The management of aquifer recharge in the European legal framework

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Title: Managed aquifer recharge in the European legal framework

Summary: This report reviews the existing European Union and selected national legislation regarding managed aquifer recharge (MAR) activities. In summary, European Union legislations (WFD, GWD, and UWWTD) do not consider specifically the requirements for MAR, but the WFD stipulates MAR as a supplementary measure and indicates that this activity will require periodic controls and previous authorization. In the considered countries (Spain, Netherlands, Switzerland, Germany and France) there is a lack of harmonisation and many countries use the limits of drinking water requirements to allow MAR. Only Spain and Switzerland regulate specifically for direct and indirect input of water setting the requirements in the same parameters but giving different limits. EOC (emerging organic compounds) are not regulated on European level for MAR, but priority substances have been defined. After the review of the existing legislation, recommendations for the implementation of MAR in compliance with EU legisaltion were developed. Possible points of compliance for different MAR techniques are discussed.

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1 Overview of European and national legislation for implementation of Managed Aquifer Recharge schemes

1.1 European Union legislation

To foster the implementation of Managed Aquifer Recharge (MAR) it is important to ensure that MAR does not compromise any of the protective goals or threshold values given in European and national legislation. The present European water directives do not specify requirements for MAR schemes and only define a broad frame in which MAR may be developed. At a regional or national level some additional legislation or guidelines regulates specific concepts to achieve the protection of human health.

Hence, the European directives do not provide a dedicated approach or guidance along which managed aquifer recharge may be implemented. In the absence of dedicated legislation concerning MAR in Europe, especially with reclaimed water as source water, the projects have to consider different points of compliance. As a consequence, different aspects have to be taken into account in order to fulfill all potential legislations:

- Characteristics of the source water (e.g. reclaimed water) to be injected/infiltrated
- Groundwater and pore water quality (saturated and unsaturated zone)
- End-use of recovered water (depending on the intended end-use different requirements may have to be met)
- Environmental impacts (e.g. groundwater dependent ecosystems)

This report provides an overview of most relevant European and selected national legislative framework in the context of MAR implementation. The scope of most relevant European directives and possible relations to MAR are highlighted in the following.

1.1.1 Water framework directive (2000/60/CE)

Within the European water framework directive (WFD) surface water bodies are required to meet “good ecological and chemical status” and groundwater (GW) bodies “good chemical and quantitative status” by 2015. The WFD demands that no deterioration in water status by any activity over the territory may occur. The WFD mentions artificial recharge/managed aquifer recharge as a possible supplementary measure and indicates that this activity will require periodic controls and previous authorization. The article 11(3f) states that “controls, including a requirement for prior authorisation of artificial recharge or augmentation of groundwater bodies are mandatory. The water used may be derived from any surface water or groundwater, provided that the use of the source does not compromise the achievement of the environmental objectives established for the source or the recharged or augmented body of groundwater. These controls shall be periodically reviewed and, where necessary, updated“.

The WFD does not fix quality limits for recharged water but specifies that the activity cannot compromise the achievement of the water bodies environmental objectives. Artificial recharge/managed aquifer recharge is explicitly mentioned as a supplementary measure to reach the “good status” objectives, but no particular measures are mentioned to implement such measures.

1.1.2 Groundwater directive (2006/118/EC)

The objective of the groundwater directive (GWD) is to protect groundwater against pollution and deterioration through the establishment of specific measure to protect and control GW pollution. The directive requires identifying the chemical status of GW:

- The directive fixes the limits for nitrates and pesticides concentration.
- The directive requires to the member States the establishment of threshold values of As, Cd, Pb, Hg, NH4, Cl, SO4, PCE, TCE and electrical conductivity. These threshold values have to take into account the intrinsic or natural concentrations.

According to WFD, the member States have to elaborate specific measures to prevent or to limit the input of contaminants with the aim to ensure that the status of groundwater is not deteriorated and the contaminants do not show an upward trend. The contaminants to be controlled and limited are listed in WFD Annex VIII: Organohalogen compounds, Organophosphorous compounds, Organotin compounds, substances which have been proved to possess carcinogenic or mutagenic properties or properties, persistent hydrocarbons and persistent and bioaccumulable organic toxic substances, cyanides, metals and their compounds, arsenic and its compounds, biocides, materials in suspension, nitrates, phosphates and substances which have an unfavourable influence on the oxygen balance and other contaminants of concern for each state member. The limits have to include the attenuation capacity of the unsaturated zone.

Nevertheless, in case of artificial recharge the allowed concentration of contaminants can be adapted to each situation by the correspondent environmental authority avoiding the violation of other regulations.

1.1.3 Urban Wastewater Treatment Directive (91/271/EEC)

The urban waste water treatment directive (UWWTD) aims to protect the environment from any adverse effect due to the discharge of wastewater. The directive indicates the wastewaters that have to be collected and stipulates the minimum treatment level thus giving a first rough estimate of the quality parameter of wastewater treatment plant effluents (Table 1 and Table 2). At the same time it stipulates water reuse when stating "Treated waste water shall be reused whenever appropriate" (Article 12 UWWTD), but it remains unclear how ”appropriate” is defined in this context.

Table 1: Requirement for discharges for urban wastewater treatment plants subject to articles 4 and 5 of the Directive. The values for concentration or for the percentage of reduction shall apply (91/271/EEC, UWWTD).

Parameters	Concentration	Minimum percentage of reduction (1)	Reference method of measurement
Biochemical Oxygen Demand, BDO5 at 20º (without nitrification (2))	25 mg/l O_2	70-90 40 under article 4 (2)	Homogenized, unfiltered, undecanted sample. Determination of dissolved oxygen before and after five-day incubation at 20ºC±1ºC, in complete darkness. Addition of a nitrification inhibitor.
Chemical Oxygen	125 mg/l O_2	75	Homogenized, unfiltered, undecanted sample potassium dichromate.

Demand (COD)			
Total suspended solids	35 mg/l (3) 35 under article 4 (2) (more than 10000 p.e.) 60 under article 4 (2) (2000-10000 p.e.)	90 % (3) 90 under article 4 (2) (more than 10000 p.e.) (4) 70 under article 4 (2) (2000-10000 p.e.)	- Filtering of a representative sample through a 45 µm filter membrane. Drying ant 105ºC and weighing. - Centrifuging of a representative sample (for at least five minutes with mean acceleration of 2800 to 3200 g), drying at 105ºC and weighing.

(1) Reduction in relation to the load of the influent
(2) The parameter can be replaced by another parameter: TOC or TOD if a relationship can be established between BOD5 and the substitute parameter
(3) This requirement is optional
(4) One population equivalent (p.e.) means the organic biodegradable load having a five-day biochemical oxygen demand (BOD5) of 60 g of oxygen per day

Table 2: Requirement for discharges for urban wastewater treatment plans to sensitive areas are subject to eutrophication as identifies in Annex II.A (a). One or both parameters may be applied depending on the local situation. The values for concentration or for the percentage of reduction shall apply (91/271/EEC, UWWTD).

Parameters	Concentration	Minimum percentage of reduction (%) (1)	Reference method of measurement
Total phosphorous	2 mg/l P (10000 – 100000 p.e.) (4) 1 mg/l P (more than 100000 p.e.)	80	Molecular absorption spectrophotometry
Total nitrogen (2)	15 mg/l P (10000 – 100000 p.e.) 10 mg/l P (more than 100000 p.e.)	70-80	Molecular absorption spectrophotometry

(1) Reduction in relation to the load of the influent.
(2) Total nitrogen means: the sum of total Kjeldahl-nitrogen (organic N + NH_3), nitrate (NO_3)-nitrogen and nitrite (NO_2)-nitrogen.
(3) Alternatively, the daily average must not exceed 20 mg/l N. This requirement refers to a water temperature of 12ºC or more during the operation of the biological reactor of the waste water treatment plant. As a substitute for the condition concerning the temperature, it is possible to apply a limited time of operation, which takes into account the regional climatic conditions. This alternative applies if it can be shown that paragraph 1 of Annex 1.D is fulfilled.
(4) One population equivalent (p.e.) means the organic biodegradable load having a five-day biochemical oxygen demand (BOD5) of 60 g of oxygen per day

Planning aspects of the Directive to designate sensitive areas (sensitive water bodies) and less sensitive areas are:

- Freshwater bodies, estuaries and coastal waters which are eutrophic or which may become eutrophic if protective action is not taken;

- Surface freshwaters intended for the abstraction of drinking water which contain or are likely to contain more than 50 mg/l of nitrates;
- Areas where further treatment is necessary to comply with other Council Directives

Regulation aspects:

Establish systems of prior regulation or authorisation for all discharges of urban wastewater and industrial wastewater into urban sewage collecting systems to ensure that no adverse effect on the environment (including receiving waters) will occur.

Monitoring aspects:

Member States are required to ensure that both discharges from urban wastewater treatment plants and receiving waters are monitored.

1.1.4 Drinking water directive (98/83/EC)

The requirements of the recharge installation will depend on the water end use. WFD includes most of the uses through its objective of ecological quality for surface waters. Other uses have to be checked with national regulations. Drinking water directive is the most restrictive and it is used as a reference in most member states to ensure that human health is protected. This Directive includes mandatory indicator values for most of the contaminants and covers microbial, chemical and physical water characteristics (Table 3).

Table 3: Target values proposed for raw water for drinking water production (IAWR, 2008).

Anthropogenic non-natural substances with known biological effects	Target value (µg/L) maximum permissible values
Pesticides and their metabolites per individual substance	0.1 *, a
Endocrine active substances per individual substance	0.1 *
Pharmaceuticals (incl. antibiotics) per individual substance	0.1 *
Biocides per individual substance	0.1 *
Other organic halogen compounds per individual substance	0.1 *
Substances with low biodegradability per individual substance µg/L 1.0	1.0[b]
Synthetic complexing agents per individual substance µg/L 5.0	5.0

*Unless toxicological information necessitates a lower value
[a] Equal to the drinking water standard
[b] If other non-natural organic substances have passed proper toxicological screening and are regulated as harmless, a target value of 1 µg/L is justified, similar to other official precaution targets. Only for complexing agents is a temporary value of 5 µg/L acceptable for technical reasons.

When dealing with drinking water uses, an additional consideration is to conduct a risk assessment following the procedures of water safety plans (WHO 2005 and 2007) as it is stated in the directive. The Water Safety Plans provides information on improved strategies for the control

and monitoring of drinking-water quality.

1.2 Spain - Royal Decree 1620/2007

This decree defines the conditions for water reuse authorization. It specifies different types of reuse and indicates the quality criteria for each different uses. In this decree groundwater recharge is classified as environmental use either by percolation or well injection (Table 4).

Table 4: Maximum admissible values for reuse of water used for aquifer recharge.

Maximum admissible value for:	Aquifer Recharge by percolation (indirect recharge)	Aquifer recharge by well injection (direct recharge)
Nematode eggs	Not specified	1 egg/10 L
Escherichia Coli	1000 UFC/100 mL	0 UFC/100 mL
Total Suspended Solids	35 mg/L	10 mg/L
Turbidity	Not specified	2 UNT
Other Criteria	Total N= 10 mg N/L NO3= 25 mg NO3/L (Art. 257 to 259 of RD 849/1986)	Total N= 10 mg N/L NO_3= 25 mg NO3/L (Art. 257 to 259 of RD 849/1986)

The different uses that this decree regulates are: urban uses (residential areas and communal services), agriculture (irrigation of different type of crops or vegetables and with specific methods), industrial uses (process waters, cleaning waters, refrigeration towers…), recreational uses (golf courses, springs…) and environmental uses (aquifer recharge, wetlands, river discharges, irrigation…).

1.3 The Netherlands

1.3.1 Water Act

The Water Act (2010) defines which authorities are due to care about water management as well as permits, registers and taxes of groundwater recharge.

1.3.2 Groundwater Act

The Groundwater Act contains rules for the extraction of groundwater and artificial infiltration of water in the soil. The objective of the Groundwater Act (1981) is to balance the interests involved with the development of groundwater resources. The provinces have the primary responsibility for groundwater management. The Groundwater Act provides the administrative framework and legal instruments (permits and general rules) to regulate abstraction of groundwater and artificial recharge of aquifers. Based on the Groundwater Act provinces may put a levy on groundwater extraction to pay investigations related to groundwater management and for financial compensation in case of withdrawal of permits and unaccounted damages. The Groundwater Act sets quality requirements with respect to the infiltration of

water into groundwater. Abstraction of groundwater or infiltration of water in groundwater requires a license issued by provincial authorities (sect. 14) and such activities shall be notified to those authorities on a monthly basis.

Drinking water in the Netherlands is supplied by companies, which are government owned, because drinking water supply is considered to be of a public and not a private interest.

In this Directive, quality aspects are mainly related to protection of recharge areas. Other groundwater-quality issues are dealt with in the Wet Bodembescherming (Soil Protection Act) of 1987, which includes regulations for prevention of subsurface pollution and for remediation of contaminated soils. Within this legislation, the provinces are obliged to set up the water monitoring and water management plan.

1.3.3 Soil Protection Act

The Soil Protection Act (1987; fully revised in 1999) includes groundwater in the definition of the soil as a liquid component. This Act aims to prevent, and if necessary, clean-up soil and groundwater pollution and. The Soil Protection Act states that the general protection level is filled in via General Administrative Orders (GAO's) which are set on a national level and include the artificial recharge of aquifers (1993), containing rules and standards for water infiltration into the soil.

Netherland's trace organic pollutants requirements for infiltration recharge are shown in the Table 5:

Table 5: Decision Infiltration Soil Protection, Appendix 1 (corresponding to Article 3, first paragraph).

PARAMETER	VALUES
Organochlorine pesticides	
som (organochlorine pesticides)	0,1 µg/L
endosulfan	0,05 µg/L
α-HCH	0,05 µg/L
-HCH (lindaan)	0,05 µg/L
DDT (incl.DDD en DDE)	0,05 µg/L
dichloropropene	0,05 µg/L
aldrin	0,05 µg/L
dieldrin	0,05 µg/L
endrin	0,05 µg/L
heptachlor	0,05 µg/L
hexachlorobutadiene	0,05 µg/L
hexachlorobenzene	0,05 µg/L
organophosphate pesticides	
azinphos-methyl	0,1 µg/L
dichlorvos	0,1 µg/L

dimethoate	0,1 µg/L
mevinphos	0,1 µg/L
parathion	0,1 µg/L
triazines/ triazinonen/ aniliden	
atrazine	0,1 µg/L
simazine	0,1 µg/L
metolachlor	0,1 µg/L
chloorfenoxyherbiciden	
2-methyl-4-chlorophenoxy acetic acid (MCPA)	0,1 µg/L
mecoprop	0,1 µg/L
2,4-dichloro-phenoxy-acetic acid (2,4 D)	0,1 µg/L
urea herbicides	
chlorotoluron	0,1 µg/L
isoproturon	0,1 µg/L
metoxuron	0,1 µg/L
linuron	0,1 µg/L
chlorophenols	
trichlophenol	0,1 µg/L
tetrachlophenol	0,1 µg/L
pentachlophenol	0,1 µg/L
various	
dinoseb	0,1 µg/L
2,4 dinitrophenol	0,1 µg/L
bentazon	0,1 µg/L
Oil	
mineral oil	200 µg/L
Polycyclic Aromatic Hydrocarbons (HAP)	
naphthalene	0,1 µg/L
anthracene	0,2 µg/L

phenanthrene	0,2 µg/L
cryseen	0,2 µg/L
fluoranthene	Σ 0,1 µg/L
benzo (a) anthracene benzo (k) fluoranthene benzo (a) pyrene benzo (ghi) perylene indeno (l23cd) pyrene	
HALOGENATED HYDROCARBONS	
trichloroethene	0,5 µg/L
tetrachlorethylene	0,5 µg/L
trihalomethanes (THMs)	2 µg/L
chlorinated phenols	0,5 µg/L
Active ingredients in Pesticides and biocidal products, including relevant metabolites	0,1 µg/L 0,5 µg/L (sum of pesticides)

1.3.4 Environmental Management Act

The Environmental Management Act (1993) does not make specific reference to artificial groundwater recharge but establish the rules to protect the groundwater quality. The provincial administration is forced to develop and bring into force provincial legislation for groundwater protection.

1.3.5 Water Management Act

The Water Management Act (1989) refers specially to surface water. This law holds planning system that includes elements as the groundwater management policy to be pursued in accordance with the Groundwater Act.

1.4 Switzerland

1.4.1 Federal law and Ordinance of water protection (LEaux and OEaux)

Two main directives regulate water sources in Switzerland, the "Federal law of water protection" (LEaux) from 1991 and the "Ordinance of water protection" (OEaux) from 1998, both revised in 2011. Both legislations make reference to MAR with the term of "installation of artificial supply to groundwater", which it applies mainly the same regulations as water catchment.

On this document, "installation of artificial supply" will be referred as "artificial recharge facilities".

There is no specific article about water quality used on MAR but it is clearly stated in LEaux Article 6 that infiltration of substances potentially able to contaminate are forbidden.

Section 1 of LEaux makes references to discharge, introduction and infiltration of substances related to water quality. In LEaux Article 7 and in OEaux Article 8 related to waste water, it is mentioned that infiltration of contaminated water must be previously treated and authorized by the Canton authorities. Canton authorities might permit infiltration of reclaimed water in specific cases.

As stated in Article 21 of OEaux, general requirement on groundwater quality are:

- The concentration of substances for which requirements are set in Table 6 should not continually increase in groundwater.
- The quality of groundwater must be such that they do not pollute surface water during withdraw or flow.
- Water temperature fluctuations are limited to 3°C.
- The infiltration of discharged water shall not result in groundwater:
    - any nuisance alteration of odor compared to the natural state;
    - lack of oxygen or any alteration of water pH;
    - no turbidity or water color, except in the case of water present in the solid rock.
- The infiltration facilities, water withdraw and other construction-related interventions should as much as possible not to damage the protective cover layers or change the hydrodynamic to the point of causing adverse effects on the water quality.

Groundwater quality supplementary requirements (Annex 2 OEaux) if to be used or with potential of use as drinking water are summarized in Table 6.

Table 6: Supplementary requirements for groundwater to be used or with potential of use as drinking water. OEaux.

Parameter	Requirement
Organic dissolved carbon (ODC)	2 mg/l C
Ammonium (sum of N-NH_4- and N-NH_3)	In oxidant conditions: 0.08 mg/l N (corresponding to 0,1 mg/l ammonium) In anoxic conditions. 0,4 mg/l N (corresponding to 0,5 mg/l ammonium)
Nitrate (N-NO_3^-)	5.6 mg/l N (corresponding to 25 mg/l nitrate)
Sulfate (SO_4^{2-})	40 mg/l SO_4^{2-}

Chloride (Cl-)	40 mg/l Cl^-
Aliphatic Hydrocarbons	0.001 mg/l for each substance
Monocyclic Aromatic Hydrocarbons	0.001 mg/l for each substance
Polycyclic Aromatic Hydrocarbons (HAP)	0.1 µg/l for each substance
Volatile halogenated hydrocarbons (HHV)	0.001 mg/l for each substance
Organic pesticides (biocides and phytosanitary products)	0.1 µg/l for each substance .
Halogenated organic adsorbable compounds (AOX)	0.01 mg/l X
Organic pesticides (biocides and phytosanitary products)	0.1 µg/l for each substance .

Following requirements in Table 6 (Annex 3 OEaux) apply to treatment plants of more than 200 EH (equivalent habitants). The authority set in each case the requirements for treatment plants of less than 200 EH (Table 7).

Table 7: General requirement for discharge into water of polluted waste communal water.

Parameter	Requirement
Total suspended solids	Installations < 10 000 EH: –concentration in discharged water: 20 mg/l Installations > 10 000 EH and more: – concentration in discharged water: 15 mg/l (filtration with 0,45 mm membrane)
BOD5 (with nitrification blockage)	Installations < 10 000 EH: – concentration in discharged water: 20 mg/l O2 and – purification rate from polluted raw water: 90 % Installations > 10 000 EH and more: – concentration in discharged water: 15 mg/l O2 and – purification rate from polluted raw water: 90 %
Organic dissolved carbon (ODC)	Installations < 2000 EH and more: – concentration in discharged water: 10 mg/l and – purification rate: 85 %, expressed as: $100 \times \left(1 - \frac{mg\ ODC\ in\ treated\ water}{mg\ of\ Organic\ Total\ Carbon\ in\ polluted\ raw\ water}\right)$
Transparency (after Snellen method)	30 cm
Ammonium (sum of N-NH4- and N-NH3)	If concentration of ammonium in polluted water might have harmful consequences to a water body, the following values apply if temperature of polluted water is higher than 10° C: – concentration in discharged water: 2 mg/l N and – effectiveness treatment rate: 90 %, expressed as: $100 \times \left(1 - \frac{mg\ N\ in\ treated\ water}{mg\ N - Kjeldahl\ in\ polluted\ raw\ water}\right)$ In this case, nitrification will be required all over the year. Note: Nitrogen from Kjeldahl method is the sum of Nitrogen in

	Ammonium, Ammonia and in organic nitrogenous substances.
Nitrite (N-NO2-)	0,3 mg/l N (indicative value)
Halogenated organic absorbable compounds (AOX)	0,08 mg/l X

As it is specified in Annex 4 of OEaux, groundwater, naturally or after an artificial recharge, in order to be considered to be exploitable or suitable for water supply, must:

- Be in a sufficient quantity to be exploited, needs not taken into consideration
- Meet, if necessary after application of a simple treatment, the requirements set for drinking water in the legislation of food products.
- The regulations of groundwater protection areas and perimeters take into consideration MAR installations (Article 20 and Article 21 of LEaux and Article 29, Article 30 and Article 31, and Annex 4 of OEaux).

The regulations of groundwater protection areas and perimeters take into consideration MAR facilities (Article 20 and Article 21 of LEaux and Article 29, Article 30 and Article 31, and Annex 4 of OEaux).

Zone S1 (catchment zone) include artificial recharge facility. Zone S1 must prevent damage and contamination of its environment.

Zone 2 must prevent germs and virus to enter into the artificial recharge facilities and must be dimensioned in order to:

- Water flow duration from zone S2 external limit to artificial recharge facilities is at least of 10 days
- Distance from zone S1 ant the external limit of zone S2, in the flow direction, is at least of 100 m; it could be less if hydrogeological studies allow to prove that the artificial recharge facilities are well protected by cover layers with low permeability and intact.
- For groundwater in karst our fractured media, S2 covers the basin areas of the artificial recharge facilities that presents high vulnerability.

Zone 3 must ensure that in case of imminent danger, there is sufficient time and space to take the imposed measures.

Article 43 of LEaux states that Canton authorities have to ensure improvement of groundwater table condition in case of overexploitation or supply reduction by decreasing withdrawal, by managed aquifer recharge or by safe drinking water storage in the aquifer.

1.4.2 DFI Ordinance on drinking water

Drinking water is governed by the food law. This includes the Law on Foodstuffs (LDAI, SR 817.0) which includes the Ordinance on Food Hygiene (OHyg, RS 817.024.1), the Ordinance on Foreign Substances and Components (OSEC, RS 817.021.23), and the Ordinance on drinking water, spring water and mineral water (RS 817.022.102).

The Ordinance on Foreign Substances and Components (OSEC) fix concentrations of foreign substances and components that can be tolerated in food and in particular drinking water. In the field of drinking water, no changes have been made since 2000. From the perspective of a future revision, the Federal Office of Public

Health (BAG) conducted a critical review of parameters proposing adaptations.

1.5 Germany

1.5.1 Groundwater Ordinance (Grundwasserverordnung, GrwV)

The German GrwV states the following concerning MAR systems:

- Groundwater systems must be described and reviewed every 6 years according to Appendix 1, No 1, i.e. among others include a review of MAR sites and the recharge processes and connections of the groundwater body to other hydrologic systems
- Endangered groundwater systems must be detailed more thoroughly according to Appendix 1, No 2, i.e. identify all sources of water addition to the aquifer (including the location, volumes of water added, chemical and physical characteristics of the water added). Moreover, the land use of the surfaces were recharge happens must be detailed.

In Annex 2 the following threshold values are defined, above which measures need to be taken to improve water quality (which would therefore be the minimum water quality, in case of infiltration, at the point of reaching the groundwater surface): NO3: 50 mg/L; Pesticides and relevant metabolites: 0.1 µg/L each (in total: 0.5 µg/L); As: 10 µg/L, Cd: 0.5 µg/L, Pb: 10 µg/L, Hg: 0.2 µg/L, NH4: 0.5 mg/L, Cl: 250 mg/L, SO4: 240 mg/L, Tri- and tetrachlorethene: 10 µg/L. A relevant indicator for groundwater quality is the 90th percentile of substance's frequency distribution in an aquifer complex. In case this value is higher than the previously defined thresholds, this value is valid for further evaluation.

1.5.2 Water Management Act (Wasserhaushaltsgesetz, WHG)

In the Water Management Act (WHG), MAR is never mentioned explicitly, and there is, to me, a very large interpretation possible. However, the following aspects relate to MAR:

- It states that no official agreement is required to infiltrate rain water in aquifers (by whatever means)
- Groundwater management options must ensure that the quality of groundwater is improved, not worsened.

1.6 France

Water policy is administered at three jurisdictional levels conditioned by directives of the European Union: the national, water basin and local water commission levels. National policies are required to simultaneously consider consumptive water use requirements and the non-consumptive needs of aquatic ecosystems, surface and groundwater quantity and quality.

Masterplans for Water Development and Management (Schéma Directeur d'aménagement et de gestion des eaux SDAGE) and Local Water Development and Management Plans (Schémas d'aménagement et de gestion des eaux SAGE) guide both the coordination of diverse and competing water users and operational implementation.

The European directive Eaux Résiduaires Urbaines 1991, transcribed into the French water law of 1992, is the legislative basis for stormwater and aquifer management. French Water law provides for two water management regimes in MAR systems: authorisation and declaration.

Declaration is less constrained than authorization, and applies when the total harvesting surface area ("superficie totale desservie") is greater than 1ha and less than 20ha. Harvesting approval is granted on submission of documentation. The granting of an Authorisation for areas greater than 20 ha is conditional on the results of preliminary environmental studies and assessments complying with prescribed water condition standards.

In France a specific site study is required in order to obtain the permission for MAR installations. The different regulations that have to be taken into account are the following:

1.6.1 Code de l'environnement

The environment is low is very complete and the part that describes the protection of water resources is: "Livre II : Milieux physiques; Titre 1er : Eau et milieux aquatiques et marins » (Water and aquatic and marine environments)

1.6.2 LOI n° 2004-338

Loi nº2004-338 du 21 avril 2004 concerning the transposition 2000/60/CE of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water (1)

2 Summary of existing MAR legislation

In summary, European legislations (WFD, GWD, and UWWTD) do not include specifically artificial recharge with treated wastewater. A summary of most relevant European legislation is given in Table 8.

Table 8: Summary of main European legislation

Directive	Limits
WFD	No limit values for reclaimed water. Chemical status of GW (baseline characterization) Elaboration of specific measures and monitoring
GWD	No GW deterioration is allowed: limit to input concentration of some substances. Limit of nitrates, pesticides Threshold values of As, Cd, Pb, Hg, NH4, Cl, SO4, PCE, TCE and electrical conductivity
UWWTD	Discharges to collecting systems receive at least secondary treatment (primary in coastal and estuaries) Discharges will not affect adversely the environment Regulates N, P, DBO, COD and TDS based on area type (sensitive areas)

In the analysed countries there is a lack of harmonisation. European directives only give brief comments for MAR systems. These directives state that degradation of groundwater quality it is not allowed and the member states have to authorize the recharge systems and verify the monitoring program. Drinking water quality is the most restrictive legislation and it is currently used in several countries to allow the MAR systems installation.

Spain and Switzerland regulates specifically the direct and indirect infiltration of water setting the requirements in the same parameters but giving different limits.

Nevertheless emergent contaminants are not regulated at European level. For priority substances Environmental Quality Standards (EQS) have been defined (EC, 2001; EC, 2008) but the list of Annex X of the WFD have not been yet updated. The Netherlands legislate the input concentration of pesticides and herbicides, among others priority substances, but do not includes the trace organic compounds that are being studied in this project.

The values that different European countries specify in their respective legislations are included in **Annex A** Table 10**.** This table with all values differentiates the values when the directives indicate water for recharge, both indirect (e.g. SAT) and direct (e.g. injection wells), and raw water or groundwater. The last refers to the quality limits for that groundwater that is going to be used for drinking purposes.

An analysis of previous research projects has been conducted. AQUAREC project (2006) and afterwards RECLAIM WATER project (2012) published a proposal of quality requirements for groundwater recharge (Table 9).

Table 9: Requirement for indirect groundwater recharge, proposed quality for direct groundwater recharge and drinking water requirements (Kazner et al., 2012 adapted from Bixio & Wintgens, 2006)

Parameter	Unit	Polishing goal for indirect infiltration	Polishing goal for direct infiltration	Drinking water quality
pH	-	7-9	>6.5 and <9.5	>6.5 and <9.5
Conductivity	mS/cm	0.7	<0.7	<2.5
Alkalinity*	mg/$CaCO_3$/L			
TSS*	mg/L			
COD	mg/L	70-100	< 5	< 5
TOC*	mgC/L			
Total N	mgN/L	< 25	< 25	
NH_4^+	mgN/L	< 0.2	<0.5	<0.5
NO_2^-	mgN/L		<0.5	<0.5
NO_3^-	mgN/L	< 25	< 25	< 11.3
Total P*	mgP/L			
PO_4^{2-}*	mgP/L			
SO_4^{2-}	mgS/L	30	< 30	< 250
As	µg/L	5	< 10	< 10
B	mg/L	0.2	< 1.0	< 1.0
Cd	µg/L	3	< 5.0	< 5.0
Cl^-	mg/L	100	< 250	< 250
Cr	µg/L	25	< 50	< 50
Hg	µg/L	0.5	< 1.0	< 1.0
Pb	µg/L	5	< 25 < 10 in 2013	< 25 < 10 in 2013
Zn*	µg/L			
Micropollutants	µg/L	< 0.1	Compound specific	Compound specific
Faecal coliforms	CFU/100 mL	$< 10^4$	0	0
Faecal streptococ.*	CFU/100 mL		0	0
Helminthova, Giardia	1/L	< 1	0	0

*not reported

3 Recommendations for possible points of compliance with the EU-GWD

A principal requirement of the GWD is to assess the actual or potential impact of the man-made recharge on groundwater in the vicinity of the site. An important element of the risk screening process is the choice of the points at which compliance with the GWD will be evaluated. Points of compliance (POC) were defined by WFD-CIS (2007a) and can be applied to MAR facilities according to:

- POC 0: this POC is located at the base of the source in the unsaturated zone. It could therefore be situated just below the point/area of recharge (e.g. infiltration pond). The purpose of POC 0 is to assess if a pollutant input takes place, what the pollutants are, and whether the groundwater could be affected.
- POC 1: this POC is located at the point of input into the groundwater; for a direct input (e.g. well injection), POC 0 is the same as POC 1, but the function is different. At POC 1 the actual concentration in the groundwater itself is primarily taken into account, whereas at POC 0 one primarily looks at the properties of the source itself as explained above.
- POC 2: this POC is located hydraulically down gradient from the recharge area in between POC 1 and a receptor. The purpose of this compliance point is to provide an early warning that the receptor might be impacted. It is also used during the risk assessment process for predicting the potential impact of the input.
- POC 3: This POC is used to assess whether the desired groundwater quality is reached and to monitor the impact at the receptor. If a risk assessment shows that the pollutant will exceed the compliance value at this POC, then pollution is likely to occur as a result of the input. Measures/controls will need to be put in place to remove this impact, or the activity should not be permitted.

Specifications at POC 0, POC 1 and/or POC 2 should be defined in a way that compliance values at POC3 are met. Applying this concept on MAR the possible POC in the frame of the GWD are illustrated in Figure 1.

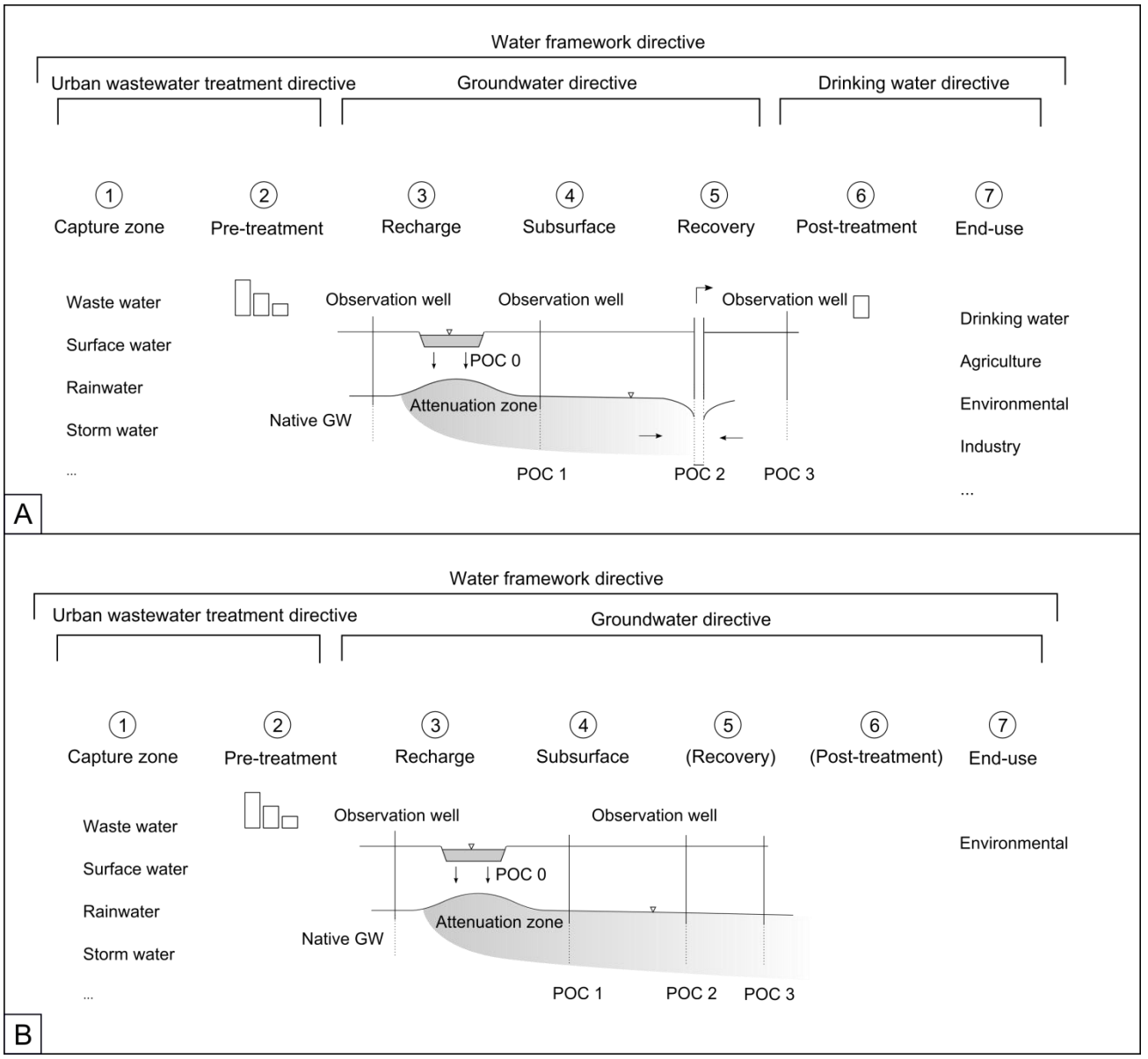

Figure 1: **Components of MAR and possible points of compliance (POC) with most relevant European legislation.**

In case of MAR schemes the receptor at risk can be defined by the groundwater beyond the attenuation zone at POC 3. The attenuation zone is the area surrounding the recharge area where groundwater quality changes takes place due to natural processes in the aquifer (e.g. straining, degradation, sorption, dissolution/precipitation, inactivation (die-off), decay or mixing). The concept of an attenuation zone in the subsurface is an integral part of MAR schemes and is useful to define the treatment barrier. Various models exist to estimate spatial extent of an attenuation zone (NRMMC-EPHC-NHMRC, 2009). If the recharge activity will be stopped the attenuation zone will vanish and previously existing hydrochemical conditions will be re-established in short time. This is in contrast to contamination plumes, where the uncontrolled input of hazardous substances to the aquifer results in long-term contamination, even if the contamination source is removed.

During MAR two different settings can be distinguished: i) MAR with managed recovery (Figure 1A) and ii)

MAR without managed recovery (Figure 1B). During MAR schemes such as deep well injection (direct input) and at many infiltration ponds unsaturated conditions below the pond are not always realized (mixture between direct and indirect input) POC 0 and POC 1 cannot be clearly distinguished. In case of SAT schemes unsaturated conditions below the recharge area are indispensable and POC 0 is important to monitor possible pollutant input from the MAR activity. If the MAR scheme does not include managed recovery, e.g. infiltration ponds for groundwater replenishment or deep well injection to create hydraulic barriers in coastal aquifers, the groundwater directive is valid alone. In this case it is important to meet the environmental value of the target aquifer/receptor. The receptor is considered to be protected if compliance values at POC 3 are met. Hydraulically up-gradient of the recharge site native groundwater monitoring is required to report on unaffected/background values.

The EU-GWD states that the input of hazardous substances to groundwater must be prevented (primarily linked to the prevent objectives in the GWD). An input is considered to have been prevented if the substance is not detectable above natural background concentrations. Procedures to define background concentrations are described in WFD-CIS (2007b). As defined by the European Communities Environmental Objectives (Groundwater) Regulations hazardous substances are “any substances or groups of substances that are toxic, persistent and liable to bio-accumulate, and other substances, or groups of substances, that give rise to an equivalent level of concern” (ECEOGR, 2010). Non-hazardous substances are not defined, but can be seen as all substances other than hazardous. For non-hazardous substances the assessment must ensure that the substances will not exceed previously defined background concentrations (primarily linked to the limit objectives in the GWD) and does not cause a significant upward trend at the receptor.

References

Bixio, D., & Wintgens, T. (Eds.). (2006). Water Reuse System Management Manual: AQUAREC. Office for Official Publications of the European Communities.

ECEOGR, 2010. European Communities Environmental Objectives (Groundwater) Regulations, 2010 (S.I. No. 9 of 2010).

IAWR (2008). Danube, Meuse and Rhine MEMORANDUM, 2008. International Association of Waterworks in the Rhine Catchment Area.

Kazner, C., Wintgens, T., & Dillon, P. (Eds.). (2012). Water Reclamation Technologies for Safe Managed Aquifer Recharge. IWA Publishing.

NRMMC-EPHC-NHMRC, 2009. Australian guidelines for water recycling - Managed aquifer recharge (Phase 2). Natural Resource Ministerial Management Council, Environment Protection and Heritage Council and National Health and Medical Research Council, Canberra.

WFD-CIS, 2007a. COMMON IMPLEMENTATION STRATEGY FOR THE WATER FRAMEWORK DIRECTIVE (2000/60/EC) Guidance on preventing or limiting direct and indirect inputs in the context of the Groundwater directive 2006/118/EC.

WFD-CIS, 2007b. COMMON IMPLEMENTATION STRATEGY FOR THE WATER FRAMEWORK DIRECTIVE (2000/60/EC), GUIDANCE ON GROUNDWATER STATUS AND TREND ASSESSMENT.

Annex-A Maximum admissible values by different European legislations

Table 10: Maximum admissible values by different European legislations.

		EU	Spain	Switzerland	Netherlands	Germany	France
BOD5 (Biochemical oxygen demand at 25°C without nitrification)	Raw water (potential to drinking water)/ groundwater						
	Injection recharge						
	Indirect infiltration recharge	25 mg/L O2	40-300 mg/L (1)	20 mg/L O2 (< 10.000 p.e.) 15 mg/L O2 (> 10.000 p.e.) (1)			
COD (Chemical Oxygen demand)	Raw water (potential to drinking water)/ groundwater						
	Injection recharge						
	Indirect infiltration recharge	125 mg/L O2	160-500 mg/L (1)				
Total Suspended Solids	Raw water (potential to drinking water)/ groundwater						
	Injection recharge		10 mg/L		0,5 mg/L (zwev.stof)		
	Indirect infiltration recharge	60 mg/L (2.000-10.000 p.e.) 35 mg/L (> 10.000 p.e.)	35 mg/L	20 mg/L (< 10.000 p.e.) 15 mg/L (> 10.000 p.e.) (1;7)			
Turbidity	Raw water (potential to drinking water)/ groundwater						
	Injection recharge		2 NTU				
	Indirect infiltration recharge						
Transparency (after Snellen method)	Raw water (potential to drinking water)/ groundwater						
	Injection recharge						

	Indirect infiltration recharge			30 cm (1)			
Organic Dissolved Carbon (ODC)	Raw water (potential to drinking water)/ groundwater			2 mg/L C (3)			
	Injection recharge						
	Indirect infiltration recharge			10 mg/L (1)			
Total phosphorus	Raw water (potential to drinking water)/ groundwater			2 mg/L C (3)			
	Injection recharge						
	Indirect infiltration recharge	2 mg/L P (10.000-100.000 p.e.) 1 mg/L P (>100.000 p.e.)	10-20 mg/L (1)	10 mg/L (1)			
Total nitrogen	Raw water (potential to drinking water)/ groundwater						
	Injection recharge		10 mg N/L				
	Indirect infiltration recharge	15 mg/L N (10.000-100.000 p.e.) 10 mg/L N (>100.000 p.e.)	10 mg N/L				
Ammonium	Raw water (potential to drinking water)/ groundwater			Oxidant cond.: 0,08 mg/L N Anoxic cond.: 0,4 mg/l N Σ (N-NH4+ + N-NH3) (3)		0,5 mg/L (NH4+) (4)	4 mg/L (2)
	Injection recharge				2,5 mg/L N (NH4+)		

	Indirect infiltration recharge			2 mg/l N (T>10°C) Σ (N-NH4+ + N-NH3) (1)			
Nitrate	Raw water (potential to drinking water)/ groundwater	50 mg/L		5,6 mg/L N (25 mg/L NO3-) (3)		50 mg/L (4)	100 mg/L (2)
	Injection recharge		25 mg/L NO3-		5,3 mg/L N		
	Indirect infiltration recharge		25 mg/L NO3-				
Nitrite	Raw water (potential to drinking water)/ groundwater						
	Injection recharge						
	Indirect infiltration recharge			0,3 mg/l N (1)			
Sulphate	Raw water (potential to drinking water)/ groundwater			40 mg/l SO42- (3)		240 mg/L (4)	250 mg/L (2)
	Injection recharge				150 mg/L		
	Indirect infiltration recharge		2000 mg/L (1)				
Chloride	Raw water (potential to drinking water)/ groundwater			40 mg/l Cl- (3)		250 mg/L (4)	200 mg/L (2)
	Injection recharge				200 mg/L		
	Indirect infiltration recharge		2000 mg/L (1)				
As	Raw water (potential to drinking water)/ groundwater					10 µg/L (4)	100 µg/L (2)
	Injection recharge				10 µg/L		
	Indirect infiltration recharge		0,5-1 mg/L (1)				
B	Raw water (potential to drinking water)/ groundwater						
	Injection recharge						
	Indirect infiltration recharge		2-10 mg/L (1)				

Cd	Raw water (potential to drinking water)/ groundwater					0,5 µg/L (4)	5 µg/L (2)
	Injection recharge				0,4 µg/L		
	Indirect infiltration recharge		0,1-0,5 mg/L (1)				
Cr	Raw water (potential to drinking water)/ groundwater						50 µg/L (2)
	Injection recharge				2 µg/L		
	Indirect infiltration recharge		Cr (III) 2-4 mg/L Cr (IV) 0,2-0,5 mg/L (1)				
Hg	Raw water (potential to drinking water)/ groundwater					0,2 µg/L (4)	1 µg/L (2)
	Injection recharge				0,05 µg/L		
	Indirect infiltration recharge		0,05-0,1 mg/L (1)				
Pb	Raw water (potential to drinking water)/ groundwater					10 µg/L (4)	50 µg/L (2)
	Injection recharge				15 µg/L		
	Indirect infiltration recharge		0,2-0,5 mg/L (1)				
Ba	Indirect infiltration recharge				200 µg/L		1 mg/L (2; surface water)
Co	Indirect infiltration recharge				20 µg/L		
Cu	Indirect infiltration recharge				15 µg/L		
Ni	Indirect infiltration recharge				15 µg/L		
Zn	Indirect infiltration recharge				65 µg/L		5 mg/L (2)
Escherichia Coli	Raw water (potential to drinking water)/ groundwater						20.000 /100 mL (2)
	Injection recharge		0 UFC/100 mL				
	Indirect infiltration recharge		1000 UFC/100 mL				

Pesticides (for substance)	Raw water (potential to drinking water)/ groundwater	0,1 µg/L 0,5 µg/L (sum of pesticides)				0,1 µg/L 0,5 µg/L (sum of pesticides)	2 µg/L 5 µg/L (sum of pesticides) (2)
	Injection recharge				0,5 µg/L (sum of pesticides)		
	Indirect infiltration recharge		0,05 mg/L (1)				
Biocides	Raw water (potential to drinking water)/ groundwater			0,1 µg/L (3;6)			
	Injection recharge						
	Indirect infiltration recharge						
Organochlorine pesticides (per substance)	Indirect infiltration recharge				0,05 µg/L		
Organophosphate pesticides (per substance)	Indirect infiltration recharge				0,1 µg/L		
Triazines/ triazinonen/ aniliden (per substance)	Indirect infiltration recharge				0,1 µg/L		
Chlorofenoxy herbicides (per substance)	Indirect infiltration recharge				0,1 µg/L		
Urea herbicides (per substance)	Indirect infiltration recharge				0,1 µg/L		
Other organic halogen substances	Raw water (potential to drinking water)/ groundwater			0,01 mg/l X (3;5)			
	Injection recharge				30 µg/L (5)		
	Indirect infiltration recharge			0,08 mg/l X (1;5)			
Aliphatic Hydrocarbons	Raw water (potential to drinking water)/ groundwater			1 µg/L (3)			
	Injection recharge						
	Indirect infiltration recharge						
Monocyclic Aromatic Hydrocarbons	Raw water (potential to drinking water)/ groundwater			1 µg/L (3)			

	Injection recharge						
	Indirect infiltration recharge						
Polycyclic Aromatic Hydrocarbons (HAP)	Raw water (potential to drinking water)/ groundwater			0,1 µg/L (3)			1 µg/L (2)
	Injection recharge				0,1 µg/L (sum)		
	Indirect infiltration recharge						
Volatile halogenated hydrocarbons (HHV)	Raw water (potential to drinking water)/ groundwater			1 µg/L (3)		10 µg/L (sum; 4)	
	Injection recharge				0,5 µg/L (per substance)		
	Indirect infiltration recharge						
Chlorophenols (per substance)	Indirect infiltration recharge				0,1 µg/L		
Dinoseb, 2,4 dinitrophenol, bentazon (per substance)	Indirect infiltration recharge				0,1 µg/L		
Mineral oil	Indirect infiltration recharge				200 µg/L		

(1): Water as treated wastewater discharge

(2): Water quality limits of waste water used for drinking water production

(3): Groundwater quality if to be used or with potential of use as drinking water

(4): Groundwater quality as Groundwater Act

(5): Halogenated organic adsorbable compounds (AOX)

(6): Organic pesticides (biocides and phytosanitary products)

(7): Filtration with 0.45 mm membrane

Annex-B Priority substances

Article 16 of the Water Framework Directive (2000/60/EC) (WFD) sets out "Strategies against pollution of water", outlining the steps to be taken. The first step was to establish a First list of priority substances to become Annex X of the WFD. These substances were selected from amongst those presenting a significant risk to or via the aquatic environment, using the approaches outlined in Article 16 of the WFD.

This first list was replaced by Annex II of the Directive on Environmental Quality Standards (Directive 2008/105/EC) (EQSD), also known as the Priority Substances Directive , which set environmental quality standards (EQS) for the substances in surface waters (river, lake, transitional and coastal) and confirmed their designation as priority or priority hazardous substances, the latter being a subset of particular concern. As required by the WFD and EQSD, the Commission subsequently reviewed the list and in 2012 it put forward a proposal for a Directive amending the WFD and the EQSD as regards priority substances.

Priority Substances and Certain Other Pollutants according to Annex II of Directive 2008/105/EC

33 substances or groups of substances are on the list of priority substances for which environmental quality standards were set in 2008, including selected existing chemicals, plant protection products, biocides, metals and other groups like Polyaromatic Hydrocarbons (PAHs) that are mainly incineration by-products and Polybrominated Biphenylethers (PBDE) that are used as flame retardants.

Table 11: List of priority substances in the field of water policy

Number	Name of priority substance (1)	Identified as priority hazardous substance
(1)	Alachlor	
(2)	Anthracene	X
(3)	Atrazine	
(4)	Benzene	
(5)	Brominated diphenyletheriv	X
	Pentabromodiphenylether (congener numbers 28, 47, 99, 100, 153 and 154)	
(6)	Cadmium and its compounds	X
(7)	Chloroalkanes, C10-13 (2)	X
(8)	Chlorfenvinphos	
(9)	Chlorpyrifos (Chlorpyrifos-ethyl)	
(10)	1,2-Dichloroethane	
(11)	Dichloromethane	
(12)	Di(2-ethylhexyl)phthalate (DEHP)	
(13)	Diuron	
(14)	Endosulfan	X
(15)	Fluoranthene (3)	
(16)	Hexachlorobenzene	X
(17)	Hexachlorobutadiene	X

(18)	Hexachlorocyclohexane	X
(19)	Isoproturon	
(20)	Lead and its compounds	
(21)	Mercury and its compounds	X
(22)	Naphthalene	
(23)	Nickel and its compounds	
(24)	Nonylphenols	X
	(4-nonylphenol)	X
(25)	Octylphenols	
	(4-(1,1',3,3'-tetramethylbutyl)-phenol)	
(26)	Pentachlorobenzene	X
(27)	Pentachlorophenol	
(28)	Polyaromatic hydrocarbons	X
	(Benzo(a)pyrene)	X
	(Benzo(b)fluoranthene)	X
	(Benzo(g,h,i)perylene)	X
	(Benzo(k)fluoranthene)	X
	(Indeno(1,2,3-cd)pyrene)	X
(29)	Simazine	
(30)	Tributyltin compounds	X
	(Tributyltin-cation)	X
(31)	Trichlorobenzenes	
(32)	Trichloromethane (chloroform)	
(33)	Trifluralin	

(1) Where groups of substances have been selected, typical individual representatives are listed as indicative parameters (in brackets and without number). For these groups of substances, the indicative parameter must be defined through the analytical method.

(2) These groups of substances normally include a considerable number of individual compounds. At present, appropriate indicative parameters cannot be given.Fluoranthene is on the list as an indicator of other, more dangerous polyaromatic hydrocarbons.**Certain Other Pollutants**

These eight pollutants, which fall under the scope of Directive 86/280/EEC (Amended by Directive 88/347/EEC and 90/415/EEC) and which are included in List I of the Annex to Directive 76/464/EEC, are not in the priority substances list. However, environmental quality standards for these substances are included in the Environmental Quality Standards Directive 2008/105/EC.

	Name of other pollutant
(6a)	Carbon-tetrachloride(4)
(9b)	DDT total (4)(5)
	para-para-DDT (4)
(9a)	Cyclodiene pesticides
	Aldrin (4)
	Dieldrin (4)
	Endrin (4)
	Isodrin (4)
(29a)	Tetrachloro-ethylene (4)

(29b)	Trichloro-ethylene (4)

(4) This substance is not a priority substance but one of the other pollutants for which the EQS are identical to those laid down in the legislation that applied prior to 13 January 2009

(5) DDT total comprises the sum of the isomers 1,1,1-trichloro-2,2 bis (p-chlorophenyl) ethane (CAS number 50-29-3; EU number 200-024-3); 1,1,1-trichloro-2 (o-chlorophenyl)-2-(p-chlorophenyl) ethane (CAS number 789-02-6; EU Number 212-332-5); 1,1-dichloro-2,2 bis (p-chlorophenyl) ethylene (CAS number 72-55-9; EU Number 200-784-6); and 1,1-dichloro-2,2 bis (p-chlorophenyl) ethane (CAS number 72-54-8; EU Number 200-783-0).