typology of the hazardous event ($Typology_{occurrence}$).

Thus, an occurrence or hazardous event can be of two types:

- discontinuous or sporadic occurrence;
- continuous occurrence.

The distinction between these two types of occurrences or hazardous event is explained in the section 2.5.1 and depends directly on the maintenance conditions of the sectorial unit responsible for the occurrence or hazardous event, as well as the periodicity of occurrence of similar situations.

The adverse effect ($Effect_{adv}$) is then obtained from the relationship between the typology of occurrence or hazardous event and the severity of the effect itself, as expressed in equation 3:

$$Effect_{adv}=Tipology_{occurrence} \text{ vs Severity} \quad (3)$$

The I_{tc} is determined separately for surface and groundwater as the same occurrence or hazardous event is likely to have significant adverse effects on both receptors. However, also in borderline situations, i.e., where the actual outcome of an occurrence or hazardous event for one of the receptors is close to the unacceptable threshold, the methodology proposes the assessment of cumulative effects.

2.2 Definition of the scale

The characterisation of the terms in equations 1, 2 and 3 is obtained by a list of factors, described in the following sections, applicable to surface water and groundwater for the determination of the corresponding I_{tc}. Each factor is assigned a value between 3 and 9, according to its importance, which reflects a certain level of gravity and severity of the adverse effect on the water resource. The importance scale defined by Saaty[7] and described in Table 1 is therefore used in this methodology.

Table 1: Scale of importance

Level of importance	Factor	Value
Weak importance	Low or undemonstrated significance	3
Essential or strong importance	Medium significance	5
Demonstrated importance	High significance	7
Absolute importance	Very high significance	9

[7] T.L. Saaty, The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation, first ed. Saaty, T.L. (1980).

2.3 Determination of the technical-scientific index for the clarification of illicit actions on water resources

As mentioned earlier, the I_{tc} is obtained from equation 1. However, to reduce the scale, a normalisation factor (N) is applied, given by equation 4, where n is the number of terms in equation 1 that can be classified with a maximum value of nine (9):

$$N = 9^{n-1} \quad (4)$$

Therefore, by normalising equation 1, equation 5 is obtained:

$$I_{tc} = \frac{P_{ocurrence} \times Effect_{adv} \times P_{impair\ WR\ (SW\ or\ GW)}}{N} = \frac{P_{ocurrence} \times Effect_{adv} \times P_{impair\ WR\ (SW\ or\ GW)}}{9^{n-1}} = \frac{P_{ocurrence} \times Effect_{adv} \times P_{impair\ WR\ (SW\ or\ GW)}}{9^2} = \frac{P_{ocurrence} \times Effect_{adv} \times P_{impair\ WR\ (SW\ or\ GW)}}{81} \quad (5)$$

2.4 Potential for the occurrence to cause an adverse effect

2.4.1 Emissions, rejections or losses of chemicals, wastewater or occurrence or hazardous event of unknown origin

The potential for the occurrence to cause an adverse effect inherent in the occurrence or hazardous event ($P_{occurrence}$) is obtained from equation 6, where f_{oc_i} are the several inherent factors to the occurrence, described in tables 2 and 3, for surface water and groundwater respectively. A normalisation factor ($n_{f_{oc}}$) is used for downscaling, which indicates the total number of individual factors considered. Therefore, the $P_{occurrence}$ varies between 3 and 9.

$$P_{occurrence} = \frac{\sum f_{oc_i}}{n_{f_{oc}}} \quad (6)$$

The factors f_{oc_i} are divided into four groups of possible occurrence or hazardous event, namely rejection of:

- chemical products or waste disposal containing chemicals or other deposition (including agro-industrial or agricultural waste/by-products) or occurrence or hazardous event of unknown origin;
- wastewater (assessment of content except microbial load);
- wastewater (exclusive assessment of microbial load).

The following issues should be considered when rejecting wastewater without a valid WRUP at the time of the occurrence or event:

- for discharges where the WRUP has expired and a new WRUP has not yet been issued, although the renewal has been submitted to the relevant permitting authority,
    - the factors for rejections with WRUP will be applied, taking into account the ELV described in the expired WRUP where applicable;
- for discharges of urban wastewater from new wastewater treatment plants (WWTP), where a WRUP has not been issued, but has been requested from the relevant permitting authority,

- the factors for rejection without WRUP will be applied according to the respective origin of the waste water, taking into account, where appropriate, the ELV described in Table 2[8] ;

- for other wastewater discharges without WRUP, the provisions of table 2 for discharges without WRUP shall be applied.

[8] ELV described in the general discharge standards applicable to non-urban wastewater (Decree-Law no. 236/98, of 1 August) and urban wastewater (Decree-Law no. 152/97, of 19 June), both as they stand at present. (TN: Portuguese legislation).

Table 2: Factors relating to the potential for the occurrence to cause adverse effect on surface waters

Factors (f_{oc_i})	Description	Classification
Rejection[9] of chemicals or waste disposal containing chemicals or other deposition (including agro-industrial or agricultural waste/by-products) or occurrence or hazardous event of unknown origin	Chemical products and/or waste or runoff/rejection containing substances not classified as hazardous (classification and labelling legislation for chemicals[10]) and causing[11] visible changes (at naked eye) in turbidity or the presence of foams or greasy stains or a colour above 50 mg/L Pt-Co or an odour at a dilution of 1:10[12], at a location considered suitable for sampling	3
	Chemical products and/or waste or runoff/rejection containing other substances classified as hazardous (harmful/irritant)[13] , or causing a temperature change of more than 3ºC, in a place considered suitable for sampling	5
	Chemical products and/or waste or runoff/rejection containing specific pollutants (defined in the River Basin Management Plan, RBMP, territorially applicable) or substances that are hazardous to environment (aquatic ecosystems)[14] or substances causing deterioration of water quality for at least one parameter supporting the ecological status[15] of the receiving water body, or substances changing the pH of the water[16], at a point considered suitable for sampling	7
	Chemicals and/or waste or runoff/rejection containing priority, priority hazardous substances or other pollutants defined in the Directives 2013/39/EU[17] and 2008/105/EC[18] or very persistent substances or very toxic, reprotoxic, mutagenic or with endocrine disrupting potential[19] or Total Petroleum Hydrocarbons C_{10}-C_{40}. Runoffs and/or rejections (with or without WRUP) causing acute anoxia (with observation of total or near-total oxygen depletion), acute pH variation in the receiving water (pH in the receiving water less than or equal to 3,0 or greater than or equal to 10,0). Sampling should be carried out at a location considered suitable for sampling	9

[9] From fixed units (e.g., industrial units) or mobile units (transport of chemical products).

[10] Information visible on labels (no hazard pictograms) or safety data sheets or through information provided on ECHA's website available at https://echa.europa.eu/pt/information-on-chemicals/registered-substances.

[11] Consider the option that best suits the conditions observed in the field.

[12] Maximum recommended values expressed in Decree-Law 236/98 of 1 August 1998 (Annex I, class A2. TN: Portuguese legislation). Colour value measured after simple filtration at a wavelength of 420 nm. Odour value measured on a sample diluted in a 1:10 ratio at 25 ºC.

[13]  .

[14]  or ammonium exceeding 10 mg/L NH_4.

[15] In accordance with the RBMP in force and territorially applicable and monitoring to support compliance with the Water Framework Directive (Directive 2000/60/EC, text in force).

[16] The pH of the water body should be between 6 and 9, provided that there are no upstream problems or that there are no other values resulting from the local geology.

[17] Directive 2013/39/EU of the European Parliament and of the Council of 12 August 2013 amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy

[18] Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy,

[19] "Toxic" or "Serious health hazard" substances:  or  .

Table 2: Factors relating to the potential for the occurrence to cause adverse effect on surface waters (cont.)

Factors (f_{oc_i})	Description	Classification
Non-urban wastewater discharge[20] without WRUP (assessment of content except microbial load)	Discharges with organic load, expressed as chemical oxygen demand (COD) or five-day biochemical oxygen demand (BOD_5) or discharges with nutrients, expressed as total nitrogen (N_{total}) or total phosphorus (P_{total}) or discharges of other parameters under the following conditions: 40 mgL^{-1} O_2 < BOD_5 ≤ 80 mgL^{-1} O_2 and/or 150 mgL^{-1} O_2 < COD ≤ 300 mgL^{-1} O_2 and/or 15 mgL^{-1} N < N_{total} ≤ 30 mgL^{-1} N and/or 10 mgL^{-1} P < P_{total} ≤ 20 mgL^{-1} P, if the discharge is into waters other than those specified below (or 3 mgL^{-1} P < P_{total} ≤ 6 mgL^{-1} P, if the discharge is into waters feeding lakes or reservoirs or 0,5 mgL^{-1} P < P_{total} ≤ 1 mgL^{-1} P, if the discharge is into ponds or lagoons) Other parameters ([X]) defined in Decree-Law 236/98, 1st August[21] and not included in any of the classifications of the following paragraphs: VLE < [X] ≤ 2xVLE	3
	Discharges with organic load, expressed as chemical oxygen demand (COD) or five-day biochemical oxygen demand (BOD_5) or discharges with nutrients, expressed as total nitrogen (N_{total}) or total phosphorus (P_{total}) or discharges of other parameters under the following conditions: 80 mgL^{-1} O_2 < BOD_5 ≤ 120 mgL^{-1} O_2 and/or 300 mgL^{-1} O_2 < COD ≤ 450 mgL^{-1} O_2 and/or 30 mgL^{-1} N < N_{total} ≤ 45 mgL^{-1} N and/or 20 mgL^{-1} P < P_{total} ≤ 30 mgL^{-1} P, if the discharge is into waters other than those specified below (or 6 mgL^{-1} P < P_{total} ≤ 9 mgL^{-1} P, if the discharge is into waters feeding lakes or reservoirs or 1 mgL^{-1} P < P_{total} ≤ 1,5 mgL^{-1} P, if the discharge is into ponds or lagoons) Other parameters ([X]) defined in Decree-Law 236/98, 1st August and not included in any of the classifications of the following paragraphs: 2xVLE < [X] ≤ 3xVLE	5

[20] Discharges from the WWTP out of the scope of the Directive 91/271/EEC (TN: Portuguese legislation Decree-Law no. 152/97, of 19th June, as amended).

[21] TN: Portuguese legislation.

Table 2: Factors relating to the potential for the occurrence to cause adverse effect on surface waters (cont.)

Factors (f_{oc_i})	Description	Classification
Non-urban wastewater discharge without WRUP (assessment of content except microbial load)	Discharges with organic load, expressed as chemical oxygen demand (COD) or five-day biochemical oxygen demand (BOD_5) or discharges with nutrients, expressed as total nitrogen (N_{total}) or total phosphorus (P_{total}) or discharges of other parameters under the following conditions: 120 mgL^{-1} O_2 < BOD_5 ≤ 160 mgL^{-1} O_2 and/or 450 mgL^{-1} O_2 < COD ≤ 600 mgL^{-1} O_2 and/or 45 mgL^{-1} N < N_{total} ≤ 60 mgL^{-1} N and/or 30 mgL^{-1} P < P_{total} ≤ 40 mgL^{-1} P, if the discharge is into waters other than those specified below (or 9 mgL^{-1} P < P_{total} ≤ 12 mgL^{-1} P, if the discharge is into waters feeding lakes or reservoirs or 1,5 mgL^{-1} P < P_{total} ≤ 2 mgL^{-1} P, if the discharge is into ponds or lagoons) Other parameters ([X]) defined in Decree-Law 236/98, 1st August and not included in any of the classifications of the following paragraphs: 3xVLE < [X] ≤ 4xVLE or Discharge containing specific pollutants (defined in the River Basin Management Plan, RBMP, territorially applicable) or substances that are hazardous to environment (aquatic ecosystems) or substances causing deterioration of water quality for at least one parameter supporting the ecological status of the receiving water body, in a location considered appropriate for sampling	7
	Discharges with organic load, expressed as chemical oxygen demand (COD) or five-day biochemical oxygen demand (BOD_5) or discharges with nutrients, expressed as total nitrogen (N_{total}) or total phosphorus (P_{total}) or discharges of other parameters under the following conditions: BOD_5 > 160 mgL^{-1} O_2 and/or COD > 600 mgL^{-1} O_2 and/or N_{total} > 60 mgL^{-1} N and/or P_{total} > 40 mgL^{-1} P, if the discharge is into waters other than those specified below (or P_{total} > 12 mgL^{-1} P, if the discharge is into waters feeding lakes or reservoirs or P_{total} > 2 mgL^{-1} P, if the discharge is into ponds or lagoons) Other parameters ([X]) defined in Decree-Law 236/98, 1st August and not included in any of the classifications of the following paragraphs: [X] > 4xVLE or Wastewater discharges containing priority, priority hazardous substances or other pollutants defined in the Directives 2013/39/EU and 2008/105/EC or very persistent substances or very toxic, reprotoxic, mutagenic or with endocrine disrupting potential[22] or Total Petroleum Hydrocarbons C_{10}-C_{40}. Sampling should be carried out at a location considered to be suitable for that purpose	9

[22] "Toxic" or "Serious health hazard" substances:  or  .

Table 2: Factors relating to the potential for the occurrence to cause adverse effect on surface waters (cont.)

Factors (f_{oc_i})	Description	Classification
Urban wastewater discharge[23] without WRUP (assessment of content except microbial load)	Discharges with organic load, expressed as chemical oxygen demand (COD) or five-day biochemical oxygen demand (BOD_5) or discharges with nutrients, expressed as total nitrogen (N_{total}) or total phosphorus (P_{total}) or discharges of other parameters under the following conditions: 25 mgL^{-1} O_2 < BOD_5 ≤ 50 mgL^{-1} O_2 and/or 125 mgL^{-1} O_2 < COD ≤ 250 mgL^{-1} O_2 and/or [24] 1. <u>Areas sensitive to eutrophication</u>: 15 mgL^{-1} N < N_{total} ≤ 30 mgL^{-1} N (if the discharge is from a WWTP with a capacity of 10000 to 100000 p.e.[25]) or 10 mgL^{-1} N < N_{total} ≤ 20 mgL^{-1} N (if the discharge is from a WWTP with a capacity of more than 100000 p.e.) and/or 2 mgL^{-1} P < P_{total} ≤ 4 mgL^{-1} (if the discharge is from a WWTP with a capacity of 10000 to 100000 p.e.) or 1 mgL^{-1} P < P_{total} ≤ 2 mgL^{-1} P (if the discharge is from a WWTP with a capacity of more than 100000 p.e.) 2. <u>Areas not sensitive to eutrophication[26]:</u> 15 mgL^{-1} N < N_{total} ≤ 30 mgL^{-1} N and/or 10 mgL^{-1} P < P_{total} ≤ 20 mgL^{-1} P, if the discharge is into waters other than those specified below (or 3 mgL^{-1} P < P_{total} ≤ 6 mgL^{-1} P, if the discharge is into waters feeding lakes or reservoirs or 0,5 mgL^{-1} P < P_{total} ≤ 1 mgL^{-1} P, if the discharge is into ponds or lagoons) Other parameters ([X]) defined in Decree-Law 236/98, 1st August and not included in any of the classifications of the following paragraphs: VLE < [X] ≤ 2xVLE	3

[23] Discharges from the WWTP under the scope of the Council Directive 91/271/EEC of 21 May 1991 concerning urban wastewater treatment (TN: Portuguese legislation Decree-Law no. 152/97, of 19 June, as amended).

[24] Select option 1 or 2 depending on the type of zone.

[25] 1 p.e. (population equivalent): the organic biodegradable load having a five-day biochemical oxygen demand (BOD_5) of 60 g of oxygen per day.

[26] For areas not sensitive to eutrophication, no separate criteria are applied according to the population served by the plant.

Table 2: Factors relating to the potential for the occurrence to cause adverse effect on surface waters (cont.)

Factors (f_{oc_i})	Description	Classification
Urban wastewater discharge without WRUP (assessment of content except microbial load)	Discharges with organic load, expressed as chemical oxygen demand (COD) or five-day biochemical oxygen demand (BOD_5) or discharges with nutrients, expressed as total nitrogen (N_{total}) or total phosphorus (P_{total}) or discharges of other parameters under the following conditions: 50 mgL^{-1} O_2 < BOD_5 ≤ 75 mgL^{-1} O_2 and/or 250 mgL^{-1} O_2 < COD ≤ 375 mgL^{-1} O_2 and/or 1. Areas sensitive to eutrophication: 30 mgL^{-1} N < N_{total} ≤ 45 mgL^{-1} N (if the discharge is from a WWTP with a capacity of 10000 to 100000 p.e.) or 20 mgL^{-1} N < N_{total} ≤ 30 mgL^{-1} N (if the discharge is from a WWTP with a capacity of more than 100000 p.e.) and/or 4 mgL^{-1} P < P_{total} ≤ 6 mgL^{-1} (if the discharge is from a WWTP with a capacity of 10000 to 100000 p.e.) or 2 mgL^{-1} P < P_{total} ≤ 3 mgL^{-1} P (if the discharge is from a WWTP with a capacity of more than 100000 p.e.) 2. Areas not sensitive to eutrophication: 30 mgL^{-1} N < N_{total} ≤ 45 mgL^{-1} N and/or 20 mgL^{-1} P < P_{total} ≤ 30 mgL^{-1} P, if the discharge is into waters other than those specified below (or 6 mgL^{-1} P < P_{total} ≤ 9 mgL^{-1} P, if the discharge is into waters feeding lakes or reservoirs or 1 mgL^{-1} P < P_{total} ≤ 1,5 mgL^{-1} P, if the discharge is into ponds or lagoons) Other parameters ([X]) defined in Decree-Law 236/98, 1st August and not included in any of the classifications of the following paragraphs: 2xVLE < [X] ≤ 3xVLE	5

Table 2: Factors relating to the potential for the occurrence to cause adverse effect on surface waters (cont.)

Factors (f_{oc_i})	Description	Classification
Urban wastewater discharge without WRUP (assessment of content except microbial load)	Discharges with organic load, expressed as chemical oxygen demand (COD) or five-day biochemical oxygen demand (BOD_5) or discharges with nutrients, expressed as total nitrogen (N_{total}) or total phosphorus (P_{total}) or discharges of other parameters under the following conditions: 75 mgL^{-1} O_2 < BOD_5 ≤ 100 mgL^{-1} O_2 and/or 375 mgL^{-1} O_2 < COD ≤ 500 mgL^{-1} O_2 and/or 1. Areas sensitive to eutrophication: 45 mgL^{-1} N < N_{total} ≤ 60 mgL^{-1} N (if the discharge is from a WWTP with a capacity of 10000 to 100000 p.e.) or 30 mgL^{-1} N < N_{total} ≤ 40 mgL^{-1} N (if the discharge is from a WWTP with a capacity of more than 100000 p.e.) and/or 6 mgL^{-1} P < P_{total} ≤ 8 mgL^{-1} (if the discharge is from a WWTP with a capacity of 10000 to 100000 p.e.) or 3 mgL^{-1} P < P_{total} ≤ 4 mgL^{-1} P (if the discharge is from a WWTP with a capacity of more than 100000 p.e.) 2. Areas not sensitive to eutrophication: 45 mgL^{-1} N < N_{total} ≤ 60 mgL^{-1} N and/or 30 mgL^{-1} P < P_{total} ≤ 40 mgL^{-1} P, if the discharge is into waters other than those specified below (or 9 mgL^{-1} P < P_{total} ≤ 12 mgL^{-1} P, if the discharge is into waters feeding lakes or reservoirs or 1,5 mgL^{-1} P < P_{total} ≤ 2 mgL^{-1} P, if the discharge is into ponds or lagoons) Other parameters ([X]) defined in Decree-Law 236/98, 1st August and not included in any of the classifications of the following paragraphs: 3xVLE < [X] ≤ 4xVLE or Discharge containing specific pollutants (defined in the River Basin Management Plan, RBMP, territorially applicable) or substances that are hazardous to environment (aquatic ecosystems)[27] or substances causing deterioration of water quality for at least one parameter supporting the ecological status[28] of the receiving water body, in a location considered appropriate for sampling	7

[27] or ammonium exceeding 10 mg/L NH_4.

[28] In accordance with the RBMP in force and territorially applicable and monitoring to support compliance with the Water Framework Directive (Directive 2000/60/EC, text in force).

Table 2: Factors relating to the potential for the occurrence to cause adverse effect on surface waters (cont.)

Factors (f_{oc_i})	Description	Classification
Urban wastewater discharge without WRUP (assessment of content except microbial load)	Discharges with organic load, expressed as chemical oxygen demand (COD) or five-day biochemical oxygen demand (BOD_5) or discharges with nutrients, expressed as total nitrogen (N_{total}) or total phosphorus (P_{total}) or discharges of other parameters under the following conditions: BOD_5 > 100 mgL^{-1} O_2 and/or COD > 500 mgL^{-1} O_2 and/or 1. Areas sensitive to eutrophication: N_{total} > 60 mgL^{-1} N (if the discharge is from a WWTP with a capacity of 10000 to 100000 p.e.) or N_{total} > 40 mgL^{-1} N (if the discharge is from a WWTP with a capacity of more than 100000 ep) and/or P_{total} > 8 mgL^{-1} (if the discharge is from a WWTP with a capacity of 10000 to 100000 ep) or P_{total} > 4 mgL^{-1} P (if the discharge is from a WWTP with a capacity of more than 100000 ep) 2. Areas not sensitive to eutrophication: N_{total} > 60 mgL^{-1} N and/or P_{total} > 40 mgL^{-1} P, if the discharge is into waters other than those indicated below (or P_{total} > 12 mgL^{-1} P, if the discharge is into waters feeding lakes or reservoirs or P_{total} > 2 mgL^{-1} P, if the discharge is into a lake or reservoir) Other parameters ([X]) defined in Decree-Law 236/98, 1st August and not included in any of the classifications of the following paragraphs: [X] > 4xVLE or Wastewater discharges containing priority, priority hazardous substances or other pollutants defined in the Directives 2013/39/EU and 2008/105/EC or very persistent substances or very toxic, reprotoxic, mutagenic or with endocrine disrupting potential[29] or Total Petroleum Hydrocarbons C_{10}-C_{40}. Sampling should be carried out at a location considered to be suitable for that purpose	9

[29] "Toxic" or "Serious health hazard" substances:  or  .

Table 2: Factors relating to the potential for the occurrence to cause adverse effect on surface waters (cont.)

Factors (f_{oc_i})	Description	Classification
Wastewater discharge with WRUP (assessment of content except microbial load)	Discharges with organic load, expressed as chemical oxygen demand (COD) or five-day biochemical oxygen demand (BOD_5) or discharges with nutrients, expressed as total nitrogen (N_{total}) or total phosphorus (P_{total}) or discharges of other parameters defined in the WRUP ([X]) and not included in any of the classifications in the other sub-items, under the following conditions: ELV < BOD_5 and/or COD and/or N_{total} and/or P_{total} and/or [X] ≤ 2xELV	3
	Discharges with organic load, expressed as chemical oxygen demand (COD) or five-day biochemical oxygen demand (BOD_5) or discharges with nutrients, expressed as total nitrogen (N_{total}) or total phosphorus (P_{total}) or discharges of other parameters defined in the WRUP ([X]) and not included in any of the classifications in the other sub-items, under the following conditions: 2xELV < BOD_5 and/or COD and/or N_{total} and/or P_{total} and/or [X] ≤ 3xELV	5
	Discharges with organic load, expressed as chemical oxygen demand (COD) or five-day biochemical oxygen demand (BOD_5) or discharges with nutrients, expressed as total nitrogen (N_{total}) or total phosphorus (P_{total}) or discharges of other parameters defined in the WRUP ([X]) and not included in any of the classifications in the other sub-items, under the following conditions: 3xELV < BOD_5 and/or COD and/or N_{total} and/or P_{total} and/or [X] ≤ 4xELV or Discharge containing specific pollutants (defined in the River Basin Management Plan, RBMP, territorially applicable) or substances that are hazardous to environment (aquatic ecosystems)[30] if: Parameter > ELV (if this is defined in the WRUP) or presents a quantifiable value in the absence of an ELV expressed in the WRUP or other substances, not specified in the WRUP, causing deterioration of water quality for at least one parameter supporting the ecological status[31] of the receiving water body, in a location considered appropriate for sampling, unless the WRUP contains another provision (i.e., with a definition of a mixing zone)	7

[30] or ammonium exceeding 10 mg/L NH_4.

[31] In accordance with the RBMP in force and territorially applicable and monitoring to support compliance with the Water Framework Directive (Directive 2000/60/EC, text in force).

Table 2: Factors relating to the potential for the occurrence to cause adverse effect on surface waters (cont.)

Factors (f_{oc_i})	Description	Classification
Wastewater discharge with WRUP (assessment of content except microbial load)	Discharges with organic load, expressed as chemical oxygen demand (COD) or five-day biochemical oxygen demand (BOD_5) or discharges with nutrients, expressed as total nitrogen (N_{total}) or total phosphorus (P_{total}) or discharges of other parameters defined in the WRUP ([X]) and not included in any of the classifications in the other sub-items, under the following conditions: BOD_5 and/or COD and/or N_{total} and/or P_{total} and/or [X] > 4x ELV Or Wastewater discharges containing priority, priority hazardous substances or other pollutants defined in the Directives 2013/39/EU and 2008/105/EC or very persistent substances or very toxic, reprotoxic, mutagenic or with endocrine disrupting potential[32] or Total Petroleum Hydrocarbons C_{10}-$C_{40,}$ if: Parameter > ELV ((if this is defined in the WRUP) or presents a quantifiable value in the absence of an ELV expressed in the WRUP Sampling should be carried out at a location considered to be suitable for that purpose, unless the WRUP contains another provision (i.e., with definition of mixing zone)	9

[32] "Toxic" or "Serious health hazard" substances:  or  .

Table 2: Factors relating to the potential for the occurrence to cause adverse effect on surface waters (cont.)

Factors (f_{oc_i})	Description	Classification
Wastewater discharge without WRUP (exclusive evaluation of microbial load[33]) and/or of unknown origin, but with suspected faecal contamination or presence of uses likely to be affected[34]	Discharge with observable effect, i.e., not more than one logarithmic unit above the upstream reference values in watercourses or outside the affected area, in reservoirs (dams), estuaries and coastal areas, at a location considered appropriate for sampling	3
	Discharge with observable effect, i.e., not more than two logarithmic units above the upstream reference values in watercourses or outside the affected area, in reservoirs (dams), estuaries and coastal areas, at a location considered appropriate for sampling	5
	Discharge with observable effect, i.e., not more than three logarithmic units above the upstream reference values in watercourses or outside the affected area, in reservoirs (dams), estuaries and coastal areas, at a location considered appropriate for sampling	7
	Discharge with observable effect, i.e., exceeding the upstream reference values by three or more logarithmic units in watercourses or outside the affected area, in reservoirs (dams), estuaries and coastal areas, at a location considered appropriate for sampling	9
Wastewater discharge with WRUP (exclusive evaluation of microbial load) [25]	Discharge with microbial load, expressed in *Escherichia coli* (or Faecal coliforms) under the following conditions: ELV < microbial load ≤ 2xELV, if ELV < 1000 cfu (or MPN)/100 mL or Microbial load is not more than one logarithmic unit above the ELV, if ELV ≥ 1000 cfu (or MPN)/100 mL	3
	Discharge with microbial load, expressed in *Escherichia coli* (or Faecal coliforms) under the following conditions: 2xELV < microbial load ≤ 3xELV, if ELV < 1000 cfu (or MPN)/100 mL or Microbial load is not more than two logarithmic units above the ELV, if ELV ≥ 1000 cfu (or MPN)/100 mL	5
	Discharge with microbial load, expressed in *Escherichia coli* (or Faecal coliforms) under the following conditions: 3xELV < microbial load ≤ 4xELV, if ELV < 1000 cfu (or MPN)/100 mL or Microbial load is not more than three logarithmic units above the ELV, if ELV ≥ 1000 cfu (or MPN)/100 mL	7
	Discharge with microbial load, expressed in *Escherichia coli* (or Faecal coliforms) under the following conditions: microbial load ≥ 4xELV, if ELV < 1000 cfu (or MPN)/100 mL or Microbial load exceeding the upstream reference values by three or more logarithmic units[35] , if ELV ≥ 1000 cfu (or MPN)/100 mL	9

[33] Indicator parameter: *Escherichia coli* or Faecal coliforms.

[34] E.g., faecal odour or visual identification. See tables 5 and 6 (e.g. bathing water, water abstraction, other).

[35] Typical order of magnitude for untreated wastewater with contamination of faecal origin.

Table 3: Factors relating to the potential for the occurrence to cause adverse effect on groundwater

Factors (f_{oc_i})	Description	Classification
Rejection[36] of chemicals or waste disposal containing chemicals or other deposition (including agro-industrial or agricultural waste/sub-products) or hazardous event or occurrence of unknown origin or wastewater discharge (assessment of water abstractions in the vicinity the location of the occurrence or hazardous event, i.e., within a maximum radius of 50 m)	Chemical products and/or waste or runoff/rejection containing substances not classified as hazardous (classification and labelling legislation for chemicals[37]) and causing a visible colour change above 20 mg/L Pt-Co or an odour at a dilution of 1:3[38]	3
	Chemical products and/or waste or runoff/rejection containing other substances classified as hazardous (harmful/irritant)[39]	5
	Chemical products and/or waste or runoff/rejection containing specific pollutants (defined in the River Basin Management Plan, RBMP, territorially applicable)	7
	Chemical products and/or waste or runoff/rejection containing substances or pollutants that may alter the pollution indicators[40] whose thresholds are defined under the Directive 2006/118/EC[41], or other pollutants classified as priority, priority hazardous substances or other pollutants defined in the Directives 2013/39/EU[42] and 2008/105/EC[43] or very persistent substances or very toxic, reprotoxic, mutagenic or with endocrine disrupting potential[44] or Total Petroleum Hydrocarbons C_{10}-C_{40}.	9

The assessment of the change in parameters in the receiving environment should be compared with upstream or off-site values in reservoirs (dams), estuaries or coastal areas.

For marketed chemicals, information can be obtained through the website of the European Chemicals Agency (ECHA), available at https://echa.europa.eu/pt/information-on-chemicals/registered-substances.

[36] From fixed units (e.g., industrial units) or mobile units (transport of chemical products).

[37] Information visible on labels (no hazard pictograms) or safety data sheets or through information provided on ECHA's website available at https://echa.europa.eu/pt/information-on-chemicals/registered-substances.

[38] Maximum recommended values expressed in Decree-Law 236/98 of 1 August 1998 (Annex I, class A1). TN: Portuguese legislation. Colour value measured after simple filtration at a wavelength of 420 nm. Odour value measured on a sample diluted in a 1:3 ratio at 25 ºC.

[39]  .

[40] $NH_4 > 10\ mgL^{-1}$ or $NO_3 > 50\ mgL^{-1}$.

[41] Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration (TN: National legislation, Decree-Law No. 208/2008, of 28 October, as amended)

[42] Directive 2013/39/EU of the European Parliament and of the Council of 12 August 2013 amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy

[43] Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy,

[44] "Toxic" or "Serious health hazard" substances:  or  .

2.4.2 Ionising radiation

For the assessment of the effects of the discharge, emission or introduction of ionising radiation into the atmosphere, soil or water, the provisions of the Council Directive 2013/59/Euratom, of 5 December 2013[45], laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, should be taken into account.

According to the definitions described in Article 4 of the above-mentioned Directive, radioactivity is a characteristic of the so-called "radioactive substances", which results in the emission of radiation which, due to its energy, causes the ionization of other substances and materials affected by it. This peculiarity gives rise to the term 'ionising radiation'. It should be noted that a given substance or matter is not ionising, but the radiation it emits is. Therefore, the term ionizing substance or material is not scientifically correct.

Under the same directive a radioactive substance is defined any substance that contains one or more radionuclides the activity or activity concentration of which cannot be disregarded from a radiation protection point of view. While ionising radiation, means energy transferred in the form of particles or electromagnetic waves of a wavelength of 100 nanometres or less (a frequency of 3×10^{15} hertz or more) capable of producing ions directly or indirectly.

Other terms contained in the above-mentioned directive that need to be considered in order to understand the issue and the adverse effects on water are:

- radioactive material, i.e., material incorporating radioactive substances;
- radioactive source means a radiation source incorporating radioactive material for the purpose of utilising its radioactivity.

The general definition, which does not appear in the directive, is that a radioactive radionuclide (or radioisotope) or nuclide (or isotope) is characterised by having an unstable atomic nucleus that releases energy when transformed into a more stable nuclide (or isotope).

The harmful effects of radioactivity are well known, as its ability to cause ionisation leads to atomic and molecular changes in the constituents of living organisms, resulting in cell mutation with possible damage to tissues, organs and systems. Uncontrolled emissions of radioactivity can result in severe chronic effects or even death. On the other hand, the decay of this property is slow, so exposure can be prolonged with aggravated chronic effects. To visualise, the half-life[46] of some sources of radioactivity listed in Directive 2013/59/Euratom, ranges from 5,3 years for cobalt 60 (Co-60), 33 years for Cesium 137 (Cs-137) or even 92 years for plutonium 238 (Pu-238). If we talk about uranium sources, for example, then we are talking about half-lives of 7.8 x 10^8 years for uranium 235 (U-235) or 4.5 x 10^9 for uranium 238.

In view of the potential harmful effects of radioactive sources on humans and the environment, certain practices are categorically prohibited under national regulatory control[47]:

- the decommissioning of radiation sources and radioactive waste;
- the unauthorised discharge of radioactive effluents into soil, air, surface, ground, transitional, coastal and marine waters and sewerage systems;

[45] TN: Decree-Law No. 108/2018, 3 December (Portuguese legislation).

[46] Half-life - the length of time it takes for half of the radioactive atoms of a specific radionuclide to decay.

[47] TN: Article 9, of Decree-Law No. 108/2018, 3 December (Portuguese legislation).

- the unauthorised disposal of radioactive biological products.

It should also be noted that in case of a release of ionising radiation into the environment, decontamination takes place through the natural decay of the radiation emitted. Depending on the nature of source, the decay process may take longer than the average life expectancy.

Thus, in case of "discharge, emission or introduction of ionising radiation into air, soil or water" is concerned, the I_{tc} should be classified as equivalent to "unacceptable outcome" for surface water and/or groundwater. Therefore, this type of event may/should represent a significant damage to water resources given its potential harmful effects on water bodies over a prolonged period of time. This exposure may result in acute or chronic effects, the latter of which may not be immediately visible to the naked eye, such as mutagenic effects, and may not be clearly measurable at the evidence-gathering stage. In the medium to long term, this type of occurrence or hazardous event may result in the total loss of the ecosystem, with possible indirect adverse effects on humans, e.g. ingestion of contaminated species.

2.5 Consequence

The consequence, as already mentioned, is the result of the product between the adverse effect and the potential to affect water resources. The determination of the adverse effect depends on two descriptors, namely the inherent severity and the typology of the occurrence or hazardous event.

2.5.1 Typology of occurrence

An occurrence or hazardous event may be the result of an unusual act of limited duration. It may be a single event or it may occur periodically. The act may also be continuous as a result of specific situations, such as poor management of premises and/or equipment, their poor operation or poor level of treatment (of wastewater) in relation to the characteristics and uses of the receiving environment. Any occurrence may therefore be the result of intentional or negligent acts, or may result from unforeseen circumstances.

Consequently, events or hazardous occurrences could be of two different types according to the definitions below:

- **discontinuous** which means an undesirable (incident) or anticipated event, occurring sporadically or regularly, which results in the discharge or emission of wastewater or pollutants into water resources and which may cause adverse effects on water resources;
- **continuous** which means an undesirable (incident) or anticipated event that occurs continuously or at short intervals and results in the discharge or emission of wastewater or pollutants into water resources and may cause adverse effects on water resources.

The classification and quantification of the type of occurrence or hazardous event is carried out using a factor, based on whether or not similar situations have occurred in the past. In order to support this exercise, the scale shown in Table 4 will be used.

Table 4: Scale applied to the term "typology of occurrence or hazardous event

Description	Type	Classification
There are no records of this type of occurrence in the last 12 months	Discontinuous occurrence	3
There has been a single occurrence in the last 12 months	Discontinuous occurrence	5
There has been more than one occurrence in the last 12 months	Discontinuous occurrence	7
Is it a continuous wastewater discharge or is there a record of more than six occurrences in the last 12 months	Continuous occurrence	9

Whenever a given occurrence lasts longer than one week (7 days), it should be classified as continuous.

2.5.2 Severity

The severity of the adverse effect considers the degree to which water resources are affected as a result of the occurrence or hazardous event in question. The severity of these effects on surface water or groundwater ($Severity_{WR\ SW\ or\ GW}$) is determined from equation 7, where $f_{Sev_{SW\ or\ GW}}$ represents the various severity inherent factors described in tables 5 and 6 for surface water and groundwater respectively. Similar to $P_{occurrence}$, for downscaling, is considered a normalisation factor ($n_{f_{Sev_{WR\ SW\ or\ GW}}}$) that identifies the total number of individual factors. So, the $Severity_{WR\ SW\ or\ GW}$ also ranges from 3 to 9.

$$Severity_{WR\ SW\ or\ GW} = \frac{\sum f_{Sev_{SW\ or\ GW_i}}}{n_{f_{Sev_{WR\ SW\ or\ GW}}}} \quad (7)$$

The factors considered for surface water are:

- mortality, impairment of anthropic uses and/or services of water bodies, and deterioration of water quality (impact on the parameters used to classify the status of water bodies);
- linear extension of the occurrence associated with the previous factors (discharge).

With the exception of mortality, the factors for surface water also apply to groundwater.

The values obtained from equation 7 are expressed as follows:

- result (eq. 7) ≤ 3 then $Severity_{WR\ SW\ or\ GW} = 3$
- 3 < result (eq. 7) ≤ 5 then $Severity_{WR\ SW\ or\ GW} = 5$
- 5 < result (eq. 7) < 7 then $Severity_{WR\ SW\ or\ GW} = 7$
- result (eq. 7) ≥ 7 then $Severity_{WR\ SW\ or\ GW} = 9$

Table 5: Factors for severity of the adverse effect on surface water

Factors ($f_{Sev_{WR\ SW_i}}$)	Description	Classification
Mortality	Number of dead specimens ≤ 10 specimens (except any specimens of protected species) in a lentic system	3
	Number of dead specimens ≤ 10 specimens (except of any specimens of protected species) in a lotic system within a linear distance of 1000 metres downstream of the occurrence, or in coastal waters (where traces of the occurrence can be seen)	5
	Number of dead specimens > 10 specimens (except any specimens of protected species) in a lentic system	7
	Number of dead specimens > 10 specimens (except any specimens of protected species) in a lotic system within a linear distance of 1000 metres downstream of the occurrence, or in coastal waters (where the traces of the occurrence can be seen) or the mortality of any specimens of protected species in a lentic system, a lotic system or coastal waters (where the traces of the occurrence can be seen)	9

Table 5: Factors for severity of the adverse effect on surface water (cont.)

Factors ($f_{Sev_{WR\ SW_i}}$)	Description	Classification
Impairment of anthropic uses and/or services of water bodies[48]	Deterioration of the quality of groundwater in at least one parameter for existing or planned industrial uses that do not require a quality, in terms of the parameters pH, colour and conductivity higher than pH - 5.5 to 9.0 Sörensen scale, Colour ≤ 50 mg/L Pt-Co scale, Conductivity ≤ 1000 µS/cm, 20° C[49].	3
	Deterioration of the quality of surface water[50] in at least one parameter for existing or planned industrial uses, excluding uses from the other paragraphs and that do not require drinking water quality. For reference, the quality standards described in the WRUP or in previous information related to the use are considered. In the absence of standards included in these documents, the impairment should be classified according to the previous paragraph (i.e., with a value equal to three)	5
	Deterioration of freshwater quality in at least one parameter for existing or planned agricultural uses, excluding crops intended for raw consumption and where the edible part is in contact with water[51]	7
	Impairment of existing or potential uses of water for human consumption, including the production of drinking water or water of higher quality (e.g. some industrial uses), animal watering, existing or planned agricultural uses for the production of crops intended for raw consumption or where the edible part is in contact with water, bathing waters, waters in protected areas for aquatic species of economic interest (e.g. shellfish and fish production areas). The specific legislation applicable to drinking water and the class A described in Regulation (EU) 2020/741 (production of crops intended for raw consumption), bathing water directive[52] or legislation applicable to shellfish production are taken as the reference for the assessment of water quality deterioration. To this end, the quality standards described in these legal documents are taken as a reference. Deterioration of water quality is also considered to be the impairment of use resulting from any restriction imposed by the competent authorities for a period of more than 48 hours.	9

[48] Within a certain radius, as far as visible traces of the occurrence (depending on the particular characteristics of the receiving water bodies, e.g., streams, canals or rivers, areas subject to tidal influence, morphology).

[49] TN: Class A3, from Annex 1 of Decree-Law 236/98, of 1 August, Portuguese legislation.

[50] Freshwater, brackish water or saline waters.

[51] TN: For this purpose, the Maximum Recommended or Admissible Values described in Annex XVI of Decree-Law 236/98, of 1 August are considered as a reference, Portuguese legislation (see annex).

[52] Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality.

Table 5: Factors for severity of the adverse effect on surface water (cont.)

Factors ($f_{Sev_{WR\ SW_i}}$)	Description	Classification
Deterioration of water quality [53]	Deterioration in water quality for at least one parameter supporting the status classification of the water body at a distance greater than 30 m and less than 75 m from the point of occurrence, or at the outer boundary of the mixing zone (where applicable, i.e., if noted in the WRUP) if this is greater than 75 m but less than 125 m from the point of occurrence, but with no observed impact beyond this distance	3
	Deterioration in water quality for at least one parameter supporting the status classification of the water body at a distance greater than 75 m and less than 125 m from the point of occurrence, or at the outer boundary of the mixing zone (where applicable, i.e., if noted in the WRUP) if this is greater than 125 m but less than 250 m from the point of occurrence, but with no observed impact beyond this distance	5
	Deterioration in water quality for at least one parameter supporting the status classification of the water body at a distance greater than 125 m and less than 250 m from the point of occurrence, or at the outer boundary of the mixing zone (where applicable, i.e., if noted in the WRUP) if this is greater than 250 m but less than 500 m from the point of occurrence, but with no observed impact beyond this distance	7
	Deterioration of water quality for at least one parameter supporting the status classification of the water body at any distance of 250 m or more from the point of occurrence or at the outer boundary of the mixing zone (where applicable, i.e., noted in the WRUP) if this is more than 500 m from the point of occurrence	9

[53] The assessment must be made:

- the worst case where the event affects more than one water body, i.e., the water body with the worst status;
- in accordance with the definition of deterioration of water quality described in this document and with the RBMP in force and territorially applicable and the monitoring results to support compliance of the Water Framework Directive (Directive 2000/60/EC, text in force);
- For the purposes of status, the overall status of the water body is considered, including the ecological and chemical status, in accordance with the Water Framework Directive (Directive 2000/60/EC, text in force. TN: Law 58/2005, 29 December, as amended, Portuguese legislation), and with the territorially applicable RBMP in force, and with Directives 2013/39/EU and 2008/105/EC (TN: Decree-Law 103/2010 of 24 September and Decree-Law 218/2015 of 7 October, Portuguese legislation).

Table 6: Factors relating to the severity of the adverse effect on groundwater

Factors ($f_{Sev_{WR\ GW_i}}$)	Description	Classification
Impairment of anthropic uses or services of water bodies	Deterioration of the quality of groundwater in at least one parameter for existing or planned industrial uses that do not require a quality, in terms of the parameters colour and conductivity higher than Colour ≤ 20 mg/L Pt-Co scale, Conductivity ≤ 1000 µS/cm, 20° C[54].	3
	Deterioration of water quality in at least one parameter for existing or planned industrial uses, excluding uses from the other paragraphs and that do not require drinking water quality. For reference, the quality standards described in the WRUP or in previous information related to the use are considered. In the absence of standards included in these documents, the impairment should be classified according to the previous paragraph (i.e., with a value equal to three)	5
	Deterioration of water quality in at least one parameter for existing or planned agricultural uses, excluding crops intended for raw consumption and where the edible part is in contact with water[55]	7
	Impairment of existing or potential uses of water for human consumption, including the production of drinking water or water of higher quality (e.g. some industrial uses), existing or planned agricultural uses for the production of crops intended for raw consumption or where the edible part is in contact with water. The specific legislation applicable to drinking water and the class A described in Regulation (EU) 2020/741[56] (production of crops intended for raw consumption) are taken as the reference for the assessment of water quality deterioration. To this end, the quality standards described in these legal documents are taken as a reference. Deterioration of water quality is also considered to be the impairment of use resulting from any restriction imposed by the competent authorities for a period of more than 48 hours.	9
Impact on the parameters used to classify the status of water bodies [57]	Deterioration in the water quality of at least one parameter supporting the classification of the status of the groundwater body within a radius of less than 50 metres from the point of occurrence. For this purpose, environmental quality standards, environmental quality objectives and threshold values shall be taken into account.	9

[54] TN: Class A1, from Annex 1 of Decree-Law 236/98, of 1 August, Portuguese legislation.

[55] TN: For this purpose, the Maximum Recommended or Admissible Values described in Annex XVI of Decree-Law 236/98, of 1 August are considered as a reference, Portuguese legislation (see annex).

[56] Regulation (EU) 2020/741 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse

[57] In situations where the event affects more than one water body, the assessment shall be made on a worst-case basis, i.e., by the water body with the worst status. For this purpose, all parameters associated with chemical status are taken into account.

2.5.3 Adverse effect

The adverse effect on water resources is defined as the result of any act that adversely and significantly affects water quality, aquatic ecosystems or their uses or services. As described in section 2, the adverse effect is the product of the typology of occurrence or hazardous event and the severity of the adverse effect itself. This product can be obtained through the matrix described in figure 1. Thus, from the results of equation 7 (related to the determination of the severity) and table 4 (direct classification of the typology), it is possible to read directly in the matrix below the value corresponding to the adverse effect, which, as can also be seen, varies from 3 to 9.

		"Typology" result			
		3	5	7	9
" Severity" result	3	3	5	5	5
	5	5	5	7	7
	7	5	7	7	9
	9	5	7	9	9

Figure 1: Adverse effect matrix

2.5.4 Potential to affect water resources

A particular occurrence or hazardous event may have a direct impact on water resources due to the nature and content of the event itself. However, the receiving water resources are likely to be affected to a greater or lesser extent due to their physical, hydrogeological, morphological characteristics and/or their uses or services.

Therefore, the description of the term "potential to affect water resources" should take into account the exposure pathways to water (in case of pollutant emissions or pollutant loads) as described in Figure 2. Observation of these pathways is assessed by correlating the uses and services of water resources and their respective distances from the occurrence or hazard event with the physical, hydrogeological and morphological characteristics of the water bodies concerned. Thus, a set of indirect factors (for surface and groundwater) and a set of direct factors (for surface water) are defined.

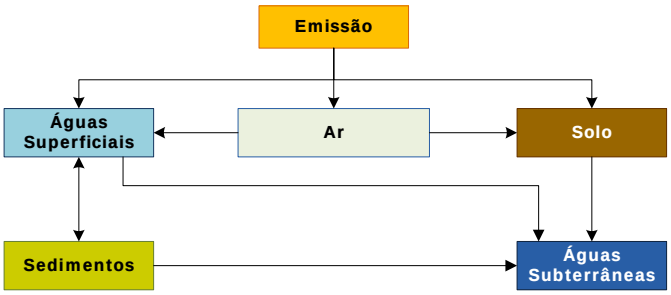

Figure 2: Pathways for water resources contamination (adapted from Rebelo et al., 2014)[58]

Indirect factors for surface water and groundwater are considered, namely:

- indirect factors for surface water, the presence in the vicinity of the occurrence or hazardous event of:
  - streams, canals, rivers, estuaries or coastal areas;
  - flooding areas;
  - reservoirs (dams);
  - public water reservoirs (dams);
  - water abstraction;
- indirect factors for groundwater, the presence in the vicinity of the occurrence or hazardous event:
  - groundwater abstraction.

Another indirect factor common to both types of water body is also taken into account in relation to water resource services, namely the impact on protected areas for habitats and wild fauna and flora and the conservation of wild birds and nature.

Direct factors related to uses and services of water bodies are also considered, namely:

- areas designated as recreational waters, including areas designated as bathing areas;
- areas for the protection of aquatic species of economic interest or to support fish life.

The classification of indirect factors is determined by matrix integration between the considered factors and the characteristics of the existing water resources, namely their sensitivity[59] (criterion a: sensitive areas to eutrophication and criterion c: protection of other uses[60]), and hydrogeological vulnerability given by vulnerability to nitrate pollution[61] and maximum infiltration zones (aquifer vulnerability to pollution). To obtain this classification, the results of the direct readings in table 7 for surface water ($f'_{WR\,SW}$), and in table 8 for groundwater ($f'_{WR\,GW}$),

[58] A. Rebelo, I. Ferra, I. Gonçalves, A.M. Marques, A risk assessment model for water resources: releases of dangerous and hazardous substances, J. Environ. Manag. 140 (2014) 51-59.

[59] Areas designated under Council Directive 91/271/EEC of 21 May 1991 concerning urban wastewater treatment (TN: Decree-Law No 152/97 of 21 June 1997, as amended, Portuguese legislation).

[60] TN: The criterion (b) laid down on Annex II of Directive 91/271/EEC was not considered since there is no area classified under this criterion in Portugal.

[61] Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (TN: Decree-Law No 235/97 of 3 September 1997, as amended, Portuguese legislation).

are entered individually in the two matrices described in figures 3 and 4, which give two different results, namely:

- result of the "vulnerable zone/maximum infiltration zone" matrix obtained from figure 3;
- result of the "sensitive area" matrix obtained from figure 5.

Table 7: "Impairment of surface water" indirect factors

Factors $(f)'_{RH\ sup}$	Description	Classification
Streams, canals, rivers, estuaries or coastal areas (distance to the occurrence) (level classification obtained from figures 3 and 4)	d[62] > 50 m	Level 1
	25 m < d ≤ 50 m	Level 2
	10 m < d ≤ 25 m	Level 3
	d ≤ 10 m	Level 4
Flooding areas (distance to occurrence) (level classification obtained from figures 3 and 4)	d > 50 m	Level 1
	10 m < d ≤ 50 m	Level 2
	d ≤ 10 m	Level 3
	Within the area	Level 4
Reservoirs/dams (distance to occurrence) (level classification obtained from figures 3 and 4)	d > 100 m	Level 1
	50 m < d ≤ 100 m	Level 2
	25 m < d ≤ 50 m	Level 3
	d ≤ 25 m	Level 4
Public water reservoirs/dams (distance to occurrence) (level classification obtained from figures 3 and 4)	d > 500 m	Level 1
	100 m < d ≤ 500 m	Level 2
	25 m < d ≤ 100 m	Level 3
	d ≤ 25 m	Level 4
Water abstraction (distance to occurrence) (level classification obtained from figures 3 and 4)	d > 500 m	Level 1
	250 m < d ≤ 500 m	Level 2
	50 m < d ≤ 250 m	Level 3
	d ≤ 50 m	Level 4

Table 8: "Impairment of groundwater" indirect factors

Factors $(f)'_{RH\ sup}$	Description	Classification
Water abstraction (distance to occurrence) (level classification obtained from figures 3 and 4)	d > 500 m	Level 1
	250 m < d ≤ 500 m	Level 2
	50 m < d ≤ 250 m	Level 3
	d ≤ 50 m	Level 4

[62] Distance from the point of occurrence (site of rejection/emission) to the water resource, measured in linear meters

	f'WR SW or GW			
	Level 1	Level 2	Level 3	Level 4
Non-classified areas	3	5	5	5
Catchment areas of a sensitive area	5	5	7	7
Sensitive areas (criterion c)	5	7	7	9
Sensitive areas (criterion a)	5	7	9	9

Figure 3: Sensitive Area Matrix[63]

	f'WR SW or GW			
	Level 1	Level 2	Level 3	Level 4
Non-classified areas	3	5	5	5
Maximum infiltration zones	5	5	7	7
Vulnerable zones for nitrate pollution	5	7	7	9
Areas vulnerable to nitrate pollution and maximum infiltration zones	5	7	9	9

Figure 4: Vulnerable zone/maximum infiltration zone matrix

The two results obtained from the reading of the two previous matrices are then integrated by the matrix in figure 5 to obtain a single value for each factor considered (f''$_{WR\ SW\ or\ GW}$):

[63] Criterion (a) is considered to be of greater importance because, if met, it is likely to involve more prolonged impacts on water resources over time as it involves chemical imbalances in water bodies in terms of nutrients.

Result of the "sensitive area" matrix	Result of the "vulnerable zone/maximum infiltration zone" matrix			
	3	**5**	**7**	**9**
3	3	5	5	5
5	5	5	7	7
7	5	7	7	9
9	5	7	9	9

Figure 5: Integration matrix "sensitive area" vs "vulnerable zone/maximum infiltration zone"

From the integrated values for the indirect factors, a partial "potential to affect surface water or groundwater" is calculated ($P'_{impair_{WR\ SW\ or\ GW}}$) using equation 8 and a normalisation factor ($n_{f_{WR\ SW\ or\ GW}}$) is used to obtain a partial value ranging from 3 to 9.

$$P'_{impair_{WR\ SW\ or\ GW}} = \frac{\sum f''_{WR\ SW\ or\ GW_i}}{n_{f_{WR\ SW\ or\ GW}}} \quad (8)$$

Where $f''_{WR\ SW\ or\ GW}$ is the factor of the potential to affect water resources, surface water or groundwater, obtained from figure 5.

The need to obtain a partial score concerns the need to include the indirect factor related to the protection of habitats and wildlife and the conservation of wild birds and nature in the "potential to affect water resources".

Thus, the "potential to affect water resources" ($P_{impar\ WR\ SW\ or\ GW}$) is obtained by the following steps:

1. Use of equation 9 to determine an intermediate value ($P''_{impar\ WR\ (SW\ or\ GW)}$), for the integration of the factor assigned to the protection of habitats and wildlife and the conservation of wild birds and nature ($f_{protection}$), whose classification can be seen in table 9:

$$P''_{impair\ WR\ (SW\ or\ GW} = \frac{P'_{impair\ WR\ (SW\ or\ GW} \times f_{protection}}{9} \quad (9)$$

Table 9: Indirect common factor relating to the effect on surface water or groundwater resources (habitat protection)

Factors ($f_{Protection}$)	Description	Classification
Habitats and wildlife and the conservation of wild birds and nature	Outside of the protected areas	3
	Surrounding areas of national parks that may have some specific protection requirements[64]	5
	National parks and other national protected areas	7
	Sites of Community interest or Special Protection Areas[65]	9

2. The result of the previous equation is then prioritised for the scale of importance, i.e., from 3 to 9, according to the relationship described in table 10. This step enables the partial value of the "potential to affect water resources" to be obtained exclusively from the indirect factors. ($P^{ind}_{impair\ WR\ SW\ or\ GW}$):

Table 10: "Potential to affect water resources" (surface water or groundwater) related to indirect factors

$P''_{impair\ WR\ SW\ or\ GW}$	$P^{ind}_{impair\ WR\ SW\ or\ GW}$
$P'' \leq 1$	3
$1 < P'' \leq 3$	5
$3 < P'' \leq 5$	7
$P'' > 5$	9

The partial "potential to affect water resources" concerning the direct factors ($P^{dir}_{impar\ WR\ SW}$) is only applicable to surface waters and is given by equation 10, which includes a normalisation factor ($n_{f^{dir}_{WR\ SW}}$) is used to obtain a partial value ranging from 3 to 9. The ranking of the direct factors is shown in table 11 and is equal to zero if none of the factors applies.

$$P^{dir}_{impair\ WR\ SW} = \frac{\sum f^{dir}_{WR\ SW_i}}{n_{f^{dir}_{WR\ SW}}} \quad (10)$$

Table 11: Direct factors for "Potential to affect water resources" (surface water)

Factors ($f_{WR\ SW}$)	Description	Classification
Areas designated as recreational waters, including areas designated as bathing areas;	d > 500 m	3
	100 m < d ≤ 500 m	5
	25 m < d ≤ 100 m	7
	d ≤ 25 m	9
Areas for the protection of aquatic species of economic interest or to support fish life	d > 500	3
	100 m < d ≤ 500 m	5
	25 m < d ≤ 100 m	7
	d ≤ 25 m	9

[64] TN: In Portugal this represents the areas classified as Pre-Park according land management plans.

[65] Designated under European legislation.

The final value for the "potential to affect water resources" for surface water ($P_{impair\ WR\ SW}$) is determined by equation 11, which also ranges from 3 to 9.

$$P_{impar_{WR\ SW}} = \frac{P^{dir}{}_{impair_{WR\ SW}} + P^{ind}{}_{impair_{WR\ SW}}}{2} \quad (11)$$

The values from equation 11 are expressed as follows:

- If result (eq. 11) < 2.5, then $P_{impair\ WR\ SW} = 3$
- If 2,5 ≤ result (eq. 11) < 3,5 then $P_{impair\ WR\ SW} = 5$
- If 3,5 ≤ result (eq. 11) < 4,5 then $P_{impair\ WR\ SW} = 7$
- If result (eq. 11) ≥ 4,5 then $P_{impair\ WR\ SW} = 9$

The final value for the "potential to affect water resources" related to groundwater is obtained directly from equation 9, since no direct factors are applicable to this type of water bodies. This implies that $P_{impair\ WR\ GW}$ is equal to $P''_{impair\ WR\ GW}$.

3 Sample collection and analysis

3.1 Sampling procedures

Sampling procedures should ensure that the sample taken is representative of the system being assessed. Therefore, good sampling practice should be adopted, taking into account the characteristics of the system, the intended objectives and the parameters to be analysed.

The sample should be as small as possible to be easily transported, but large enough to allow analytical testing and to ensure that the sample is representative.

Procedures for collection, preservation, storage and transport must ensure the integrity of the sample and prevent contamination.

Individuals responsible for sampling, whether they are part of a Judicial Authority, Criminal Police Department or Entities with responsibility for inspection or supervision, must be trained in good sampling practice.

Sample collection, preservation, storage and transport procedures shall be based on national and/or international standards. In the case of water sampling, an example is ISO 5667-3 - " *Water quality — Sampling — Part 3: Preservation and handling of water samples*", as amended.

The following documents also recommend good practice for sampling:

- RELACRE Guide 28 on Water Sampling (http://www.relacre.pt/assets/relacreassets/files/commissionsandpublications/GuiaRELACRE28_Amostragem%20de%20Aguas_VF_20171218.pdf), only in Portuguese;
- INTERPOL Pollution Crime Forensic Investigation Manual - Volume I (https://www.interpol.int/content/download/5170/file/INTERPOL%20Pollution%20Crime%20Forensic%20Investiation%20Manual%20-%20volume%201%20.pdf?inLanguage=eng-GB);
- INTERPOL Pollution Crime Forensic Investigation Manual - Volume II (https://www.interpol.int/es/content/download/5171/file/INTERPOL%20Pollution%20Crime%20Forensic%20Investiation%20Manual%20-%20volume%202%20EN.pdf).

Whenever justified, police authorities, inspection bodies or other competent authorities (e.g., national or regional environmental agencies) should cooperate in the selection of sampling points and relevant parameters.

Wherever possible, it is advisable to contact the laboratory responsible for the analysis beforehand. This prior communication will promote the use of appropriate bottles (in terms of material and volume) for each parameter or group of parameters to be analysed and the adoption of appropriate procedures for collection, preservation and transport until delivery of the samples to the laboratory.

As far as sampling procedures are concerned, they should be collected:

- punctual samples in the receiving water body (surface water or groundwater) for the determination of any parameter;
- punctual samples for wastewater to determine parameters that may change in a short period of time or other specificities, e.g., volatile organic compounds, microbiological

parameters or oils and fats, as well as to determine any other parameters that may characterise ongoing discharges or emissions;
- samples taken over a period of time representing the conditions of the discharge into water resources.

The reference documents mentioned above (RELACRE Guide 28 on Water Sampling and INTERPOL Pollution Crime Forensic Investigation Manual - Volume I and II) provide guidance on different types of sampling.

As an example, some indications for the subsurface collection of water samples in streams, rivers or canals, directly with the collection bottles, are given below (adapted from RELACRE, 2017):

- open the vials immediately prior to sampling and never before;
- wash the bottle with water from the site (not applicable in cases where the bottle is sterile or contains preservatives);
- hold the bottle by its base;
- dive with the mouth facing downwards about 30 cm (if the characteristics of the sampling point allow);
- place the mouth of the flask so that it is against the flow (to take the samples in the opposite direction to the flow);
- slowly invert the position of the bottle, under water, by turning the mouth upwards so that the neck is slightly higher than the base;
- avoid the inclusion of sediment, branches and leaves;
- allow to fill completely (if applicable);
- bring the bottle to the surface;
- add the preservatives (if applicable);
- put the lids on immediately after sampling and close hermetically.

In situations where is intended to analyse parameters involving dissolved or volatile gases or others that are correlated with these, the flask should be completely filled avoiding as much as possible contact with air or the formation of air bubbles in the flask. Adopt these recommendations, for example, when sampling for dissolved oxygen, BOD_5, COD and volatile organic compounds (VOC). Where conditions allow and the addition of preservatives is not required, it is desirable to seal the vial in water.

It is also desirable to close the flask immersed in water when microbiological parameters are to be analysed. However, in these situations the bottle should not be completely filled (fill to approximately ¾ of its capacity). When the bottle has been filled to the top, remove the excess by turning the bottle upside down and opening the cap slightly.

If immiscible substances such as detergents, hydrocarbons, oils and fats or others are intended to be analysed, sampling should be carried out at the air/water interface. In these cases, the bottle should not be completely filled either, but should be filled to the top but below the neck.

Sampling should start with the microbiological parameters, followed by dissolved oxygen, BOD_5, COD and then the other parameters.

Groundwater sampling should take into account the intended goals, namely to assess[66]:

1. the quality of water in an aquifer;
2. the quality of the water from the well/borehole/piezometer;
3. the quality of the water as used by the consumer (drinking water purposes).

Case 1 requires intensive pumping to replace well/bore/piezometer water with groundwater (30 hours or 3 renewal cycles).

For case 2, follow the same procedure as for case 1, without intensive pumping.

In case 3, the sample should be taken from the same container (e.g., bucket) used by consumers to draw water from the well/hole/piezometer.

For case 2, some guidelines for wells, boreholes or fixed piezometers are as shown below:

- at water abstraction sites equipped with a permanent pump, the sample should be taken from a tap upstream of the storage tank or cistern, if any. The tap should be disinfected with alcohol or by flaming prior to sampling;
- water from wells and boreholes lined with materials susceptible to corrosion should always be extensively pumped prior to sampling to remove any accumulated corrosion products from the system;
- in the case of boreholes that have been inactive for some time, it is advisable to allow the water to flow freely for 15-30 minutes (depending on the length of inactivity) before sampling to ensure that the water sampled is representative and not merely from the surface layer.

The procedures to be adopted must ensure the safety of personnel, particularly as regards to the use of personal protective equipment.

Sample flasks must be properly labelled and identified (i.e. indelibly and unambiguously) so that they can be easily traced to the sampling sheet/request form to be submitted to the analytical laboratory.

After collection, the samples should be stored in the dark and kept refrigerated during transport, e.g., in cooler bags with ice coolers, to ensure proper refrigeration until delivery to the laboratory.

Samples must be delivered to the laboratory for analysis as soon as possible and the maximum time between collection and start of analysis must be respected for each parameter or group of parameters. In the case of analysis of microbiological parameters, samples must be delivered to the laboratory within 8 hours of collection.

As mentioned above, the laboratory will specify the conditions to be met in each individual case of sampling.

3.2 Analytical methodologies

The analytical methods used to verify compliance with the provisions of this document relating to physico-chemical and microbiological parameters should preferably be carried out by laboratories accredited for this purpose. If this is not possible, samples should be sent to

[66] According RELACRE Guide 28 on Water Sampling (only available in Portuguese).

laboratories that maintain a duly documented and updated system of analytical quality control. The analytical methods should comply with the Directive 2009/90/EC[67] or, where it is not possible to demonstrate compliance with the criteria laid down in the Directive, properly accredited methods should be used to verify the quality standard.

[67] Commission Directive 2009/90/EC of 31 July 2009 laying down, pursuant to Directive 2000/60/EC of the European Parliament and of the Council, technical specifications for chemical analysis and monitoring of water status. TN: Decree-Law 83/2011, 20 June, Portuguese legislation.

4 Expression of the technical-scientific index for the clarification of illicit actions on water resources

4.1 Additional factors

As already mentioned in section 2.3, the technical-scientific index of clarification of the illicitness on water resources is determined by equation 5. Each term of the equation is determined as explained in the previous sections, in accordance with the description in Figure 6:

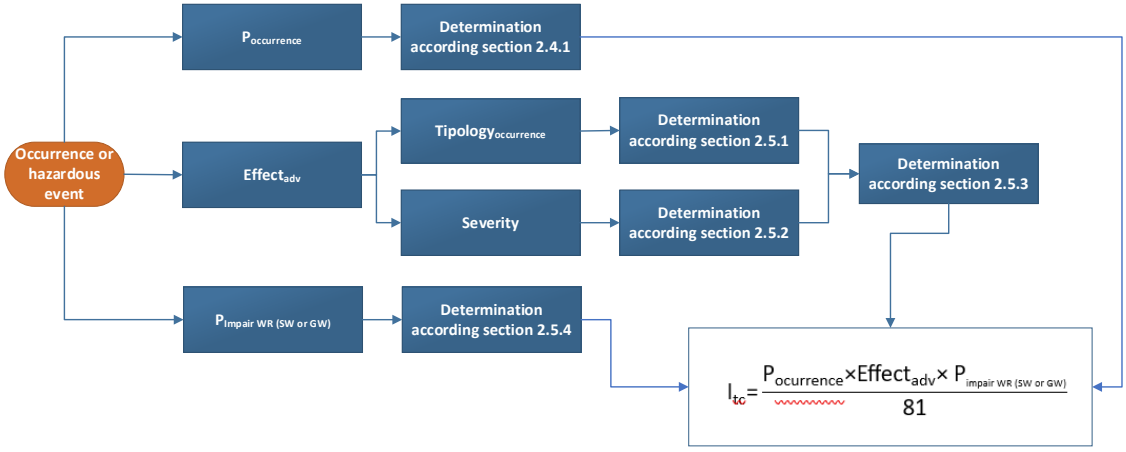

Figure 6: Scheme for determination of I_{tc}

Once this index has been obtained, it must be corrected to integrate additional factors arising from the need to measure the impact of the occurrence or hazardous event on the status of the water body. At the same time, situations of recurrence and/or non-implementation of measures previously identified by the competent authorities as required to prevent situations of pollution of water resources should also be distinguished.

The introduction of these factors relates to the fact that a particular occurrence or hazardous event may compromise the Member States obligations in terms of compliance with the WFD. From a different point of view, the practice of pollution may also represent a significant financial gain for the infringer/operator.

Following these concerns, equation 5 is improved to equation 12 by introducing a correction factor (f_{add}), which is obtained by equation 13 in conjunction with Table 12:

$$I_{tc}=\frac{P_{occurrence}\times Effect_{adv}\times P_{impair\ WR\ (SW\ or\ GW)}}{81}\times f_{add} \quad (12)$$

$$f_{add}=1+\sum f_{i\ add} \quad (13)$$

Table 12: Additional factors for correction of the technical-scientific index for the clarification of illicit actions on water resources (surface or groundwater)

Factor	Description	Increment	additional fi
A	Status of the water body[a] less than good[b] (see severity descriptor (table 5): "Factors for severity of the adverse effect on surface water"	20%	0,2
B	The non-compliant parameter(s) are coincident with those in support of the classification "less than good" (see severity descriptor (table 5): "Factors for severity of the adverse effect on surface water"	30%	0,3
C	Water body status good or better" and severity of adverse effect[c] on water resources (SW or GW) equal to or higher than seven	50%	0,5
D	Recurrence of discharge/disposal in contravention of applicable legislation	10%	0,1
E	Failure to implement, in whole or in part, the preventive and/or corrective measures required by the competent authorities as a result of previous discharges/disposals; or failure to meet the corresponding implementation deadlines	10%	0,1

[a] Status considers the overall status of the water body, including ecological and chemical status, in accordance with the WFD, the locally applicable RBMP and Directives 2008/105/EC and 2013/39/EC (national transposing legislation should be taken into account). TN: Law 58/2005 of 29 December, Decree-Law 103/2010 of 24 September and Decree-Law 218/2015 of 7 October, Portuguese legislation.
Surface water: ecological and chemical status; Transitional water: ecological and chemical potential status; Groundwater: chemical status. In surface waters, the classification is given by the worst state e.g., Ecological status equal to good and chemical status less than good, the final classification will be "less than good", according to the provisions of WFD ("One out, all out" principle).
[b] In situations where the event affects more than one water body of the same type, the assessment shall be made on a worst case basis, i.e. the water body with the worst status.
[c] Value obtained in accordance with section 2.

The status of the water body will always be the reference situation as defined in the applicable RBMP. The additional factors are cumulative as described in Equation 13. However, it should be noted that factors A and C can never be observed simultaneously. Whenever the final result is equal to or higher than nine, the index value takes the maximum value of significance, i.e., nine (9).

4.2 Prioritisation

Once the I_{TC} for surface water and groundwater has been obtained, it must be prioritised to determine the extent to which the actual outcome of the event is unacceptable for the water resources and thus demonstrate the existence of a significant adverse effect, which may be considered as significant or major damage.

Therefore, the quantitative results obtained for the technical-scientific index for the clarification of illicit actions on water resources (I_{tc}) are prioritized on a qualitative scale according to the correspondence described in table 13.

Table 13: Prioritization of the technical-scientific index for the clarification of illicit actions on water resources (surface or groundwater)

I_c	Description
$I_{tc} \geq 4$	The event or hazardous occurrence determines an unacceptable outcome for the surface water and/or groundwater, and therefore can/should be considered as significant for water resources
$I_{tc} < 4$	The event or hazardous occurrence determines an intermediate to acceptable outcome for water resources

4.3 Cumulative effects

The I_{tc} for both surface water and groundwater should be assessed in order to estimate the significant adverse effect on both types of water body. The I_{tc} for surface water and groundwater should then be summed. The results of the cumulative assessment are prioritised on a qualitative scale according to Table 14:

Table 14: Prioritization of the technical-scientific index for the clarification of illicit actions on water resources (surface and groundwater)

I_c (SW + GW)	Description
$I_{tc} \geq 8$	The event or hazardous occurrence determines an unacceptable outcome for the surface water and/or groundwater, and therefore can/should be considered as significant for water resources
$I_{tc} < 8$	The event or hazardous occurrence determines an intermediate to acceptable outcome for water resources

A result below the minimum thresholds does not mean that there are no adverse effects on water bodies. In fact, some events are likely to have some significant effects on water bodies, even if they do not have a significant adverse effect. Therefore, below the minimum thresholds, it should be noted that the result may vary from an intermediate to an acceptable level, depending on the extent of impairment observed.

5 Final remarks

This work defines a conceptual methodology, supported by the classical methods of risk characterisation, to determine whether a given occurrence or hazardous event on water resources leads to a significant adverse effect on them. Such situation can be measured and classified by the technical-scientific index for the clarification of illicit actions on water resources (I_{tc}).

The methodology developed aims to define, through a systematic and effective approach, the effective outcome of a given occurrence or hazardous event resulting from actions likely to cause significant adverse effects on surface water and/or groundwater.

When the I_{TC} expresses an unacceptable outcome for water resources, it means that the occurrence or hazardous event has resulted in significant adverse effects on water that are considered to cause significant damage to surface water and/or groundwater resources.

This document is therefore a tool to promote the enforcement of the law in relation to illegal acts affecting the water resources.

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Annex

Assessment of water quality for existing or planned agricultural uses

(when $f_{Sev_{WR\ SW_i}} = 7$, tables 5 and 6)

Parameters	Units	Maximum recommended value	Maximum admissible value
Aluminium (Al)	mg/L	5,0	20
Arsenic (As)	mg/L	0,10	10
Barium (Ba)	mg/L	1,0	
Beryllium (Be)	mg/L	0,5	1,0
Boron (B)	mg/L	0,3	3,75
Cadmium (Cd)	mg/L	0,01	0,05
Lead (Pb)	mg/L	5,0	20
Chlorides (Cl)	mg/L	70	–
Cobalt (Co)	mg/L	0,05	10
Copper (Cu)	mg/L	0,20	5,0
Total chromium (Cr)	mg/L	0,10	20
Tin (Sn)	mg/L	2,0	
Iron (Fe)	mg/L	5,0	
Fluor (F)	mg/L	1,0	15
Lithium (Li)	mg/L	2,5	5,8
Manganese (Mn)	mg/L	0,20	10
Molybdenum (Mo)	mg/L	0,005	0,05
Nickel (Ni)	mg/L	0,5	2,0
Nitrates (NO_3)	mg/L	50	
Salinity: EC TDS	 dS/m mg/L	 1 640	
SAR		8	
Selenium (Se)	mg/L	0,02	0,05
Total suspended solids (TSS)	mg/L	60	
Sulphates (SO_4)	mg/L	575	
Vanadium (V)	mg/L	0,10	1,0
Zinc (Zn)	mg/L	2,0	10,0
pH	Sorensen Scale	6,5-8,4	4,5-9,0
Faecal coliforms	/100 mL	100	
Intestinal nematodes (helminth eggs)	N/L		1