MARSOL

Demonstrating Managed Aquifer Recharge as a Solution to Water Scarcity and Drought

Workshop on Legal Issues, Policy and Governance of MAR Activities, 21-23 October, Water Services Corporation Head Office, Luqa, Malta

Local organizer: Sustainable Energy and Water Conservation Unit (SEWCU), Luqa, Malta

AGENDA

WEDNESDAY October 21st

Meeting location: Head Office of the Water Services Corporation, Luqa (Malta)
Triq Ħal Qormi, Ħal Luqa LQA 9043

Transport will depart from the hotels at 08:15 am

Introduction Session

09:00 - 09:30	Workshop Opening Session (Mr. William Wait, Executive Chairman of the Board of Directors of the Water Services Corporation; Prof. Christoph Schüth, MARSOL Coordinator)
09:30 - 10:30	Overview of WP 17 and the Draft Regulatory Structure for MAR (Manuel Sapiano, SEWCU)
10:30 - 11:00	*Coffee break*

Session 1: Horizontal Work Packages - contribution to the development of the regulatory tests

11:00 - 11:30	WP 11 - Monitoring (tbc)
11:30 - 12:00	WP 12 - Modelling (Joao Paulo Lobo-Ferreira, LNEC)
12:00 - 12:30	WP 13 - Technical Solutions (Enrique Fernández Escalante, TRAGSA)
12:30 - 13:00	Discussion
13:00 - 14:00	*Lunch*
14:00 - 14:30	WP 14 - Water Quality (tbc)
14:30 - 15:00	WP 16 - Risk Assessment (Xavier Sanchez-Vila, UPC)

WP-13

MARSOL TECHNICAL SOLUTIONS APPROACH AND DEVELOPMENT OF THEIR REGULATORY TEST

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MAR SOL MANAGED AQUIFER RECHARGE SOLUTIONS

*http://www.marsol.eu

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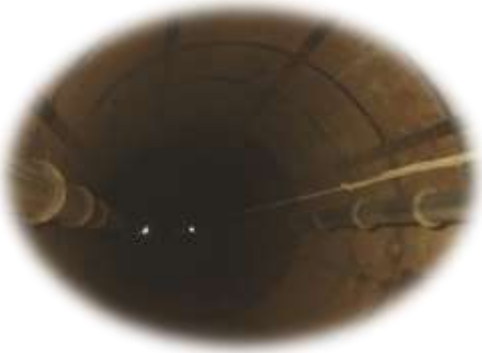
6- CONCLUSIONS

MAR SOL MANAGED AQUIFER RECHARGE SOLUTIONS



1- INTRODUCTION.

REGULATION AND WATER QUALITY ASSESSMENT

- **Strong connection between technical solutions for MAR and their regulatory development**
- **Solutions must be “legal” in the places they are proposed**
- **Unfeasibility of a common strategy or regulations in some cases**

1- INTRODUCTION.

REGULATION AND WATER QUALITY ASSESSMENT

The MAR Guidelines say aquifer water quality should be protected beyond a defined attenuation zone to sustainably continue to meet all its existing environmental values/beneficial uses, and that recovered water quality should meet the water quality parameters relevant to its uses.

We do not specify water quality requirements on recharge water directly because of the biogeochemical processes that occur in aquifers, that affect the achievement of these essential objectives.

Here are some examples to demonstrate that setting criteria on injectant does not necessarily assure you of achieving your water quality objectives … Reducing the ionic strength of water by purifying it to a high degree invokes increased dissolution of aquifer material, and may yield worse quality than a less pure injectant. You can add low arsenic water to a low arsenic aquifer and get water with high arsenic concentrations that exceed drinking guidelines. You can chlorinate water to remove harmful bacteria and viruses but in some aquifers chlorine continues to react and you can recover unacceptably high concentrations of trihalomethanes.

That is product water is a function of recharge water quality, groundwater quality and aquifer mineralogy. These dictate the redox conditions and temperatures which result in quite varied reactions between these three components.

Dillon, 2013

1- INTRODUCTION. *-NEED FOR A REVIEW OF THE EU WATER FRAMEWORK*

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Europe's water sector and the Water Framework Directive revision.

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Protecting Europe's water resources

EurEau members affirm that it is time to work on the Water Framework Directive.

European water providers declared their positions on the revision of the EU Water Framework Directive and are calling on stakeholders to engage now on this critical review of European environment law.

The call to action on the Water Framework Directive came at the EurEau Congress 2015 as part of the Milan Expo/Festival dell'acqua.

EurEau's members – public and private water providers from 28 European countries - are in firm agreement for a strong directive, and are clear about the directive's strengths and weaknesses. Ultimately, water providers want the outcome of the revision to safeguard Europe's water supply for future generations.

European water providers declared their positions on the revision of the EU Water Framework Directive and are calling on stakeholders to engage now on this critical review of European environment law.

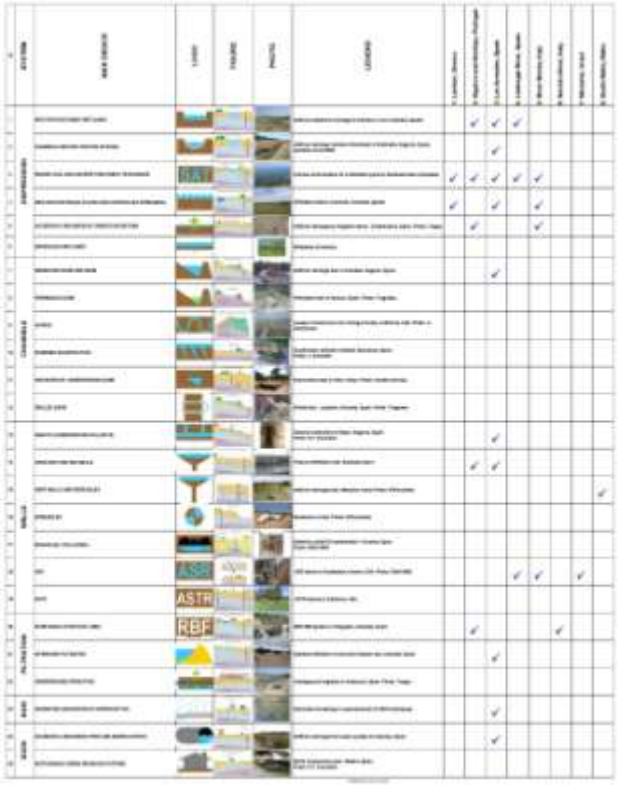
2- INTERNATIONAL REGULATIONS COLLECTED REGARDING MAR

Vast amount of regulations interspersed at WP 5 presentation.

Within MARSOL framework we have been collecting international regulations requested by means of IAH MAR channels. The inputs received by collaborators have been:

- **WHO** guidelines
- "Water Quality Guide to Managed Aquifer Recharge in **India** "
- **Australian** water quality guidelines, under water recycling you will find guideline 24: Managed Aquifer Recharge. http://www.environment.gov.au/topics/water/water-quality/national-water-quality-management-strategy#guidelines
- **Israel**
- **California**
- **Chile**
- **México**
- **Netherlands**
- **Belgium**
- **Spain**
- **Portugal**

3- MARSOL TECHNICAL SOLUTIONS PROPOSAL



Facilities inventory

Existing *tech sols* in the literature

Problem-solution binomias

Existing *tech sols* in the DEMO SITES (under improvement)

3- MARSOL TECHNICAL SOLUTIONS PROPOSAL

Problem-solution binomias

PROBLEMS	Main impacts on the aquifer area	1-LAVRION	2-ALGARVE	3-ARENALES	4-LLOBREGAT	5-BRENTA	6-SERCHIO	7-MENASHE	8-MALTA S
Scarcity (Overexploitation)	Quantitative issues because of overconsumption	X	X	X		X	X		X
Scarcity (Climate Change)	Drought, rising temperatures trend, lower precipitation cycles...	X				X	X	X	
Salinity (Seawater intrusion)	Associated to coastal aquifers	X							X
Heavy metals (Mining, Industry)	Metals from agrochemicals, urban, industrial sources: Pb, Fe, Al, Cr, Cd, Hg....	X							
Agriculture contamination (mainly N)	Agriculture diffuse contaminants: N, P K...	X	X	X					
Organic pollution (agrochemicals and antibiotics)	Toxic pollutants as pesticides and antimicrobials	X	X	X					
Wastewater discharge	Insufficiently treated effluents			X					
Wetland desiccation	Deterioration by water Table decline, Run-off shortage....			X		X			
Floods	Flooding events caused by CC, extreme rain...								
Others	*To be specified along the rest of the project*								

WP 13- Technical solutions… - Deliverable 13.1

Existing *tech sols* in the DEMO SITES (under improvement)

There have been distinguished five sorts of operations:

1. **Applied to water from its original source (quantity).**
2. **Applied to water from its original source (quality).**
3. **Applied to the receiving medium (in both soil and aquifer).**
4. **Applied to management parameters plus cleaning and maintenance operations.**
5. **Applied to the combination of all of them (integrated system).**

- 1.1 Water quantity aspects (T.S. 1 to 5).
- 2.1. Pre-treatment-treatment (T.S. 6 to 12).
- 2.2. Surface facilities (T.S. 13 to 16).
- 2.3. Deep injection (T.S. 17 to 19).
- 2.4. Receiving medium (T.S. 20 to 24).
- 2.5. Others (T.S. 25).
- 3.1. Previous studies (T.S. 26 to 27).
- 3.2. Surface facilities (T.S. 28 to 35).
- 3.3. Injection facilities and piezometers (T.S. 36 to 41).
- 3.4. Operative aspects (T.S. 42 to 46).
- 4.1. Operation (T.S. 47 to 53).
- 4.2. Maintenance (T.S. 54 to 56).
- 4.3. Decision support systems (T.S. 57 to 63).
- 4.4. Management (T.S. 64 to 70).
- 4.5. Reuse (T.S. 71 to 73).

Minimum of 73 real tech sols (under permanent revision)

WP 13- Technical solutions…
- Deliverable 13.1

73 real *tech sols* in the DEMO SITES (under improvement)

RECHARGE WATER (QUANTITY)

1-Preselecting: selective criteria for the origin of recharge water when several sources are available
2-Temporary storage of MAR water in surface reservoirs
3-Control of the flow velocity of MAR Water (stopping devices…)
4-Manage/avoid operations during specific events/periods, e.g. freezing weather, heat waves…
5-Security structures for overflow events, run-off tramps, spillways, etc.

RECHARGE WATER (QUALITY)

6-Pretreating of water for MAR in origin: (WWTP, membranes, mud lines, filters, packets…) (specify)
7-Pretreating of water for MAR in the heading of the structure: Filtering beds, decantation/stagnation structures, deaeration, etc.
8-Pretreating of MAR water using unsaturated zone as a pretreatment natural filter
9-Treatment structures intercalated along the construction for surface facilities, e.g. control of pH by means of mudstone gravel filters (specify)
10-Pretreating by Disinfection By Products (DBPs), e.g. Cl, I, O3, H2O2, UV rays, etc. (specify)
11-Chemical additives to eliminate clogging layers (specify)
12-Combination of different MAR facilities to improve the MAR water quality, e.g. a "triplet scheme" (WWTP, green biofilter, artificial wetland)?
13-SURFACE FACILITIES: Design and preservation of slope (rubble works, gabions…) (specify)
14-Limitation/control of the water layer thickness
15-Denitrification processes/additives (e.g. anammox)
16-Mechanisms to force the mixture of the different layers of MAR water, e.g. for canals let the water jump over or below stopping devices alternatively
17-DEEP INJECTION FACILITIES: Employ of anticorrosion materials in the MAR devices
18-Changes in the depth of the pump for wells/boreholes
19-Induced changes in water quality for irrigation. Fertilizers… (specify)
20-RECEIVING MEDIUM: Avoid aeration on AR waters: communicating vessels, open/buried structures, velocity control (specify)
21-Deaeration techniques: piezometers, increase distance between injection-extraction points… (specify)
22-Isolation from atmosphere/sunlight structures (specify)
23-Avoid natural salinization: Induced recharge, e.g. barriers in salty areas (specify)
24-Recycling effect of water in the MAR system (describe)
25-OTHERS: Specific fishes/exotic species introduced to reduce clogging (e.g. medaka)

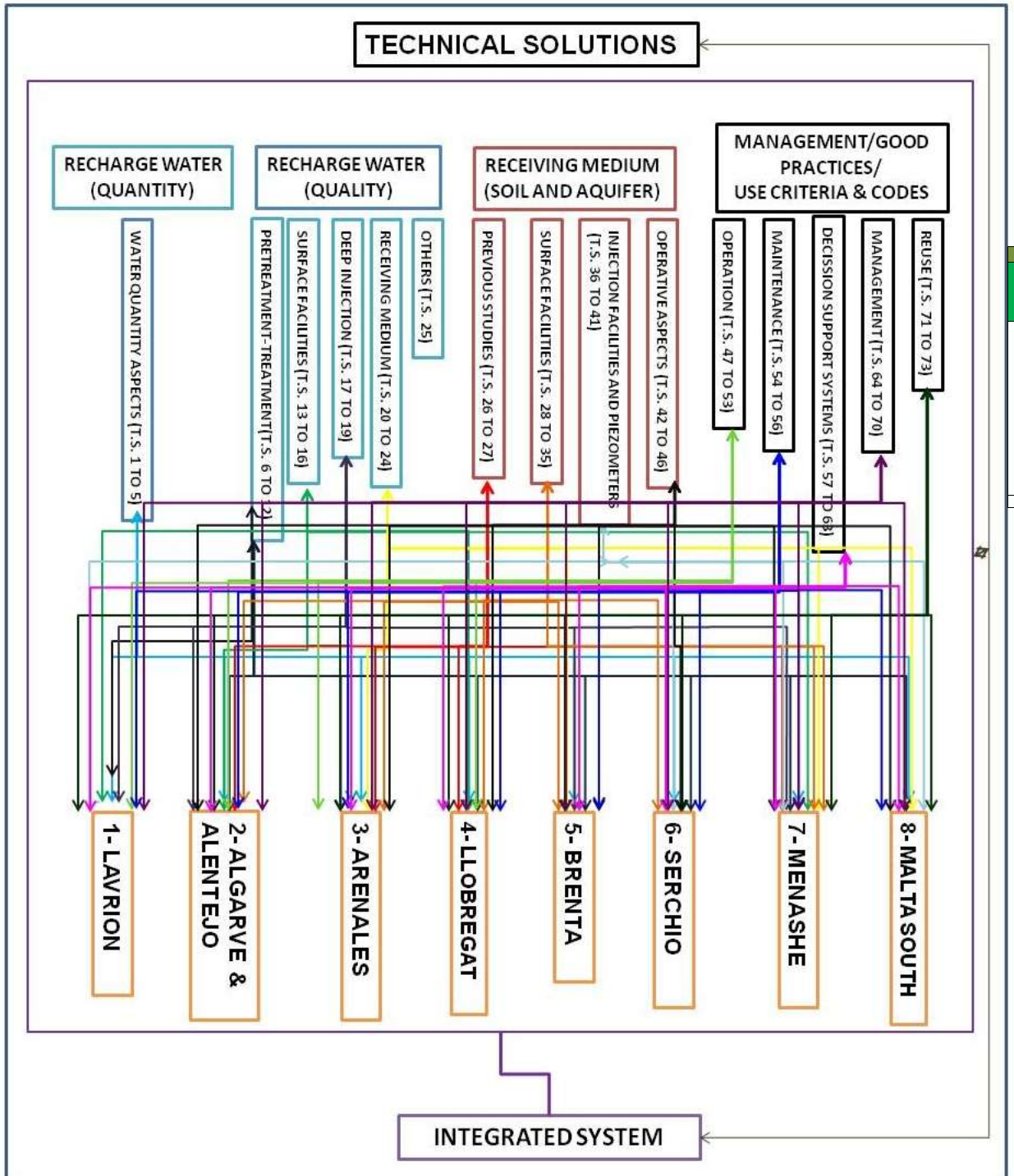
Grupo Tragsa

WP 13- Technical solutions…
- Deliverable 13.1

73 real *tech sols* in the DEMO SITES (under improvement)

RECEIVING MEDIUM (IN BOTH SOIL AND AQUIFER)

26-PREVIOUS STUDIES: The knowledge of the environmental conditions for the receiving medium might be considered sufficient? (describe)
27-Regarding the selection of the site, are there "natural fences" to avoid water to leave the system?
28-SURFACE FACILITIES: Changes in the receiving medium design. Furrows in the bottom, width, shape... (describe)
29-Changes in the receiving medium design. Geofrabrics in the bottom/slopes (specify)
30-Inverse pumping in wells pits close to a MAR canal or pond
31-Backwashing in geo fabrics, membranes and filters
32-Use of jet type cleaning techniques
33-Chemical cleaning (use of chemical additives) (describe)
34-Operations in the bottom: Algae drying, natural bed drying, cryotreating, cracking (cake) (specify)
35-Mechanical cleaning (scarification or silting zones and cleaning /replacement) (specify)
36-INJECTION FACILITIES AND PIEZOMETERS: Alternate normal and inverse pumping and frequency
37-Mechanical cleaning (wall brushing, scratching...)
38-Chemical cleaning (use of chemical additives) techniques for the regeneration of recharge wells
39-Selection of casing materials for wells according to groundwater characteristics (quality, quantity, durability...)
40-Employ of water level control automatic systems (alarm systems, buoys…)
41-Employ of clogging preventive systems, e.g. cathodic protection…(specify)
42-OPERATIVE ASPECTS: Use of dual systems allowing cleaning of one of them whilst the other is operating
43-Cleaning of the vegetation in the MAR facilities (specify)
44-Specific plantation during any season
45-Cleaning techniques frequency (specify)



TECHNICAL SOLUTIONS DATABASE STRUCTURE

Example

SORT OF TECHNICAL SOLUTION		DEMO SITE							
	Recharge water (quantity)	1-LAVRON	2-ALGARVE	3-ARENALES	4-LLOBREGAT	5-BRENTA	6-SERCHIO	7-MENASHE	8-MALTA S
WATER QUANTITY ASPECTS	1-Preselecting: selective criteria for the origin of recharge water when several sources are available	only WWTP		x	I	Single	Single	X (rain, WWTP, desalination)	two sources
	2-Temporary storage of MAR water in surface reservoirs	X tanks, lagoon	F (Cerro do Bardo)	x				X (settlement)	X agriculture plant
	3-Control of the flow velocity of MAR Water (stopping devices...)			x		X heading gate		X (gates, valves...)	
	4-Manage/avoid operations during specific events/periods e.g. freezing weather, heat waves...	X		x	x	use during irrigation period		according to rainfall	Supedited to high demand
	5-Security structures for overflow events, run-off tramps, spillways, etc.		X (huse spillway in Cerro do Bardo and Rio Seco)	x	x			spillway	
	To be specified in latter stages								

Technical solutions database structure, relating the sort of T.S., the category, the specific T.S. applied and the demo-site where it is being tested and deployed. Notice: This figure might change after the development of the ongoing activities.

SPECIFIC DISSEMINATION ACTIVITIES

-Inclusion of legal aspects in all the workshops, at least a presentation
-Personal request of a major in MAR4FARM WS

- *Directed at end-users*
- *Irrigation comuners involved*
- *Two of the very few workshops held in rural areas*
- *Scarce number of assistants*
- *Training character*
- *Some sport*

4- ACTIONS WILLING TO FACE LEGAL CONSTRAINTS

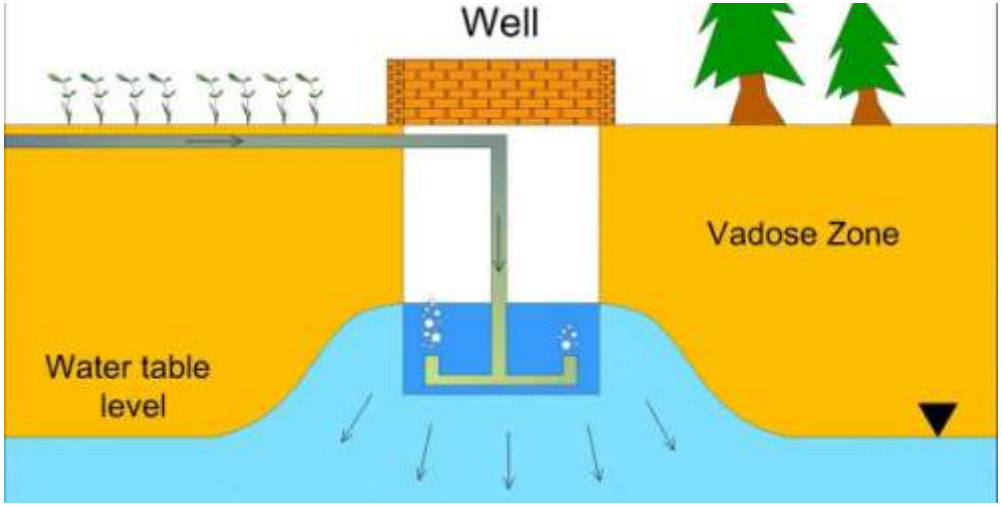
R&D activities focussed in the following aspects:

(A) LACK OF A HOMOGENEOUS DEFINITION FOR ARTIFICIAL RECHARGE

(B) THEORIC INSUFFICIENT EXPERIENCE ON ARTIFICIAL RECHARGE.

(C) CONTROL OF THE OPERATION, SURVEILLANCE

(D) ENSURE A CERTAIN CONTINUITY OF THE EXPERIENCES



5- FUTURE LINES OF ACTION TO BE ACCOMPLISHED

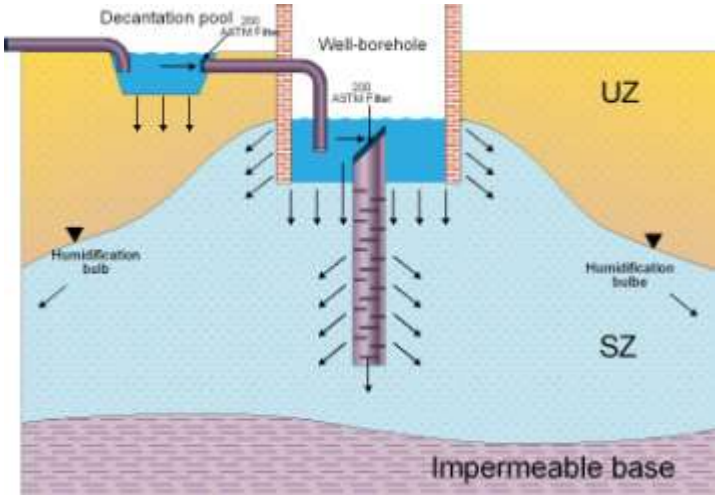
Demand for an unique and specific regulation for MAR in Europe, including, at least, the following aspects:

(A) SPECIFIC PROCEDURE FOR AUTHORIZATIONS

(B) ARTIFICIAL RECHARGE CONSIDERED AN SPILL IN SOME CASES.

(C) FINANCIAL ASPECTS ON ARTIFICIAL RECHARGE OF AQUIFERS.

(D) STUDY FOR EACH CASE IF THE PROPOSED TECHNICAL SOLUTIONS ARE LEGALLY VIABLE IN EACH COUNTRY PRIOR ITS PROJECT.



TABLES OF STANDARDS COLLECTED REGAR MAR IN THE INTERNATIONAL REGULATIONS

AS AN ADDITION TO THOSE EXPOSED IN DELIVERABLES 17-1 AND 17-2:

- **WHO guidelines**
- **India.** "Water Quality Guide to Managed Aquifer Recharge". 2014. Besed on WHO and Australian guidelines stating "Appendix 3. Example applications of these Guidelines to selected recharge sites in India".
- **Australian** water quality guidelines with parameters:
  - •Document 4 ANZECC (2000) guidelines for fresh and marine water quality; Document 6 Australian drinking water guidelines (2011);
  - •Document 21 Water recycling guidelines managing health and environmental risks (phase 1) which contains tables for crop and plant protection;
  - •Document 22 water recycling guidelines- augmentation of drinking water supplies which contains procedures for setting limits for all manner of organic compounds-.
- **Belgium.** MAR quality standards in Flanders. In Belgium the regions, as Flanders, are responsible for drinking water and environmental (e.g. permits) aspects.
- **California** does not have regulation specific to MAR, however there are regulations for groundwater replenishment with recycled water available at http://www.cdph.ca.gov/services/DPOPP/regs/Documents/DPH-14-003E%20Final%20Text.pdf There are also 'discharge requirements' for injecting drinking water into aquifers (ASR) available at http://www.swrcb.ca.gov/water_issues/programs/asr/index.shtml (State Water Resources Control Board).

TABLES OF STANDARDS COLLECTED REGARDING MAR IN THE INTERNATIONAL REGULATIONS-2

AS AN ADDITION TO THOSE EXPOSED IN DELIVERABLES 17-1 AND 17-2:

- **Chile.** Reglamento Aguas Subterraneas 2014. Art 47 & 48 (content of the technical application).
- **Netherlands**. **73** parameters. These are rather old acts and the limits are currently under debate, however, they are the legal limits right now. http://wetten.overheid.nl/BWBR0005957/geldigheidsdatum_09-09-2014
- **Israel**. Maximum concentrations of **25** parameters in recharged effluents in the Shafdan project.
- **México**. Norma 14 Conagua (2003), DOF: 18/08/2009 . **71** parameters.
- **Portugal**. No legislation “with numbers”. A sentence in DL69_2000 an EIA is needed for several type of projects including: "Groundwater abstraction or artificial recharge of groundwater where the annual volume of water abstracted or recharged is equivalent or greater than 10 million m^3 / year". In the Water Law (Lei 58_2005) there is a reference in article 30º, 3r) "Prohibition of direct discharges of pollutants in groundwater unless specific situations indicated in paragraph 4 that do not compromise compliance with environmental objectives, and control of artificial recharge of groundwater, including the establishment of a licensing regime".
- **Spain…**

Parameter	Regulations		Average concentration in 2013* (mg/l)
	Annual average concentration (mg/l)	Operational concentration (mg/l)	
Suspended solids	10	15	6
BOD	10	15	6
COD	50	80	2
N-NH_4	10	15	2.6
Total N	15	20	7.1
Total P	5	7	1
Turbidity (NTU)	5	10	2.8
pH	6.9 – 9.5	6.5 – 9.5	7.28
Anionic detergents	2	3	<0.12
Mineral oils	1.5	2.5	<0.3
Cyanide	0.1	0.15	<0.005
As	0.1	0.15	<0.002
Cd	0.01	0.025	<0.0002
Pb	0.1	0.2	<0.002
Hg	0.002	0.005	<0.001
Se	0.02	0.05	<0.002
Cr	0.08	0.12	<0.003
Ba	1	2	0.041
Cu	0.2	0.5	0.023
Fe	1.5	2.5	No data
Mn	0.2	0.5	0.022
Mo	0.01	0.02	<0.003
Ni	0.2	0.5	<0.005
B	0.4	0.5	0.22
Co	0.05	0.1	<0.003

MAR QUALITY STANDARDS IN THE SPANISH LAW

Spanish regulation. Specific Royal Decree 1620/2007

USO DEL AGUA PREVISTO	VALOR MÁXIMO ADMISIBLE (VMA)				
	NEMATODOS INTESTINALES	*ESCHERICHIA COLI*	SÓLIDOS EN SUSPENSIÓN	TURBIDEZ	OTROS CRITERIOS
5.- USOS AMBIENTALES					
CALIDAD 5.1 a) Recarga de acuíferos por percolación localizada a través del terreno.	No se fija límite	1.000 UFC/100 mL	35 mg/L	No se fija límite	N_T [1]: 10 mg N/L NO_3 : 25 mg NO_3/L
CALIDAD 5.2 a) Recarga de acuíferos por inyección directa.	1 huevo/10 L	0 UFC/100 mL	10 mg/L	2 UNT	Art. 257 a 259 del RD 849/1986

ANEXO I.B: FRECUENCIA MÍNIMA DE MUESTREO Y ANÁLISIS DE CADA PARÁMETRO

El control deberá realizarse a la salida de la planta de regeneración, y en todos los puntos de entrega al usuario.

La frecuencia de análisis se modificará en los siguientes supuestos:

i. Tras 1 año de control se podrá presentar una solicitud motivada para reducir la frecuencia de análisis hasta un 50%, para aquellos parámetros que no sea probable su presencia en las aguas.
ii. Si el número de muestras con concentración inferior al VMA del Anexo I.A es inferior al 90% de las muestras durante controles de un trimestre (o fracción, en caso de periodos de explotación inferiores), se duplicará la frecuencia de muestreo para el periodo siguiente.
iii. Si el resultado de un control supera al menos en uno de los parámetros los rangos de desviación máxima establecidos en el Anexo I.C, la frecuencia de control del parámetro que supere los rangos de desviación se duplicará durante el resto de este periodo y el siguiente.

Las frecuencias mínimas de análisis se especifican en la tabla siguiente:

USO	CALIDAD	NEMATODOS INTESTINALES	ESCHERICHIA COLI	SS	TURBIDEZ	N-T y P-T	OTROS CONTAMINANTES	OTROS CRITERIOS
1.- USO URBANO	1.1 y 1.2	Quincenal	2 veces semana	Semanal	2 veces semana	---	El Organismo de cuenca valorará la frecuencia de análisis sobre la base de la autorización de vertido y del tratamiento de regeneración.	Mensual
2.- USO AGRARIO	2.1	Quincenal	Semanal	Semanal	Semanal	---		Mensual
	2.2	Quincenal	Semanal	Semanal	---	---		Quincenal
	2.3	Quincenal	Semanal	Semanal	---	---		---
3.- USO INDUSTRIAL	3.1	---	Semanal	Semanal	Semanal	---		Mensual
	3.2	Semanal	3 veces semana	Diaria	Diaria	---		Legionella spp. 3 veces semana
4.- USO RECREATIVO	4.1	Quincenal	2 veces semana	Semanal	2 veces semana	---		---
	4.2	---	Semanal	Semanal	---	Mensual		---
5.- USO AMBIENTAL	5.1	---	2 veces semana	Semanal	---	Semanal		---
	5.2	Semanal	3 veces semana	Diaria	Diaria	Semanal		Semanal
	5.3	---	---	Semanal	---	---		---
	5.4							Frecuencia igual al uso más similar

PROPOSALS FOR IMPROVEMENT

B- *FOR A LOCAL QUALITY STANDARD*

Quality standard for artificial recharge water in the specific case of Los Arenales aquifer applicable to other parallel scenarios. Data based on bibliographic references and experiences obtained in field, laboratory and office (slightly modified from Fdez. Escalante, 2005).

GROUNDWATER QUALITY
Proposal for a standard

DETERMINATIONS / RANGES	QUALITY STANDARD
TSS 5-8 ppm	TSS < 10 ppm
TDS 101,8 ppm	TDS < 150 ppm
TOC < 5,5 mg/l	TOC < 10 mg/l
DOC 1,8-2,8 mg/l	DOC < 2 mg/l
DO 5,1-8,8-11 mg/l	DO < 8 mg/l
$[CO_2]$= 0,5 – 0,9 mg/l	$[CO_2]$ < 0,50 mg/l
pH = 8	pH < 7,5-8
Cond = 191 μS/cm	Cond < 200 μS/cm
Tª W = 5,9 ºC	Tª water ≈ Tª soil
Tª SOIL = 6,1 ºC	Tª water > Tª aquifer
Alcalinity= 64 mg/l CO_3Ca	Alcalinity <200 mg/l CO_3Ca
$[NO_3]$= 2 mg/l	$[NO_3]$< 10 mg/l
Sobresaturation SiO_2 = 35 mg/l.	Sobresaturation ≈ 0
Sobresaturation$CaMg(CO_3)_2$=37,86 mg/l.	Sobresaturation ≈ 0
Salinity = 0.1 – 0.7	Salinity ¿? to be determined
H_2S ≈ 0	Avoid H_2S
MFI: 25 - 30 s/l^2	MFI < 3-5 s/l^2
Bacteria and virus to be determined	Bacteria and virus to be determined

6- CONCLUSIONS

1. "*You don t need to be a scientist to deploy a MAR project*" (outcomes of the Algarve training workshop, 2015 June), neither a lawyer

2. Before implementing a MAR activity, it is necessary to choose the most appropriate method and study its legal feasibility for each context
3.
4. WFD must be updated accordingly to MARSOL outcomes

5. The majority of the problems raised during MAR devices deployment can be avoided or reduced conducting prior detailed technical and legality studies.

6. A joint strategy for the conservation of water, would be an important asset to satisfy the water growing demand.

7. The competent authorities should include during the planning, development, and implementation of MAR projects, the joint integration of MAR systems, at national, regional and basin level, as part of the set of strategies to be adopted for modern water management.

QUESTIONS AND DEBATE

Thank you
Malta 2015 October 21th