Managing Aquifer Recharge

Final Project meeting
17th – 18th June, Dübendorf

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Objectives

Managed Aquifer Recharge (MAR) in Europe

Impact assessment and feasibility

• Pre-requisites and feasibility studies
• Risk and impact assessment
• Fate and transport of emerging pollutants

Towards an EU authorisation for MAR

Conclusions
Overall objective

To support the implementation and optimization of MAR schemes in Europe in compliance with the European Union Water Directives

Infiltration pond for drinking water production in Berlin (D), operated by Berliner Wasser Betriebe
**Surface Spreading**
- Gravitational recharge by structures at or near to surface level (incl. shafts, pits, reverse drainage etc.)

**Well Injection**
- Injection of water into a borehole (incl. ASR/ASTR)

**Induced Bank Filtration**
- Infiltration of surface water induced by pumping from nearby well
Example of pre-requisites

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Criteria</th>
<th>Suitability assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target aquifer permeability, $k_f$ (m/s)</td>
<td>$&lt; 10^{-6}$</td>
<td>Very low, limited suitability</td>
</tr>
<tr>
<td></td>
<td>$10^{-6} - 10^{-5}$</td>
<td>Low, limited suitable</td>
</tr>
<tr>
<td></td>
<td>$10^{-5} - 10^{-4}$</td>
<td>Medium, suitable</td>
</tr>
<tr>
<td></td>
<td>$10^{-4} - 10^{-3}$</td>
<td>High, suitable</td>
</tr>
<tr>
<td></td>
<td>$&gt; 10^{-3}$</td>
<td>Very high, suitable</td>
</tr>
<tr>
<td>Saturated thickness in target aquifer (m)</td>
<td>&lt;10</td>
<td>Thin, high potential recovery rate</td>
</tr>
<tr>
<td></td>
<td>10-50</td>
<td>Medium, medium potential recovery rates</td>
</tr>
<tr>
<td></td>
<td>&gt;50</td>
<td>Thick, low potential recovery rate</td>
</tr>
</tbody>
</table>

- Objective criteria for 9 essential hydrogeological parameter
- Unsaturated zone
- Saturated Zone
- Valid for surface spreading and well injection

from Deliverable 12.2 (2015)
Investigation procedure and methods

- Detailed description of field methods
- From (pre-)feasibility to site screening to operational design
- For Surface spreading and Well injection

Taken from Deliverable 12.2 (2015)
Calculation of travel time by heat tracer

**Numerical engine (VS2DI)**
- Saturated and unsaturated flow
- Heat and solute transport

**GIS data (QGIS)**
- Pond extent
- Well design

**Calibration**
- Water levels
- Temperature

**Reporting**

<table>
<thead>
<tr>
<th>Monitoring Well</th>
<th>Dominant travel time (day)</th>
<th>Share of infiltrate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSV-2</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>BSV-5</td>
<td>5.1</td>
<td>100</td>
</tr>
<tr>
<td>BSV-3</td>
<td>6.8</td>
<td>100</td>
</tr>
<tr>
<td>BSV-6_3</td>
<td>7.8</td>
<td>99</td>
</tr>
<tr>
<td>BSV-10</td>
<td>9.6</td>
<td>98</td>
</tr>
<tr>
<td>BSV-9</td>
<td>10.9</td>
<td>95</td>
</tr>
<tr>
<td>BSV-6_1</td>
<td>13.4</td>
<td>88</td>
</tr>
</tbody>
</table>

**Data input**
- Time series (water level, temperature, water volume etc.)
- Hydrogeology

Tool Box: http://demeau-fp7.eu/toolbox
Case study: Infiltration Pond Berlin Tegel

Data
- Source (n=36)
- Impacted (n=33)
- Ambient (n=18)

Background values:
- anthropogenic
- natural

* from FUGRO and HYDOR (2002)

Conceptual Understanding

Taken from Deliverable 11.2 (2015)
Managing health and environmental risks – The Australian approach

- The only risk assessment approach for MAR worldwide
- Based on different levels of assessment, questionnaires, simple analytical models for flow and transport
- Applied for infiltration pond in Berlin-Tegel and well injection in Castellon

(NRMMC-EPHC-NHMRC 2009)
Human health disease burden

- expressed as 1 additional µDALY per person per year (pppy) recommended by the WHO
- aquifer treatment barrier was assessed for its log(10) removal capacity

Case study: Infiltration Pond Berlin Tegel

<table>
<thead>
<tr>
<th>Class</th>
<th>Additional 1 µDALY</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>&gt; 10 fold excess</td>
</tr>
<tr>
<td>B</td>
<td>1-10 fold excess</td>
</tr>
<tr>
<td>C</td>
<td>&lt; 10 times</td>
</tr>
<tr>
<td>D</td>
<td>&lt; 100 times</td>
</tr>
<tr>
<td>E</td>
<td>&lt; 1000 times</td>
</tr>
</tbody>
</table>

82% probability below 1µDALY at Berlin-Tegel
Assumptions:
- Chemical specific retardation (Log D)
- First order decay (half life) and dilution

- kinetic order of biotransformation for many organic chemicals is not known
- laboratory attenuation studies are unlikely to simulate the microbial community that develops in an aquifer

In this case compliance with Drinking water thresholds or Health-oriented guidance values
• Deconstruction of MAR in 7 functional elements

**Groundwater Directive (GWD)**

- Recharge water quality should meet the end-use requirements beyond a defined attenuation zone
- Points of compliance (POC) to meet GWD “good ecological and chemical status”

from Deliverable 12.1 (2014)
MAR in Europe

- MAR plays an important role in the European water sector (drinking water but also environmental benefits)
- Potential for MAR in the Mediterranean region

Risk assessment

- Australian guidelines constitute a robust basis for risk management for MAR schemes in the EU

Towards authorisation

- Integration of the attenuation zone to account for natural removal processes
- Monitoring concept (points of compliance) and aquifer background levels
Please visit the MAR tool box

- Pre-treatment options
- Tracers for MAR
- DEMEAU case studies
- R-software tools
- Long-term performance evaluation
- MAR profiling
- And more....

http://demeau-fp7.eu/toolbox
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Case study: Infiltration Pond Berlin Tegel

Assumptions:

<table>
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<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquifer thickness (m)</td>
<td>30</td>
</tr>
<tr>
<td>Porosity of the aquifer (%)</td>
<td>20-30</td>
</tr>
<tr>
<td>Distance between point of infiltration and recovery well (m)</td>
<td>100</td>
</tr>
<tr>
<td>Average pumping rate of well 20 (m³/d)</td>
<td>1920-2400</td>
</tr>
<tr>
<td>Minimum depth to the mounded water table beneath the infiltration basin or gallery (m) (not yet available)</td>
<td>0.5-6</td>
</tr>
<tr>
<td>Saturated hydraulic conductivity (m/s)</td>
<td>1.5×10⁻⁴-1.1×10⁻³</td>
</tr>
</tbody>
</table>
Disease burden in DALYs without any reduction measures in place. Assumptions (1L drinking water consumption per day, disease per infection ratio (0.5), susceptible fraction (6%), dose response parameters for Rotavirus from (Haas et al. 1999), severity factor (1.4*10^-3 DALYs/case of disease)).

Number of log removal (LRV) required to be in compliance with a tolerable level of risk of 1 μDALY pppy. Assumptions: 1L drinking water consumption per day, disease per infection ratio (0.5), susceptible fraction (6%), dose response parameters for Rotavirus from (Haas, 1999)).
Impact assessment of MAR

- Characterization of MAR flow regime
  - General flow field, travel times, hydraulic impact zone
- Water quality impact assessment
  - Reliability check (ion balances)
  - Comparison of water quality data with background values
Natural Background Levels

Aquifer typology
only if limited data of groundwater chemistry is available

Pre-selection method
certain chemical compounds can be used as tracers indicating exclusively anthropogenic influence
Müller et al. 2006

Component separation
scientific sound but data intensive and applicable by experts only

Kunkel et al. 2004

Pauwells et al. 2006

EU funded project BRIDGE –
Background cRiteria for the IDentification of Groundwater thrEsholds

05.12.2013