

## 0. Publishable Executive Summary

### 0.1 Summary Description of Project Objectives

This final annual activity report summarizes the project progress and major achievements towards the project objectives of the research project GABARDINE (Groundwater Artificial Recharge based on Alternative Sources of Water: Advanced Integrated Technologies and Management) between November, 1<sup>st</sup> 2007 and April, 30<sup>th</sup> 2009. The international research project GABARDINE aims for the following major objectives:

- ❑ Explore the viability of supplementing existing water resources in semi-arid areas with alternative sources of water that could be exploited in the context of an integrated water resources management approach. Such alternative water sources are surface water surpluses generated during rainy seasons (runoff water, flash-floods etc.), treated effluent continuously produced in urban areas, surpluses of desalinated water, that are expected in periods of low water demand or high water availability (from natural resources) and exploitation of saline water bodies that could be used for adequate agricultural practices or used as raw material for low-cost desalination. The exploitation of these water sources requires a seasonal and long-term storage of large quantities of water.
- ❑ Investigate the feasibility of using aquifers as the primal facility for the large scale storage of these alternative water sources and investigation techniques for artificial recharge and injection of the produced alternative water, including a monitoring of water quality and purification by natural attenuation and filtration processes.
- ❑ Evaluate and quantify the potential impact of degrading factors, such as climate change, changes in water quality, salt water intrusion etc. on the usability of the resource, by developing tools for risk mapping, for modeling and for monitoring, and to propose measures for preventing or minimizing, and mitigating their impact.

To achieve these major goals a research strategy along lines of action with the following secondary objectives has been developed:

- Development of an integrative methodology for: 1) the evaluation of aquifer water budgets and hydrologic deficits; 2) mapping of areas according to groundwater quality and vulnerability to contamination factors; 3) identifying areas potentially suitable for seasonal and long-term storage; 4) GIS-based delineation and characterization of replenishment areas to groundwater aquifers and identification of propitious areas for artificial replenishment.
- Development of technologies for the storage of waters of various qualities and the assessment of the impact on the aquifer overall groundwater quality as well as the expected quality of the water to be produced in existing and planned well fields, including the aspects of recovery efficiency and water losses. The role of the unsaturated zone as a filtration medium will be investigated.
- Development of novel tools for the efficient and robust simulation of the flow and reactive transport processes related to the implementation of Artificial Groundwater Recharge Systems (ARS).
- Studying water quality and water treatment requirements related to the water to be artificially recharged.
- Studying the regional impact of large-scale artificial recharge of water of various qualities, applying sophisticated groundwater flow and solute transport models.

- Investigating the mechanisms of climate change effects on precipitation patterns, aquifer natural replenishment, as well as quality and availability of scarce groundwater resources.
- Development of a methodology for evaluating, in a physically-based way, the vulnerability of the aquifer to stress factors such as climate change, injection and storage of waters of various qualities in the aquifer, salinization processes and salt water intrusion, in order to optimize the management of the resource and land use planning in the area.
- Investigating future water demand scenarios and potential operational measures to meet the overall water resources management objectives, focusing on the implementation and operation of ARS.
- Evaluation of the socio-economic impact of the suggested approaches and solutions on the respective communities as well as further requirements for implementation.
- Development of a Decision Support System (DSS) for the planning and management of ARS together with a knowledge base platform.
- Application of the suggested schemes to test sites at Thessaloniki (Greece), the Gaza strip (Israel and Palestine), the Algarve region (Portugal) and the Llobregat river basin (Spain).

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## 0.4 Work Performed and Results Achieved

During the final year of the GABARDINE project considerable progress was achieved towards the above cited research objectives. The most important work and results achieved are:

- Creation of statistical downscaling model with the neural networks. (WP2: climate change analysis);
- Development of innovative tools or estimation of rainfall and temperature on daily and monthly basis and implementation in each test site (WP2: climate change analysis);
- Development of a new software tool (GIS-Circulation types) in order to simulate daily circulation type calendar everywhere in Europe. (WP2: climate change analysis);
- Estimation of natural groundwater recharge for the whole Campina de Faro aquifer system using a sequential daily water balance model (WP2: climate change analysis);
- Inventory of alternative water sources for each test site (WP3),
- Laboratory experiments on the biodegradation of organic carbon and on the fate of a selected set of emerging organic micropollutants in saturated soils under different redox conditions (WP3: Mixing Process);
- New mathematical expression to find reaction rates in terms of mixing ratios at chemical equilibrium (WP3: Mixing Process);
- Filed campaign for soil physical and chemical analysis at the Greek test site, identification of representative xenobiotics as well as combination and optimisation of analytical procedures for high risk target xenobiotics (WP3: Mixing Process);
- Development of a robust meshless numerical approach based upon a radial basis function (RBF) collocation technique and implementation to Greek and Portuguese test sites (WP4: Mathematical Tools);
- Improvement of the previously simplified 1D-model for flow and multi-component reactive transport (WP4: Mathematical Tools)
- Adaptation of the LHI method to allow the solution of problems involving multiple zones and implementation of an extension of the CV-RBF code to handle multi reactive transport problem for confined aquifers (WP4: Mathematical tools)
- Application of groundwater vulnerability approach and rating method (GABA \_IFI) to different test site (WP4: Mathematical tools)
- Detailed characterization of each of the GABARDINE test sites in Spain (Barcelona), Portugal (Algarve), Greece (Thessaloniki) , Israel and Palestine (coastal aquifer) (WP5: test site development);
- Development of GIS platform for each of the Gabardine test sites (WP5: test site development);
- Completion of artificial recharge experiments and analysis in all test sites (WP5: test site development)
- Completion of a three dimensional model for the simulation of groundwater flow and salt transport, including density dependent flow at the sea-aquifer interface for the coastal aquifer, Israel. (WP5: test site development)
- Development of Gabardine Geo –Spatial Database, implementation and validation of the database - with GIS links (WP6: Integration);
- Interface development of all GDSS modules (WP6: Integration)
- Implementation of Spatial multi-criteria analysis (site selection module) for Algarve region, Portugal (WP6: Integration)
- Development and Application of MCA module for GAZA test site (WP6: Integration)
- Completion of the questionnaire and data sheet for social, environmental and economical issues, that is common to all test sites for Gabardine Project (WP7: Socio-economic aspects);
- Completion of “Do nothing Approach” for Gaza test site (WP7: Socio-economic aspects)

- Socio-economic and environmental impact assessment for GAZA test site (WP7: Socio-economic aspects)
- Multi-criteria Analysis for AR management scenarios for the planned new wastewater treatment plants and infiltration ponds completed and implemented in DSS ((WP7: Socio-economic aspects)
- Dissemination of the GABARDINE research activities at numerous international events, to various scientific communities and end-users (WP8: Dissemination)
- Development of the Gabardine website (WP8: Dissemination);
- Dissemination of project concepts to various scientific communities and end-users (WP8).
- Number of articles, as an output of research from GABARDINE, have been published in peer reviewed international journal (WP 8: Dissemination)

## **0.5 Expected End Results, Intentions for Use and Impact**

During the project life all efforts have been given to achieve all main and secondary research objectives presented in the summary description. The theoretical background, technologies, methodologies, guidelines, mathematical tools, platforms and decision support elements developed in the project has been implemented at GABARDINE test sites and intensively disseminated in order to promote the worldwide application of the produced knowledge.

The innovative concepts for vulnerability and impact assessment, the innovative groundwater simulation tool, spatial multi-criteria analysis for site selection, knowledge base platform and GABARDINE Decision Support System, between other research products, will offer efficient support to ARS planning and management to various potential end users, such as water supply companies or governmental agencies, in order to contribute to the achievement of the overall water resources management objectives as well as water resources and policy development.

Therefore, and due to the increasing water scarcity and importance of groundwater resources in semiarid regions, we expect a strong impact of the project results on a large community interested in the implementation of ARS and their operation with alternative sources of water such as treated effluent.

## **0.6 Dissemination**

**Representatives of the GABARDINE research project participated and presented the research work at numerous international and national Congresses, Conferences, Symposia and other public events:**

- International Conference of the European Geosciences Union – EGU, Vienna, Austria, April 2006.
- International Conference on Computer Methods in Water Resources (CMWR-XVI), Copenhagen, Sweden, 2006.
- International Conference IAMG - Liege, Belgium, 2006.
- International Symposium on Integrated Water Resources Management, Reducing the Vulnerability of Societies Against Water Related Risks at the Basin Scale, Ruhr-University Bochum, Germany, September 2006.
- IWA World Water Congress 2006, Beijing, China.
- International Conference AQUA 2006, Athens, Greece, 2006.
- Romanian Workshop on Intelligent Embedded Systems, Bucharest, Romania, 2006.
- Public meeting for GABARDINE dissemination at the Regional Development Coordination Commission of Algarve (CCDR-Algarve), Portugal, 2006.

- Portuguese Water Congress, Lisbon, 2006
- Public meeting for Gabardine dissemination at the regional Development coordination Commission of Algarve- Algrave, Portugal, November, 2006
- Stand for Gabardine presentation in the International Fair WATERTEC- Athens, Greece, November 2006
- Workshop for the ecological crisis in the cities- Thessaloniki, Greece, December 2006
- Media briefing EYATH's efforts to sustainable use of water resources,- Thessaloniki, Greece, February 2007
- BIWA conference (Belgium), March 21, 2007
- 1st Joint EU-Workshop projects RECLAIMWATER – GABARDINE on Artificial Recharge- Sabadel, Barcelona, Spain, March 2007
- Conference “Aguas Subterraneas 2007”- Portugal, March 2007
- Participation at International Water Day: March, 2008
- 9th Portuguese water Congress, April 2008
- Reclaim Water Final Meeting, Maribor, Slovenia , September 2008

A list of the oral and poster presentations as well as published papers is included in the main report.



Figure 1: Gabardine Consortium Meeting in Greece, 2008 and Special Dissemination session in the Algarve 2007

**Gabardine website: [www.gabardine-fp6.org](http://www.gabardine-fp6.org)**

