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COMPARATIVE TRANSNATIONAL REPORT OF CE LEGISLATION AND POLICIES ON MAR

D.T4.1.2

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Abbreviations

AP	Associated Partner
CE	Central European
DWD	Drinking Water Directive
EIA	Environmental Impact Assessment
GW	Groundwater
GWB	Groundwater Body
GWD	Groundwater Directive
HACCP	Hazard Analysis and Critical Control Points
LAWA	German Working Group of the Federal States on Water Issues *(relevant to Germany)*
MAR	Managed Aquifer Recharge
PGWWP	State Water Holding "Polish Waters" *(relevant to Poland)*
PoM	Programme of Measures
PP	Project Partner
RBD	River Basin District
RBF	Riverbank Filtration
RBMP	River Basin Management Plan
SHMI	Slovak Hydrometeorological Institute
UWTD	Urban Wastewater Treatment Directive
WFD	Water Framework Directive *(relevant to the European Union)*
WLA	Water Law Act *(relevant to Poland)*
WQ	Water Quality
WSP	Water Safety Plan

Introduction

This comparative transnational report on the legislation and policy of managed aquifer recharge (MAR) is the output of WP4 work package of the DEEPWATER-CE project on the legislation and regulation of MAR in the project partner (PP) countries Germany, Hungary, Poland, Slovakia and Croatia. The report is based on the questionnaires survey of D.T4.1.1, completed by each PP country and contains also contribution from the Italian associated partner (AP). Therefore, deliverable D.T4.1.1 should be referred as the documentation of complete, and detailed survey results. The current status of legislation on MAR in the DEEPWATER-CE PP countries is evaluated by the overview and comparison of the three main pillars of legislation and policy environment which need any direct MAR-specific regulations to be established and harmonized for MAR applications (Figure 1). The pillars are the regulatory framework (including national and regional legislation, as well as, local regulations and soft rules; the institutional framework and stakeholders; good practices and gaps. Conclusions are drawn based on the above considerations, in order to further mitigate and harmonize legislation in the central european (CE) countries.

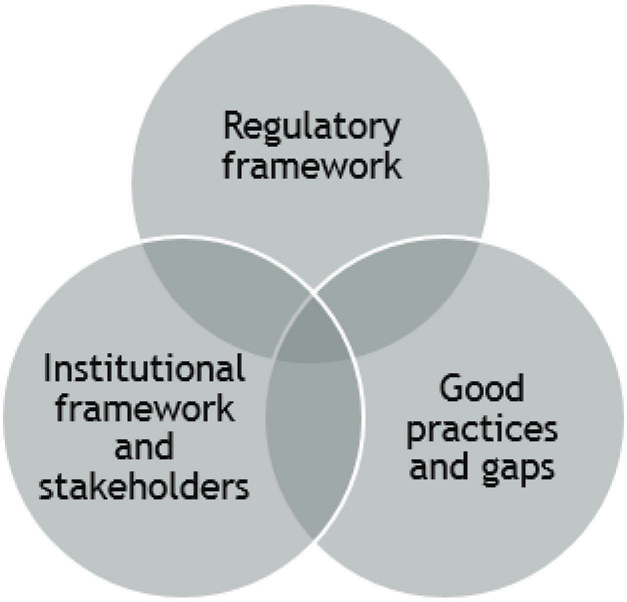

Figure 1. Component pillars of the legislative environment for policy making

A. Regulatory framework

In the European Union in order to fulfil strategic goals within European policy the general governing instruments are the EU Directive and EU Framework Directive. In the Member States of the European Union the European legislation needs to be transposed into the respective national legislation. The national or regional legal instruments are provided by laws and acts, government decrees and ministerial decrees for regulation and implementation.

I. National and regional regulations

1 Explicit MAR/ artificial recharge specific regulations in the national legislation

The most relevant EU legislation related to the governance of MAR applications in the field of water policy are the Water Framework Directive (WFD, 200/60/EC) and the Groundwater Directive (2006/118/EC) and in environmental policy, the Environmental Impact Assessment Directive (2011/92/EU).

1.1 State-of-the-art of transposition of MAR specific EU legislation

Member States are obliged to transpose European Union policies into national legislation, with specific conditions and deadlines for its successful implementation. European legislation is explicit about Managed Aquifer Recharge (MAR)/artificial recharge. These specific regulations are included in the above groundwater, wastewater, environmental related directives and the water framework directive which need to be transposed into national legislation in a harmonised way. These are summarized in Table 1.

1.1.1 WFD – authorisation and control

The article 11(3f) of WFD 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”.

Table 1. Regulatory framework – transposition of explicit MAR specific EU regulations into national and regional regulations in the DEEPWATER-CE PP countries

Explicit MAR specific regulations	Regulatory issues	Germany	Hungary	Poland	Slovakia	Croatia
MAR (artificial recharge) related EU regulations transposed into national and/or regional legislation and (WFD, GWD, EIA)	Prior authorisation of artificial recharge or augmentation of GW bodies (rules regulating the MAR-specific permitting procedure as prescribed in WFD)	✓	✓	✓	✓	✓
	Periodical review and update of controls of artificial recharge or augmentation of GW bodies (rules regulating the MAR-specific control/ monitoring regime as prescribed in the WFD	✓	✓			✓
	EIA requirement for artificial groundwater recharge schemes (larger than 10M m3)	✓	✓	✓	✓	
	WQ standards set specifically for MAR schemes for water to be injected or infiltrated (source water)					
	WQ standards for the GW body (receiving medium)	✓				
Any other direct MAR-specific regulations besides the above EU legislative requirements, in national/ regional legislation that explicitly refer to artificial recharge (but not reinjection)?						

WFD is transposed into national legislation by acts in all PP countries. These are the Federal Water Acts in Germany, the Water Management Act in Hungary, the Water Law Act in Poland, Water Act in Slovakia, and Ordinance on Content of River Basin Management Plan in Croatia.

In **Germany**, the transposition of prior authorisation into regional legislative instruments is also implemented, as there are 16 different Länder laws, based on the German federal system. Even with the national laws in place the Länder have some specific rights to adapt them. For example, according to the Bavarian Court of Administration, MAR can only be allowed, if there is an improvement to the water management situation. Groundwater quality values shall be achieved nation-wide based on the Federal Water Act and are defined in the Groundwater Ordinance. Regarding periodical review and update of controls of artificial recharge or augmentation of GW bodies in Germany, Wastewater Ordinance and Groundwater Ordinance provide the legal basis and also recommendations of the German Working Group of the Federal States on Water Issues (LAWA) are accounted for. In **Hungary**, there are several Government decrees exist for the implementation of the Water Act. These regulations also set out conditions with respect to ground water, geological media and pollutant, and also MAR related interventions and make it subject to official water protection authorization; interventions for achieving good status of groundwater. Since environmental objectives can be implemented only by concerning prior environmental protection measures, using the best available technology, it is the river basin management plan (RBMP) that harmonizes the measures, tasks, and programs for coherent implementation in order to reach and sustain good status of water. The respective legislation in **Poland**, considers MAR as a specific use of water, i.e. it is the use of water beyond the common or ordinary use. The RBMP assumes limitation of artificial groundwater recharge with respect to obligations on the achievement of environmental objectives. The construction of devices for water transfers or artificial groundwater recharge requires obtaining prior authorisation (water-legal assessment). In the RBMPs the artificial restoration of resources is taken into account by the characterisation of GWBs and for the identification of significant anthropogenic effects. From the point of view of WFD transposition, important is the regulation on the detailed scope of the development of water management plans in river basin districts. According to this, the artificial restoration of resources needs to be taken into account during the characterisation of GWBs, as specified in the annexes. In **Slovakia,** specific permission is required for the artificial increase of groundwater amount using the surface water, according to the MAR related content of the National Law. For water quality implications the Water Act requires recording of data on amounts and water quality in respective water bodies including their influencing by human activities in places of artificial increase of groundwater amounts. In **Croatia** as a result of the transposition of EU legislation RBMP is implemented. Measures to control groundwater recharge are not foreseen in the recent RBMP, since no activities are carried out in the Republic of Croatia that would result of groundwater recharge. However, as a result of the process of strategic impact assessment of the RBMP, e.g, the forestry sector introduced 3 measures to establish control over the maintenance of a favourable connection between surface and groundwater in floodplain forest areas. In the annexes of the Ordinance on content of RBMP, however the methodology for the characterisation of the groundwater body is included.

1.1.2 GWD – water quality standards

Regarding water quality (WQ) standards, there are no such standards set specifically for MAR schemes (not generally for GW) in the PP countries, neither the terms “source water” and “receiving water” are defined.In the German regulations, as it is not allowed to have a negative impact on WQ, the limit values defined in the Federal Water Act and in the Groundwater Ordinance apply. Hence, for sulphate, arsenic, cadmium, lead, quicksilver, ammonium, chloride, as well as, for tri-and tetrachloroethylene limit values were defined. For nitrate, and pesticides, their metabolites, degradation and reaction products values from 2006/118/EG were taken (for nitrate (50 mg/l) and pesticides and respective compounds (0.1 µg/l each and 0.5 µg/l in total). Therefore, the German Working Group of the Federal States on Water Issues (LAWA) has developed recommendations/soft rules based on the regulation 2008/105/EG for insignificant threshold values. When implementing a MAR scheme, these values can be used to justify the injection or infiltration of water. Water quality (WQ) standards for source water are defined indirectly, as it is not allowed to have a negative change in WQ dueinjection of water into the aquifer e.g. through MAR. Also, according to the German Ordinance on soil protection and contaminated sites, it has to be checked if recharging water exceeding certain threshold values. The measurements shall be taken in the transition between unsaturated to saturated zone. Hence, the accepted value from contaminated sites reaching groundwater is defined here. Overview on values that have to be checked when recharging water passes from unsaturated to saturated zone is given based on the ordinance on soil protection and contaminated sites. Water quality (WQ) standards for receiving medium are based on the values defined in the Water Framework Directive.

1.1.3 EIA – environmental impact assessment

The article 11 of the Annex I of the EIA Directive states that “groundwater abstraction or artificial groundwater recharge schemes where the annual volume of water abstracted or recharged is equivalent to or exceeds 10 million cubic metres” are subject to an EIA.

In **Germany** the Environmental Impact Assessment Act is the transposing national legislation instrument. As, as it is not allowed to have a negative change in WQ due to MAR, compliance with this needs to be proved, as well. In **Hungary,** the attachments of the transposing legislation contain the list and conditions of activities where environmental impact assessment is needed. Similarly, in **Poland** the respective regulation stipulates that devices or sets of devices enabling the intake of groundwater or artificial groundwater supply systems, with a water intake capacity of not less than 1110 m3/h, are classified as projects that can always have a significant impact on the environment and require an EIA report. On the other hand, devices or sets of devices enabling the intake of groundwater or artificial groundwater supply systems, other than those listed above, with a water intake capacity of not less than 10 m3/h, were classified as projects that may have a potential impact on the environment. In **Slovakia** the regulation stipulates that wells enabling the abstraction of groundwater or artificial groundwater recharge, with a water abstraction capacity of not less than 10 million of m3/year, are classified as projects that can always have a significant impact on the environment and require an EIA report. On the other hand, wells enabling the abstraction of groundwater or artificial groundwater recharge with a water abstraction capacity from 3 million m3/year to 10 million m3/year, are classified as projects that may have potential impacts on the environment and should undertake the process of determining whether the projects shall be made subject assessments.

1.2 Other explicitly MAR related legislation in force

Besides the above mentioned, EU legislative requirements, there are no other MAR-specific regulations in the national/regional legislation that explicitly refer to artificial recharge (but not reinjection) in the PP countries.

2 Regulations with relevance for MAR in the national legislation

In addition to the legislative instruments having explicit MAR regulations, there are some other regulations, such as, the Urban Wastewater Treatment Directive or the Drinking Water Directive, which can be of relevance for MAR. These regulations need to be accounted for, together with the other national legislative instruments, which regulate facilities for water retentions or abstraction, water quality and monitoring issues of both source water and receiving water for drinking water and irrigation purposes or other end-uses. The relevant EU legislation tools (Figure 2), as well as the status of other national legislations which are in compliance with the above specified issues are summarized in Table 2.

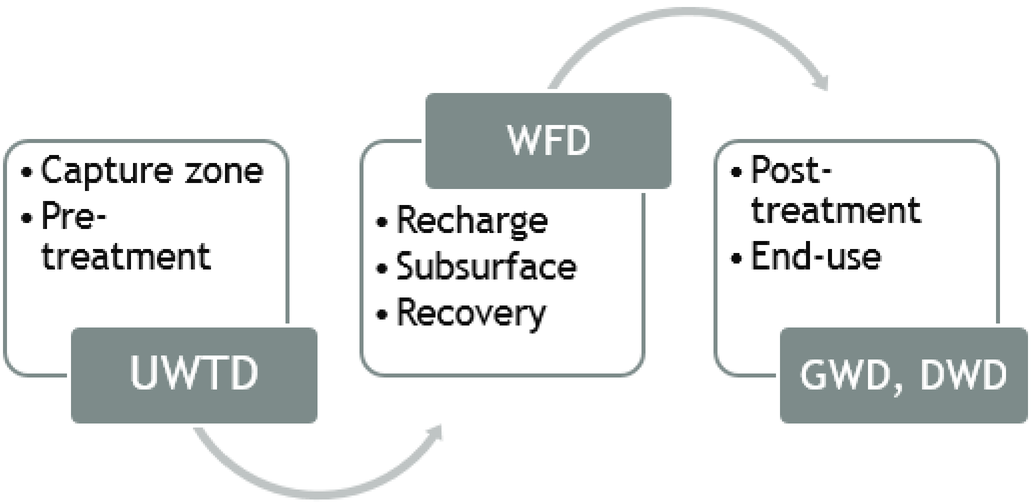

Figure 2. Compliences of the most relevant directives (Urban Wastewater Treatment Directive, Groundwater Directive, Water Framework Directive) to the phases of MAR application (modified after Fig. 2 in Miret et al. 2012 (deliverable of the DEMEAU Project)).

2.1 EU regulations with relevance to MAR

2.1.1 UWTD - mandate to reuse treated wastewater

The Urban Wastewater Treatment Directive (UWTD) contains the provision of the legitimacy of water reuse in general and specifically, that treated wastewater shall be reused whenever appropriate (e.g. treated wastewater, as a water source for MAR systems).

However, the UWTD and hence, the transposing national regulations in the PP countries, do not mention MAR. In the **Croatian legislation**, however, the UWTD Ordinance makes it possible, to discharge treated wastewater into the groundwater, its permission is exceptional and specific conditions should be met, also. In **Slovakia**, when giving permission to waste water discharge into surface water, in addition to the general provisions, the following issues are also considered: (i) provision of good status of surface and groundwater, water ecosystems and land ecosystems and (ii) decreasing waste water pollution and possibilities of waste water reuse.

2.1.2 DWD - possible additional monitoring

The Drinking Water Directive (DWD) contains the most stringent limit values for water end-use, thus need to be considered when establishing regulations for possible additional monitoring, in case of MAR systems. Also, DWD does not explicitly define requirements for the source of water. This guidance is transposed into the national legislations of the DEEPWATER-CE PP countries.

Table 2. Regulatory framework – regulations with relevance for MAR in the national legislation in the DEEPWATER-CE PP countries

Regulations with relevance for MAR	Regulatory issues	Germany	Hungary	Poland	Slovakia	Croatia
Regulations with relevance to MAR – transposition of related EU regulations into national legislation	Provision of legitimacy of water reuse in general - Treated wastewater shall be reused whenever appropriate (UWTD, 91/271/EC)	✓	✓	✓	✓	✓
	In case of drinking water use (post-treatment, end use) (DWD, 98/83/EC)	✓	✓	✓	✓	
	In case of drinking water use - improved strategies for the control (WSP)	✓	✓		✓	
Legislative instruments that regulate the requirements of source water used for recharge (with possible relevance related to MAR schemes)		✓	✓	✓	✓	
If no direct MAR-related regulations for prior authorisation (permitting) and control (monitoring and surveillance) exist specification of the relevant regulations for facilities for water retention/ abstraction		✓	✓	✓	✓	
If WQ standards are not regulated specifically for MAR schemes, the regulations for preservation of GW quality is general	Water and groundwater quality regulations related to abstraction and groundwater quality regulations related to recharge.	✓	✓	✓	✓	✓
	Water and groundwater quantity related to abstraction.	✓	✓	✓	✓	✓
Rules for irrigation and drinking water besides water abstraction-related rules with relevance for MAR schemes	Generally Irrigation Drinking water	✓		✓		✓
Groundwater monitoring requirements	Quantitative monitoring	✓	✓	✓	✓	✓
	Qualitative monitoring	✓	✓	✓	✓	✓
Other legislative/ policy instruments that include specific rules in the indicated fields that might have relevance for MAR schemes, particularly in terms of drinking water supply and irrigation.		✓	✓	✓	✓	✓

2.1.3 Water Safety Plan - ensuring good drinking-water supply with a risk assessment approach

For ensuring a good drinking-water supply the Water Safety Plan (WSP) provides a risk assessment approach "from source water to the tap water" (eg. from MAR system to the consumer). Partially, the WSP is incorporated into the legislation transposing the DWD (eg. in **Germany**and**Hungary**), thus the improved strategies (water safety guidelines) are fine tuned with the regulations on drinking water. In Slovakia, a separate decree regulates the specifics of drinking water quality, control of drinking water quality, monitoring programme and risk management by drinking water supply, as amended.

2.2 Specific regulations, requirements related to source water used for recharge

As it is mentioned earlier, at section 1.1.2, in **Germany**, for instance, the German Working Group of the Federal States on Water Issues (LAWA) has developed recommendations/soft rules regarding the acceptable threshold values based on the regulation 2008/105/EG. When implementing MAR schemes these values can be used to justify injections or infiltration of water. In **Hungary**, quality protection rules are established to prevent or limit the recharge of pollutants into the groundwater in order to protect and maintain the good qualitative status of groundwater. Environmental preventive measures and technical protection need to be applied, as well. For pollutants listed in annexes of the WFD, it is forbidden in general to recharge directly into groundwater or recharge indirectly into groundwater in areas of increased vulnerability (eg karstic areas, also intermittent rivers). During licencing, controlling of activities or remediation the pollution threshold values defined for groundwater should be considered. For substances with high risk to environment more strict values than defined in the respective regulation can be applied if needed to protect surface water from harmful effects of the activity. Nonetheless, threshold values cannot be stricter than those determined for surface water pollution which is regulated separately. According to legislation in **Poland**, substances particularly harmful to the aquatic environment and the conditions to be met when discharging sewage into waters or soil, as well as discharging rainwater or meltwater into waters or into water facilities, the Water Law Act (WLA) provisions should be followed. The WLA allows the transfer of water from the drainage of mining plants in order to increase groundwater resources, as long as they are unpolluted. The discharge of mine waters is regulated by the Geological and Mining Law and the WLA. Water discharge requires a water permit, in accordance with the WLA. In **Slovakia** sewage water and special water containing dangerous compounds are prohibited to be recharged into groundwater. Sewage water or special water containing contaminants which are not dangerous, but potentially risky for groundwater quality, can be released into groundwater body only under condition that the entry of contaminants will be constrained and no deterioration and significant increasing trend of contaminants in groundwater will occur. Discharging of any kind of water into groundwater must be permitted by the State Water Administration Authority.

2.3 Regulations on permitting and monitoring of facilities[1] for water storage/retention and water abstraction

In the **German** legislation if permitting and monitoring of facilities for water storage/retention and water abstraction are not specified in the transposed UWTD, GWD, DWD regulations local authorities may decide. Rules on land occupation/expropriation are according to the German Constitution, also Regional legislations define law on this basis (eg. for Bavaria, this is the Bavarian law on expropriation). In **Hungary**, it is the Water Management Act, which contains general regulations related to the utilisation, sustainable use, protection of water in harmonisation with environmental and nature protection regulations. A separate government decree is available on the general rules and regulations on activities and facilities related to the utilisation, management and protection of the water resources. Conditions of water utilisation for irrigation are also specified with regards to permitting and land occupation. Regulations on the protection of

[1]The term ‘facilities’ is used in this report as an equivalent to ‘hydraulic establishment’ which is used in the D.T4.1.1 template.

vulnerable water supplies are also considered relevant here, as this regulation establishes the protection measures and the criteria of water protection zones. Also, the regulation on the professional requirements of intervention and water well drilling is relevant. It contains the definition of recharge well, as a facility used for the recharge or direct injection of water into the underground water. It contains regulations on facilities related to the production, recharge and monitoring of underground water, as well as, related rules on waterworks planning, implementation, maintenance, and termination; the conditions and content of documentation; data needed for permitting. In **Poland**, these aspects are mainly regulated by the Water Law Act (WLA). The WLA contains the relevant legislation regarding permitting, monitoring. Permitting is obtained at the request of the applicant in the case of special use of water. Presentation of water licensing legal documents and decision on environmental conditions are needed. Water law permits are issued by the State Water Holding "Polish Waters" authority. In **Slovakia,** rules for licencing and control of hydraulic facilities are regulated in the Water Act. Facilities for discharging sewage water and special water into groundwater are listed in it. A Wide number of rules on their permitting and monitoring are explicitly listed. Pursuant to the Water Act, natural flowing surface water and groundwater are not owned privately, i.e. water is a state property according to the Slovak Constitution. The land can be owned privately, the purchase of the land is governed by general principles under market conditions. The Water Act defines only obligations of landowner, land administrator or land user on which the hydro-amelioration establishments are built. Obligations concern their duty to bear existence of the establishment on their land, to bear the accession of the establishment owner on the land for operation, maintenance, revision or necessary building reconstruction, not to deteriorate the establishment and to announce any establishment failure or repair necessity to the establishment owner. The conditions of water usage are listed in the Permit for Water Usage. Regarding expropriation of land and establishments and on compulsory restriction of ownership the Water Act specifically mentions only roads and highways, harbours as parts of navigation passes, and buildings listed under cultural heritage. Water establishments are not listed in the Water Act.

2.4 Water and groundwater quality regulations related to abstraction and groundwater quality regulations related to recharge

2.4.1 General

Water quality (WQ) values are defined in the transposed GWD in **Germany**. Hence for sulphate, arsenic, cadmium, lead, quicksilver, ammonium, chloride, as well as, tri- and tetra-chloro-ethylene values are defined, for nitrate, pesticides and metabolites values from 2006/118/EG are taken (see also above at section 1.1.2). As it is already summarized above, GWD does not allow deterioration in WQ, and German Ordinance on soil protection and contaminated sites (BbodSchV in **German** legislation) defines threshold values for contaminated water that can reach groundwater. Similarly, to drinking water protection areas, it could be done for MAR schemes for potential pollution to be decreased. Also, In **Hungary,** WQ-related requirements described in the national regulation are transposed from GWD. Accordingly, the indicative list of priority pollutants, which provide major or potential threat and quality requirements for groundwater which should be a minimum condition; for nitrate 50 mg/l; for pesticides 0.1 µg/l; and for total pesticide concentration 0.5 µg/l are listed. Also, for the protection of the geological media and groundwater from pollution, threshold values and limit values for pollutants are defined. In **Poland** besides the Water Law Act (WLA), there are several regulations in force that are related to WQ. These are regulations (i) on methods of monitoring surface water bodies and groundwater bodies; (ii) on the criteria and method of assessing the status of groundwater bodies; (iii) on the criteria and method of assessing the status of groundwater bodies and (iv) on the detailed scope of the development of river basin management plans. The 2006/118/EC Groundwater Directive (GWD) has been implemented into the WLA. In **Slovakia** also regulations of the Water Act apply. General groundwater quality norms explicitly listed in the Water Act are limits for the concentration of nitrates (50 mg/l) and active substances in pesticides, including their relevant metabolites, degradation and reaction products (0.1µg/l or 0.5 µg/l total), as well as a minimal list of 13 contaminating matters or ions with estimated threshold values. Specific quality norms are listed in state regulations for drinking water supply and irrigation.

2.4.2 Drinking water

Those mentioned above in Section 2.4.1 apply in general in most PP countries. In addition to the aboves, in **Poland**, drinking water aspects are regulated by the Act on collective water supply and collective wastewater disposal and the resulting Regulation of The Minister of Health on the quality of water intended for human consumption. In particular, the maximum contents of the individual components have been defined. However, there can be certain specifications. In **Slovakia** specific quality norms are listed in state regulations for drinking water supply. These are most importantly, regulations (i) on specifics of drinking water quality, control of drinking water quality, monitoring programme and risk management by drinking water supply; (ii) setting up requirements to reach the good water status; (iii) on threshold values and list of groundwater bodies (also threshold values of inorganic and organic pollution are listed). In **Croatia** there is an Ordinance on compliance parameters, methods of analysis, monitoring and water safety plans for human consumption and procedure for keeping the register of legal entities performing public supply activities. Health parameters (microbiological and chemical), indicator parameters (microbiological and chemical) and parameters of radioactive substances in water for human consumption are described besides parameter values, frequency of water sampling for human consumption, sampling methods and points, methods of laboratory testing of water for human consumption, analyses and the number of required water samples for human consumption, monitoring of water for human consumption, risk assessment in the implementation of water monitoring programs for human consumption, safety plans, register of legal entities performing the activity of public water supply.

2.4.3 Irrigation

Those mentioned above in Section 2.4.1 apply in general in most PP countries. In **Slovakia** specific quality norms are listed in state regulations for irrigation, also. This is a Standard Procedure on Water Quality and Irrigation Water.

2.5 Water and groundwater quantity regulations related to abstraction

2.5.1 General

Regarding water abstraction fee-related rules in **Germany**, in general, 13 of the 16 Länder ask for a fee when water is abstracted. There is rather a difference between extraction of surface and groundwater in abstraction for irrigation or for drinking water supply. E.g. Bavaria does not ask for payment on abstracted water. Instead, the municipalities can then decide on water abstraction fees to cover their costs. The water sector is a public sector. Besides water abstraction-related rules, for irrigation and drinking water the following rules can also be relevant for MAR. The standardization body for the gas and water industry in **Germany** defines soft rules on how the drinking water supply shall be handled. These soft rules are also partly referenced in laws and hence are required to be used. Often this is overlooked by the water authorities because costly certification can be related to the DVGW standards for the planners (engineering offices) and construction companies. However, it could be helpful if these soft rules/handbooks could be implemented for MAR as well.

In **Hungary, in** general, the Water Management Act complies with these issues. Accordingly, for achieving the environmental objectives, conditions for the good quantitative status of groundwater body should be met. Among these, for example, calculated average water abstraction for a longer term (at least 6 years) cannot exceed the quantitative limit value for exploiting water resources of the groundwater body, determined in the RBMP. Also, sustained decrease in water levels and potentiometric heads, as a result of significant water abstraction cannot be more than defined in RBMP. The ecological and chemical status of the connected surface water should not be harmed due to groundwater related reasons or result in failure of environmental objectives. Another condition is that change in direction of water flow due to abstraction, does not cause a significant and sustained trend in the chemical and physical status of groundwater, which would result in the subsequent failure of its environmental objectives. Likewise, no harm should be done, as a result of groundwater abstraction to groundwater dependent terrestrial ecosystems considered in the RBMP. In general, both direct water abstraction and indirect water abstraction need licencing, which is assessed in relation to other abstractions within the groundwater body. These, altogether, should not exceed the quantitative limit value of the water resource utilization, defined in the RBMP. For the purpose of non-drinking water abstraction, groundwater can be used only, if the use of surface water would be of unproportionally high cost (based on cost-benefit analysis), or unreasonable due to natural conditions. The activity cannot harm water quality, and the natural protection capacity of the aquitard on top of the aquifer from which the water is abstracted. The effects of water abstraction on water resources need to be monitored and reported to the authorities by the user, as prescribed in the licence.

In **Poland**, special water use is the use of water beyond the common use of water and ordinary water use, including the use of water from ponds and ditches, water transfers, and artificial groundwater recharge (WLA). Special water use requires a water permit (article 289 of the WLA). The application for a water permit is submitted to the seat of State Water Holding "Polish Waters" (PGWWP). The authority competent to issue the permits is the director of the catchment management board or the director of the regional water management board of the PGWWP. The application must be accompanied by a technical and legal study (prepared by the applicant/ investor) with the date of its implementation and a description of the intended activity.

Determination of the impact of the planned water facilities or water use on surface water and groundwater is required, in particular on the condition of these waters and the implementation of the environmental objectives specified for them in the technical and legal study. The issuance of a water permit means the granting of a water permit of the WLA. A water permit may not violate the local development plan, water management plan, protection plans for protected areas. It is valid for no more than 30 years (WLA). Regarding water fees, there are fixed and variable fees. Fixed fees are charged according to the amount of abstracted water relative to the average low surface water flows and available groundwater resources (WLA). In the context of MAR, the use of wastewater for power supply is debatable.

In general, the Water Act regulates water abstraction for both irrigation and drinking water purposes, in **Slovakia**. According to the regulations, groundwater abstraction must be permitted by the State Water Administration Authority. In the permission, both the annual abstraction amount (in the case of abstraction longer than 1 year) and abstraction conditions are stated. The permission is accorded for not more than 10 years. The amount of non-regulated payments, amount of charges and specifics connected to payment for water use. Abstraction fee for agricultural land irrigation is 0.001 EUR per cubic meter, the abstraction fee for public water supply systems was estimated at 0.0332 EUR per cubic meter. Other general requirements exist on price regulation of production, distribution and supply of drinking water by water supply network and wastewater discharge and cleaning by public sewerage. The fee is differentiated for respective groups of purchasers using calculation formulas listed in the respective decree.

2.5.2 Drinking water

Water and groundwater quantity related to abstraction for drinking water purposes is based on the Water Laws of the Länder in **Germany**. In **Hungary** the water abstraction fee related rule for drinking water for public consumers define a base fee according to categories of daily consumed water. For private consumers, there is a drinking water base fee and a water fee proportional to the consumption. In **Poland** for water abstraction for drinking water supply similar regulations apply as for irrigation use, which is that of the Water Law Act (WLA). Variable fees, depending on the amount of water abstracted under a water permit or an integrated permit for water abstraction, treatment and supply. Water abstraction for drinking water supply in **Croatia** is regulated by the Ordinance on conditions for determination of well field area sanitary protection zones. This Ordinance prescribes the conditions for determining the zones of sanitary protection of springs used for public water supply, measures and restrictions implemented in them, deadlines and the procedure for making decisions on the protection of springs. Other general water abstraction requirement with any relevance to MAR which applies is the Law on water for human consumption. This includes section on the health safety of water for human consumption.

2.5.3 Irrigation

Water and groundwater quantity related to abstraction for irrigation purposes is based on the Water Laws of the Länder in **Germany.** In **Hungary** the following rules apply for water abstraction for irrigation. The 4th amendment of the Water Management Act modifies the regulation of water abstraction for irrigation of agricultural land. Regarding water abstraction under certain conditions, instead of licencing the simple provision of relevant, basic information is accepted.

The well for water abstraction, however, can not affect water protection area, water protection zones, karst water and groundwater below the first confining hydrostratigraphic unit. Well depth must be less than 50 m and should not reach the first confining unit, abstracted water must be used only for the land of cultivation and has to be supplied with a water meter. These apply for existing and new wells. Regulations also address the legalisation of illegal wells. In case the above conditions are not met licencing is needed. As for the irrigation water abstraction fee, wells without the need for licensing have no administrative fees. There is a separate regulation for the components and calculation of fees related to agricultural water use. In **Poland** water abstraction for irrigation purposes is regulated by the Water Law Act (WLA), which allows for irrigation of land and crops in the annual average amount of >5 m3/24h only after obtaining a water permit. Regarding water abstraction fees, there are fixed and variable fees. Fixed fee is charged depending on the amount of abstracted water, related to the average low surface water flows and available groundwater resources. The upper levels of fees are variable. Besides the above rules, for agricultural use, wastewater is allowed to be used for irrigation and/or fertilization, restrictions are found in the WLA.

2.6 Monitoring requirements

In this section both the quantitative and the qualitative monitoring practices are overviewed in the PP countries, considering regulations with respect to groundwater, drinking water and irrigation water, as well. As it can be seen provisions of the EU legislations are transposed in general. For example, groundwater surveillance and operational monitoring are carried out with similar concepts.

2.6.1 Quantitative monitoring

Quantitative monitoring for groundwater in **Germany** is defined by the WFD (defined values can be found above). For drinking water this is the transposition of the DWD. Routinely defined frequency is defined by produced water and varies as 1-4 per year.

In **Hungary** the quantitative surveillance monitoring program is set according to WFD for groundwater. The quantitative surveillance monitoring enables assessment of quantitative status of the groundwater body, provides data for quantitative status tests, programmes with definition of the water abstraction limit value of the groundwater body, determination of groundwater reserves, controlling; frequency of monitoring should ensure controlling the effects of water abstraction and recharge on groundwater levels. There are two programmes within the quantitative surveillance monitoring, related to water level measurements and measurements of discharges mainly of springs. Water level measurements are carried out at 1692 monitoring points, monitoring frequency is dependent on the groundwater body type. Thermal water is measured monthly, but at least one data is needed yearly, at minimum. Otherwise, the frequency is monthly, in case of shallow groundwater reserves, sampling is needed twice in a week. Discharge measurements are carried out at 114 sampling point, at least once in a year. In certain cases quarterly or monthly. There is documentation available for operating the surveillance and operational monitoring.

In **Poland** monitoring of the quantitative status of groundwater in terms of measuring the location of the groundwater table is carried out with a frequency sufficient to assess the quantitative status of groundwater bodies, taking into account short-term and long-term variability in the supply of groundwater bodies. The amount of groundwater exploitation is also compared with its established resources.

In **Slovakia** the groundwater quantity monitoring is done in accordance with WFD requirements. The groundwater quantity monitoring network in Slovakia consists of springs monitoring and wells (piezometers) monitoring. Springs are monitored within the primary network. The Monitoring network consists of free flowing as well as captured springs for drinking water use in all main hydrogeological regions of Slovakia. In total, 356 springs were monitored in 2019. Observations at 179 springs are taken weekly. Furthermore, 174 springs were outfitted with automatic and limnigraphic recorders with hourly or continuous recording. Water temperature is measured in addition to spring yield on the majority of observed springs. The primary and secondary network of groundwater monitoring wells (piezometers) operated by SHMI consists of 1,146 sites (in 2019). Groundwater level and temperature are in general recorded weekly by voluntary observers in 273 wells. Automatic recorders with hourly intervals and limnigraphic recorders with continuous recording are installed at 860 sites. In all 860 sites the water temperature is measured daily and at 26 sites weekly.

In **Croatia** surveillance monitoring is performed on piezometers and wells at sites where water for public water supply systems is abstracted or at most significant karst springs. Surveillance monitoring covers chemical status and other parameters specified in EU Groundwater Directive for all groundwater bodies in Croatia, although the number of stations varies significantly. The Frequency of monitoring is four times a year in karst aquifers and in unconfined aquifers with intergranular porosity, while only once a year in confined aquifers with intergranular porosity. Operational monitoring is performed on groundwater bodies which have deteriorated chemical status or are at risk. Monitoring sites are located at piezometers, wells and springs which are under direct influence of pollution source. Six groundwater bodies are currently under operational monitoring. Minimum frequency of operational monitoring for groundwater bodies which are at risk is four times a year.

2.6.2 Qualitative monitoring

Qualitative monitoring for groundwater in **Germany** is according to those defined in the WFD and GWD.For drinking water additional parameters, such as smell, colour or taste are also examined. The following parameters are to be examined routinely, whereby the individual examination can be omitted for parameters for which measured values are continuously determined and recorded: aluminum, ammonium, Clostridium perfringens, Coliform bacteria, iron, specific electrical conductivity, Escherichia coli (E. coli), colour, odour, taste, number of colonies (at 22 °C and 36 °C), Pseudomonas aeruginosa, turbidity, hydrogen-ion concentration. More detailed evaluation is carried out by 1-10 times per year, which is defined by produced water. The parameters are aluminum, ammonium, Clostridium perfringens (including spores) Coliform bacteria, iron, specific electrical conductivity, Escherichia coli, Enterococci, Pseudomonas aeruginosa, acrylamid, benzol, boron, bromat, chromium, cyanid, 1,2,-dichlorethan, fluoride, nitrate, pesticides, quicksilver, selenium, uranium, antimon, arsenite, tetrachlorethylene and trichlorethylene, number of colonies at 22 ° C and 36 °C, pseudomonas aeruginosa, turbidity, hydrogen ion concentration (some more details can be found at e.g. https://www.gesetze-im-internet.de/trinkwv_2001/BJNR095910001.html). For irrigation water different parameters and values apply.

In **Hungary** the qualitative surveillance monitoring program is set according to WFD for groundwater. The qualitative surveillance monitoring enables the assessment of effects related to activities, includes the monitoring of parameters such as, dissolved oxygen, pH, specific electric conductivity, nitrate, ammonium, main chemical components of water, chemical pollutants thatcause the risk or failure of the good status; includes also components or indicators occurring naturally and also as a result of anthropogenic input for which threshold values are established, such as arsenic, cadmium, lead, mercury, ammonium, chloride, sulphate, nitrite, total phosphorus or ortho-phosphate, TOC, trichloroethylene, tetrachloroethylene, AOX. There are four programmes within the qualitative surveillance monitoring. In the vulnerable outer areas, at 868 sampling points, general chemical parameters are monitored twice a year and in addition around 30 pesticides and their methabolites and toxic metals are measured once in every six years. For the vulnerable inner areas, general chemical parameters measured twice a year at 286 monitoring points, and mainly industrial organic pollutants. The protected artesian groundwater is monitored at 758 sampling points, once every year basic chemical parameters, like pH, TDS, TOC are measured. Toxic substances are measured also, every six year. The thermal water programme has 90 monitoring points, where basic chemical parameters are measured every six year. There are altogether 407 chemical operative monitoring points, in groundwater bodies which failed or are at risk of failing the good status. There are three types of operative chemical monitoring. There is a documentation available for operating the surveillance and operational monitoring. For drinking water producing wells, the respective Decree contains general and technical operating regulations and/or the water safety plan specifies in detail the requirements of qualitative monitoring. The WFD defines that groundwater bodies where drinking water abstraction exceeds 10 m3 daily, needs to be monitored. The Government Decree on the quality requirements of drinking water lists parameters, methods and minimum number of samples to be analysed and contains general water quality requirements for drinking water. A separate regulation on the operation of waterworks contain parameters list and frequency of monitoring, as well.

In **Poland**, the monitoring of the chemical status of groundwater includes (i) surveillance monitoring and (ii) operational monitoring. Surveillance monitoring of the chemical state is carried out at least every 6 years. The scope of determination of physicochemical parameters is specified in the regulation, and includes : pH, TOC, EC, temperature, dissolved O2, NH4, Sb, As, NO3, NO2, B, Cl, Br, CN, F, P, Al, Cd, Mg, Mn, Cu, Ni, Pb, K, Hg, Se, SO4, Ag, Ca, HCO3, Fe, Ba, Be, Sn, Zn, Co, Mo, Tl, Ti, U, V, adsorbable organohalogens, Benzo (a) pyrene, benzene, BTX, phenols, pesticides, total pesticides, anionic surfactants, anionic and non-ionic surfactants, tetrachloroethene, trichlorethhene, petroleum hydrocarbons, PAHs. Surveillance monitoring of the chemical status of groundwater bodies and monitoring of the quantitative status of groundwater bodies are carried out in groundwater bodies that provide an annual average of more than 100 m3/24h of water intended for human consumption. Based on the monitoring, 5 water quality classes and two groundwater states are defined. Groundwater states refer to both quality and quantity. Operational monitoring of the chemical status of groundwater bodies is carried out if the groundwater bodies are considered to be at risk of not meeting their environmental objectives and/or the presence of significant and sustained trends in increasing concentrations of pollutants caused by anthropogenic impacts will be found. The frequency of operational monitoring is at least once a year. The operation of the monitoring network and the data are publicly available (http://mjwp.gios.gov.pl/ (in Polish).

Drinking water requirements are specified in the regulation on the quality of water intended for human consumption. The MAR aspect as well as, the water used for irrigation purposes is not regulated specifically. However, for irrigation water requirements should be met to fulfil the regulation on substances particularly harmful to the aquatic environment, also, when considering discharging sewage water into the soil, as well as discharging rainwater or meltwater into waters or into water facilities.

In **Slovakia** the monitoring of groundwater quality and chemical status was divided in accordance with the WFD into surveillance monitoring (175 sites) and operational monitoring (415 sites). The sampling frequency is from 1 to 4 times per year depending on the type of the geological environment. The samples are taken in spring and autumn when the extreme condition of groundwater could be monitored. In 2019 in Slovakia, 480 sampling sites were monitored within the state groundwater quality monitoring network (including spring, wells and separate layers in multi-layered wells).

Totally 396 sites (springs, wells) were located in the Žitný ostrov area, where the potential input of pollution to the groundwater from potential pollution sources were expected. The region of Žitný ostrov represents a separate part of the SHMI monitoring network since this region is the most significant drinking water resource. The monitoring network of Žitný ostrov comprises 34 piezometric multilayer wells (84 layers totally) that are monitored from 2 to 4 times per year. Concerning the protection of waters against pollution caused by nitrates from agricultural sources, within the operational monitoring there were 110 sites monitored in nitrate vulnerable zones. In 2019, totally 140 indicators (field indicators, basic physico-chemical indicators, trace elements, relevant substances, pesticides and other specific organic substances) were monitored. The selection of parameters for the evaluation of the groundwater quality has been adapted to the requirements of the WFD. Separate regulation lays down requirements on water intended for human consumption and quality control of water intended for human consumption.

2.7 Other environmental and risk management related regulations with a relevance for MAR systems

2.7.1 Environmental

In **Germany**, as it is not allowed to have a negative impact and shall stick to the values defined in the Federal Water Act and in the Groundwater Ordinance (German Environment Agency, 2017). As it is already summarized in Section 1.1.2 and 2.2, recommendations/soft rules based on the regulation 2008/105/EG were developed for insignificant threshold values, by the German Working Group of the Federal States on Water Issues (LAWA). Therefore, when implementing a MAR scheme, these values can be used to justify injection of water which is decreasing the existing groundwater quality. In Poland, the Environmental Protection Law regulates environmental issues in the field of protection and impact on individual components of the environment. The Spatial Planning and Dev elopment Act regulates the issues of the spatial development of the country. According to the act, preparation of a study is required on the conditions and directions of spatial development in communes, local communal spatial development plans, and voivodeship spatial development plans. In spatial development plans, it is required to take into account environmental protection, including water management. In **Slovakia** regulation on the prevention and remediation of environmental damage and amendments to some acts applies to environmental damage or an imminent threat of such damage caused, regardless of culpability, by these occupational activities, e.g. consumption of water and damming of water requiring an authorisation pursuant to the relevant specific provisions), including authorisation for associated hydraulic works. In **Croatia** environmental regulations besides EIA include completion of the Guidelines for the application of the combined approach which regulates the obligation to calculate the impact of the load on the condition of the surface water body with regard to the average flow and a flow of 90% of the duration. The guidelines have been published and are in use.

2.7.2 Risk management

As risk management is concerned, HACCP and WSP are applied, In **Germany**. Whereas, in **Poland** the WLA defines the rules for the implementation of the risk analysis for water intakes. It is an assessment of health hazards, taking into account factors that negatively affect the quality of water abstracted, based on (i) hydrogeological or hydrological analyses, (ii) hydrogeological or hydrological documentation, (iii) the quality of water and (iv) identification of sources of threat resulting from the method of land development. In **Slovakia**, regulation on the prevention and remediation of environmental damage apply. The operator is liable to prevent the occurrence of environmental damage and imminent threat of environmental damage and need to secure financial coverage of liability for environmental damage throughout the operational cycle.

2.7.3 Financial

In **Hungary** the River Basin Management Plan (RBMP) includes cost-benefit-analysis. In **Slovakia**, a separate regulation lays down details on the definition of the river basin district, environmental objectives, economic analysis and water planning. This includes also evaluation of the payback period and analysis of cost effectiveness.

2.7.4 Other

In **Germany** there are also soft rules of e.g. standardization body for the gas and water industry. There are many soft-rules and regulations which have semi-legal character. They are related to well construction, drinking water storage, pipe systems, etc.

3 MAR in national water strategies and river basin management plans

Explicit or MAR related regulations which are planned to be included in water strategy or river basin management plans (RBMP), together with other potentially relevant strategic documents are summarized in the following sections and in Table 3.

Table 3. Regulatory framework – MAR in national water strategies and river basin management plans in the DEEPWATER-CE PP countries

MAR in national water strategies and river basin management plans	Germany	Hungary	Poland	Slovakia	Croatia
Explicit MAR-related (planned) measures involved in national water strategy and/or river basin management plan (RBMP)	✓	✓	✓		
Measures involved in national water strategy and/or river basin management plan (RBMP) not directly related to MAR, but might have a relevance to MAR schemes	✓	✓	✓	✓	

3.1 Explicitly MAR related measures

There are many different regional and federal strategies in **Germany**. The planned MAR related measures e.g. in Bavaria are extensions of the groundwater storage measures, in general. Regarding specific and planned measures e.g. Bavaria has also declared, that until 2050 they want to implement methods for water storage. Thus, it can be interpreted that MAR shall play a significant role. To achieve the above objective there is financial support for house owners that are building rainwater retention schemes, such as infiltration ditches or permeable pavements. Also, the Federal Ministry of Education and Research is funding projects on how water can be retained from extreme rain events. The German river basin management plans cover controls of water abstraction and recharge, measures to promote efficient and sustained water use and measures for the recovery of costs for water services. The basic measures mostly already existed, mainly in the form of federal legislation and individual "Länder" laws and by-laws regulating permits, authorisations, registers etc. This means that in RBDs shared by several "Länder", the operative measures vary from one 'Land' to another (EP & EC Report, 2012).

In **Hungary**, the draft 3rd River Basin Management Plan (RBMP) contain a specific planned Programme of Measures (PoM) which is related to the regulation of the artificial recharge of aquifers. It suggests general regulation of all sorts of recharge into the underground water, but also that differentiation should be necessary according to recharge quantity.

In **Poland** the detailed scope of the development of water management plans in river basin districts includes artificial restoration of resources in the characterisation of groundwater bodies. However, the MAR aspect in Poland is marginal. For example, in the Vistula RBMP, MAR can be found in the summary of activities contained in the update of the National Water and Environmental Program, taking into account the methods of achieving the environmental goals, only as mentioning.

In **Slovakia** River Basin Management Plans (Danube, Vistula) had actualization, in December 2020. Measures are related to the increase of frequency and duration of the inundation flooding, prevention of water reservoirs silting, increase of water retention in the catchment – water retention establishments, runoff slowing, restoration of original riverbed and river course shape.

3.2 Measures with a relevance on MAR systems

There are relevant strategic documents in **Hungary**, e.g. the National Water Strategy in which there are new alternative water management strategies, such as, consideration of the reutilisation of treated wastewater and the possibility in periods of drought to use treated wastewater for artificial recharge to mitigate the effects of water scarcity. Other relevant strategies might be (i) the National Development Strategy 2030 – on National Development, Landuse Planning and Development Concepts; (ii) the National Sustainable Development Framework Strategy;(iii) Flood Risk Management Plan of Hungary or (iv) the 2nd National Climate Change Strategy.

The National Water and Environment Program (2016) in **Poland** which is relevant did not mention the issue of artificial supply or replenishment of groundwater bodies. The only exception is for the Groundwater Body No. 1, where groundwater transfer from the neighbouring GWB is planned to cover the water balance deficit. As part of the currently implemented update of the National Water and Environmental Program, it is proposed to develop a methodology and activities to identify the amount of drainage water (mining) to be returned to the river basin and its aquifer system. There is no need to replenish water bodies in terms of drinking water between GWBs, except for GWB No. 1, as discussed above.

In **Slovakia** there are other relevant documents such as the (i) Flood Risk Management Plans; (ii) Strategy on climate change adaptation in Slovak Republic (2018); (iii) Water is value – Action plan on drought and water scarcity impacts (2018) and (iv) Slovak Water Policy (in preparation, finished by the end of 2021). In new constructions and buildings – there is obligation of water retention (rain gardens, etc.).

II. Local regulations and soft rules

Local regulations and soft rules which are not having legal binding) can also help the enhancement of successful MAR schemes. Situation with respect to the PP countries is summarised in Table 4.

Table 4. Regulatory framework – Local regulations and soft rules in the DEEPWATER CE PP countries

Local regulations and soft rules	Germany	Hungary	Poland	Slovakia	Croatia
Local level MAR regulations, including rules of operators of MAR schemes that might be considered as a good policy practice and has a potential for a national level roll-out	✓				
Soft rules elated to MAR scheme planning, development or operation, such as guidelines or technical recommendations?	✓		✓		

4 Local level MAR related regulations

In **Germany**, local level MAR related regulations (e.g. by municipalities, MAR operators etc.) are considered, as not advanced enough yet. They also depend too much on the regional water authorities.

5 Soft rules related to MAR planning, development and operation

In **Germany**, soft rules which include legally not binding guidelines and recommendations are summarised by LAWA and in HACCP or in WSP. Furthermore, there is a DVGW guideline on MAR for drinking water supply. In the guideline, there are references to several norms and technical guidelines. They also refer to water treatment and the protection of the catchment area of the MAR scheme.

In **Poland** soft rules are promoting small retention forms. Ponds up to 1000 square metres and a depth of 3 metres fed only by rainwater are not subject to fees, in accordance with the provisions of the Water Law. Subsidies under the project "My Water" for the construction of ponds that collect rainwater can get some additional financing.

B. Institutional framework and stakeholders

This section summarizes the institutions which are in charge of permitting and control related to MAR schemes in the PP countries, at national, regional and local levels. In particular, the focus is on licensing and control of facilities and abstraction, as well as, water quality control.

6 Institutions in charge of MAR licencing and control

In **Germany** licencing and control of MAR related rules, also the rules related to recharge, water facilities and water abstraction for both drinking water and irrigation purposes are in charge of the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety at the national level. The regional level authority is the District Government and Offices of District Government e.g. Bavarian State Ministry of the Environment and Consumer Protection. Local level authorities are the Water Resources Authorities, Environmental Protection Authorities. In **Hungary** licencing at the national level is the responsibility General Directorate of Disaster Management within the Ministry of the Interior, except for licencing for irrigation water for which the National Land Centre of the Ministry of Agriculture is in charge. Control is done by the General Directorate of Water Management. At the regional level, licencing is in charge of the Regional Government Offices while regarding control, the Regional Water Directorates (12 Regional Directorates) are responsible. For specific local cases, local level licencing is in charge of the Municipalities (notary). In **Poland** the National Water Management Board is the licensing institution, on a regional level, the Regional Water Management Boards, while on local scale the Water Surveillances. In **Slovakia** the respective authority at both national and regional levels is the State Water Administration Authority, Department of Environment. The Slovak Water Management Enterprise, state enterprise (SVP, š.p.) is the administrator of water courses, the payments for abstracted water are specified in the

Regulation. The amounts of abstracted water are registered in Slovak Hydrometeorological Institute (SHMI). MAR licencing and regulations on national scale in **Croatia** are in charge of the Ministry of Economy and Sustainable Development and Croatian Waters, respectively. While on regional and local scales, Water Management Departments and Water Management Branch Offices are the institutions in charge.

7 Institutions in charge of water quality control

In **Germany** the same institutions are in charge of WQ control as above in Section 6. Regarding the control on WQ, in **Hungary** the General Directorate of Water Management is in charge at the national level. At the regional level these are the Regional Water Directorates (12 Regional Directorates). In specific issues related to WQ at local scale Municipalities (notary) are in charge. In **Poland** national scale WQ control is in charge of the Chief Inspectorate of Environmental Protection and the Chief Sanitary Inspector, as well as, the State Hydrogeological Service - Polish Geological Institute. Respectively, at the regional level these are the Provincial and Voivodship Inspectorates and Regional Offices. At the local level, there is the County Inspector, who is in charge of WQ control. In **Slovakia** the Slovak Environmental Inspectorate is responsible for WQ control at both national and regional levels. For WQ control in **Croatia** the Ministry of Health, Ministry of Economy and Sustainable Development and Croatian Waters are responsible. On the other hand, on regional and local scales Croatian Public Health Institute and also Croatian Waters are the responsible institutions.

C. Conclusions

8 Good policy practice on MAR in the DEEPWATER-CE PP countries in CE

This section comprises of two parts. In the first part, a review is given on relevantand explicit MAR legislation by the Italian associated partner (AP) of the DEEPWATER CE project. In the second part examples are summarised from the PP countries for good policy practices

8.1 Italian legislation

At Italian national level, the "Decreto Legislativo n. 152 del 2006" is the Italian reference legislation that transposes the European Waters Frame Directive (WFD). Groundwater controlled recharge on aquifers represents an additional measure to contribute to the achievement of the environmental quality aims of groundwater bodies, in line with the measures aimed at preventing or limiting the inputs of pollutants into the groundwater referred to the article 7 of "decreto legislativo 16 marzo 2009, n. 30".

The groundwater artificial recharge is also controlled by the regulation on Environmental Impact Assessment (Decreto legislativo 152/06 and subsequent amendments) which is also implemented at regional level (Regione del Veneto, Aquor Life project, 2015)). Among other Italian laws, following the above mentioned Dl.vo 152/2006, the "Decreto ministeriale 2 maggio 2016, n. 100

(Ministero dell'Ambiente e della Tutela del Territorio e del Mare, 2016) regulates the "criteria for granting the authorization to recharge or raise the groundwater bodies artificially in order to achieve the quality aims".

According to the law the following terms are defined (D.M. 100/2016):

- *donor water body*: water body that contains water that perform the controlled groundwater recharge in the receiving groundwater body;
- *receiving groundwater body:* groundwater body under controlled recharge by water deemed suitable according to the law;
- *controlled recharge*: work aimed to recharge the groundwater body by direct or indirect recharge from donor water bodies, with the aim to raise the piezometric level and to contribute to the achievement of the environmental quality aims;
- *direct recharge:* recharge of water into the receiving groundwater body without filtration processes through the soil and subsoil surface layers;
- *indirect recharge*: recharge of water into the receiving groundwater body by filtration processes through the soil and subsoil surface layers;

The donor and receiving water bodies are previously identified by Regions and included / updated in their own program measures and also in the management plans of the river basin districts.

Recharge is only allowed for groundwater bodies not in good status or for groundwater bodies in good status, but with a standing/negative trend in the presence of pollutants (Enrique Fernández Escalante, june 2020) and/or particular quantitative critical issues. Recharging can take place with water coming exclusively from water bodies (surface or underground) in a good chemical state (the decree identifies the maximum concentrations allowed for various substances and parameters) and with the aim to qualitatively and quantitatively improve the groundwater body without affecting the achievement of the quality aims.

The "Decreto ministeriale 2 maggio 2016, n. 100" provides, among others, criteria to release the authorization of controlled recharging, the designer must submit a preliminary and final project drawn up also on the basis of monitoring data and measurements.

In more detail it is foreseen:

1. A preliminary project that must include information relating to the receiving groundwater body and the donor water body, explaining the recharge action aims (qualitative improvement, reactivation of downstream springs, salt intrusion contrast, etc.), highlighting the need for the intervention in terms of qualitative- and quantitative status and trend. It is also necessary to provide:
    a. general information on the receiving groundwater body (at water body scale) that includes a conceptual hydrological model and its balance on the groundwater body; the location and type of controlled recharge chosen (Forest infiltration areas - AFI, infiltration wells, infiltration trenches, subsurface dispersion, etc.); interactions between water surface and groundwater, saturated and unsaturated geological and geochemical characteristics and also for water ones, knowledge of current uses with regard to the drinking water;

b. details relating to the site characteristics under recharge (at site scale) that include geological, geomorphological, hydrological knowledge of the site, the anthropogenic activities and their potential interferences with the site itself;
c. knowledge on the surface or underground donor water body which are necessary for the pressure analysis, the ecological and chemical status and the water balance; while for underground "donors" a conceptual hydrogeological model of the aquifer and an analysis of the pressures and their qualitative and quantitative states are required.

2. A definitive groundwater recharge project designed also on the basis of monitoring data „ante-operam“ which reports methods to recharge groundwater, the hydraulic, hydrochemical and socio-economic scenarios that occur after the intervention. Particular importance is given to the monitoring and the control system:
   a. ante operam: lasting at least 12 months and at least monthly frequency which has the purpose of defining the chemical and quantitative base level to evaluate the action effectiveness, and to optimize the final project. The monitoring network will be designed with upstream and downstream points of both for the groundwater recharging site / sites and the sampling site / sites;
   b. post operam: which will use the same network ante operam that has the aim to evaluate the effectiveness of the intervention and identify a possible deterioration state of the receiving water body and/or the donor water body;
   c. first alert monitoring: the infrastructures for controlled groundwater recharge must be equipped, upstream the derivation point, with a high frequency or continuous monitoring system using, for example, multiparameter probes, to measure significant changes on representative physico-chemical variables. This system must be implemented in a way to organize management protocols for stopping the refill groundwater flow within a time frame that prevents any impact. The same is also applied to the problems inherent to water scarcity which will have a different dynamic according to the phenomenon under observation.

8.2 Examples from the PP countries

Deliverable D.T1.2.1, which is the Transnational Report on the Collection of good practices and benchmark analysis on MAR solutions in the EU (DEEPWATER-CE project, 2020), summarised the good practices in the PP countries. Here, we highlight the lessons learnt regarding good policy practice from the examples of MAR applications in Germany, Hungary, Poland, Slovakia and Croatia which might enhance the establishment and harmonization of policies and good practices for MAR schemes.

In **Germany** MAR is regionally a fundamental part of sustainable water management and water supply. On the federal level 17.4 % of the overall water supply is obtained from MAR schemes, either from riverbanks infiltration or from groundwater recharge through wells or infiltration basins. MAR is incorporated into Federal Water Act and Federal Wastewater Regulation. In Germany, MAR schemes are established in areas with limited drinking water supply (Kuehn and Mueller, 2000) and for irrigation purposes.

In the Hessian Ried area, in Germany, since 1989, surface water from the river Rhine is treated and then infiltrated into the aquifer. The MAR scheme is required to stabilize the groundwater recharge to support the supply of groundwater for drinking water purposes and maintaining the groundwater ecosystem in seasonal fluctuations. Several methods for well injection and enhanced infiltration trenches are chosen in the Hessian Ried area. The MAR type is aquifer storage, transfer and recovery (ASTR) according to the definition by Gale, 2005; Dillon et al., 2008; Sprenger et al., 2017.

8.2.1 Good policy practice learned from MAR applications in the Hessian Ried area

The MAR sites at Hessian Ried are parts of an integrated groundwater management plan. 800 groundwater monitoring wells are evaluated monthly and the MAR sites are managed within the regulatory requirements. Chemical and quantitave groundwater quality is supervised, in accordance with the Federal Water Act (Bundesministerium der Justiz, 2014; Manger, 2018).

Bank-filtered aquifers play a key role in drinking water supply in **Hungary**. 35-40 % of the population of Hungary is provided from bank-filtered aquifers which is 52 % of current water supplies. 75 % of the future water supplies are to be bank-filtered water, making it a key player in future water management. Examples are the bank-filtered water resources of the Szentendre and Csepel Islands. These systems are situated along the Danube.

8.2.2 Good policy practice learnt from the RBF systems of Szentendre and Csepel Islands

In case of bank-filtration the particular challenge is the necessity of protection from both the river side and the background, so the system is exceptionally vulnerable. In the frame of the Drinking water Protection Program, detailed hydrogeological studies were done to save the bank filtered drinking water reserves and supply on the basis of outlining protection zones.

There are other examples related to two waterworks at Borsodszirák and at Bátonyterenye. They have already artificial recharge systems for drinking water supply. Responsibility for the implementation of MAR system is subject to the owners of water supplies (local administrations) and operating companies of the waterworks. In order to maintain active protection of the water aquifer, the waterwork shall always operate at 120 % recharge (regarding the produced water quantity). This is because the groundwater is highly polluted in the vicinity of the Borsodszirák waterworks, resulting from industrial and communal pollution. Enhanced infiltration technique creates a hydraulic potential dome in the water table (about 5 cm high), and changes the water flow direction, which prevents entering of any contamination to the area of the water base.

8.2.3 Good policy practice learnt from MAR operations at Borsodszirák and Bátonyterenye infiltration ponds

Several problems related to risk and sustainability (e.g. climate vulnerability) issues associated with MAR operation need to be accounted for when considering good practices. For example, in case of heavy rainfall, when the groundwater level rises by 5 cm, the system does not work properly. Therefore, it is necessary to wait until the flood wave passes. In summer, the reproduction of algae in the infiltration ponds can inhibit the infiltration. Due to the colmation of the infiltration ponds the gravel beds needs to be replaced every 2 years.

In **Poland**, for instance, at the riverbank filtration site in Krajkowo the RBF operation enables to reduce concentrations of organic micro-pollutants considerably. The research performed at the investigated site demonstrates a gradual lowering of concentrations along the flow path. In the RBF wells the reduction rate of the sum of pharmaceutical concentrations is greater than 50 %. Lower reduction rates (approximately 30 %) were found for the horizontal collector well. Results of pesticides investigation show also gradual decrease of concentrations along the flow path. High reduction rates are visible in RBF wells (about 80 % for the sum of pesticide concentrations).

8.2.4 Good policy practice learnt from RBF operations

It was observed that the RBF systems are sensitive to extreme climatic conditions (floods and droughts). The main risk during and after floods is the influence of poor water on river water quality with respect to organic matter occurrence on RBF systems. During long-term hydrologic droughts the main risk is clogging the riverbed which limits the infiltration rate. The clogging processes are enhanced by the creation of a cone of depression caused by intensive water exploitation during drought periods.

The presented results prove a high efficacy of contaminants removal by the riverbank filtration system. Significantly lower contaminant removal was documented in the horizontal well, which received river water after a very short travel time. For RBF sites with similar conditions, the suggested distance from the river should be at least 60 m. However, higher removal rates can be achieved for wells located at a distance of 250 m from the river.

In **Slovakia** there is no legal framework for MAR. The conditions for water abstraction are specified under the Water Act (364/2004 Coll.), but not specifically on MAR. In Slovakia, there are just riverbank filtration types of MAR sites. These are used as one of the most common methods to abstract water in the Danube lowland, but also near other big Slovak rivers (Hron, Váh, Hornád). None of the institutions is responsible for the implementation of these types of MAR, since it is considered as a common technical solution to abstract water from river fluvial sediments. The reason why “MAR schemes” i.e. bank filtration are used in Slovakia is to abstract high-quality groundwater for drinking water supply.

8.2.5 Good policy practice learnt from MAR operations in Žitný ostrov at the Danube River

Although the MAR solutions have no established legislation in Slovakia, in fact they are widely used for abstraction of water for public water supply, especially in Žitný ostrov from Danube River. This definitely shows the necessity to include these solutions into the Slovak legislative framework; improve technical solutions of proper MAR schemes and their financial evaluation; and to prepare the conditions to implement them for various purposes, for instance agriculture, during drought periods within the current climate change conditions.

Managed aquifer recharge (MAR) is not often discussed in **Croatia** since groundwater reserves generally satisfy the water demand. Hence, the need to manage aquifer recharge is not pronounced. Nevertheless, there are some springs used for public water supply which require enhanced recharge during periods of hydrologic drought as well as public wellfields deliberately positioned near rivers in order to either enhance the capacities of pumping wells through river bank filtration, or diminish wellfield protection zones which in many cases occupy urban areas.

8.2.6 Good policy practice learnt from MAR practice in Croatia

The MAR operation has proven that it is possible to directly increase Gradole spring yield during summer dry season by direct pumping of Lake Butoniga source water into the sinkhole Čiže, a rather simple but expensive procedure. This MAR operation was terminated due to construction of water treatment facility directly at Lake Butoniga, which enabled direct distribution of drinking water to consumers and made further MAR actions unnecessary.

9 Gaps in MAR related legislation in the DEEPWATER-CE PP countries in CE

The following key gaps were identified by the PP countries in related legislation. Primarily, the lack of explicit national legislation, despite that local studies were feasible and had been demonstrated. The German PP also raised the issue of regulations on infiltrating water quality and the application of soft rules. It is seen that regulation for infiltration water is perhaps too strict, as drinking water standards are applied. Therefore, there is a missing out on the potential of water purification through MAR schemes and on water quantitative augmentation (German Working Group of the Federal States on Water Issues (LAWA)). Also, the existing soft rules/guidelines refer to MAR for drinking water, and it would be wise to implement them also for irrigation water.

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