WaterJPI project

SMARTControl

Smart framework for real-time monitoring and control of subsurface processes in managed aquifer recharge (MAR) applications

Deliverable D6.2a

Training courses on the use of the SMART-Control software
Part 1: Implementation of first training course in Cyprus

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Training course on the use of the SMART-Control software

Part 1: Implementation of first training course in Cyprus

Short summary

This report summarizes the content and main outcomes of the first series of training activities within the SMART-Control project. The events are focused on the introduction of the tools and approaches developed within the project to a designated audience of technical and managerial stakeholders in Cyprus. The activities included a preliminary needs assessment to identify and characterize the interest of the participants in the content provided, followed by the implementation of public workshops and specialized training courses in SMART-Control software.

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ABSTRACT

The SMART-Control trainings aim at providing the management and technical operators of the SMART-Control pilot sites an introduction to the use of the innovative SMART-Control instruments. In addition, new technical and operational improvements are to be worked out with the participants on concrete use cases. Besides that, the project consortium aims to examine the applicability of SMART-Control tools for different needs. This will ensure a sustained and large-scale application of the project approach. The training program is characterized by close cooperation between developers and users and conclude with a series of meetings to initiate replication activities within the project and beyond (WP 7).

Part 1 of the Deliverable 6.2 covers the first training course implemented at the SMART-Control pilot site in Cyprus. This includes preparatory activities (Chapter 3), the detailed training program (Chapter 4), and a summary of the impressions and results of the interactive sessions (Chapter 5). Once the second part of the training courses can be conducted, this report will be completed and finalized.

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ABBREVIATIONS

KWB	Kompetenzzentrum Wasser Berlin (engl.: Competence Center Water Berlin)
RMCS	real-time monitoring and control system
TUD	Technical University Dresden
UCY	Univeristy of Cyrus
QMRA	Quantitative microbial risk assessment
WDD	Water Development Department
CBA	Costs-benefits analysis

1. INTRODUCTION

1.1 AIM OF THE TRAINING COURSE

The training provides management and technical operators with an introduction to the use of the innovative SMART-Control instruments. Furthermore, new technical possibilities and possible operational improvements of a concrete MAR system are elaborated. The training programme is characterized by close cooperation between developers and users. The training conclud-ed with a replication workshop with the management level to initiate replication activities within the SMART-Control project (WP 7).

1.2 ABOUT THE SMART-CONTROL PROJECT

Managed aquifer recharge is a nature-based, worldwide successful process for sustainable water resource management. By storing temporarily excess water in geologically suitable subsoils, groundwater-dependent ecosystem services can be restored such as the production of fresh water, prevention of saltwater intrusions and improvement of water quality. This contributes significantly to increasing the security of water supply. However, the lack of detailed and real-time data continues to hinder reliable monitoring as well as forecasting and avoidance of risks in aquifer recharge processes.

SMART-Control aims at reducing these risks in the application of sustainable groundwater management techniques, by the development of an innovative web-based, real-time monitoring and control system (RMCS) in combination with risk assessment and management tools. At pilot sites in-situ-real-time monitoring systems consisting of state-of-the-art online sensors are installed and new web-based tools for control, modelling and prediction are developed. Following key risks in water reuse applications will be considered against quantifiable performance indicators (PI):

- public health (PI: microbial concentration in water reuse below 10^{-6} µDALYs per person per year)
- environmental risks (PI: spatial and temporal extent of infiltration bubble by water quality parameters e.g. nitrogen concentration, salinity)
- clogging management (PI: maintenance intervals)
- recovery efficiency (PI: recovery of water with defined quality in %)
- residence time (PI: subsurface residence time in days from estimation-based approach with unknown uncertainties to real-time assessment with quantifiable uncertainties).

The approach will be tested at a total of six pilot sites in Brazil, Cyprus, France and Germany under different environmental and operating conditions to reach a wide range of objectives: increase water availability in urban areas, prevent saltwater intrusion in coastal aquifers and mitigate extreme climatic events. Reducing the risks associated with MAR facilities increase their manageability and controllability. This will lead in a broader sense to the promotion of social acceptance of water reuse technologies and demonstrates the feasibility of MAR as climate change adaptation measures.

2. TRAINING PREPARATION

2.1 TRAINING NEEDS ASSESSMENT QUESTIONNAIRE

2.1.1 Aim of the Needs Assessment

To best tailor the SMART-Control Training to the needs of the participants, adelphi in cooperation with the tool developers (TUD and KWB) conducted a needs assessment in the form of an online questionnaire using the tool Lime Survey (https://www.limesurvey.org). The resulting priorities of the participants in terms of learning

objectives and the stated experience levels and existing knowledge of the participants were incorporated into the design of the training modules.

2.1.2 Structure of the Needs Assessment

The needs assessment comprised two main questions that asked about learning priorities and the existing experience and knowledge of the participants regarding SMART-Control topics. Five SMART-Control topics were in the foreground: groundwater modelling, real-time monitoring of MAR systems, groundwater model-based predictions, microbial risk assessment, and cost benefit analysis for MAR systems. All these five topics are addressed by SMART-Control tools, except for the CBA analysis, which, however, is also an important product of the SMART-Control project. The participants could give a score of 0-3.

A: Learning priority: Which of the following topics in the field of improved MAR management do you want to learn more about or are most relevant for your work? **Rating:**		**B: Experience/knowledge: What experiences and knowledge do you already have?** **Rating:**	
0 = No interest, or not applicable for my organisation	2 = Yes, some interest	0 = Have not yet heard of the topic, would need introduction from scratch	2 = Basic experience in dealing with the topics, but not specifically with the mentioned tools
1 = Little interest, not very relevant for my organisation	3 = Yes, very much interested in learning about this topic	1 = I'm familiar with the mentioned terms, but have not yet dealt with them professionally	3 = I'm regularly dealing with these topics in my day to day work and use the mentioned tools

	A: What is your learning priority?				B: What is your existing experience/knowledge?				
	0 - no interest	1	2	3 - very much interested	0 - not yet heard of	1	2	3 - well known	No answer
Development of an groundwater model and application of groundwater softwares (e.g. MODFLOW, FEFLOW, HYDRUS)	○	○	○	○	○	○	○	○	●
Real-time monitoring with online sensors and visualization/interpretation of the results	○	○	○	○	○	○	○	○	●
Groundwater model-based predictions and running of different scenarios	○	○	○	○	○	○	○	○	●
Microbial risk assessment (QMRA) and application of QMRA tools	○	○	○	○	○	○	○	○	●
Cost-Benefit-Analysis for managed aquifer recharge systems	○	○	○	○	○	○	○	○	●

Figure 1. Online questionnaire for assessing the needs of key stakeholders of the pilot site in Cyprus

2.1.3 Results

In the online questionnaire, 15 participants took part from different institutions, such as Water Development Department of Cyprus (WDD), Cyprus Geological Survey, Water Board of Larnaca, Union of Cypriot Farmers, Cyprus University of Technology and the University of Cyprus (NIREAS International Water Research Center). The Needs Assessment revealed a generally high level of interest in the SMART-Control Tools with the following ranking shown in Figure 2 ranging between 2 (some interest) and 3 (very much interested in learning about this topic). The experience of the participants varies between 1 (participants are familiar with the terms mentioned but have not yet dealt with them professionally) and 2 (basic experience in dealing with the topics) for all topics.

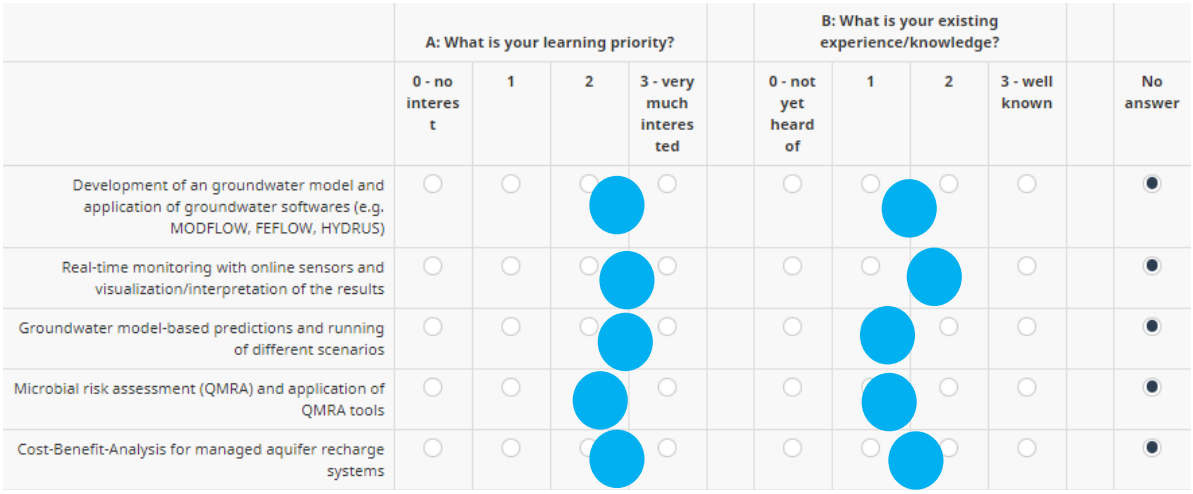


Figure 2. Results of the needs assessment questionnaire

2.1.4 Conclusion

The participants' responses indicate that there is a basic understanding of the SMART-Control tool topics. Thus, the basic terminology can be used without much explanation. On the other hand, there are only a few, who deal with the topics professionally. Most of the interviewees do not deal with the topics on a daily basis. In order to address this, adelphi designed the training course more comprehensive in terms of content in order to cover all needs.

2.2 TRAINING SCHEDULE

Based on the results of the needs assessment and the time availability of the participants, a training schedule was developed. In addition, the planning and implementation of the training was affected by pandemic-related restrictions on travel abroad and larger meetings in Cyprus. As a result, the first training (in Cyprus) could only take place in an online format instead of an originally planned physical format. For a successful delivery of the training with maximum impact, it was important to consider this format shift also in the planning of the training structure and concept. To ensure maximum attention span of the training participants, the training was divided into 4 thematic modules. In addition, care was taken to ensure that at least one representative from the key organizations takes part, so that knowledge can be passed within the organizations. Table 1 shows the resulting training schedule:

Table 1. Training schedule

Time	Mon	Tue	Wed	Thu	Fri
11:00-13:00	**Public Workshop**	**Training I:** Setup of an groundwater model	**Training II:** Real-time monitoring with online sensors and visualization/interpretation of the results	**Training IV:** Groundwater model-based predictions and running of different scenarios assessment of requirement for tool development	**Replication meeting**
15:00-17:00			**Training III:** Microbial risk assessment (QMRA) and application of QMRA tools AND Heat transfer tool		

3. DETAILED TRAINING PROGRAMME

3.1 DAY 1, MON 23 NOV (11:00-13:00) – PUBLIC ONLINE WORKSHOP

Targeted participants: all interested stakeholders are welcome

- NIREAS International Water Research Center
- Water Development Department (WDD)
- Geological Survey Department
- Cyprus Institute (The Energy, Environment and Water Research Center (EEWRC))
- Limassol/Lemesos Water Board
- Paphos Water Board
- Larnaca Water Board
- ERATOSTHENES Centre of Excellence (ECoE)
- Agricultural organisations

Table 2. Training programme - public workshop

Time	Programme	Objectives	Content	Materials and methods	Resource Person
10:45	*Tuning in and introduction*	Everyone introduces by answering a few questions	What is your name and for which orgnaisation are you here? Please answer with: Name, Organisation	Mentimeter	Moderator: Anika Conrad (adelphi)
11:00	Official welcome	Welcome and introduce the speakers of todays session	Welcome and introduction to the programme	Free speech	Speaker: Panos Papanastasiou (UCY)
11:10	Introduction to SMART-Control project	Overall objective: present the SMART-Control approach to a wider audience with a practical example from the local case study (Ezousa)	• SMART-Control project • Web-based platform, its application potential and benefits	PPT	Speaker: Catalin Stefan (TUD)
11:20	Introduction to the Ezousa site		General information on the site-specific MAR scheme and its associated risks	PPT	Speaker: Maria Axilleos (WDD)
11:30	Introduction to SMART-Control tools	The participants have an overview of the possibilities of the web-based platform, they can better assess whether they are interested in participating in the Technical Workshop (day 3-4)	• Tool 1. Initial risk assessment • Tool 2. Real-time monitoring • Tool 3. Real-time model update and simulation • Tool 4. Model-based predictions	PPT	Speaker: Catalin Stefan (TUD)

Time	Programme	Objectives	Content	Materials and methods	Resource Person
11:50	**Risk assessment**	Presenting current results of SMART-Control	Risks assessed for the Cyprus site and other project locations based on the KWB Project report	PPT	Speaker: Ronjon Heim (adelphi)
12:00	**Groundwater model developed for Ezousas**	Focus: presenting current results, only briefly the development	Information Basis, concept and scope of the developed GW model	PPT	Speaker: Konstantinos Panagiotou (UCY)
12:15	**Upcoming stakeholder interaction in Cyprus**	The participants have an overview of the upcoming project activities in which they could be involved	● Needs Assessment ● Training ● Replication identification ● Project development	PPT	Speaker: Ronjon Heim (adelphi)
12:35	**Q & A**	The participants find answers to their questions, but also the SMART-Control project team gets to know potential stakeholders better by asking questions on e.g. ● Experiences with MAR? ● Which risks they find most critical? ● Etc.	Questions, Comments and Suggestions to the presentation and upcoming programme of the next days		Moderator: Anika Conrad and Ronjon Heim (adelphi)

3.2 DAYS 2-4 – TECHNICAL ONLINE TRAININGS

Participants:

Introduction (Day 2 11:00-11:30) and final discussion round (Day 4 12:30-13:00) for technical and management level:

- Respresentatives of Water Development Department (WDD) and WDD Ezousa

All other timings only of interest for technical level:

Technical operators of the SMART-Control pilot site at Ezousa:

- Technical personnel from WDD
  (2 new technicians at SMART-Control pilot site Ezousa)

Other technical operators:

- from Akrotiri site

Stakeholders with technical knowhow from potential replication sites:

- Kiti region, Germasogeia region

Others possibly interested:

- Further representatives from Water Development Department

- Representatives from NIREAS International Water Research Center

Table 3. Training programme – technical online trainings

Time	Programme	Objectives	Content	Materials and methods	Resource Person
Day 2, Tue 24 Nov (11:00-13:00) - Interactive training on Tool 3. Developing of a GW Model with the INOWAS platform					
10:45	*Tuning in*		What are the risks you see when operating MAR in Cyprus?	Mentimeter	Moderator: Anika Conrad (adelphi)
11:00	**Introduction to and overview presentation of the training agenda and its scope**	Inform on the overall objectives of the three training days: (for management level)	Introduction to the training contents and the scope of knowledge achieved with the training	PPT	Speaker: Ronjon Heim (adelphi)
11:10	**Introduction to INOWAS modelling platform**	Participants see how to navigate through the platform	• Software architecture • Introduction to the user interface	Live platform presentation	Speaker: Catalin Stefan (TUD)
11:30	**Presentation on setup of the Ezousas GW model**	Participants know how to upload/create a GW model on the SMART-Control platform and how the model can be automatically updated with the extracted sensor data	• Introduction to the setup of the Ezousas Groundwater Model, its functionality directly on the online tool	Live tool presentation	Speaker: Konstantinos Panagiotou (UCY)
12:15	**Interactive session on using the platform**	Participants will receive access to the INOWAS platform Participants learn how to basically navigate on the platform • Participants will actively: 1. login to the platform, 2. copy model into their dashboard, 3. making changes, 4. run the calculation, 5. report on something and 6. read the results	• Registration to the platform (all participants will get a password and user name) • Participants will create a clone of the Cyprus model and get familiar with the platform	Live tool training Every participant uses their own computer, TUD will provide every participant with an account	Trainer: Catalin Stefan (TUD)
12:45	**Discussion and Feedback round**				Moderator: Ronjon Heim (adelphi)

Time	Programme	Objectives	Content	Materials and methods	Resource Person
Day 3, Wed 25 Nov (11:00-13:00) - Real-time monitoring with online sensors					
10:45	*Tuning in*		What parameters should be monitored online when operating a MAR system?	Menitmeter	Moderator: Anika Conrad (adelphi)
11:00	**Presentation on real-time monitoring**	Objective: Participants know how to prepare data for data monitoring, chemical analysis, modeling	Introduction on connecting data sets and sensors to the platform, sensor data processing and data visualization	Live tool presentation	Trainer: Catalin Stefan (TUD) Support: adelphi (available for individual support for technical and content related questions)
11:45	**Interactive training on Real-time monitoring**	Participants know how to upload real-time data to the monitoring tool, to assign data to real sites and how to visualize the results.	Participants work directly on the Monitoring tool using a real case site for assessing various sources of data including real sensor data	Every participant uses their own computer Data sets are prepared and sensor connection are prepared	Trainer: Catalin Stefan (TUD) and Konstantinos Panagiotou (UCY) Support: adelphi (available for individual support for technical and content related questions)
12:45	**Discussion and Feedback round**				Moderator: respective trainer
Day 3, Wed 25 Nov (15:00-17:00) - Microbial risk assessment (QMRA) and application of QMRA tools and heat transport tool					
14:45	*Tuning in*		What kind of water quality related problems do you see for MAR operation in Cyprus?	Mentimeter	Moderator: Anika Conrad (adelphi)
15:00	**Presentation on Microbial risk assessment**	Participants see how to assess the microbial risks of a MAR system with the SMART-Control approach	Introduction to QMRA and best practices and studies. Usage of the QMRA tool: What data is	PPT	Speaker: Christoph Sprenger (KWB)

Time	Programme	Objectives	Content	Materials and methods	Resource Person
			requirement, what can be adjusted and what results do we receive		
15:20	**Presentation of the Ezousa case result of the QMRA tool**	Participants apply the SMART-Control microbial risk assessment approach of an MAR example	Presentation of Ezousa Case results of the QMRA tool	PPT	Speaker: Kostas Panagiotou (UCY)
15:3	**Presentation on the heat transport tool**	Participants get to know the usage of environmental tracer (temperature) for residence time estimation	Introduction on heat transport tool and its usage Linkage to QMRA and residence time Presentation of application example	PPT	Speaker: Christoph Sprenger (KWB)
16:10	**Interactive training on the heat transport tool**	Participants use the HRT tool	Hand On Training on the HRT tool: Make use of existing data sets, participants will upload the dataset into the platform and perform residence time calculation while adapting the calculation parameters	Datasets are prepared Every participant uses their own computer	Trainer: Ronjon Heim (adelphi)
16:40	**Discussion and Feedback round**	• Do you see application opportunities of the tools: QMRA, HRT Yes/no • Where do you think could you apply the QMRA tool • Where could you apply the HRT tool? • What kind of risks do you see addressed with the tools • A) QMRA • B) HRT How do you rate the user friendliness of the HRT tool? 1-10?	Application options and useability of the tools	Open discussion	Moderator: Anika Conrad (adelphi)

Time	Programme	Objectives	Content	Materials and methods	Resource Person
		Do you have any suggestions for improvements?			
Day 4, Thu 26 Nov (11:00-13:00) - Groundwater model-based predictions and running of different scenarios					
10:45	*Tuning in*		What challenges do you think do MAR systems have to face in future in Cyprus?		Moderator: Anika Conrad (adelphi)
11:00	**Presentation on Model-based predictions**: ● Short introduction	Participants know how to run different scenarios on the SMART-Control platform.	How to change boundary conditions of the GW model, e.g.: ● Societal changes: Infiltration and extraction rate, add new wells ● Climatic changes: rain fall, GW level, sea level, Temperature ● Sensitivity analysis of the above parameters	Overview PPT slide of possible scenarious translated into GW model changes	Speaker: Anika Conrad (adelphi) Support: TUD team, UCY (available for individual support for technical and content related questions)
11:15	**Interactive training on Model-based predictions**:	Elaboration of two different scenarious on the platform	Participants work directly on the uploaded model and make changes to the boundary conditions and other input data Groupwork in two groups: one on climate change (geohydological changes) One on societal changes (urban development)	Group work in two breakoutsessions on own computers with live tool presentation	Trainer: Anika Conrad (adelphi + Konstatinos Panagiotou (UCY) (Societal Change) and Ronjon Heim (adelphi) + Catalin Stefan (TUD) (Climate Change) Support: TUD team, UCY (available for individual support for technical and content

Time	Programme	Objectives	Content	Materials and methods	Resource Person
					related questions)
12:00	**Other possible scenarios which could be of interest**	Which impacts of societal change do you see as relevant for operating MAR? (e.g. availability of treated waste water for infiltration, demand of water quantity and quality for agriculture,) Which impacts of climate change do you see as relevant for operating MAR? (changing rainfall pattern,	Assessment of possible future scenarios and their implementation on the tool	Open discussion with guiding questions on objectives column	Moderator: Ronjon Heim (adelphi)
12:30	**Discussion and Feedback round**	Feedback questions: What additional features on the platform do you need? Are there specific parameters not addressed yet by the real time monitoring tool you want to monitor? Further feedback	General feedback on the tools and requirement for further tool development	Continuation of Miro Board with questions in the objective column	Moderator: Anika Conrad (adelphi)

3.3 DAY 5, FRI 27 NOV 11:00-13:00 – VIRTUAL MEETING WITH SITE-SPECIFIC KEY STAKEHOLDER

Targeted stakeholders (key institutions of potential replication sites):

- NIREAS
- ECoE
- WDD
- Water board of region

Table 4. Training programme – replication meeting

Time	Programme	Objectives	Content	Materials and methods	Resource Person
11:00			Main benefits of SMART-Control for MAR sites		Speaker: Catalin Stefan (TUD)

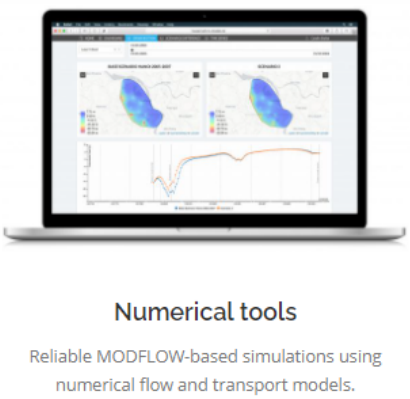
Time	Programme	Objectives	Content	Materials and methods	Resource Person
11:10	Open discussion on the replication potential at Akrotiri region with key stakeholders	• (pre)explore the application potential of SMART-Control concept at other sites (= opportunities for further projects) • Strengthening of network with core stakeholders • Elaboration of replication workshop programme Guiding questions: • What are the risks to be mitigated at the site? • Which kind of sensors are of interest? • What questions should the modelling answer? • Which scenarios are to be assessed?	Explore application potential for the site, discuss site characteristics and risks and benefits for using the SMART-Control approach. Define the way forward for developing the technology transfer	Pre-assessment of potential replication sites Miro Template for fact sheet that will be filled with the key stakeholders to capture all the information for the preparation of the technology transfer concept on the miro platform accessible to all participants (adelphi) Every participant should use their own computer for accessing miro	Moderator: Anika Conrad, Ronjon Heim (adelphi) Support: Jana Glass, Catalin Stefan (TUD), Kanstantinos Panagiotou (UCY)
12:10	Open discussion on the replication potential at Germosia region with key stakeholders				
12:50	Closing speech				Speaker: Kanstantinos Panagiotou (UCY)

4. SUMMARY OF THE TRAINING IMPRESSIONS AND RESULTS

4.1 OUTCOMES OF TRAINING ACTIVITIES

The training course with interactive discussions brought together actors from different Cypriot institutions from science and practice. Among them were the Water Development Department of Cyprus, Cyprus Geological Survey, Water Board of Larnaca, Union of Cypriot Farmers, Cyprus University of Technology and the University of Cyprus (NIREAS International Water Research Center). The training courses provided both management and technical operators with an introduction to the use of selected innovative SMART-Control instruments. The focus laid on improved real-time data management to reduce risks associated with Managed Aquifer Recharge systems (MAR). Among the presented tools were:

- connecting real-time sensors with the INOWAS platform to upload, process and visualize data for real-time monitoring of MAR systems -> Link to Tool 10,
- using temperature measurements as an easy alert system for microbial risks assessment -> Link to Tool 19,
- assessing microbial risks associated with MAR systems -> Tool will be rolled out on the platform soon,
- setting up and revising a new numerical groundwater flow model -> Link to Tool 3 and
- analyzing and comparing user-defined model scenarios with each other -> Link to Tool 7.



In discussion rounds, the training participants discussed current water issues of the island such as saltwater intrusion into the groundwater. A possible application of the heat transport tool (HRT) in Cyprus was also of interest, which uses temperature measurements to calculate the residence time of the recharged water in the subsurface. Due to different soil characteristics and climatic conditions, an adaptation of the German 50-days rule would be necessary to make use of the HRT tool. Correctly calibrated, the tool offers a cost-effective and fast method for monitoring microbial risks of MAR systems.

The participation of various institutions from Cyprus made it possible to examine the applicability of the SMART-Control tools for different needs. Thanks to various comments and suggestions, the team is able to further improve the online platform in the last remaining year of the SMART-Control project.

The training course concluded with a replication workshop. Together with representatives of the Water Development Department of Cyprus, Cyprus Geological Survey, Water Board of Larnaca, Union of Cypriot Farmers, Cyprus University of Technology and the University of Cyprus (NIREAS International Water Research Center), two replication sites in Cyprus could be identified at which an application of the SMART-Control approach for improved water management seems promising: Akrotiri site and Germasogeia site. With the help of MIRO, a tool to support online collaboration in teams, factsheets were jointly filled for both sides. By doing so, the participants focused on the identification of local risks of the current water management systems, risk reduction as well as identification of the beneficiaries of applying the SMART-Control approach. The MIRO Board is still accessible to the public for additions and changes: Link to the factsheets on MIRO. Based on the information gathered, the SMART-Control team will develop a transfer concept that investigates and identifies potential future activities and opportunities at the two sites. This concept will be presented and potential implementation will be discussed with key stakeholders at replication workshops in Cyprus in the second half of the project (towards the end of 2021).

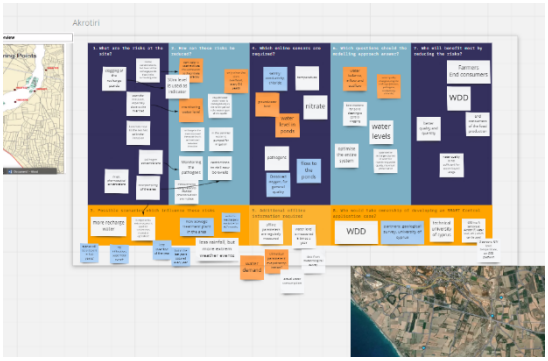


Figure 3. Screenshot of MIRO Board showing collected information during replication meeting

4.2 INFORMATION COLLECTED DURING MEETING ON THE POTENTIAL REPLICATION SITE: AKROTIRI REGION

4.2.1 MAR system

At the Akrotiri MAR system, the Water Development Department (WDD) infiltrates tertiary treated water from the Limassol Amathus Wastewater Association into the Akrotiri aquifer in winter via artificial ponds along the riverbed (see Figure 4) and recovers the same mixed with groundwater via wells in summer at times of higher demand for irrigation needs. For this purpose, 17 recharge ponds have been constructed along the Kouris Riverbed, covering a total area of 56,000 m^2 (Achilleos et al. 2019). The volumes of water recharged into the Akrotiri aquifer were 847,340 m^3 in 2016 and 1,566,520 m^3 in 2017.

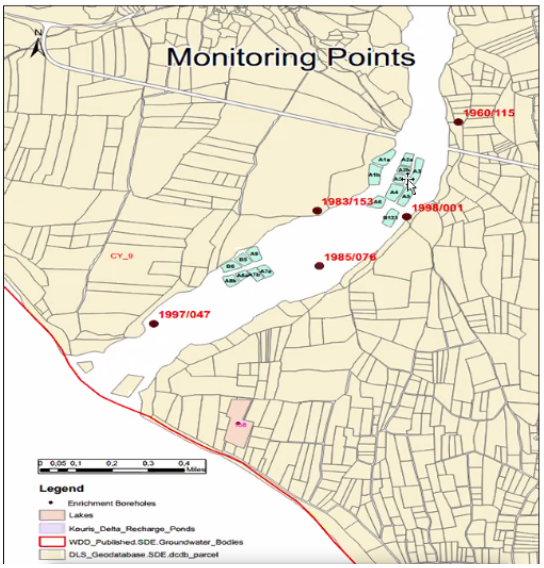


Figure 4. Akrotiri MAR system overview

4.2.2 Local water-related risks given by key actors

The MAR system at the Akrotiri site is operating in a fragile area. Due to high agriculture activity in the area, the aquifer suffers from high nitrate concentrations. Overexploitation of the groundwater resources promotes seawater intrusion. Some wells near the coast had to be closed due to their water level being below the sealevel leading to salinization. This process is believed to increase in the furture. The use of treated wastewater carries the risk of increased concentrations of pathogens and pharmaceuticals in the infiltrated water. Likewise, clogging of the recharge ponds is a constant risk that the WDD is striving to better monitor.

4.2.3 Measures in place to reduce the risks

The WDD has already enacted several measures to prevent the risks associated with MAR and to counteract high pollution concentrations in the aquifer. Restriction of drilling new wells should regulate overpumping and allow water levels to slowly recover. The installation of a MAR system could already decrease the water levels and thus reduce seawater intrusion. To minimize the risks from wastewater seapage, water from a nearby dam is used to dilute the infiltrate. Moreover, an offline monitoring system controls the safety of the MAR plant and the reclaimed water for irrigation purposes. Several parameters are measured, however, only at long intervals. A plan for the purification of the infiltration pond beds addresses the risk of clogging.

4.2.4 Possible future scenarios that influence risks and MAR system

With regard to increasing water consumption, a new wastewater treatment plant is planned in the area providing more wastewater to operate a MAR system. It is expected that water-intensive agriculture will increasingly relocate from the area, giving space to less water-consuming new settlements. In addition, recent years in Cyprus have shown a decrease in rainfall towards more extreme weather events. Heavy rain events have the disadvantage of allowing less water to infiltrate naturally into the aquifer, resulting in more surface runoff lost to the sea. MAR provides one solution to counteract this process.

4.2.5 Existing monitoring system

The operation of the MAR system at Akrotiri is regularly monitored through offline, laboratory-based measurements by WDD. However, these measurements are too time-consuming and the intervals too long, serving more for research purposes than as an alert system to minimize risks. Water levels are measured 6 times per year. Quality parameters are measured 4 times per year at 6 sites in the recharge period (October-April) covering a wide measurement range of heavy metals, pesticides, pharmaceuticals, etc. (Achilleos et al. 2019). Metereological data are provided by the Cyprus Meterological Survey.

4.2.6 Potential online sensors for an improved monitoring system

The participants of the replication workshop discussed a possible scope of a RMCS system installed at the Akrotiri site. With regard to the previously identified and analyzed risks, the following objectives and questions were identified, which a model-based approach including online sensors for an improved monitoring for risk reduction should pursue:

- to monitor seawater intrusion (online sensors: electrical conductivity and groundwater levels);
- to monitor changes in water quality during recharge and recovery (online sensors: nitrate, pathogens, dissolved oxygen);
- as an easy alert system for microbial risk assessment during MAR operation, the SMART-Control team developed a HRT tool that calculates the residence time of infiltrated water in the subsurface based on temperature measurements (online sensors: temperature);
- to monitor clogging and optimise clogging management of the infiltration ponds (online sensors: water level and water quality (see previous point 3);
- to optimise recovery efficiency of the MAR system while maintaining good water quality of the recovered water (online sensors: water balance of the system (water levels and water flow), water quality sensors).

4.2.7 Beneficiaries and potential pilot owner

The WDD is responsible for the water resource management on the island, operates the MAR facility and thus would be responsible for installing and implementing a comprehensive monitoring program. However, they could very well imagine following a co-creation and citizen science approach. Possible partners would be Cyprus Geological Survey Department, University of Cyprus, Technical University of Cyprus and enduser of the recovered water such as farmer organisations. In addition, views and needs of other beneficiaries affected by an optimized MAR system such as end consumers of the food production should be included in certain decision-making processes.

5. REFERENCES

Achilleos, M.; Tzoraki, O.; Antunes, M.H.R. (2019). Monitoing of the managed aquifer recharge (MAR) system by treated wastewater reuse in Akrotiri Limassol Cyprus. Conference proceedings: ISMAR 10: International Symposium on Managed Aquifer Recharge. DOI: 10.13140/RG.2.2.26201.16486