EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

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STSM Applicant: Dr. Jannis Epting
Topic: Development of concepts for the management of thermal resources in urban areas
Host: Prof. Enric Vàzquez-Suñé (Consejo Superior de Investigaciones Científicas (CSIC)), Institute of Environmental Assessment and Water Research (IDÆA), UPC, Barcelona, Spain

Dear Hans,

Please find below my report of the Short-term Scientific Mission (STSM) I made from 5. to 10.01.2015 to the Institute of Environmental Assessment and Water Research (IDÆA), UPC, Barcelona, Spain. The objective of the cooperation partners is to develop concepts and methods for the monitoring and management of thermal resources in urban areas.

Our collaboration already started with Alejandro Garcia Gil's visit to Basel during the Work-group 2 meeting in Basel from 20. to 21.11.2014 and now was continued by my STSM to Barcelona in January 2015. Our intention is to advance our collaboration and publications by further STSMs to the individual collaboration partners and to directly implement our results in the reporting of the different work tasks of the WG2 Subgroup "City-scale groundwater and geothermal data and modelling – a review of best practice". This report reiterates the original plan, summarises the activities and the attached document compiles the relevant information of our publication intentions for the two selected case study cities in Basel (CH) and Zaragoza (S).

Rationale

In urban areas the shallow subsurface often is used as a heat resource (so-called shallow geothermal energy), i.e. for the installation and operation of a broad variety of geothermal systems. At the same time, groundwater is increasingly used as a cheap cooling medium, e.g. for buildings. Further impacts like the so-called urban heat island effect also influence the thermal regime in the subsurface. As a result, significantly increased groundwater temperatures have been observed in many urban areas.

For the two selected case study cities in Basel (CH) and Zaragoza (S) already comprehensive monitoring networks (hydraulics and temperature) as well as calibrated high-resolution numerical heat-transport models have been developed by the individual collaboration partners (Epting et al. 2013; Epting and Huggenberger2013; Garcia Gil et al. 2014). This previous work showed that an understanding of the variable influences of hydraulic and thermal boundary conditions due to specific geological and hydrogeological conditions in urban settings is crucial. It also could be shown that good quality data are necessary to appropriately define and investigate thermal boundary conditions and the temperature development in urban systems.

Objectives

These existing datasets and models allow compiling and comparing the different hydraulic and thermal boundary conditions for both groundwater bodies, including: (1) River boundaries (River Rhine and Ebro); (2) Regional hydraulic and thermal settings; (3) Interaction with the atmosphere under consideration of urbanization; as well as (4) Anthropogenic quantitative and thermal groundwater use.

For both groundwater bodies potential natural states are investigated for different urban settings and varying processes concerning groundwater flow and thermal regimes.

From the experience of both case study cities concepts for the monitoring and management of thermal resources in urban areas are derived and the transferability of the applied methods to other urban areas discussed. The methods should allow an appropriate selection of parameters (spatio-temporal resolution) that have to be measured for representative interpretations of groundwater flow and thermal regimes of specific water bodies (settings and boundary conditions).

Description of the work carried out during the STSM

- General agreement on the work plan and time schedule.
- Compilation of the relevant information for the two selected case study cities in Basel (CH) and Zaragoza (S).
- Outline of publications and elements to be implemented into the reports of the different work tasks of the WG2 Subgroup “City-scale groundwater and geothermal data and modelling – a review of best practice”.

Description of the main results obtained

- For both urban areas the basic data and models are existent which allow an adequate comparison and derivation of guidelines for other urban areas (transferability).
- The collaboration partners agreed to focus on two main topics focusing on (1) monitoring and (2) management, which will allow an independent advancement of the individual partner (see attachments). Regular exchange will be performed by telephone and SKYPE conferences as well as during future COST meetings (e.g. Zagreb, Bucharest) and further STSMs.
- Further data sets within other urban settings (e.g. Barcelona) will allow supplementing the information on specific boundary conditions as e.g. infiltrating surface waters.
- The requirements for the involvement of further urban areas to be compared have been determined and will be discussed in Zagreb (see below).

Future collaboration and work plan with the host institution

- STSM to the Applied and Environmental Geology, Department of Environmental Sciences, University of Basel, Switzerland.
  End of February 2015
  This follow-up STSM will again involve several meetings and discussions of the current state of the publications at the host institute in Basel.
- Engagement of a wider group of COST participants.
  3-4 March 2015
  Collaboration with further participants of the WG2 Subgroup “City-scale groundwater and geothermal data and modelling – a review of best practice”. The transferability of the applied methods will be discussed and highlighted in a wider European context. Discussion and presentation of this work at COST workshop or meeting at Zagreb COST meeting.
- STSM to at Institute of Environmental Assessment and Water Research (IDÆ); UPC, Barcelona, Spain.
  June 2015
  This follow-up STSM will again involve several meetings and final discussions of the publications at the host institute in Barcelona.
- English Publication, summer 2015 paper submission.

Foreseen publications/articles resulting from the STSM

- Development of concepts for the management of thermal resources in urban areas – Transferable concepts on the basis of the experience gained from the Basel and Zaragoza case studies.
- The monitoring network policies of shallow geothermal exploitation systems and its optimal design in urban areas - Experiences gained from the Basel and Zaragoza case studies.

(See attachments for outlines)

Development of concepts for the management of thermal resources in urban areas – Transferable concepts on the basis of the experience from the Basel and Zaragoza case studies

Contributors (preliminary alphabetical)

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1. General aspects

a. Challenges

Heated groundwater ressources – waste or resource?
How to use and store geothermal energy in the shallow subsurface?

Which are the main problems/questions of both cities?
Which problems/questions is site specific, which are general?
How to evaluate new concessions and protect existing groundwater users?
How to define maximum-minimum injection temperature and thresholds?

b. Context of studies

Historical development of cities => long term geothermal input

- Old <-> Young cities
- Buildup of city centers and agglomeration; use of historical maps to trace evolution of city area; historical Information on subsurface structures?

Interaction with rivers -> temperature of river water

Geotechnical/geothermal systems
Cooling and/or heating
Open and/or closed systems (currently only open systems considered in the models of Basel and Zaragoza

Subsurface structures
In Zaragoza only a few buildings reach into the groundwater
Cities will grow into the subsurface => Traffic systems in the underground => how can the energy potentially be used? How much energy is available?

Ancient contaminated sites have to be considered in Basel, since groundwater use will influence groundwater flow

Interaction with other use of the aquifer
E.g. mining of gravel
Use of groundwater as process & drinking water

c. Risks

Geology of the deeper subsurface: Increased pumping rates can lead to dissolution of minerals → sinkholes/dolines (both possible in Zaragoza and Basel). Pumping can modify geochemical equilibria→subsidence (by means of mixing or thermal induced)

Flooding and interaction with rivers (Ebro and Rhine), inundation of subsurface structures
Contaminated sites
Possible interference with contaminated areas?

Contamination-degradation of water supply from aquifers because of geothermal use

Interaction between users (installation of wells; coefficient of performance). Thermal interferences (intrinsic and extrinsic) between shallow geothermal stakeholders

Extraction of water and release of warm water to the river (Rhine in Basel)
Closed systems vs. open systems
Future questions: thermal impact on bacterial communities

d. Legal Aspects

Compile information in current legal status (Switzerland, Spain,….)
e.g. current processes/status in different Cantons in Switzerland
Need of remediation measures to correct bias to accomplish European Framework directive?
Maximum groundwater temperature threshold (catalysis of biodegradation of pollutants, growth of prejudicial bacteria)

2. Definition of present state / process identification

a. Comparability of settings / data sets

Comparison of balances across the boundaries
Bias in energy balance (overheating of the aquifer) results in reduction of geothermal potential (need of remediation measures to correct bias to accomplish European Framework directive)

b. Quantification of natural and anthropogenic impacts (water body approach)

Which processes contribute to the present state? => which contributions play a major role? (e.g. how important is the unsaturated zone?)
Which boundary conditions have to be considered in what detail?
How can the regional components be quantified (groundwater regime; inflow from adjacent hill slopes), where are the best locations for capturing them? Where are no flow and no thermal exchange boundaries adequate?
Which data are necessary for adequately capturing the influence of quantitative and qualitative groundwater use? E.g. are monthly data sufficient?
How detailed has the city structure (subsurface buildings; tunnel constructions, etc.) be represented?

c. Interaction of processes / activities

How to quantify the dynamic (thermal) exchange processes across river beds? E.g. by means of riverine T-monitoring and the derivation of Conductance models.
Which processes are irreversible, which processes are reversible (e.g. long term temperature increase, flood events, …) => how does this affect the monitoring strategy?

d. Transferability

Which data should be measured?
Which boundary conditions are transferable?
Where additional investigations have to be conducted?

e. Installation of geotechnical systems

3. Transfer of scientific results to the public

a. Regulations

b. Implementation in legal framework

c. Instruments, concepts, which can be implemented

4. Strategies

What can be done when the aquifer gets too much energy?

=> energy storage?

=> combined uses of open and closed loop system

=> artificial recharge

Energy potential mapping to analyses the availability of geothermal energy

Which instruments do we have to implement the strategies in the legal framework?

Who is paying management (monitoring, numeric model maintenance, burocracy, policy-vigilance, remediation costs) of the aquifer? Estate? Stakeholder’s community?

High transient-dynamic activity of shallow geothermal exploitations+ great heterogenic urban materials-media => numerical modelling

The monitoring network policies of shallow geothermal exploitation systems and its optimal design in urban areas. Experiences in Basel and Zaragoza cities

Optimizing monitoring networks for capturing the influence of geothermal exploitation systems in urban areas – Experience gained from the case studies in Basel and Zaragoza

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1. General aspects

- *Objectives*
    i. Give guidance for monitoring network design considering shallow geothermal exploitations scheme in urban environments.
    - Optimal location to capture specific boundary conditions, as: (1) river-groundwater interaction; (2) regional context of groundwater flow; (3) inflow from adjacent hill-slopes; as well as (4) anthropogenic influence of (a) groundwater and/or geothermal use; and (b) subsurface building structures.
    - Guidance on necessary spatiotemporal resolution of monitoring, including operational data of groundwater users (esp. taking into account the transient influence of groundwater users).
    - Definition of zones in urban groundwater bodies with specific groundwater water flow and thermal regimes, including boundary conditions and subsurface usages.

    ii. Show existent monitoring networks and the results obtained. Comparison and efficiency analysis.
    - Comparison of conventional and high-resolution depth-oriented groundwater temperature monitoring (see previous work, especially M. Köhler). Are existing monitoring networks, which originally were installed for other purposes (e.g. hydraulics, sampling) appropriate for temperature measurements?

    iii. Establishing the principal monitoring policies for good practices and its possible implementation in legal framework.

- Comparison of current state of thermal groundwater regimes and necessary as well future developments. Estimation of investments/costs?

- **Discussion of management measures for the sustainable development of urban groundwater resources. (1) use of groundwater for heating purposes and reinjection of comparably "cold" water to the aquifer; (2) artificial recharge of comparably "cold" water to the aquifer; (3) seasonal storage of heat within the unconsolidated rock and underlying bedrock.**

- Necessary amendments of legal frameworks concerning the current legislation in Spain and Switzerland.

- *Thermal management concepts-problems*
  i. Natural thermal regime of aquifers VS impacted thermal regime of aquifers.
     - Comparison of present to potential natural thermal state of the aquifer, including seasonal variations of the thermal groundwater regime of specific aquifer regions.
  ii. Thermal interferences (intrinsic and extrinsic): The need to identify those with monitoring network.
     - Link to the direct and indirect thermal impact (see concept relaxation factor).
     - Selection of examples from the two case-studies.
  iii. The role of monitoring in the quantification of ground water flux and thermal processes within the groundwater bodies.
     - Exemplified by examples from the two case-studies.

- *Study sites: Description of existing monitoring networks:*

  Monitoring network description: Number of monitoring points, devices installed, vertical discretization or not, state variables measured (Temperature, hydraulic head, electrical conductivity, chemical samples), monitoring of exploitation variables **(capitation-injection temperatures, Pumping rates)** and frequency of measurements. Biologic sampling?

  Evaluation of existing data-sets; Optimization, especially at localities that describe: (1) boundary conditions; (2) areas with high thermal variability, especially near (a) rivers, (b) reinjection, or (c) subsurface structures reaching below the groundwater table.

  i. Case Study I: City of Basel
  ii. Case Study II: City of Zaragoza
     (data availability has to be agreed with the authorities)

2. Definition of optimal monitoring network

- High sensitivity zones to geothermal exploitation (see above, description of methodological approach, maybe also refer to master thesis of M. Köhler)
- Longitudinal and transversal dispersivity importance- uncertainty
- Interaction of processes / activities (natural and anthropogenic boundary conditions influence in the measurements)
- Already existing monitoring networks…It is really necessary to construct new ones?

Which are adequate, which not (also here we have already much information and have evaluated various constellations)? Where are additional monitoring systems for more reliable temperature measurements necessary and in what spatiotemporal resolution?

3. Transfer of scientific results to managers and stakeholders community

- *Monitoring policies (maybe integrate within a preliminary discussion in the introduction and then recapitulate in the final discussion)*
  I. The appropriate design of the monitoring network provides the tool for the vigilance of each stakeholder concession (a given amount of heat power exchange licence) and guarantees the correct-sustainable operation of the installations and the community itself.
  II. The monitoring network is primary source of information of the hydraulic, thermal and chemical processes taking place in the subsurface and the shallow geothermal installations.
  III. In practice the understanding of flow and thermal groundwater regimes are indispensable to assess the impact and interaction of existing and new groundwater users. How to convince stakeholders for investment which allow correct working of the monitoring systems to ensure the sustainability of their shallow geothermal exploitations and the interaction with other subsurface users.
  IV. Transparency of datasets as the main strategy to explain stakeholders the restrictions adopted.

- *Implementation in legal framework (integrate in the final discussion)*

  i. Outline ways, how to amend existing legislations and ordinance for the thermal use of the shallow subsurface.
  ii. Development of Indicators to define the state of the aquifer systems; overheated-over exploited or good state. The importance of indicators to evaluate the risk for stakeholder's investments.

  - For a comprehensive view of geothermal systems and their interaction numerical flow and heat-transport models are necessary. Such models allow: (1) integrating the data of the various monitoring systems; (2) evaluating groundwater flow and heat-transport regimes for different zones and settings, as well as (3) investigating scenarios of future use and systems changes.
  - The need of numerical flow and heat-transport models to design optimal monitoring network, then the model it is needed to integrate all the datasets obtained from the monitoring network and continue the optimization process of the monitoring network as it develops with new installations.
  - Need of detailed geological description of the boreholes in monitoring points, pumping test and TRT.
  - Monitoring down-hydraulic gradient point to control injection should be operated by thermal managers and should be public (transparent) to stakeholder's community.

- Monitoring Capitation-production wells should be operated by installation stakeholder but should be reported to thermal managers and subject to thermal manager’s in situ verification-checking. Specify requirements.
- Every big shallow geothermal installation (more than X Kw) should be monitored. Specify requirements. Example showing what information gets lost if the extraction and reinjection is not adequately monitored.