

TOWARDS CLEAN GROUNDWATER: FROM STRATEGY TO ACTION

Management Strategy on groundwater
contamination in Functional Urban Areas of
Central Europe D.T3.3.7

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1. Scope of this handbook

The strategy presented below is the result of an international team within the framework of AMIIGA project. AMIIGA “Integrated Approach to Management of Groundwater quality in functional urban areas” was funded by the EU Interreg Central Europe program from 2016 to 2019 and included 12 European partners. During this project groundwater management plans were established for seven pilot sites, hereby considering technical, financial and legal aspects.

Groundwater contamination is a problem of general concern throughout Europe, as many urban areas were severely polluted by industrial processes in the past. Finding strategies for mitigation and remediation is one of the major challenges today.

Although this should be a matter of general acceptance, responsibilities for groundwater protection are not always clear, especially if several administrative units are affected and if there is no direct visible threat. Here groundwater Management plans can be powerful tools (Vasin et al., 2016).

A groundwater Management plan is a strategic instrument that

- × Defines the problem and indicates upcoming risks following an extensive evaluation of the current situation
- × Defines and approves appropriate measures to solve the problems and manage upcoming risks
- × Defines targets, responsibilities and ways of operation
- × Provides a detailed list with steps of action, time schedule and ways of financing.

Please note that groundwater Management plans established by public administrations do not diminish the responsibility of polluters to pay for implemented measures.

This Guidance shall assist you in the process of setting up, establishing and implementing a groundwater Management plan. This process may last several years, depending on the complexity of the problem, the need for further investigations, administrative issues, level of knowledge, etc. Its structure follows some central questions, which automatically come up during the procedure:

1. Why establish a management plan?
2. What are legal requirements to be considered?
3. Contents and structure of a Management plan
4. Which steps should be followed for the process of development?
5. Who should be included? The instrument of Regional Implementation Groups
6. Prototypes for realization - examples from AMIIGA

A Good Practice Report providing a summary of experiences from seven AMIIGA pilots is included in Annex 1.



2. Why establish a Management plan?

Establishing a Management plan makes sense when there is no clear evidence that a single source is responsible. Then there is a need to enforce attention, to bundle interests and to structure required measures in order to solve a groundwater contamination problem threatening public health and the environment. This may be especially the case in one of the following situations:

- × The contamination goes beyond administrative and/or private borders, which means that several parties are affected like different municipalities, industrial areas, etc., therefore several administrative institutions and levels and maybe private stakeholders have to be involved (if allowed by the local laws)
- × A clear comprehensive picture about (hydro-) geology as well as nature and spreading of the groundwater contamination in the affected area is not available, due to lack of knowledge, complex hydrogeologic conditions, difficulty of investigation in urban areas, unknown sources of contamination etc.
- × There are different potential sources of contamination affecting water intakes; their respective quantitative contribution is not known and responsibilities are not clear
- × Sources for financial funding to solve or mitigate the contamination problem are not readily available.

3. Legal requirements to be considered

The necessity of measures defined in a Management plan has to be justified on base of the relevant legislative framework. European as well as national and/or regional legislation has to be considered. The Good Practice Report (Annex 1) describes the specific legal requirements in each of the seven pilots, differing from country to country. This Chapter provides an overview about relevant European legislation.

3.1. Water Framework Directive (WFD, 2000/60/EC) and Groundwater Directive (GWD, 2006/118/EC)

Both legislations concur to establish the framework to protect and restore clean water across Europe and ensure its long-term, sustainable use. They require member states to define groundwater bodies within river basin districts, establish groundwater monitoring networks, classify “bodies at risk” and define a program of measures to achieve a “good status” and reverse pollution trends.

The assessment process for these European Directives is carried out at large scale for the defined groundwater bodies according to well established procedures.

However, the scale of groundwater monitoring setup by European legislation is frequently too large and does not take in account local problems and/or the established monitoring system does not consider local pollution sources. Therefore the possibilities to handle groundwater contamination on local/regional scale based on European acts are restricted. If there is no direct legal need for action, this frequently results in lacking awareness and unclear responsibilities of local actors.



3.2. Drinking Water Directive (Council Directive 98/83/EC)

This law concerns the quality of water intended for human consumption and applies to drinking water distribution systems. The Directive laid down the essential quality standards at EU level. A total of 48 microbiological, chemical and indicator parameters must be monitored and tested regularly. Member States can include additional requirements, but are not allowed to set lower standards as the level of protection of human health should be the same within the whole European Union.

3.3. Directive 2001/42/EC - Strategic Environmental Assessment Directive (SEA)

The SEA Directive applies to a wide range of public plans and programs (e.g. on land use, transport, energy, waste, agriculture, etc.). The SEA procedure can be summarized as follows: an environmental report is prepared in which the likely significant effects on the environment and the reasonable alternatives of the proposed plan or program are identified. The public and the environmental authorities are informed and consulted on the draft plan or program and the environmental report prepared.

3.4. Management of contaminated sites

Procedures for investigation and remediation of single contaminated sites (point sources) are included in national or regional laws. They differ from country to country and are described in the Good Practice Report, Annex 1.

Their basic concept is derived from methodology of Directive 2004/35/CE on environmental liability with regard to the prevention and remedying of environmental damage, keeping in mind that this directive is valid for groundwater contaminations caused no longer than 30 years ago.

3.5. Gap in legislation

Current practices of environmental management and measures for mitigation of groundwater pollution are often not sufficient. The legal framework in most countries offers mainly two handling scales: the European scale focusing on large scale groundwater bodies and the small local scale, where responsible local authorities regulate the investigation and remediation of single contaminated sites.

However, groundwater contamination is a problem that goes beyond the administrative boundaries of local public authorities. In order to predict groundwater quality trends and developments and to design potentially required remediation measures, contaminant plumes and large scale pollutions up to regional scale have to be identified and described.

Whereas the European handling scale is often too large and does not take in account local/regional problems, the scale of single contaminated sites is usually too small. This requires effective intervention at a medium scale, neglected in existing legislation. This scale is characterized by multiple point sources causing a quasi-diffuse contamination in a wide area.

Therefore handling in AMIIGA pilots focused on Functional Urban Areas (FUAs), defined and delineated by natural conditions of geology and groundwater contamination and representing the



aerial dimension of multiple point sources. Relevant actors and participating institutions within the FUA boundaries were invited to participate in the process.

4. Contents and structure of the Management plan

The Management plan document should contain the following chapters:

Current situation at start of the process

The groundwater flow and contaminant situation should be described and evaluated in a comprehensive conceptual model, by means of maps, cross sections and text descriptions, including:

- × Extension of area to be considered
- × Geology and hydrogeology
- × Available datasets and existing monitoring networks
- × Groundwater contamination: type and range of contaminants, measured concentrations, extension of contamination spreading, affected aquifers, etc.
- × Knowledge about contamination sources
- × Affected receptors like wells or springs
- × Problems to be solved
- × Results of numerical model, if available.

Definition of target values and goals of Management plan

The definition of targets is essential. They should be realistically achievable on the one hand and in line with current legislation and agreed with responsible authorities on the other hand. To find a balance between these requirements is a challenging task.

- **Groundwater quality targets**

Groundwater quality targets are distinct quantitative values (for example contaminant concentrations in mg/l, contaminants loads in g/d, etc.) for specific contaminants to be achieved in specified locations. They can be remediation targets for hotspots and/or plumes, quality targets for receptors (specific wells) or targets for defined monitoring points. In any case, the contaminant and unit to be measured and the location of measurement have to be specified.

Groundwater quality targets in AMIIGA's pilots were defined in different ways. Methods ranged from the straight application of national thresholds to the elaboration of health risk expert assessments.



- **Development targets**

Development targets are strategic targets securing the long term achievement of groundwater quality targets. As cornerstones of the Action plan (see below) they are linked to specific planned measures. They can be defined for specific areas and/or aquifers. Development targets can for example be: “prevention of water quality deterioration”, “improvement of water quality at drinking water intakes” or “protection of deep mineral water aquifer”.

- **Definition of priorities**

If appropriate, priorities can be defined for both kinds of targets, if some targets are more urgent than others. For example, pilot Novy Bydzov defines as its first priority the reduction of public health risks in the area of a former industrial site. The mitigation of groundwater contamination in the remaining quaternary aquifer is of second priority.

Setting the necessary measures - Action plan

When comparing the established targets with the current situation, a need for action results, which may focus on specific areas, pollution sources or receptors. The Action plan defines specific measures required to achieve the defined targets in specified time intervals.

The Action plan provides a clear schedule. A detailed table or list is set up with development targets, associated measures and steps of implementation. Each step/measure is described indicating details like:

- × Location
- × Estimated completion date
- × Possible limitations (legal/organizational or technical)
- × Way or possibilities of financing
- × Who is responsible for implementation?

Examples for Management plan documents may be seen from the English Summaries from seven pilots in Good Practice Report, Annex 1.

5. Steps of Management plan development

In AMIIGA it proved successful to establish milestones (steps) to be achieved in certain time intervals:

1. Framework and background
2. Draft of Management plan
3. Final Management plan

However, this is only a general schedule. The process of management plan establishment is a continuous process lasting several years and accompanied by repeated investigations, evaluations and discussions. While knowledge about the problem increases with project time, some “backward loops” may be necessary to go back to the start and improve the framework and background knowledge.



5.1. Framework and background - first steps

The conceptual understanding of natural conditions and the groundwater contamination is of highest importance. This requires big efforts of data collection, evaluation, ongoing discussions, etc.

Initially the area of relevance should be defined in a precise manner, taking in account that:

- × The extension has to be defined by the core problem, i.e. areas affected by groundwater contamination
- × The boundaries have to be justified from a hydrogeologic point of view, for example, they can be equivalent to the catchment areas of water supplies.

It may be appropriate (as done by some pilots in AMIIGA) to distinguish between

- × Large functional urban areas (FUAs) of regional extension according to hydrogeologic boundaries
- × Smaller local working areas where investigation and remediation measures are performed.

Having defined and delineated your area or FUA, all involved parties and responsible institutions should be identified and invited to join a Regional Implementation Group (RIG), see Chapter 6 for detail information.

In a next step it is necessary to collect and evaluate existing and available data with respect to:

- × Geologic and hydrogeologic conditions
- × Groundwater contamination, nature and spreading
- × Contamination sources, affected receptors, etc.

In AMIIGA a specific questionnaire was prepared (see Annex 2). Filling in the questionnaire shall help to identify and describe remaining knowledge gaps and may define the need for further investigations. It is clearly recommendable to invest some time on answering these questions before entering the further process.

5.2. Framework and background - analysis and characterisation

In course of data collection, it is recommendable to check their quality, indicating an estimate of measurement uncertainties due to different sampling or analytic procedures.

Based on results of data evaluation and investigation results, a conceptual model should be established properly describing the geologic/hydrogeologic conditions and the groundwater contamination by means of text, graphical illustrations and cross sections. If appropriate a numerical model can be established to check plausibility and allow scenario calculations. Possibly conceptual and/or numerical models are already available, which can be used and extended or updated.



5.3. Draft Management plan

Having defined the problem of relevance, the affected area and involved actors, the groundwater quality targets according to legislation should be determined (see Chapter 4). A need for action evolves from the aim to achieve them.

Involved actors like responsible authorities and technical experts have the task to establish realistic milestones and part goals on the long term path of achieving quality targets. They should reflect on feasible measures to improve the situation and mitigate the contamination in the short term as far as possible.

To structure the required measures, development targets have to be established. For example a development target can be the stepwise improvement of groundwater quality in a certain area, even if the achievement of groundwater quality targets seems very far away.

Required measures are defined according to location of relevance and time of realistic implementation. This may indicate the protection of groundwater intakes by emergency measures, but can also mean the large scale monitoring of regional contamination plumes. According to level of urgency, different priorities may be defined.

The Draft Management plan gives a first comprehensive overview about groundwater flow and contaminant situation, established targets and planned measures based on a rough time schedule.

5.4. Detail planning of measures

The Draft Management plan is a working tool serving as a basis for further discussion and detail evaluation between the involved actors. In preparation of the final decisions, established targets and planned measures should be checked for their purpose and necessity once more. Detail discussions may show that there is a need for feasibility studies, evaluation of possible options and/or cost benefit analysis. Possibly additional investigations have to be done to update or complete the conceptual (and possibly numerical) models.

5.5. Final Management plan

This finally leads to an exhaustive document, explaining in detail the current situation, targets and need for action. Agreed with the responsible authorities clear development targets are fixed and a strict schedule of required measures for their fulfillment defined, including location, time of execution, way of financing, etc. (see Chapter 4).

Despite this very detailed character, the plan should remain flexible and offer the possibility to implement future adaptations, for example in case of new findings, investigation and monitoring results. It is recommended to define specific regular time intervals for a check and possible update. It is also recommended to define frequency of supervision and verification/reporting of the Management plan's implementation progress as well as the responsible body for this task.

For example it may be appropriate to modify the design of a monitoring network after having evaluated the results of new findings provided by additional investigations.



6. Regional Implementation Groups

A Regional Implementation Group (RIG) is an instrument for stakeholder and public authorities' engagement. A RIG is a specific panel that contributes to Management plan development and guarantees its proper implementation. It accompanies and supports the whole process and provides specific advice to upcoming questions.

The constitution of invited members can vary according to the specific contents and targets of a workshop. Public authorities within the FUA boundaries should be addressed in any case.

Members should come from:

- × Local public authorities, like municipalities
- × Regional public authorities
- × Public sectoral agencies, like environmental agencies, health authorities
- × National public authorities, like ministries
- × Infrastructure and service providers, like water companies
- × Institutions for higher education and research, like universities
- × Interest groups, like NGOs (non-governmental organizations), land owners, polluters, residents, consultants, individuals with particular expertise (technical or personal)
- × Local industry - large enterprises
- × Local SMEs (small and medium sized enterprises)
- × and other institutions relevant for problem solving, according to national and local specifics.

A properly working RIG can fulfill functions as follows:

- × Technical support by facilitating the process of data collection, providing technical assistance and consultancy, discussing, commenting and confirming the expert basis for decision makers
- × Guidance about needed and acceptable development targets by bundling knowledge about relevant policies and legislation
- × Fostering of the coordination process by bundling interests of stakeholders, determining the possibilities of cooperation and assigning tasks
- × Fostering awareness on a higher administrative level, prepare the basis and propose legally binding decisions
- × Dissemination of knowledge achieving an enforced public awareness for groundwater contamination.

Working in successful RIGs facilitates and fastens the decision and implementation process, raises the general acceptance and enables the access to investigation areas. But to be successful and effective, RIG-meetings (or workshops) need thorough and attentive preparation and organization.

Lessons learned from AMIIGA are:

1. Identify, inform and involve all relevant bodies/institutions from the very beginning. Perform a thorough analysis to identify potential members.



2. Consider to include higher administrative levels of regional/national relevance like for example national ministries.
3. Clarify commitments to select persons participating in the process.
4. Clarify rules for participation from the very beginning, inform about possible roles, and assign tasks.
5. Adapt and increase the frequency of meetings if required.

7. Prototypes for realization - examples from AMIIGA

Within AMIIGA, seven different prototypes of groundwater Management plans were developed. Each of them had its own specific focus arising from frame conditions like geology/hydrogeology, type and scale of contamination, groundwater use, goals/focus, legal framework, responsibilities, level of knowledge, etc. and resulting in clear development targets and strategies of action. Management plans have been proved as appropriate and flexible tools for planning, coordinating and implementing necessary measures.

The following sketches focus on the specific peculiarities of each pilot, which makes them singular.



IMPACT OF “ECOLOGICAL BOMB” ON GROUNDWATER BODY STATUS



The extension of Jaworzno FUA is equivalent to a groundwater body (No. 146) defined according to WFD requirements. A major issue in this area is the ecological bomb Organika Azot - former landfills for hazardous waste from the Chemical Plant "Organika Azot" in Jaworzno, heavily contaminated especially by pesticides. Nevertheless, due to results of the operated national monitoring program, this groundwater body has been assigned a good chemical status.

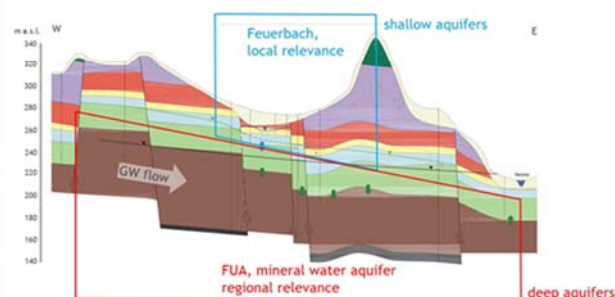
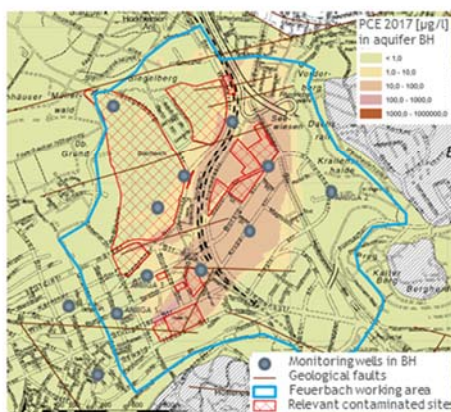
As a result of AMIIGA, the monitoring program will be adapted to take in account this area and other contaminated sites. An official announcement of significant pressure has been prepared to make visible the problem of groundwater body (No. 146) in National Water Management Plan for next planning period 2022-2027.



Pilot Jaworzno



EARLY WARNING SYSTEM FOR PROTECTION OF DEEP MINERAL WATER AQUIFER



A severe CHC contamination in Feuerbach's local shallow aquifers threatens the mineral water aquifer that has regional relevance. The management plan based on conceptual and numerical modelling focuses on a early warning system to prevent depth transfer of contaminants and, at the same time, a reduction of the pollution in the shallow aquifer.



Pilot Feuerbach STUTTGART



TAILORED APPROACHES FOR HOT SPOT AND PLUME REMEDIATION



The MP defines specified measures for distinct areas according to their intensity of contamination. Specific quality targets and priorities of urgency have been defined for each of these areas on base of a risk assessment procedure. For each area a specific method of remediation and/or monitoring has been defined.

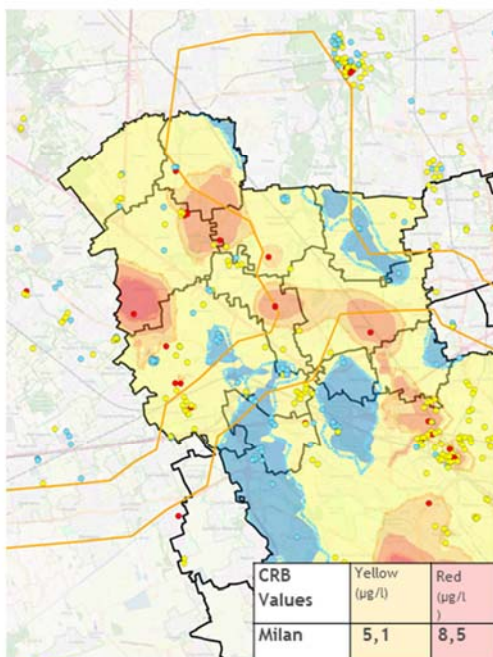
GOAL	Reducing public health risks caused by pollution of the rock environment and groundwater to an acceptable level			Ensuring a good chemical status of the groundwater aquifer in FUA Novy Bydovz
PARTIAL GOAL	To prevent GW pollution from primary source - soil pollution	To prevent GW pollution from primary source - GW pollution	To reduce GW pollution to an acceptable level determined by Risk Assessment	
PRIORITY	1	1	1	2
RECEPTOR	Soil polluted by CHC	GW in source of pollution	GW at cont. site	GW at FUA outside c.s.
TARGET	CHC conc. < 50 mg/kg	TCE conc. < 1400 µg/l PCE conc. < 700 µg/l	TCE conc. < 100 µg/l PCE conc. < 150 µg/l	TCE conc. < 10 µg/l PCE conc. < 10 µg/l
MEASURES	all cont. sites with CHC > 50 mg/kg in KOWOPLAST: remediation at site	all plumes with TCE conc. > 1400 µg/l PCE conc. > 700 µg/l in KOWOPLAST: Pig T, RCO	all plumes with TCE conc. > 100 µg/l PCE conc. > 150 µg/l: ERMG	all plumes with TCE conc. > 10 µg/l PCE conc. > 10 µg/l: NA



Pilot Novy Bydovz



ACTION PLAN FOR PLUMES AND DIFFUSE CONTAMINATION



Milan region is affected by a significant groundwater pollution due to an intense historic industrialization. In some areas a diffuse pollution occurs which cannot be attributed to specific sources.

The National Law in Italy charges regions to regulate this kind of contamination.

Based on requirements of regional law, the Management plan defines specific measures and remediation targets for groundwater contamination due to plumes and diffuse pollution. It assigns roles and duties to the administrations for the management of these areas.

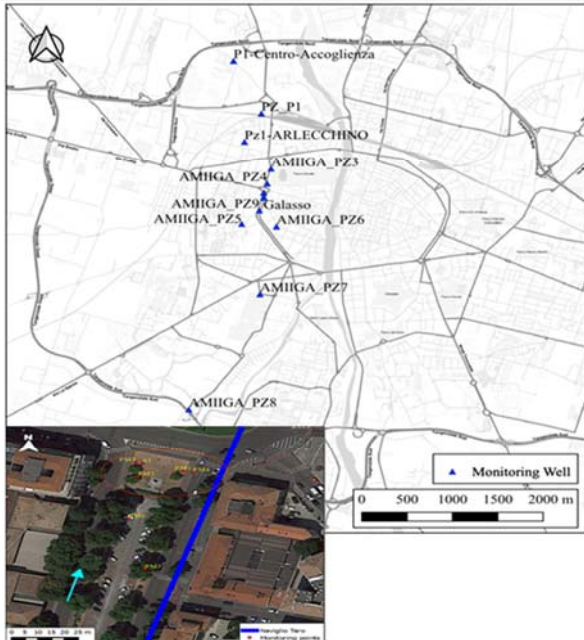


Pilot Milan





RISK ANALYSIS AND MNA



The city of Parma is covered by a diffuse* CHC contamination on comparatively low level. Although there is no specific known pollution source, legal quality targets require action. Priorities will be defined on base of a risk analysis scheduled in the management plan. AMIIGA showed that NA is not possible due to bacterial low concentrations: monitoring the system is a needed long term action.

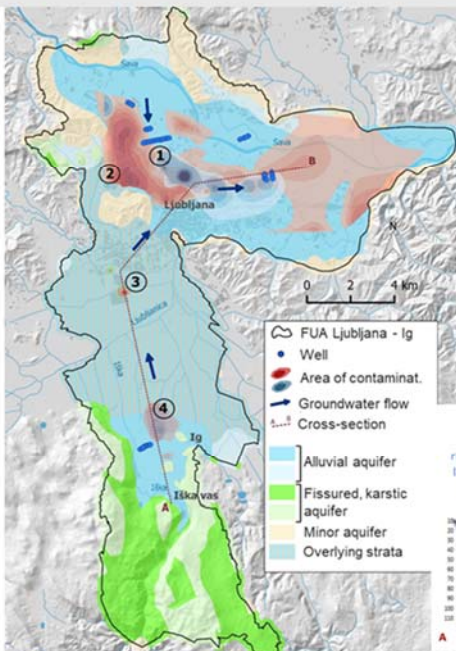
* = not codify with regards to Italian laws



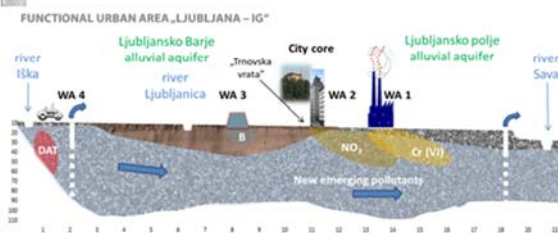
Pilot Parma



FOCUS ON CRITICAL AREAS THREATENING DRINKING WATER SUPPLY



Drinking water supply for the cities of Ljubljana and Ig is threatened by a contamination in four specific delineated areas, each of them different from geological and hydrogeological aspects and characterized by a specific kind of contamination. Based on a risk analysis priorities of action were defined and catalogue of measures established for each area, due to specific contaminant conditions and associated risks.



Pilot Ljubljana





STRATEGIES FOR MANAGEMENT OF WATER INTAKES



Zadar's drinking water supply is threatened mainly by a bacterial contamination due to household sewage. The pilot struggles with a lack of technical data, because there are only few piezometers in a huge area. The focus lies therefore on an improvement of conceptual understanding by planning and initiating further investigations and on a management of groundwater abstractions to avoid harmful influences.



Pilot Zadar



Literature

Vasin, S., Carle, A., Lang, U. and Kirchholtes H.J. (2016): A management plan for Stuttgart. Science of the total environment. 704-712.

Annex 1: Good Practise Report - Summary of gained knowledge and experiences in seven pilot areas (Deliverable D.T3.3.6)

Annex 2: Questionnaire on local experiences on management plans (Deliverable D.T3.3.2)



ANNEX

Annex 1: Good Practise Report - Summary of gained knowledge and experiences in seven pilot areas (Deliverable D.T3.3.6)



GOOD PRACTICE REPORT

Good Practice Report on Groundwater
Management Plan D.T3.3.6

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Summary of gained knowledge and experiences in seven pilot areas

Annex 1 to Management Strategy D.T3.3.7





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Attachment 1: Summaries of management plans in seven AMIIGA pilots



1. Introduction

This document, compiled as an annex to the Management strategy handbook, summarizes the experiences from seven pilot sites. It describes gained knowledge and experiences from regional to municipal scale showing the variety of conditions with their differences and similarities and reflecting on lessons learnt. Fehler! Verweisquelle konnte nicht gefunden werden. gives a first impression about the variety of initial conditions in AMIIGA pilots.

Table 1 Range of initial conditions in AMIIGA project

Pilot Area	Size [ha]	Hydrogeology - kind of aquifer	Contaminants of concern
Bokanjac-Policnik (Zadar)	52.100	karst aquifer	bacterial contamination
Ljubljana	3.750	fractured and porous	nitrate, pesticides
Milan	24.500	porous	chlorinated hydrocarbons
Piazzale Santa Croce (Parma)	25.000	porous	chlorinated hydrocarbons
Novy Bydzov	20.190	porous	chlorinated hydrocarbons
Jaworzno	4.810	fractured and porous	pesticides, heavy metals, organic solvents
Stuttgart-Feuerbach	1.035	fractured and porous	chlorinated hydrocarbons

This report is structured as follows: Chapter 1 provides a short outline of the Management plans from each pilot site. Chapter 2 gives an overview about the relevant legislation in each country. Chapter 3 describes the Regional Implementation Groups with their various constitutions and functions. Chapter 4 and Chapter 5 reflect on achievements, problems and lessons learnt, whereas Chapter 6 provides some final conclusions and recommendations.

2. Outline of Management plans in seven pilot areas

This Chapter gives a short overview about the structure and contents of Management plans in each pilot, describing shortly the initial situation, the established development targets and the major elements of the Action plan. More extensive information is provided by Management plan summaries of the pilots (Attachment 1).

Pilot Jaworzno

Jaworzno FUA struggles with a complex groundwater contamination, arising mainly from “Organika Azot” chemical plant with associated toxic waste landfills, which has been recognized by the Helsinki Commission as one of the most important industrial (chemical) "hot spots" in the Vistula River Basin - dangerous sources of potential contamination for the Baltic Sea basin¹. The most important poisons accumulated in the landfills are pesticides, organic solvents and heavy metals.

¹ A list of significant pollution sites around the Baltic Sea - HELCOM Hot Spots - was established in 1992; <http://www.helcom.fi/Documents/Action%20areas/Industrial%20releases/List%20of%20hot%20spots%20as%20per%20December%202015.pdf>



Due to complex hydrogeological conditions, a clear and actual picture of groundwater contamination is missing and a threatening of the water intakes cannot be excluded.

The aim of the management plan is to setup an extensive common monitoring and control system for protection of water supplies. Development targets are:

- × Protection of groundwater quality in FUA
- × Prevention of contamination migration downstream Organika Azot area
- × Prevention of groundwater quality deterioration at Organika Azot location.

Major elements of the Action plan are:

- × A monitoring concept, dividing between pilot scale, local scale and regional scale
- × A remediation concept for the area Organika Azot.

Pilot Stuttgart-Feuerbach

The city district Feuerbach faces a severe CHC contamination from approximately 140 contaminated sites. Despite running remediation activities since 30 years, target values at some single sites could not be fully achieved with reasonable efforts and budget. Consequently large contaminant plumes developed in public areas with conflicts for water use and lacking responsibilities for remediation and/or mitigation.

The management plan summarizes the results of the integral investigation and the actions required to ensure the good groundwater status and ensure the protection of the deep mineral water aquifer “Upper Muschelkalk”. The Action plan summarizes the required measures that have the following development targets:

1. Reduction of CHC contamination in the local groundwater resources of Feuerbach (Quaternary and Gipskeuper aquifers) by
 - Investigation and remediation of contaminant inputs
 - Continuation of the ongoing remediation measures
 - Integral monitoring of the major aquifer BH
2. Securing good groundwater quality in the Muschelkalk aquifer through an integral monitoring program.
3. Ensuring the implementation of the necessary measures. The results will be summarized and evaluated in reports approximately each 5 years.

Pilot Novy Bydzov

The city of Novy Bydzov faces a severe CHC groundwater contamination arising from the former industrial production in Novy Bydzov. The investigation and evaluation of groundwater pollution has started from 2008 in FUA Novy Bydzov. The plant KOVOPLAST, closed and abandoned in early 90s of 20th century, was evaluated as the major CHC contamination source in Novy Bydzov city center.



The Management plan defines the priorities for dealing with groundwater pollution in the FUA territory in order to meet the requirements for the protection of human health and the environment set by applicable legislation. There are two development targets:

- × Reducing public health risks in the former KOVOPLAST area caused by soil and groundwater pollution to an acceptable level. Meeting this goal is of urgent priority. The Action plan defines remediation measures for soil and groundwater as well as monitoring activities to reduce contaminant concentrations to quality target established by a risk analysis.
- × Ensuring a good chemical status of the quaternary aquifer in FUA Novy Bydzov. This long term target is expected to be fulfilled after termination of corrective measures in the KOVOPLAST area. The Action plan requires the implementation of monitoring activities.

Pilot North West of Milan area

In the last decades Lombardy Region achieved important results to improve soil and groundwater quality of contaminated sites at local scale. However the data provided by polluters, improving the knowledge on the distribution of groundwater contamination, highlighted the possible presence of a second form of contamination, the so named diffuse pollution. This pollution, which cannot be led back to single sources, is one of the main reasons for not reaching water quality objectives according to EU Groundwater Directive in the Milan city area.

Lombardy Region started dealing with diffuse CHC pollution in the metropolitan area of Milan by evaluating available data, delimiting areas of diffuse pollution and defining management measures for these areas. The pilot area (about 12 municipalities included a part of Milan city with 617.773 inhabitants) is densely populated, and especially near the northern border of Milan it is heavily industrialized. Within AMIIGA several plumes originating North-West of Milan were explored, having a significant effect on Milan city. Numeric modelling in combination with statistic methods enabled a comprehensive picture of CHC distribution, distinguishing punctual sources or plumes from diffuse contamination. Concentration ranges representative for diffuse contamination were defined.

The management plan summarizes the results of the investigations and the actions required to protect the public health and increase the awareness of the population on groundwater pollution in Milan north-west pilot area. Development targets are:

- × Protection of the public health: secure good groundwater quality and reach the good ecological status of groundwater by 2027 (2000/60/EC, PTUA).
- × Guarantee the quality of drinking water and the safety of the water uses. Associated measures are regular checks and specific treatments for quality improvement.
- × Manage the groundwater pollution. Associated measures are actions on known plumes and management of diffuse contamination.
- × Prevent further contamination. Associated measures are monitoring activities and evaluation of effectiveness by data evaluation and trend assessment.
- × Increase the awareness of the population to the groundwater contamination. Associated measures are public relations activities website, brochures and specific events.



- × Ensuring the implementation of the necessary measures by a setting up a strict time and action schedule with attribution of responsibilities.

Pilot Parma

In Parma city, a PCE pollution of groundwater was discovered during the remediation of an old petrol station at the beginning of the current century. As a consequence, legal threshold values for PCE are exceeded in a large area. Despite many monitoring campaigns, the contamination source is still unknown. Recent campaigns discovered maximum values in the area of a kindergarten.

The Management plan foresees several activities to control and monitor plumes and mitigate the groundwater contamination. Development targets and required measures are:

- × Long term monitoring of the shallow aquifer. This will be done by continuing the bi-annual sampling campaigns started in AMIIGA; possibly the monitoring network will be extended.
- × Risk analysis for the kindergarten area.
- × Regular update of an existing numerical groundwater model developed by university of Parma with the long term aim to detect contamination sources.

Pilot Ljubljana

The drinking water supply in the larger city area of Ljubljana is threatened by different kinds of pollutants: chromium, nitrate, pesticides, boron and different emerging pollutants. Although the concentrations are mostly moderate and the collected groundwater does not yet require chemical treatment, a careful control of the pumping regime is required to prevent an abstraction of polluted groundwater into the water supply system.

There are four major problem areas (WA) with a need for action, all belonging to one common aquifer system and situated within groundwater protection zones of water supply wells:

- × Working area 1 Stegne - Hrastje: hexavalent chromium (Cr VI) plumes;
- × Working area 2 Dravlje - Moste: nitrate and new emerging pollutants contamination;
- × Working area 3 Barje: boron contamination;
- × Working area 4 Brest: desethyl-atrazine plumes.

For the Management plan, development targets and priorities ranging from 1 to 4 have been established as follows:

1. Brest area: Retain the capacity of 170 l/s for Brest well field in dry periods with the possibility to improve the capacity and securing the achievement of defined groundwater quality targets
2. Stegne - Hrastje area: Retain the full capacity of Hrastje and Kleče well fields for long-term drinking water supply and securing the achievement of defined groundwater quality targets
3. Dravlje - Moste area: Protect Kleče and Hrastje well fields against increasing trends of new emerging pollutants



4. Barje unhazardous municipal landfill: Retain the landfill on present location with possibility of improved functionality of the area. Natural attenuation monitoring.

Pilot Zadar

Zadar extracts its drinking water from the Bokanjac-Poličnik aquifer, a complex and highly sensitive karst aquifer which has not been sufficiently investigated. Results of monitoring from several groundwater wells show a microbiological contamination mainly caused by farming and unsuitable disposal of waste water. A numerical model has been setup and is the starting point for a stepwise conceptual understanding of the groundwater contamination. It helps to decide about drilling location and is the basis for a definition of emergency measures in case of incidents. It will be updated with additional investigation data as soon as available.

Development targets are:

- × Reduce the recognized pollution
- × Prevent polluted groundwater from entering the water supply system.

The Action plan foresees measures as follows:

- × Improvement of groundwater quality control. New laboratory equipment acquired during AMIIGA enables an increase of analytical capabilities to detect potential pollution. In order to further improve the quality control, continuous training of employees is needed.
- × Improvement of GW monitoring concept. Planned measures are drilling and installation of new piezometers with subsequent sampling campaigns. All existing and new piezometers will be equipped with new measuring and signalling devices.
- × Update of database. The QGIS database established during AMIIGA contains up to date known and accessible information about GW in the area of Bokanjac-Policnik aquifer. It is planned to be complemented with all new relevant data about GW in this area.
- × Upgrade of existing numerical model. Data obtained from new observation wells (new piezometers) combined with better quality (new devices) and wider (new sampling location) analysis of GW quality will further improve and upgrade the existing numerical model.
- × Supplementation of defined accident measures. The existing plan of emergency measures will be updated and supplemented by results of the numerical model.

3. Legal framework

This Chapter provides a short overview about the name, topic and contents of laws referred to for setting up the Management plans in each pilot and defining strategic aims (Tables 2 to 8).



Table 2 Legal background for pilot action Jaworzno

Name	Topic	Content of law	National/regional
Polish Water Act, 2017	Water management	Rules, requirements and obligations for water management in Poland. Changes in responsibilities	National
Water Management Plan for Wisla Watershed, 2016	Water management	Assessment of groundwater body status	National
Regulation of Minister of Environment, Dz.U. 2016 poz. 85 (repealed and planned to be replaced by the Regulation of Minister of Maritime Economy and Inland Navigation)	Water management -	Requirements and criteria for the assessment of the chemical status of bodies of groundwater. Indicates thresholds values to determine good status of groundwater bodies.	National
Regulation of Minister of Health, 2017 (Dz. U. 2017 poz. 2294)	Health protection/Drinking water	Requirements and guidelines to guarantee good drinking water quality. Indicates thresholds values for pollutants content in the drinking water to protect the public health	National
Regulation of the Minister of the Environment, 2016 (Dz.U. 2016 poz. 1395)	Soil and earth surface protection	Requirements for permissible levels of risk-producing substance in soil. Provides methodology for the identification of pollution, indicates threshold values for risk substances and pollutants.	National

Table 3 Legal background for pilot action Stuttgart-Feuerbach

Name	Topic	Content of law	National/regional
BBodSchV (Federal Soil Protection and Contaminated Sites Ordinance), 1999	Soil and groundwater protection	Regulation for investigation, evaluation and remediation of contaminated sites and landfills Defines test values as indicators for soil/groundwater contaminations with a need for further investigations Defines thresholds as indicators for a remediation need on base of detail investigations	National
Groundwater Regulation, 2010 / 2017	Groundwater protection	Defines action values for groundwater contamination as indicators for measures to prevent or mitigate contaminant input into groundwater	National, implementation of EU Water Framework Directive



Table 4 Legal background for pilot action Novy Bydzov

Name	Topic	Content of law	National/regional
Health Protection Act No. 258/2000 Coll.	Health protection	Conditions, principles, rules and measurements to protect the public health	National
The Water Act No. 254/2001 Coll.	Water management	Rules, requirements and obligations for water management in Czech Republic	National, implementation of EU Water Framework Directive
Decree No. 6/2003 Coll.	Indoor environment	Sanitary thresholds for indoor air in accommodation facilities	National
Decree No. 5/2011 Coll.	Water management	Delineation and assessment of groundwater bodies, indicates thresholds to determine good status	National, implementation of EU Water Framework Directive
Government Regulation No. 401/2015 Coll.	Surface waters	Requirements for discharge of waste water, gives indicators and thresholds for permissible pollution	National
Methodical guideline of the ministry of environment of the Czech Republic for risk analysis of contaminated areas	Risk analysis	General principles and requirements for risk analysis of contaminated areas	National

Table 5 Legal background for pilot action Milan

Name	Topic	Content of law	National/regional
Dlgs 152/06, 2006	Groundwater protection Remediation of polluted sites	Indicates threshold values for water protection and for polluted sites Indicates exceptions/conditions for diffuse contamination Delegates regions to enact actions when diffuse contamination is recognized	National
D.Lgs 31/2001	Drinking water	Indicates threshold values for drinking water	National
Regional Remediation Program - Lombardy Region, 2014	Groundwater protection	Regional Remediation Program (RRP) for Lombardy Region, defines actions in order to: <ul style="list-style-type: none"> • assess existing contaminant plumes • prepare the Management plan for groundwater diffuse pollution • promote the development of innovative remediation technologies 	Regional
Regional Water Protection Plan 2016 - Lombardy Region	Surface and groundwater protection	Regional Program for Water Protection and Use (2000/60/EC) to ensure ecological status of water (surface and groundwater)	Regional, implementation of EU Water Framework Directive



Table 6 Legal background for pilot action Parma

Name	Topic	Content of law	National/regional
Dlgs 152/06 e smi, 2006	Environmental (groundwater, water, soil, air)protection	Indicates threshold values for water protection and for polluted sites	National
ISPRA - Manuale per le indagini ambientali nei siti contaminati. APAT, Manuali e linee guida 43/2006	Environmental survey	Operating procedures to perform environmental investigations	National
Decreto legislativo 30 giugno 2016, n. 127	Decision rules	Decision rules of the local authorities planning conference (the decision-making conference on the remediation procedure)	National
Decreto legislativo 18 aprile 2016, n. 50 e smi	Procurement of services and public works	Regulates the public procurement to assign remediation works, environmental characterizations, monitoring interventions, development of risk analysis	National
DGR Regione Emilia Romagna n. 1106 dell'11 luglio 2016: istituzione dell'Anagrafe regionale dei Siti da Bonificare	Remediation of contaminated sites	Regione Emilia Romagna's official list for remediation of contaminated sites	Regional

Table 7 Legal background for pilot action Ljubljana

Name	Topic	Content of law	National/regional
Rules on Drinking Water, 2004	Drinking water	Quality standards for drinking water	National
Rules on groundwater status monitoring, 2017	Groundwater monitoring	Guidelines for operational monitoring including natural attenuation control Determination of operational monitoring performance if there is probability for direct or indirect pollutants inflow into ground-water Determination of monitoring performance for monitoring of measures efficiency	National
Decree on groundwater status, 2016	Groundwater protection	Defines quality standards and threshold values Defines use of prevent and limit objectives, definition of critical points to start measures and points of compliance, trends evaluation and specific objectives definition Defines the methodology of groundwater status assessment	National, implementation of EU Water Framework Directive
Decree on Ljubljansko polje aquifer, 2003	Health and groundwater protection	Handling restrictions for the use of plant protection products and volatile chlorinated hydrocarbons	National



Table 8 Legal background for pilot action Zadar

Name	Topic	Content of law	National/regional
Regulation about target values NN 125/2017 from 23.12.2017	Groundwater	Ordinance on compliance parameters, analysis methods, monitoring and water safety plans for human consumption	National
Drinking water law NN 104/2017 from 02.11.2017	Drinking water	<p>Health care of water for human consumption</p> <p>Competent bodies for the implementation of this Act and manner of reporting to the European Commission</p> <p>Obligations of legal entities performing the supply of water for human consumption</p> <p>Methods of treatment and reporting in case of deviation</p> <p>Monitoring and other official controls of the health and safety of water for human consumption and their financing</p>	National

Comprehensive evaluation

Stated regulations are mainly national with the exception of pilot Milan focussing on regional laws or plans. The regulations can be grouped in categories as follows:

- × Water management, national implementation of EU Water Framework Directive
- × Regulations about quality targets, referring to:
 - Groundwater quality (most common)
 - Drinking water quality
 - Surface water quality
 - Indoor air
- × Regulations defining procedures for investigation, remediation and monitoring
- × Guidelines for risk assessment and operational monitoring.

To get an idea about different requirements throughout Europe, the following table shows as an example the different legal quality targets for chlorinated hydrocarbons (CHC) applied within AMIIGA:



Table 9 Legal CHC thresholds applied within AMIIGA

Pilot Area	Component	Threshold Value
Milan and Parma, Italy		
D.Lgs. 152/06 e smi (quality standard)	PCE	1.1 µg/l
D.Lgs. 152/06 e smi (quality standard)	TCE	1.5 µg/l
D.Lgs. 152/06 e smi (quality standard)	TCM	0.15 µg/l
D.Lgs. 31/2001 (drinking water)	Sum of TCE and PCE	10 µg/l
Novy Bydzov, Czech Republic		
Actualized Risk Analysis (2016) - contamination plume	PCE	700 µg/l
Actualized Risk Analysis (2016) – contamination plume	TCE	1400 µg/l
Actualized Risk Analysis (2016) – source of pollution	PCE	150 µg/l
Actualized Risk Analysis (2016) – source of pollution	TCE	100 µg/l
Jaworzno, Poland		
Human Consumption (2017) ²	Sum TCE and PCE	10 µg/l
Groundwater Condition (2015)	PCE (5 Classes)	0,001->0,1 mg/l
	TCE (5 Classes)	0,001->0,1 mg/l
Stuttgart-Feuerbach, Germany		
Groundwater regulation	CHC total	10 µg/l

PCE = Perchloroethylene, TCE = Trichloroethylene, TCM = Trichloromethane

As the table shows, legal thresholds for CHC vary strongly. They are particularly low in Italy and Poland and comparably high in Czech Republic. However, the stated values for Novy Bydzov were developed on base of a case-specific risk analysis and apply only to the source of contamination in KOVOPLAST site and to the contamination plume in the plant's vicinity.

² Regulation of the Minister of Health of 7 December 2017 on the quality of water intended for human consumption (Dz.U. 2017 poz. 2294)



4. RIG coordination process

Table 10 shows the key data of RIG processes from AMIIGA. Among the seven pilots there is a great variety concerning the number and size of meetings as well as the number and kind of participating institutions. Whereas pilots Ljubljana, Milan and Jaworzno had a large organization, the remaining pilots had less institutions involved.

As a general fact, local public authorities (municipalities) play a fundamental role. The contribution of regional public authorities is very often needed. All pilots had universities or private research institutes participating in their RIG. Pilot Novy Bydzov organized specific events for interested citizens living in the affected area to inform about the contamination problem and the measures taken, while Parma involved the local industrial union. However there is no general rule about a recommendable size of meetings or number and kind of institutions to be invited. These factors depend strongly on the specific local conditions.

In general, RIGs were essential to disseminate the information on AMIIGA project idea and results, to evaluate possible solutions and prepare decisions. Their support was essential to define the contamination framework and decide on instruments and procedures to be applied. They commented and confirmed the expert basis for the decision makers and proposed feasible solutions. In some countries legally binding decisions could be achieved. In Novy Bydzov the RIG even had the function of a direct decision making body.

Although not all attending parties were actively involved in the process, the pilots benefitted from knowledge exchange and consultancy. The bundled knowledge about relevant policies and legislation as well as technical issues provided the optimal basis to decide about the feasibility of proposed actions and measures as well as needed and accepted development targets.

By facilitating the cooperation among involved institutions and lifting the issue on a higher administrative level, the RIG-process achieved an increased awareness for local or regional groundwater contamination problems and strengthened handling capacities in FUA scale.

Table 10 Key data of RIG processes in AMIIGA

Pilot	Number of meetings/workshops	Number of persons per meeting [from - to]	Participating Bodies/Institutions, Number of								
			Local public authority	Regional public authority	Sectoral agency	Infrastructure and service provider	Higher education and research	Interest groups including NGOs	National public authority	Large enterprises	SME
Jaworzno	6	31 - 35	7	4	1	1	2	1	-	1	-
S-Feuerbach	6	9 - 29	6	4	-	1	1	1	-	5	6
Novy Bydzov	5	11 - 19	1	2	-	-	1	-	1	-	3
Milan	13	31 - 35	14	5	4	2	4	-	-	-	-
Parma	12	4 - 16	9	1	2	-	2	1	-	-	-
Ljubljana	24	25 - 29	4	-	1	4	4	2	5	-	1
Zadar	3	8 - 9	1	1	-	2	1	-	-	-	-



5. Achievements from AMIIGA

The following Chapter summarizes the experiences collected in seven pilots.

Technical results for local pilots

The pilots fundamentally improved their conceptual understanding of the hydrogeological and contaminant situation. On this basis numerical models could be established or further extended and updated.

Monitoring networks were improved and extended according to updated technical knowledge. The feasibility and efficiency of specific remedial technologies was tested and verified.

Innovation for practise

AMIIGA enabled some pilots to test the application of innovative tools, like for example CSIA and BMT techniques, summarize lessons learnt and provide the basis for targeted future applications, see Deliverable D.T2.8.3.

Transnational cooperation

The established expert panel platform enabled an

- Exchange of knowledge between international partners
- Transfer of technical expertise
- Sharing of experiences
- Mutual recommendations
- Interdependent consultations.

In this way a basis for far-leading and successful technical discussions was provided, which will continue after AMIIGA lifetime.

Awareness rising and institutional cooperation

Public awareness about groundwater pollution issues increased as a result of AMIIGA. Affected municipalities were made aware about the risks of groundwater contamination in their area. The involvement of regional and/or national administrations increased the significance.

The RIG process established a basis for cooperation between different institutions, which had not (always and regularly) been in touch before and are now ready to find specific future solutions for the problem of groundwater pollution. It enabled a constructive dialogue between administrative institutions, involved citizens and stakeholders like the local industry.



6. Problems and obstacles, ways of solution

Based on the experiences from seven pilots, occurred problems and obstacles as well as possible ways of solution are summarized in the following Chapter.

6.1. Lack of knowledge / technical data

General lack of technical data

Some pilots struggle with a general lack of technical knowledge due a lack of available data. For example in pilot Zadar, there are only very few piezometers in a large area, which were investigated a long time ago.

In these cases conceptual and numerical models can be a step on the way to the solution. They present powerful tools to evaluate assumptions and define targeted investigations with the aim to improve the technical knowledge.

Complex and time consuming process of data collection

In some pilots data were available but it caused a lot of efforts to find out who owned the data and how they could be collected. Here again the RIG process was very helpful and enabled a smoother procedure. In some cases regional/national environmental agencies were involved who possessed their own data base and/or facilitated the communication to data owners.

As experience showed, the data collection process is often more time consuming and complex than expected, this should be taken in account for time planning.

6.2. Lacking willingness for participation or inter-institutional cooperation

Many pilots experienced a lacking willingness of involved administrations to cooperate and involve actively in the process. Experience from AMIIGA showed that the motivation of participants can be achieved by

- Informing all parties according to their specific state of knowledge by clear, understandable descriptions and appealing illustrations
- Making them aware about the complexity of the problem and complexity of solution
- Providing continuous update about the actual state of knowledge, regularly inform about extended knowledge from recent investigations.

Some pilots encouraged an active participation by involving administrations from a higher level (regional/national authorities) in the process.

For an efficient RIG-procedure, it is important to define specific tasks and assign them to individual RIG-members and/or groups.

6.3. Legal quality targets for groundwater not achievable

Legal groundwater quality targets cannot always be achieved in clearly projectable time intervals. This may be obvious from the experience of past remediation procedures in the area. Nevertheless



groundwater quality targets as specified by legislation have to be discussed in the groundwater management plan, in order to evaluate the useful way to approach the legal process.

A possible “way out” is the definition of specific areas with a prevalent need for action. For example in Stuttgart-Feuerbach the Management plan defines specific actions to mitigate the contamination in areas where quality targets are exceeded.

6.4. Local pollution not recognized according to WFD standards

A frequent experience when establishing a groundwater Management plan is, that the quality monitoring network established due to WFD requirements does not depict the local pollution. For example in Jaworzno the monitoring network for groundwater body No. 146, which has been assessed as having a good status, does not recognize the contamination caused by “Organika Azot”, a chemical plant that is considered by the Helsinki Commission as one of the most dangerous “hot spots”, i.e. sources of potential contamination for the Baltic Sea.

This circumstance quite often results in lacking awareness of local actors and not existing communication between the local and regional/national administrative level as there is no direct legal need for action. It is difficult to assign responsibilities and find feasible ways of financing.

In these cases, it is generally important to enforce local responsibilities and establish financing mechanisms. As a result of AMIIGA, Jaworzno pilot succeeded to include the local contamination as an “important pressure” into the national water Management plan.

Pilot Milan established a regional water Management plan. The Regional Programme for Water Protection and Use with the aim to ensure a good status until 2027 represents a direct implementation of EU Water Framework Directive requirements.

7. Essential conclusions, recommendations

The following Chapter collects all the conclusions and recommendations from seven pilots reflecting their lessons learnt during the AMIIGA process.

Management plans are no „static solutions“

Management plans, as soon as established, are not valid for infinite time, but have to be checked and updated in regular time intervals. This may be accompanied by the regular update of conceptual and numerical models, or for example it may be appropriate to modify the design of a monitoring network after having evaluated the results of new findings provided by additional investigations. A Management plan is therefore a flexible tool, designed to be adapted due to provided feedback.

Consequently, as part of the Management plan, deadlines for regular checks should be defined.



Definition of milestones

Establishing a groundwater Management plan can be an extensive, time consuming process lasting several years. It therefore makes sense to establish a time schedule with milestones at the beginning of the process. In AMIIGA the following milestones were defined: framework and background, draft of Management plan and final Management plan.

Participation of higher administrative levels (regional, national) in the decision process recommended

It is highly recommended to invite higher administrative levels like regional agencies or ministries to participate in the process. This raises the importance of the issue, helps to clarify responsibilities and facilitates the communication and cooperation between involved administrative levels and participating local actors.

Management plan process offers strategies for specific local/regional requirements

The legal framework, provided by national/European legislation, does frequently not offer appropriate solutions for local problems. For example, legal quality targets may not be achievable in the downstream plume of contaminated sites despite decades of remediation.

The process of Management plan setup is an instrument to cope with the management of complex situations. It provides technical expertise on a high level and initiates a long-lasting dialogue between technical experts and responsible administrations/institutions. It enables the definition of realistic and reachable targets that could be considered in the legal process, involves stakeholders, considers pollution at medium scale and applies knowledge management (data, information and know-how).

Consequently, it paves the way for developing and establishing tailored strategies for local or regional groundwater contamination.

Literature

AMIIGA Report DT2.8.3 (2019): Report on final evaluation of realized pilot actions and recommendation to WPT3.

Attachment: Management plan summaries of the pilots

MANAGEMENT PLAN FOR PILOT ZADAR BOKANJAC-POLIČNIK

D.T3.1.3 | Pilot Zadar Bokanjac-Poličnik

Final Version
05 2019

1. Intro

AMIIGA is a project bringing together 12 partners from central Europe all with an interest in improving the quality of groundwater in urban areas. Long-term and widespread use of contaminants in those urban areas has resulted in a significant contamination of groundwater aquifers.

The main goal of the AMIIGA project is to improve the process of managing and making decisions in terms of dealing with contaminated groundwater at the functional urban area level (FUA) i.e. groundwater protection within urban areas through the adoption of the management plan and implementation of concrete measures from it.

The focus of the technical work package 3 (WP T3) is to establish a groundwater management plan for each of the seven pilot sites, considering technical, financial and legal aspects. PP11 and PP12 shall develop the groundwater management plan for Zadar pilot. The goal of this deliverable is to present the framework and background of the FUA Bokanjac-Poličnik for the development of management plan.

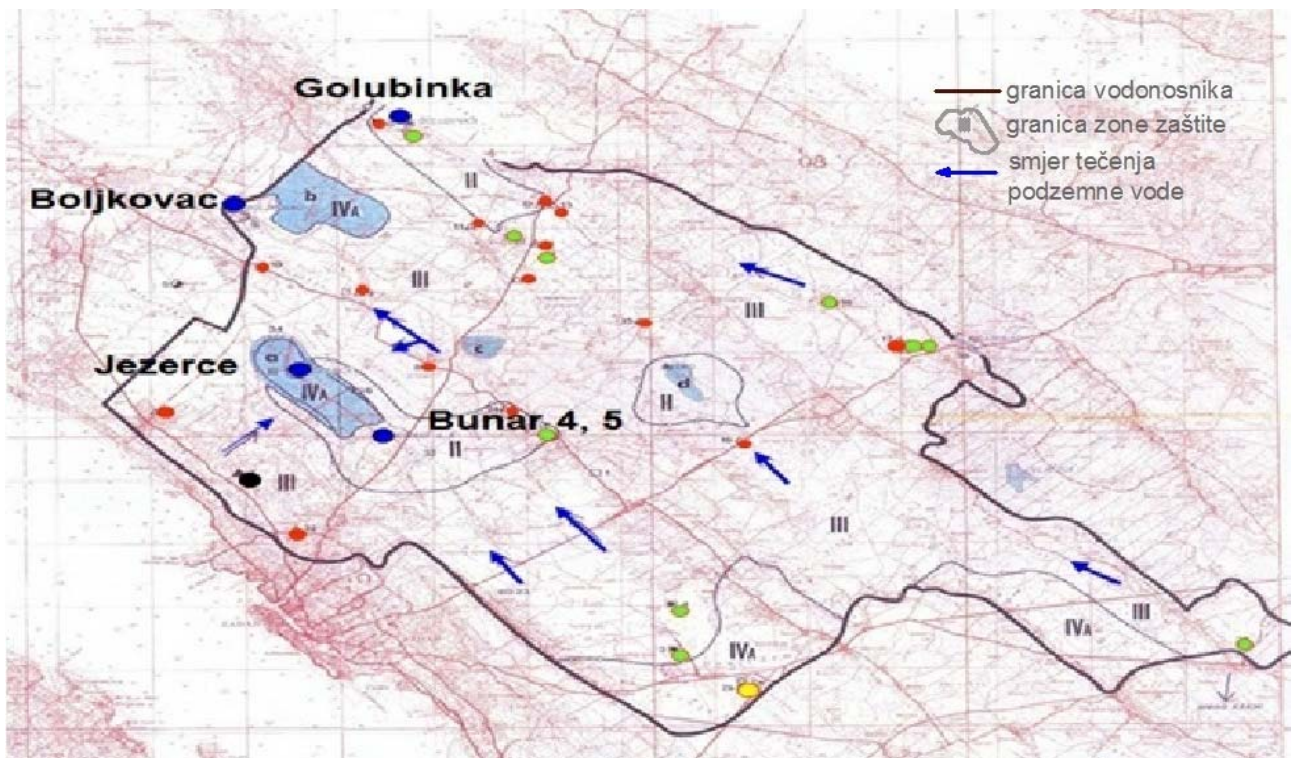
City of Zadar (Figure 1) supplies its drinking water from the aquifer Bokanjac- Poličnik, where several potential polluters upstream of the intake wells are known.



Slika 1 - Grad Zadar i njegovo zaleđe- pogled iz zraka u smjeru istoka

2. FUA

Functional urban area (FUA) of the pilot Zadar is hydro-geologically delineated according to the aquifer borders Bokanjac-Poličnik, Figure 2 (black line is aquifer border). The area of FUA is 245 km². Beside Zadar, FUA comprises parts of seven other municipalities, Figure 3 (pink line is FUA, yellow lines are municipality borders).



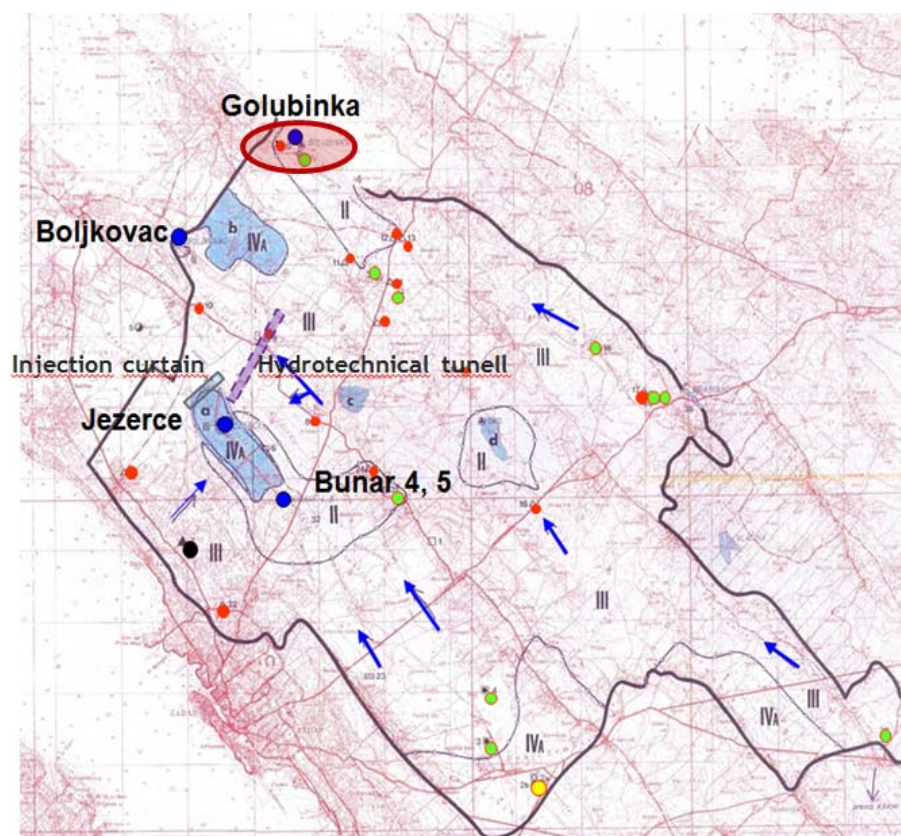
Slika 2 - Vodonosnik Bokanjac-Poličnik (područje omeđeno tamnom linijom)



Slika 3 - Preklapanje granica vodonosnika (ljubičasta linija) i JLS-a (žute linije)

3. Hydro-geological and contaminant description of FUA

The aquifer Bokanjac-Poličnik is a complex and highly sensitive karst aquifer, which is not sufficiently investigated. The general groundwater flow direction is from east to west, Figure 4 (blue arrows show flow direction, blue dots represent drinking water intakes).

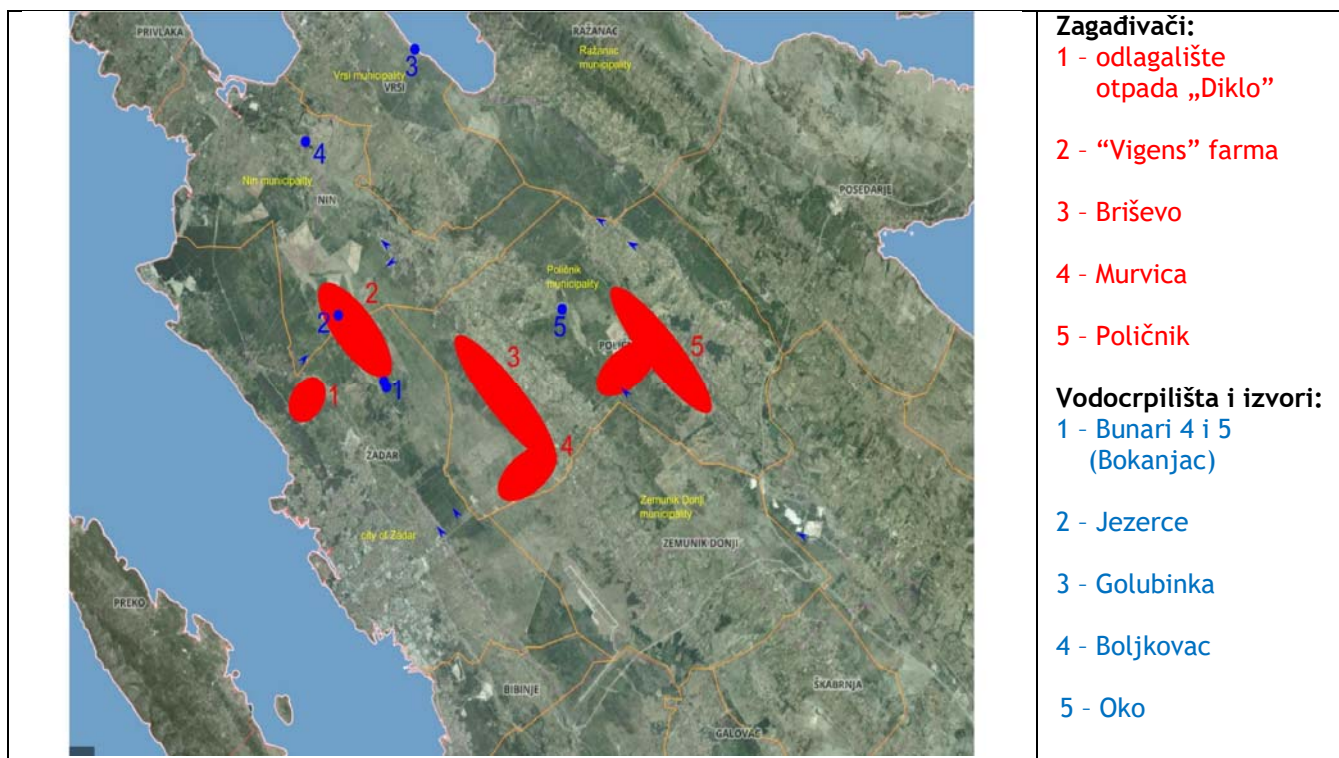


Slika 4 - Hidrotehnički tunel (ljubičasti pravokutnik) i zagat (sivi pravokutnik)

Results of monitoring from several groundwater wells show microbiological contamination in FUA. The main sources for bacterial contamination are farming and unsuitable disposal of waste water. In FUA there are only 43 % of inhabitants that are connected to the sewage system. The others are using septic tanks, which discharge effluent directly to the karst aquifer, Figure 6 (yellow dots represent drinking water intakes, red areas represent municipalities with no sewage systems). Altogether, several contaminated sites are known in the area: city landfill, an animal farm, and three villages without sewage systems, Figure 7 (blue dots show drinking water intakes, red areas represent contaminated sites). Investigations performed so far on groundwater and surface water quality show that water resources in FUA Bokanjac- Poličnik are very vulnerable to the environmental pollution.



Slika 6- Grad Zadar sa zaleđem – smeđa boja-naselja bez javnog sustava odvodnje- žute oznake predstavljaju vodozahvate



Slika 7 – Lokacije vodocrpilišta i zagađivača kao i smjer tečenja podzemne vode (crveno – potencijalni zagađivači, plavo – vodozahvati)

4. Numerical model

In order to define the GW flow in Bokanjac-Policnik aquifer, the numerical models of GW flow were made. The goal of numerical model was to determine the flow direction, the amount of infiltrated precipitation and relationship between the flow through the pores and the flow through the conductors based on the existing data of GW levels. MODFLOW was used to create the model. A detailed model description and modelling results are presented in *D.T2.1.3 Solution of the inverse problem on the Zadar-Bokanjac-Poličnik site* report.

The first step in planning was to make a numerical model of GW flow and it has been done by OUR PP from Zagreb. The basis for making numerical model was the data obtained during the hydrogeological tests carried out in the 60s and 70s of the last century. Also, 2 IPTests were conducted for the needs of model. In March 2018 an ombrograph (rain gauge) was installed on water intake Bokanjac, to receive accurate data on precipitation rates in this area. GW sampling was done on 4 active piezometers.

During development of model we met some problems. Since the subject pilot area is located on karst area that is hydrogeologically very complex, it is very difficult to determine the exact course of groundwater. Therefore, in order to make the most accurate model, it is necessary to have data as much accurate as possible. Unfortunately, most of the hydrogeological research in this area was carried out in the 60s and 70s of the last century and the majority of the piezometers then built is no longer active or does not exist anymore.

To get as much accurate model we need to have as many input data as possible. Tests conducted during AMIGA project, for the need of development of numerical model were limited by a small number of active piezometers (only 4). This model is starting point for understanding the GW flow in our pilot area and will be complemented with new data. Of course, to make the new data as accurate as possible, it is necessary to drill new piezometers, which will require local community assistance (funding, EU funds, etc.). Ultimately, when completed, a numerical model will be a tool for implementing some of the goals of this management plan. The model provides us with essential information on the GW flow, and as a result helps us identify the polluting site or pollutant. It's trying to explain the way of GW flow and thus the correlation between pollution that is detected and polluters located in our pilot area. With greater number of input data, greater accuracy will be gained from the model itself. This way, future potential pollution can be predicted and a chance to prevent them. Numerical model will help us determine the optimal drilling location of piezometers and is it is also a basis for supplementing defined measurements in case of incident events. It will also give us data on direction and flow rate as well as the time required for the pollution plume to reach the water intakes.

5. Legal regulations

Drinking water quality is defined in two regulations: (i) regulation about target values (Pravilnik o parametrima suglasnosti, metodama analize, monitoring i planovima sigurnosti vode za ljudsku potrošnju te načinu vođenja registra pravnih osoba koje obavljaju djelatnost javne vodoopskrbe, NN 125/2017 from 23.12.2017) and (ii) drinking water law (Zakon o izmjenama i dopunama zakona o vodi za ljudsku potrošnju, NN 104/2017 from 02.11.2017). All target values of microbiological and chemical parameters are defined in those regulations.

6. Goals of Management plan

Improvement of GW quality control

The main goal of AMIIGA project is to ensure good GW quality as well as a sustainable water supply system based on its own technological and human potentials. The first step in improving the GW quality control is made. By acquiring new laboratory equipment, we have increased our laboratory's analytical capabilities and enabled the detection of new potential GW pollution. The long-term goal of improving GW quality control is to further improve the analytical capabilities of Water supply company Zadar through the purchase of new equipment (for which procurement will be needed in the future), the full potential of the above, newly-supplies devices through AMIIGA project, which will increase the number of analyzes, shorten their implementation time, find new potential groundwater pollution. For the purpose of this goal is further professional training and education of laboratory staff.

Improvement of GW monitoring concept

To be able to monitor quality of GW in order to prevent pollution or to make timely reactions in the event of the occurrence of these pollutions, it is necessary to improve monitoring system. In order to do this it is necessary to foresee the drilling of new piezometers and their equipment with the necessary measuring equipment.

It is important to emphasize that the most important thing is detecting pollution in time so that we can react in the right way and initiate predefined measures. The existence of piezometers just in the vicinity of the water intakes is not enough because detecting pollution on the samples taken at those locations means that contaminated water has already entered the water supply system. By the existence of "distant" piezometers and keeping track of the direction and time of GW flow, we can respond in timely manner and prevent the introduction of such contaminated water into the water supply system.

Supplementation of defined accident measures

The aim is to complement the existing plan of defined measures in case of incident events based on new findings obtained with future numerical model upgrades. Of course, the upgrade of the numerical model will depend on obtaining new input data for the



model of the improved GW monitoring system (by building new piezometers, supplementing GIS database, etc.).

7. Necessary measures to achieve goals

Education and training of laboratory staff and procurement of new laboratory equipment

In order to get maximum results, beside high-quality equipment it is necessary to have high quality and educated staff. Through AMIIGA project, existing laboratory equipment was upgraded through the purchase of two new devices. In order to further improve the quality control of GW, further and constant training of employees is needed in order to improve and utilize the existing laboratory equipment. Through further work, experience and new knowledge, the need for additional laboratory equipment will emerge, which will result in GW quality control going to an even higher level than the existing one.

Drilling a new piezometers

Drilling new piezometers is an indispensable measure for the implementation of further planned goals.

New piezometers (along with existing ones) will be used to install certain alarm systems or to improved GW monitoring network. Of course, a larger number of piezometers will also get a greater amount of new data essential for further enhancement of the numerical model (more data leads to more accurate model). Due to the large financial expenditures for drilling new piezometers, the deadlines for their construction are unknown.

Numerical model developed through AMIIGA project gave us information on areas where new piezometers should be located. Exact locations of new piezometers will depend on the possibility of solving property-legal relations, access ability, etc.

So far, numerical model gave us 4 different areas in which the piezometers should be drilled. The recommendation is to drill 2-3 new piezometers in every of those 4 areas.

Drilling costs will depend on selected location ie. drilling depth (different location means different drilling depth). Estimated drilling cost is 3000 kn/m' (ca. 400 €/m²).

Upgrade an existing numerical model

The numerical model that will be developed through the implementation of the AMIIGA project is based on existing data and those collected through duration of the project itself. Unfortunately, the major limitation in the development of the model is the absence of a large number of active piezometers. Data obtained from new observation wells (new piezometers) combined with better quality (new devices) and wider (new sampling location) analysis of GW quality will further improve or upgrade the existing numerical model.



By upgrading the numerical model, it opens up the possibility of getting new information of the mode and speed of GW flow, which can directly affect the addition of defined measures in case of incidents.

Provision of piezometers with new measuring equipment

One of the important measures for achieving the foreseen future goals is the installation of new measuring and signaling equipment on piezometers, both existing and future ones. We need to define what equipment is needed for which piezometer, ie. We need to define what kind of data we want to get from certain piezometers. This can be a water sampling equipment, measurement of different parameters in water quality, water level measurement etc. Financing of such equipment is also one of the points to be defined. It is desirable if each of the future piezometers (since, for the first step, only a few piezometers are to be drilled) would be equipped with as many measuring equipment as possible, but it will all depend on the future finances.

Updated of database with new data

One of the measures initiated through the AMIIGA project, which will continue even after its formal completion, is an updating of the QGIS database. The same database was made during implementation of AMIIGA project and contains up to date known and accessible information about GW in the area of Bokanjac-Policnik aquifer. The existing database is planned to be complemented with all new relevant data about GW in this area.

8. Implementation

RIG

In order to successfully implement the MP it is necessary to have cooperation of larger number of relevant institutions, which can be “found” under joint name “Regional implementation group”. It is made up of representatives of various institutions that have the possibility of acting in order to implement the activities for the realization of the groundwater management plan. At different stages of implementation of AMIIGA project, there is a need to add new or omit some of existing RIG members, all in line with the current project implementation needs. At the moment, the RIG is attended by representatives of Water supply company Zadar and Faculty of Civil Engineering from Zagreb (also project partners in the implementation of AMIIGA project), City of Zadar (Departments for EU Funds) and Zadar County (Administrative Department for Physical Planning, Environmental Protection and Utilities). The first RIG meeting was held in September 2017 and the second in June 2018. The RIG Plan is an extension and inclusion of representatives of individual municipalities in whose area our FUA is located, ie. Representatives of municipalities that have an impact on the quality of GW (this is primarily the case of villages without a public sewerage system and from whose septic tanks pollution comes to the GW and ultimately to the water supply system), primarily the Poličnik Municipality. At the 2nd RIG meeting were also invited representatives of the Poličnik Municipality, but unfortunately they had to cancel their appearance at the



last minute. Nonetheless, their representatives were informed about the project, the steps taken so far as well as the project's ultimate goal.

The 3rd RIG meeting is scheduled for the first half of June.

The RIG is of crucial importance for the successful implementation of the project, so it is planned to involve the wider community and its objective information about the importance of the project, the goals and the expected results.

9. Time frames

Upon completion of the AMIIGA project, further 3 goals are envisaged to ensure effective corrective measures in case of pollution incidents, to have a better quality of GW and ensuring safe water for human consumption.

It is difficult to determine the deadlines for implementation of certain goals because they depend on the realization of several necessary measures and, consequently, on the closure of the financial structure. Improving groundwater monitoring depends on drilling new piezometers and setting up new metering devices. The update of the measures in case of accidents depends on the upgrading of the numerical model which depends on new piezometers, new devices and new GW sampling etc. From this we can see that the future goals are to improve GW management as well as the necessary measures for achieving these goals mutually interwinded. One of the ways of achieving the goals is also through the implementation of some new future EU projects.

Action Plan for Zadar

Development target	Action / Phase of action	Scale	Description / explanation	Beginning of action within AMIIGA project duration [y/n]	Estimated completion date			Legal / organizational limitations Is the implementation legally / organizationally possible? [y/n]	Technical / technological measures Which technical / technological measures are necessary?	Financing / responsibilities		Who is responsible for the implementation of measures?
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)			Public (EU / national / regional)	private	
Development target 1: Improvement of groundwater quality control												
1. Improvement of groundwater quality control		FUA Zadar	The main goal of AMIIGA project is to ensure good GW quality as well as a sustainable water supply system based on its own technological and human potentials. Some new laboratory equipment has been purchased.									
1.1	Education and training of laboratory staff		The long-term goal of improving GW quality control is further improvement of the analytical capabilities of laboratory and continuous professional training and education of laboratory staff in order to improve the quality and utilization of existing laboratory equipment, follow new trends and knowledge in terms of better GW protection.	y	x	x	x	y	further and constant training and education of employees	x	-	Water supply company
1.2	Procurement of new laboratory equipment		Through further work, experience and new findings a need for the purchase of additional laboratory equipment will emerge.	n		x	x	y	no measures	x	-	Water supply company
Development target 2: Improvement of GW monitoring concept												
2. Monitoring program for the FUA, as an early warning system for GW pollution		FUA Zadar	There are just few active piezometers in FUA area and they are located in the vicinity of water intakes. More piezometers (specially the ones farther from the water intakes) will give new data about GW and can be used as an early warning system for GW pollution.									
2.1a	Drilling a new piezometers		Initial areas for drilling piezometers were defined by numerical model developed through AMIIGA project. Further development of a model will give new and more accurate locations for drilling.	n		x	x	y	Further development of the numerical model.	x	-	Water supply company, local municipalities, Croatian waters
2.1b	Provision of piezometers with a new measuring equipment		To get data from new piezometers they have to be equipped with different measuring equipment.	n		x	x	y	Drill new piezometers. Depending on the total number of new piezometers, number and installation position of new measuring equipment will be determined.	x	-	Water supply company, local municipalities, Croatian waters
2.2	Update of database		Through implementation of AMIIGA project a new GIS data base was created and contains all so far gathered data about GW on FUA area. It is available online and it can (should) be supplement with a new data.	y	x	x	x	y	Drilling new piezometers and installation of new measuring equipment	x	-	Water supply company, local municipalities, Croatian waters



Development target	Action / Phase of action	Scale	Description / explanation	Beginning of action within AMIIGA project duration [y/n]	Estimated completion date			Legal / organizational limitations Is the implementation legally / organizationally possible? [y/n]	Technical / technological measures Which technical / technological measures are necessary?	Financing / responsibilities		Who is responsible for the implementation of measures?
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)			Public (EU / national / regional)	private	
Development target 3: Ensuring the implementation of the necessary measures												
3. Supplementation of defined accident measures		FUA Zadar	The aim is to complement the existing plan ie. defined measures in case of incident events based on new findings obtained with future numerical model upgrades. The upgrading of the numerical model will depend on obtaining new input data for the model of the upgraded GW monitoring system (drilling new piezometers, new measuring equipment, supplementing GIS database, etc.)									
3.1 Further development of numerical model			Numerical model developed through AMIIGA project was based on data gathered from just 4 active piezometers. It is necessary to work on further model development. To get more precise and accurate model we need more data.	n		x	x	y	Installation of measuring equipment on a new piezometers located father from the water intakes (early warning system).	x	-	Water supply company, local municipalities, Croatian waters
3.2. Supplementation of defined accident measures			Addition of the existing measures will go in the direction of defining the actions to be taken in the event of a deterioration in the quality of GW on the basis of the expected changes in weather condition (expected very intensive precipitation and droughts), ie. proposal to determine the working regime of water intakes in case of "clouds" avoiding or reducing the need to exclude certain water intakes from the water supply system.	n		x	x	y	Further development of numerical model.	x	-	Water supply company



MANAGEMENT PLAN

D.T3.1.3 | Pilot Ljubljana - Ig (Summary)

Version 1
04 2019



MOTIVATION

City of Ljubljana and Municipality of Ig have developed a groundwater contamination management plan for the functional urban area of Ljubljana - Ig. The management plan was prepared in a cooperation between municipalities supported by JP VOKA Snaga (Ljubljana city water works operator), Geological Survey of Slovenia (GeoZS), and strong support from Regional Interest Group. Investigations, the development and preparation of management plan were co-financed by the Interreg Central Europe programme granting the AMIIGA project.

“The project AMIIGA has been initiated due to a significant contamination of groundwater caused by the long-term and widespread use of contaminants in Central European urban areas. The goal of the project is to develop and promote a strategic transnational management tool to manage groundwater contamination.

The focus of the AMIIGA was to establish a groundwater management plan for each of the seven AMIIGA partner pilot sites, considering technical, financial and legal aspects in different environments and for diverse contaminations in urban areas and appertaining hinterlands.”

Functionality of urban area in Ljubljana - Ig depends considerably on quality of groundwater in the aquifer below the city core and its hinterland. There are numerous contaminants present in the groundwater, some of them are originating from the past activities (sulphates from past air pollution, TCE and PCE from past urbanization activities, chromium from past industrial activities, atrazine and desethyl-atrazine from past agricultural activities), others from actual activities (nitrates from agriculture and sewerage losses, new emerging pollutants in traces - pesticides from agriculture, plasticisers, corrosion and fire inhibitors, pharmaceuticals from sewage system losses). All those have mainly characteristics of dispersed pollution; however, we can recognize also the characteristics of plumes and multipoint pollution contamination sources, which, in some cases, are threatening also the actual and future long-term potential for water supply.

The groundwater management plan was designed defining the priorities of those contaminations and contaminants and setting up remediation and prevention actions, specifically from the waterworks perspective. We have effectuated 11 steps approach for four selected working areas and their significant contaminants. These are, by the order of the risk ranking: desethyl-atrazine plumes, chromium VI plumes, new emerging organic pollutants in traces and boron plume. The management plan defines development targets and target values that must be achieved for safe water supply and high-level functionality of urban area in next decades.

Thanks to the AMIIGA project co-financing and international cooperation, we were able to use and demonstrate beneficial use of FOKS and AMIIGA tools, such as GIS - protocol to establish common database of monitoring data, numerical modelling and backtracking the pollution origins, biomolecular tool (BMT) and compound stable isotope analysis (CSIA) as well as the rich experiences of pollution management in cities of Jaworzno, Milano, Novy Bydzov, Parma, Stuttgart and Zadar.

Groundwater contamination management plan of Ljubljana - Ig deals with four different contaminations that are typical for functional urban areas. These are past and present contaminations in the aquifer from industry and sewage losses within the city core, and municipal landfill and agriculture in the hinterland. At the same time, the same aquifer is used for drinking water supply and numerous other uses of the groundwater. Such management plan is the first in Slovene territory and the ambition is to be also demonstrative case for other functional urban areas.



Management plan area

Standing in the Ljubljana city centre, just below our feet, there is an extraordinary rich groundwater aquifer in sandy gravel sediments. These sediments were deposited in a long geological history by Sava and Ljčka rivers and their tributaries. The aquifer is 100 m deep. About 20 % of the volume of sandy gravel material represents voids which porosity enables to store a huge groundwater reservoir. We find the groundwater level already from 0 to 30 m deep below the ground. High permeability of the aquifer allows us to abstract enough water for drinking water supply of the city and moreover also for the surrounding towns and settlements. One water well can abstract even 100 l/s of groundwater. Actual drinking water supply system exploits approximately 1 m³/s of groundwater. Today, the groundwater is used for the entire range of possible water uses: drinking water on the first place, as well as for manufacturing of food, bottling of drinks, process water, heat exchange for heating and cooling, irrigation and ecosystems services. The hydrogeological potential of the aquifer is not only enough for the actual population but also promises to cover the demands for long-term future development.

This groundwater is recharged by annual precipitation, infiltration of Sava and Ljčka rivers and from groundwater inflows from hinterland territories of Ljubljana city municipality and Municipality of Ig. Both communities are strongly connected and interdependent, not only by the common natural aquifer system but also by the common waterworks and sewage systems. This interdependency is a strong motivation to elaborate commonly reconciliated groundwater management plan. The functional urban area Ljubljana - Ig, which is the subject of the groundwater management plan, has a surface over 70 km². Distance from the most faraway recharge area on the south of Ig municipality to the north-eastern discharging boundary of the aquifer is approximately 21 km, while the width of the area is till 6 - 7 km.

Within this area, four the most significant contamination working areas are delimited where specific measures and actions are foreseen in the management plan:

Working area 1 Stegne - Hrastje: hexavalent chromium (Cr VI) plumes;

Working area 2 Dravlje - Moste: nitrate and new emerging pollutants contamination;

Working area 3 Barje: boron contamination;

Working area 4 Brest: desethyl-atrazine plumes.

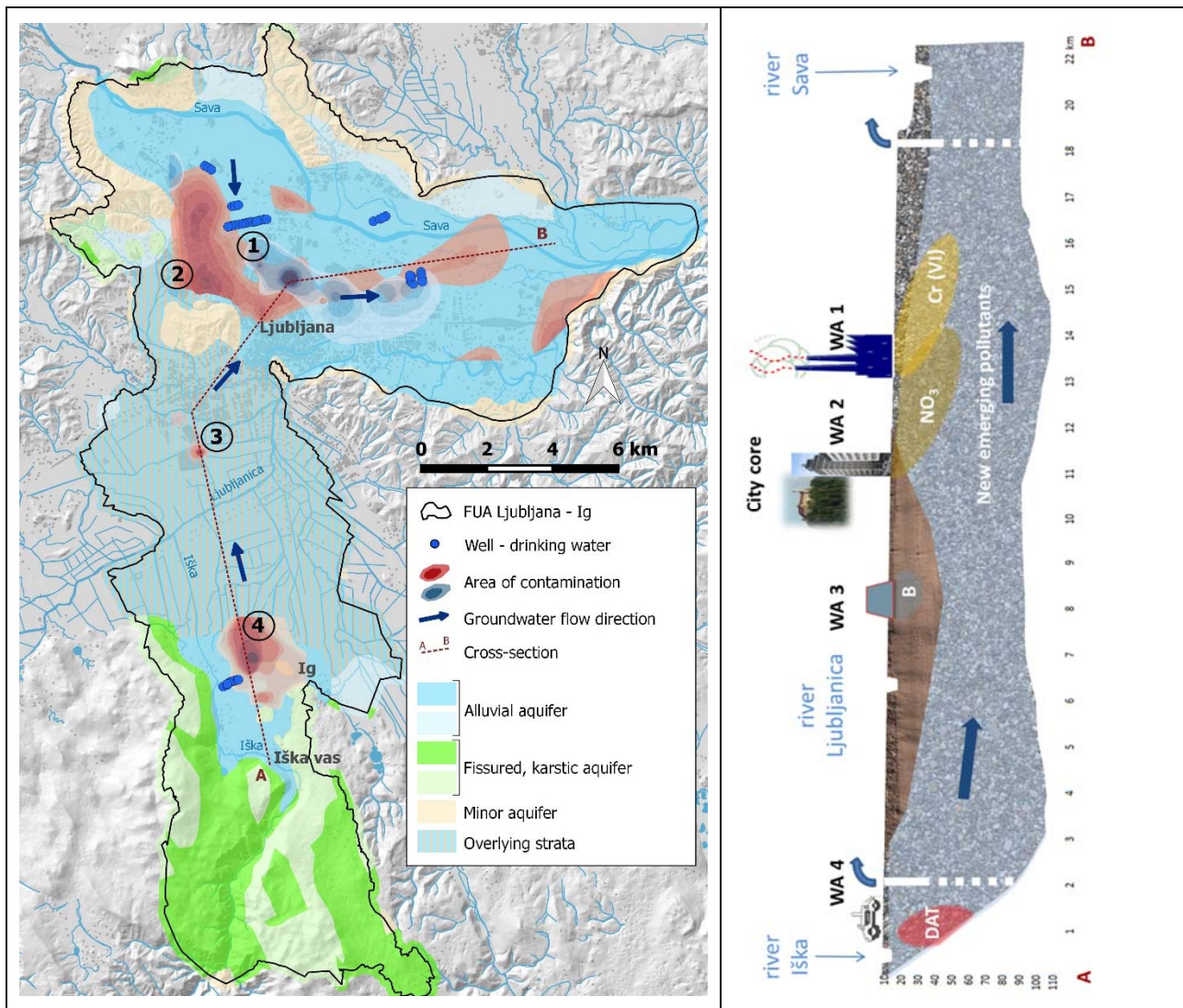


Figure 1. Functional urban area Ljubljana - Ig with significant contamination working areas (WA 1 Stegne - Hrastje: hexavalent chromium (Cr VI) plumes; WA 2 Dravlje - Moste: nitrate (NO₃) and new emerging pollutants contamination; WA 3 Barje: boron (B) contamination; WA 4 Brest: desethyl-atrazine (DAT) plumes).

Environmental trends and actual status of contaminations

Efforts from last decades to decrease pressures and impacts on groundwater quality in the Functional urban area of Ljubljana - Ig have already provided significant success. Probably, one of the most courageous decisions was to stop the use of coal for heating by its substitution with gas and district heating. Other such decisions are to prohibit the use of atrazine, to regulate and limit the use of chlorinated hydrocarbons, to implement the programme of treatment of wastewaters and to promote the sustainable agricultural practices. However, also the decrease of water losses from waterworks and lower water demand contributed to more efficient groundwater quality protection.

Effects of those decisions are clearly proved by continuous and significant decreasing trends of sulphates, nitrates, as well as atrazine and desethyl-atrazine in groundwater. Also, the concentrations of chlorinated hydrocarbons (PCE, TCE) are decreased below quality standards, they are not appearing in form of contamination plumes, but they are present only as a low-level background contamination around the limit of quantification. The same is valid also for atrazine and desethyl-atrazine. Nitrates have significant



decreasing trends after 1992 and as well as in the last decade 2007 - 2016, when the trend of decrease is - 0.25 mgNO₃/l per year.

Nevertheless, this success can not release us from further management of contaminations and further courageous decisions and actions to prevent the safety of water supply for next decades. While the previous measures were substantially focused to dispersed pollutions on regional and wider scale, the future measures will have to deal with local specific contaminations from point sources in forms of plumes and from multipoint sources which are threatening specific receptors or plots in the area. Therefore, they must be managed by the local management plans for specific working areas.

- Working area 1 Stegne - Hrastje: Cr VI plumes

Actual status of Cr VI contamination shows a distinct area of contamination with significantly higher concentrations than natural background concentrations. While natural background level is approximately 1 µg/l or less, several monitoring points shows concentrations even higher than 25 µg/l. By the aid of numerical modelling of dilution, we identify at least two plumes discharging approximately 900 g of Cr VI per day. Flow paths of these plumes are passing slightly south of Hrastje well field, touching also the southern wells. Although the trend of Cr VI is decreasing in the most contaminated drinking water well (15.7 µg/l), the concentrations of Cr VI and Cr_{tot} in the upstream of groundwater flow were increased between 2011 and 2013. This proves that sources of Cr are still active. Additionally, we discovered the existence of contamination significantly higher than 50 µg/l Cr VI, which is a value above the quality standard even of Cr_{tot}. Using the analytical dispersion model, we estimated that a stronger source of contamination could be expected very near, only a few hundred meters upstream of this location. We delimited the narrower area where three possible sources should be investigated for the detailed localization of the contaminated ground and contamination source.

- Working area 2 Dravlje - Moste: nitrate and new emerging pollutants contamination

Actual contamination with nitrate is now significantly lower than 10 years before. The average concentration in monitoring points decreased from approximately 18 mg/l to 16 mg/l. A slight part of this decrease could be contributed to the higher dilution while the main part could be contributed to decrease of surpluses of nitrogen from agriculture and excessive losses from undefined sources. In spite that statistical trend of decrement is very evident, its forecasting cannot be just prolonged for the next decade. The main reason is that the potential of further reduction of surpluses from agriculture couldn't be assessed. Beside this, the possibility of eventual change of hydrological conditions and lower dilution must be considered. However, there are areas and locations where actual average annual concentrations of nitrates are excessive, higher than 25 mg/l or even higher than 30 mg/l, while the background concentration of nitrate in groundwater is approximately 5 mg/l.

Actual drinking water supply system is capable to deliver the water containing less than 18 mg/l of nitrate. Minor number of drinking water wells had average concentrations up to 24 mg/l in the last decade. However, none of them exhibits increasing trend of nitrate.

To retain the actual decreasing trend of nitrate, it is important to promote basic measures in agriculture for optimization of nitrogen surpluses, restoration of sewage system, but also additional measures to continuously identify and sanitize locations of excessive losses from undefined sources.

The locations of excessive losses of nitrogen from undefined sources can be also sources of new emerging pollutants. In last years, the existing groundwater monitoring is continuously adapted to detect those contaminants. There are numerous contaminants already detected in groundwater on the level of traces, and the main concern is to find out in a good time whether their concentrations have any significant increasing spatial or temporal trends. Using the innovative approach and combining three already established methods of passive sampling, analysis of frequency of occurrences and analytics till zero, we identified significant spatial and temporal trends of three new emerging pollutants in groundwater. These are desethyl-terbutylazine, carbamazepine and benzotriazole. The first one is the degradation product of pesticide terbutylazine; it is used in agriculture, substituting the atrazine. The second one is



pharmaceutical substance (mainly from sewage losses) and the third one is a corrosion inhibitor substance which is widely used also for households (expected from sewage losses or waste waters).

- Working area 3 Barje: boron contamination

Boron is the most significant contaminant from municipal landfill Barje. Approximately 26 g of boron is released per day from the landfill. The contaminant leaks out from the unsealed bottom of the old part of landfill. The highest leakage and concentration over 1 mg/l of boron in the groundwater is observed in the south-eastern margin of the landfill. However, this mass of boron is attenuated in the area very close to the landfill. After 30 years of the municipal waste depositing, the impact reached the distance less than 400 m from the landfill, where the natural background concentration is in the order of magnitude 0.001 - 0.010 mg/l. We estimate that in 100 years period such an impact could reach 1,100 m, however the contamination over 1 mg/l, which is a quality standard for drinking water, would remain in the range of 125 m from the margin of the landfill. Actual trends of boron concentration in the impact area are showing that only in one observation point just near the landfill will be still above 1 mg/l after 2021.

Organic synthetic pollutants are only present in traces. They are mainly degraded by chemical process of reduction. Microbiological population in the groundwater proves that there is no abundant mass of organic synthetic substances leaking from the landfill. Natural attenuation capacities of the geological layers around landfill are thus quite favourable. Propyphenazone, the organic synthetic substance, which is persistent against chemical degradation in such conditions, is present in the concentration lower than 0.5 µg/l. This proves that the leakage is low, but the trends of such persistent substances must be monitored carefully by the operational monitoring of the landfill.

The problem is, what we found out, that concentrations of boron are elevated also in the groundwater downstream of the landfill but from other contamination sources. The mass of boron discharging towards Ljubljansko polje aquifer is about 100 g/day, 4 times higher than the mass of boron which is attenuated near the landfill. So, for the management of the contamination from the landfill, it is very important to distinct this contamination from the other sources of contamination.

- Working area 4 Brest: desethyl-atrazine plumes

Contamination of desethyl-atrazine appears in two plumes, southeast and northeast of Brest well field. Two old gravel pits are the most probable point sources of the contaminant. Approximately 23 kg of this substance is present in groundwater and the decrease of the mass is only 0.3 kg/year. This decrease is a consequence of dilution, degradation and abstraction. The natural attenuation capacity is apparently low. Decades or even a century would be needed to remediate the aquifer by the natural process. In the centres of plumes, the concentrations of desethyl-atrazine are several times higher than groundwater quality standard (0.1 µg/l).

The geometry and the mass of pollutant at the sources has still to be investigated in detail. It is evident, that the abstraction of groundwater for water supply draws the southern contamination plume towards the well field, especially in dry period. The contamination is spread in the deep part of gravel aquifer and in the fissured dolomite and limestone aquifer in the basement. In the natural conditions, it is partly discharged through springs to surface streams.

The capacity of Brest well field for the water demand of 170 l/s is obstructed in dry period by the desethyl-atrazine contamination. Higher abstraction from deep aquifer can give the rise of concentrations above the drinking water standard (0.1 µg/l). Also, the main natural spring is still contaminated. After 2008 decreasing trend of desethyl-atrazine in this spring stops and the concentration is held up around the limit value of groundwater quality standard (0.1 µg/l).



Risk assessment from water supply perspective for diverse contaminants

Contaminants in the groundwater represent a certain risk for water supply. The level of this risk must be assessed for the safety plan of waterworks. Firstly, the risk is assessed depending on the severity of contamination and how frequently does it occur. If the concentration of contaminant exceeds some quality standard or recommended safety value, then the severity of contamination is high. Secondly, the risk depends on how often this occurs, for example, continuously, once per year or once per ten years. Beside the severity and frequency of contamination, the risk is assessed from two perspectives, this is regarding actual contamination and, on the other hand, regarding potential pollution that could eventually occur by the instantaneous release of contaminant.

The risk assessment clearly shows that desethyl-atrazine pollution at Brest area represents the highest risk for water supply, as well as for present status as for a potential pollution. Contamination is highly severe and continuously present in the groundwater, threatening also the operation of drinking water wells.

The second highest rank of risk is the Cr VI pollution. The risk is high for potential pollution from unknown sources. The unknown sources are evidently present, and they already cause highly severe and continuous contaminations in groundwater. Also, instantaneous releases of Cr VI from those sources are possible, for example, during excavating for construction works, or in case of specific hydrological conditions. Such releases could then provoke severe contaminations also in drinking water wells, not only in Hrastje but also in Kleče wellfield.

Nitrate concentrations and new emerging pollutants represent the medium risk at present status, but high risk to drinking water wells in the case of potential pollution. Local excessive nitrogen inputs obstruct us to lower the severity of contaminations in water wells. Some new emerging pollutants have significant increasing trends from year to year, which warns us that the present status is deteriorating in a short-term timeframe.

Contamination from municipal landfill, most of all by boron, is of low risk for present status of water supply system. Advancement of contamination downstream of the landfill on the flow path towards drinking well is possible, however only lower than medium severity and longer period occurrence, so the level of this risk is medium.

Development targets and target values

General development target is to reduce the risks for the water supply system. The goal is to reduce it at least to the medium level for desethyl-atrazine contamination at Brest wellfield and the low level for Cr VI, nitrate, new emerging pollutants and boron contaminations.

For each working area of contamination, the development targets and target values are set up in the groundwater contamination management plan.

The first specific development target is to retain the capacity of 170 l/s for Brest well field in dry period with the possibility to improve the capacity. The goal is to reach < 0.1 µg/L desethyl-atrazine in wells, < 0.5 µg/L in plumes and < 0.1 µg/L in springs.

The second specific development target is to retain the full capacity of Hrastje and Kleče well fields for long-term drinking water supply. Target values are < 25 µg/L of Cr VI in plumes, < 10 µg/L in drinking water wells; < 25 mg/L of nitrate on hot spots, < 18 mg/L in wells,

The third development goal is to prevent Hrastje and Kleče well fields against new emerging pollutants. Target values are < 0.1 µg/L of individual compound and < 0.5 µg/L for sum of all compounds of new emerging pollutants.



The fourth development target is to maintain the municipal landfill on present location with the possibility of improved functionality of the area. Target values are < 1 mg/L of boron in plumes in the first gravel layer at the downstream margin, and < 0.5 mg/L at the distance of 250 m downstream from the landfill, as well as in overlaying strata as in the first gravel aquifer.

Why development targets and target values are important to be set in the management plan? The main aim is to quantify the mass and geometry of contaminant at the source and thus to be able to reliably assess the effects and costs of the feasible measures and actions. Decisions should be taken by decision makers based upon proportionality of the costs and cost resources analysis, which is not possible without quantification.

Need for action

One of the most essential benefits of groundwater contamination management plan is to ensure the most efficient consequence of actions and synergy with basic measures in next coming years, leading us to achieve development targets and goals.

Actions and priorities are designed based upon thorough analysis of actual status, trends, risks and efficiency of feasible measures that are elaborated in expert basis of present management plan. The actions are compiled in the Action Plan.

- The first priority Brest area:

In the Brest area where desethyl-atrazine concentrations exceed the groundwater quality standards (0,1 $\mu\text{g/L}$), there is the strongest need for action. The first priority is to inspect the status of two identified the most probable sources at the southern and northern gravel pit D1, D2.

The next action is the additional development of the capacity of shallow drinking water wells and the western margin of the resource. At the same time, the capacity of the enhanced abstraction of contaminated water from deeper part of the aquifer has to be tested. Those actions will enable to take further decisions for the most efficient remediation measures that were elaborated in the feasibility study.

- The second priority Stegne - Hrastje area:

In the critical area of Cr VI contamination, where the concentrations above 25 $\mu\text{g/l}$ are observed, it is needed to take the actions for closer localization of the source of contaminant because it could provoke exceeding concentration in the drinking water wells. The most important is closer localization of three possible contaminant sources (C1, C2, C3) in two identified main plumes. The first priority is the southern plume, where concentration exceeding quality standard > 50 $\mu\text{g/l}$ of Cr VI was discovered, and the location presents the risk for both waterworks Hrastje and Kleče.

The next most important action is to ensure the investigation monitoring of soil contamination in the excavations for constructions in the critical area. At the same time, the expert advisory team has to be organized to prepare the implementation of possible remediation solutions.

- The third priority Dravlje - Moste area:

All groundwater measuring wells with higher concentration of 25 mg/L of nitrate on hot spots, 18 mg/L in drinking water wells, and locations of significant increasing trends of new emerging pollutants are identified. The first priority action is to initiate optimization of terbutilazine use and surpluses with agricultural sector and to find out the uses of benzotriazole, which provoke the highest losses to the environment with industrial sector. At the same time, the continuous and regular information exchange of data about new emerging pollutants in groundwater and their use has to be established. The second priority is to implement the sanitation measures of sewerage on the locations with excessive inputs of nitrate and pharmaceuticals.

- The fourth priority area around Barje unharzardous municipal landfill:



Although investigation and remediation measures are implemented on the landfill by the obligation of landfill manager, there are some losses from the landfill into groundwater, which are above all, the consequence of lower environmental standards in the past in the time of landfill conception. The first priority action is the use of natural attenuation monitoring technique focused primarily on the area close to the landfill where identified concentration exceeding the quality standard 1 mg/l of the boron in groundwater. The second priority action is the establishment of additional points of compliance downstream of the landfill to distinct impacts of external resources of boron. The third priority action is further elaboration and design of sealing the infiltration in the waste body after the closure of the landfill.

Implementation

Groundwater contamination management plan of Ljubljana - Ig will be mainly implemented by the Environmental protection programme of Municipality of Ljubljana (2021-2026) and Operational program for drinking water supply of Municipality of Ig (2022-2025). Both programs will be adopted by the intersectoral reconciliation conferences in 2020 (especially development goals, targets and measures).

Some of the actions that are beyond the municipal competencies will be implemented by updates of the Decree on Ljubljansko polje aquifer (from 2003), such as adopting of special requirements for soil and water sampling on Cr VI critical area, or measures about the use of relevant substances.

Some of the actions that are in competencies of municipal services have already started, such as additional pumping tests, targeted monitoring, detailed localization of contamination sources, and others.

Action Plan for FUA Ljubljana - Ig

Development target	Action / Phase of action	Scale	Description / explanation	Beginning of action within AMIGA project duration [y/n]	Estimated completion date			Legal / organizational limitations Is the implementation legally / organizationally possible? [y/n]	Technical / technological measures Which technical / technological measures are necessary?	Financing / responsibilities		Who is responsible for the implementation of measures?
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)			Public (EU / national / regional / local)	private	
Development target 1: Retain the capacity of the Brest well field 170 l/s in dry period with the possibility to improve the capacity.												
1.1. Operational test of DAT plume redirection		Brest										
1.1a	Free-level observation well on the western boundary of the aquifer		To catch the unpolluted water from the western side of the catchment area	y	x			y	Well drilling, installation of equipment	x	-	MOL, Ig Municipality
1.1b	Additional pumping test of in 9 wells VD1-VD9 in dry period		To develop shallow wells artificial recharge for higher productivity 170 l/s in dry period	y	x			y	Pumping tests	x	-	MOL, Ig Municipality
1.1c	Restoration of water level measuring equipment in Ig water supply well		To more reliable definition of southern boundary conditions of recharge by unpolluted water			x		y	Restoration of the well equipment	x	-	Ig Municipality
1.1d	Test abstraction from the new well on the western margin and enhanced extraction of DAT from VD1a well		For the redirection of DAT plume away from deep wells and to select the most appropriate pumping regime and hydrotechnical interventions	y	x			y	Dewatering conducts / Integrated pumping tests	x	-	JP VOKA SNAGA d.o.o.
1.2. Ascertainment of the mass and geometry of DAT in two the most threatening sources D1, D2												
1.2a	Sampling boreholes in southern gravel pit D1		To prove the location and position of DAT source D1			x		y	Drilling / soil investigation	x	-	MOL, Ig Municipality
1.2b	Observation well at the southern gravel pit D1		To calculate the emission of DAT in g/day			x		y	Observation well drilling, sampling and analysis of groundwater, risk assessment	x	-	MOL, Ig Municipality
1.2c	Sampling boreholes in northern gravel pit D2		To prove the location and position of DAT source D2			x		y	Drilling / soil investigation	x	-	MOL, Ig Municipality
1.2d	Observation well at the northern gravel pit D2		To calculate the emission of DAT in g/day from D2			x		y	Observation well drilling, sampling and analysis of groundwater	x	-	MOL, Ig Municipality
1.3 Enhanced microbiological degradation of DAT												
1.3a	In situ investigation of DAT degradation conditions		To identify natural population of microbial capable to degrade DAT			x		y	Remediation measures	x	-	MOL, Ig Municipality
1.3b	Laboratory testing of enhanced degradation		To define the most efficient way enhancing microbial activity for DAT degradation				x	y	Remediation measures	x	-	MOL, Ig Municipality
1.3c	Upscaling and pilot system testing		Implementation of enhanced microbiological degradation or selecting the most efficient hydrotechnical solution (ref. to 1.1d)				x	y		x	-	MOL, Ig Municipality
1.4. Operational monitoring												
1.4a	Geometry of DAT contamination plume		To follow development of DAT plume extension, movement and dispersion	y			x	y		x	-	JP VOKA SNAGA d.o.o.

Development target	Action / Phase of action	Scale	Description / explanation	Beginning of action within AMIIGA project duration [y/n]	Estimated completion date			Legal / organizational limitations Is the implementation legally / organizationally possible? [y/n]	Technical / technological measures Which technical / technological measures are necessary?	Financing / responsibilities		Who is responsible for the implementation of measures?		
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)			Public (EU / national / regional / local)	private			
1.4b	Measure efficiency		To follow the efficiency of enhanced microbiological degradation of DAT at the source				x	y		x	-	JP VOKA SNAGA d.o.o.		
1.6.	Communication / dissemination		Informing on the development of a pollution plume	y				x	y	/	x	-	JP VOKA SNAGA d.o.o. Ig Municipality	
Development target 2: Protect Kleče and Hrastje well fields against intrusions of Cr (VI)														
2.1. Localization of the three the most threatening Cr VI point contamination sources (C1, C2, C3)		Stegne-Hrastje												
2.1a	Locations 1-3 downstream in the nearest vicinity of the expected contamination origins C1d, C2d, C3d		To define the sources of contaminants in a range of 100 m precision	y			x		y	Drilling observation wells, groundwater and soil investigation, risk assessment	x		x	MOL
2.1b	Locations 1-3 upstream in the nearest vicinity of the expected contamination origins C1g, C2g, C3g		To define the exact location of sources of contaminants in the precision of a plot	y			x		y	Drilling observation wells, groundwater and soil investigation, risk assessment	x		x	MOL
2.1c	Locations 1-3 at the sources C1, C2, C3		To inspect the depth, geometry and emission rate of contaminant				x		y	Soil and groundwater investigations, risk assessment, remediation investigation	x		x	MOL
2.2. Targeted and continuous detection of Cr VI multipoint sources														
2.2a	Detailed identification of geometry of CrVI distribution in the "CrVI critical area"		Implement obligation for private wells and plot owners in the "CrVI critical area" to enable sampling of groundwater and soil	y				x	y	Numerical modelling and backtracking, natural attenuation capacities	-		x	MOL
2.2b	Following the CrVI contamination plumes development		To precisely follow the development of the multipoint plume towards water supply wells	y				x	y		x		-	MOL
2.3 Remediation of the three the most threatening CrVI point contamination sources (C1, C2, C3)														
2.3.	Communication / dissemination	Incentives to reduce the emissions of Cr VI into wastewater.	y				x	y	/	x		-	JP VOKA SNAGA d.o.o. MOL	
Development target 3: Protect Kleče and Hrastje well fields against increasing trends of new emerging pollutants														
3.1. Prevention of increasing trends of new emerging pollutants		Dravlje-Moste												
3.1a	Adaptation of monitoring to detect increasing trends of new emerging pollutants		To implement the monitoring of trends of new emerging pollutants in traces, in the regular monitoring system	y	x				y	Agreement on new monitoring program with monitoring contractors	x		-	JP VOKA SNAGA d.o.o. MOL ARSO
3.1b	Reporting protocol for new emerging pollutants		To implement the protocol of reporting the rising trends of pollutants to relevant sectors which can regulate the use of substances and prevent or limit spreading	y	x				y		x		-	JP VOKA SNAGA d.o.o. MOL ARSO



Development target	Action / Phase of action	Scale	Description / explanation	Beginning of action within AMIIGA project duration [y/n]	Estimated completion date			Legal / organizational limitations Is the implementation legally / organizationally possible? [y/n]	Technical / technological measures Which technical / technological measures are necessary?	Financing / responsibilities		Who is responsible for the implementation of measures?
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)			Public (EU / national / regional / local)	private	
			into the environment to stop the rising trends									
3.2. Continuous detection of excess nitrogen inputs												
3.2a	Detection of high in-situ nitrification areas		To locate the concrete sources of leakages from sewage system	y	x			y		x	-	JP VOKA SNAGA d.o.o. MOL
3.2b	Sanitation of sewerage at critical points		To sanitize the locations with the evident impact on water supply wells			x		y		x	-	JP VOKA SNAGA d.o.o. MOL
3.4. Communication / dissemination			Informing the general public and agricultural and industrial sectors of new pollutants with increasing trends and their locations	y			x	y	/	x	-	JP VOKA SNAGA d.o.o. MOL
Development target 4: Retain the landfill on present location with possibility of improved functionality of the area. Natural attenuation monitoring.												
4.1. Establishment of additional points of compliance		Barje										
4.1a	Technical adaptation of existing wells for sampling		To use existing wells instead of installation of new ones		x			y		x	-	MOL
4.1b	Adaptation of surveillance monitoring		To distinct external sources of contaminants and as a for warning system		x			y		x	-	MOL, ARSO
4.2. Natural attenuation monitoring												
4.2a	Including additional markers to detect losses from the landfill		To adapt operational monitoring with the new markers of leakage, identified within AMIIGA project	y	x			y		x	-	JP VOKA SNAGA d.o.o.
4.2b	Further detailed localization of the source of losses from the landfill		To identify micro location (point source) of the highest leakage from landfill		x			y		x	-	JP VOKA SNAGA d.o.o.
4.3. Communication / dissemination			Information about external sources of boron and from landfill	y			x	y	/	x	-	JP VOKA SNAGA d.o.o. MOL

Detailed procedure of each action is provided in special documents.

MANAGEMENT PLAN FOR NORTH WEST AREA OF MILAN

D.T3.1.3 | Pilot North West of Milan area

Final version
09 2019

AMIIGA Project

The concept of AMIIGA project originated considering that in Central European urban areas many groundwater are affected by a significant contamination caused by the long-term and widespread use of polluting substances. Moreover, groundwater contamination is a problem that goes beyond administrative boundaries of a local public authority and in Europe there is little experience on the management of groundwater contamination at the proper scale, the Functional Urban Area (FUA).

The goal of the project is then to develop a Management Strategy on groundwater contamination in Functional Urban Areas of Central Europe. To do this, a groundwater Management Plan for each of the seven AMIIGA partner pilot sites has been developed.

Lombardy Region has developed a groundwater management plan for the north-west area of Milan. The Management Plan for the pilot area integrate the activities and the plan issued for the area north-east Milan giving a more complete framework of Milan FUA.

1. Introduction

The northern part of metropolitan area of Milan, Milan FUA, has been historically characterised by a dense agglomeration of industries (automotive, refineries, chemical plants, steel and tires production) that led, over the years, to a significant contamination of soil and groundwater. Because of the high hydraulic conductivity and the high groundwater withdrawal rate, the groundwater contamination reached Milan that represents the natural drainage area of the groundwater in the north.

In the last decades Lombardy Region spent many efforts to push polluters to characterize and reclaim soil and groundwater in their sites, having important results in terms of water and soil quality at local scale. Moreover, the data provided by polluters, improving the knowledge on the distribution of groundwater contamination, highlighted the possible presence of a second form of contamination, the so named “diffuse pollution”.

The reference standard that defines the concentration thresholds for aquifers are defined by the national decree (d.lgs 152/06) and, among the others, establish the limit values for PCE (1.1 µg/l) and for TCE (1.5 µg/l).

Lombardy Region started dealing with diffuse pollution in the metropolitan area of Milan since 2013 with an important work of systematization and integration of the existing data. Based on the results of the studies carried out, in 2017, Lombardy Region delimited the first area affected by diffuse pollution and approved management measures and the discipline for remediation procedures. The area, which is north - east of Milan (and includes the City of Milan), is affected by diffuse contamination of chlorinated hydrocarbons (CHC).

Furthermore, the studies developed highlighted that several plumes that originate North - West of Milan have a significant effect on the deterioration of the groundwater quality in Milan and affect some pumping stations used for the water supply services and also the presence of a contamination characterized by low concentrations and stability during the time that seemed to be of diffuse nature.

The plumes origins, their shape and the characteristics contamination outside the plumes (extension, magnitude, temporal and spatial distribution) have been investigated under AMIIGA project. The pilot action area covers the surface of 12 Municipalities at north west of Milan (including a part of Milan).

The management plan summarizes the results of the investigations and the actions required to protect the public health and increase the awareness of the population on groundwater pollution in Milan north-west pilot area.

Definitions:

Concentrations representative for the diffuse contamination (CRDC): represent the magnitude of the diffuse contamination in the area.

Reference concentration for remediation (RCR): these values are set as new thresholds and act as new targets for the remediation in an area affected by diffuse pollution. They can differ from the CRDC, being generally lower, depending on other constraints like the results of the risk analysis.

2. The Pilot Area of Milan FUA

The pilot area covers 12 municipalities in the north-west of the Milan FUA and is about 157 km² wide; within the area live about 617.773 inhabitants.

From the hydrogeological point of view, the main aquifers interested by the contamination are the shallow aquifer and semi-confined aquifer that, in the area under study, are separated in the northernmost part and communicating in the southern portion.

The extensive dataset available for the Milan FUA, with the main hydro-chemical groundwater features, was analysed by the statistical analysis (exploratory data analysis) in order to identify the Perchloroethene (PCE) and Trichloroethene (TCE) hot spots and distinguish punctual sources from diffuse contamination.

Then, thanks to the inverse transport model (Monte Carlo analysis), it was possible to track the particles of the contaminants both forward to estimate the influence of parameter uncertainty on simulation, and backward in order to find, in a probabilistic way, the areas where the pollution takes its origin.

Moreover, the numerical transport and flow modelling (MODFLOW, MT3DMS¹) was applied to represent the groundwater flow and contaminant transport phenomena in the studied aquifers allowing to feature/depict the PCE and TCE plume extensions, the mass flow rate released from sources and their spatial evolution (from 1954 to 2017).

Diffuse groundwater contamination identified at medium-scale (FUA scale) allows public administrations to introduce specific management measures making local remediation actions more sustainable.

Finally, a multivariate analysis and factorial, in association with geostatistical analysis, was applied to the dataset in order to give a picture of the distribution and to determine the concentrations representative for the diffuse contamination. Maps of diffuse PCE and TCE contamination distribution, were provided for the shallow and the semi-confined aquifers, split in 3 levels associated to ranges of concentrations representative for the diffuse contamination.

The model tools and elaborations developed on the groundwater data base, allowed to:

- depict an extensive profile on the contamination by chlorinated solvents in the pilot Area of Milan
- detect the six main plumes of contamination, depicting their extension, feature, possible evolution in time and space and the most probable origin/historical potential sources
- distinguish both punctual sources and plumes from diffuse contamination
- draw the maps of diffuse PCE/TCE contamination distribution associated to ranges of concentrations representative for the diffuse contamination.

Given above technical outcomes representing the picture of the groundwater contamination of the pilot area, the management plan deals with the major challenges and critical issues highlighted.

3. Goals of the Management Plan and of the measures

The strategic aim of the Management Plan is to protect the public health in areas affected by diffuse pollution, control and manage diffuse contamination and of its effects on environment and increase the awareness of the population on groundwater pollution

Measures are aimed to:

- protect citizens health from eventual risks deriving from chlorinated hydrocarbons in groundwater;
- achieve the “good ecological status” of groundwater as forecasted by 2000/60/EC;
- intervene on plumes origins to stop their contribution to the contamination;

¹Harbaugh, A. W., Banta, E. R., Hill, M. C., & McDonald, M. G. (2000). MODFLOW-2000, the US Geological Survey modular ground-water model: User guide to modularization concepts and the groundwater flow process. *U.S. Geological Survey*, 121.
Zheng, C., & Wang, P. P. (1999). http://www.geo.tu-freiberg.de/hydro/vorl_portal/gw-modellierung/MT3DMS_Ref_Manual.pdf

- monitor the evolutive trend on groundwater quality;
- Increase of the population awareness on groundwater contamination.

4. Measures

To achieve the main goals, the MP the following measures are defined:

- Protection of water supply system
 - Periodical monitoring of the drinking water
 - Activation of specific treatments for potabilization of water
 - Periodical check of the efficiency of potabilization systems
- Remediation procedures and actions on plumes
 - CHC contaminated Sites
 - Periodical check on the advancement of remediation procedures and activities
 - Eventual support to the Municipalities on the procedure management
 - Actions on priority plumes
 - Periodical check on the advancement of remediation procedures and activities
 - Activation/reactivation of the administrative procedures for the remediation
 - Identification of the polluter
 - Eventual substitution of the polluter in the remediation activities
 - Eventual support to the Municipalities on the procedure management
- Management of diffuse contamination
 - **Milan City:** confirmation of the reference concentration for remediation (RCR), estimated in the previous studies and confirmed with AMIIGA. These values will be the target values for the remediation

Valori di CRB [$\mu\text{g/l}$]	Fascia Gialla	Fascia Rossa
Comune di Milano (acquifero A)	PCE 5,1	PCE8,5
	TCM 0,7	TCM 1,5

- **Other municipalities** of the pilot area: definition of a range of concentrations representative for diffuse contamination (CRDC) in the other

Municipalities. RIG decided not to adopt CRDC nor RCR for other Municipalities due to the inhomogeneity on the data distribution and transferred thresholds definition to further, deeper investigations.

- Improvement and update of the knowledge framework
 - Hydrogeological Data Base updating
 - Monitoring of groundwater quality
 - identification of a monitoring network for the plumes
 - identification of a monitoring network for the diffuse contamination
 - periodical monitoring
- Diffusion of knowledge on groundwater contamination and on enacted measures
 - Regional web page dedicated to groundwater contamination
 - Organization of dedicated events
- Monitoring on the implementation of the management measures and eventual introduction of corrective actions
 - the implementation of the forecasted measures will be guarantee by the settlement of a Technical Table, same structure and members of the RIG, in charge for the implementation of the plan and, if the case, the modify, integration, revision of the measures of the Management Plan.

5. Implementation

In the following table, the duties and responsibilities are set for each public body involved in the management plan implementation.

Lombardy Region	Municipalities	Provinces	Regional Agency for Environmental Protection	Water supply providers
Prioritizes polluted plumes in the area	Carry out procedures for the remediation of source of contamination of plumes	Give support to the identification of the polluters	Supports RL in the monitoring of performed measures	Provide data of their own monitoring networks
Coordinates local authorities for the implementation of MP measures (RIG)	Carry out remediation activities in place of the polluters (substitution)	Give support in the monitoring of the networks	Manages a specific monitoring network for plumes	Activation of specific treatments for potabilization of water
Coordinates the application of the Monitoring plan to evaluate the evolution of diffuse pollution and the effects of the intervention measures	Apply the new threshold values, the reference concentration for remediation (RCR)		Manages the monitoring network for diffuse pollution	Periodical monitoring of the drinking water



Monitors the evolution of plumes of contamination			Implements the hydrochemical Data Base of the FUA with new data	Periodical check of the efficiency of potabilization systems
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Actions will be implemented during the all life of the Management Plan and will be eventually revised after 6 year during the review of the Regional Plan for Water Protection. The RIG will be extended after AMIIGA Project, in the form of a Technical Table, aimed to monitor and coordinate the Management Plan implementation.



ACTION PLAN AFTER AMIIGA PROJECT FOR MILAN FUA

Goal	Action / Phase of action	Scale	Description/ explanation	Beginning of action within AMIIGA project duration [Y/N]	Estimated completion date - perspective			Legal / organizational limitations in the current legal state. (If the limitation occurs what steps are necessary to carry out the activities?)	Technical/ technological limitations in the current state. (If the limitation occurs what detailed measures are necessary for the action to be realistic?)	Possible financing of activities		Who should be responsible for the implementation of activities?
					short-term (till 2021)	mid-term (till 2027)	long-term (till 2033)			public (EU/ national/ regional)	private	
GOAL 1: Protection of the public health: secure good groundwater quality												
1.1 Protection of citizens health from eventual risks deriving from chlorinated hydrocarbons in groundwater												
1.1.a	Protection of water supply system											
1.1.a.1	Periodical monitoring of the drinking water	Pilot Area/FUA	The quality of the water at hydropotable stations will be monitored following the timetable given by the law prescription. Moreover, the sampling frequency will be intensified in case the contamination will increase	N	X			N	N		X	Water supply providers
1.1.a.2	Activation of specific treatments for potabilization of water	Pumping stations	Specific treatment systems are implemented to achieve the potable requirements at level of the pumping stations	N	X			N	N		X	Water supply providers
1.1.a.3	Periodical check of the efficiency of potabilization systems	Local/ Pumping stations	The efficiency of the water treatment (activated carbon filters) at hydropotable stations will be periodically checked, the timetable will be defined by the Water Supply Companies	N	X			N	N		X	Water supply providers
GOAL 2: Achievement of the good ecological status of groundwater by 2027 (2000/60/EC, PTUA)												
2.1 Achievement of the "good ecological status" of groundwater as forecasted by Dir. 2000/60/EC												
2.1.a	Remediation procedures and actions on plumes											
2.1.a.1	CHC contaminated Sites											
2.1.a.1.1	Periodical check on the advancement of remediation procedures and activities	Pilot Area	The advancement of the remediation procedures for contaminated sites liable for CHC groundwater pollution will be periodically monitored to monitor the efficiency of actions implemented (both for monitoring and remediation)	Y	X			N	N		X	Lombardy Region/ Regional Agency for the Environment/ Provinces/Municipalities



Goal	Action / Phase of action	Scale	Description/ explanation	Beginning of action within AMIIGA project duration [Y/N]	Estimated completion date - perspective			Legal / organizational limitations in the current legal state. (If the limitation occurs what steps are necessary to carry out the activities?)	Technical/ technological limitations in the current state. (If the limitation occurs what detailed measures are necessary for the action to be realistic?)	Possible financing of activities		Who should be responsible for the implementation of activities?
					short-term (till 2021)	mid-term (till 2027)	long-term (till 2033)			public (EU/ national/ regional)	private	
	2.2.a.1.2	Pilot Area	Eventual support to the Municipalities on the procedure management	N	X			N	N		X	Lombardy Region/ Regional Agency for the Environment/ Provinces/Municipalities
	2.1.a.2	Actions on priority plumes										
	2.1.a.2.1	Pilot Area	Periodical check on the advancement of remediation procedures and activities	Y	X			N	N		X	Lombardy Region/ Regional Agency for the Environment/ Provinces/Municipalities
	2.1.a.2.2	Pilot Area	Activation/reactivation of the administrative procedures for the remediation	N	X			N	N		X	Lombardy Region/ Regional Agency for the Environment/ Provinces/Municipalities
	2.1.a.2.3	Pilot Area	Identification of the polluter	N	X			N	N		X	Lombardy Region/ Regional Agency for the Environment/ Provinces/Municipalities
	2.1.a.2.4	Pilot Area	Eventual substitution of the polluter in the remediation activities	N	X			N	N		X	Lombardy Region/ Regional Agency for the Environment/ Provinces/Municipalities
	2.1.a.2.5	Pilot Area	Eventual support to the Municipalities on the procedure management	N	X			N	N		X	Lombardy Region/ Regional Agency for the Environment/ Provinces/Municipalities
2.2 Management of diffuse contamination												



Goal	Action / Phase of action	Scale	Description/ explanation	Beginning of action within AMIIGA project duration [Y/N]	Estimated completion date - perspective			Legal / organizational limitations in the current legal state. (If the limitation occurs what steps are necessary to carry out the activities?)	Technical/ technological limitations in the current state. (If the limitation occurs what detailed measures are necessary for the action to be realistic?)	Possible financing of activities		Who should be responsible for the implementation of activities?
					short-term (till 2021)	mid-term (till 2027)	long-term (till 2033)			public (EU/ national/ regional)	private	
2.2.a.1	Confirmation of the reference concentration for remediation (RCR), for Milan municipality. These values will be the target values/thresholds for the remediation.	Pilot Area	The concentration for remediation (RCR), that were estimated in the previous studies and have been confirmed with AMIIGA project studies, will be confirmed (thus adopted) for Milan municipality. These values will be the target values/thresholds for the remediation.	Y	X			N	N	-	-	Lombardy Region/RIG
2.2.a.2	Definition of a range of concentrations representative for diffuse contamination (CRDC) in the other Municipalities.	Pilot Area/FUA	Currently RIG decided not to adopt CRDC nor RCR for other Municipalities due to the inhomogeneity on the data distribution and transferred thresholds definition to further, deeper investigations The RIG will evaluate the new elaborations and propose concentrations representative for the diffuse contamination (CRDC)	Y	X			N	N	X		Lombardy Region/RIG
2.3 Improvement and update of the knowledge framework												
2.3.a	Hydrogeological Data Base updating											
2.3.a.1	Update and upgrade of the hydrochemical Databases	FUA	The new monitoring data and that of eventual new piezometers/wells will be integrated in the existing Databases	Y		X		N	N	X		Regional Agency for the Environment
2.3.b	Monitoring the quality of groundwater											
2.3.b.1	Identification of a monitoring network for the plumes	Pilot Area	A specific network of piezometers/wells suitable to monitor the contamination of the main plumes and their evolution in time will be defined	N	X			N	N	X		Lombardy Region/Regional Agency for the Environment/RIG
2.3.b.2	Identification of a monitoring network for diffuse contamination	Pilot Area	A specific network of piezometers/wells suitable to monitor the diffuse contamination and its evolution in time will be defined	Y	X			N	N			Lombardy Region/Regional Agency for the Environment/RIG



Goal	Action / Phase of action	Scale	Description/ explanation	Beginning of action within AMIIGA project duration [Y/N]	Estimated completion date - perspective			Legal / organizational limitations in the current legal state. (If the limitation occurs what steps are necessary to carry out the activities?)	Technical/ technological limitations in the current state. (If the limitation occurs what detailed measures are necessary for the action to be realistic?)	Possible financing of activities		Who should be responsible for the implementation of activities?
					short-term (till 2021)	mid-term (till 2027)	long-term (till 2033)			public (EU/ national/ regional)	private	
	2.3.b.3	Periodical monitoring of the networks	Pilot Area	The networks will be monitored at least once a year to assess the evolutive trend on groundwater quality	N	X		N	N	X		Regional Agency for the Environment
GOAL 3: Increase the awareness of the population to the groundwater contamination												
3.1.	Diffusion of knowledge on groundwater contamination and on enacted measures											
	3.1.a	Upgrade and update of the Regional web page dedicated to groundwater contamination	-	The data and the results of the studies will be uploaded in the diffuse pollution section of the Regional website	N			N	N	X		Lombardy Region
	3.1.b	Organization of dedicated events	-	Specific events will be organized to ensure the proper information of the population/stakeholders	Y			N	N	X		Lombardy Region
GOAL 4: Ensuring the implementation of the necessary measures												
4.1	Settlement of a Technical Table, same structure and members of the RIG, in charge for the implementation of the plan and, if the case, the modify, integration, revision of the measures of the Management Plan											
	4.1.a	At least an annual meeting	Pilot Area	The technical table will meet at least one a year in order to evaluate the advancement and the results of the studies, to assess the effectiveness of the measures enacted and, if the case, change them	N	X				X		Lombardy Region

SITO PILOTA PIAZZALE SANTA CROCE, PARMA

MANAGEMENT PLAN

Revisione 2° semestre 2019



ABSTRACT

On January 29th 2019 was held the last RIG Workshop regarding the european project AMIIGA - Integrated Approach to management of Groundwater quality - cofinanced by the Interreg CENTRAL EUROPE program.

The participants were: all Environmental and Health Local Authority, stakeholders, University of Parma and Municipality of Parma.

During the meeting, all participants discussed about the final version of the Management Plan (MP), focused on a wide area around the pilot site of P.le Santa Croce (1.035,42 ha).

After the presentation, the RIG participants highlighted some gaps in the presented draft version, gaps that are solved in the current, final version; the gaps:

- a) deepening the activities and results of the Biological Molecular Tools and metagenomic studies;
- b) trying to use a less technical language, as the MP has to be addressed and transposed by a wide and heterogeneous audience.

At the end of the workshop, the Regional Implementation Group approved the Management Plan of the pilot site of Parma.

The general framework of the Management Plan is the following:

- 1) description of the studied area (geographical, geological and hydrogeological);
- 2) performed activities regarding AMIIGA;
- 3) state of the contamination;
- 4) state of the remediation procedure (according to Italian laws);
- 5) targets to achieve after the end of AMIIGA;
- 6) list of the needed actions to reach the targets.

The MP also:

- a) contains the Action Plan of the next activities;
- b) tries to make a list with some critical items that could appear after the end of AMIIGA project.

According to the deliverable D.T3.1.3, the Municipality of Parma formally approved the Management Plan by a specific administration deed.

▪ Studied area

The area (1.035,42 ha) studied thanks to AMIIGA's grant is in the center of the city, characterized by an high concentration of residential, trade and service industry activities; only the north and south borders characterise the transition to the rural side of the territory (Fig. 1 and 2).

The stratigraphy of the area presents a sequence of permeable (gravel, sand) and impervious (silt, clay) sedimentary layers: AMIIGA's focused on the shallow groundwater (named „Compleso acquifero A0 or A1“), the acquifer level not used for the public acqueduct (Fig. 4 and 5).

During AMIIGA, PP8 has drilled n. 7 new monitoring wells, but the studied area has been monitored with a network of n. 11 - 12 piezometers, five of which were already present before the start of the european project (Fig. 6 and 7).

▪ Contaminant situation

At the beginning of the current century, the remediation action of an old petrol station showed a PCE pollution of the shallow groundwater (up and downstream of the station), the source of which is still unknown.

During about last ten years, PP8 has performed many monitoring campaigns in the monitoring wells present in the pilot site of P.le Santa Croce (3 - 6 piezometers), showing a contamination by PCE (Fig. 3); also the samplings carried out in the AMIIGA lifetime have underlined the main presence of the PCE pollutant (Tab. 3; max value 21,28 µg/l - Italian limit value 1,1 µg/l). One of the most important targets of the project is to evaluate the presence and behavior of the contamination plumes: the processing of the groundwater numerical model is ongoing.

The highest level of PCE (tetrachloroethene) was detected in the area of the kindergarden „Arlecchino“ (Fig. 9); ARPAE SAC (the local environmental authority) established to start a remediation sub-procedure for that area: the public authorities will elaborate a risk analysis by the end of the year. For the remaining side of the studied area, a remediation procedure will continue after the end of AMIIGA, also under the guidelines of the MP.

Moreover, interesting studies were focused on the biological molecular analyses (BMT and community profiling by NGS sequencing): they have highlighted that the bacterial community present in the groundwater collected in the various piezometers along the

groundwater pathway, is mainly composed of aerobic bacteria. The samples from the most contaminated piezometers unveiled a community containing a higher percentage of methophiles belonging to different genera, all known for being endowed with methane monooxygenase.

At the end, in order to identify the possible sources of the contamination, were carried some CSIA (Compound Specific Isotope Analysis) analysis out on carbon (^{13}C) and chlorine (^{37}Cl) isotopes: the results will be available at the end of the project (thanks to PP7 contribution).

▪ Management Plan

Evaluating the results of the studies, the Regional Implementation Group decided and approved three main goals to achieve after the end of our project:

- 1) to continue the biannual sampling campaigns in the AMIIGA network; if necessary, the Local Authorities Planning Conference will be able to decide to extend the existing monitoring network (at the moment n. 11).
- 2) to elaborate a Risk Analysis for the kindergarden „Arlecchino“ area and evaluation of possible developments; according to the results, the Municipality of Parma will evaluate and implement the eventual remediation action enabled by the Italian law.
- 3) processing the groundwater numerical model to assess the presence and behavior of the contamination plumes and to identify the actual (or the remote) sources of the contamination; the points of release identification could be an important goal to share with the whole territory of the FUA. Also in this 3rd case, according to the results, the Municipality of Parma will evaluate and implement the potential remediation action.

▪ Action Plan and critical issues

Last part of the Management Plan shows a timeline of the future steps to perform and a list of critical issues that could happen during the remediation procedure managed by the criteria illustrated in the present MP. The RIG considers that the most critical point could be, in the case we will need to extend the monitoring network, the existing lack of an uniform distribution of available and well-known piezometers in the studied area: this situation would mean to find an extra source of funding.

UPGRADE (revision 2nd semester 2019)

During the summer 2019, some months after the MP formal approval (March 2019), the Municipality of Parma and the Environmental local Authorities have had some meetings to decide and plan the framework, and the activities to perform to elaborate the Risk Analysis in the Arlecchino kindergarden area.

In view of the delicacy of the area and the target (children), three new interventions have been established:

- 1) phytoscreening in the trees of the garden (by ARPAE -Environmental local Authority),
- 2) drilling 1 or 2 new monitoring wells in the «Arlecchino» area, by Parma Municipality (in the case a groundwater level will be found in the shallow soil sediment - less than 10 m deep, it will be necessary to drill 2 new piezometers)
- 3) a new sampling campaign in the old and new/next monitoring wells, by ARPAE.

Those activities will be performed in the second semester of 2019: probably, the phytocharacterisation before the end of October 2019.

Phytoscreening is a monitoring method evaluating the roots capacity to absorb VOC present in the soil or in the groundwater, and more specifically:

- PCE;
- TCE;
- BTEX;
- light hydrocarbons.



Action Plan for the City of Parma - PP8

Development target	Action / Phase of action	Scale	Description / explanation	Beginning of action within AMIIGA project duration [y/n]	Estimated completion date			Legal / organizational limitations Is the implementation legally / organizationally possible? [y/n]	Technical / technological measures Which technical / technological measures are necessary?	Financing / responsibilities		Who is responsible for the implementation of measures?
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)			Public (EU / national / regional)	private	
Development target 1: Long Term Monitoring												
1. Monitoring campaigns of the shallow groundwater		City of Parma	<p>The development of the AMIIGA project brought to the creation of n. 7 open tube piezometers installed in the shallow aquifer, 25 - 30 meters deep from the ground.</p> <p>The groundwater monitorings carried out in this network have showed the presence of some exceedances of the tabular limits for the PCE.</p> <p>The RIG decided to carry on with the monitoring</p>									
1.1a	What monitoring wells to sample		Local Authority Planning Conference has the task to decide	n	x			y	Low-flow method, according to Italian laws	x	-	Municipality of Parma
1.1b	What analytes to search		Local Authority Planning Conference has the task to decide	n	x			y		x		Municipality of Parma
Development target 2: Risk Analysis kindergarden "Arlecchino" area												
2. Evaluation of the Risk Analysis in the Arlecchino kindergarden area		In the territory of the Municipality of Parma										
2.a	Decision about the need to elaborate the Risk Analysis		The RIG and the Local Authority Planning Conference assessed and established the need to develop a specific Risk Analysis in the area of the Arlecchino kindergarden area, in consideration of the high PCE values found in the monitored piezometer (> 20µg / l)	y	x			x	According to Italian laws	x		Municipality of Parma
2.b	Evaluation the need to drill a second monitoring well		During the implementation of the Risk Analysis, the processors will evaluate the need to create a second piezometer in reference to the area in question: the local authorities will establish the potential location.	maybe	x			y	According to Italian laws	x	-	Municipality of Parma
2.c	Evaluation of developments		The local Authorities, based on the outcome of the specific Risk Analysis, will evaluate the possible developments of the remediation procedure in the chosen area.	maybe	x			y		x	-	Municipality of Parma



Development target	Action / Phase of action	Scale	Description / explanation	Beginning of action within AMIIGA project duration [y/n]	Estimated completion date			Legal / organizational limitations Is the implementation legally / organizationally possible? [y/n]	Technical / technological measures Which technical / technological measures are necessary?	Financing / responsibilities		Who is responsible for the implementation of measures?
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)			Public (EU / national / regional)	private	
Development target 3: Research the sources of the contamination (numerical modellin)												
3. Research the sources of the contamination		FUA, or, more probably, in the territory of the Municipality of Parma	The responsible sources of contamination (contaminated sites) have to be handled.									
3.a	Research the sources by the numerical modelling		The search for possible sources of contamination is one of the most important points to continue the remediation procedure of the P. le Santa Croce site: if the research will end successfully, the results may be multiple: 1) to contain the spread of contamination; 2) to decrease or control the criticality of secondary sources of contaminant diffusion; 3) identify the possible responsible for the pollution; 4) to pay the costs of remediation works by responsible for the contamination.	y	y	y		y	No measures	x		Municipality of Parma
3.a	Task of the University of Parma		The University of Parma, thanks to the mandate given by the Municipality of Parma (within the funding of the AMIIGA project), has been developing the numeric model of groundwater behavior: the hope is that, through this implementation, it will be possible to identify the potential sources of contamination (whether single or more than one) of the shallow aquifer.	y	y	y		y	No measures	x		University of parma, Municipality of Parma



MANAGEMENT PLAN

Deliverable D.T3.1.3 Pilot Novy Bydzov

Version 1
05 2019



SUMMARY

The project AMIIGA has been initiated due to the long-term and widespread use of contaminants in Central Europe urban areas, which has resulted in a significant contamination of groundwater aquifers. The goal of the project is to develop a strategic transnational management tool to deal with groundwater contamination, in order to reach the remediation targets in a reasonable time.

The focus of the technical work package 3 (WP T3) is to establish a groundwater management plan for each of the seven pilot sites, considering technical, financial and legal aspects. Partner PP4 City of Novy Bydzov has developed the groundwater management plan for the central district of the city Novy Bydzov. The goal of this deliverable is to present the management plan.

Introduction

Novy Bydzov belongs to the smaller towns in the Czech Republic, with the population of about 7,200 people. It covers the area of 3528 ha. The town was founded in 1305, originally as a royal town, and it was an important administrative centre of the Cidlina Region in the past.



Figure No.1: The aerial photo of the town centre

Industry in the city has developed in the 19th and 20th century. Industrial plants, such as machinery plants, metal cutting plants, metal foundry plants, plants for chemical treatment of metals etc., were scattered within the town and a lot of them were situated in the vicinity of residential areas. State owned enterprises were privatized in the 90s of the last century. Some industrial plants were later abandoned



or closed as a consequence of bankruptcy or economic inefficiency. The improper handling of hazardous compounds (such as chlorinated hydrocarbons, mineral oils etc.) caused during the communist period uncontrolled contamination of Quaternary aquifer. Environmental burns threaten public health, preventing residents use groundwater for drinking and utility water, complicating prepared investment projects in Novy Bydzov area and affecting the quality of surface water of the river Cidlina that represents the main drainage bases of Quaternary aquifer in region.

Project area

The working area of the pilot Novy Bydzov (9,1 ha) has been selected as the area of the main priority for performing measures to mitigate impacts of groundwater pollution on public health, surface water and the next development of the FUA. The working area was determined based on previous investigations (project FOKS - 2008-2013).

FUA Novy Bydzov is hydrogeologically delineated and extends to an area over 3750 ha (Fig. 2). FUA Novy Bydzov can represent a significant source of pollution of the river Cidlina basin which is extent in area over 176 km². The river Cidlina basin is shown in the Figure 2, the working area and FUA are then depicted in the Figure 3.

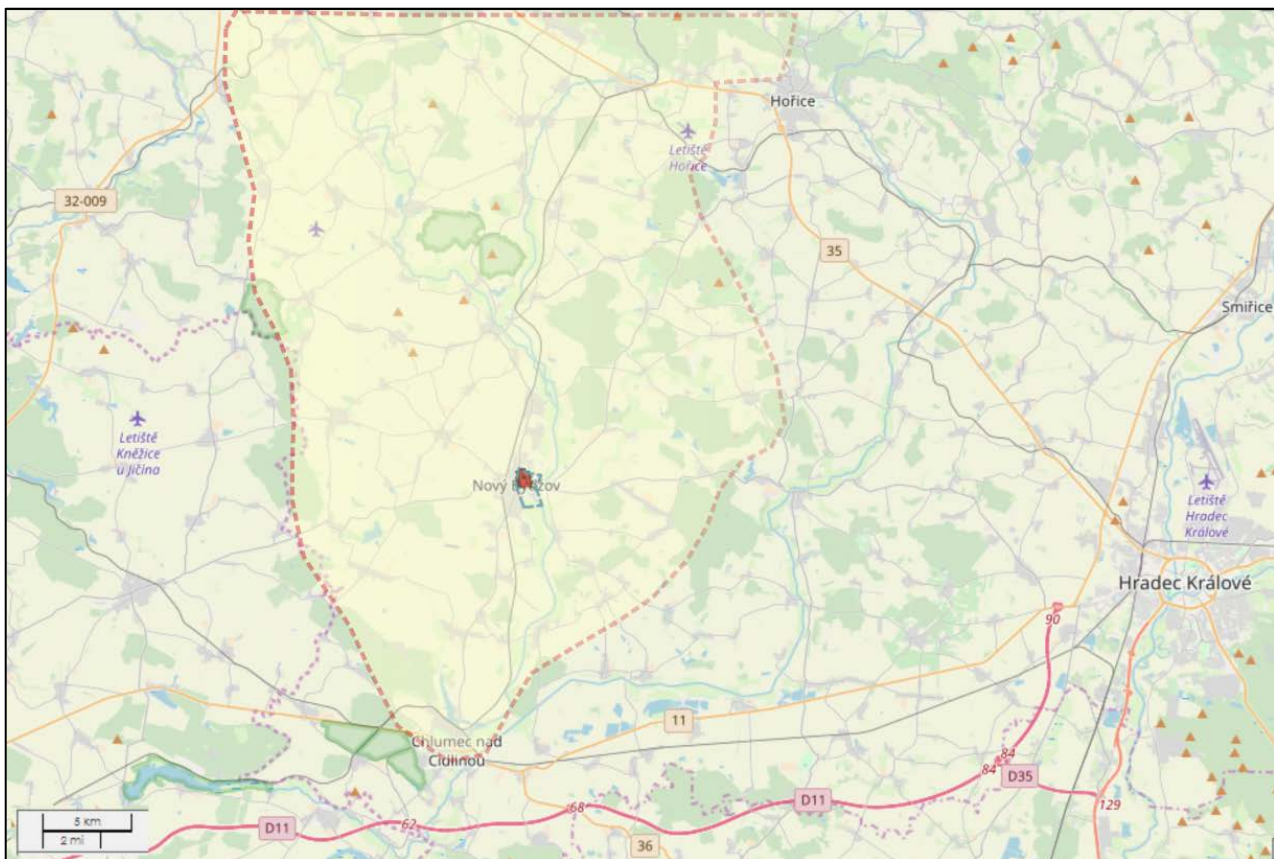


Figure No.2: Delineation of River Cidlina Basin



The working area, FUA and river basin of Cidlina are situated in similar hydrogeological conditions. The quaternary aquifer supplies the surface water of the Cidlina River. Quaternary aquifer is shallow, about 4-5 meters thick, composed of sandy gravel with the hydraulic conductivity of 10^{-4} m.s^{-1} , quaternary aquifer is delimited by an impermeable Mesozoic strata of 400 meters thickness.

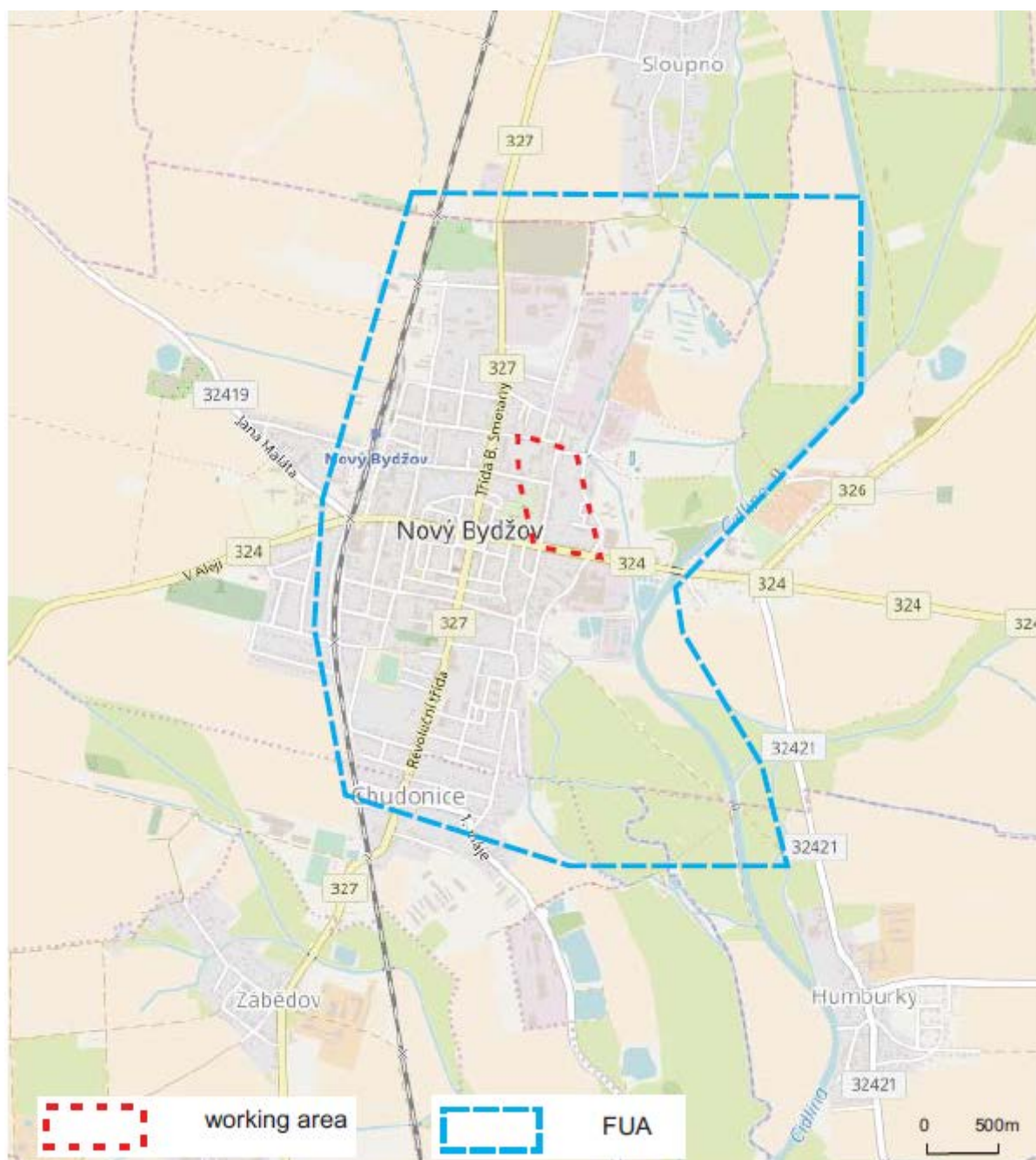


Figure No.3: Delineation of FUA Nový Bydžov and working area



Description of the initial groundwater contaminant situation

A serious health problem of a citizen living beside a ruined and closed KOVOPLAST Plant was discovered in 2007 as a consequence of drinking contaminated water from a private well. The level of groundwater contamination from chlorinated aliphatic hydrocarbons has reached thousands of micrograms per litre. The municipality of Novy Bydzov has started to undertake measures to protect the public health. Exploitation of groundwater from private wells in the area surrounding the plant was banned. Simultaneously, the municipality initiated groundwater investigation to identify precisely the source of contamination and to evaluate the range of contamination in the former plant KOVOPLAST and in its surrounding. Also other potential risks of groundwater contamination have aroused from the historical character and disposition of industrial plants in the city of Novy Bydzov. The frame of the project FOKS (2008-2013) implemented through the CENTRAL EUROPE Programme where the City participated as an associated partner has enabled to continue in identification of these hot spots, to evaluate risks and to prepare mitigation measures.

The two main tasks were performed under the FOKS project (2008-2012) in Novy Bydzov:

- assessment of health risks arising from previously identified contamination of groundwater in the premises of the former KOVOPLAST Plant (Case 1 - KOVOPLAST - Risk analysis)
- identification of other potential local points of groundwater contamination in the territory of the City Novy Bydzov, their verification and assessment with regard to possible health impacts on the population, sources of drinking water and other environmental aspects (Case 2 - Identification of potential sources of contamination in the territory of the town).

The investigation identified the main source of contamination in the area of the former KOVOPLAST Plant. The high level of contamination of the shallow aquifer with volatile organic compounds represents a risk for the health of citizens living in the vicinity of the contamination source due to the release of contaminants into indoor air and their accumulation in the environment of confined space in buildings (in cellars, living rooms etc.).

During the investigation of the Case 2 the identification of potential sources of contamination in the town were carried out. The preliminary activities had started with a comprehensive research of findings on geological inspection in the territory of Novy Bydzov and identification of potential sources of groundwater contamination in this town. On the basis of these investigations about 13 potential sources of contamination were identified (Fig. 4).

The administrative authorities of Novy Bydzov responsible for groundwater



management had selected six key contamination sources for further investigation taking into consideration potential risks for human health, groundwater protection and future development of the town.

Twelve wells were drilled through the whole thickness of the Quaternary aquifer in the vicinity of the selected potential sources for performing integral pumping tests.

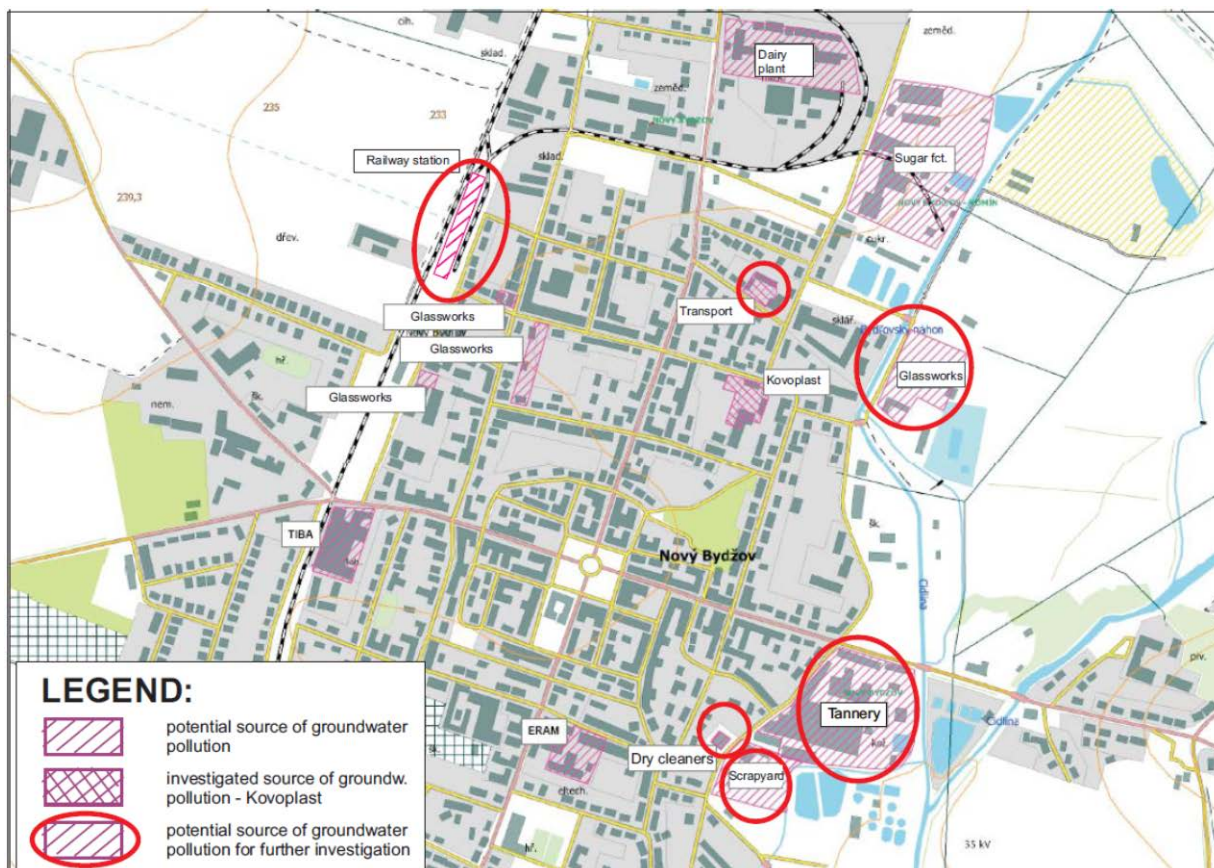


Figure No.4: Review of potential and identified sources of groundwater pollution in Nový Bydžov (FOKS 2008-2012)

Three new sources of groundwater contamination were confirmed using the IPTs, instead of the six originally identified:

- Former Transport Services- contamination of groundwater with oil substances,
- Glassworks - Sklárny Bohemia - contamination of groundwater with chlorinated hydrocarbons,
- Dry cleaning factory - contamination of groundwater with chlorinated hydrocarbons

The above-mentioned localities are presented in Fig. No.5.



A numerical model of groundwater flow was developed for the city of Novy Bydzov, which evaluated the source of pollution in the former KOVOPLAST as the most serious risk from all other sources of pollution in the territory of Novy Bydzov (Figure No.5).

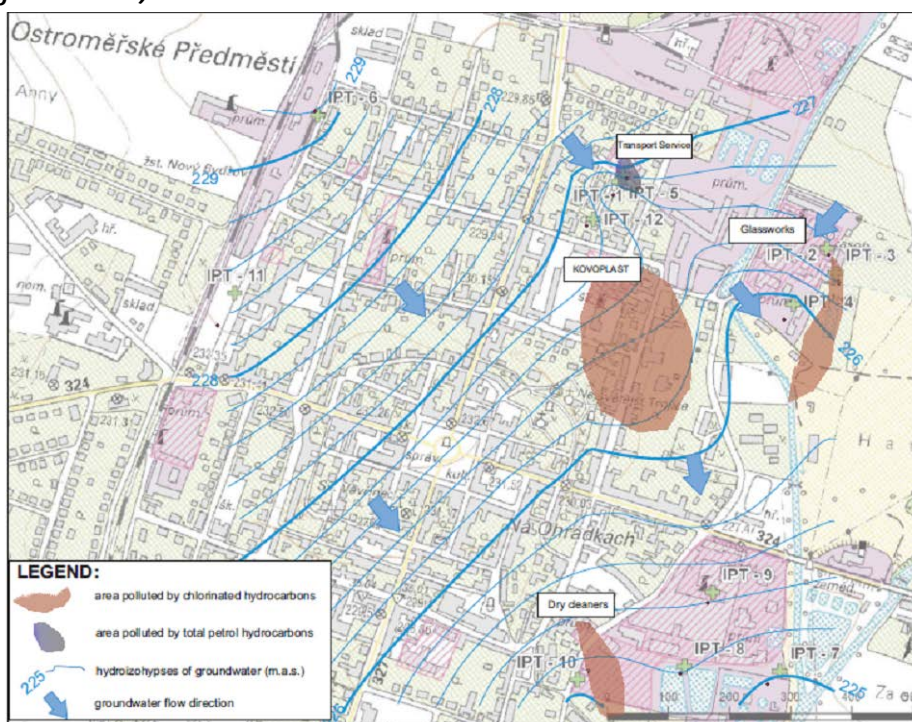


Figure No.5: Sources of groundwater contamination in Novy Bydzov (FOKS 2008-2012)

The processed analysis of risks from a source of pollution from the former plant KOVOPLAST enabled the City of Novy Bydzov to request financial support from the EU fund Operation Programme - Environment to prepare mitigation measures of contaminated land. The request for financial support was approved by the State Fund of the Environment of the Czech Republic in 2010 and the remedial activities in pilot scale have been in progress from February 2012 to December 2015.

The remedial measures were divided into two main areas:

- Detailed supplementary exploration of the polluted locality, together with a wider area, in order to specify the geological and hydrogeological situation at the locality, and to specify the distribution of polluted chlorinated aliphatic hydrocarbons for further design of remedial measures.
- Testing of suitable remedial technologies for removal of the pollution source and reduction of the pollution of groundwater with chlorinated hydrocarbons in a wider surrounding area around the source of pollution.

Two basic sets of innovative technologies suitable for decreasing the contents of chlorinated hydrocarbons in groundwater were tested in hot spot KOVOPLAST - In Situ



Chemical Oxidation - ISCO, and the method of Biological Enhanced Reductive Dehalogenation (BRD). These methods have demonstrated a high efficiency rate for removal of chlorinated hydrocarbons from groundwater in the given conditions and the operational parameters have been optimized for the full scale application. The development of groundwater pollution during the testing of innovative technologies is illustrated in the Figures No. 6.

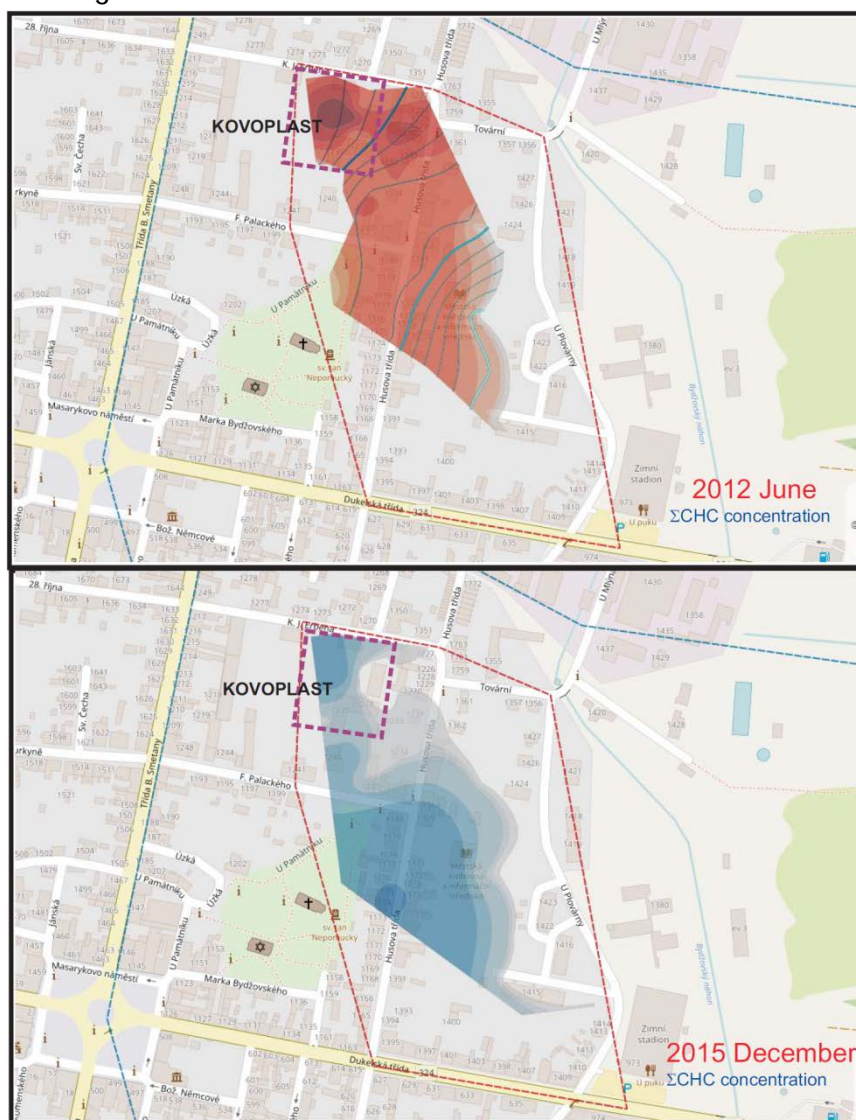


Figure No.6 Development of concentrations of suma chlorinated hydrocarbons in groundwater - the former plant KOVOPLAST and its vicinity (2012-2015)

Initial mitigation measures (2012-2015) were completed by an actualized risk analysis for assessing the impact of groundwater contamination in the surroundings of the former plant KOVOPLAST on human health and the environment (surface water of the River Cidlina). The actualized risk analysis has included the updated groundwater



transport model and has defined target limits for groundwater contamination in the area of former KOVOPLAST and in the contamination plume that shall be reached.

The project AMIIGA (under Programme Central Europe - 2016-2019) has started 6 months after termination of the initial mitigation measures (2012-2015). Five campaigns of groundwater monitoring were performed each time in 20 monitoring wells in working area, the BRD technology (Biologically Enhanced Reductive Dehalogenation) were tested with the AMIIGA project and refined in delimited zone. At the beginning of the AMIIGA project a detail investigation of soil pollution was carried out in KOVOPLAST and new hot spots were identified in KOVOPLAST area. The detail investigation confirmed occurrence of DNAPL in soil in two hot spots and defined the range and amount of soil heavily polluted by CHC in DNAPL.

The results of activities performed in AMIIGA and in previous projects determined arrangement of goals of the Management Plan for the area of the former plant KOVOPLAST and for FUA Novy Bydzov.

Goals of the Management Plan for FUA Novy Bydzov

The management plan defines the priorities for dealing with groundwater pollution in the FUA territory in order to meet the requirements for the protection of human health and the environment set by applicable legislation (the Czech legislation - Act No. 250/2000 Coll., on public health protection, Act No. 254/2001 Coll. on Water and EU directives - Water Frame Directive 2000/60/EC, Groundwater Directive 2006/118/EC).

The Management Plan for FUA Novy Bydzov defines two basic quality goals:

1. Reducing public health risks caused by pollution of the rock environment and groundwater to an acceptable level (to fulfill conditions determined in Actualized Risk Analyses).
2. Reducing the risk of endangering the surface water body in the Cidlina river basin from the polluted quaternary aquifer in Novy Bydzov according to the Water Frame Directive 2000/60/EC.

Goal No. 1: Reducing public health risks caused by pollution of the rock environment and groundwater to an acceptable level

The achieving the first goals has the highest priority of MP. Proposed measures to ensure the first goal are focused on the area of the former plant KOVOPLAST and its surrounding vicinity - the North-East part of the city. This area has been evaluated as



the highest threat for FUA groundwater quality as well as for the public health of citizens living in this residential part of the City.

Quality of groundwater in the area of former plant KOVOPLAST and in contamination plume surrounding the vicinity of KOVOPLAST in Novy Bydzov is defined in the actualized risk analysis (G-servis Praha Ltd., December 2015):

- Groundwater quality target for TCE and PCE in groundwater in the sources of contamination (the former plant KOVOPLAST) - TCE - 1400 µg/l, PCE - 700 µg/l.
- Groundwater quality target for TCE and PCE in groundwater in the area of contamination plume - TCE - 100 µg/l, PCE - 150 µg/l.

Goal No. 2: Reducing the risk of endangering the surface water body in the Cidlina river basin from the polluted quaternary aquifer in Novy Bydzov according to the Water Frame Directive 2000/60/EC.

The previous integral groundwater investigation performed with the project FOKS (2008-2013, Central Europe) has identified three additional sources of groundwater CHC contamination in the FUA Novy Bydzov. These sources have been evaluated with numerical flow and transport modeling that has not confirmed the significant impacts of pollution on human health and the environment. Groundwater pollution has negative impact on a good chemical status of quaternary aquifer as groundwater samples on selected monitoring wells exceed threshold values required for the classification of good chemical status of aquifer according to the EU Groundwater Directive 2006/118/EC and Decree No. 5/2011 Coll. on the assessment of groundwater status. Thresholds are set at 10 µg/l for TCE and 10 µg/l for PCE.

The quaternary aquifer supplies the surface water of the Cidlina River. Although no endangering of Cidlina River has not be confirmed yet and concentrations of CHC still haven't exceeded thresholds determined for a good status of surface water bodies (10 µg/l for TCE and 10 µg/l for PCE), polluted quaternary aquifer in FUA Novy Bydzov can represent a risk of pollution of the Cidlina and causes a poor status of surface water body in the Cidlina River basin.

Need for Action

Meeting the Goal No.1 is an urgent priority. The results of the actualized risk analysis (G-servis, 2015) revealed a risk to human health caused by pollution in the area of the former plant KOVOPLAST and in the North-East part of the city Novy Bydzov. This leads the city's leadership to provide political support for representatives of the City council, the Region Hradec Kralove and the Ministry of the Environment, and funding to achieve goal 1.



The priority to meet Goal No.2 was assessed by the RiG representatives significantly lower than the priority to meet Goal No.1., fulfilling the second goal is expected over the longer term after termination of corrective measures in working area of the former plant KOVOPLAST and its vicinity.

Action Plan

The action plan summarizes the required measures that have the following development targets:

- Development target 1: Reducing public health risks caused by pollution of the rock environment and groundwater to an acceptable level.
- Development target 2: Ensuring a good chemical status of quaternary aquifer in FUA Novy Bydzov according to the Water Frame Directive 2000/60/EC.

The basic characteristics of Action plan for FUA Novy Bydzov are summarized in the Annex No.1.

Development target 1: Reducing public health risks caused by pollution of the rock environment and groundwater to an acceptable level

The main development target is divided to 4 partial development targets:

- 1.1 To prevent groundwater pollution from primary source - soil pollution
- 1.2 To prevent groundwater pollution from primary source - GW pollution
- 1.3 To reduce groundwater pollution to an acceptable level determined by Risk Analysis
- 1.4 Groundwater monitoring network for North West part of Novy Bydzov

Proposed measures to fulfil the partial development targets 1.1 and 1.2 are targeted on the area of the former plant KOVOPLAST, corrective actions to achieve the partial development target 1.3 and 1.4 are focused on the North-East part of the city Novy Bydzov.

Specification of areas intended for the implementation of the partial development targets in shown at picture No.6.



Figure No.7: Specification of areas intended for the implementation of the partial goals 1a)-1c)

Based on conclusions of the actualized risk analysis, detailed soil investigation and performed Feasibility Study of proposed measures, the achievement of the partial development targets can be ensured by the following measures:

DT 1.1: To prevent groundwater pollution from primary source - soil pollution

- Detailed specification of DNAPL pollution (to identify heterogeneities in sources of contamination in the area of the former plant KOVOPLAST to specify the application wells location and of excavation operations) - Figure No.8
- Ensuring the stability of buildings in the extraction of polluted soil (The construction of protective anchorage of buildings adjacent to excavated



pitches)

- Implementation of remediation measures (soil contaminated by CHC in concentration above 50 mg/kg in the area of the former KOVOPLAST shall be excavated and remediated off site to thresholds defined by the Waste Law for landfilling of waste).



location of DNAPL polluted soils for excavation



location of MIP probes

Figure No.8: The delineation of soils polluted in NAPL

DT 1.2: To prevent groundwater pollution from primary source - GW pollution

- Network of wells for ISCO method - application and pump wells (Construction of network of wells for ISCO method - application and pump wells) - *the network of ISCO well is depicted at Figure No.9.*
- Implementation of remediation measures (Implementation of the groundwater remediation in the area of the former plant KOVOPLAST)
- Operational Monitoring of remediation efficiency and health safety (Implementation of the groundwater monitoring and indoor air monitoring during remediation in the area of the former plant KOVOPLAST)

Quaternary aquifer in the source of pollution in the area of former KOVOPLAST shall fulfil the quality target for concentration of TCE (1400 µg/l) and PCE (700 µg/l).



Figure No.9: The network of ISCO wells

DT 1.3: To reduce groundwater pollution to an acceptable level determined by Risk Analysis

- Network of wells for BRD method - application and pump wells (Construction of network of wells for BRD method - application and pump wells) - *the network of BRD well is depicted in the Figure No. 10.*
- Implementation of remediation measures (Implementation of the groundwater remediation in the contamination plume).



- Operational Monitoring of remediation efficiency and health safety (Implementation of the groundwater monitoring and indoor air monitoring during remediation in the area of contamination plume).

Quaternary aquifer in the area of contamination plume in working area shall fulfil the quality target for concentration of TCE (100 µg/l) and PCE (150 µg/l).



Figure No.10: The network of wells for BRD method - application and monitoring wells



DT 1.4: Groundwater monitoring network for North West part of Novy Bydzov

- Implementation of the monitoring activities (Implementation of the monitoring measures described in the Management Plan)
- Evaluation of the monitoring results (Compilation and evaluation of the monitoring results).

The basic groundwater monitoring network is shown in the Figure No.11



Figure No.11: The network of monitoring wells for North West part of Novy Bydzov



Development target 2: Ensuring a good chemical status of quaternary aquifer in FUA Novy Bydzov according to the Water Frame Directive 2000/60/EC

The achievement of the development target can be ensured by the following measures:

- Implementation of the monitoring activities (Monitoring of groundwater and surface water pollution development on basic monitoring network)
- Evaluation of the monitoring results (Compilation and evaluation of the monitoring results)

Remediation Concept

An achievement of the threshold determined by actualized risk analysis and a reduction of the groundwater pollution to an acceptable level in the area of the former plant KOVOPLAST and its vicinity in the North-East part of Novy Bydzov cannot be reachable without implementation of corrective measures in working area (Figure No.7).

The remediation concept has been discussed by the Regional implementation group during the AMIIGA project in August 2017 and RiG has approved the basic framework of the work. Subsequently, the remediation concept was assessed and evaluated using a procedure of feasibility study. The Czech Ministry of Environment, the Department of Environmental Damage has approved the feasibility study of remediation concept in January 2018.

The suitable methods for groundwater remediation have been tested and their efficiency has verified during project funded by Operational Program Environment (2012 - 2015) and project AMIIGA (2016 - 2019) on a laboratory and on a pilot scale. The testing has affirmed the high efficiency of proposed methods for remediation of CHC in Novy Bydzov, as well as the feasibility study of remediation concept has confirmed suitability and sustainability of proposed procedures.

The area of the former plant KOVOPLAST excluding hot spots intended for excavation is characterized by a lower level of CHC contamination in groundwater (hundreds and thousands micrograms per liters in summa CHC). It is assumed that the contamination occurred by migrating the CHCs dissolved from the hot spots. The pollutant is thus in the saturated zone in the dissolved and sorbed phase.

The In Situ Chemical Oxidation Method will be applied to reduce groundwater pollution to acceptable level (the target limits for concentration of TCE is 1400 µg/l and PCE is 700 µg/l). The application of the solution KMnO_4 (as oxidant) is designed for oxidation of CHC. The KMnO_4 solution will be distributed in the saturated zone by a network of injection and pumping wells. The layout of these boreholes is designed to achieve homogeneous distribution of KMnO_4 as well as to prevent the dissemination of KMnO_4 and contaminants out of the area of interest.



The preliminary network of injection and pumping wells is shown in the Figure No.9. The final location of the wells will be designed based on the data obtained by the remediation survey (Figure No.8).

The oxidant solution will be distributed into the ISCO application wells. The solution will be injected gravitationally to the wells in 9 rounds with period of 4 to 5 months.

The area east and south of the former plant KOVOPLAST is characterized by a lower level of CHC contamination in groundwater (from tens to thousands micrograms per liters in summa CHC). The contamination is occurring in dissolved phase of CHC.

The remediation method - Biologically Enhanced Reductive Dehalogenation (BRD) has been verified as the most perspective technology to mitigate groundwater pollution to the level accepted by the Actualized Risk Analysis (the target limits for concentration of TCE is 100 µg/l and PCE is 150 µg/l).

Conditions for stimulated reductive dehalogenation will be created by repeated application of whey to contaminated aquifers.

In the first 6 months, 3 rounds of organic media are designed with an interval of 2-3 months; in the next 24 months the application is designed for 6 rounds. In total, 9 substrate applications with a total of 120 tons of organic matter and an expected concentration of 5 - 5.5% are projected.

The preliminary network of injection and pumping wells is shown in the Figure No.10.

Monitoring Concept

The concept of monitoring is divided into two basic parts:

- Operational monitoring to control remedial actions and
- Basic monitoring to evaluate the course of corrective actions

Operational Monitoring to Control Remedial Actions

The operational monitoring will be performed separately for ISCO method and for BRD method.

In Situ Chemical Oxidation

Operational groundwater monitoring during ISCO remediation will be conducted on ISCO monitoring wells. In the framework of the operational monitoring, a total of 12 monitoring wells will be sampled. During the application of the ISCO method, monitoring will be performed before and after the application of manganese and also during the manganese application (i.e., a total of 4 rounds of monitoring will be



performed during 1 round of ISCO 2-month application).

At the beginning of the application (between 1st and 2nd round ISCO), monitoring will be performed once a month.

In total, 20 rounds of ISCO operational monitoring are planned within the ISCO application.

Biologically Enhanced Reductive Dehalogenation

Operational monitoring of groundwater during the BRD remediation will take place on the BRD monitoring wells. The first round of monitoring will be carried out before the BRD application starts. During the BRD application, the monitoring will be performed at intervals of at least 1 month after substrate application.

A total of 8 rounds of monitoring on BRD monitoring wells are planned within the BRD application.

Basic monitoring to evaluate the course of corrective actions

Groundwater Monitoring

The objective of the monitoring is to monitor the development of CHC pollution in groundwater, to efficiently manage the remediation technologies and to check their effectiveness in removing contamination and identifying any negative accompanying effects using applied methods throughout the working area.

The monitoring will be carried out on the wells of the basic monitoring network made up of newly built and existing monitoring wells and house wells.

Within the monitoring, a total of 25 monitoring wells and 19 house wells will be sampled.

The first round of monitoring will be carried out before the remediation work begins within the initial monitoring.

During the remediation monitoring of groundwater contamination will be carried out with a 4-month interval.

Demonstration of achievement the quality targets will be carried out on selected monitoring wells. Wells are designed to best cover the area of interest.

The 80/20/100 rule will be used to achieve the target remediation threshold in the area of the former plant KOVOPLAST, where 80% of the samples must be less than the PCE (700 µg/l) and TCE (1400 µg/l) and the remaining 20% of the samples must not exceed the established limit by more than 100%.

In order to demonstrate compliance with the quality targets in the area of the contamination plume (the area east and south of KOVOPLAST), the rule 80/20/100 will be applied, where 80% of the samples must be less than the PCE (150 µg/l) and TCE (100 µg/l) limits and the remaining 20% of the samples must not exceed the



established limit by more than 100%.

In total, 30 objects minimally 6 months after completion of remediation within three months interval. In total, 2 rounds of monitoring will be carried out as part of the final monitoring.

In-Door Air Monitoring

The objective of the monitoring is to monitor and to control the quality of in-door air in residential houses located above plume of groundwater contamination, as well as to identify any negative effects accompanying remediation action.

Within the monitoring, a total of 5 residential houses will be sampled for estimation of the quality of in-door air.

The first round of monitoring will be carried out before the remediation work begins within the initial monitoring.

During the remediation action the monitoring of in-door air quality will be carried out with a 1-year interval.

The final monitoring of in-door air quality will be carried out minimally 6 months after completion of remediation with aim to demonstrate compliance with the quality target thresholds (TCE < 150 µg/m³, PCE < 150 µg/m³). In total, 2 rounds of monitoring (within three months interval) will be carried out as a part of the final monitoring.

Implementation

Identification of financial sources

The total costs related to the implementation of corrective actions to reduce groundwater contamination in the former plant KOVOPLAST and its neighborhood in the North-East part of the City were estimated at 3.2 million Euros.

Finding funds is a prerequisite for implementing corrective actions and meeting management plan goals. City management, in cooperation with RIG, has explored potential opportunities to raise funds for following periods.

The most promising source of financing was evaluated from a group of operational programs in the Czech Republic to draw on support from European Union funds -

The Operational Program Environment for the period 2014 - 2020. The main objective of the Operational Program Environment (OP Environment) is to protect and ensure a quality environment for the life of the Czech population, to promote the efficient use of resources, to eliminate the negative impacts of human activity on the environment and to mitigate the impacts of climate change. The process of mitigating environmental damage is included in the OP Environment among the thematic



objectives - Objective 5 - Limitation of natural risks, floods and ecological burdens.

The problem of remediation of polluted groundwater belongs to the supported areas of the OP Environment and is included in the two priority axes of this program: Priority axis 1: Improvement of water quality and flood risk reduction Priority Axis 3: Waste and material flows, ecological burdens and risks.

The city's management decided to submit an application for support from the operational program and submitted a project to remove the environmental burden in Novy Bydzov in the spring 2018.

The timeframe of remediation works

Corrective measures will be implemented for a period of 66 months according to the schedule developed in the Management Plan. The timetable for the fulfillment of the individual phases of the project is given in the annex part of the Czech version of the Management Plan.

ANNEXES:

- Annex No.1: Action Plan for FUA Novy Bydzov
- Annex No.2: Management Plan (Czech version)
-



Annex No.1: Action Plan for FUA Novy Bydov

Development target	Action / Phase of action	Scale	Description / explanation	Beginning of action within AMIIGA project duration [y/n]	Estimated completion date			Legal / organizational limitations Is the implementation legally / organizationally possible? [y/n]	Technical / technological measures Which technical / technological measures are necessary?	Financing / responsibilities		Who is responsible for the implementation of measures?
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)			Public (EU / national / regional)	private	
Development target 1: Reducing public health risks caused by pollution of the rock environment and groundwater to an acceptable level												
1.1	To prevent groundwater pollution from primary source - soil pollution	Novy Bydov - the former plant KOVOPLAST	The actualized risk analysis has defined remediation targets for soil contamination in the area of former KOVOPLAST that shall be reached.									
1.1a	Detailed specification of DNAPL pollution		Identification of heterogeneities in sources of contamination in the area of the former plant KOVOPLAST to specify the application wells location and of excavation operations	n	x			y	Membrane Interphase Probing, soil investigation	x	-	City of Novy Bydov
1.1b	Ensuring the stability of buildings in the extraction of polluted soil		The construction of protective anchorage of buildings adjacent to excavated pitches.	n	x			y	Construction works	x	-	City of Novy Bydov
1.1c	Implementation of remediation measures		The excavation of NAPL contaminated soils in primary sources of pollution	n	x			y	Remediation technologies (excavation of contaminated soils, remediation off site)	x	-	City of Novy Bydov
1.2	To prevent groundwater pollution from primary source - GW pollution	Novy Bydov - the former plant KOVOPLAST	The actualized risk analysis has defined quality targets for groundwater contamination in the area of former KOVOPLAST that shall be reached.									
1.2a	Network of wells for ISCO method - application and pump wells		Construction of network of wells for ISCO method - application and pump wells	n	x			y	Drilling works	x	-	City of Novy Bydov
1.2b	Implementation of remediation measures		Implementation of the groundwater remediation in the area of the former plant KOVOPLAST	n	x	x		y	Remediation technologies (In situ Chemical Oxidation - ISCO)	x	-	City of Novy Bydov
1.2c	Operational Monitoring of remediation efficiency and health safety		Implementation of the groundwater monitoring and indoor air monitoring during remediation in the area of the former plant KOVOPLAST	n		x		y	Sampling and analysis of groundwater samples, sampling and analysis of indoor air	x	-	City of Novy Bydov
1.3	To reduce groundwater pollution to an acceptable level determined by Risk Analysis	North West part of Novy Bydov	The actualized risk analysis has defined quality targets for groundwater contamination in the contamination plume that shall be reached.									
1.3a	Network of wells for BRD method - application and pump wells		Construction of network of wells for BRD method - application and pump wells	y	x			y	Drilling works	x	-	City of Novy Bydov
1.3b	Implementation of remediation measures		Implementation of the groundwater remediation in the contamination plume.	y	x	x		y	Remediation technologies (Biologically enhanced Reductive Dehalogenation - BRD)	x	-	City of Novy Bydov
1.3c	Operational Monitoring of remediation efficiency and health safety		Implementation of the groundwater monitoring and indoor air monitoring during remediation in the area of contamination	n		x		y	Sampling and analysis of groundwater samples, sampling and analysis of indoor air	x	-	City of Novy Bydov



Development target	Action / Phase of action	Scale	Description / explanation	Beginning of action within AMIIGA project duration [y/n]	Estimated completion date			Legal / organizational limitations Is the implementation legally / organizationally possible? [y/n]	Technical / technological measures Which technical / technological measures are necessary?	Financing / responsibilities		Who is responsible for the implementation of measures?
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)			Public (EU / national / regional)	private	
			plume.									
Development target	Action / Phase of action	Scale	Description / explanation	Beginning of action within AMIIGA project duration [y/n]	Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)	Legal / organizational limitations Is the implementation legally / organizationally possible? [y/n]	Technical / technological measures Which technical / technological measures are necessary?	Public (EU / national / regional)	private	Who is responsible for the implementation of measures?
Development target 1: Reducing public health risks caused by pollution of the rock environment and groundwater to an acceptable level												
1.4	Groundwater monitoring network for North West part of Novy Bydzov	North West part of Novy Bydzov	Monitoring of groundwater pollution development and remediation success									
1.4a	Implementation of the monitoring activities		Implementation of the monitoring measures described in the Management Plan	y	x	x		y	Sampling and analysis of groundwater samples	x	-	City of Novy Bydzov
1.4b	Evaluation of the monitoring results		Compilation and evaluation of the monitoring results	y	x	x		y	Report at the end of remediation measures in North West part of Novy Bydzov	x	-	City of Novy Bydzov
Development target 2: Ensuring a good chemical status of quaternary aquifer in FUA Novy Bydzov according to the Water Frame Directive 2000/60/EC.												
2.	Groundwater monitoring network for North West part of Novy Bydzov	FUA Novy Bydzov	Monitoring of groundwater pollution development									
2.a	Implementation of the monitoring activities		Implementation of the monitoring measures described in the Management Plan	y			x	y	Sampling and analysis of groundwater samples	x	-	City of Novy Bydzov
2.b	Evaluation of the monitoring results		Compilation and evaluation of the monitoring results	n			x	y	Report each 5 years	x	-	City of Novy Bydzov



MANAGEMENT PLAN FOR JAWORZNO FUA - ABSTRACT

WP T3, Deliverable D.T3.1.3

Final version
09.2019



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1. Introduction

The project AMIIGA - “Integrated Approach to Management of Groundwater quality in functional urban areas” is funded by the EU Interreg Central Europe program and running between September 2016 - October 2019.

The project has been initiated due to the long-term and widespread use of contaminants in Central Europe urban areas, which has resulted in a significant contamination of groundwater aquifers. The goal of the project is to develop a strategic transnational management tool to deal with groundwater contamination, in order to reach the remediation targets in a reasonable time.

WP T3 main goal is to establish a common transnational management strategy to deal with groundwater contamination, starting from the development of groundwater management plan for each of the seven pilot sites and whole FUAs, considering technical, financial and legal aspects. Groundwater management plans are planned to be a decision support tools, developed in each region with the cooperation of so-called “Regional Implementation Groups” (RIGs). Work within WP T3 package is based on the results of the pilot actions realized under WP T2 and the results of the tools developed in WP T1.

Groundwater management plan for FUA in Poland is a result of project activities and its main aim is to support an implementation of local and regional activities to improve groundwater quality and quantity status in the pilot area and whole “functional urban area” (FUA) understood as functional area of groundwater flows (groundwater body) - specifically for Homogenous groundwater body No 146 (PLGW2000146), which covers, among others, the area of the city of Jaworzno.

The plan was developed by AMIIGA project team of the Central Mining Institute and Municipality of Jaworzno (AMIIGA project partners) in cooperation with the Regional Implementation Group, created for the needs of the project. The RIG included, apart from representatives of the project partners and associated partners (Regional Directorate for Environmental Protection in Katowice (RDOŚ), Upper Silesia & Zagłębie Metropolis (GZM)¹ and Jaworzno Waterworks Ltd. (Wodociągi Jaworzno Sp. z o.o.), also representatives of Chemical Plant “Organika-Azot” S.A., the Silesian Voivodeship Office in Katowice, the Marshal's Office of the Silesian Voivodeship and communes located in the functional area, as well as representatives of institutions responsible for water and environmental management, such as the National Water Management Holding „Polish Waters” (specifically from Regional Water Management Board in Gliwice), Regional Inspectorate of Environmental Protection (WIOŚ) and Polish Geological Institute - Polish Research Institute.

The whole document has been prepared in Polish.

¹ Since 1st January 2018, when the new Metropolitan Law came into force. Till that moment (December 2017) the associated partner cooperating in AMIIGA works was Metropolitan Association of Upper Silesia.

2. Project area(s)

Functional area (FUA) Jaworzno is located in the southern Poland, in the eastern part of the Silesian Voivodeship and the north-western part of the Małopolska (Lesser Poland) Voivodeship. Jaworzno FUA covers the main part of Jaworzno and partly surrounding cities and municipalities.

The functional area covers the area of 201.9 km², covering the boundaries of JCWPd No. 146. In the functional area there are (partially) the following communes: Jaworzno, Mystowice, Sosnowiec, Bieruń, Imielin, Łędziny and Chelm Śląski (Silesian Voivodeship) and Libiąż, Chrzanów, Chelmek and the rural commune of Oświęcim (Małopolska Voivodeship). Geographical coordinates of the area: 19°07'13.702" - 19°24'04.228" and 50°03'53.689" - 50°14'51.041".

The Jaworzno FUA boundaries were established for the purposes of the AMIIGA project based on:

- the existing drinking water supply system (mainly from groundwater intakes),
- boundaries of the Homogeneous Groundwater Body No. 146 (HGB No. 146, PLGW2000146),
- hydrogeological and geological structure - due to the high sensitivity of groundwater,
- high urbanization of the area.

The location of the analyzed area is shown in the figures below

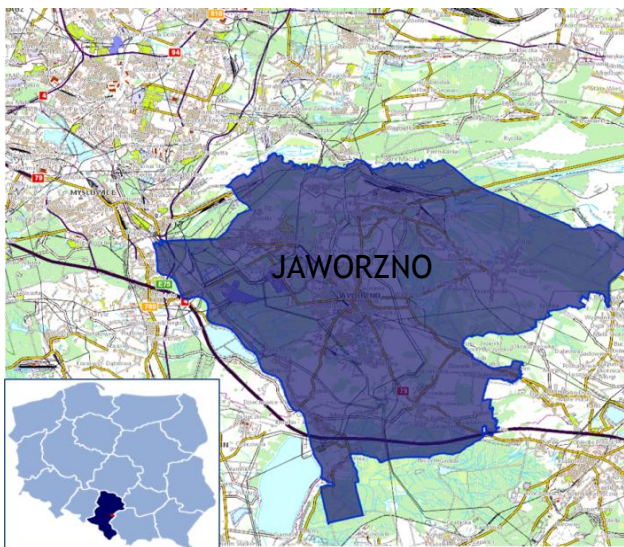


Figure 1 Location of the Jaworzno City.

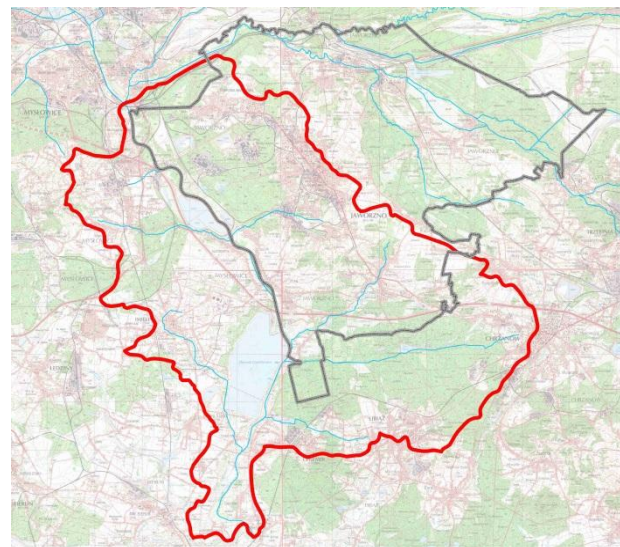


Figure 2 Range of Jaworzno FUA (red line marks the borders) with the indicated boundaries of the Jaworzno commune (gray color of borders).

Source: Own study by GIG based on
<http://mapy.geoportal.gov.pl>,
<https://commons.wikimedia.org>

Source: Own study by GIG

The functional area (JCWPd 146) is located in the Vistula basin, in the water region of Little Vistula, area administered by the Regional Water Management Board in Gliwice (RZGW Gliwice). The main watercourse in the functional area is the Przemsza River - a left-bank tributary of the



Vistula - in its lower section below the mouth of the River Biała Przemsza to the Przemsza River, and above the mouth of the Przemsza River to the Vistula.

The geology of Jaworzno FUA is dominated by the block tectonics. On the hills the Triassic sediments are present, consisting mainly of limestones and dolomites (up to approximately 150 meters thick) with only very thin and fragmented Quaternary cover. In the valleys and lower-laying areas, the very thick Carboniferous sediments - sandstones and mudstones with coal seams (few hundred meters thick) - are present under thicker (approximately 10 meters) and continuous Quaternary cover formed of sandy and clayey layers. The main Quaternary feature is post-glacial, buried valley of the Przemsza River, which cuts across both Carboniferous- and Triassic-dominated areas. The buried valley of Przemsza River is filled with thick (over 30 meters) Quaternary sediments dominated by sands and gravels). Similar, but smaller buried valleys are also present along the tributaries of the Przemsza River, e. g. Wąwolnica stream.

The groundwater aquifers in Jaworzno FUA are present in Quaternary, Triassic and Carboniferous deposits.

Quaternary porous aquifers are found in sandy layers, the thickness of which ranges from a few to over 10 meters, as well as in the post-glacial, buried valleys of the Przemsza River and the side buried valleys such as the Wąwolnica Stream valley. Hydraulic conductivity of Quaternary aquifer is around 10^{-4} m/s.

Triassic aquifers are of fractured-porous-karst character, with fractures responsible for conducting the water and pore volume being important as regards storage. Karst conduits are rather rare, but present. There are two main aquifers: Muschelkalk aquifer and Roet aquifer. Their conductivity is from $3,59 \cdot 10^{-5}$ m/s to $2,44 \cdot 10^{-4}$ m/s. The Triassic aquifers are very important for municipal water supply.

Carboniferous aquifer is found in sandstone layers of thick Carboniferous complex of sediments. It is of porous-fracture character. In many cases, there is a strong hydraulic connection between the shallowest Carboniferous, poorly cemented sandstones and the overlaying Quaternary sands and gravels.

3. Description of the flow and contaminant transport

3.1. Contamination in the scale of contaminated site (the Wąwolnica Valley and Chemical Plant "Organika-Azot" S.A.)

The toxic waste landfill in the Wąwolnica stream valley is one of the largest "ecological bombs" in the entire Silesian Voivodeship and even in the country. In the Central Landfill and the other three landfills in the old mining site of Rudna Góra, over 195 thousand tons of post-production waste (toxic to humans and other organisms) from chemical plants as well as more than half a million cubic meters of contaminated soil was gathered. Many of them are on the list of substances particularly harmful to the aquatic environment. The most hazardous poisons accumulated in the landfills are substances posing a particular threat to the environment. They include: lindane (χ -HCH) and other hexachlorocyclohexane isomers (α -HCH, β -HCH, δ -HCH, ϵ -HCH), DDT, DDD, DDE, dieldrin, endrin, aldrin, toxaphene, heptachlor and other pesticides, organic solvents (such as chlorobenzenes, phenols and chlorinated aliphatic hydrocarbons), as well as inorganic pollutants - cyanides, mercury, chromium and others. Altogether, they account for over 100 different toxic substances.

The area was considered by the Helsinki Commission as one of the most dangerous "hot spots", i.e. sources of potential contamination for the Baltic Sea.

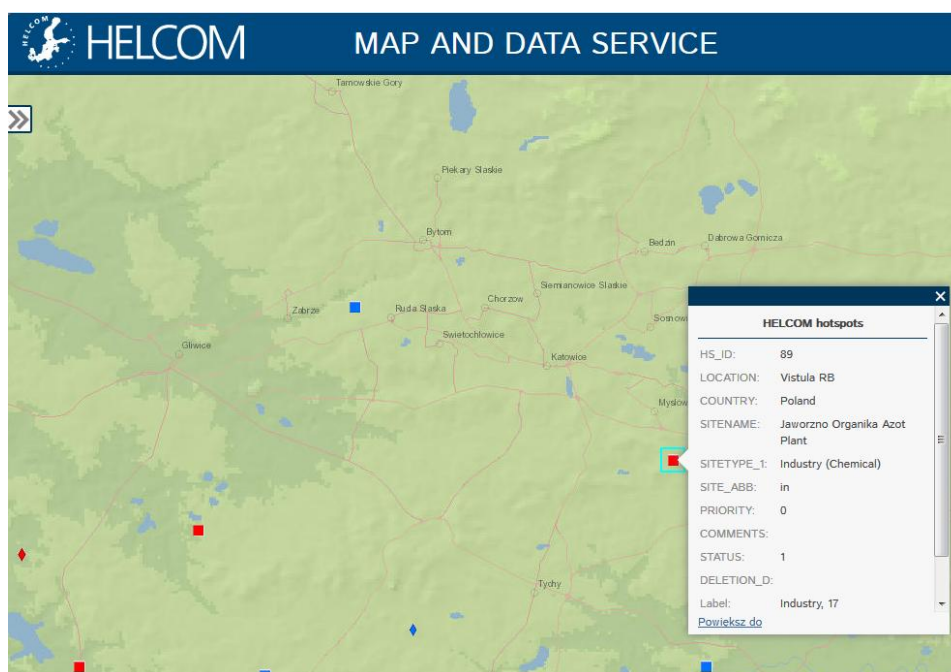


Figure 3. Fragment of the map of hot spots diagnosed by the Helsinki Commission (HELCOM)

Source: <http://www.helcom.fi/action-areas/industrial-municipal-releases/helcom-hot-spots>, date of access: 05.06.2019

3.2. Contamination in FUA scale

FUA project area = homogeneous groundwater body no. 146 (PLGW2000146) is located in Little Vistula water region, for which the Water Management Plan for Vistula Watershed (PGW) applies. The PGW (National Water Management Plan for Vistula Watershed) and its regulations are the part of legal system of water management in Poland. Principle of the plan is to maintain the water status of both surface and groundwater as "good" or improve it, at least, to this level, if it's worse. Water status is assessed according to results of water monitoring, which in the case of groundwater bodies, it is generally based on monitoring on water intakes and, in particular cases, also of groundwater wells. Quality (chemical) water status of homogeneous groundwater body 146 is assessed as 'good' according to monitoring results and periodical assessment done in accordance to this national level Water Management Plan. At the same time coal mines dewatering quantity status is assessed as 'poor' and in general groundwater body no. 146 has 'poor' status.

4. Need for action

The need for action results from the urgent necessity of solving the contamination problem around Chemical Plant "Organika-Azot" S.A. in Wąwolnica Valley located in Jaworzno FUA occurred before 1989. The contaminated site is classified as an ecological bomb in Poland and the monitoring of contamination is undertaken by Chemical Plant on the basis of a concept originated in the 90s' of the 20th century.



The important problem is also an existing contradiction between the results of monitoring conducted at different scales: (1) on the scale of local monitoring, pesticide concentration limits are exceeded several thousand times, in particular by HCH, (2) on the scale of monitoring JCWPd 146, the results indicate good chemical status of groundwater (as the existing monitoring of groundwater quality within the boundaries of the groundwater body, is based on three sampling points), (3) on the scale of the Baltic Sea drainage basin, where site of Chemical Plant "Organika-Azot" S.A. is treated by the Helsinki Commission HELCOM (Baltic Marine Environment Protection Commission) as a significant industrial source of pollution of the Baltic Sea, i.e. one of the five Polish industrial hot spots.

Therefore, the most important aspect of works is raising awareness and knowledge about the importance of the holistic management of groundwater in Jaworzno FUA on local, regional and national level. Engaging in the project works representatives of different institutions with their competences in order to solve the problem, was therefore, one of greatest achievements in the end.

5. Goals of the an action plan supporting the existing groundwater management system within Jaworzno FUA

The aim of the management plan is to establish an extensive common monitoring and control system for protection of water supplies. Development targets are:

GOAL 1: Protection of groundwater resources quality in Jaworzno FUA (homogeneous groundwater body no. 146 (PLGW2000146))

GOAL 2: Prevention of contamination migration downstream "Organika - Azot" S.A. area

GOAL 3: Prevention of groundwater quality deterioration at "Organika - Azot" S.A. location



6. Action plan

As part of the AMIIGA project, an action plan is created to support the existing groundwater management system at FUA Jaworzno. The action plan elaborated during AMIIGA project consists of the following elements:

Action 1.1. The establishment of FUA-scale monitoring system for the purpose of a warning system for groundwater intakes

As part of the AMIIGA project, concept for the regional monitoring network as a base for an including new proposed monitoring points have been developed. The location of new piezometers are proposed, which should be included in the future warning system for Triassic groundwater intakes. The location of the proposed piezometers is determined based on the emerging regional model, which was built to identify the inflow zones to the most important groundwater intakes. The developed model allowed to identify the directions of groundwater flow and the appropriate location of monitoring points. Their appropriate location allow, on the one hand, for appropriate responses in the event of threat posed to groundwater quantitative or qualitative status, and on the other hand will enable appropriate identification of the status of a homogeneous body of groundwater. The principles of functioning of groundwater monitoring operating under the future warning system are also proposed.

Action 1.2. Notification of “significant pressure” for homogeneous groundwater body No. 146 as part of update of River Basin Management Plans (aPGW) for years 2022-2027

Current (2016 - 2021) works on national level on the second update of the official Polish Water Management Plans for River Watershed (II aPGW) gives the opportunity to take into account the need of activities related to JCWPd146 preventing the deterioration of the state (chemical status) of the homogeneous groundwater body under consideration. This way, the second update of the Water Management Plans gives the opportunity to take into account the measures in relation to homogeneous groundwater body No. 146 preventing the deterioration of the state of water (the chemical status).

As part of the analyses carried out in the project, discrepancies regarding the determination of the state of homogeneous groundwater body No. 146 were identified. The most importantly - whereas on the scale of local monitoring, pesticide concentration limits are exceeded several thousand times, in particular by HCH, on the scale of homogeneous groundwater body (JCWPd 146) monitoring, the results indicate good chemical status of groundwater (because of different location of sampling points between local and official, national level monitoring).

In the course of the AMIIGA project, the Jaworzno City Hall, in an official letter of 27 May 2019², submitted a “significant pressure” on JCWPd 146 to the President of National Water Management Holding “Polish Waters”, as part of the official update of the PGW. In the next

² With explanations, including the results of analyses done

step, a list of specific proposals for actions to be undertaken are to be introduced into the Water Management Plan for the Vistula Watershed in relation to JCWPd 146 will be developed.

Reporting of significant pressure and indication of activities such as: reduction of environmental objectives, increase of the scope of monitoring, taking corrective actions will be a legal tool facilitating the implementation of activities.

Action 2.1. The reorganization of groundwater monitoring network around Chemical Plant “Organika-Azot” S.A.

As part of the AMIIGA project, the concept of groundwater monitoring was elaborated.

plumes monitoring concept includes various available monitoring points („Organika-Azot” S.A. monitoring network, FOKS wells and piezometers, mining company’s piezometers, AMIIGA new piezometers). The change of points within currently functioning „Organika-Azot” monitoring network (local monitoring which is carried out around the storage sites of Chemical Plant “Organika-Azot” S.A.) is proposed as a result of a local model mapping the extent of the contamination of groundwater with pesticides downstream of Chemical Plant “Organika-Azot” S.A. The proposition included removal from the monitoring network some of piezometers indicated in documents from the 90s of 20th century, which now are faulty (due to their too low depth, notoriously no groundwater is observed, or their amount for research is insufficient). In exchange for these points, it is proposed to include wells and piezometers built within the FOKS and AMIIGA projects for official monitoring of „Organika-Azot” S.A. Additionally the modernization concept covers the change in the scope with new compounds, in order to make it more reliable.

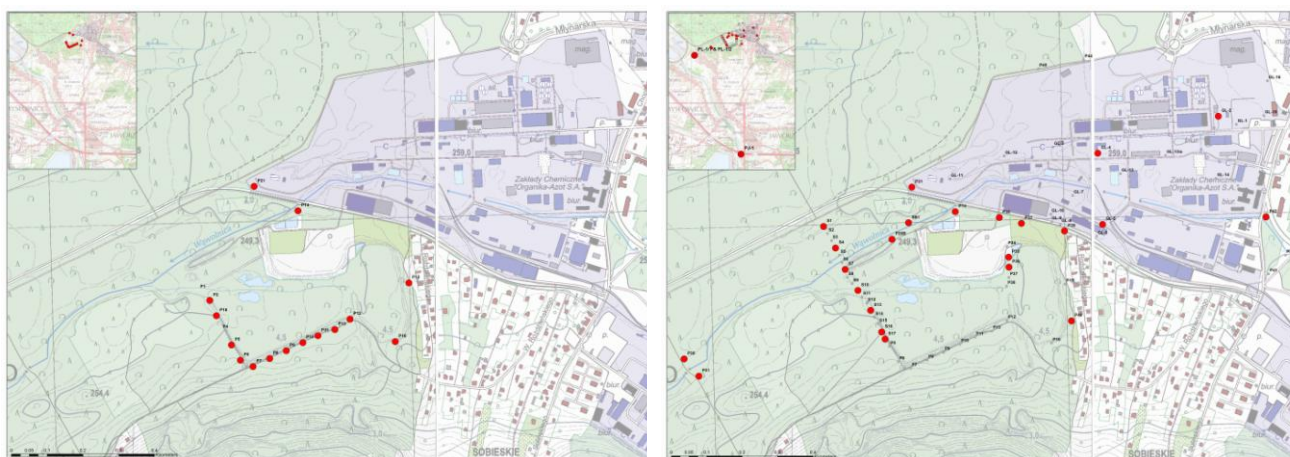


Figure 4. Existing (left) and proposed (right) monitoring network

Source: GIG team own study, AMIIGA project archive

Action 2.2. Monitoring data management for the needs of environmental institutions

A number of institutions is involved in groundwater management, with the National Water Management Holding „Polish Waters” playing a key role (including the Regional Water Management Boards (RZGW). For the groundwater management system, it is extremely important that RZGW use data on the quality and quantity of groundwater provided by other institutions. The existing monitoring network focuses primarily on existing groundwater intakes.



The result is that the information about the poor condition of groundwater appears only when there are quantitative and qualitative shortages on the intakes. Also on the basis of these data, the status of water bodies in groundwater is assessed. This leads to a situation where the condition of waters is assessed as good, despite the fact that in the area of the water body there is a source of pollution (or more sources) causing a significant reduction in water quality.

Action 2.3. The reactivation and functioning of an advisory group for the hazardous waste from Chemical Plant “Organika-Azot” S.A. in Jaworzno (so called “ecological bomb”)

As a result of the AMIIGA project, an advisory group for the contaminated area of so called ecological bomb in Jaworzno at the Marshal Office of the Silesian Voivodeship will be reactivated, connecting various specialists, representatives of different departments of the Marshal's Office, Jaworzno Municipality and from institutions dealing with environmental protection and researchers.

Its main tasks should include lobbying for changes in law that would enable them to conduct remedial actions on contaminated sites in the Wąwolnica valley (including special act for contaminated site), as well as coordination of further works.

Action 3.1. The proposal of legal solutions (special act), including the establishment of a limited purpose company to solve the problem of ecological bombs.

Within AMIIGA project duration, a draft of special act with special rules for the removal of pollutants that were particularly hazardous to the environment that occurred before 1989 has been elaborated. The need of elaboration of such an act has resulted from incorrect legal regulations preventing remediation activities. The proposal of the special act was sent to the Ministry of the Environment in 2017. In next steps, this draft of special act should be consulted with Advisory group at the Marshal Office of the Silesian Voivodeship (see action 3.1). The draft of the mentioned special law should also be consulted with representatives of Tarnowskie Góry and Bydgoszcz - cities also dealing with the historical contamination.

Action 3.2. Carrying out actions reducing the impact of the identified groundwater contamination plume

Within AMIIGA project, a bioreactive semi-permeable passive barrier in the area of groundwater contamination with pesticides downstream the Chemical Plant “Organika-Azot” S.A. in the Wąwolnica valley was built. The barrier was filled with active material, which has been additionally inoculated with specially selected microorganisms capable of decomposing contaminants from groundwater.

As part of AMIIGA project, the GIG team has developed a concept and is currently monitoring the work of the existing pilot bioreactivity barrier implemented in the region of Chemical Plant “Organika-Azot” S.A. The task is carried out on an ongoing basis as part of the AMIIGA project and should be continued by the Municipality of Jaworzno in the future (including wetlands systems within LIFEPOPWAT project, starting since January 2020).

Action 3.3. Conducting remediation activities on pollution hot spot - continuation of activities resulting from the technical documentation for reclamation /remediation of contaminated sites in the valley of the Wąwolnica stream (WATS)

The remediation concept is based on the Variant Technical and Environmental Analysis (WATS³) carried out by GIG in 2015 at the request of Jaworzno Municipality as part of the project titled "Activities aimed at solving the problem of hazardous waste accumulated in the valley of the Wąwolnica stream in Jaworzno - stage 1".

During the analysis of archival materials and field vision, as well as using the output of the FOKS project, characteristic areas of key pollutants and accumulations of waste resulting in emissions of Persistent Organic Pollutants (POPs) to the environment were identified. They are schematically presented in Figure 5.



Figure 5. Remediation plan for Central landfill „Rudna Góra”

Source: GIG own elaboration during AMIGA Project - 2018, strongly based on the document (in Polish) Wariantowa Analiza Techniczno-Środowiskowa (WATS) pn. „Działania zmierzające do rozwiązania problemu odpadów niebezpiecznych zgromadzonych w dolinie potoku Wąwolnica w Jaworznie - etap 1”, Główny Instytut Górnictwa, Katowice 2015

Although, the technical documentation is ready, this task is currently not feasible due to existing legal obstacles. The current Polish legal system obliges the perpetrator (or landlord) - in our case Chemical Plant “Organika-Azot” S.A. (which according to the decision of the Voivodship

³ Wariantowa Analiza Techniczno-Środowiskowa (WATS) pn. „Działania zmierzające do rozwiązania problemu odpadów niebezpiecznych zgromadzonych w dolinie potoku Wąwolnica w Jaworznie - etap 1”, Główny Instytut Górnictwa, Katowice 2015 / "Variant Technical and Environmental Analysis" entitled ""Activities aimed at solving the problem of hazardous waste accumulated in the valley of the Wąwolnica Stream in Jaworzno-stage 1", Central Mining Institute, Katowice, 2015



Administrative Court are the legal successor of the "polluter") to take remedial actions related to pollution in the Wąwolnica valley. Unfortunately, at present, this small employee company has no financial opportunity to bear the consequences of the activities of its great state predecessor, which existed at that site before 1989.

7. Implementation.

The action plan elaborated during AMIIGA project is presented in the form of a structured table describing precisely phase of actions within particular goals of Management Plan including: time perspective (short-term, mid-term, long-term), legal and organizational as well as technical and technological limitations, indicating financial possibilities and responsible bodies for implementation of activities on different scales of management plan (FUA scale, scale of contaminated site, scale of groundwater contamination plume) was assigned in action plan table (see the table presented in Annex).



ANNEX - Action plan table

Available in separate file

Annex 3 ACTION PLAN AFTER AMIIGA PROJECT FOR JAWORZNO FUA

Goal	Action / Phase of action	Scale	Description/ explanation	Beginning of action within AMIIGA project duration [Y/N]	Estimated completion date - perspective			Institutions necessary for coordinating the works to be done	Limitations (legal / organizational, technical / technological, financial, other) limitations in the current legal state ¹ .	Possible sources of financing activities			Additional remarks
					short-term (till 2021)	mid-term (till 2027)	long-term (till 2033)			public (EU/national/regional)	private		
GOAL 1: Protection of groundwater quality in Jaworzno FUA (homogeneous groundwater body no. 146 (PLGW2000146))													
1.1. The establishment of FUA-scale monitoring system for the purpose of a warning system for groundwater intakes													
1.1.a	Adaptation / drilling new monitoring points	Jaworzno FUA scale	Based on the monitoring network concept developed by GIG in frame of AMIIGA project, it will be necessary to build new piezometers and / or adapt existing ones. The location of the proposed piezometers is determined based on the emerging regional model, which was built to identify the inflow zones to the most important groundwater intakes.	N	X			City of Jaworzno, Jaworzno Waterworks, Marshal's Office of the Silesian Voivodeship	Financial limitations	X			This task may be carried out on condition that co-financing is obtained for the implementation of the necessary research wells.
1.1.b	Conducting monitoring in a new reorganized groundwater monitoring network in FUA scale	Jaworzno FUA scale	It will be necessary to conduct regular research in the adapted monitoring network. The test results will serve as the basic data for the operation of an warning system for groundwater intakes.	N	X	X	X	City of Jaworzno, Jaworzno Waterworks, Marshal's Office of the Silesian Voivodeship	Financial limitations	X			
1.1.c	The agreement on operating procedures for an warning system for groundwater intakes	Jaworzno FUA scale	On the basis of the preliminary assumptions developed within AMIIGA project, the procedures for the operation of an warning system for groundwater intakes will be agreed.	N	X			City of Jaworzno, Jaworzno Waterworks, Marshal's Office of the Silesian Voivodeship	none	X			In connection with the planned resuming the activities of the Advisory Group for hazardous waste from Chemical Plant Organika-Azot S.A. S.A. in Jaworzno, at the Marshal of the Silesian Voivodeship, it should be possible to use the Advisory Group as a body to agree the rpoedures and to give opinions on remedial actions envisaged for the warning system for groundwater intakes.
1.1.d	Undertaking the prevention actions provided for a warning system for groundwater intakes in consultation with advisory group	Jaworzno FUA scale	Based on agreed procedures, prevention actions will be taken, if necessary.	N	X	X	X	City of Jaworzno, Jaworzno Waterworks, Marshal's Office of the Silesian Voivodeship	Organizational limitations ² , financial limitations	X			

¹ If the limitation occurs what steps are necessary to carry out the activities

² From organizational reasons, the Advisory Group for hazardous waste from Chemical Plant Organika-Azot S.A. S.A. in Jaworzno will be able mostly to recommend prevention actions to be undertaken.



Goal	Action / Phase of action	Scale	Description/ explanation	Beginning of action within AMIIGA project duration [Y/N]	Estimated completion date - perspective			Institutions necessary for coordinating the works to be done	Limitations (legal / organizational, technical / technological, financial, other) limitations in the current legal state ¹ .	Possible sources of financing activities			Additional remarks
					short-term (till 2021)	mid-term (till 2027)	long-term (till 2033)			public (EU/national/regional)	private		
1.2. Notification of "significant pressure" for homogeneous groundwater body No. 146 as part of update of River Basin Management Plans (aPGW) for years 2022-2027													
1.2.a	Preparation of official announcement of significant pressure for homogeneous groundwater body No. 146.	Jaworzno FUA scale	As part of the analyses carried out in AMIIGA project, discrepancies regarding the determination of the state of homogeneous groundwater body No. 146 were identified. As so far (for the needs of actualization of Water Management Plan) the review of significant pressures on the water environment has not include the problem of hot spot in the Wąwolnica valley and in the area of homogeneous groundwater body No. 146.	Y	X			City of Jaworzno	none	X			
1.2.b	Update of the provisions of the Water Management Plan for the Vistula River Basin in relation to JCWPd 146	Jaworzno FUA scale	Current (2016 – 2021) works on national level on the second update of the official Polish Water Management Plans (II aPGW) gives the opportunity to report significant pressure and indicate activities such as: reduction of environmental objectives, increase of the scope of monitoring, possible corrective actions in relation to homogeneous groundwater body No. 146 preventing the deterioration of the state of water (the chemical status).	N	X			the National Water Management Holding „Polish Waters”	none	X	X		
GOAL 2: Prevention of contamination migration downstream Organika Azot S.A. area													
2.1. The reorganization of groundwater monitoring network around Chemical Plant Organika-Azot S.A. S.A.													
2.1.a	The agreement on the scope of the groundwater monitoring network reorganization around Chemical Plant Organika- Azot S.A.	scale of groundwater contamination plume	In frame of AMIIGA project, the GIG team developed the concept of reorganization of the groundwater monitoring network around the Chemical Plant Organika- Azot S.A. The agreement on the scope of the new reorganized monitoring network with representatives of Chemical Plant Organika- Azot S.A. and the City of Jaworzno is necessary.	Y	X			Central Mining Institute (GIG), Chemical Plant Organika-Azot S.A. S.A. City of Jaworzno	none	?	?		



Goal	Action / Phase of action	Scale	Description/ explanation	Beginning of action within AMIIGA project duration [Y/N]	Estimated completion date - perspective			Institutions necessary for coordinating the works to be done	Limitations (legal / organizational, technical / technological, financial, other) limitations in the current legal state ¹ .	Possible sources of financing activities		Additional remarks
					short-term (till 2021)	mid-term (till 2027)	long-term (till 2033)			public (EU/national/regional)	private	
2.1.b	Applying to the Provincial Environmental Protection Inspectorate in Katowice and to Marshal's Office of Silesian Voivodeship for acceptance of the scope of the groundwater monitoring network around Chemical Plant Organika- Azot S.A. reorganization.	scale of groundwater contamination plume	Chemical Plant Organika Azot S.A. as an entity conducting local monitoring has to address Provincial Environmental Protection Inspectorate in Katowice as the supervising body to accept the scope of changes in the local monitoring network.	Y	X			Chemical Plant Organika-Azot S.A.	none		?	
2.1.c	Carrying out the necessary adaptations /drilling new monitoring points for the groundwater monitoring network around Chemical Plant Organika- Azot S.A.	scale of groundwater contamination plume	Chemical Plant Organika Azot S.A. as an entity conducting local monitoring will adapt existing piezometers or wells to include them in the local monitoring they carry out, or to build new monitoring points in their place, if necessary.	N	X			Chemical Plant Organika-Azot S.A.	financial limitations		X	it is necessary to consider the possibility of obtaining external financing for the change of the existing monitoring system.
2.1.d	Conducting monitoring in a new reorganized groundwater monitoring network around Chemical Plant Organika- Azot S.A.	scale of groundwater contamination plume	Chemical Plant Organika Azot S.A. will continue local groundwater monitoring in a reorganized network.	N	X	X	X	Chemical Plant Organika-Azot S.A.	financial limitations		X	
2.1.e	Complementing the scope of monitoring carried out as part of project sustainability for scientific and research purposes	scale of groundwater contamination plume		N	X	X	X	City of Jaworzno	Task possible only on the area owned by the City of Jaworzno	X		
2.2. Monitoring data management for the needs of environmental institutions												
2.2.a	Creating a tool for data collection for environmental institutions	scale of groundwater contamination plume	A number of institutions are involved in the management of groundwater, with the National Water Management Holding „Polish Waters” playing a key role (including the Regional Water Management Boards (RZGW). For the groundwater management system, it is extremely important that RZGW use data on the quality and quantity of groundwater provided by other institutions in one clear system.	N	X	X		City of Jaworzno	none	X	X	Task planned to be partially carried out within the LIFEPOPWAT project, starting in January 2020.



Goal	Action / Phase of action	Scale	Description/ explanation	Beginning of action within AMIIGA project duration [Y/N]	Estimated completion date - perspective			Institutions necessary for coordinating the works to be done	Limitations (legal / organizational, technical / technological, financial, other) limitations in the current legal state ¹ .	Possible sources of financing activities			Additional remarks
					short-term (till 2021)	mid-term (till 2027)	long-term (till 2033)			public (EU/national/regional)	private		
2.2.b	A coherent presentation of data results	scale of groundwater contamination plume		N	X	X	X	Provincial Environmental Protection Inspectorate in Katowice (WIOŚ)	none	X			
2.3. The reactivation and functioning of an Advisory Group for hazardous waste from Chemical Plant Organika-Azot S.A. in Jaworzno (so called "ecological bomb" in Jaworzno) at Marshal's Office of Silesian Voivodeship													
2.3. a	Reactivation of an Advisory Group for hazardous waste from Chemical Plant Organika-Azot S.A. in Jaworzno (so called "ecological bomb" in Jaworzno)	scale of groundwater contamination plume	An advisory group, linking persons with different specializations, representatives of different institutions dealing with environmental protection and departments.	Y	X			Marshal's Office of the Silesian Voivodeship	none	X			The Advisory Group should include representatives of the Marshal's Office of the Silesian Voivodeship (as the Host), the Municipal Office in Jaworzno, Chemical Plant Organika-Azot S.A., Polish Waters, Jaworzno Waterworks, Regional Directorate for Environmental Protection in Katowice (RDOŚ) and Chief Inspectorate for Environmental Protection (GIOŚ).
2.3. b	Reviewing, supporting and initiating investment activities aimed at preventing the spread of pollutants in the Wąwolnica valley	scale of groundwater contamination plume	The main tasks of the Advisory Group should include: reviewing and supporting the protection actions undertaken (see task 1.1.d), undertaking activities related to lobbying for changes in the law, enabling to carry out remedial actions of contaminated sites in the Wąwolnica valley, including proposing a special act (see task 3.1).	N	X	X	X	Marshal's Office of the Silesian Voivodeship	none	X			
2.3.c	Undertaking control activities of entities holding permits for waste management in the Wąwolnica Valley	scale of groundwater contamination plume		N	X	X	X	Marshal's Office of the Silesian Voivodeship, City of Jaworzno, Provincial Environmental Protection Inspectorate in Katowice (WIOŚ)	none	X			

Goal	Action / Phase of action	Scale	Description/ explanation	Beginning of action within AMIIGA project duration [Y/N]	Estimated completion date - perspective			Institutions necessary for coordinating the works to be done	Limitations (legal / organizational, technical / technological, financial, other) limitations in the current legal state ¹ .	Possible sources of financing activities			Additional remarks
					short-term (till 2021)	mid-term (till 2027)	long-term (till 2033)			public (EU/national/regional)	private		
GOAL 3: Prevention of groundwater quality deterioration at Organika Azot S.A. location													
3.1. The proposal of legal solutions (special act), including the establishment of a limited purpose company to solve the problem of "ecological bombs".													
3.1.a	Elaboration of a draft of special act with special rules for the removal of pollutants being particularly hazardous to the environment that occurred before 1989.	scale of contaminated site	Within AMIIGA duration, a draft of special act with special rules for the removal of pollutants being particularly hazardous to the environment that occurred before 1989 has been elaborated. Elaboration of a draft of special act has resulted from inadequate legal regulations preventing remediation activities.	N	X			City of Jaworzno	none	X			A draft of this special act was sent by the employees of the Jaworzno Municipal Office to the Ministry of the Environment in 2017. The draft of the said special law should also be consulted with representatives of Tarnowskie Góry and Bydgoszcz – cities also dealing with the historic contamination.
3.1.b	Consultation the proposed legal solutions with the Ministry of the Environment	scale of contaminated site		N	X			City of Jaworzno	none	X			
3.2. Carrying out actions reducing the impact of the identified groundwater contamination plume													
3.2.a	The concept of monitoring of the existing pilot bio-barrier work	scale of contaminated site	For the bio-barrier built within AMIIGA project, the concept of monitoring of the bio-barrier effectiveness was developed by the GIG team.	Y	X			Central Mining Institute (GIG)	none				
3.2.b	Monitoring of the work of the existing pilot bio-barrier	scale of contaminated site	The task is carried out on an ongoing basis as part of the AMIIGA project by GIG and should be continued by the Municipality of Jaworzno in the future	Y	X	X	X	City of Jaworzno, Central Mining Institute (GIG)	financial limitation	X			
3.2.c	Wetland systems	scale of contaminated site		N		X		City of Jaworzno, in the frame of new project	none	X	X		Task planned to be carried out within the LIFEPOPWAT project, starting in January 2020.

Goal	Action / Phase of action	Scale	Description/ explanation	Beginning of action within AMIIGA project duration [Y/N]	Estimated completion date - perspective			Institutions necessary for coordinating the works to be done	Limitations (legal / organizational, technical / technological, financial, other) limitations in the current legal state ¹ .	Possible sources of financing activities			Additional remarks
					short-term (till 2021)	mid-term (till 2027)	long-term (till 2033)			public (EU/national/regional)	private		
3.3. Conducting remediation activities on pollution hot spot - continuation of activities resulting from the technical documentation for reclamation /remediation of contaminated sites in the valley of the Wąwolnica stream (WATS)													
3.3.a	Implementation of remediation actions on the area of Chemical Plant Organika-AZOT S.A. including reactive bio-barrier of iron and coal nanoparticles with use of existing barrier wells as a control piezometers	scale of contaminated site	<p>The remediation concept is based on the Variant Technical and Environmental Analysis (WATS³) carried out by GIG in 2015 at the request of Jaworzno Municipality as part of the project titled "Activities aimed at solving the problem of hazardous waste accumulated in the valley of the Wąwolnica stream in Jaworzno - stage 1".</p> <p>During the analysis of archival materials and field vision, as well as using the output of the FOKS project, characteristic areas of key pollutants and accumulations of waste resulting in emissions of Persistent Organic Pollutants (POPs) to the environment were identified.</p>	N	X	X	X	Chemical Plant Organika-Azot S.A.	<p>Legal obstacles - "the polluter pays" principle</p> <p>Up - date of technical project, well restoration, selection and purchase of fillings</p>	?	?	<p>Although, the technical documentation is ready, this task is currently not feasible due to existing legal obstacles The current legal system obliges the perpetrator (or landlord) - in our case Chemical Plant Organika-Azot S.A. (which according to the decision of the Voivodship Administrative Court are the legal successor of the "polluter") to take remedial action related to pollution in the Wąwolnica valley. Unfortunately, at present, this small employee company has no possibilities (financial and organizational) to bear the consequences of the activities of its great state predecessor, which existed at that site before 1989.</p>	
3.3. b	Implementation of measures of reduction of pollutant concentrations directly in Wąwolnica stream	scale of contaminated site		N	X			Polish Waters, watercourse administrator	Elaboration of technical project				

³ Wariantowa Analiza Techniczno-Środowiskowa (WATS) pn. „Działania zmierzające do rozwiązania problemu odpadów niebezpiecznych zgromadzonych w dolinie potoku Wąwolnica w Jaworznie - etap 1”, Główny Instytut Górnictwa, Katowice 2015



MANAGEMENT PLAN FOR STUTTGART- FEUERBACH

D.T3.1.3 | Pilot Stuttgart-Feuerbach

Version 2
09 2019

SUMMARY

The project AMIIGA has been initiated due a significant contamination of groundwater caused by the long-term and widespread use of contaminants in Central European urban areas. The goal of the project is to develop a strategic transnational management tool to manage groundwater contamination.

The focus of the AMIIGA is to establish a groundwater management plan for each of the seven AMIIGA partner pilot sites, considering technical, financial and legal aspects. The Department for Environmental Protection of the City of Stuttgart has developed a groundwater management plan for the city district Feuerbach.

Introduction

The city district Feuerbach (Fig. 1) is historically characterized by many industries and small commercial entities, handling with hazardous substances, which led to severe soil and groundwater contamination generated over the past decades. Thus, since 1983/84, the private responsables and municipality have investigated and remediated sites in Feuerbach that are contaminated with volatile chlorinated hydrocarbons (CHC). CHCs are of particular interest as pollutants, because they are (i) persistent and mobile in the underground, (ii) spread over a large area and (iii) endanger the quality of groundwater i.e. Stuttgart's mineral springs. The integral investigation of CHC contamination in soil and groundwater of Feuerbach has been also previously supported by EU-funded projects MAGIC and FOKS.



Figure 1 City district Feuerbach.



The integral groundwater investigations for Feuerbach performed in AMIIGA 2017 and 2018 indicated that the reference values (CHC concentration < 10 µg/l and load < 20 g/d) at some sites in Feuerbach could not be fully achieved with reasonable efforts and budget. Still it was unclear whether and how the CHC contamination of Feuerbach affects the regional mineral water aquifer Muschelkalk. Unreached reference values as well as the potential influence on the mineral springs were addressed in the management plan for Stuttgart-Feuerbach. The management plan has (i) summarized the results of the integral investigation, (ii) evaluated remediation effects, (iii) developed an action plan required to ensure the good groundwater status in Stuttgart-Feuerbach and (iv) defined an integral monitoring network for controlling the remediation effect.

Project area

Feuerbach is a city district in Northern part of Stuttgart. The long-term industrial and commercial use have caused considerable soil and groundwater contamination in certain areas. This contamination hinders the necessary conversion of industrial sites into new residential areas.

The geology of Feuerbach is characterized by a multi-layered groundwater aquifer system, which is divided into the (i) Quaternary aquifer, (ii) several Gipskeuper aquifers, (iii) Lower Keuper aquifer and (iv) mineral water aquifer Muschelkalk, see Fig 2.

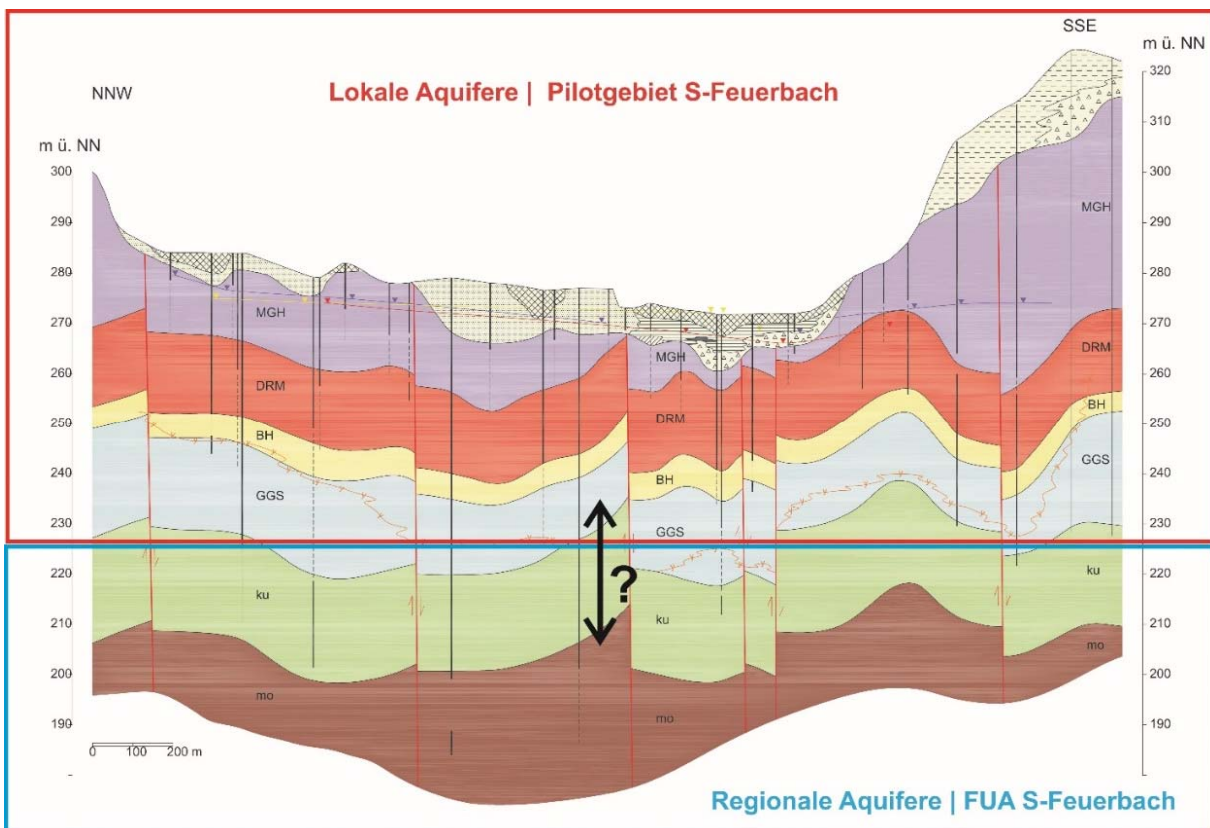


Figure 2 Geological build-up.

In the Gipskeuper, four aquifers are distinguished: Mittlerer Gipshorizont (MGH), Dunkelrote Mergel (DRM), Bochinger Horizont (BH) and Grundgipsschichten/Grenzdolomit (GGs/GD). In the Gipskeuper, the permeability and therefore the groundwater flow are heavily dependent on the lithological structure and the gypsum leaching (subrosion). A vertical groundwater or mass transfer can occur depending on pressure conditions and along tectonic faults.

Based on described hydrogeological conditions, in the project area Stuttgart-Feuerbach, two major types of areas are distinguished, dependent from the expected influence of contamination in the underground:

- × Working area is the area, where the former and present industry of Feuerbach is allocated. The working area of the pilot Stuttgart-Feuerbach has in total 530 ha and was hydrogeologically delineated in the previous project MAGIC (see Fig. 3, blue area). In total there are more than 140 known abandoned industrial sites located in the working area that are suspected and/or confirmed to emit CHCs in the groundwater of shallow aquifers. CHC inputs, which can cause a large-scale groundwater contamination and extend over several aquifers, have been detected at several sites.
- × Functional urban area (FUA) Stuttgart-Feuerbach is the area, which extends beyond the city administrative borders. Contaminated sites with CHC inputs exist both in the city and in the surrounding area. Contaminants that are localized in the city can influence the groundwater quality in the surrounding area and vice versa no matter from the administrative borders. Consequently, groundwater flow and contaminant transport in a large-scale aquifer system have to be considered also at the regional level (FUA). FUA Stuttgart-Feuerbach was delineated based on the groundwater flow in the Muschelkalk aquifer. FUA extends to an area over 4,810 ha (Fig. 3, red line).

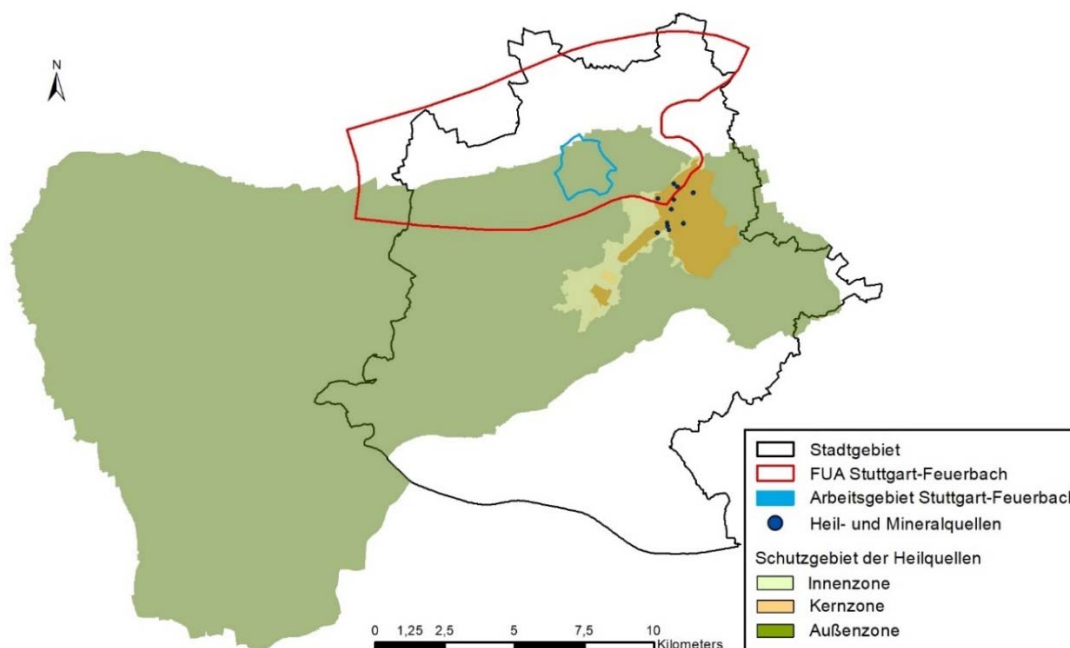


Figure 3 Project areas (working area and FUA) with mineral spring's protection zones.

Working area (blue line), FUA (red line), administrative city border (black line), mineral springs (blue dots) and mineral spring's protection zones are shown in Fig. 4.

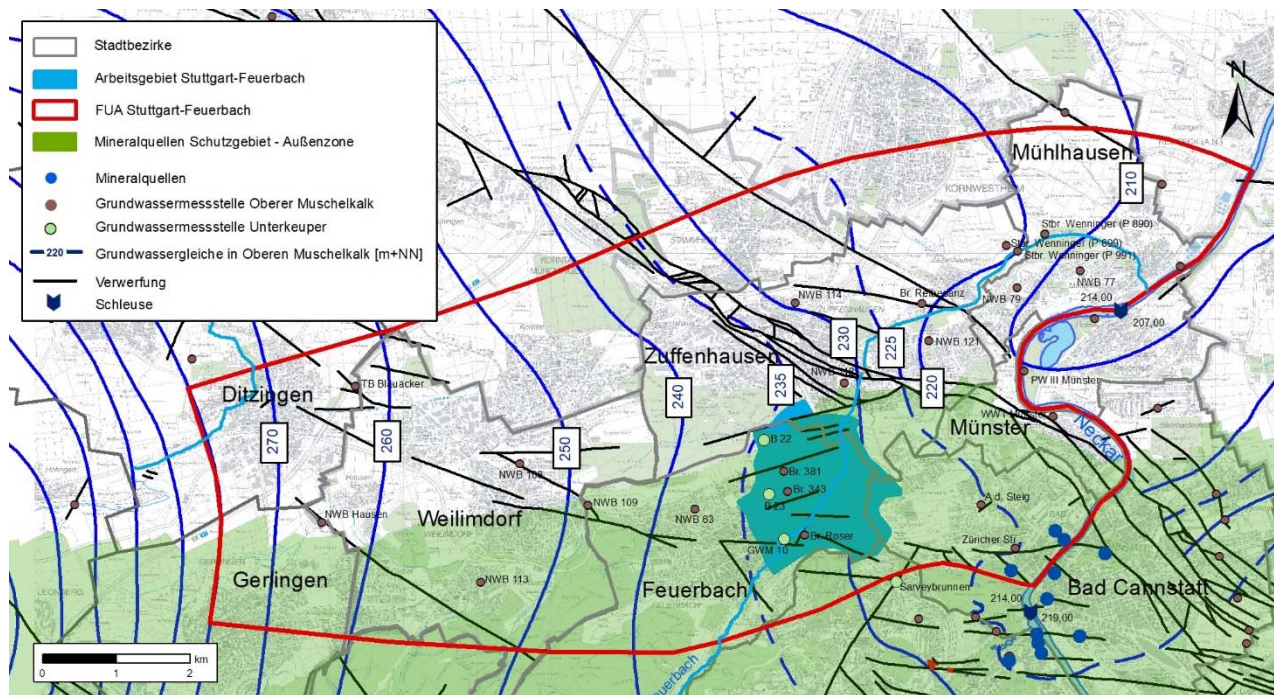


Figure 4 Project areas Stuttgart-Feuerbach: working area und FUA including the flow situation in deep aquifers.

In order to investigate the groundwater flow and contaminant situation as well as to design an integral monitoring network, three new groundwater wells were drilled:

- × AMIIGA 1, screened in Bochinger Horizont (BH), 21.3 m deep
- × AMIIGA 2, screened in Muschelkalk (mo), 94 m deep
- × AMIIGA 3, screened in Bochinger Horizont (BH), 21.1 m deep.

Groundwater Flow

Figures 3 and 4 and the geological build-up (Fig. 2) illustrate the complexity of the groundwater flow due to highly structured geological stratigraphy and numerous faults. Due to those hydraulic properties, the aquifers in the project area were divided into two aquifer units that interact with each other:

- × Local shallow aquifers (upper aquifer system) - Quaternary and Gipskeuper were investigated on the local scale of the working area
- × Regional deep aquifers (lower aquifer system) - Lower Keuper and Muschelkalk were investigated on the regional FUA scale.

The characterization of the groundwater flow for the period between 2007 and 2017 was conducted by means of (i) existing hydrogeological model, (ii) measurements of groundwater levels in the new drilled wells, (iii) available groundwater level data between



2008 and 2016 and (iv) extraction rates of the operated wells. Based on these data and information, a hydrogeological and a 3D transient flow numerical models were developed.

The main results can be summarized as follows:

- × The groundwater levels in shallow aquifers are in the falling trend since 2007. The observed drop was explained by (i) the lower groundwater recharge between 2007 and 2017 that was 15 % lower than in the decade before 2007, (ii) numerous withdrawals of groundwater and (iii) Pump & Treat remediation measures. Quaternary and MGH aquifers were completely dry in some areas. This caused a significant change in groundwater flow directions in shallow aquifers.
- × The mean drop of the groundwater level were as follows: Quaternary -3.1 m, MGH -2.7 m, DRM -2.6 m and BH -2.5 m. The major drop of groundwater levels occurred in the BH, where the level drop was more than 8 m in the southwestern part of the working area as compared to the 2007 measurements.
- × A depression in the southwest of the working area around AMIIGA 1 was detected, which produced an important effect on vertical exchange processes.
- × The aquifer BH is the major aquifer, with hydraulic conductivities of approximately 10^{-3} m/s, fed mainly by the southwest inflow from the Feuerbach valley. In the model, this water (approximately 14 l/s) flows together with the remaining water via aquifers GGS/GD and Unterkeuper (ku) into the underlying Oberer Muschelkalk (mo). This implies that the inflow from the working area in the Muschelkalk aquifer is about 10 % of the total Muschelkalk flow.
- × In contrary to the shallow aquifers, groundwater levels in deep aquifers have increased in 2017 compared to the 2007 measurements. The observed increase of the groundwater levels in deep aquifers had no impact on groundwater flow direction.
- × The numerical model results indicate that the groundwater in Muschelkalk aquifer originating from the Feuerbach area flows independently of the vertical connection towards the River Neckar.

CHC Contamination

The description of the CHC contamination for 2007 and 2017 was done by means of (i) existing hydrogeological model, (ii) performed groundwater sampling, (iii) available CHC concentration data between 2008 and 2016 from the municipal database and (iv) CHC concentration data gained from new drillings AMIIGA 1-3. Based on these data and information, a 3D transient contaminant transport numerical model was developed.

It was observed that CHCs affect significantly the groundwater quality of shallow aquifers (Quaternary and Gipskeuper aquifers). Due to their mobility, the dominant components of CHC are the tetrachloroethene (PCE) and trichloroethene (TCE). At some locations the degradation products dichloroethene (DCE) and vinyl chloride (VC) occur.



For the numerical transport modeling of CHC, the transport of all chloroethene were simulated based on stoichiometric ratios, as PCE equivalents.

The main results are:

- × The realized remediation measures at relevant contaminated sites were successful. Since 2007, there has been a significant decline in CHC emissions by more than 60 %.
- × 75 % of the still emitted CHC loads were taken from the groundwater system through ongoing remediation measures at the main contaminated sites. Therefore, maintaining these measures is of great importance for improvement of groundwater quality. Accordingly, 25 % of the emitted CHC loads reach the groundwater and via geological faults can percolate in the deeper aquifers.
- × In addition to applied groundwater remediation measures, a natural degradation and attenuation play a role in a degradation process. Both aerobic and anaerobic degradation processes are taking place in the working area. As a result, only 20 % of the emitted CHC loads that have reached the groundwater are flowing downstream.
- × The PCE equivalent concentrations in the shallow aquifers decreased significantly with depth below the ground (from 100 to 1000 µg/l in DRM, from 10 to 100 µg/l generally in BH. In case of deeper Muschelkalk aquifer, the groundwater model simulated a PCE equivalent plume, which spread from Feuerbach towards the river of Neckar. The maximal simulated concentrations for 2017 were 2 to 3 µg/l.
- × There was a significant decrease in the CHC pollution from 2007 to 2017, i.e. the CHC concentrations in 2017 were significantly lower than in 2007.
- × Based on the results of the new drilled well AMIIGA 1, it was concluded that there are unknown contaminated sites, which emit a significant PCE contamination reaching Bochniger Horizont.
- × In the well AMIIGA 2, traces of CHC were found (mostly TCE). During an integral pumping test (IPT), the PCE concentration increased to 2.4 µg/l. By evaluating the IPT results, a maximum of PCE concentrations up to approx. 12 µg/l could be calculated under certain conditions in the center of an assumed plume.
- × The results of the integral investigation showed that the vertical CHC migration within shallow aquifers occurs. If CHC contaminations reach BH, there is a high probability that the contamination percolate into the deep aquifers. Approximately 4 g/d of CHCs are percolating from BH and GGS/GD into the Muschelkalk. Therefore, CHC contamination in the working area endangers the groundwater quality of the deep aquifers and Muschelkalk. Nevertheless, the groundwater quality of Muschelkalk is good due to ongoing remediation measures, natural attenuation and dilution by 10 time thicker aquifer.



Goals of the Management Plan

The reference values for groundwater quality are defined in existing regulations. In Germany, legal regulations are primarily included in the Federal Soil Protection and Contamination Ordinance (BBodSchV) that is valid from 12.06.1999. The legal document "Grundwasserverordnung" fully corresponds to the EU Groundwater Directive from 2006. According to these documents a reference value of 10 µg/l for CHC (PCE+TCE) and a maximal CHC load of 20 g/d have been established downstream of contaminated sites (quality targets).

The regulations can be used to derive general quality targets for groundwater:

- × Priority 1: Reduction of contamination inputs from the Gipskeuper into the Muschelkalk up to 10 µg/l.
- × Priority 2: Reduction of the CHC load in the Quaternary and Gipskeuper aquifers outside contaminant sites, so that CHC concentration of 10 µg/l is not exceeded. This requirement should be applied to the main aquifer BH.
- × Priority 3: Reduction of emissions from contaminated sites to achieve the quality targets (CHC concentration <10 µg/l and CHC load <20 g/d downstream of a contaminated site).

Contaminated sites with direct influence on Muschelkalk aquifer have therefore a higher priority than sites, where CHC concentrations have only a local impact on the Quaternary and Gipskeuper aquifers.

Achievement of quality goals should be monitored by suitable "integral monitoring network" (IMN), which was defined for Stuttgart-Feuerbach.

Based on practical experience, in many cases it was not possible to reach the quality target value for CHC concentration with reasonable efforts and costs (principle of proportionality). Even 100 µg/l could often not be reached. Therefore, it is necessary to adjust and redefine a realistic and achievable target values for CHC. This could be defined based on the maximum allowed load of 20 g/d, e.g. the remediation goal was to reach 10 % of required CHC load, i.e., 2 g/d, by taking into account the principle of proportionality.

Taking into account the threat to the Muschelkalk through vertical connections of aquifers and the low observed CHC concentrations in Muschelkalk, the management plan for Stuttgart-Feuerbach primarily considered the areas, in which CHC concentration of 100 µg/l are exceeded. Firstly, it has to be achieved that no CHC concentrations higher than 10 µg/l occur in the Muschelkalk. A good groundwater status shall be ensured, if also in the Bochinger Horizont CHC concentrations of 10 µg/l are not exceeded.

Discussion

The integral investigation for 2017 proved that the remediation measures taken so far were absolutely necessary. They are still effective and necessary in order to prevent vertical percolation of CHCs to the lower aquifer system.

The reduced groundwater recharge in the upper aquifer system, which can also be considered as a consequence of climate change, has a negative effect on the groundwater balance in the Feuerbach work area. Therefore, realized Pump & Treat measures have reached their limits. A further increase of a withdrawal is only possible and reasonable to a limited extent.

The integral investigation also showed that there are still undetected pollutant sources in some areas of Feuerbach, which in some groundwater monitoring wells lead to an increase of CHC concentration compared to 2007. In these cases, investigation and possibly remediation measures are needed. Furthermore, the development of an integral monitoring network (IMN) in the Bochinger Horizont, as the main aquifer of the upper system, is technically and economically reasonable solution.

Fig. 5 and Table 1 show groundwater wells in Quaternary, MGH and DRM with concentrations above 100 µg/l as well as groundwater wells in Bochinger Horizont and GGS/GD above 10 µg/l. Table 1 also shows whether a decrease or an increase in concentration in these wells occurred, compared to 2007. Based on this information, investigation and/or remediation measures are defined for these areas. High concentrations in combination with an increase in CHC concentrations indicated an urgent need and high priority for action.

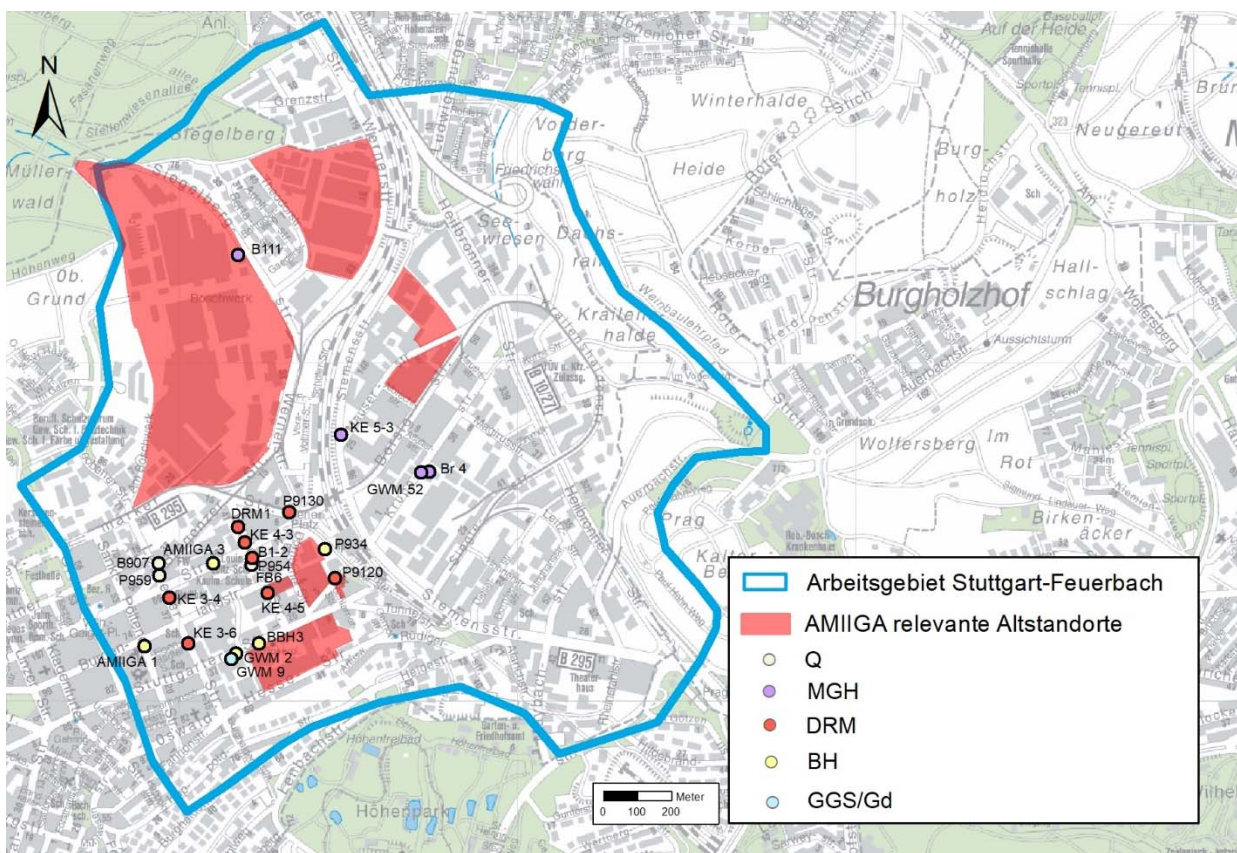


Figure 5 Monitoring wells with CHC concentration in 2017 of more than 100 µg/l in Q, MGH and DRM and more than 10 µg/l in BH und GGS/GD.

Table 1 Monitoring wells with CHC concentration in 2017 of more than 100 µg/l in quaternary (Q), Mittleren Giphshorizont (MGH) or Dunkelroten Mergeln (DRM) and more than 10 µg/l in Bochinger Horizont (BH) and Grundgipsschichten/Grenzdolomit (GGs/GD).

#	GWM	Aquifer	2007	2017	Location
1	P 954	Q	3.755 µg/l	9.440 µg/l	public area, Bludenzer Str.
2	P 959	Q	27 µg/l	105 µg/l	public area, Leobener Str.
3	B 907	Q	k.A.	3.776 µg/l	public area, Leobener Str.
4	FB 6	Q	4.712 µg/l*	2.966 µg/l	public area, Bludenzer Str.
5	Br 4	MGH	68 µg/l	122 µg/l	public area, Kruppstraße
6	B 111	MGH	33 µg/l	1.051 µg/l	downstream of contaminated site 4508
7	GWM 52	MGH	k.A.	137 µg/l	public area, Kruppstraße
8	KE 5-3	MGH	262 µg/l	137 µg/l	public area, Siemensstraße
9	P 9130	DRM	185 µg/l	547 µg/l	public area, Wiener Platz
10	B 9120	DRM	90 µg/l	119 µg/l	public area, Wiener Platz
11	B 1-2	DRM	678 µg/l	1.895 µg/l	public area, Bludenzer Str.
12	DRM 1	DRM	k.A.	112 µg/l	public area, Bludenzer Str.
13	KE 3-4	DRM	450 µg/l	110 µg/l	public area, Leobener Str.
14	KE 3-6	DRM	497 µg/l	346 µg/l	public area, Leobener Str.
15	KE 4-3	DRM	366 µg/l	148 µg/l	public area, Bludenzer Str.
16	KE 4-5	DRM	400 µg/l	210 µg/l	public area, Bludenzer Str.
17	AMIIGA 1	BH	k.A.	210 µg/l	public area, St. Pöltener Str.
	AMIIGA 1	GGs/GD	k.A.	79 µg/l	public area, St. Pöltener Str.
18	AMIIGA 3	BH	k.A.	20 bis 87 µg/l	public area, Wiener Str.
19	P 934	BH	54 µg/l	118 µg/l***	downstream of contaminated site 2430
20	GWM 8/GWM 2	BH	128 µg/l**	33 µg/l***	downstream of contaminated site 4567
21	BBH 3/BBH 4	BH	22/140 µg/l	23 µg/l /k.A.***	downstream of contaminated site 4567
22	GWM 9	GGs/GD	178 µg/l**	140 µg/l	vertical percolation or input at contaminated site 4567

k.A. = no data available

* 2011

**2010

***2019

In order to define the need for action, three levels of consideration are distinguished:

1. Upper shallow aquifers (Quaternary, MGH, DRM)

These are mainly fed by groundwater recharge, almost no lateral CHC inflows. Locally high CHC concentrations reach the underlying BH. High concentrations of CHC show that the remediation measures have not completely prevented percolation into deeper aquifers.



There is a need for action in three areas: (i) wells P 954 and FB 6, (ii) well B 907 and (iii) well B 1-2. The location and CHC concentrations are shown in Table 1 and Fig. 5.

2. Middle aquifers (Bochinger Horizont and Grundgipsschichten/Grenzdolomit)

CHCs that are not removed by remediation measures in the overlying aquifers are gathered in the Bochinger Horizont, as the main aquifer of the upper aquifer system.

Due to a high PCE concentration of 210 µg/l in the well AMIIGA 1, there is an urgent need for investigation in this area. The contamination in BH is caused by an unknown pollutant source upstream of AMIIGA 1, which has to be investigated and remediated. Furthermore, the results of the numerical modelling showed that a vertical percolation of pollutants is possible in this area up to Muschelkalk. Since, hydraulic remediation in the BH and GGS/GD is not very efficient, remediation is needed in upper layers. In BH, the integral monitoring is appropriate measure.

3. Lower deep aquifers (Unterkeuper, Muschelkalk)

The results of the numerical flow model showed that BH and GGS/GD aquifers are at least locally connected to the Muschelkalk and that a vertical percolation of CHC contaminants is possible.

Despite this vertical migration, the investigations carried out in the Mueschelkalk showed no evidence of significant CHC inputs from the working area Feuerbach. This was confirmed by CHC measurements in the downstream groundwater well, also in AMIIGA 2.

Therefore, there are no indications of any conflicts with the general quality goals and priority 1 (maximum CHC concentration of 10 µg/l) in Feuerbach. The CHC inputs at AMIIGA 1 are of local relevance and do not affect the quality of the water in the FUA.

Action Plan for Stuttgart-Feuerbach

The action plan summarizes all necessary measures, see also Annex 1. Those measures have the following development targets:

- × Minimisation of CHC inputs in the shallow aquifers by (i) continuation of the ongoing remediation measures, (ii) optimization of the danger prevention in the area of the well B 111, (iii) investigation measures at four areas (P 954 and FB 6, P 907, B 1-2 and AMIIGA 1) and (iv) detailed investigation and remediation of identified sources.
- × Integral monitoring of groundwater yield and quality by (i) integral monitoring network - monitoring in 8 wells of Bochinger Horizont, see Fig. 6; yearly water level measurements and sampling, (ii) monitoring in Muschelkalk; yearly collection of data, since other institutions perform the measurements and sampling and (iii) evaluation of monitoring results.
- × Ensuring the implementation of the necessary measures. The results will be summarized and evaluated in reports approximately each 5 years.

The detailed Action Plan with development targets, measures, responsibilities, timetables and additional remarks is given in Annex 1 “Action Plan for Stuttgart-Feuerbach”.

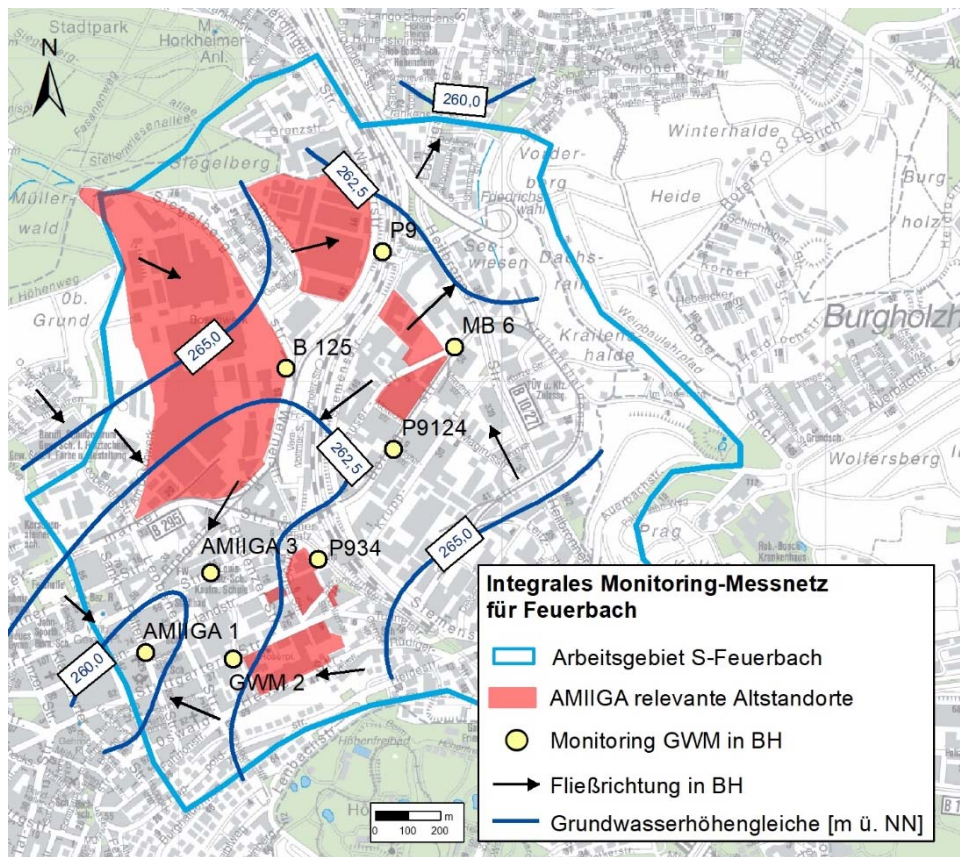
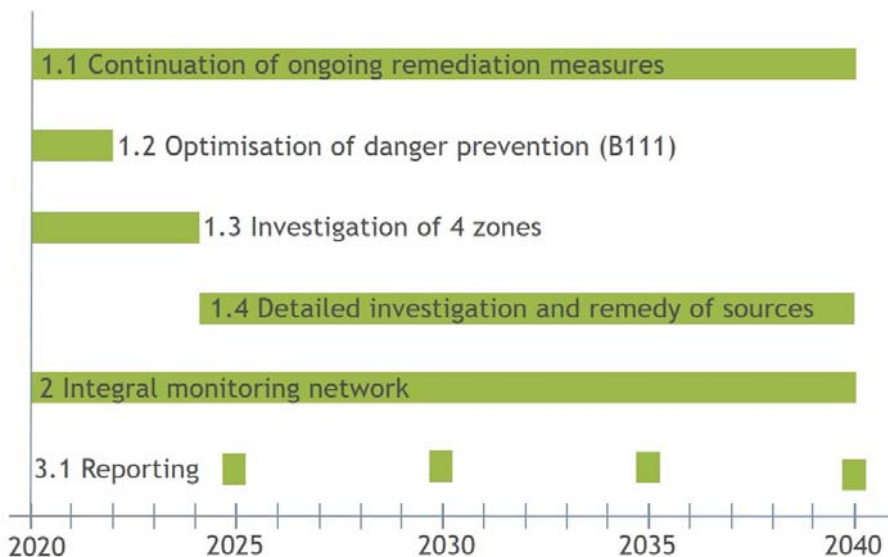


Figure 6 Integral monitoring network for Stuttgart-Feuerbach.

Implementation

The costs of the necessary measures are calculated for 20 years (from 2021 to 2040). Costs of the Measure 1.3 are approximately 560,000 €, costs of the Measure 2 area approximately 240,000 €. Therefore, the total costs of the municipality for 20 years are estimated to approximately 800,000 €, i.e. yearly costs are 40,000 €.





Action Plan for Stuttgart-Feuerbach

Development target	Action / Phase of action	Scale	Description / explanation	Beginning of action within AMIIGA project duration [y/n]	Estimated completion date			Legal / organizational limitations Is the implementation legally / organizationally possible? [y/n]	Technical / technological measures Which technical / technological measures are necessary?	Financing / responsibilities		Who is responsible for the implementation of measures?
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)			Public (EU / national / regional)	private	
Development goal 1: Minimization of CHC inputs into the upper aquifers												
1.	Identification, investigation and remediation of the not yet remediated relevant CHC sources of contamination	Feuerbach	In the AMIIGA project, it was proved that the continuation and optimization of ongoing remedial measures is necessary. In addition, four areas were identified in which significantly increased contaminant concentrations occur. The responsible sources of contamination are, as far as possible, to be identified and remediated.									
1.1	Continuation of ongoing remediation measures		Continuation of on-going remediation measures, till achievement of local goals	n	x	x	x	y	Remediation technologies for each site	x	x	Case-by-case responsibility
1.2	Optimization of danger prevention at the well B111		Optimization in cases of outflowing CHC plumes	n	x			y	Evaluation and competition of ongoing remediation		x	Polluter or owner
1.3	Investigation of 4 areas (B954/FB6, P907, B1-2, AMIIGA1)		Investigation measures to identify the source of contamination	n	x			y	Groundwater investigation	x		Water authority
1.4	Detailed investigation and remediation of identified sources		Investigation and remediation measures	n		x	x	y	Investigation and remediation technologies for each site	x	x	Case-by-case responsibility
Development goal 2: Integral monitoring of groundwater yield and quality												
2.1	Integral monitoring of GW-yield and GW-quality	Feuerbach and FUA	The AMIIGA project demonstrated that groundwater yield and groundwater quality are subject to significant changes. In order to be able to react appropriately, a monitoring in the Bochsinger Horizont in an integral monitoring is necessary. In the Upper Muschelkalk, a collection and analysis of gathered data is sufficient.									
2.1.1	Implementing the monitoring activities	Feuerbach	Yearly monitoring of 8 monitoring wells	y	x	x	x	y	Sampling and analysis of groundwater, installation of data loggers	x	-	AfU
2.1.2	Collecting the existing monitoring data	FUA	Gathering of the available data by other institutions	n		x	x	y	Input of data in the database	x	-	AfU
2.2	Evaluation of monitoring results	Feuerbach and FUA	Yearly evaluation of monitoring results (2.1.1 and 2.1.2)	n	x	x	x	y	-	x	-	AfU
Development goal 3: Ensuring the implementation of the necessary measures												
3.	Financing and reporting	Feuerbach and FUA	Providing financial resources, reporting each 5 years	n		x	x	y	-	x	x	AfU



ANNEX

Annex 2: Questionnaire on local experiences on management plans (Deliverable D.T3.3.2)



QUESTIONNAIRE ON LOCAL EXPERIENCES ON MANAGEMENT PLANS

WP T3, Deliverable D.T3.3.2

Final version
22.02.2017

This Document contains a number of specific questions. In addition to the collection of detail data within WP 1 it will help to:

- Get a general idea about core features and problems to be addressed for each partner area
- Get an overview about available data and existing knowledge gaps
- Show consistencies or differences between the different partner areas concerning issues like size of area, geology, kind of contaminants, etc.

Name of project partner:

Name of pilot area:

Contact persons to answer possible further questions:

Name:

eMail:

Phone number:

1. Problem and target

1.1. What is your core problem?

Describe in 1-2 sentences

1.2. What is the aim of your local project?

Describe in 1-2 sentences



2. Working area - FUA

2.1. How large is your working area, which will be covered by your management plan?

Size [ha or km²]:

2.2. Does it coincide with the extension of your FUA?

yes or no

If no, please describe briefly how you define your FUA (for example the catchment area of specific drinking water wells) and indicate its approximate size.



2.4. Which municipalities and administrative districts are involved?

The most relevant to be listed firstly

1.
2.
3.
4.
5.
6.

2.5. Which are receptors and specific subjects of protection in groundwater (like for example drinking water catchment areas, springs, etc.)?

The most relevant to be listed firstly

Name and identification ¹	Subject of protection	Specific concern/target for AMIIGA (if applicable)

¹ID to be identified on regional map (see Question 3)



2.6. Which water withdrawals are operating in your working area?

The most relevant to be listed firstly

Name and identification ¹	Type of withdrawal (drinking water, process water, dewatering drains, etc.)	Public or private	Number of withdrawals	Total withdrawal rate [m ³ /h]

¹ID to be identified on regional map (see Question 3)

2.7. Are there any water uses, for example infiltrations from irrigation or sewage losses, river discharges from power plant?

yes or no

If yes, please describe briefly

3. Maps and graphic illustrations

3.1. Please attach a regional map of your working area, showing

- contamination pattern (hot spots and plumes)
- involved municipalities and administrative districts (Question 2.4)
- contaminated sites (Question 2.3)
- surface waters like rivers and lakes
- water withdrawals and other water uses (Questions 2.6 and 2.7)
- receptors and subjects of specific protection (Question 2.5).

3.2. Please attach one or two geologic cross sections through your project area.

3.3. Are there any further maps or graphic illustrations available?

(not to be attached)

Kind of map	Available (yes or no)	How many, for which aquifers ?
Groundwater contour maps		
Distribution of hydraulic conductivities		
Spatial distribution of groundwater recharge		
Time variation curves of hydraulic heads		
Time variation curves of surface water levels		
Other		

4. Geology and hydrogeology

4.1. Which are the groundwater aquifers to be considered in the project?

(from the top to the bottom)

Name and geologic age	Thickness [m]	Porous or fractured	Confined or unconfined	Direction of groundwater flow known? (yes or no)

4.2. What are the annual values in your working area for:

Precipitation [mm/year]	Evaporation [mm/year]	Groundwater recharge [mm/year]



4.3. Do you have detail knowledge and understanding about specific questions like:

Issue	Known (yes or no)	Comment
Vertical interactions, hydraulic windows		
Ranges of hydraulic conductivity		
Surface water levels, time variation		
Hydraulic connection between groundwater and surface waters		
Planned groundwater abstractions due to construction measures		

5. Groundwater contamination

5.1. Do you have any indicators for microbial degradation and/or chemical transformation processes of your contaminants?

yes or no

If yes, please describe in 2-3 sentences



5.2. Are groundwater monitoring and sampling campaigns operated in your working area?

Regular monitoring performed (yes or no)	If yes, how many piezometers?	If yes, how are sampling intervals?

5.3. Which groundwater remediation and/or safety measures are running or planned?

The most relevant to be listed firstly

Name and ID (according to Question 2.2) ¹	Running or planned	Contaminants	Kind of measure (technology)	Involved aquifers

¹ID to be identified on regional map (see Question 3)

5.4. Is there any relevant diffuse pollution upstream of your known sources?

yes or no

If yes, please describe briefly: contaminants of concern, level of concentrations, extension known or not



6. Data existence and availability

6.1. Which kinds of data sets are existent to work with? Please indicate in the following table. Comment on their quality and reliability.

Kind of data	Available (yes or no)	Comment
Contamination Data		
Results of analytic groundwater investigations: <u>hydrochemic data</u> , <u>mineral content</u> , <u>contaminant concentrations</u>		
<u>Groundwater sampling protocols</u>		
<u>Contaminant emissions/loads from integral pumping tests</u>		
<u>Results of isotope measurements</u>		
Hydraulic data		
Position (spatial coordinates) and height (m NN) of piezometers		
Borehole logs, piezometer construction drawings		
Hydraulic heads (current and historic), time variation curves		
<u>Groundwater withdrawal and/or infiltration rates</u>		
Hydraulic conductivities, <u>storage coefficients</u> , <u>effective porosities</u> , <u>leakage coefficients from pumping tests</u>		
<u>Flow velocities</u>		
Water balance issues		
<u>Climatic data (current and historic) like temperature, precipitation, evaporation</u>		
<u>Surface water levels (current and historic)</u>		
<u>Results from flow records/flow gauging at rivers</u>		

(underlined are questions/aspects not included in the WP 1 questionnaire)



7. Legal framework

7.1. How and why does the current situation in your working area not comply with legal requirements?

Please describe in 2-3 sentences

7.2. What are relevant remediation targets and threshold values for contaminants of concern in groundwater?

Please list them with their respective legal acts

Contaminant	Value [unit]	Where to find

7.3. Please describe the legal acts your action is currently built on (if necessary)



7.4. Are there any further legal acts of key relevance for your planned actions?

If so, please describe briefly in 2-3 sentences

7.5. Do you have any previous experience with groundwater management plans?

yes or no

If yes, please describe briefly: size of area, contaminants of concern, involved actors