AMIIGA - INTEGRATED APPROACH TO MANAGEMENT OF GROUNDWATER QUALITY IN FUNCTIONAL URBAN AREAS

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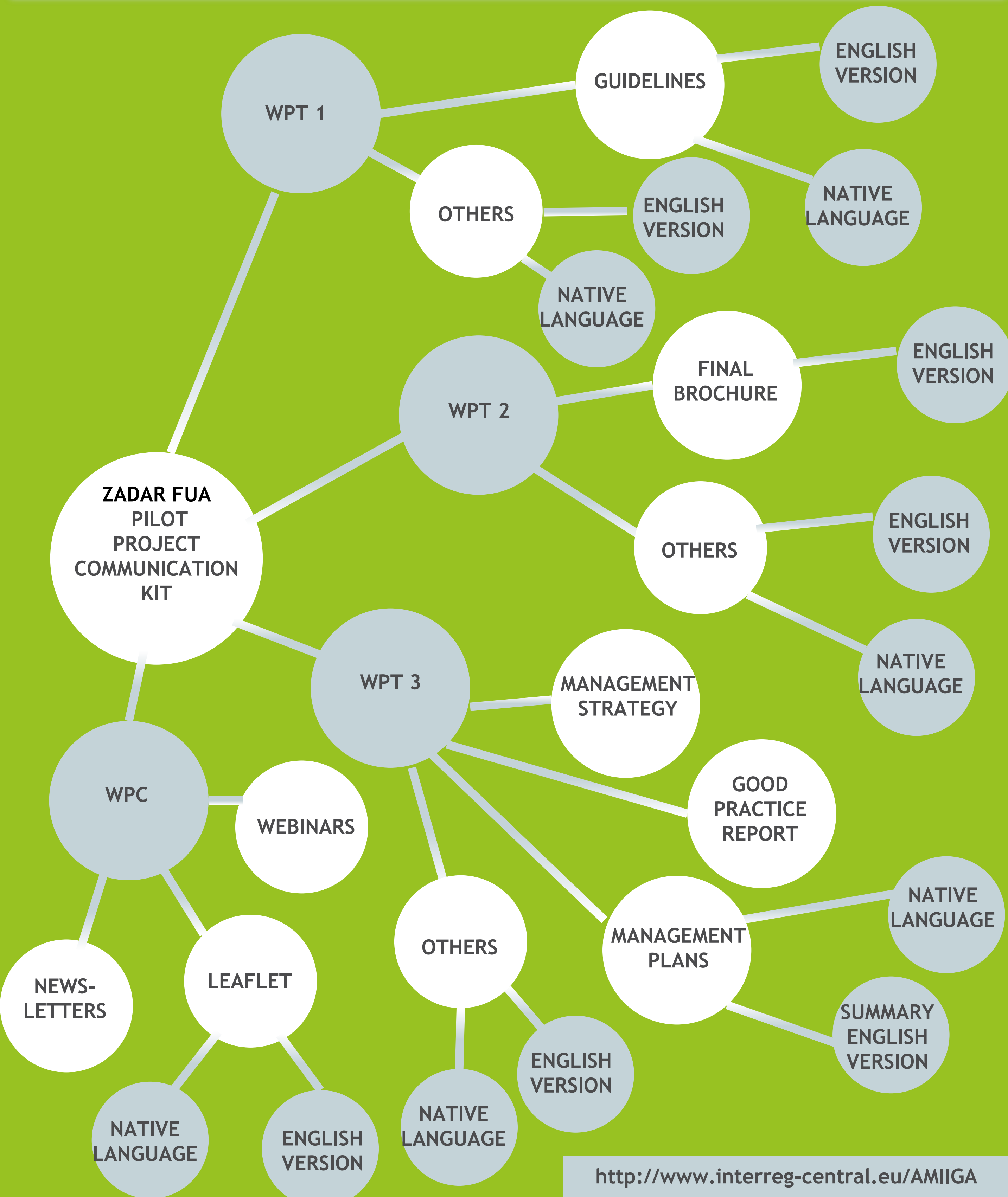

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AMIIGA projekt CE 32 realizirao se u okviru programa Interreg CENTRAL EUROPE koji se financira iz Europskog fonda za regionalni razvoj.

Trajanje projekta:
01.09.2016 – 31.10.2019

Projekt menadžer: dr inż. Grzegorz Gzyl
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Institucije koje sudjeluju u projektu:

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PP2 Miasto Jaworzno (PL)
PP3 Landeshauptstadt Stuttgart (DE)
PP4 Město Nový Bydžov (CZ)
PP5 Technicka Univerzita v Liberci (CZ)
PP6 Regione Lombardia (IT)

PP7 Politecnico di Milano (IT)
PP8 Comune di Parma (IT)
PP9 Geološki Zavod Slovenije (SI)
PP10 JP VODOVOD KANALIZACIJA SNAGA d.o.o. (SI)
PP11 Sveučilište u Zagrebu, Građevinski Fakultet (HR)
PP12 Vodovod d.o.o. Zadar (HR)

te 10 pridruženih partnera: Wodociągi Jaworzno sp. z o.o. (PL), Regione Emilia Romagna (IT), Hrvatske vode (HR), Mestna občina Ljubljana (SI), Górnośląski Związek Metropolitalny (PL), Krajský úřad Libereckého kraje (CZ), Krajský úřad Královéhradeckého kraje (CZ), Občina Ig (SI), Regierungspräsidium Stuttgart (DE), Regionalna Dyrekcja Ochrony Środowiska w Katowicach (PL)

Opis projekta:

Glavni cilj projekta AMIIGA je poboljšati proces upravljanja i odlučivanja u smislu upravljanja kontaminiranom podzemnom vodom na razini funkcionalnog urbanog područja (FUA).

Cilj projekta je i razviti i testirati u praksi zajednički pristup uključivanja zainteresiranih dionika na FUA razini kako bi zajedno radili na uspostavljanju „planova upravljanja“.

Projekt AMIIGA fokusiran je na razvijanje integrirane strategije procjene, kao i revitalizaciju i upravljanje kvalitetom podzemnih voda. Strategija se koristi kao osnova za sedam „planova upravljanja“ za funkcionalna urbana područja definirana u projektu. To uključuje aktivnosti na razvoju i primjeni tehničkih (uključujući metode biološke melioracije), procesa i organizacijskih inovacija koje pojednostavljuju proces upravljanja vodnim resursima u odgovarajućim upravnim tijelima.

Rezultati projekta:

- ✓ implementirani sustav praćenja podzemnih voda na FUA razini omogućava pravilno upravljanje podzemnom vodom
- ✓ razvoj postupaka za podršku pri odabiru metode za sanaciju podzemnih voda,
- ✓ uspostava redovne platforme za koordinaciju aktivnosti različitih dionika iz različitih sektora i razina uključenih u upravljanje i nadzor podzemnih voda na FUA razini.

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Interreg CENTRAL EUROPE
AMIIGA

AMIIGA project CE 32 is realized within the Interreg CENTRAL EUROPE Programme funded under the European Regional Development Fund.

Project period:
01.09.2016 - 31.10.2019

Project manager: dr inż. Grzegorz Gzyl
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The institutions engaged in the project are:

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Description of the Project:

The main goal of the AMIIGA project is to improve the management and decision-making process in terms of dealing with contaminated groundwater on a functional urban area (FUA) scale.

The project is also intended to develop and test in practice a common approach to engaging interested stakeholders on an FUA scale to work together to establish "management plans"

The AMIIGA project focuses on developing an integrated assessment strategy, as well as the reclamation and management of groundwater quality. The strategy is used as a basis for seven "management plans" for functional urban areas defined in the project. It includes activities to develop and implement technical (including biological reclamation methods), process, and organizational innovations that streamline the process of managing water resources in the relevant administrative bodies.

Results of the Project - benefits for the region:

- ✓ an implemented system for monitoring groundwater on an FUA scale allows for the proper management of groundwater,
- ✓ the development of procedures for decision support in terms of the selected groundwater rehabilitation method,
- ✓ the establishment of a regular platform for joint coordination of activities of various parties from different sectors and levels involved in the management and monitoring of groundwater on an FUA scale.

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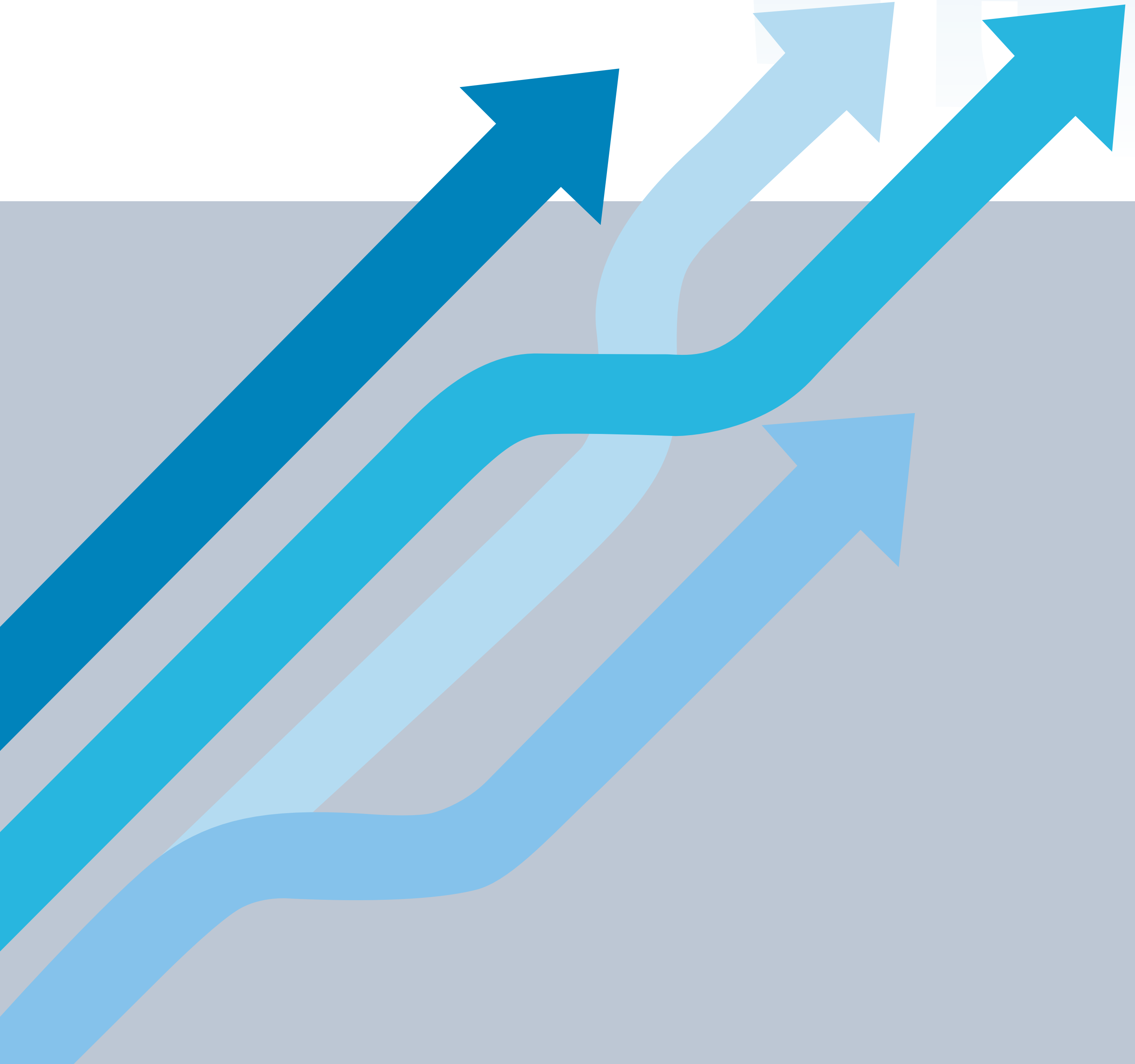
INTEGRATED APPROACH TO MANAGEMENT OF GROUNDWATER QUALITY IN FUNCTIONAL URBAN AREAS



INTRODUCTION

- **“Groundwater is the most sensitive and the largest body of freshwater in the European Union and, in particular, also a main source of public drinking water supplies in many regions.**
- **Groundwater is a valuable natural resource and as such should be protected from deterioration and chemical pollution. This is particularly important for groundwater dependent ecosystems and for the use of groundwater in water supply for human consumption” (from Directive 2006/118/EC).**
- **Functional Urban Areas consist of an urban core and its commuting zone whose labour market, urban development and environmental issues are highly integrated with the city (OECD, 2012)**

Many countries in Central Europe are dealing with the impacts of environmental damages that occurred since the late 19th century and in the 20th century as a result of improper handling of hazardous substances, especially in industrial production.

With the development of urban areas in the second half of the 20th century, many industrial sites became part of residential areas. Although in some urban areas industrial enterprises have gradually ceased their activities and production or have been disposed of outside residential areas (to protect the health of the population and the environment in the cities), in many cases the pollution of the rock environment and groundwater has remained unresolved. As a result, polluted sites are part of the cities in Central Europe. National management approaches developed to reduce the negative effects deal with single sites. Groundwater contamination however is a problem that goes beyond sites and any administrative boundaries. Focusing on single sites does not solve the problems of polluted groundwater and thus even becomes a risk to further development of Functional Urban Areas (FUAs).

The approach of the Groundwater Framework Directive of the European Union (Directive 2006/118/EC) is to identify, to assess and manage pollution in groundwater bodies. This approach however neglects point sources and single sites.

Moreover, the mitigation of groundwater pollution is an extensive, long-term, complex and very expensive process. Even large investments may not provide the expected improvement in groundwater quality, as can be seen in many examples.

In this situation, it is very decisive that the EU Interreg Central Europe program offers a suitable platform for the countries of Central Europe to improve procedures and strategies of groundwater pollution management. The program enables the development of new technical tools and means for refining pollution information on the level of Functional Urban Areas. Their purpose is to prepare and implement appropriate remedial actions that are sustainable in the long term and will address existing risks and threats.

Contamination sources located in "city core" affect the groundwater quality of "hinterlands" downstream and vice versa. It requires effective intervention at this medium (FUA) scale, neglected in the existing legislation. The AMIIGA project is focusing on integrated assessment, remediation and management strategies, as well as on development of tools for characterization/prioritization of groundwater contamination sources. The innovative instrument "groundwater management plan" is a selective further development of the decision-support strategies described in Trzaski et al. 2012. Key elements of this integrated management instrument are characterization, remediation and monitoring plus the management strategy and the plan itself. This involves both technical and process innovation and strengthens water management capacities in the related administrative bodies among a FUA.

Each project partner has an individual problem with groundwater pollution at his FUA (pilot FUA) as in other EU countries. Each pilot FUA represents a serious problem for local or regional authorities they need to address. They differ in the type of pollution, hydrogeological conditions and threats from pollution (e.g. risk of damage to drinking water sources, degradation of mineral springs, threat to the health of the population etc.). In addition, the levels of knowledge about all aspects related to pollution are different: some partners are just beginning with groundwater solutions at FUA, others are already in the phase of preparing the implementation of remediation works.

Each FUA pilot at the beginning of the AMIIGA project faced the challenge of developing a long-term management plan to address groundwater pollution. In order to be prepared, it was necessary to broaden the level of knowledge on the aspects of pollution in specific areas of crucial importance for further decision-making by local or regional authorities.

12 project partners have prepared sets of pilot activities for 7 pilot FUAs, which have helped to clarify specific uncertainties, thus enabling the development of a management strategy and a long-term management plan to address pollution on specific FUAs. In all pilot actions, the new technical tools developed in the AMIIGA project were used (from dealing with data collection and evaluation of all former investigation, through compilation and mapping of all available information in a data base on GIS platform, conceptual hydrogeological modelling, integral pumping tests, delineation of plumes of pollution, numerical modelling of contaminated plumes and CSIA data, backtracking of pollutants, risk assessment for sources and plumes of pollution, identification of natural attenuation processes, development of remediation concepts and realization of remediation by using BMTs), which enabled these innovative resources to be successfully verified in practice.

In the following text, individual FUAs and their solutions are introduced and the achievements that each partner has brought are described in detail.

AMIIGA
(INTEGRATED APPROACH TO MANAGEMENT OF GROUNDWATER QUALITY IN FUNCTIONAL URBAN AREAS)
is a project funded by the EU CENTRAL EUROPE Interreg program 2016-2019 with 6 countries, 12 project partners, 8 regions, 7 pilot actions, 2.9 million euro project budget and 2.4 million euro ERDF. AMIIGA project is building on and capitalizing the results of previous projects especially MAGIC and FOKS (Gzyl and Gzyl 2008; Trzaski et al. 2012; Vasin et al. 2016).

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Figure No.1 - Zadar peninsular Old Town

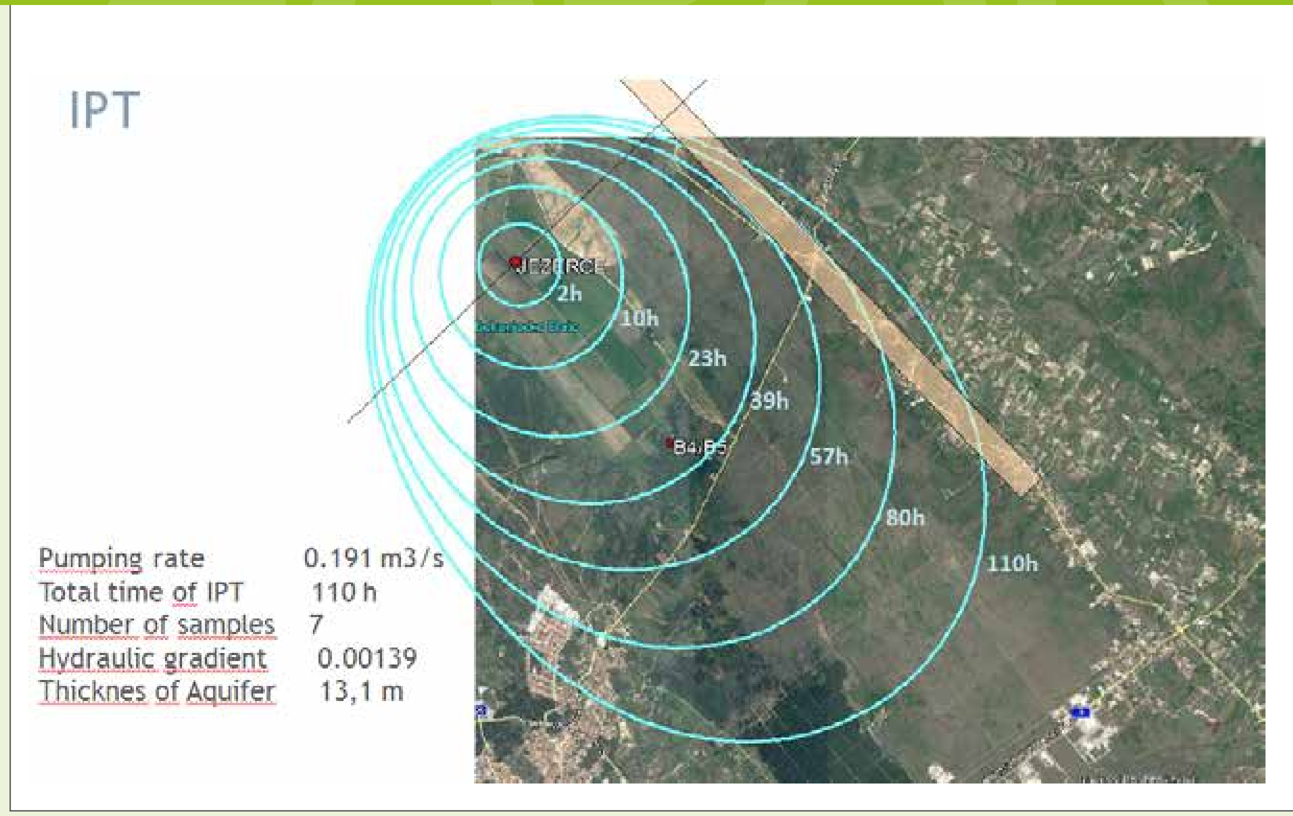


Figure No. 3 - Results of IPT

SOLVING THE INVERSE PROBLEM USING THE FOKS TOOLS IN KARST AQUIFER (ZADAR FUA, CROATIA)

Introduction

Zadar is the oldest continuously inhabited city in Croatia. It is situated on the Adriatic Sea, at the north western part of Ravni Kotari region. Zadar serves as the seat of Zadar Country and the wider northern Dalmatian region. The city covers the area of 25 km^2 with a population of 75,082 in 2011, making it the fifth largest city in Croatia. It is known for the Roman and Venetian ruins of its peninsular Old Town.

Figure No.2 - Zadar and its hinterland

Threat to groundwater in FUA Zadar

Water supply of Zadar is based on groundwater exploitation in the Zadar hinterland. In the hinterland of Zadar there are some villages without sewage system (brown areas in Fig. 2) and only 43 % of the population in this area is connected to the sewage system. Other households use septic tanks that are mostly permeable and leak directly into the karst underground. Pollution from these areas can very fast infiltrate in the groundwater according to absence of confining layer.

Between the villages, there is some agriculture area where farmers use fertilizers and pesticides. So far, there is no significant pollution caused by agricultural activities registered. The pesticide levels in groundwater are below the threshold values due to relatively low use. The level of nitrogen in groundwater is below the threshold values as well (nutrient management plans have been introduced in the EU accession process).

The general direction of groundwater flow is from southeast to northwest and during the rainy season, the pollution can reach pumping wells (yellow dots on Fig. 2) very fast. Results of monitoring from several groundwater wells show microbiological contamination in FUA. The main sources for bacterial contamination are unsuitable disposal of wastewater.

Figure No.4 - Discrete Analyzer-Gallery

Benefits from project AMIIGA to FUA Zadar

Within AMIIGA project, Integral Pumping Tests (IPT), an innovative tool developed within the project FOKS, were conducted in karst aquifer. The results of IPT (Fig. 3) confirmed the previously adopted assumption that the main source of microbiological pollution is inadequate septic tanks that released the effluent in groundwater.

In order to define the groundwater flow and transport of pollution in Bokanjac-Policnik aquifer, the numerical model of groundwater flow was developed within the project AMIIGA. The goal of numerical model was to determine (i) the flow direction, (ii) the amount of infiltrated precipitation and (iii) relationship between the flow through the pores and the flow through the fractures based on the existing data of groundwater levels.

The main goal of AMIIGA project was to ensure good groundwater quality as well as a sustainable water supply system based on its own technological and human potentials. Therefore, the first step in improving the groundwater quality control was made by acquiring new laboratory equipment that increased the laboratory's analytical capabilities: Discrete Analyzer-Gallery (Fig. 4) and Gas chromatograph (Fig. 5). The devises enabled the detection of new potential groundwater pollution, increased the number of analyzes and shortened their implementation time. For this purpose professional training and education of laboratory staff were performed.

Finally, the project AMIIGA helped to develop the Management plan and approve it with the Regional Implementation Group members. In the Management plan for FUA Zadar, the location of new observation wells were suggested, the improvement of groundwater monitoring concept was developed, supplementation of defined accident measures were described and the next upgrade of existing numerical model was suggested.

Figure No.5 - Gas chromatograph (GC-2010Plus)

REMEDIATION CONCEPT FROM DRINKING WATER PERSPECTIVE FOR DIVERSE POLLUTANTS IN TYPICAL SLOVENIAN FUA (SLOVENIA)

Introduction

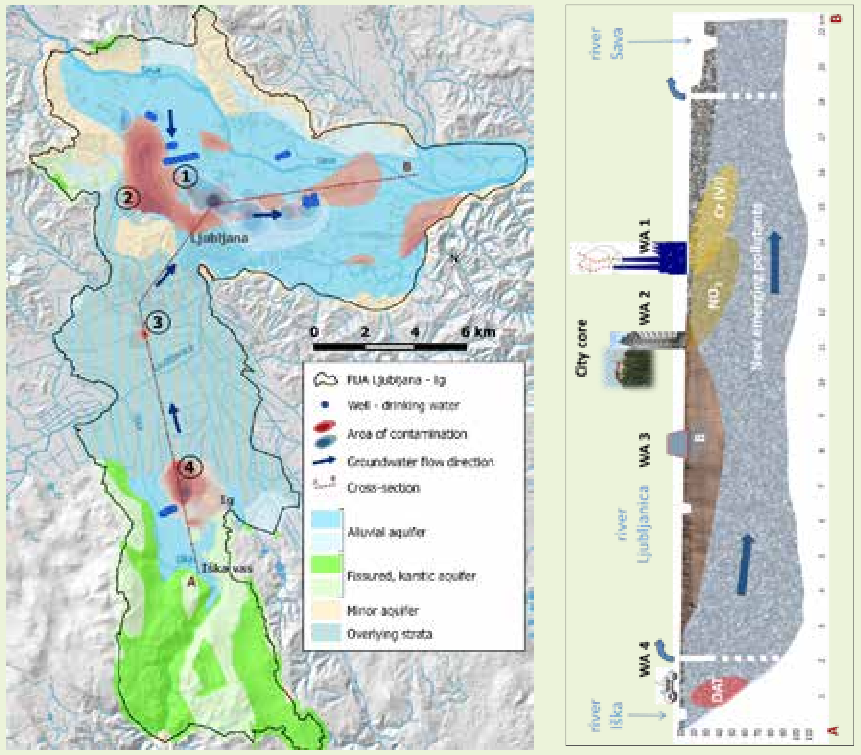
Functional Urban Area (FUA) of Ljubljana – Ig consists of two administrative entities, i.e. Municipality of Ig and Municipality of Ljubljana City. Both municipalities are interconnected by the main common aquifer system, waterworks system and sewage system.

The main common aquifer is composed of alluvial sediments (Fig. 6 – right side), i.e. mostly of highly permeable gravel and sand layers, locally lithified as a conglomerate lenses. Level of groundwater is mainly unconfined, up to 30 m below the surface, but also artesian, covered by low permeable overlaying strata of clayey and silty sediments. Iška River and Sava River are very important recharge and drainage hydraulic boundaries. Groundwater flow velocities range from 0.03 m/day (Barje area) up to about 10 m/day (Stegne-Hrastje and Dravlje-Moste area). The depth of aquifer is around 100 m.

There are numerous contaminants present in the groundwater, originating from past and recent activities. Investigation of groundwater contamination in alluvial aquifers under the highly urbanized area of the City of Ljubljana has been already conducted by the EU-funded project INCOME (2009 - 2012). Comprehensive chemical analyses of groundwater were performed in order to detect and identify variety of contaminants that occur in the subsurface.

In AMIIGA project, we focused our activities on four major contamination sources, working areas FUA Ljubljana – Ig (Fig. 6 – left side). Two of them have characteristics of plumes from point and multipoint pollution, which have highly severe and continuously present risk for the operation of drinking water wells. The aim of the pilot action was to establish the remediation and other measures that will efficiently preserve and improve the quality of the groundwater. The main development goal is drinking water supply without treatment, even from the ground below highly populated city core area and agricultural hinterland, in the next decades.

Figure No. 6 - FUA 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)



Threat to groundwater in FUA Ljubljana - Ig

Desethyl-atrazine pollution in Brest area represents the highest risk for water supply among all four working areas (Fig. 7). The risk is high in the present status and potential pollution. The threat of severe contamination of Brest wellfield (exceeding 0.1 µg/l quality standard) is continuously present.

The risk of chromium VI pollution in Stegne - Hrastje area is also high, because of potential severe pollution, which is continuously present. There are multipoint sources, locally exceeding 25 µg/l of chromium VI (Cr VI) in groundwater. Instantaneous releases of Cr VI from not yet identified point 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 in Dravlje – Moste area represent the medium risk at present status, but high risk to drinking water wells in the case of potential pollution. The latter is continuously present for some drinking water wells having concentration of nitrate close to 25 mg/l. Some new emerging pollutants have significant increasing trends, which means that the present status is deteriorating in a short-term timeframe.

Contamination from municipal landfill in Barje, 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, but only of lower severity and longer period of occurrence. However, some measurement points have still significant upward trend or highly oscillating concentrations, so the level of this risk is medium.

Benefits from AMIIGA Project to FUA Ljubljana - Ig

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.

The groundwater contamination Management plan of Ljubljana – Ig is our key output. Such Management plan is the first in Slovene territory and the ambition is to be also demonstrative case for other functional urban areas. It defines development targets and target values that must be achieved for safe water supply and high-level functionality of urban area in next decades.

The Management plan was elaborated by executing activities in eleven steps for all of four working areas in FUA Ljubljana – Ig.

- **(1) Assessment of actual status and (2) Additional targeted sampling**

Additional sampling campaign enabled us to interpolate data and delineate the Cr (VI) contamination plume in Stegne – Hrastje area for the first time (Fig. 8). At the same time, we identified additional location of excessive Cr (VI). We were also able to observe the changes of DAT contamination plume through 6 years period in Brest area to reveal its progress.

- **(3) Improved numerical models, (4) Actualized mass balance, and (5) Trends and long-term forecasts**

We found out that the majority of DAT in wider Brest area most probably originates from two old gravel pits (Fig. 9). The storage of DAT within wider area of Brest was assessed to approximately 25 kg in 2011 (INCOME) and 23 kg in 2017. On the basis of improved numerical model, we simulated possible scenarios for remediation in order to determine feasible measures.

We found out that the downward trend of nitrate in Dravlje-Moste area cannot be expected to continue, because the potential for further decline is lower, hence the long-term forecast is uncertain. In addition, desethyl-terbutilazine concentrations are already above the limit of detection (LOD) at western side of Kleče wellfield with significant upward trend, which makes it necessary to introduce measures to reduce inputs.

- **(6) Assessment of natural attenuation potential**

Organic pollutants in (3) Barje area are identified only in traces, which is confirmed also by the low microbiological activity of degradation of these pollutants. Hence, we focused on dilution and dispersion potential of the boron, as the most significant pollutant.

By fitting calculations on each observation well to measured values, we evaluated, that one of the most

Risk rank	Working Area (WA)	Present status	Potential pollution	Target status
1	Brest WA 4	High risk	High risk	Medium risk
2	Stegne-Hrastje WA 1	Medium risk	High risk	Low risk
3	Dravlje-Moste WA 2	Medium risk	High risk	Low risk
4	Barje WA 3	Low risk	Medium risk	Low risk

Figure No. 7 - Evaluation of risks from waterworks perspective

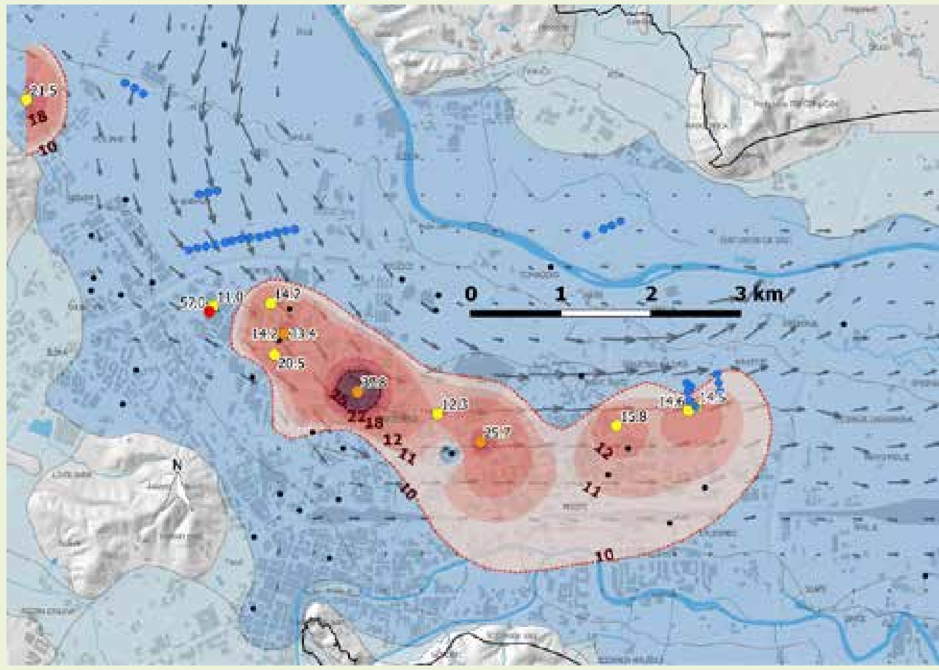
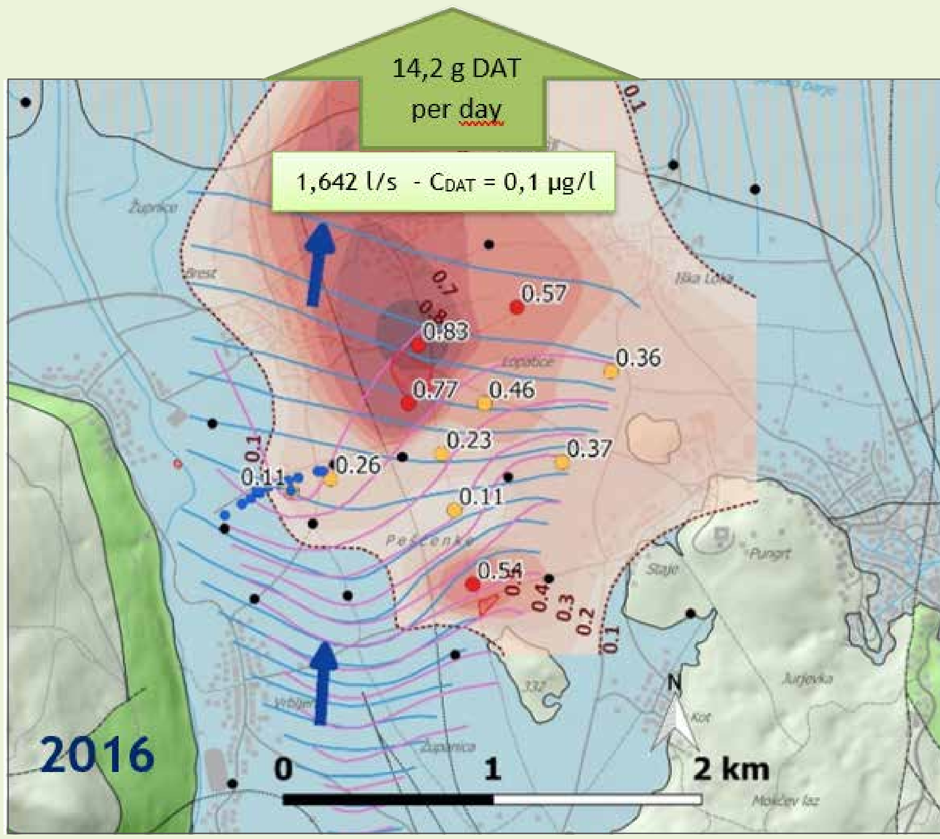


Figure No. 8 - Cr (VI) contamination plume in Stegne-Hrastje area (WA 1)

Figure No. 9 - Evaluated mass balance of DAT in Brest area (WA 4)



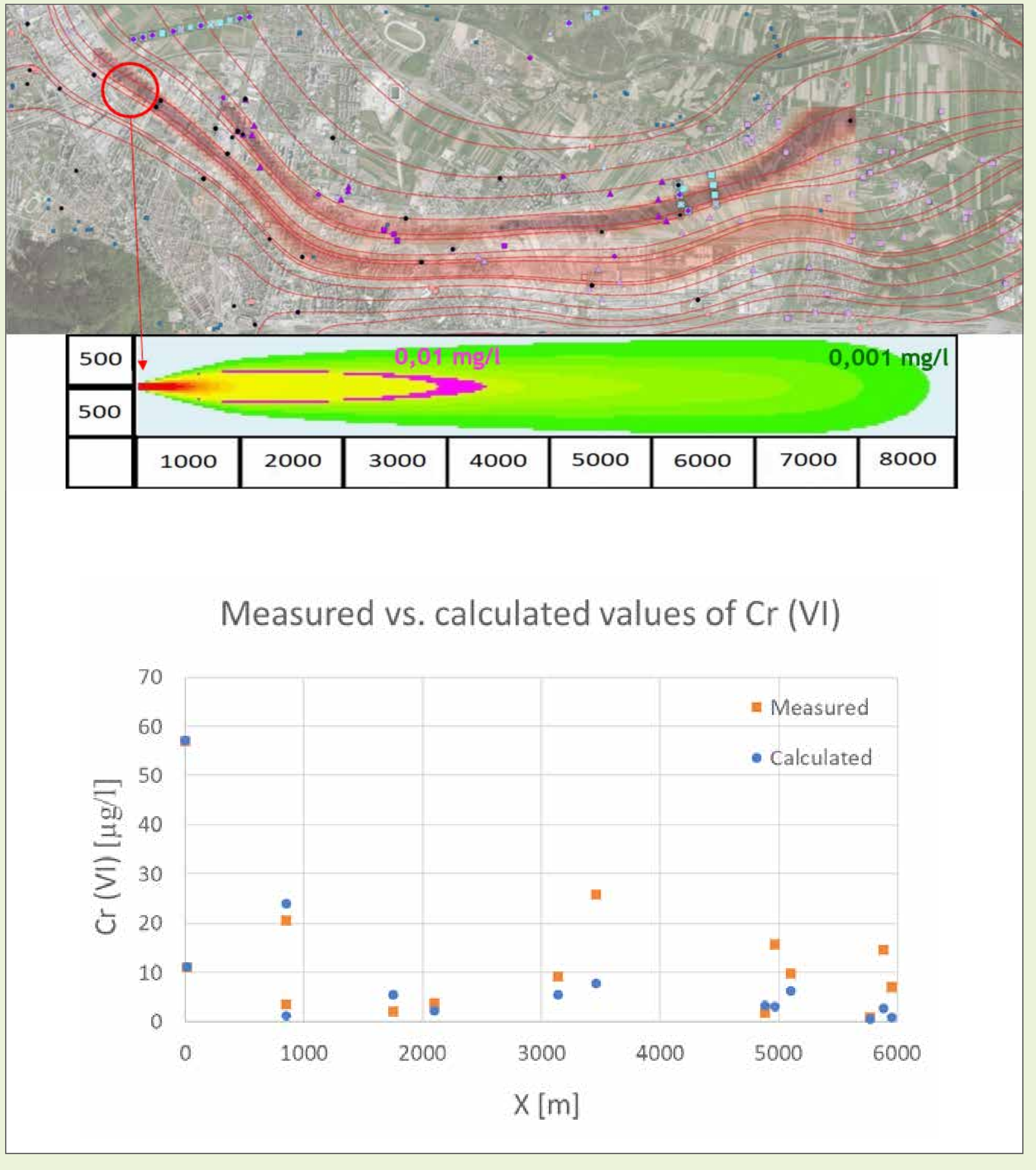


Figure No. 10 - Measured vs. Calculated values of Cr (VI) when the source of pollution is 400 m away from borehole LTH-2/15 (WA 1)

probable sources of Cr (VI) at (1) Stegne-Hrastje area is 400 m upstream from LTH-2/15 observation well (Fig. 10).

- **(7) Most probable scenarios threatening groundwater and (8) Evaluation of risks from waterworks perspective**

Based on analysis of severity and recurrence of contaminations, for present status and for potential pollutions, we ranked the levels of risks of all four working areas from waterworks perspective (Fig. 7). This analysis was crucial for further preparation of program of measures, with emphasis on working areas (4) Brest (desthy-atrazine) and (2) Stegne – Hrastje (Cr VI).

- **(11) Determination of feasible measures, milestones and indicators of progress, via (9) Preinvestment analysis and (10) Feasibility of measures**

For (4) Brest working area of desethyl-atrazine plume we elaborated cost-efficiency for four hydrotechnical remediation measures: redirection of plume, active protection barrier, accelerated abstraction of pollutant and artificial recharge of unpolluted shallow part of aquifer. We also elaborated the procedures for enhanced microbiological degradation. We set up the next steps of investigation measures that will finally enable us to select the most efficient remediation.

At (1) Stegne-Hrastje area of Cr (VI) contamination we delineated three narrower areas of the highest sources of contamination. Further steps are elaborated to localize those point sources and to prepare remediation procedures.

In (2) Dravlje-Moste area we defined reporting protocol to relevant sectors to reduce the input of relevant substances of new emerging pollutants. We also determined critical points to inspect losses from sewerage.

In Barje (3) the main plan is to perform natural attenuation monitoring, additional points of compliance to lower the risk and to identify external sources of boron.

Finally, we set up procedure, tasks and milestones for the implementation of those measures in relevant documents. We are continuing with the activities of cost resources identification and dissemination.

SEPARATION OF HOT SPOT & MULTIPLE POINT DIFFUSE CONTAMINATION IN MILAN FUA (ITALY)

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.
In the last decades, Lombardy Region spent many efforts to push polluters to characterize and remediate soil and groundwater in their sites, having important results in terms of water and soil quality at local scale. Moreover, the available dataset highlighted the presence of a contamination not linked directly to a polluter or a restricted area, but to a multiple source clustered in a large area. This kind of contamination, called diffuse pollution, needs to be treated with different tools and procedure.

Lombardy Region has started dealing with diffuse pollution in the metropolitan area of Milan since 2013 with an available data organisation and integration. Based on the results of studies the carried out in 2017, Lombardy Region has delimited the first area affected by diffuse pollution and approved management measures and the penalty for remediation procedures. The area (Fig. 11), which is northeast of Milan (and includes the City of Milan), is affected by diffuse contamination of chlorinated hydrocarbons (CHC).

Furthermore, the performed studies highlighted that several plumes, originating from the north-western part 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. Moreover, a presence of a contamination was observed, which was characterized by low concentrations and permanence that could be matched to a diffuse nature.

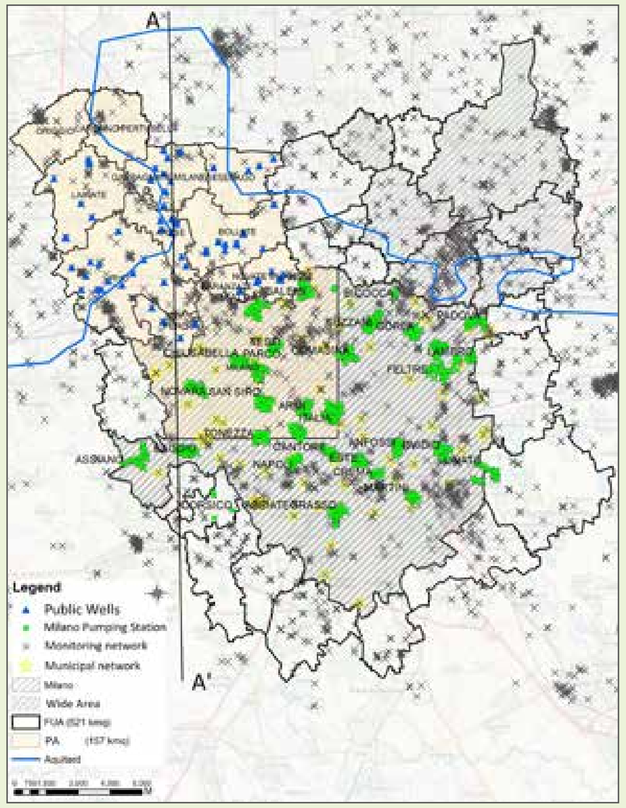


Figure No.11 - Milan FUA (521 kmq, more than 2.2 milion inhabitants) is in black biold, pilot area (PA) is colored in pink. Cross section AA' is represented in Fig. 12.

For this reason, the northwestern part of Milan and some municipalities located at the northern boundary of the city have been selected as the pilot action area for AMIIGA project.

The pilot area (Fig. 11) is covering 12 municipalities in the northwest of the Milan FUA and is about 157 km^2 wide; within the area live more than 600.000 inhabitants.

Threat to groundwater in Milan FUA

Due to the high hydraulic conductivity and high groundwater withdrawal rate, the groundwater contamination reaches the territory of Milan, since it represents the natural drainage area of the groundwater in the north.

From a hydrogeological point of view, the main aquifers relevant for contamination are the shallow aquifer and semi-confined aquifer that are separated in the southern part and connected in the northern part of the studied area (Fig. 12).

The main challenge of AMIIGA project in the pilot area was to define tailored management measures assuring local remediation actions more sustainable. Therefore, the key task of Pilot Action was to distinguish contamination plumes originated from point pollution sources from diffuse pollution in the area of interest.

Benefits from project AMIIGA to Milan FUA

AMIIGA project enabled (i) the implementation of tools aimed at distinguishing point sources of pollution from diffuse contamination and (ii) developing a set of measures, the Management plan, to monitor and manage pollution and prevent further groundwater contamination.

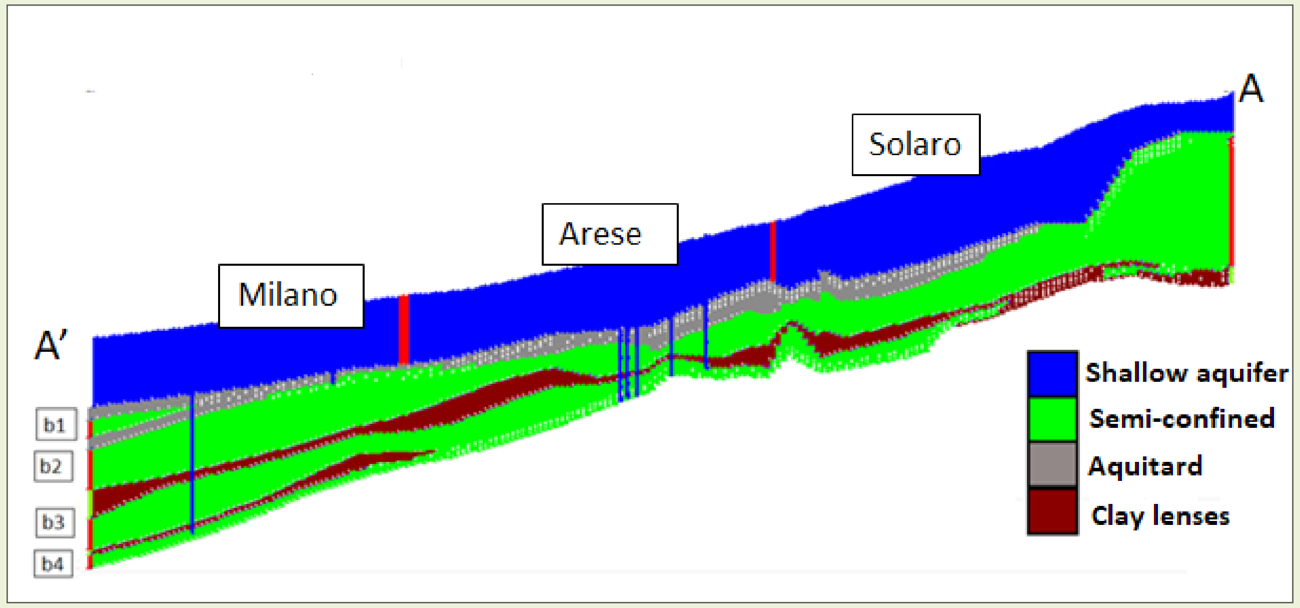
The main goal of the pilot area was the assessment of groundwater contamination, distinguishing diffuse and site-specific contributions, for Perchloroethene (PCE) and Trichloroethene (TCE).

To this aim, the main plumes, their source area, their extension and the characteristics of the contamination outside of them (temporal and spatial distribution) have been investigated and studied within AMIIGA project.

In order to fulfil the goals, the following activities have been carried out:

- ***Hydrogeological and groundwater monitoring data collection***
  - The available dataset from previous studies was integrated and updated for the pilot area and the FUA.
  - The documentation available for the contaminated sites in the pilot area (more than 20 sites in regional registry) was analysed and new data were included in the existing dataset (i.e. hydro-chemical data and hydraulic pumping tests).
  - The data has been implemented in a database and shared among the project partners, through a Web – GIS.
- ***Optimization of existing groundwater network: a new monitoring network***

Figure No. 12 - Cross section N-S of the pilot area, the colors represent the different aquifers (blue and green) and aquitard (grey and brown)



– Analysis of the localization of monitoring wells already existing in the area and their effectiveness in the spatial definition of the phenomena has been performed.

– Six new piezometers have been drilled in order to improve the monitoring network in the pilot area, both for shallow and semi-confined aquifer (Fig. 13).

- ***Realization of three monitoring campaigns***

– Chlorinated solvents (PCE, TCE, TCM, cis-DCE), hydrochemicals and isotopic parameters were monitored in order to survey the extension of plumes and support the calibration of the numerical models.

Figure No. 13 - Realization of deep (left) and shallow piezometers (right)

- ***Hydro-geological and numerical model implementation***

The numerical (Groundwater Vistas 6 interface) groundwater transport (MT3DMS) and flow (MODFLOW2005) model were developed:

– Groundwater flow was calibrated (i.e hydraulic conductivity parameter) based on the observed data (campaign in March 2018) by using automatic inverse calibration (PEST).

– Plume extensions, the mass flow rate released from sources, the spatial evolution of contaminants (from 1954 to 2017) were determined. The plumes contours were used to divide monitoring points linked to point sources from monitoring points linked to diffuse contamination.

- ***Inverse transport model (uncertainty analysis on hydrogeological parameters, i.e. hydraulic conductivity by means of Monte Carlo approach)***

By means of the inverse advection transport model, it was possible to track the particles of the contaminants both (i) forward starting to a suspected sources in order to estimate in a probabilistic way the influence of contamination downgradient, i.e. sensitive receptors like public wells, and (ii) backward starting from contaminated piezometers or wells in order to find, in a probabilistic way, the areas where the pollution takes its origin.

- ***Multivariate analysis and factorial analysis, in association with geostatistical analysis***

The Multivariate and factorial analyses, in association with geostatistical analysis applied on the previous outcomes have allowed to: give a picture of the distribution and to determine the concentrations representative for the diffuse contamination. Maps of diffuse PCE contamination distribution, were provided for the shallow and the semi-confined aquifers, split in three levels associated to ranges of concentrations representative for the diffuse contamination.

All the performed activities, as the modelling tools and elaborations developed on the upgraded groundwater database, have allowed to:

– Depict an extensive profile on the contamination by chlorinated solvents in the pilot area of Milan: the CHC pollution is mainly linked to a diffuse con-

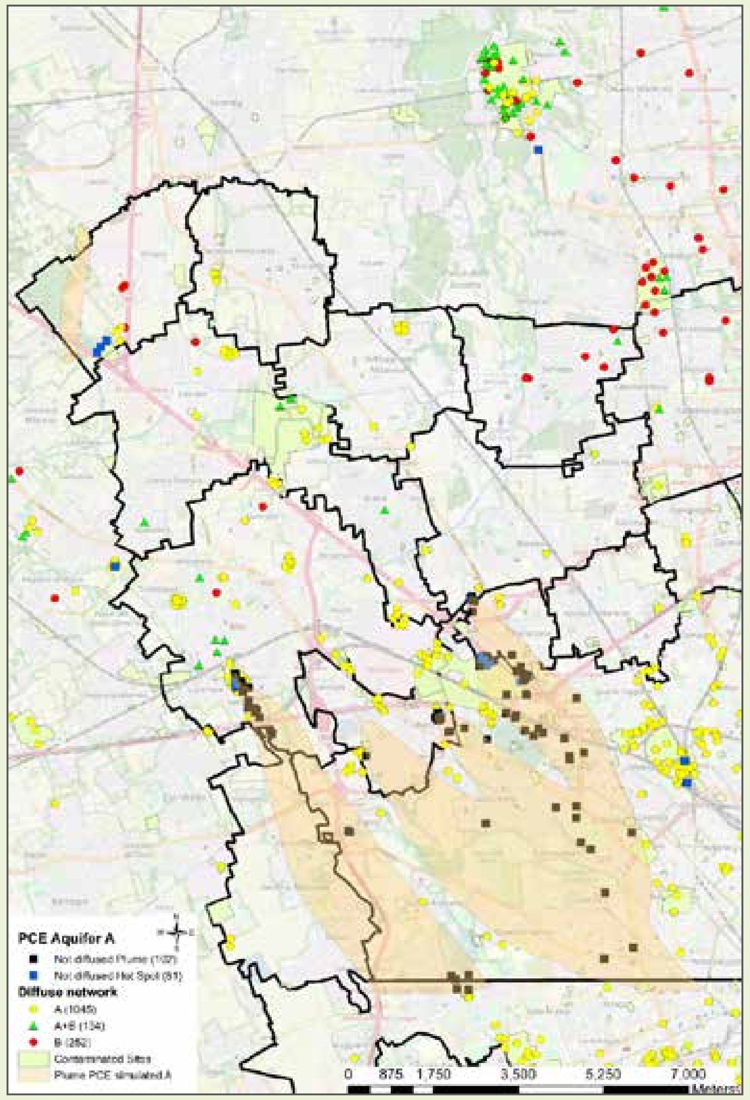


Figure No. 14 - Plumes representation using the modelling results in shallow aquifer

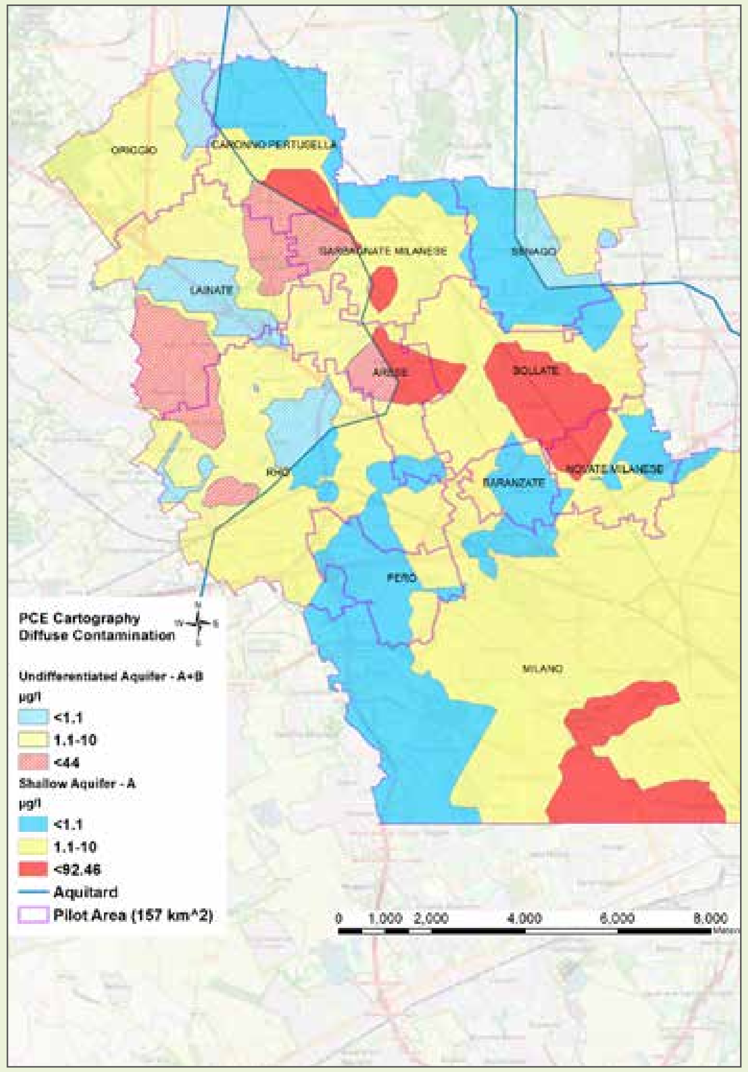


Figure No. 15 - Spatial distribution of the diffuse PCE contamination in the undifferentiated and shallow aquifers

tamination and the monitored values are in general less than 10 µg/l. The median values (2010-2017) show that values in large part of the pilot area are under the threshold values for drinking water, whereas nearby the suspected sources the values are higher than 100 µg/l. The reference standard that defines the concentration thresholds for aquifers to guarantee human health are defined by the decree and, among the others, establish the limit values for PCE (1.1 µg/l) and for TCE (1.5 µg/l).

- 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 point sources of contamination and relevant plumes from diffuse contamination (Fig. 14).
- Draw the maps of diffuse PCE contamination distribution associated to three ranges of concentrations representative for the diffuse contamination (Fig. 15).

The major critical issues emerged from the above technical outcomes, representing the picture of the groundwater contamination of the pilot area, have been dealt with the Management plan. In the Plan, specific actions for groundwater contamination prevention, monitoring and management have been defined with the aim to protect the public health and increase the awareness of the population on groundwater pollution in north-western Milan pilot area

ASSESSMENT OF NA POTENTIAL AS A REMEDIATION OPTION IN PARMA FUA (ITALY)

Introduction

Study area

Parma is a town in the North of Italy, with a population of about 200.000 inhabitants. The study area is placed in the urbanized territory of the Municipality of Parma (Fig. 16), and includes the historical downtown and recent settlements. The area is subjected by a dense urbanization, with a concentration of residential built up areas, trading and services. Historical gardens (Parco Ducale) are the North boundary of the study area. The mean ground elevation is about 55 m above sea level.

Hydrogeology

The area presents a flat morphology softly sloping to N-NE, following the course of alluvial conoids that have been deposited by the Taro, Parma and Baganza Rivers (all the waterways flow through the municipal territory). The study area is located in hydrographic left of the Parma River (Fig. 18).

The Quaternary drifts present ribbon-like and lens-like structures that lengthen following the stream that laid them down and that are mostly made of

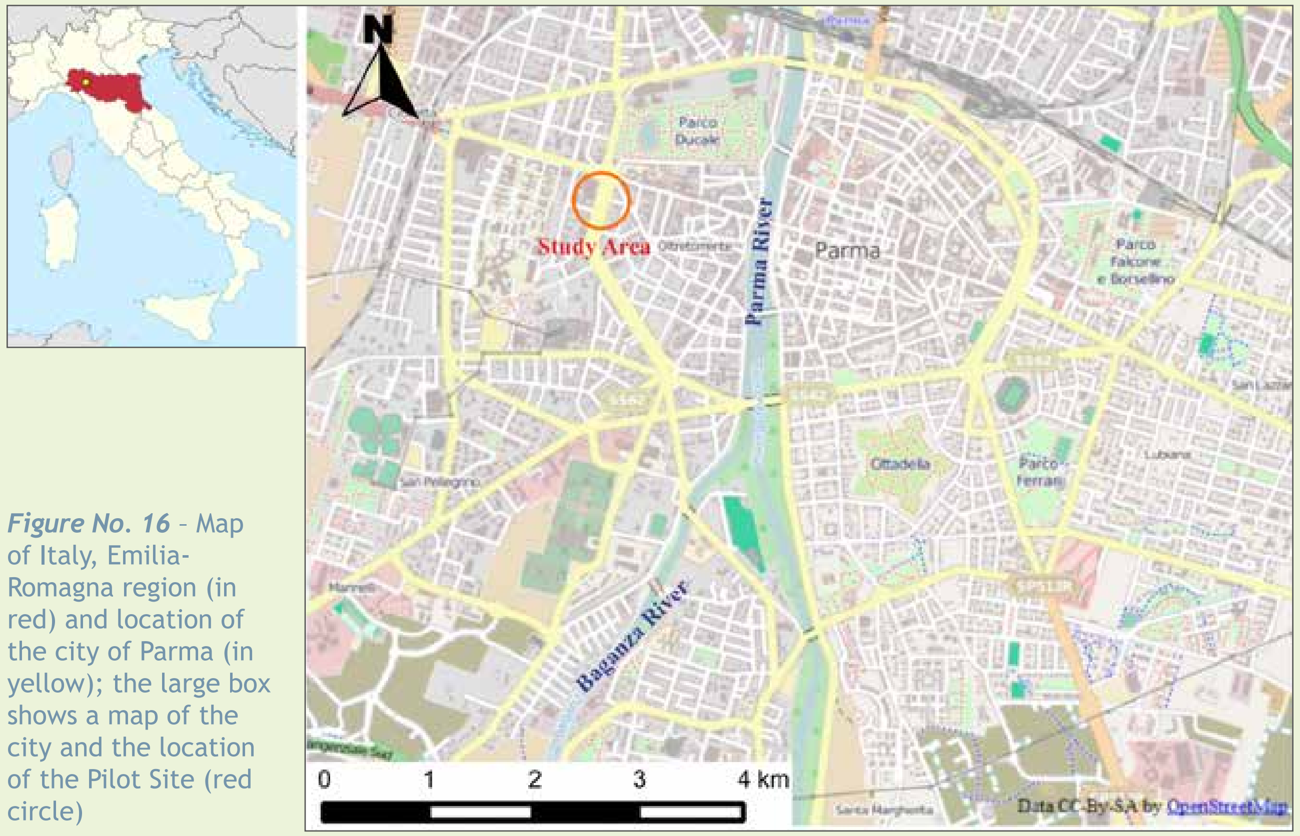


Figure No. 16 - Map of Italy, Emilia-Romagna region (in red) and location of the city of Parma (in yellow); the large box shows a map of the city and the location of the Pilot Site (red circle)

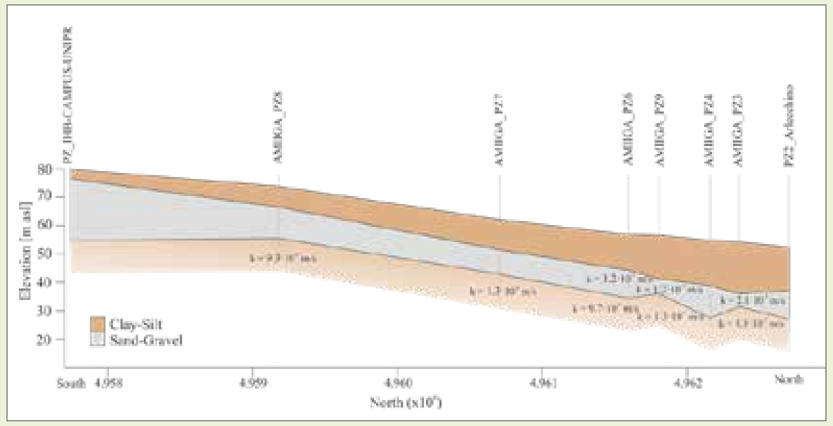


Figure No. 17 - North-South hydrogeological cross section

heterogeneous clastic sediments, from gravelly to clayey (with sudden spatial variations). Fig. 17 shows, as example, the North-South hydrogeological cross section that crosses at the pilot site.

Contamination

The first information about the groundwater pollution (presence of hydrocarbons, Methyl tert-butyl ether - MTBE, Benzene, Toluene, Ethylbenzene, Xylenes - BTEX) was collected in 2002 during a reclamation procedure on an area in which was located a gas station. At the end of the procedure, the sampling analysis showed PCE concentrations in groundwater higher than the law limits, even in piezometers upstream the gas station. From 2005 to 2015 the Perchloroethylene (PCE) concentration presents a positive trend up to 18-24 µg/l.

In February 2013 an historical analysis of the commercial activities, which potentially used PCE and were close to the study area in the 20-25 past years, has been carried out.

The knowledge at the beginning of the AMIIGA project did not allow to identify the source of the pollution and the extent of the plume; for this reason it was necessary to design and improve the environmental investigations.

In order to evaluate the Natural Attenuation as potential remediation method, seven sampling campaigns (from September 2017 to March 2019) were carried out on the designed monitoring network. During the sampling campaigns, water samples were collected for the analysis of the following compounds: Nitrate, Nitrite, Trichloromethane, Vinyl Chloride (VC), Trichloroethylene (TCE), Perchloroethylene (PCE), 1,1-Dichloroethylene (1,1-DCE), 1,2-Dichloroethylene (1,2-DCE), Ethylene, Trichloroacetate and Ethanediol. Moreover, water sample were collected for the evaluation of the bacteria that are present at the pilot site and for isotope analysis.

The sampling campaigns performed by AMIIGA have showed that the main pollutant was PCE. TCE was always below law limits; 1,1 DCE had values above law limits only in the second sampling round (December 2017) and VC was detected only at AMIIGA_PZ5 during the second sampling campaign and at AMIIGA_PZ9 during the third SC, but with very low values.

At the moment, since the responsible of the contamination is unknown, according to Italian laws the Municipality of Parma has to bear the costs of the investigation and remediation. At the present state, the sources of the pollution are still unknown.

Threat to groundwater pollution in Parma FUA

- The hydrostratigraphic system is composed of aquifer reservoirs, juxtapose, overlapping and partially or totally isolated by barriers of permeability made of sedimentary bodies, whose predominant element is fine.

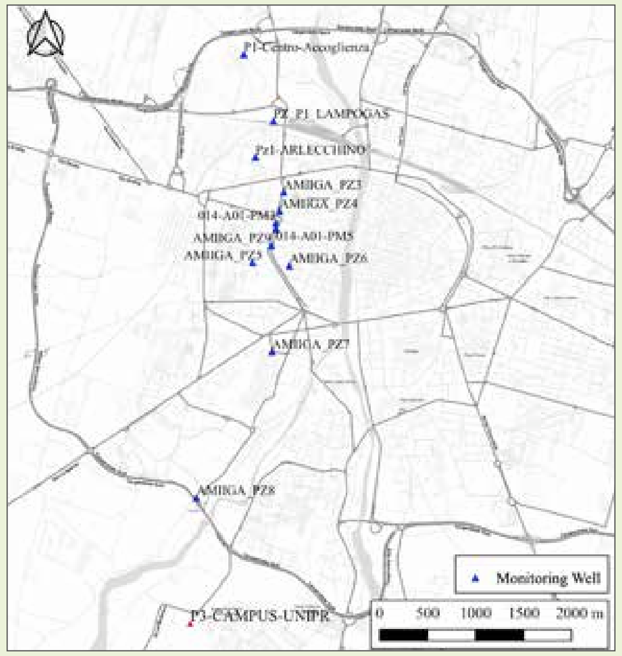


Figure No. 18 - Monitoring network

- The groundwater interested by the pollution is between 9.0 to 18.0 m depth.
- The first aquifer that feeds the city aqueduct is at least 36.00 m deep the ground level.
- The local environmental authorities are aware that the pollution could be drained in the deeper aquifer (feeding the city aqueduct).

Benefits from AMIIGA project to Parma FUA

The application of the AMIIGA project has led us to identify a new situation of contamination of the shallow aquifer around the Arlecchino kindergarten: the adopted consequence is the start of a technical-bureaucratic process that will lead to manage the pollution phenomenon: a risk analysis will be elaborated.

A second action was the development of the groundwater monitoring network within the urbanized area of Parma: seven new piezometers were drilled, that allowed and will allow to control the quality of the groundwater environment in the area of the Oltretorrente (Fig. 18). These infrastructures could also be used for general clean-up operations should the need arise.

The Technical University of Liberec analysed the water samples of two sampling rounds (December 2017 and May 2018) using the innovative Bio-Molecular Techniques. These analyses allowed to identify the presence of denitrifying bacteria, sulfate-reducing bacteria and BTEX degraders and only slightly active organohalide respiration.

These results indicated that there was not an effective degradation of CHCs, which meant that the Natural Attenuation at this stage was not an option in the remediation process of Parma pilot site. On the other hand, the observed concentrations were not very high and presented a variability during the hydrological year.

Nitrite was always close or below the detection limits except in the Galasso Channel, whereas Nitrate was always below law limits. Furthermore, denitrifying bacteria were detected. The Nitrites and Nitrates now do not represent a contamination problem at the pilot site; however a Natural Attenuation of Nitrate is already observed.

The isotope analysis on 18O and 2H performed by University of Parma indicate that surface water and groundwater coming from the Apennines are feeding the shallow aquifers within the Parma plain. Groundwater and surface water have a strict connection upstream the city of Parma. The isotope analysis on 13C performed by Politecnico di Milano, unfortunately, due to the low PCE concentration values did not provide any significant result.

Two groundwater numerical models have been developed. The first was developed at FUA scale in order to evaluate the main groundwater flow direction and to roughly identify the hydraulic parameters of the aquifer, whereas, the second model was developed at pilot site scale and aimed at reproducing with high details the geometry of the shallow investigated aquifer. The local model kept into account all the data collected during the project development. Both numerical models were calibrated in transient conditions, thanks to the available and new data. The model at FUA scale covers an area of about 630 km^2 and spans from Apennines to the Po River, whereas the local model (about 9 km^2) is focused just upstream and downstream the pilot site area. The numerical model at pilot area scale was applied to: identify the mean flow direction at local scale; estimate the mean hydraulic conductivity of the aquifer; reproduce the seasonal variability of the water table; perform transport simulations starting from potential sources.

After the calibration, the numerical model was applied to perform backtracking analysis in order to delimit the potential source areas. Thanks to the work carried out by the Municipality of Parma to list the potential contaminant source sites and the Web-GIS, it was possible to overlap the backtracking results to potential sources, such as: Car Garage, Deposit, electrical Plant, Laundry, Leather works and Mechanical Construction. After an analysis of the potential sources, timing and groundwater velocities, one source was identified as the most probable.

A simplified transport simulation was performed to reproduce the hypothetical contaminant evolution from the identified source. In particular, it was assumed to consider a conservative contaminant and a constant injection (1 mg/L) at a potential source for ten years; then the plume evolution was observed for other 20 years. Fig. 19 shows the plume evolution for 30 years with a time step of 5 years.

Performed Pilot Action A.T2.4 - Implementation of Pilot Action 4: Assessment of NA potential as a remediation option in Parma FUA (IT) has met planned expectation and brought the following achievements:

- collection and organization of all available hydrogeological and chemical data on Web GIS and GIS platform,
- development of a new monitoring network with the drilling of seven new to monitor the development of groundwater pollution,
- development of groundwater numerical model at FUA scale and at local scale,
- chemical, isotope and BMT analyses were performed to evaluate the NA feasibility.

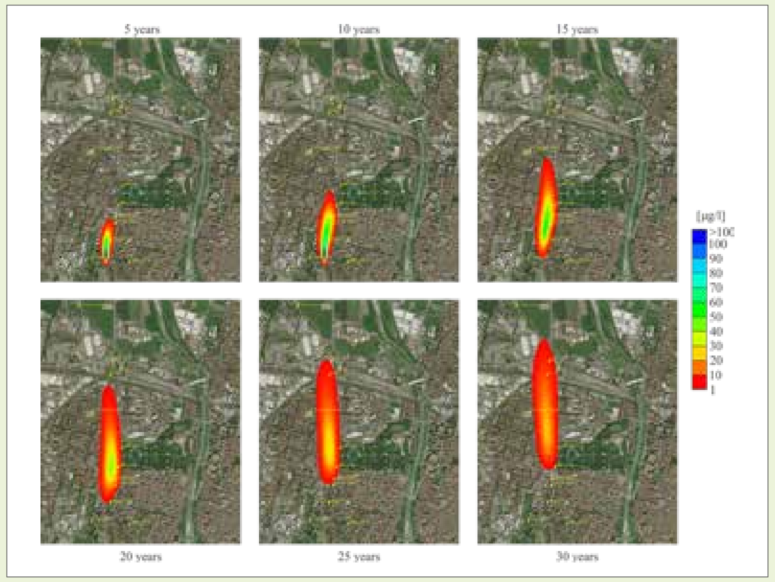


Figure No. 19 - Contamination plume evolution from hypothetical source

Figure No. 20 - The aerial photo of the town centre

N-SITU BIOLOGICALLY ENHANCED REMEDIATION IN NOVY BYDZOV FUA (CZECH REPUBLIC)

Introduction

Novy Bydzov (Fig. 20) 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.

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.

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 City of Novy Bydzov as the responsible authority for groundwater, drinking water and contaminated site management and as land owner has started to initiate measures to protect the public health and has carried out groundwater investigations in the first two decades of 21st century:

- ***Participation in the project FOKS (CE 2008-2013)***
  - Assessment of health risks arising from previously identified contamination of groundwater in the premises of the former KOVOPLAST Plant.

- Identification of other potential hot spots 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.

- ***Participation in the EU fund Operation Programme – Environment (EU 2012-2015)***

  - Detailed supplementary exploration of the polluted locality for further design of remedial measures.

  - Testing of suitable remedial technologies for removal and reduction of the pollution of groundwater.

Threat of groundwater pollution to FUA Novy Bydžov

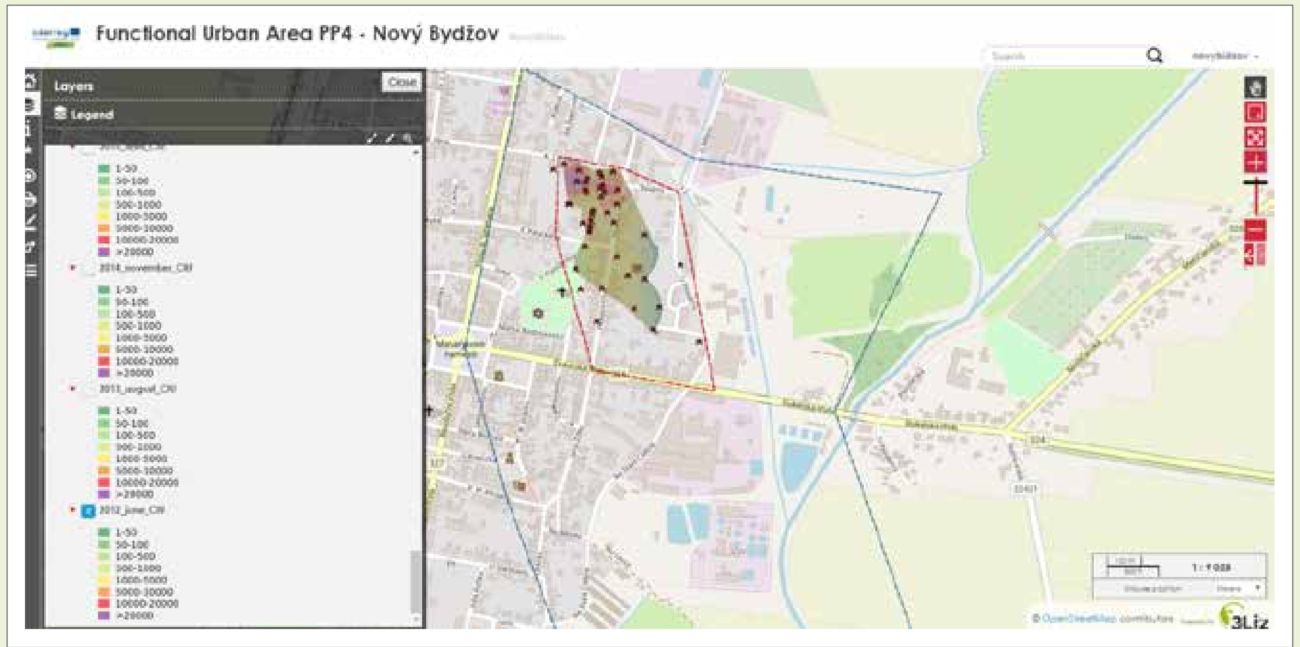
The processed Risk analyses (2010, 2015) have confirmed serious potential risks on human health in residential area surrounding the former plant KOVOPLAST. A numerical model of groundwater flow developed for the city of Novy Bydzov has confirmed that quality of the groundwater body in FUA Novy Bydzov as well as the quality of the surface water body in the Cidlina river basin (covering the area of 176 km^2) could be affected from the pollution if no mitigation action is performed.

Environmental burns (Fig. 21) 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.

Benefits from Project AMIIGA to FUA Novy Bydžov

In the project AMIIGA, the innovative remedial technology Biological Enhanced Reductive Dehalogenation (BRD) has been applied for decreasing the contents of chlorinated hydrocarbons in groundwater in the working area in FUA Novy Bydzov. The

Figure No. 21 - Concentration of suma chlorinated hydrocarbons in groundwater - FUA Novy Bydzov (June 2012) (webGIS toll developer in AMIIGA)



Pilot Action Novy Bydzov demonstrates the exemplary case study of processing the biologically enhanced remediation of groundwater polluted with chlorinated hydrocarbons. Pilot Action in FUA Novy Bydzov performs the key steps assuring the effective and sustainable remediation- testing remedial procedures in laboratory scale, then verifying in the field in pilot scale before the full scale application.

During AMIIGA project the following activities were performed in Pilot Action Novy Bydzov.

- ***Supplementing of monitoring network***

  - The existing system of monitoring wells at the Novy Bydzov built in the years 2012-2015 were supplemented with 5 new monitoring wells.

  - The location of the new wells was based mainly on the possibility to fill in the missing data on the actual extent of groundwater contamination and to improve the planned remediation of the groundwater therein.

- ***Monitoring the development of groundwater pollution in the working area***

  - The monitoring program was carried out twice a year. The initial groundwater monitoring campaign was carried in January 2017. The next campaigns were performed in June 2017, in November 2017, in July 2018 and in December 2018.

- ***Specification of groundwater and dissolved pollution transport pathways***

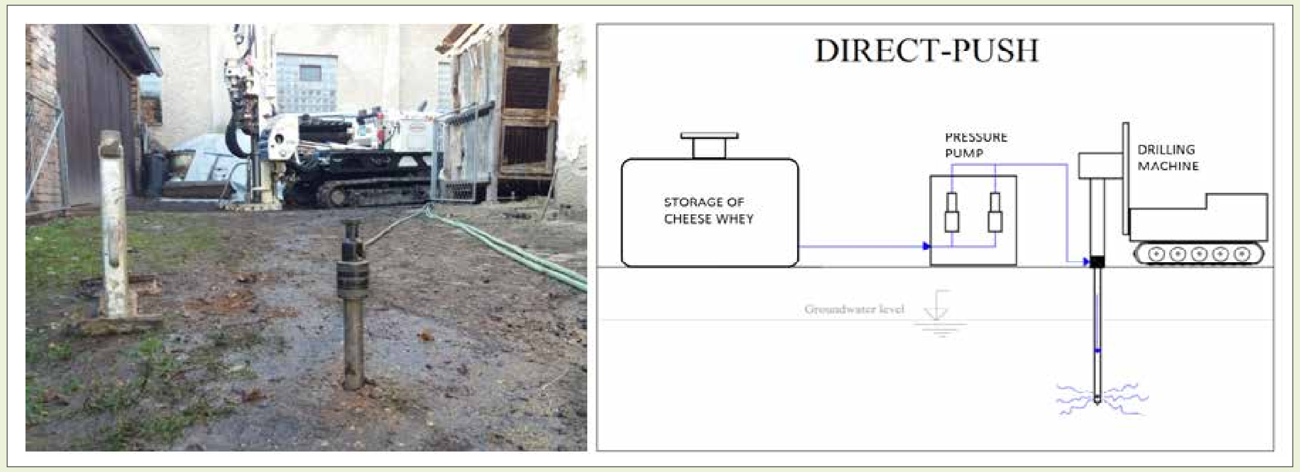
  - Evaluation of datasets with historical data from remediation works (2012 – 2015).

- ***In-situ biologically enhanced attenuation***

  - Laboratory test of remedial technique was conducted in laboratories of Technical University in Liberec between January and April 2017 Four different carbon sources (lactate, glycerol, cheese whey and PHB (polyhydroxybutyrate)) have been tested and basing on several analyses (BMT, pH, ORP, conductivity) the best one was chosen for application in situ. Further, various oxidants were tested in order to evaluate the removal of contaminants from Novy Bydzov groundwater. The tests helped to specify the parameters of the remediation in the scale of field test.

  - Field Pilot Test of technology BRD (biologically enhanced dehalogenation) was tested in area located eastward from the former plant Kovoplast (the main source of groundwater pollution). Application of cheese whey was performed in three separate rounds via direct-push technique in the inflow area of the monitoring wells. Particular application rounds were conducted in November 2017, December 2017 and May 2018 (Schema of the direct-push application is shown in the Fig. 22).

Figure No. 22 - Schema of direct-push injection.



- Groundwater operational monitoring was performed with the objective to evaluate efficiency and progress of remedial technology BRD. Monitoring was conducted once before the first injection of cheese whey in November 2017 and then monthly until nowadays. Bio-molecular tests (BMT) were used to characterize microbial specific degraders according to relevant contamination of CHC.

Performed Pilot Action A.T2.5 - In-situ biologically enhanced remediation has met planned expectation and brought the following achievements:

- Collection and systematization of all available hydrogeological and chemical data on Web GIS and GIS platform,
- Creation of a supplementary network of monitoring wells to monitor the development of groundwater pollution,
- Reduction of CHC groundwater pollution at the testing site (Fig. 23),
- Defining the extent of the contamination plume in the southern part of the area of interest and identifying 2 new sources of pollution,
- Confirmation of suitability of BRD application as the main procedure for removal of CHC contamination in the contamination plume on the site of Novy Bydzov,
- Processing methodology for BMT application in biodegradation method BRD,
- Processing methodology for the removal of groundwater contamination CHC.

The development of groundwater pollution during the testing of innovative technologies is illustrated in the Fig. 23.

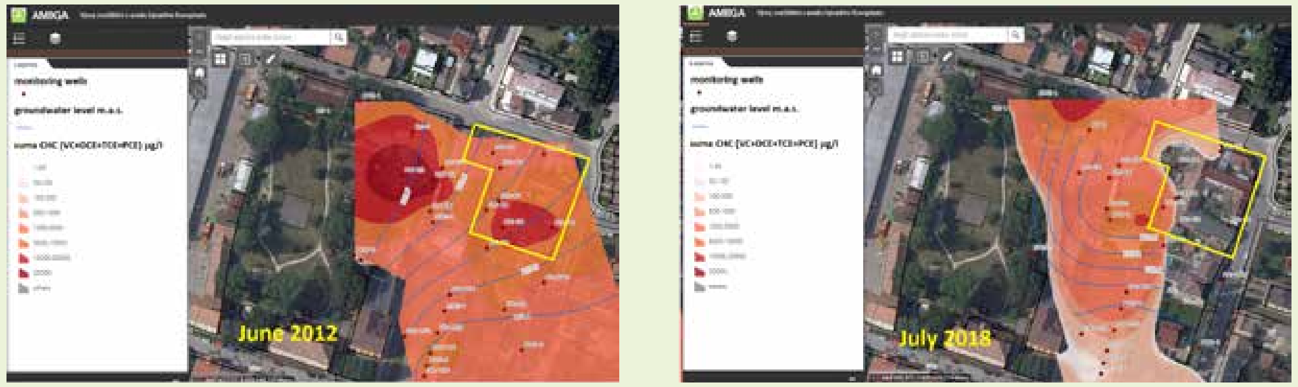
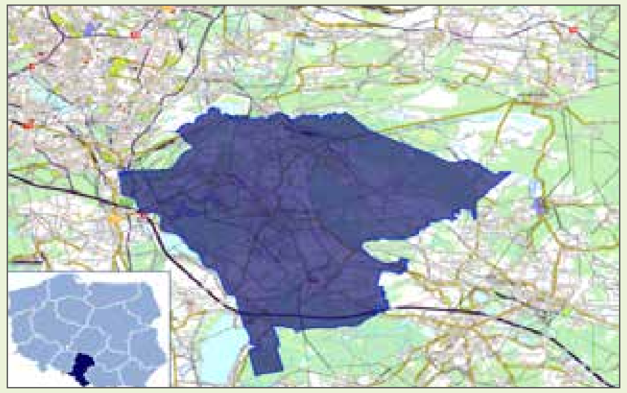


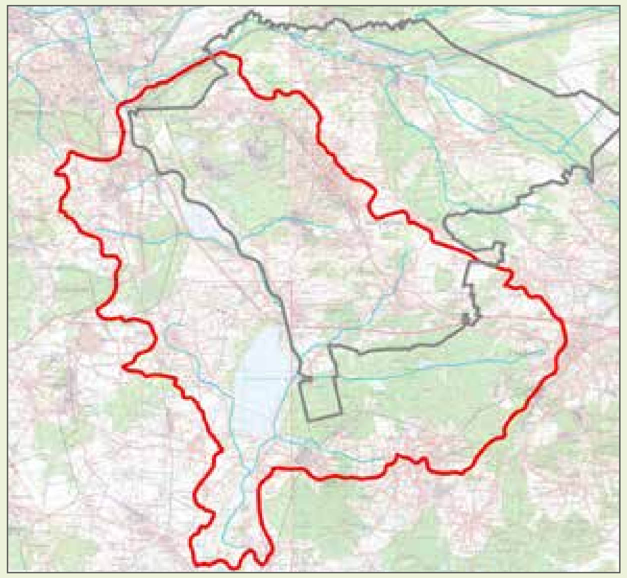
Figure No. 23: Development of concentrations of suma chlorinated hydrocarbons in groundwater - the former plant KOVOPLAST and its vicinity (2012-2018) (webGIS toll developed in AMIIGA)

CONSTRUCTION AND MONITORING OF BIOREACTIVE BARRIER WORKING IN JAWORZNO FUA (POLAND)

Introduction

The city of Jaworzno is located in the southern part of Poland, in the eastern part of the Silesia Province - the most industrialized area in Poland. Jaworzno FUA covers core part of the Jaworzno Municipality and adjacent cities partially located within the boundaries of the groundwater body No. 146 (Fig. 24 and Fig. 25).





Jaworzno is among the largest towns in Poland - its area is 152.7 km^2 with more than 94.000 inhabitants. In 20^{th} century Jaworzno's economy has been based on power engineering connected with the extractive industry, cement and chemical industry which have affected far-reaching transformations of components of the environment. The most significant transformations affected surface water and groundwater. Jaworzno's biggest environmental problem is the impact of pollutants from the chemical industry in the valley of the Wąwolnica stream (Fig. 26).

The valley of the Wąwolnica stream is contaminated as a result of activity of chemical industry dating back to the 1st World War period, with the highest intensity from the 60's to 80's of the 20th century. The site of former Chemical Plant Organika-Azot S.A. plant was 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 basin[1]. Up to now more than 195 thousand tons of hazardous wastes have been recorded in this area

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

Figure No. 24 - Location of Jaworzno Municipality (source: GIG elaboration based on http://mapy.geoportal.gov.pl and https://commons.wikimedia.org)

Figure No. 25 - FUA Jaworzno (red colour of boundaries) with indicated boundaries of Jaworzno Municipality (grey colour) (source: GIG elaboration)

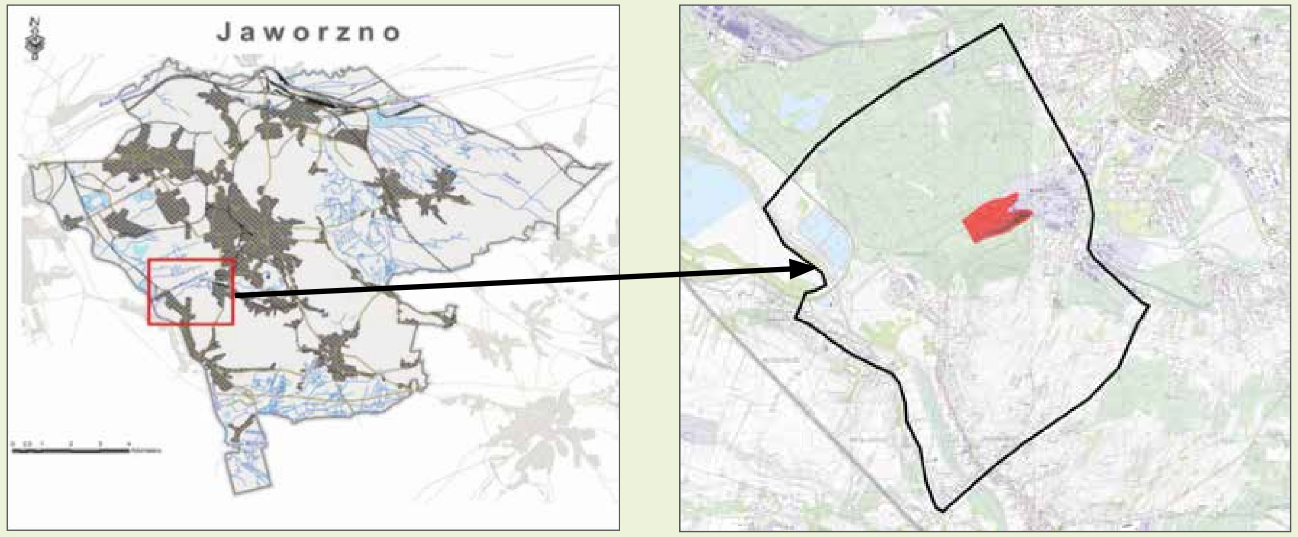


Figure No. 26 - The location of contaminated site in Jaworzno Municipality with indicated plume of contaminants, Trzaski et al. 2012

and their adverse effect on the environment, especially soil, groundwater and surface water has been confirmed[2]. Among the disposed wastes there are hundreds of dangerous, persistent toxic substances, such as: pesticides, their semi-finished products and partial decomposition products. Some of them, like - DDT, DDE, DDD, dieldrin, endrin, alpha-HCH (α-HCH), beta-HCH (β-HCH), gamma-HCH (δ-HCH) are considered as posing particular threat to the environment and are included in the list of persistent organic pollutants (POPs) under the Stockholm Convention.

AMIIGA project, focused on multiple characterization, assessment and management strategies, intended to build and capitalize on the results of former Interreg Central Europe project FOKS (Focus On Key Sources of Environmental Risks), which had been realized in the years 2008-2012 by Central Mining Institute with the City of Jaworzno. The activities implemented within FOKS project concerned the identification of key sources of groundwater contamination in the most contaminated area of Chemical Plant Organika-Azot S.A. and the nearby waste disposal area – Central Landfill (CSO) in the Wąwolnica stream valley (including a former sand pit "Rudna Góra"), as well as selection of best technology to stop the contamination emission and development of general concept of remediation.

The further and more detailed remediation concept for Jaworzno contaminated site was developed in the years 2014-2015 within Multi-variant Technical and Environmental Analysis (WATS[3]) carried out by GIG in 2015 at the request of the City Council of Jaworzno 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".

2 • For example: in regional documents, such Environmental Protection Program for the Silesian Voivodship until 2019, with a view to the year 2024, https://www.slaskie.pl/download/content/67075

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

Threat of groundwater pollution to Jaworzno FUA

The main waste collection place in Jaworzno is the former sand pit "Rudna Góra". Although part of the contaminants is being captured through a trench system constructed at the bottom of the former sand pit, the groundwater is still being contaminated. The level of groundwater contamination from HCH is being from several to hundreds of micrograms per liter.

The contaminant plume migrated downstream, along the post-glacial valley of the Wąwolnica stream, according to the general groundwater flow direction. The analyses of risk carried during FOKS project have confirmed serious environmental risk in Jaworzno site. As part of AMIIGA project, a groundwater Management plan has been created, including, among others, concept for the regional monitoring network and specific action plan covering activities to be performed in different periods of time.

Within AMIIGA project also actions reducing the impact of the identified groundwater contamination plume have been carried out, including modernization of the monitoring network in the area of the Wąwolnica stream valley and in the Przemsza river valley for better tracing of the contamination of groundwater pollution. The results of AMIIGA project showed that there are two plumes of contaminants differing in types of HCH isomers and their concentration. The northern plume is mostly contaminated with b-HCH. And the second plume containing α-HCH, β-HCH and δ-HCH with the concentration of sum HCH even above 100 ug/l was noticed on the south of the Wąwolnica stream (Fig. 27).

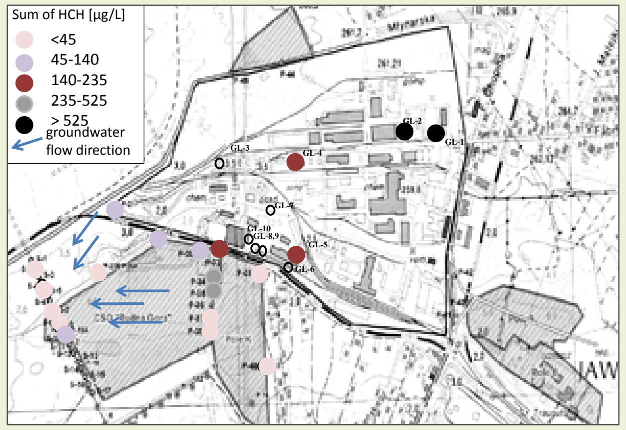
The one plume with the concentration of HCH between 10-100 μg/l was observed in the north of the Wąwolnica stream (Fig.4).

Benefits from AMIIGA Project to Jaworzno FUA

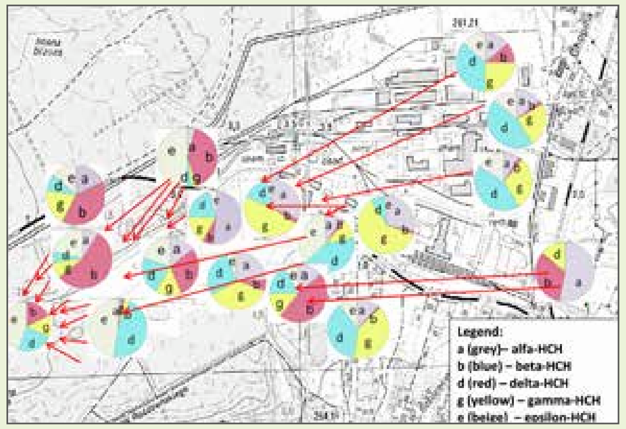
In the AMIIGA pilot action, the novel technology of passive bioreactive barrier (PRB) has been applied for decreasing the contents of HCH in groundwater in the area of groundwater contamination with pesticides downstream the Chemical Plant Organika-Azot S.A. PRB technology is a novel groundwater remediation method which allows to combine of physical, chemical and bio-

Figure No. 27 - The spatial distribution of HCH: A. The differences in concentration of HCH in the northern and southern plume of contaminations; B. The proporotion between various isomers of HCH in the monitoring points: aHCH (a, grey); bHCH (b, red); dHCH (d, blue); gHCH (g, yellow); eHCH (e, beige) - Jaworzno FUA (June, 2017) (source: results of sampling campaigns during AMIIGA)

A.



B.



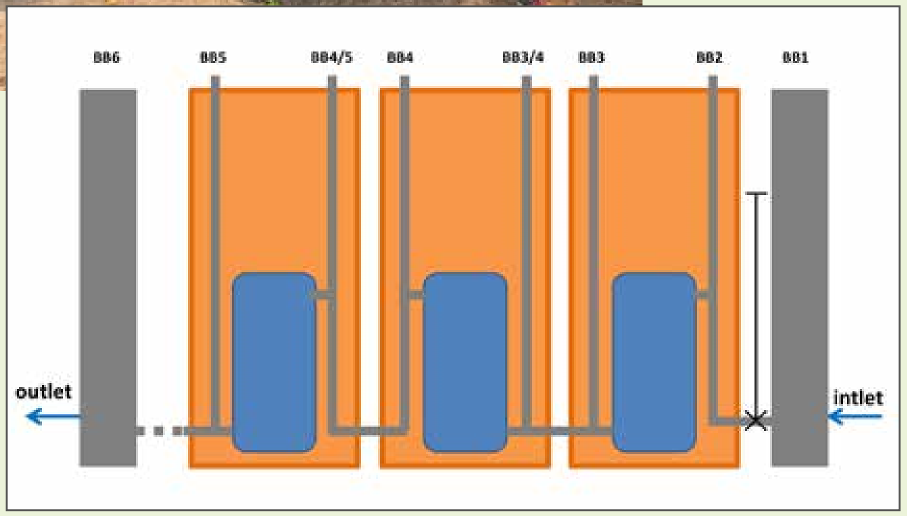


Figure No. 28 - Scheme of the reactive barrier (source: GIG elaboration, AMIIGA)

logical in situ treatment of contaminated groundwater using different reactive materials, such as: iron chips, sand, peat, biochar and bacteria inoculum. The barrier was built in the funnel and gate system with impermeable funnel walls and 3 chambers connected together (gates). (Fig. 28).

The impermeable funnel is used to channel the contaminant plume into chambers 1, 2 and 3 (I stage) or 1 and 2 (II stage) which contains the reactive material. The main goal of investment implementation is to test the effectiveness of the reactive barrier with microbiological deposit (especially prepared for this pilot action), as an appropriate component used for bioremediation of groundwater environment contaminated with persistent organic compounds, to eliminate migration of contaminants, as well as to identify possible difficulties and the potential impact of carried works on the health of residents and the environment.

Within AMIIGA project the following activities were performed in the contaminated sites of Jaworzno FUA.

- ***Supplementing of monitoring network***

  – Upgrading system of monitoring wells which was built in 2010 in the framework of FOKS project, by cleaning existing research points (partially devastated and clogged) and construction of three new monitoring wells.

  – The implementation of new wells was necessary to improve monitoring process of the current state of the environment at the Jaworzno site and to obtain the missing data on the actual extent of groundwater contamination.

- ***Monitoring the development of groundwater pollution in the working area***

  – The monitoring program was carried out once a year. The initial groundwater monitoring campaign was carried in June, 2017. The next campaigns were performed in June, 2018.

- ***Modelling of dissolved pollution transport in a different scenarios***

  – Development of dissolved pollution transport pathway in a 5- and 25- years perspective.

- ***Monitoring the efficiency of groundwater treatment by the bioreactive barrier***

  – Pilot test of bioreactive barrier technology was provided in the area so-called "old heap near the tracks" located nearly the Chemical Plant Organika Azot S.A. in Jaworzno.

  – Implementation of the bioreactive barrier was preceded by the preparing actions:

    - Determination of geotechnical conditions in the place of localization of the barrier.
    - Selection of appropriate sorbent for the barrier.
    - Isolation and preparation of bacteria inoculum to application into the reactive zone of barrier in order to enhanced the treatment of groundwater.
    - Development the concept and then the technical project of the reactive barrier.
    - Acquisition of necessary permissions and the installation.

  – The operational monitoring of the bioreactive barrier was performed with the objective to evaluate efficiency and progress of remedial technology.

  – Monitoring was conducted from May 2018 until nowadays. The samples for physical, chemical and biological analysis were taken twice a month. Laboratory tests were conducted in laboratories of Technical University in Liberec. The isotope analysis of groundwater samples was conducted in laboratory of Polytechnic of Milan.

  – Three different reactive materials (reactive iron, peat&sand and biochar) have been tested separately and in combination in order to evaluate the effectiveness of HCH sorption and reduction. During sampling process, several physicochemical analyses (pH, ORP, conductivity, temperature and oxygen concentration) were measured. The test help to determination of sorption capacity of peat&sand bed, the reduction process effi-

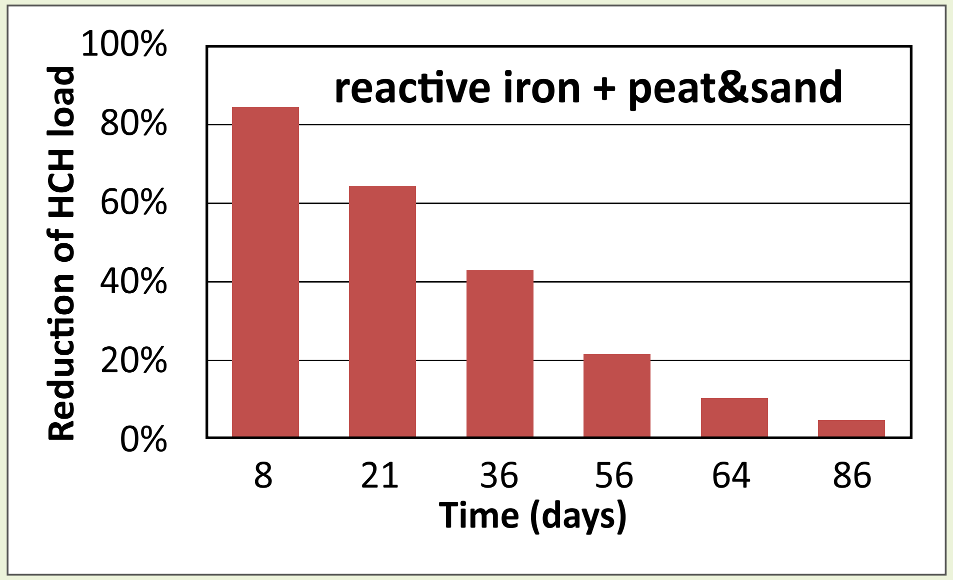


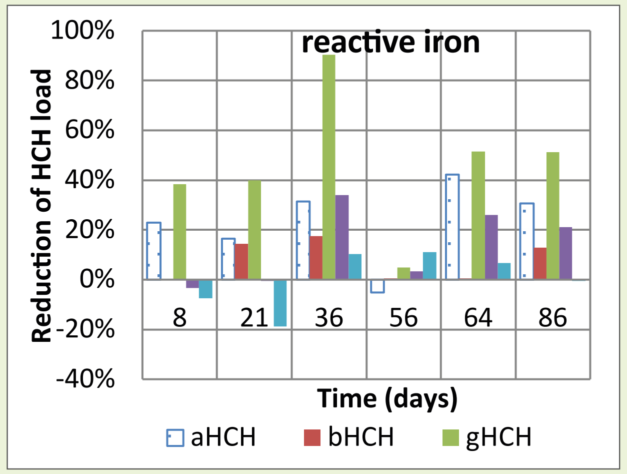
Figure No. 29 - The effectiveness of HCH load reduction by 2 chambers reactive biobarrier contains: cartridge I: (reduction process by reactive iron) and cartridge II: (sorption process with peat&sand bead) (source: GIG elaboration, AMIIGA) ciency by using iron chips, and to specify the parameters of the remediation in the pilot scale.

Performed Pilot Action A.T2.6 - Passive GW treatment by bioreactive wall in Jaworzno FUA (PL) has met planned expectations and brought the following achievements:

- Reduction of HCH groundwater pollution at the testing site (Fig. 29).
- Confirmation the potential of the passive bioreactive barrier technology for groundwater treatment application, especially in the term of HCH pollution removal.
- Indicating the technical guidelines for groundwater treatment by using reactive materials as sorbents in the passive reactive barrier technology.
- Processing methodology for BMT application in monitoring of treatment progress by the passive bioreactive barrier.
- Processing methodology for the removal of groundwater contamination with HCH.

The effectiveness of sum HCH and various HCH isomers reduction by 2 chambers reactive biobarrier is illustrated in the Fig. 29 and Fig. 30.

A.



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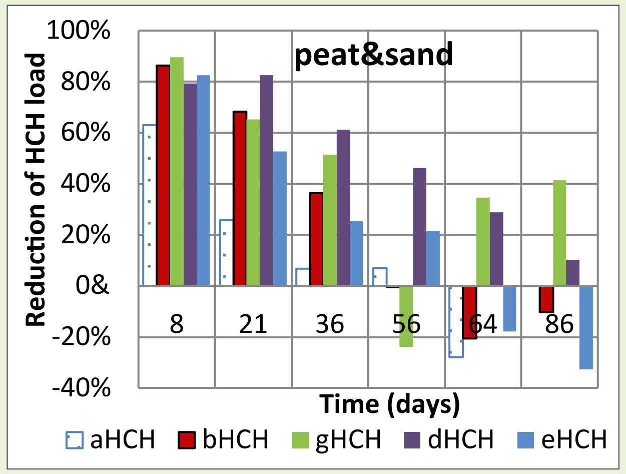

Figure No. 30 - The effectiveness of various HCH isomers reduction by 2 chambers reactive biobarrier: A) The effectivness of HCH isomers reduction via cartridge I: (reduction process by reactive iron); B) The effectivness of HCH isomers reduction via cartridge II: (sorption process with peat&sand bead) (source: GIG elaboration, AMIIGA)

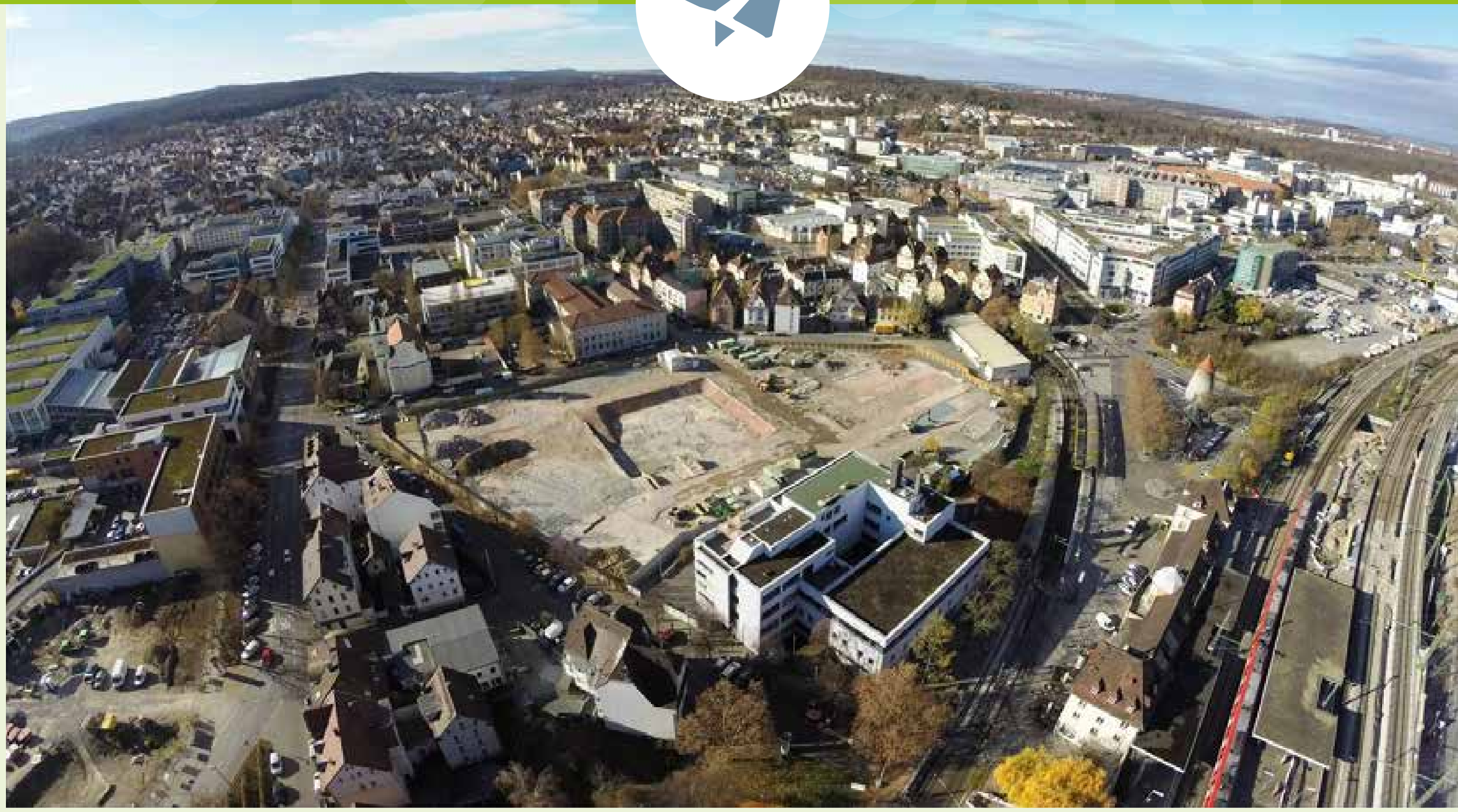

Figure No. 31 City district Feuerbach.

INTEGRAL MONITORING OF REMEDIAL MEASURES EFFICIENCY (STUTTGART-FEUERBACH FUA, GERMANY)

Introduction

The city district Feuerbach (Fig. 31) 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. Since 1983/84, the private responsibles 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 easily mobile in the underground, (ii) spread over a large area and (iii) endanger the quality of groundwater i.e. the Stuttgart's mineral springs (Vasin et al., 2016).

The integral investigation of CHC contamination in soil and groundwater in Feuerbach has been also previously supported by the EU-funded projects MAGIC and FOKS. Those projects focused on flow and contaminant description of the shallow aquifers (Fig. 32, working area). AMIIGA broadened the scope on the deep, regional aquifers (Fig. 32, FUA). Those are of particular importance in Stuttgart as they discharge 19 mineral springs, which are used for medical and spa purposes.

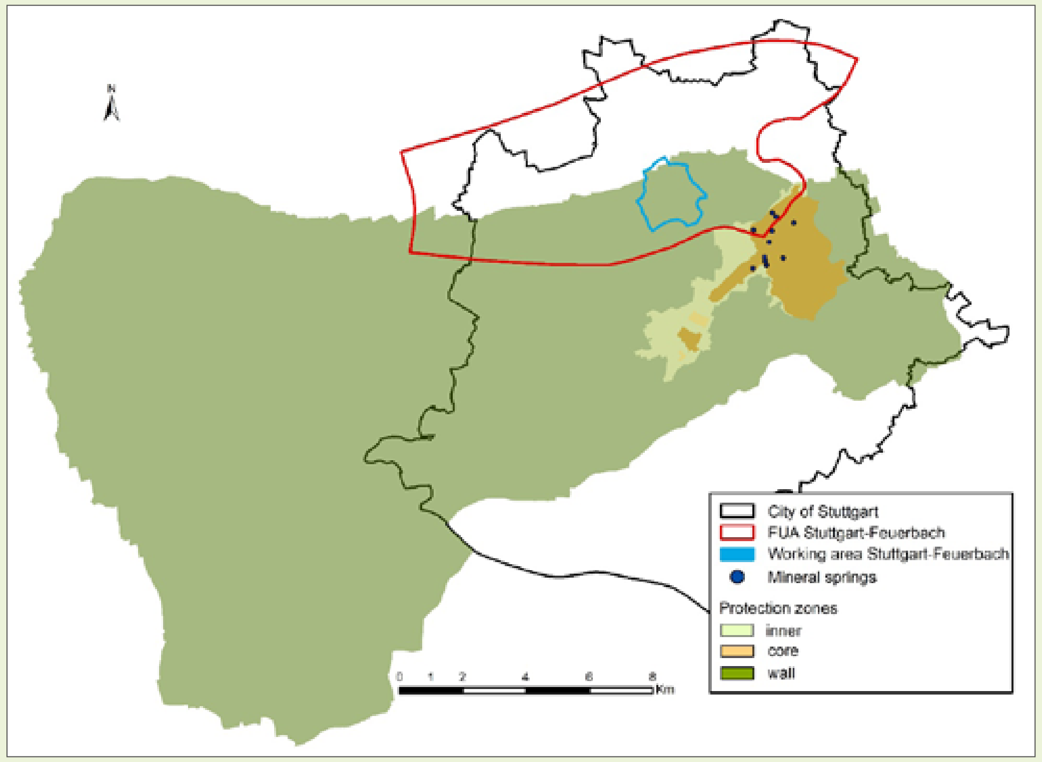

Figure No. 32 - Project areas (working area and FUA with mineral springs and their protection zones).

The goal of the pilot action was (i) to clarify the flow and contaminant situation in both shallow and deep aquifers, (ii) to understand potential pathways of contaminant migration into the deep mineral water aquifer and (iii) to design an efficient monitoring network that captures the integral contaminant situation. The pilot action met the planned expectations and achieved its goals.

Threat to groundwater in FUA Stuttgart-Feuerbach

Despite carried investigation and remediation measures over decades and current practices of environmental management, soil and groundwater are still remaining polluted in Stuttgart-Feuerbach. The integral groundwater investigations indicated that the threshold values (CHC concentration < 10 µg/l and load < 20 g/d) could not be fully achieved at some sites with reasonable efforts and budget. Still it was unclear whether and how the CHC contamination of Feuerbach affects the regional mineral water aquifer (Muschelkalk). A system to monitor the development of groundwater quality is missing.

Benefits from project AMIIGA to FUA Stuttgart-Feuerbach

AMIIGA project enabled the City of Stuttgart to address the issue of the existing mixed CHC-plumes in public areas and their potential threat to deep aquifers. Performed integral investigations in pilot action and investments enabled to update and improve the knowledge about groundwater flow and transport of CHCs in complex hydrogeological conditions. By identifying one major groundwater aquifer (Bochinger Horizont – BH) out of seven, it was possible to design an integral monitoring network (IMN), which was tested and proved to be effective for description of the integral contaminant situation in Stuttgart-Feuerbach. The obtained findings helped establishing a groundwater management plan for the working area Stuttgart-Feuerbach as well, aiming at a reduction of groundwater contamination and ensuring the good groundwater status.

During AMIIGA project, the following activities were performed:

- ***Data assessment***

All available data on flow and contamination were assessed. The origins of data and information were mainly from (i) the municipal database (BOISS/AquaInfo), (ii) the previous projects MAGIC and FOKS and (iii) several investigation reports of contaminated sites. The collected data and data gained in the project were imported into the database and evaluated.

- ***Development of conceptual models***

In order to develop a conceptual model, the following investigations were performed: (i) measurements of groundwater level on 227 monitoring wells, (ii) sampling and analysing CHC concentrations on 55 monitoring wells, (iii) 15 isotopic analysis on 10 monitoring wells, (iv) BMT groundwater analysis on 9 monitoring wells and (v) 10 BMT carrier analysis on 5 monitoring wells. Evaluation of all results enabled the development of the conceptual models for shallow and deep aquifers, describing the flow and contaminant situation in FUA Stuttgart-Feuerbach (Fig. 33).

- ***Development of a numerical model***

A 3D transient groundwater model was developed, based on the conceptual models and previous investigations. The model included seven aquifers from the quaternary to the limestone mineral water aquifer Muschelkalk. The program system MODFLOW with extended functions was used. Flow and transport of CHC were calculated between 2007 and 2017 for each aquifer (Fig. 34). The results were essential for the development of the management plan.

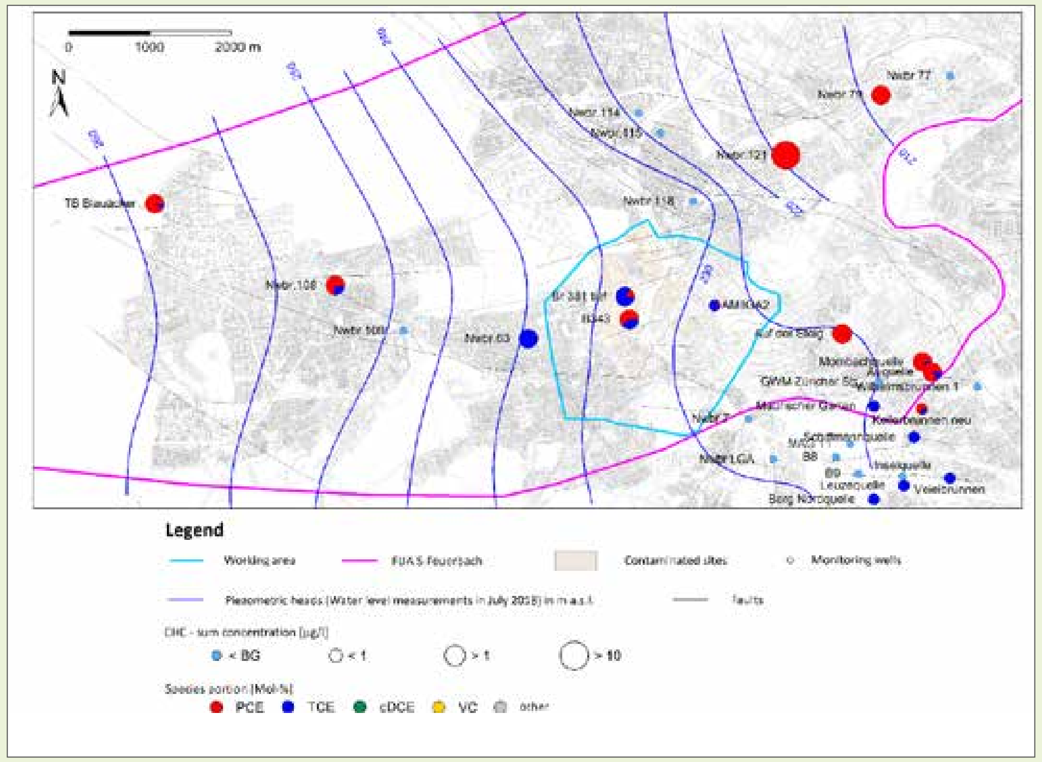

Figure No. 33 - Flow and contaminant situation in the mineral water aquifer Muschelkalk in FUA scale.

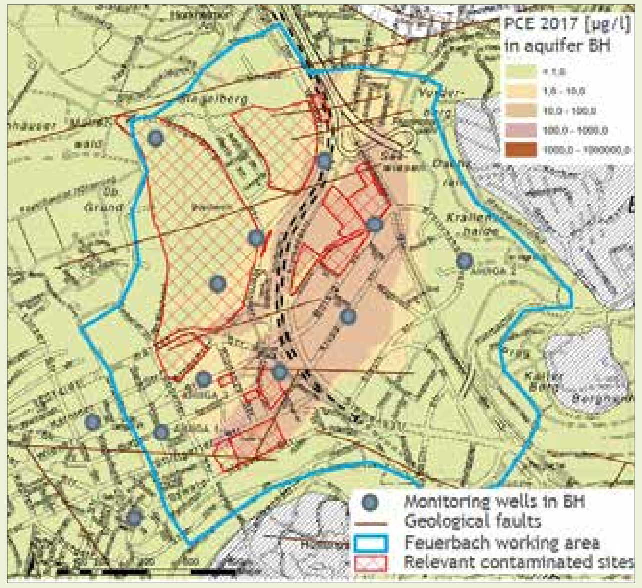

Figure No. 34 - Numerical model results for the CHC contaminant transport in the major groundwater aquifer.

- ***Drilling of new monitoring wells***

Within investment activities, three monitoring wells were constructed (Fig. 35):

(i) AMIIGA 1 with a depth of 32 m in order to check the vertical percolation of CHCs in the area of depression, built in the major groundwater aquifer BH,

(ii) AMIIGA 2 with a depth of 94 m in order to extend the monitoring network in deep mineral water aquifer, built in Muschelkalk and

(iii) AMIIGA 3 with a depth of 21 m to capture the northeastern gradient and to describe, evaluate and quantify a possible vertical transfer of CHCs to deeper aquifers, built in the major groundwater aquifer BH.

Figure No. 35 - Drilling cores of AMIIGA 2 monitoring well.

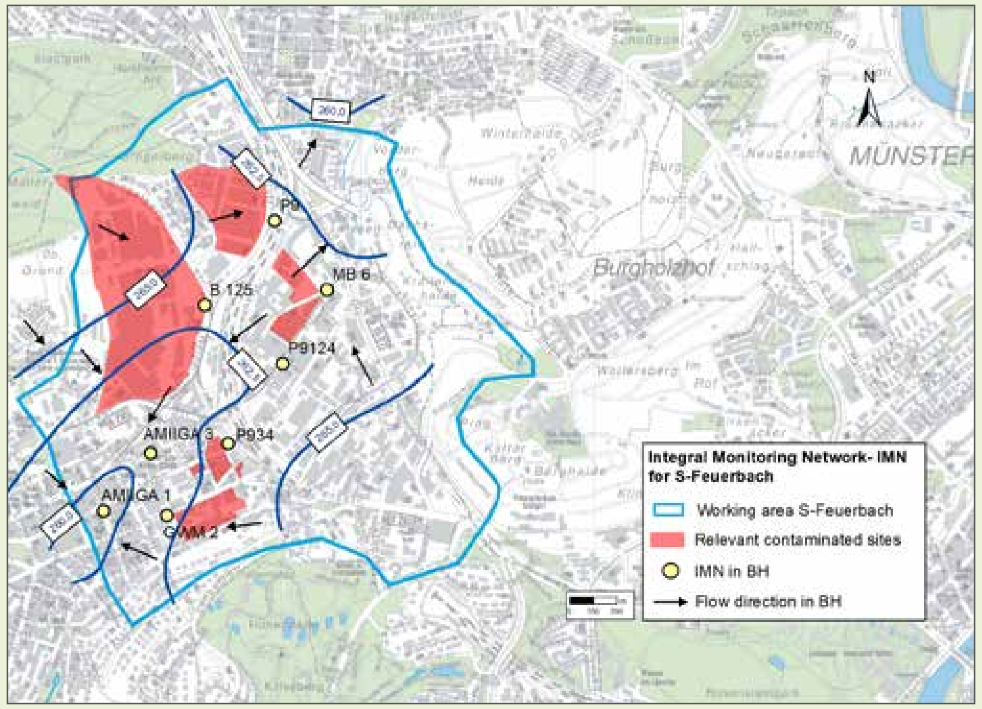

Figure No. 36 - Integral monitoring network in the working area Stuttgart-Feuerbach.

- ***Establishing of the integral monitoring network***

An efficient monitoring network (IMN) for Stuttgart-Feuerbach was designed. The wells of the IMN were selected to capture and describe the integral contaminant situation in the major aquifer BH (Fig. 36). One sampling campaign has been performed, which confirmed that IMN is efficient, enables further reduction of long-term monitoring costs and is easily transferable to other FUAs.

Literature

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www.interreg-central.eu/AMIIGA

TOWARDS CLEAN GROUNDWATER: FROM STRATEGY TO ACTION

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

Version 3

30.09.2019

Annex 1:

Good Practise Report – Deliverable D.T3.3.6: Summary of gained knowledge and experiences in seven pilot areas

Annex 2:

Questionnaire on local experiences on management plans – Deliverable D.T3.3.2

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 an 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

Interreg CENTRAL EUROPE AMIIGA

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.

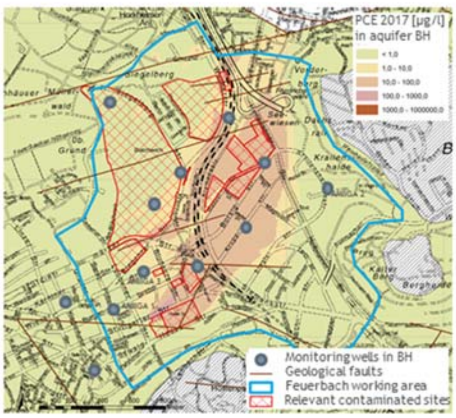
As a result of AMIIGA, the monitoring program will be adapted to take in account this area and other contaminated sites. An official announcement of significant pressure has been prepared to make visible the problem of groundwater body (No. 146) in National Water Management Plan for next planning period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

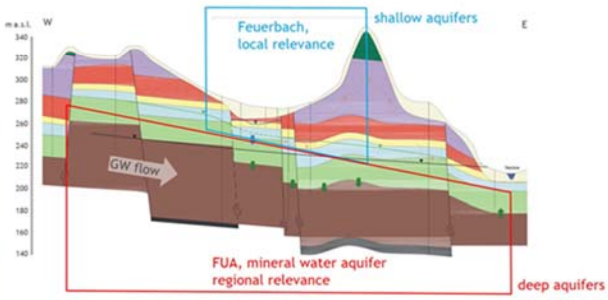
Pilot Jaworzno

Jaworzno GIG

EARLY WARNING SYSTEM FOR PROTECTION OF DEEP MINERAL WATER AQUIFER

Interreg CENTRAL EUROPE AMIIGA





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

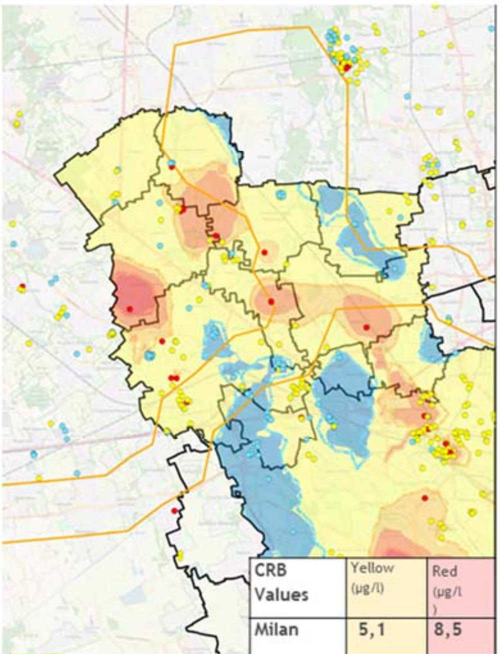
TAILORED APPROACHES FOR HOT SPOT AND PLUME REMEDIATION

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 quaternary aquifer in FUA Novy Bydzov
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 Analysis	
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.<1400µg/l PCE conc.< 700µg/l	TCE conc.<100µg/l PCE conc.<150µg/l	TCE conc.<10µg/l PCE conc.<10µg/l
MEASURES	all cont. sites with CHC>50 mg/kg in KOVOPLAST: remediation at site	all plumes with TCE conc.>1400µg/l PCE conc.>700µg/l in KOVOPLAST: P&T, ISCO	all plumes with TCE conc.>100µg/l PCE conc.>150µg/l: EBRD	all plumes with TCE conc.>10µg/l PCE conc.>10µg/l: NA

Pilot Novy Bydzov

ACTION PLAN FOR PLUMES AND DIFFUSE CONTAMINATION



CRB Values	Yellow (µg/l)	Red (µg/l)
Milan	5,1	8,5

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.

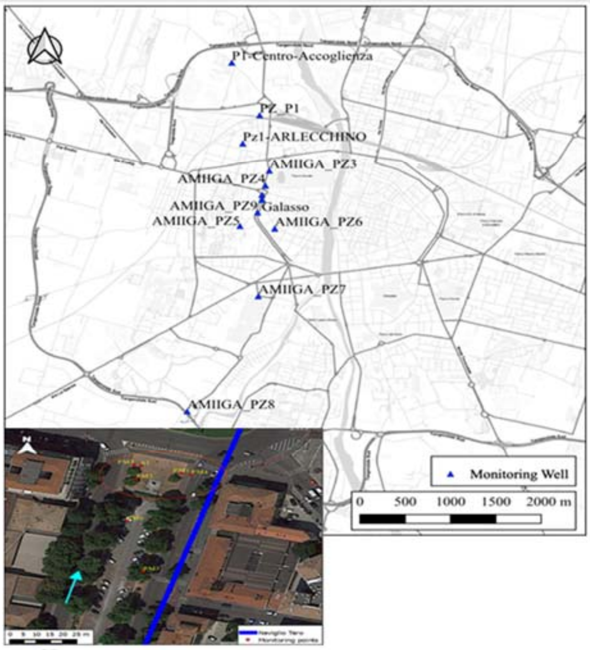
The National Law in Italy charges regions to regulate this kind of contamination.

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

Regione Lombardia

RISK ANALYSIS AND MNA



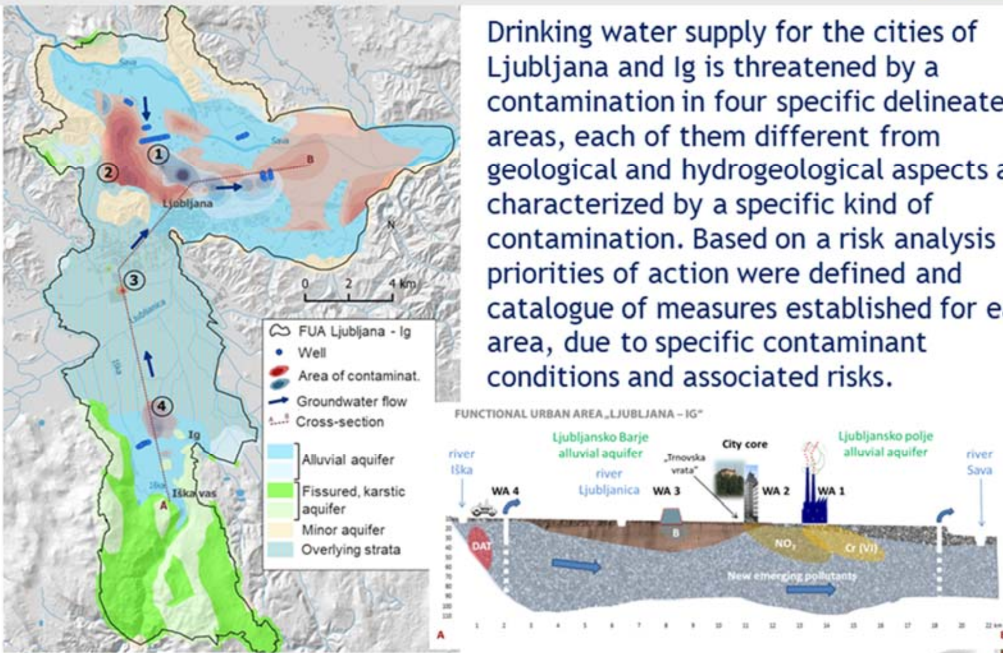
The city of Parma is covered by a diffuse* CHC contamination on comparatively low level. Although there is no specific known pollution source, legal quality targets require action. Priorities will be defined on base of a risk analysis scheduled in the management plan. AMIIGA showed that NA is not possible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

* = not codify with regards to Italian laws

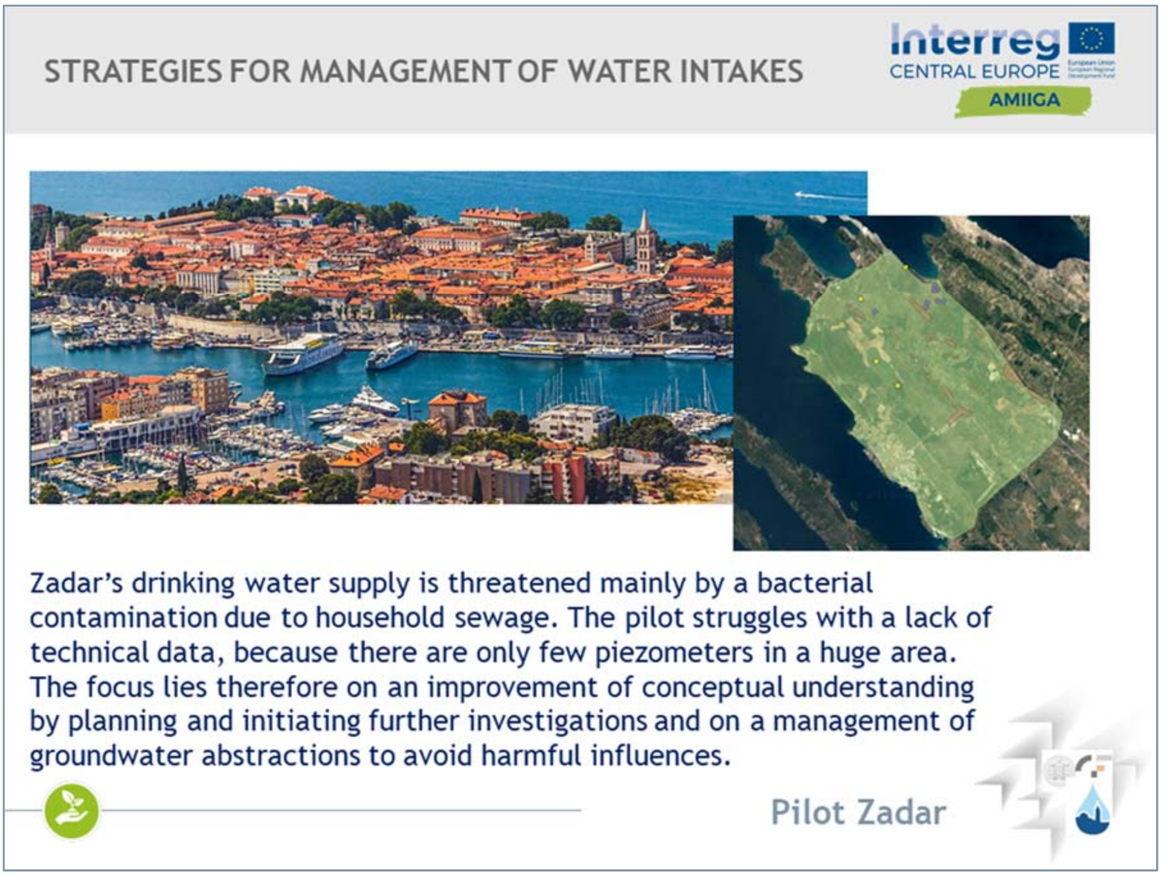
Pilot Parma

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



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)

GOOD PRACTICE REPORT

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

Version 3
30.09.2019

Summary of gained knowledge and experiences in seven pilot areas

Annex 1 to Management Strategy D.T3.3.7

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 basin[1]. 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 sits	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: • 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	Health care of water for human consumption Competent bodies for the implementation of this Act and manner of reporting to the European Commission Obligations of legal entities performing the supply of water for human consumption Methods of treatment and reporting in case of deviation Monitoring and other official controls of the health and safety of water for human consumption and their financing	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 AMIGA

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 AMIGA. 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

			Participating Bodies/Institutions, Number of								
Pilot	Number of meetings/ workshops	Number of persons per meeting [from - to]	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.

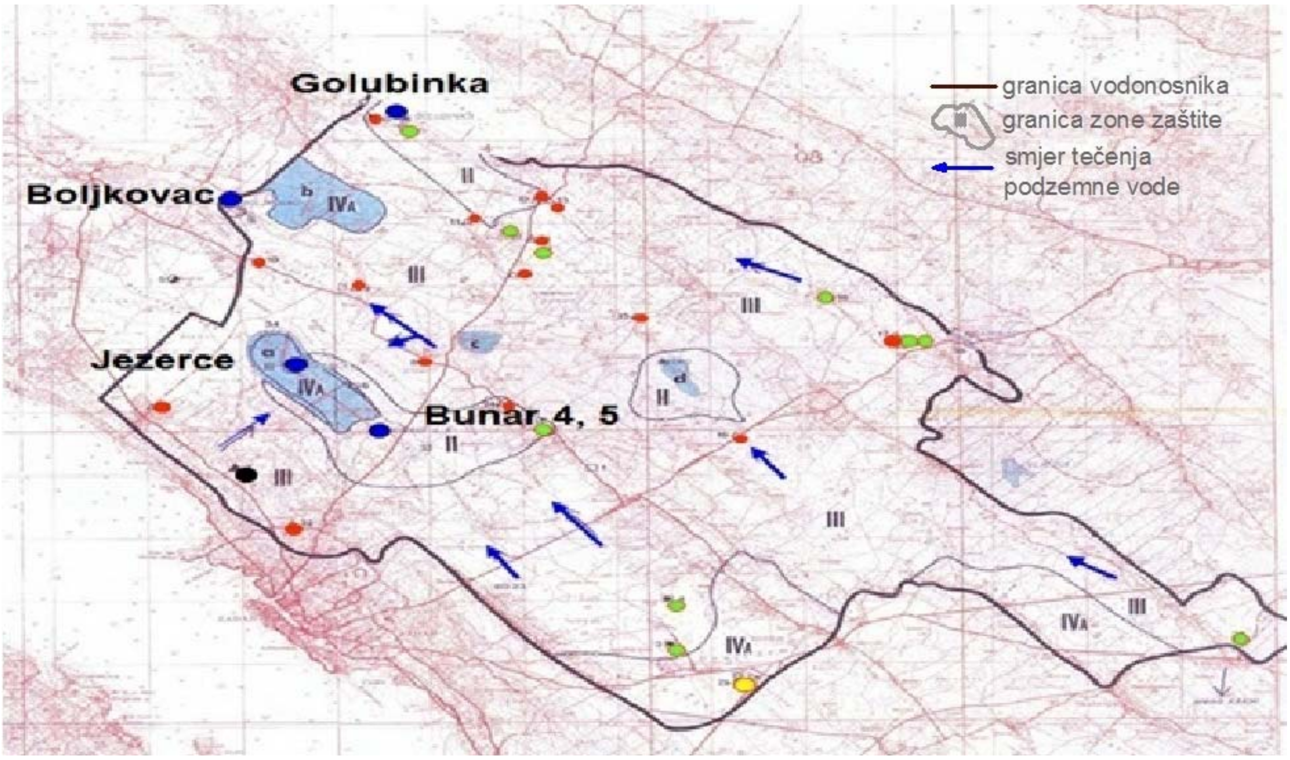
The focus of the technical work package 3 (WP T3) is to establish a groundwater management plan for each of the seven pilot sites, considering technical, financial and legal aspects. PP11 and PP12 shall develop the groundwater management plan for Zadar pilot. The goal of this deliverable is to present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

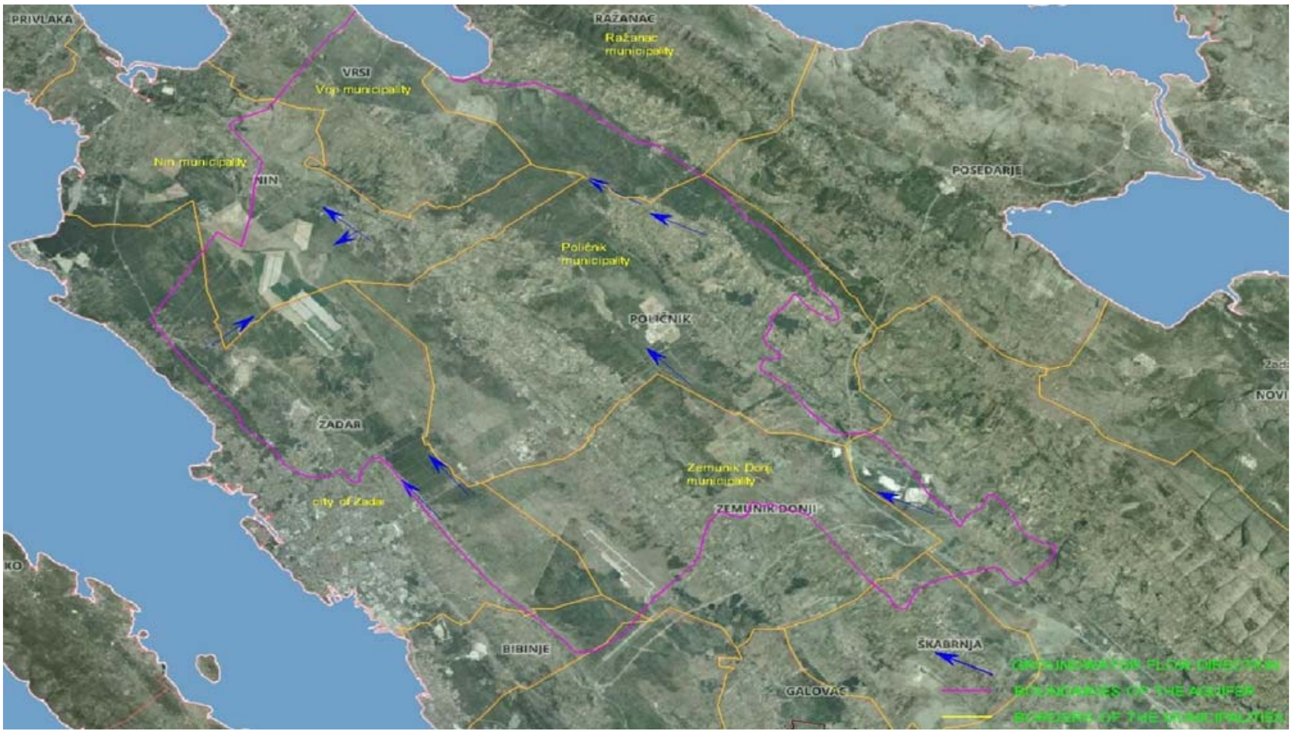
Slika 1 – Grad Zadar i njegovo zaleđe- pogled iz zraka u smjeru istoka

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 km^2. Beside Zadar, FUA comprises parts of seven other municipalities, Figure 3 (pink line is FUA, yellow lines are municipality boarders).



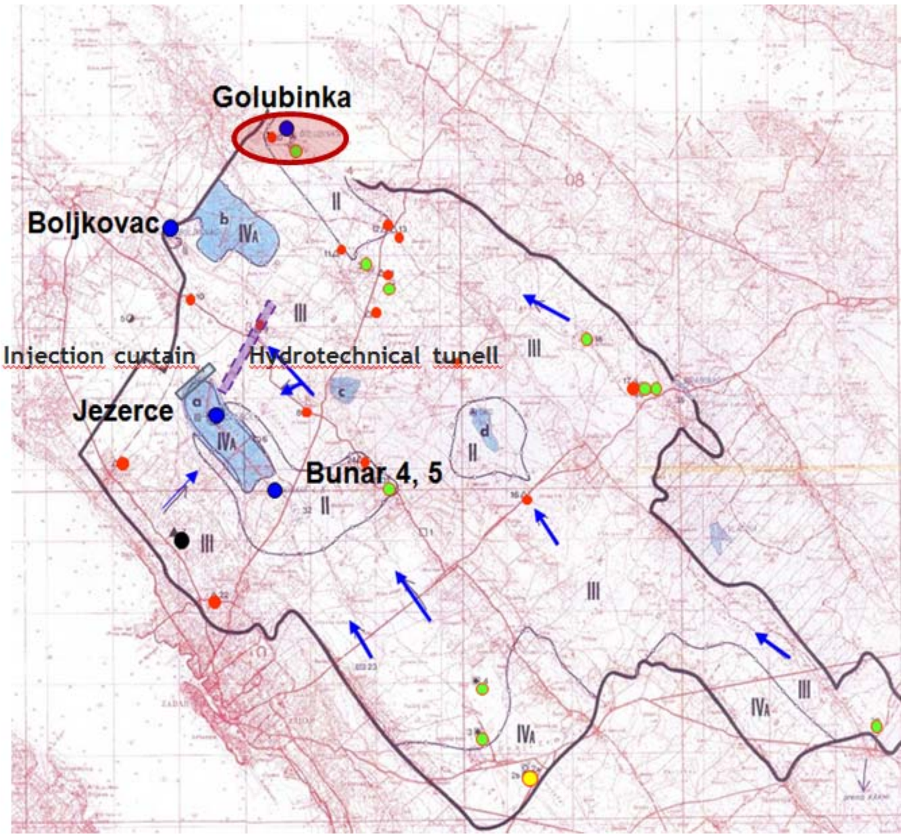
Slika 2 – Vodonosnik Bokanjac-Poličnik (područje omeđeno tamnom linijom)



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

3. Hydro-geological and contaminant description of FUA

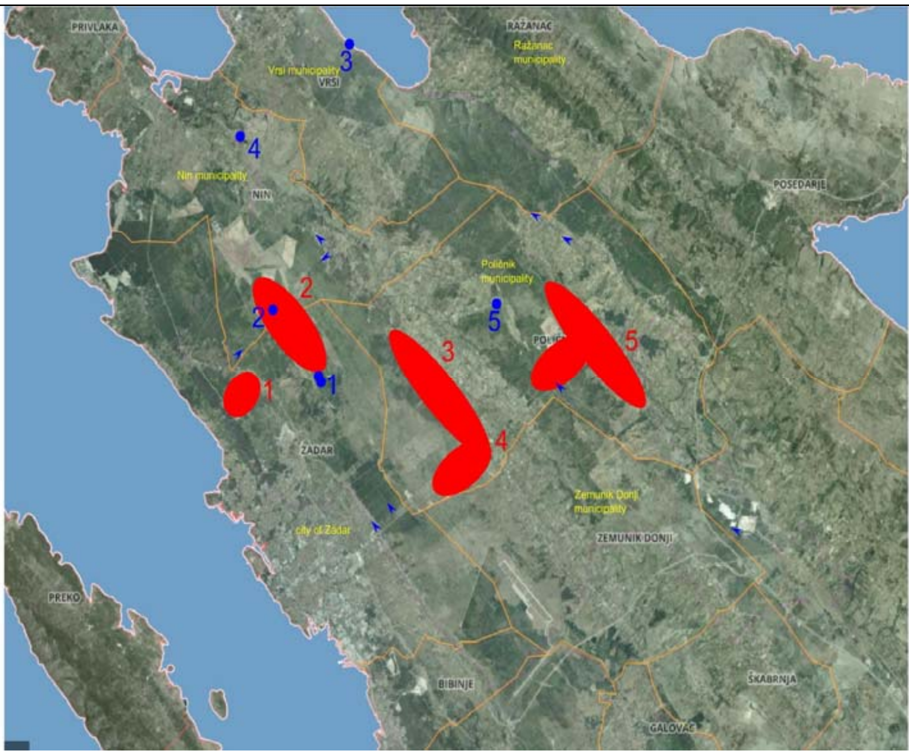
The aquifer Bokanjac-Poličnik is a complex and highly sensitive karst aquifer, which is not sufficiently investigated. The general groundwater flow direction is from east to west, Figure 4 (blue arrows show flow direction, blue dots represent drinking water intakes).



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 di-rectly to the karst aquifer, Figure 6 (yellow dots represent drinking water in-takes, red areas represent municipalities with no sewage systems). Altogether, several contaminated sites are known in the area: city landfill, an animal farm, and three vil-lages without sewage systems, Figure 7 (blue dots show drinking water in-takes, 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



Zagađivači:
1 - odlagalište otpada „Diklo”

2 - “Vigens” farma

3 - Briševo

4 - Murvica

5 - Poličnik

Vodocrpilišta i izvori:
1 - Bunari 4 i 5 (Bokanjac)

2 - Jezerce

3 - Golubinka

4 - Boljkovac

5 - Oko

Slika 7 – Lokacije vodocrpilišta i zagađivača kao i smjer tečenja podzemne vode (crveno – potencijalni zagađivaći, 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 AMIIGA 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 sig-urnosti vode za ljudsku potrošnju te načinu vođenja registra pravnih osoba koje obavljaju djelatnost javne vodoopskrbe, NN 125/2017 from 23.12.2017) and (ii) drink-ing 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 parame-ters 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 puture), the full potential of the above, newly-supplies devices throught 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 occurance of these pollutions, it is necessary to improve monitoring sytem. 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 then 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 piezomteres 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 throught the implemenation of the AMIIGA procjet is based on existing data and those collected throught duration of the project itself. Unfortunately, the major limitation in the development of the model is the absence of a large numer of active piezometers. Data obtained from new observation wells(new piezometers) combined with better quality (new devices) and wider (new sampling location) analasys of GW quality will further improve or upgrade the exsiting numerical model.

By upgrading the numerical model, it opens up the posibility 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 datebase with new data

One of the measures initiated through the AMIIGA project, which will continue even after its formal competion, 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. Implemenattion

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 Municipalitiy. 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	Technical / technological measures	Financing / responsibilities		Who is responsible for the implementation of measures?
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)	Is the implementation legally / organizationally possible? [y/n]	Which technical / technological measures are necessary?	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	Driling 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	Technical / technological measures	Financing / responsibilities		Who is responsible for the implementation of measures?
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)	Is the implementation legally / organizationally possible? [y/n]	Which technical / technological measures are necessary?	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 Iška 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 m^3/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 Iška 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 km^2. 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 delimitated 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.

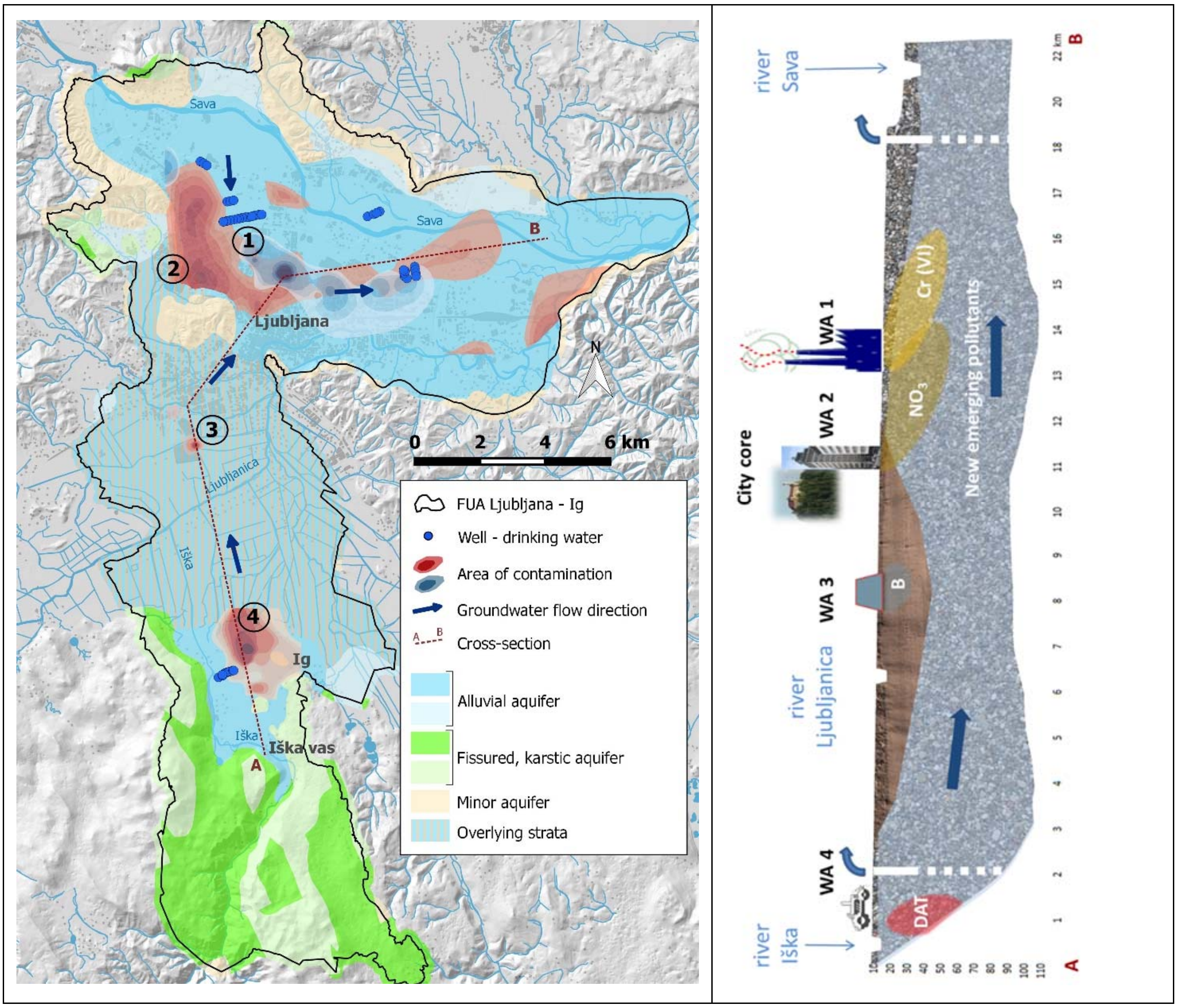


Figure 1. Functional urban area Ljubljana – Ig with significant contamination working areas (WA 1 Stegne - Hrastje: hexavalent chromium (Cr VI) plumes; WA 2 Dravlje - Moste: nitrate (NO_3) and new emerging pollutants contamination; WA 3 Barje: boron (B) contamination; WA 4 Brest: desethyl-atrazine (DAT) 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 $mgNO_3$/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 delimitated 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 prolongated 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 sanitate 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-terbuthylazine, carbamazepine and benzotriazole. The first one is the degradation product of pesticide terbuthylazine; 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 µg/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 µg/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 µg/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 unhazardous 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 AMIIGA project duration [y/n]	Estimated completion date			Legal / organizational limitations	Technical / technological measures	Financing / responsibilities		Who is responsible for the implementation of measures?
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)	Is the implementation legally / organizationally possible? [y/n]	Which technical / technological measures are necessary?	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	Technical / technological measures	Financing / responsibilities		Who is responsible for the implementation of measures?
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)	Is the implementation legally / organizationally possible? [y/n]	Which technical / technological measures are necessary?	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)							x		Plan for remediation and remediation measures	x	x	MOL
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	Technical / technological measures	Financing / responsibilities		Who is responsible for the implementation of measures?
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)	Is the implementation legally / organizationally possible? [y/n]	Which technical / technological measures are necessary?	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 sanitate 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 I 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 km^2 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, MT3DMS[1]) 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;

[1]Harbaugh, 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 [µg/l]	Fascia Gialla	Fascia Rossa
Comune di Milano (acquifero A)	PCE 5,1 TCM 0,7	PCE8,5 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

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: short-term (till 2021)	Estimated completion date - perspective: mid-term (till 2027)	Estimated completion date - perspective: long-term (till 2033)	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: public (EU/ national/ regional)	Possible financing of activities: private	Who should be responsible for the implementation of activities?
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	Eventual support to the Municipalities on the procedure management	Pilot Area	Municipalities will be supported in the management of remediation procedures in the case they are not able to manage them by themselves	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	Periodical check on the advancement of remediation procedures and activities	Pilot Area	The advancement of the remediation procedures for CHC priority plumes 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
		2.1.a.2.2	Activation/reactivation of the administrative procedures for the remediation	Pilot Area	If the case, the remediation procedure of contaminated sites liable for plumes of CHC will be activated/reactivated if suspended	N		X		N	N		X	Lombardy Region/ Regional Agency for the Environment/ Provinces/Municipalities
		2.1.a.2.3	Identification of the polluter	Pilot Area	If the case, detailed studies will be developed to identify the polluter responsible for the plumes contamination	N		X		N	N		X	Lombardy Region/ Regional Agency for the Environment/ Provinces/Municipalities
		2.1.a.2.4	Eventual substitution of the polluter in the remediation activities	Pilot Area	If the case, Municipality will substitute the defaulter polluters in the remediation procedures. The costs of the remediation will be charged to the polluter.	N		X		N	N		X	Lombardy Region/ Regional Agency for the Environment/ Provinces/Municipalities
		2.1.a.2.5	Eventual support to the Municipalities on the procedure management	Pilot Area	Municipalities will be supported in the management of remediation procedures of plumes in the case they are not able to manage them by themselves	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

COMUNE DI PARMA - SETTORE MOBILITA' E AMBIENTE

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 Molecolar 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, characherized 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 „Complesso 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 goundwater (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 and 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 piezometrs in the studied area: this situation would mean to find an extra source of funding.

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	Technical / technological measures	Financing / responsibilities		Who is responsible for the implementation of measures?
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)	Is the implementation legally / organizationally possible? [y/n]	Which technical / technological measures are necessary?	Public (EU / national / regional)	private	
Development target 1: Long Term Monitoring												
1. Monitoring campaigns of the shallow groundwater		City of Parma	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. The groundwater monitorings carried out in this network have showed the presence of some exceedances of the tabular limits for the PCE. The RIG decided to carry on with the monitoring									
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	Evaluatrion 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	Technical / technological measures	Financing / responsibilities		Who is responsible for the implementation of measures?
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)	Is the implementation legally / organizationally possible? [y/n]	Which technical / technological measures are necessary?	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 probabily, 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 responsibles 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

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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 km^2. The river Cidlina basin is shown in the Figure 2, the working area and FUA are then depicted in the Figure 3.

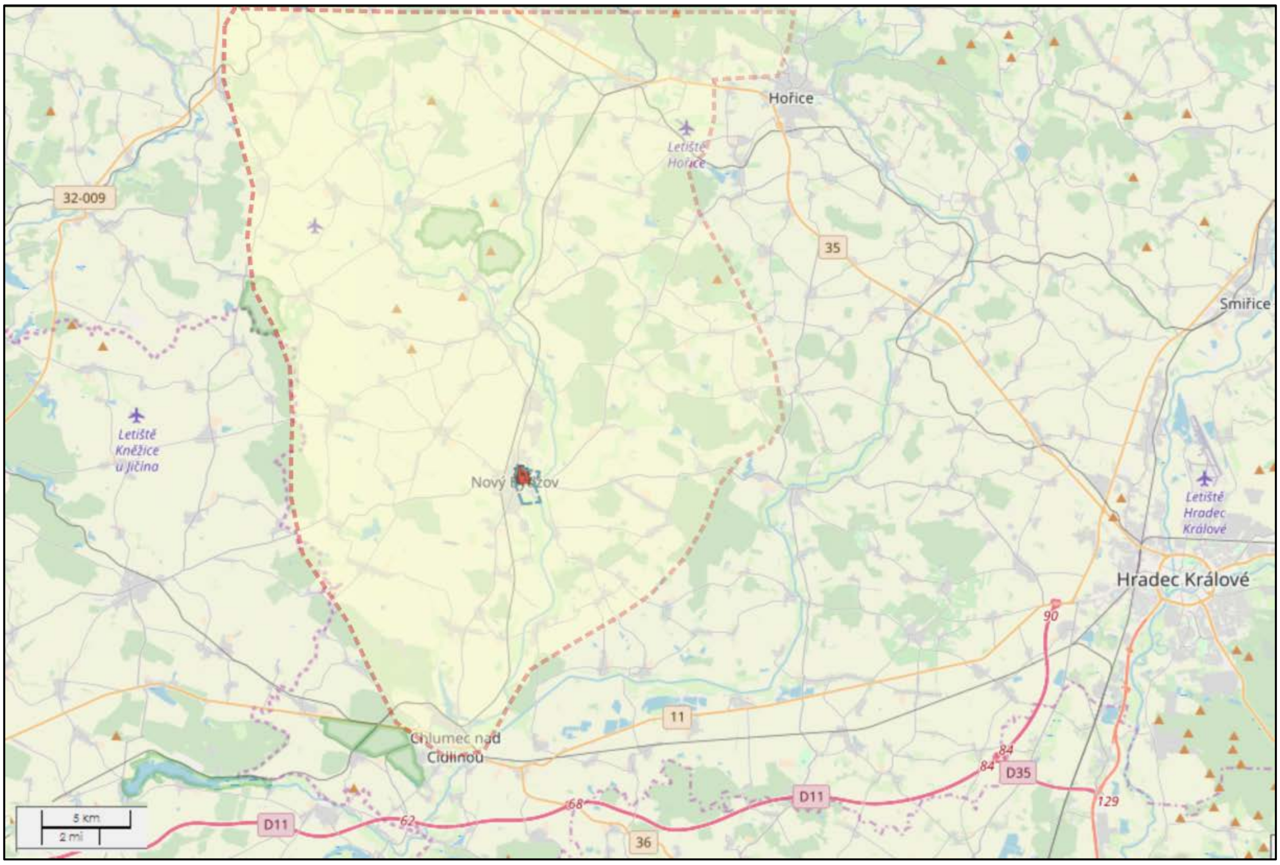


Figure No.2: Delineation of River Cidlina Basin

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.

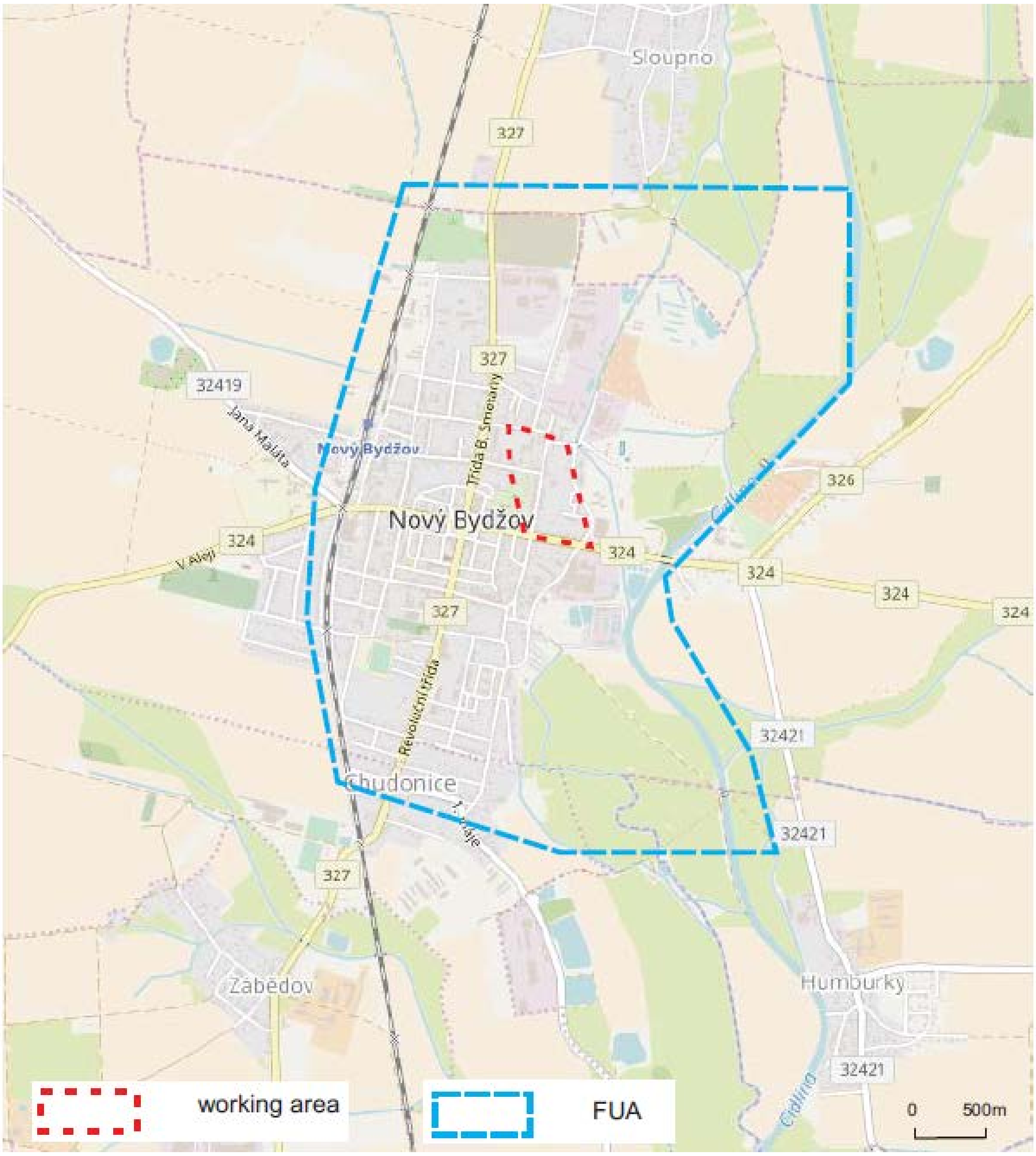


Figure No.3: Delineation of FUA Novy Bydzov and working area

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.

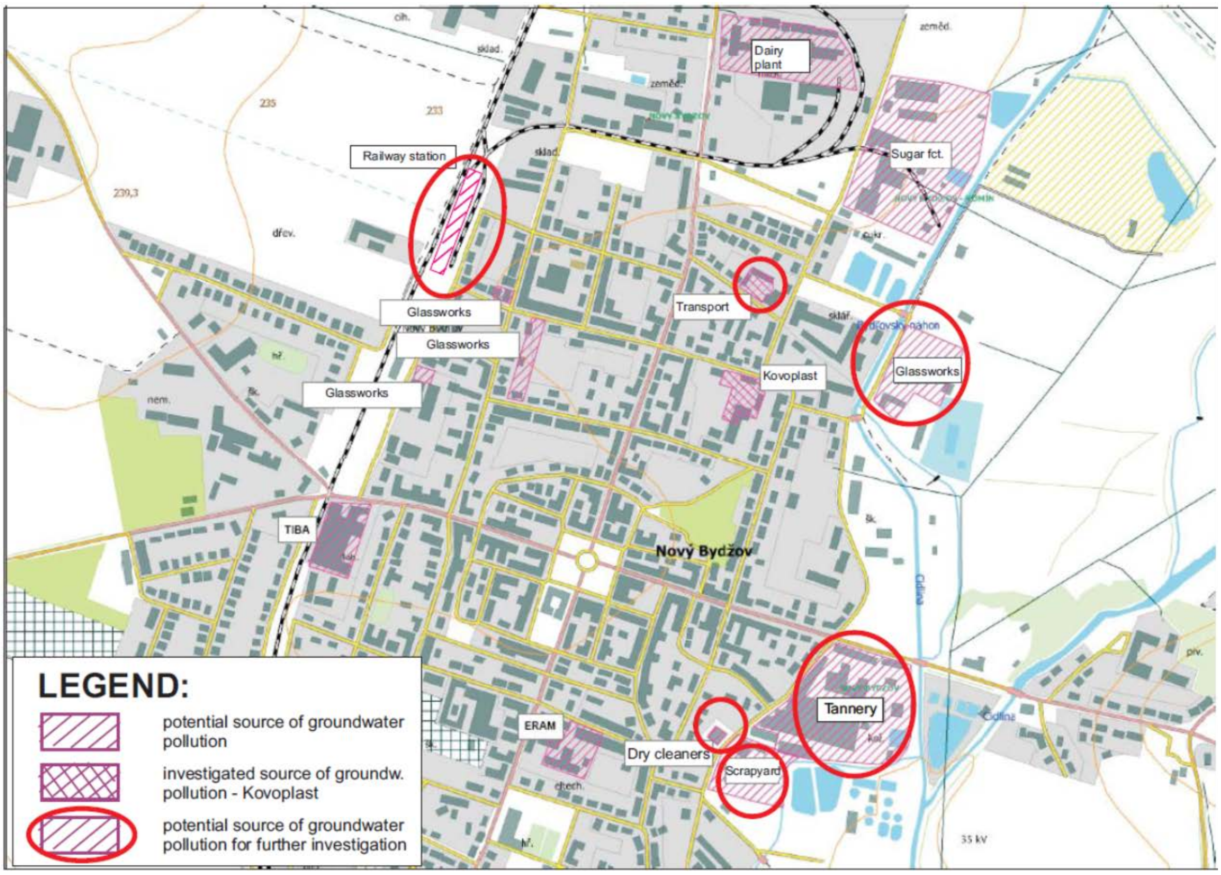


Figure No.4: Review of potential and identified sources of groundwater pollution in Novy Bydzov (FOKS 2008-2012)

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).

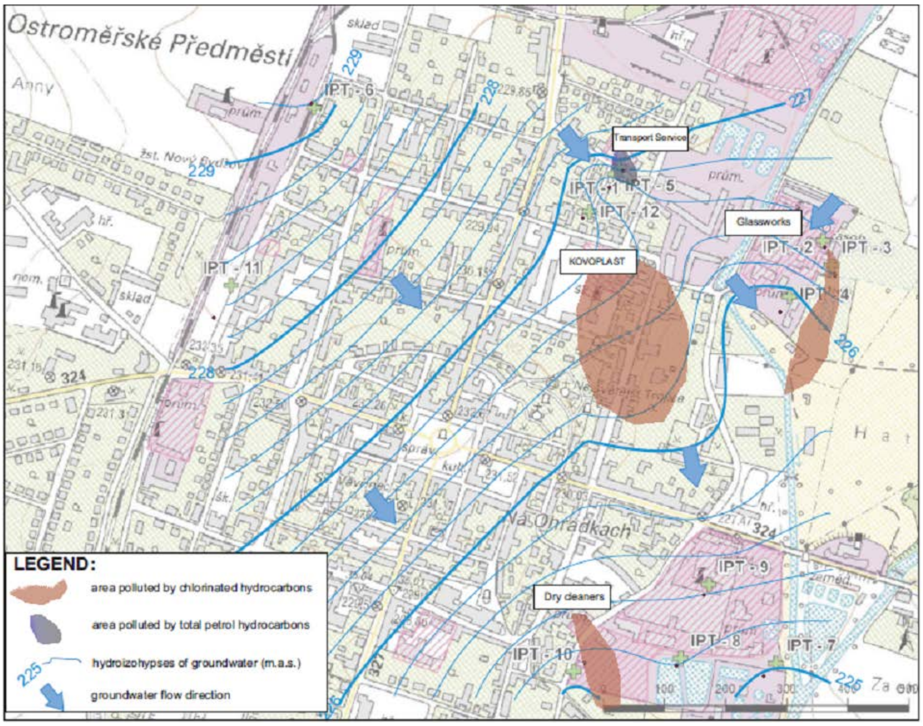


Figure No.5: Sources of groundwater contamination in Novy Bydzov (FOKS 2008-2012)

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 <u>Goal No.1</u> 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.

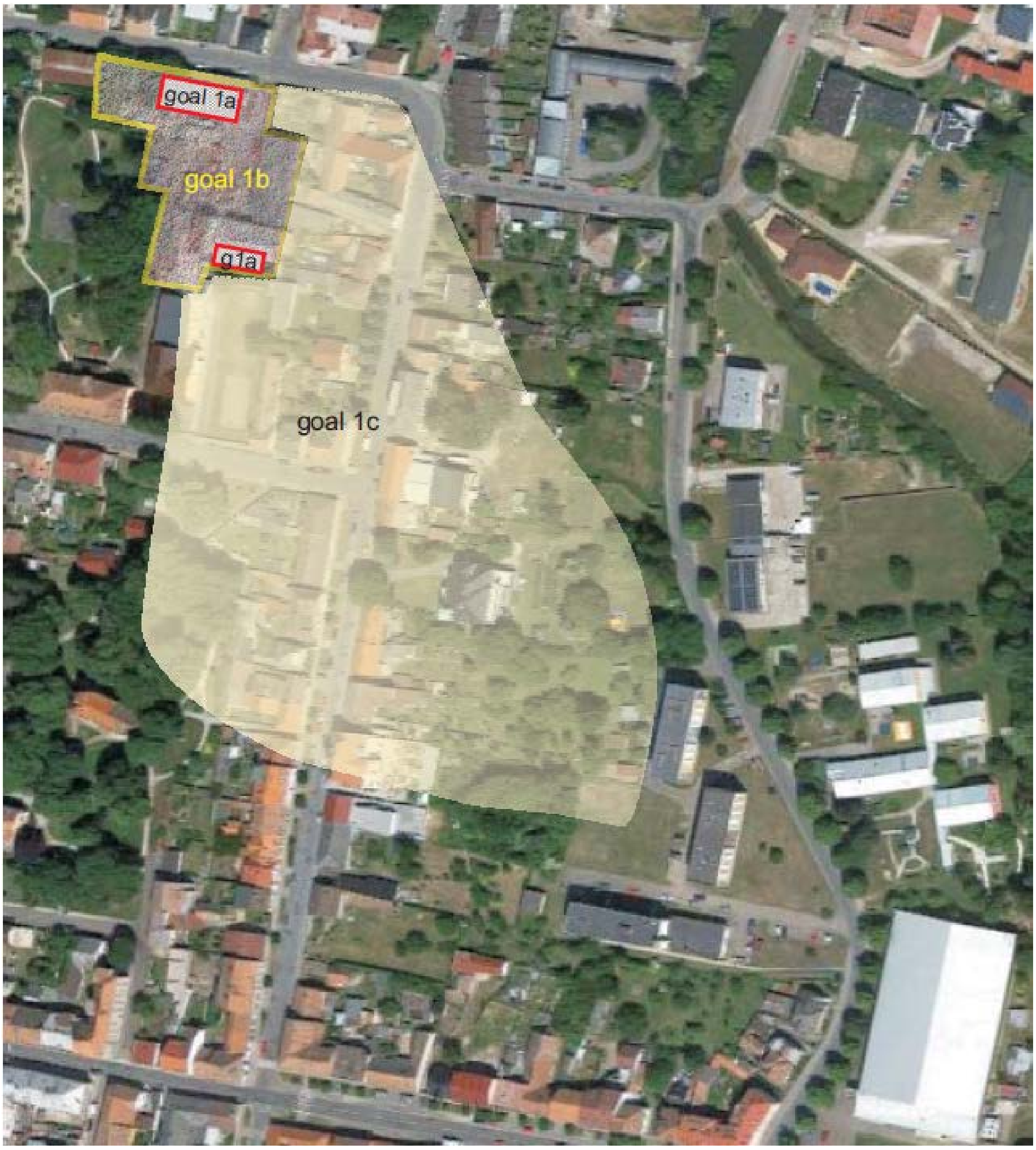


Figure No.7: Specification of areas intended for the implementation of the partial goals 1a)-1c)

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).

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

<u>DT 1.2: To prevent groundwater pollution from primary source – GW pollution</u>

- 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

<u>DT 1.3: To reduce groundwater pollution to an acceptable level determined by Risk Analysis</u>

- 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).

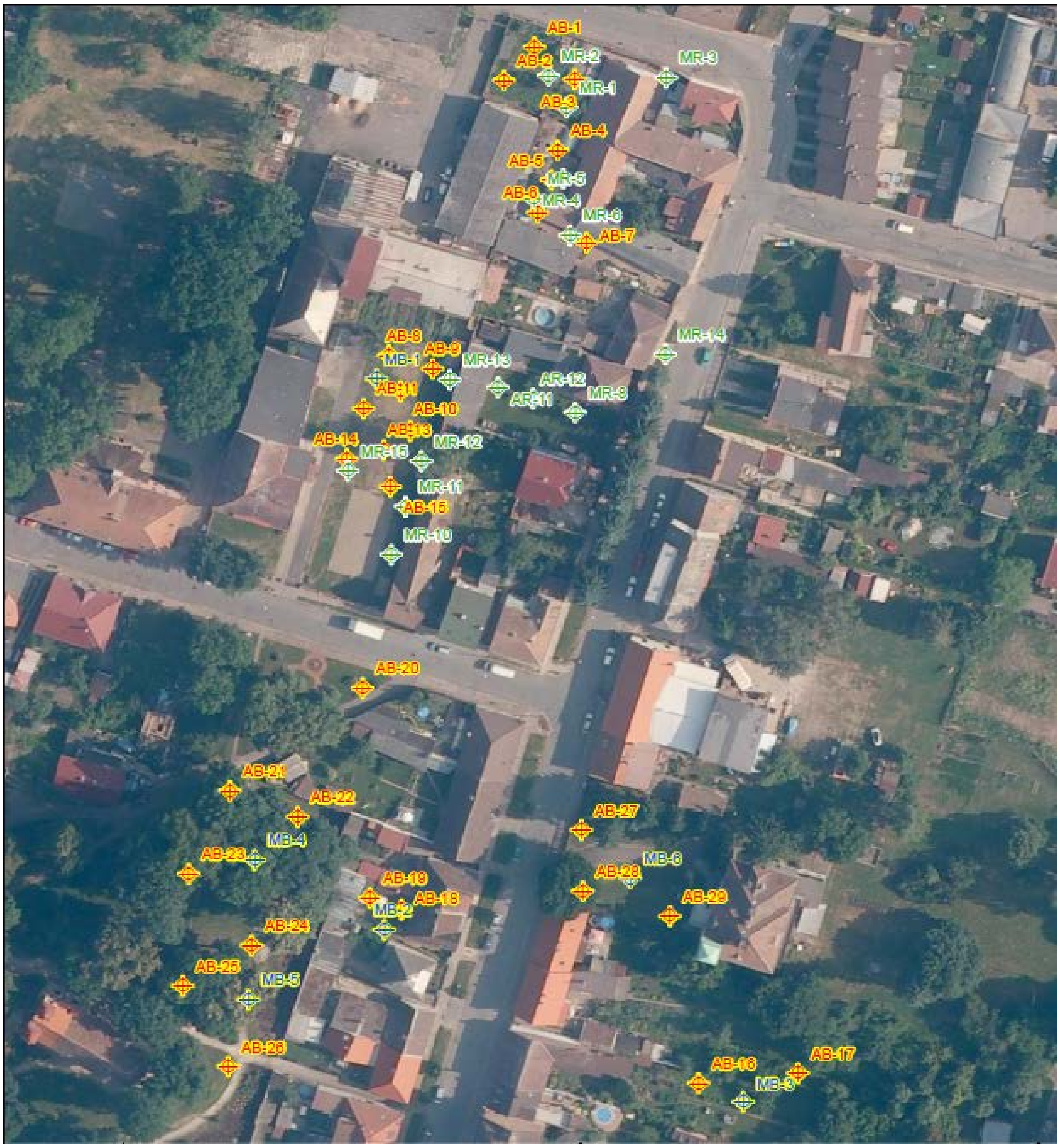


Figure No.10: The network of wells for BRD method – application and monitoring wells

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 $\mu g/m^3$, PCE < 150 $\mu g/m^3$). 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 Bydzov

Development target	Action / Phase of action	Scale	Description / explanation	Beginning of action within AMIIGA project duration [y/n]	Estimated completion date			Legal / organizational limitations	Technical / technological measures	Financing / responsibilities		Who is responsible for the implementation of measures?
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)	Is the implementation legally / organizationally possible? [y/n]	Which technical / technological measures are necessary?	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 Bydzov – 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 Bydzov
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 Bydzov
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 Bydzov
1.2 To prevent groundwater pollution from primary source – GW pollution		Novy Bydzov – 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 Bydzov
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 Bydzov
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 Bydzov
1.3 To reduce groundwater pollution to an acceptable level determined by Risk Analysis		North West part of Novy Bydzov	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 Bydzov
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 Bydzov
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 Bydzov

Development target	Action / Phase of action	Scale	Description / explanation	Beginning of action within AMIIGA project duration [y/n]	Estimated completion date			Legal / organizational limitations	Technical / technological measures	Financing / responsibilities		Who is responsible for the implementation of measures?
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)	Is the implementation legally / organizationally possible? [y/n]	Which technical / technological measures are necessary?	Public (EU / national / regional)	private	
			plume.									
Development target	Action / Phase of action	Scale	Description / explanation	Beginning of action within AMIIGA project duration [y/n]	Estimated completion date			Legal / organizational limitations	Technical / technological measures	Financing / responsibilities		Who is responsible for the implementation of measures?
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)	Is the implementation legally / organizationally possible? [y/n]	Which technical / technological measures are necessary?	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												
1.4 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

D.T3.1.3

VERSION 2.1

05 2019

A. 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 - August 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 shared 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 will be a decision support tool, developed as a result of work of the so-called "Regional Implementation Groups (RIGs). Work within WP T3 package is based on the results of the pilot activities under WP T2 and the results of the tools developed in WP T1.
Management plan for FUA in Poland is the result of project activities and its main scope and aims is to support an implementation of local and regional activities to improve groundwater quality and quantity status in pilot area and whole FUA. The aforementioned management plan In has been developed for a "functional area" (FUA) understood as functional area of groundwater flows (groundwater body) – specifically for groundwater body No 146, which covers, among others, the area of the city of Jaworzno.
The plan was developed by the project team of the Central Mining Institute and Jaworzno City Hall (project partners of the AMIIGA project) in cooperation with the Regional Implementation Group, created for the needs of the project. The group included, apart from representatives of the project partners and associated partners (Regional Directorate for Environmental Protection in Katowice (RDOŚ), Upper Silesia - Zagłębie Metropolis and Jaworzno Waterworks), as well as representatives of Chemical Plants Organika-Azot S.A.. and representatives of institutions responsible for water and environmental management, such as the Regional Water Management Board in Gliwice, Voivodeship Inspectorate of Environmental Protection (WIOŚ), Polish Geological Institute - Polish Research Institute, as well as the Silesian Voivodeship Office in Katowice, the Marshal's Office of the Silesian Voivodeship and communes located in the functional area, including JCWPd 146.
The whole document has been prepared in Polish.

B. Project area(s)

Functional area (FUA) Jaworzno is located in the southern part of Poland, in the eastern part of the Silesian Voivodship and the north-western part of the Małopolska Voivodship. Jaworzno FUA covers the main part of the municipality 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, Mysłowice, Sosnowiec, Bieruń, Imielin, Lędziny and Chełm Śląski (Silesian Voivodship) and Libiąż, Chrzanów, Chełmek 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 set for the purposes of the AMIIGA project based on:

- the existing drinking water supply system (mainly from groundwater intakes),
- boundaries of the Groundwater Bodies JCWPd 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.

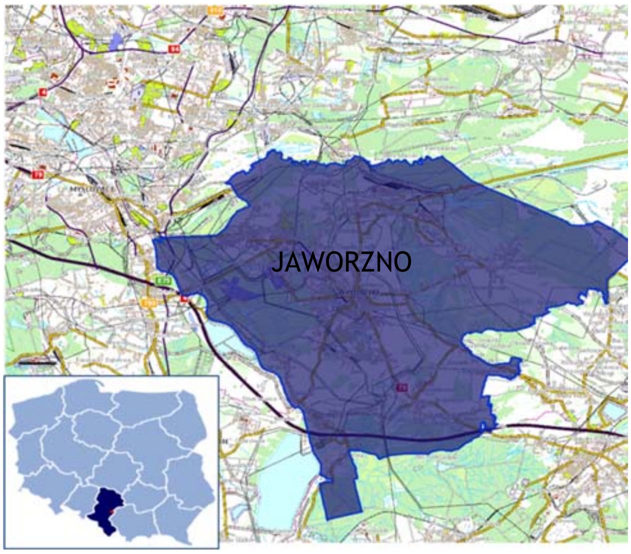


Figure 1 Location of the city of Jaworzno.

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

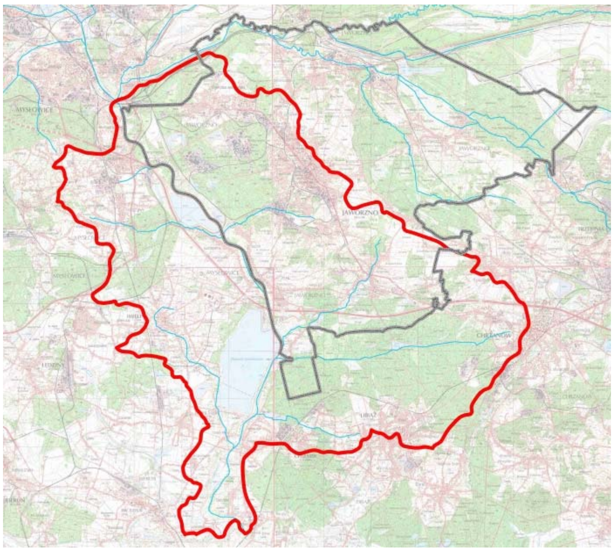


Figure 2 Range of FUA Jaworzno (red color of borders) with the indicated boundaries of the Jaworzno commune (gray color).

Source: Own study by GIG

The functional area (JCWPd 146) is located in the Vistula basin, in the water region of Little Vistula, in the area of 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 Biała Przemsza to Przemsza, and above the mouth of 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 around 150 meters thick) with only very thin and fragmentary 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 (around 10 meters) and continuous Quaternary cover formed of sandy and clayey layers. The main Quaternary feature is post-glacial buried valley of river Przemsza, which cuts across both Carboniferous- and Triassic-dominated areas. The buried valley of Przemsza 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 Przemsza river, e. g. Wąwolnica brook.

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

Quaternary porous aquifers are known 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 Przemsza river and the side buried valleys such as the Wąwolnica brook 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. The conductivity is from 3,59·10-5 m/s to 2,44·10-4 m/s. The Triassic aquifers are very important for municipal water supply.

Carboniferous aquifer is known 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 with overlaying Quaternary sans and gravels.

C. Description of the flow and contaminant transport

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, was gathered 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. Many of them are on the list of substances particularly harmful to the aquatic environment. The most important poisons accumulated in the landfills are substances posing a particular threat to the environment, such as lindane (¤-HCH) and other hexachlorcyclohexane isomers (α-HCH, β-HCH, δ-HCH, ε-HCH), DDT, DDD, DDE, dieldrin, endrin , in addition aldrin, toxaphene, heptachlor and other pesticides, organic solvents such as chlorobenzenes, phenols and chlorinated aliphatic hydrocarbons, in addition, inorganic pollutants - cyanides, mercury, chromium and others - altogether 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.

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

Goals of management plan and measures necessary to be done within AMIIGA project duration – as a base of ACTION PLAN realization are as follows:

- GOAL 1: Protection of groundwater resources quality in FUA
- GOAL 2: Prevention of contamination migration downstream Organika Azot area
- GOAL 3: Prevention of groundwater quality deterioration at Organika Azot location

E. Need for action

The need for action results from the urgent necessity of solving the contamination problem around Chemical Plan “Organika-Azot” in Wąwolnica Valley located in Jaworzno FUA created 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 1990s'.
Moreover important aspect is raising awareness and knowledge about the importance of the holistic management of groundwater in Jaworzno FUA on local, regional and national level .

F. 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. The location of new piezometers are proposed, which should be included in the 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 (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 water body under consideration.
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. 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. Currently, for the purposes of the second update of the Water Management Plan, 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.
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).

Action 2.1. The reorganization of groundwater monitoring network around Chemical Plant Organika-AZOT

As part of the AMIIGA project, the concept of groundwater monitoring was elaborated.
plumes monitoring concept includes various available monitoring points („Organika Azot" 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 Zakłady Chemiczne Organika-AZOT) is proposed as a result of a local model mapping the extent of the contamination of groundwater with pesticides downstream of Zakłady Chemiczne Organika-AZOT. The proposition included removal from the monitoring network some of piezometers indicated in documents from the 90s of, which now are faulty (because 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 within the FOKS and AMIIGA projects for official monitoring of „Organika Azot".

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

A number of institutions are involved in the management of groundwater, with the National Waters Company Polish Waters (PGW WP) playing a key role, including the Regional Water Management Boards (RZGW). For the underground water 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. Reactivation and functioning of an advisory and working group for the contaminated area of the ecological bomb in Jaworzno

As a part of the AMIIGA project, an advisory group / task force for the contaminated area of the ecological bomb in Jaworzno linking persons with different specializations, representatives of different departments of Marshall Office and the city council and from institutions dealing with environmental protection (when necessary) will be reactivated. The aim of this advisory and working group is trying to find solutions that require interinstitutional action and reviewing planning and investment activities planned for implementation in contaminated areas in the Wąwolnica valley in Jaworzno.

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.

As a part of the AMIIGA project, a draft of special act with special rules for the removal of pollutants that were particularly hazardous to the environment that occurred before 1989 will be elaborated. The need of elaboration of a draft of special act has resulted from incorrect legal regulations preventing remediation activities.

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

As part of the AMIIGA project, the monitoring network has been modernized and supplemented in the area of the Wąwolnica valley and in the Przemsza river valley in order to enable tracing of the contamination of groundwater pollution with pesticides. For this purpose, existing piezometers have been tested to verify which ones require corrective actions (e.g. cleaning, replacement, closures, etc.).
Moreover, a bioreactive semi-permeable passive barrier in the area of groundwater contamination with pesticides downstream the Chemical Plant Organika-AZOT 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.
In the scale of functioning of the bio-barrier created as part of the AMIIGA project, monitoring of its functioning is already carried out as part of the project. The results of the monitoring of the first months of the bio-barrier will allow the development of recommendations both on the functioning of the bio-barrier after the implementation of the AMIIGA project, as well as on the functioning of the monitoring of its operation.
The figure below presents the photographic documentation and the location of new piezometers and the bioreactive barrier.

Figure 3. Location of new piezometrs and bioreactive barrier in Jaworzno FUA

Source: UM Jaworzno, AMIIGA Project archive

Action 3.3. Conducting remediation activities on pollution hot spot - continuation of activities resulting from the technical documentation entitled "Reclamation/ remediation of contaminated sites in the valley of the Wąwolnica stream"

The remediation concept is based on the Variant Technical and Environmental Analysis (WATS[1]) carried out by GIG in 2015 at the request of the City Council of Jaworzno 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 1.

[1] 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

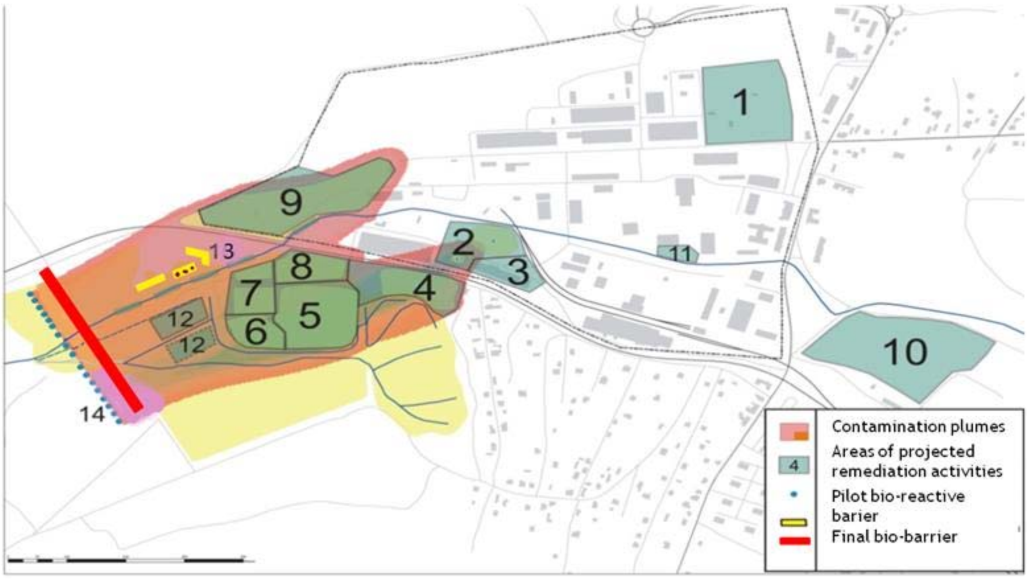


Figure 4. Remediation plan for Central landfill „Rudna Góra”

Source: GIG own elaboration during AMIIGA Project - 2018, strongly based on 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

G. 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 scale of management plan (FUA scale, scale of contaminated site, scale of groundwater contamination plume) was assigned in action plan table (see the table below).

H. Monitoring of management plan realization

This water management plan requires a precise monitoring system dedicated to its records. Due to the complexity of the issue, the monitoring system is adjusted to the possibilities of monitoring the progress of the implementation of organizational and legal activities, such as: reporting significant pressure in the environment, data management, setting up an advisory group or developing a proposal for a special law and actions requiring investment works (such as: building a network of piezometers enabling verification and ongoing control of groundwater status, both on a local scale and on the scale of the entire functional area, or remedial actions).
The proposed monitoring system emphasises the frequency of monitoring and indicates the entities involved in monitoring the progress of works.
The frequency of monitoring has been adjusted to the necessity to carry out investment works, as well as to the frequency of collecting and sharing data and information in the systems of environmental protection institutions and other potential data sources.

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			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 groundwater resources quality in FUA												
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.	N	X			none	none	?		Jaworzno Waterworks?
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	none	none	?		Jaworzno Waterworks?
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			none	none	?		?
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	none	none	?		Jaworzno Waterworks?
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. 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).	Y	X			none	none			City of Jaworzno (?), Polish Waters?

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	
1.2.b	Including the pressure in accordance with the notification into Water Management Plan (aPGW) in the area of the Vistula River Basin with reference to the homogeneous groundwater body No. 146	Jaworzno FUA scale		N				none	none			City of Jaworzno (?), Polish Waters?
GOAL 2: Prevention of contamination migration downstream Organika Azot area												
2.1. The reorganization of groundwater monitoring network around Chemical Plant Organika-AZOT												
2.1.a	The agreement on the scope of the groundwater monitoring network reorganization around Chemical Plant Organika-AZOT	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 plant. The agreement on the scope of the new reorganized monitoring network with representatives of Chemical Plant Organika-AZOT and the City of Jaworzno is necessary.	Y	X			none	none	?	?	GIG/Jaworzno/AZOT
2.1.b	Addressing the Provincial Environmental Protection Inspectorate in Katowice for accepting the scope of the reorganization of the groundwater monitoring network around Chemical Plant Organika-AZOT	scale of groundwater contamination plume	Chemical Plant Organika AZOT 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			none	none		?	AZOT
2.1.c	Carrying out the necessary adaptations /drilling new monitoring points for the groundwater monitoring network around Chemical Plant Organika-AZOT	scale of groundwater contamination plume	Chemical Plant Organika AZOT 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			none	none		X	AZOT
2.1.d	Conducting monitoring in a new reorganized groundwater monitoring network around Chemical Plant Organika-AZOT	scale of groundwater contamination plume	Chemical Plant Organika AZOT will continue local groundwater monitoring in a reorganized network.	N	X	X	X	none	none		X	AZOT
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	only on the area owned by the City of Jaworzno	none	X		City of Jaworzno
2.2. Monitoring data management for the needs of environmental institutions												

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	Creating a tool for data collection for environmental institutions	scale of groundwater contamination plume		N	X			none	none			City of Jaworzno (?)
2.2.b	A coherent presentation of data results	scale of groundwater contamination plume		N	X	X	X	none	none			Provincial Environmental Protection Inspectorate in Katowice
2.3. The establishment and functioning of an advisory group for the contaminated area of the ecological bomb in Jaworzno												
2.3. a	Establishment of an advisory group for the contaminated area of the ecological bomb in Jaworzno	scale of groundwater contamination plume	An advisory group, linking persons with different specializations, representatives of different departments of the city council and from institutions dealing with environmental protection (when necessary)	Y	X			?	none			City of Jaworzno
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	Reviewing planning and investment activities planned for implementation in contaminated areas in the Wąwolnica valley in Jaworzno.	N	X	X	X	none	?			City of Jaworzno in cooperation with Jaworzno Waterworks, Municipal Management of Roads and Bridges, TAURON, Provincial Environmental Protection Inspectorate in Katowice, GIG, etc.
2.3.c	Monitoring of activities carried out in the Wąwolnica valley in the field of waste management in the Municipality of Jaworzno	scale of groundwater contamination plume		N	X	X	X	none	?			City of Jaworzno
GOAL 3: Prevention of groundwater quality deterioration at Organika Azot 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.												

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	
3.1.a	Elaboration of a draft of special act with special rules for the removal of pollutants that were particularly hazardous to the environment that occurred before 1989.	scale of contaminated site	Elaboration of a draft of special act has resulted from incorrect legal regulations preventing remediation activities.	N	X			?	none			City of Jaworzno
3.1.b	Consultation the proposed legal solutions with the Ministry of the Environment	scale of contaminated site		N	X			?	none			City of Jaworzno
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			none	none			
3.2.b	Monitoring of the work of the existing pilot bio-barrier	scale of contaminated site		Y	X	X	X	none	none / financial limitation	?		Jaworzno
3.2.c	Wetland systems	scale of contaminated site		N		X		none	?			City of Jaworzno, in the frame of new project
3.3. Conducting remediation activities on pollution hot spot (continuation of WATS)												
3.3.a	Implementation of remediation actions on the area of Chemical Plant Organika-AZOT including reactive bio-barrier of iron and coal nanoparticles with use of existing barrier wells as a control piezometers	scale of contaminated site		N	?	X	?	none	Up - date of technical project, well restoration, selection and purchase of fillings			Chemical Plant Organika-AZOT + City of Jaworzno
3.3. b	Implementation of measures of reduction of pollutant concentrations directly in Wąwolnica channel	scale of contaminated site		N	X			none	Elaboration of technical project			Polish Waters, watercourse administrator

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 responsibles 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.

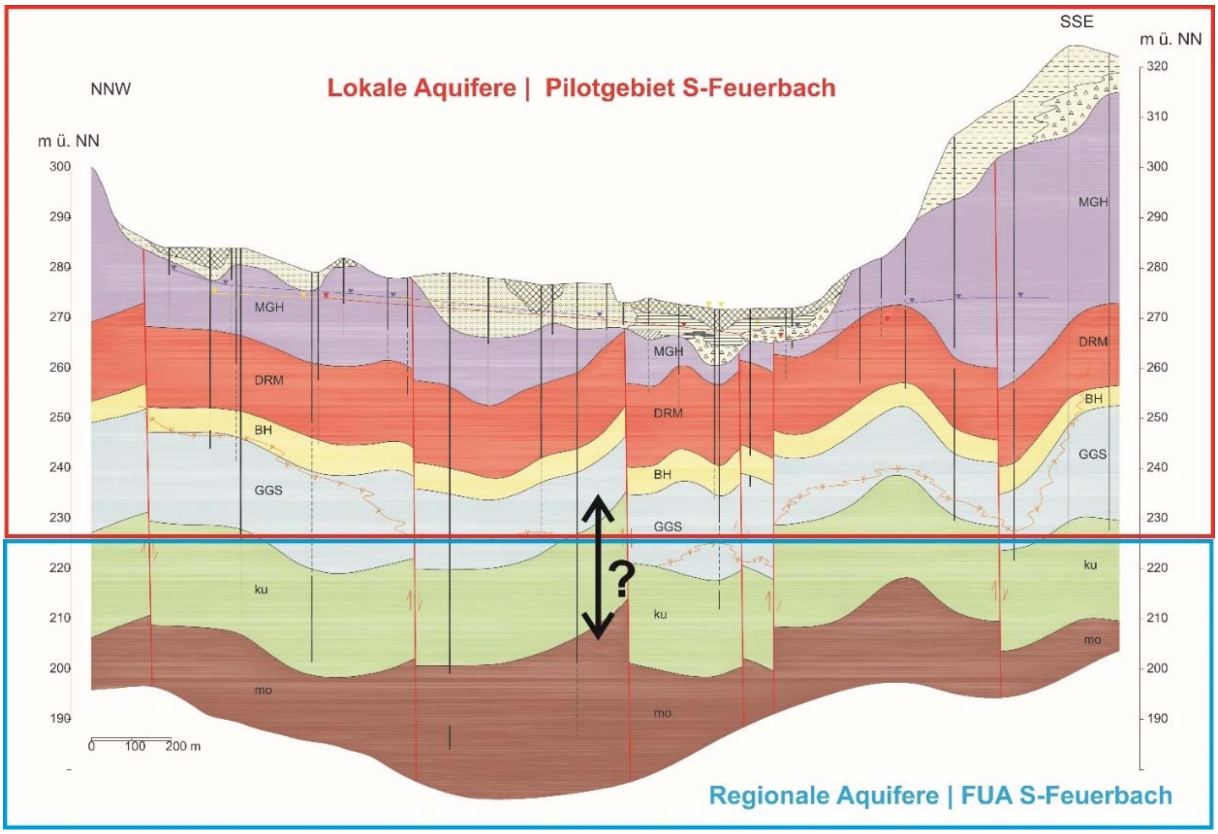


Figure 2 Geological build-up.

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 boarders. 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).

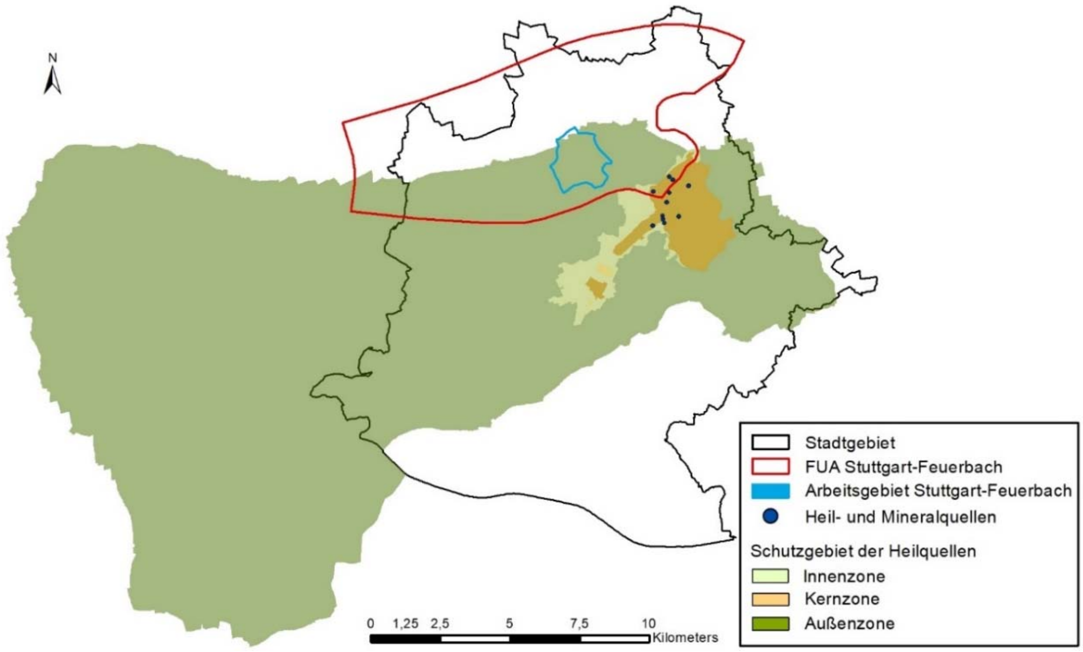


Figure 3 Project areas (working area and FUA) with mineral spring's protection zones.

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.

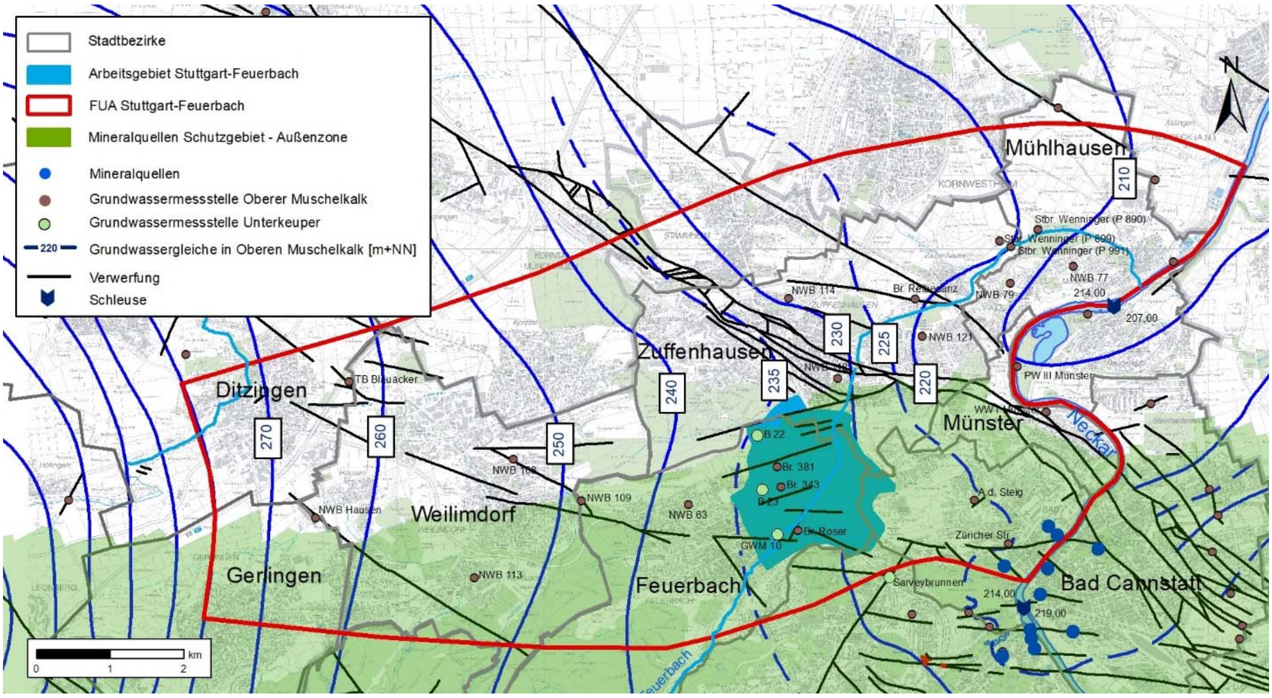


Figure 4 Project areas Stuttgart-Feuerbach: working area und FUA including the flow situation in deep aquifers.

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 rations, 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.

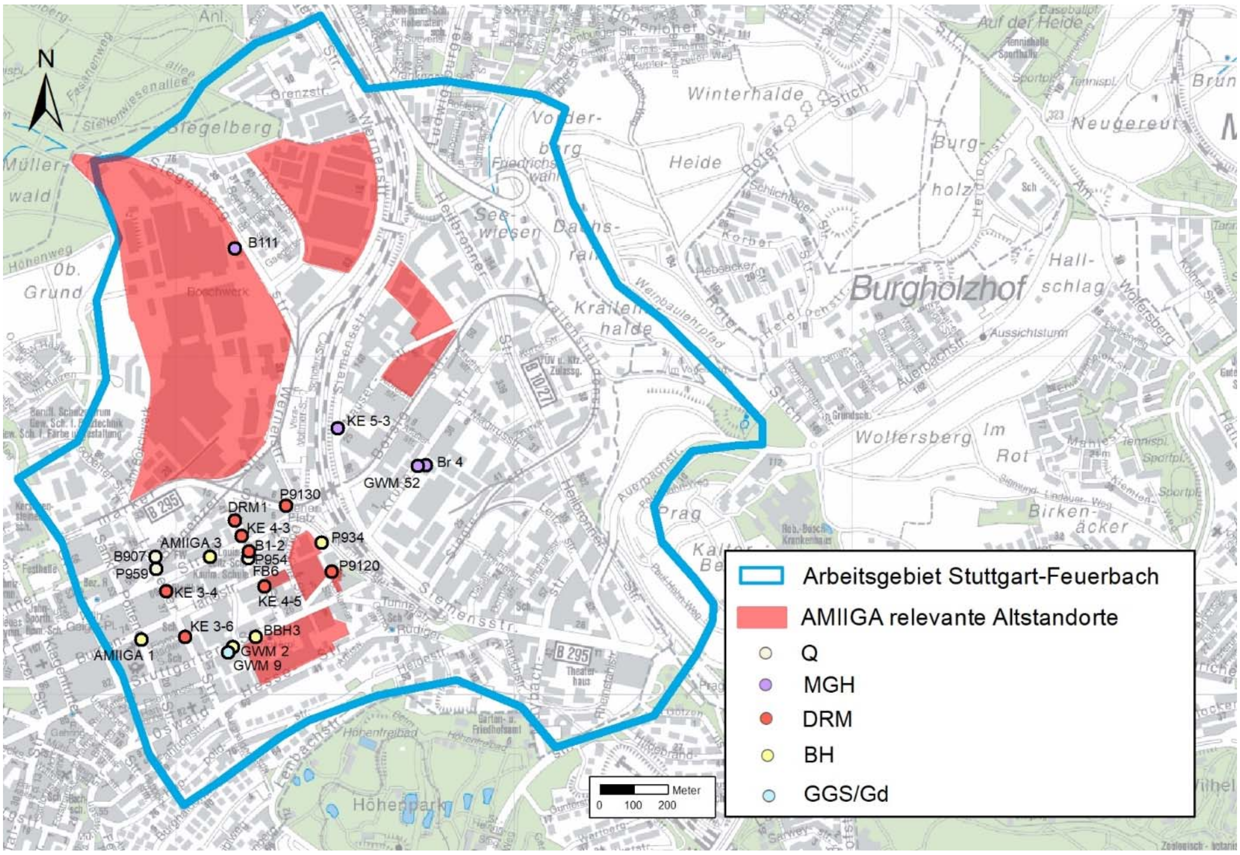


Figure 5 Monitoring wells with CHC concentration in 2017 of more than 100 µg/l in Q, MGH and DRM and more than 10 µg/l in BH und GGS/GD.

Table 1 Monitoring wells with CHC concentration in 2017 of more than 100 µg/l in quaternary (Q), Mittleren Gipshorizont (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 yeald 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”.

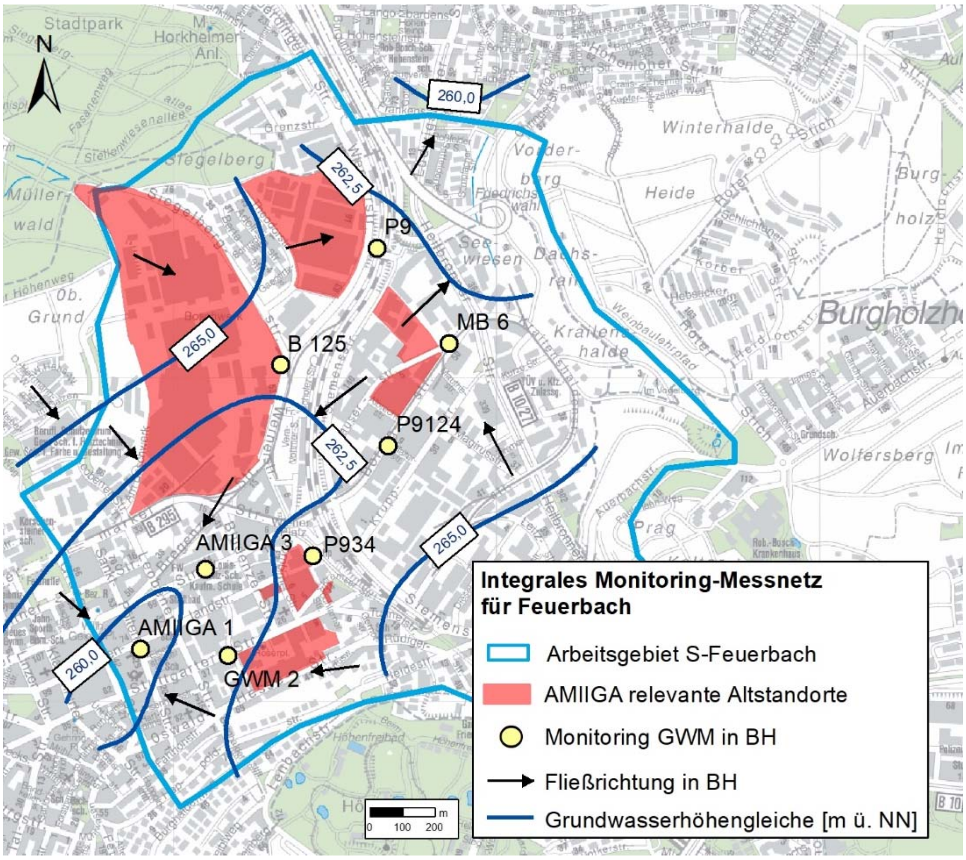
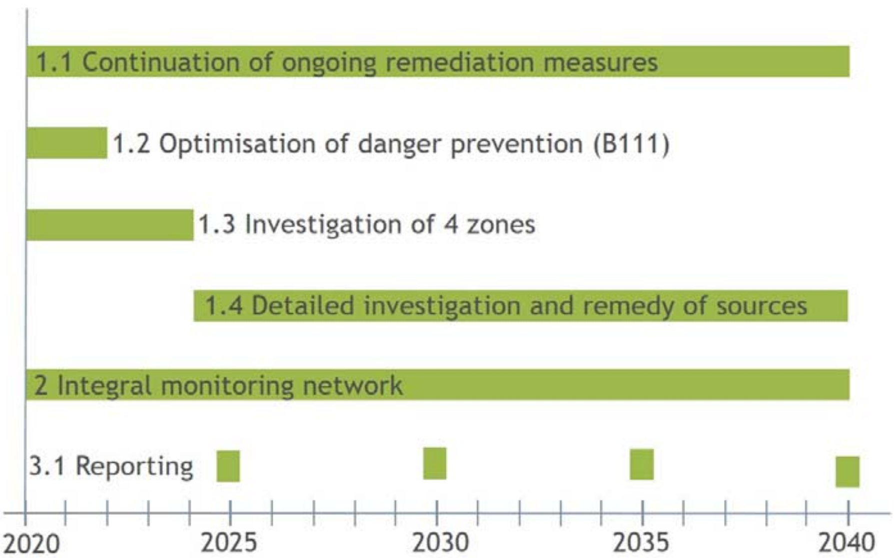


Figure 6 Integral monitoring network for Stuttgart-Feuerbach.

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	Technical / technological measures	Financing / responsibilities		Who is responsible for the implementation of measures?
					Short-term (till 2021)	Mid-term (till 2025)	Long-term (till 2030)	Is the implementation legally / organizationally possible? [y/n]	Which technical / technological measures are necessary?	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 yeald and groundwater quality are subject to significant changes. In order to be able to react appropriately, a monitoring in the Bochinger 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

SMJERNICE ZA KONTROLU KVALITETE PODZEMNIH VODA

WP T1, Deliverable D.T1.4.3

Izrađeno
12.2018

Sadržaj

POPIS SKRAĆENICA

BMT:	biološko-molekularni alat (eng: Biological Molecular Tool)
BTEX:	benzen, toluen, etilbenzen i ksilen (eng:benzene, toluene, ethylbenzene and xylene)
CE:	klorirani eten (eng: Chlorinated ethane)
CHC:	klorirani ugljikovodik (eng: Chlorinated Hydrocarbon)
cis-DCE:	cis-dikloretilene (eng:cis-Dichloroethylene)
CSIA:	specifična analiza izotopa (eng: Compound Specific Isotope Analysis)
DSS:	sustav potpore odlucivanju (eng: decision support system)
FUA:	funkcionalno urbano područje (eng: Functional Urban Area)
GIS:	geografski informacijski sustav (eng: Geographical Information System)
GW:	podzemna voda (eng: groundwater)
MPS:	više izvora zagađenja (eng: Multiple Point Sources)
NGS:	sekvenciranje slijedeće generacije (eng: next-generation sequencing)
NPS:	raspršeni izvori zagađivala (eng: Non-Point Sources)
PCE:	perchloretilen (eng: Perchloroethylene)
PCR:	lančana reakcija polimeraze (eng: polymerase chain reaction)
PS:	pojedinačni izvori zagađivala (eng: Point Sources)
qPCR:	lančana reakcija polimeraze u stvarnom vremenu (eng:real-time polymerase chain reaction)
TCE:	trikloreten (eng:Trichloroethene)
VC:	vinil klorid (eng:vinyl chloride)

1. Svrha dokumenta

Upravljanje raspršenim (difuznim) onečišćenjem podzemnih voda koje se promatraju na širokom području pokreću nadležna državna tijela. Pod nadležnim tijelima se podrazumijevaju korisnici vodoopskrbnih objekata koji služe za zahvaćanje podzemne vode za potrebe vodoopskrbe ili vlasti zadužene za zaštitu okoliša i upravljanje podzemnim vodama.

Ovaj je dokument namijenjen stručnjacima spomenutih grupa dionika i pruža alate za kvalitetno podupiranje njihovih zadataka:

- Otkrivanje stupnja onečišćenja podzemne vode,
- Definiranje porijekla te širenja oblaka zagađivala,
- Procjena razine onečišćenja antropogenom pozadinom
- Kvantifikacija procesa prirodne degradacije ili prirodnog razrijeđenja u tijelu podzemne vode, uzimajući u obzir i dodatne mjere sanacije za postizanje zadanih ciljeva kvalitete podzemne vode
- Dijeljenje podataka i informacija koje podržavaju proces donošenja odluka za provedbu Plana upravljanja.

Kvaliteta vode u vodoopskrbi je u Hrvatskoj definirana sa dva pravilnika: *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 od 23.12.2017 i *Zakon o izmjenama i dopunama zakona o vodi za ljudsku potrošnju*, NN 104/2017 od 02.11.2017. Sve granične vrijednosti za mikrobiološke i kemiske parametre su definirane u tim dokumentima.

Alati predstavljeni u ovom dokumentu su inovativni i prikladni za postizanje dobre kakvoće podzemnih voda u slučaju pojave raspršenog izvora zagađivala. Njihova provedba zahtijeva stručnost osoblja koje ih primjenjuje. Tržište kvalificiranih pružatelja usluga za istraživanje, provedbu i procjenu postignutih rezultata vrlo je ograničeno. Stoga je važno da korisnik može detaljno odrediti mjere sanacije i procijeniti tehničku kvalitetu odgovarajućih ponuda.

Ovaj dokument naručiocima nudi pregled inovativnih tehnoloških postupaka za praćenje difuznog zagađenja koje se može kretati velikim područjima i omogućuje kvalificiranu procjenu prednosti i ograničenja predstavljenih alata. Dokument pruža osnovu za precizan opis usluga stručnjaka, kompetentni nadzor nad provedbom i procjenu kvalitete postignutih rezultata.

2. Uvod

Kontinuirani razvoj urbanih područja (uključujući izgrađena područja, prigradska naselja i industrijske četvrti) ima sve učestaliju prisutnost zagađenja podzemnih voda, pri čemu je teško utvrditi izvore kontaminacije.

AMIGA-ini alati pogodni su za funkcionalna urbana područja (FUA prema OECD-a, 2012) koja se sastoje od gradske jezgre i predgrađa u kojem je intenzivni urbani razvoj i industrija te je pitanje zaštite okoliša integrirano s gradom. Prije nastavka važno je definirati različite vrste kontaminacije i njihovu razmjeru.

Oblici kontaminacije

Općenito, uzroci onečišćenja podzemne vode mogu se grubo razvrstati u tri različita skupine: a) Pojedinačni izvori (PS), koji predstavljaju pojedinačne onečišćivače koji na određenoj lokaciji koncentrirano ispuštaju visoke koncentracije zagađivala; b) Više izvora zagađenja (MPS), gdje opterećenje kontaminantima dolazi iz niza izvora koji ispuštaju malu masu zagađivala i stoga ih je teško identificirati. Oni su odgovorni za difuzno onečišćenje podzemnih voda koje se mogu definirati i kao antropogena pozadina razina kontaminacije; i) Raspršeni izvori (NPS), gdje opterećenje zagađivalima dolazi iz razvoja antropogenih aktivnosti na velikim površinama (na primjer pesticidi iz poljoprivredne prakse).

Veličina (intenzitet) zagađenja

Pojedinačni izvori se često nalaze unutar onečišćenog područja mjesta koje je najčešće ili industrijsko ili napušteno industrijsko područje (eng: brownfield). Pri tome zagađenje može uključivati samo industrijsko područje ili se može proširiti izvan njegovih granica, uključujući neki sektor FUA-e. Više izvora se često nalazi na relativno večem području (npr. industrijska zona), a povezano onečišćenje ima dimenziju koja se odnosi na čitav FUA. Konačno, raspršeni izvori se nalaze na vrlo velikim područjima a i s njima povezano kontaminacija mora se promatrati na prostoru koja je veće od područja ljestvice FUA.

Mreža za praćenje i mjere sanacije moraju biti planirane tako da se zajamče ciljevi kakvoće vode propisani EU Direktivom o podzemnim vodama iz 2006. Neuspjeh u planiranju i sanaciji ima znatan utjecaj na društvo zbog velikih troškova upravljanja prirodnim resursima i s time povezanih sukoba oko korištenja tla. Projekt AMIIGA fokusiran je na prostoru FUA-a, jer onečišćenje podzemne vode većim brojem zagađivačima zahtijeva intervenciju na srednjoj skali (FUA-skala) što je zanemareno u postojećem zakonodavstvu i nalazi se u prostoru između EU propisa koji se odnosi na izvore koji nisu koncentrirani na jednoj lokaciji i nacionalnog zakonodavstva u vezi s pojedinačnim izvorima. Često je problem u FUA-ima taj što se mnogim područjima u kojima je raspršen izvor kontaminacije ne može upravljati uobičajenim tehnikama sanacije koje se koriste za mala kontaminirana mjesta (pojedine zagađivače), uglavnom iz dva razloga: a) poteškoća u identificiranju pojedinih manjih izvora zbog male ispuštene mase zagađivala i b) veličine onečišćenih područja. Oba aspekta zahtijevaju alternativne pristupe, jer standardni postupci sanacije nisu učinkoviti i ekonomski održivi za difuzno zagađenje.

Navedeni uvjeti uglavnom su povezani s urbanim i prijašnjim industrijskim područjima, gdje su mogući izvori kontaminacije često vrlo stari i podvrgnuti mnogim promjenama (prenamjena korištenja promatranog područja, djelomična sanacija itd.). I posljednje, ali ne najmanje bitno, javna tijela trebaju procijeniti stupanj onečišćenja u područjima u kojima ima više zagađivača u pojedinom FUA-u kako bi uveli održiva ograničenja za lokalne akcije sanacije.

Projekt AMIIGA se nadograđuje na prethodni projekt Srednje Europe FOKS (2008-2012). Opći cilj projekta FOKS bio je usredotočiti napore sanacije na degradiranim područjima na ključne izvore kontaminacije.

Specifični ciljevi FOKS projekta su bili:

- prikazivanje i primjena inovativnih alata za integralno upravljanje rizikom od podzemnih voda na degradiranim područjima kao što su onečišćene lokacije i nekadašnji zagađivači
- mjere smanjenja unosa onečišćenja u podzemne vode i u tlo
- provođenje pilot akcija i studija izvodljivosti za aktivnosti sanacije izvora
- prilagođavanje Europske direktive o podzemnim vodama na skalu kontaminiranih lokacija i smeđih polja (brownfield area).

FOKS projekt je ukazao i primjenio inovativne alate za integralno upravljanje rizikom od zagađenja podzemnih voda na degradiranim područjima i uglavnom se fokusirao na lokalnu razinu. Alati kao što su: integralni pristup podzemnim vodama, pasivno uzorkovanje, traženje izvora zagađenja, modeliranje i modeliranje unatrag, pristup temeljen na analizi rizika i robustan tretman podataka demonstrirani su u nizu radionica i uspješno primijenjeni na FOKS testnim mjestima.

AMIIGA projekt djeluje u opsegu većem od FOKS-a, a fokusiran je na FUA-e, jer je onečišćenje podzemnih voda pitanje koje nadilazi administrativne granice lokalne vlasti. Glavni cilj AMIIGA-e je jačanje kapaciteta za planiranje, upravljanje i odlučivanje javnog sektora vezano za upravljanje podzemnim vodama u FUA-ima. AMIIGA je dodatno razvila alate i sustav potpore odlučivanju koji je FOKS pripremio i implementirao za urbana područja kako bi ih učinili prikladnima za FUA.

Stoga su posebni zadaci AMIIGA projekta:

1) pružanje javnim upravama alate i postupke za sveobuhvatnu karakterizaciju onečišćenja podzemnih voda u FUA-ima
2) pružanje javnim donositeljima odluka inovativnim biološkim tehnologijama za poboljšanje kvalitete podzemnih voda u FUA-ima
3) izrada *Plana upravljanja podzemnim vodama* kao strateškog alata za regionalna tijela podzemnih voda.

Ovaj dokument je namijenjen kao praktični priručnik koja sažima alate razvijene u projektu AMIIGA i razmatra sinergije s FOKS alatima, pomažući korisniku u odabiru najpovoljnijih alate za praćenje i sanaciju onečišćenja s kojim se korisnik mora suočiti. U tu svrhu ovdje je prikazano stablo odluka (slika 1), gdje se svi alati prikazuju ukratko, dijeleći ih na FUA i lokalno mjerilo. Prateći stablo i odgovarajući na pitanja, korisnik može provjeriti i odabrati alate korisne za povećavanje spoznaja o onečišćenju te na osnovu toga izraditi odgovarajući plan upravljanja.

I u slučaju kad se promatra zagađenje u FUA-a i kad se promatra na samoj lokaciji (odnosno u srednjem i lokalnom mjerilu) prvi korak je prikupljanje svih dostupnih informacija korisnih za procjenu stanja onečišćenja (npr. karakteristike mreže opažačkih bušotina, vrijednosti koncentracije pojedinih tvari u vodi, razine podzemne vode, karakteristike vodonosnika, povijesni podaci o onečišćenim mjestima itd.).

U okviru FOKS projekta su alati za diagnosticiranje bili naznačeni kao učinkovita metoda za poboljšanje analize podataka na lokalnoj skali tj. za pojedino zagađenje. U AMIIGA projektu, na FUA skali, podaci dolaze i iz privatnih, općinskih i regionalnih mreža, a skup podataka vrijednosti koncentracija vrlo je velik i složen za analizu.

Podaci prikupljeni i sistematizirani tijekom mnogih godina praćenja imaju ključnu ulogu za identifikaciju oblaka zagađivala i izvora onečišćenja. Iz tog razloga, uobičajene statistike dodane su gnostičkom alatu FOKS kako bi se detaljnije proučio veliki skup podataka prikupljen u FUA. Istraživačka analiza podataka može se primijeniti za postavljanje strukture baze podataka, otkrivanje otpada, pogrešaka i nedostajućih vrijednosti te za identifikaciju PS i MPS bušotina za nadzor (vidi D.T1.1.2).

Kako bi podržao implementaciju konceptualnog modela praćenja kvalitete podzemne vode, AMIIGA uvodi *biološki molekulski alat* (BMT) (vidi D.T1.3.4) za procjenu sposobnosti prirodnih (tj. autohtonih) mikrobnih zajednica za razgradnju određenih onečišćenja in situ. Nadalje, BMT pruža dokaze o napretku podržane biološke razgradnje ili opisuje utjecaj pojedinih metoda sanacije na autohtone mikroorganizme tijekom različitih faza sanacije.

Nadalje, kako bi razumio odnos između izvora zagađenja, odgovarajućeg oblaka i konceptualnog modela pronosa zagađivala, AMIIGA dodaje nove sljedeće alate:

Specifična analiza izotopa (eng: Compound Specific Isotope Analysis (CSIA) (vidi D.T1.2.4), kako bi se razlikovali izvori kontaminanta, predstavljajući dragocjen pristup u identificiranju pojedinih izvora onečišćenja na lokalnoj i srednjoj razini i / ili demonstriranja procesa razgradnje, budući da od velikog interesa za potrebe sanacije;

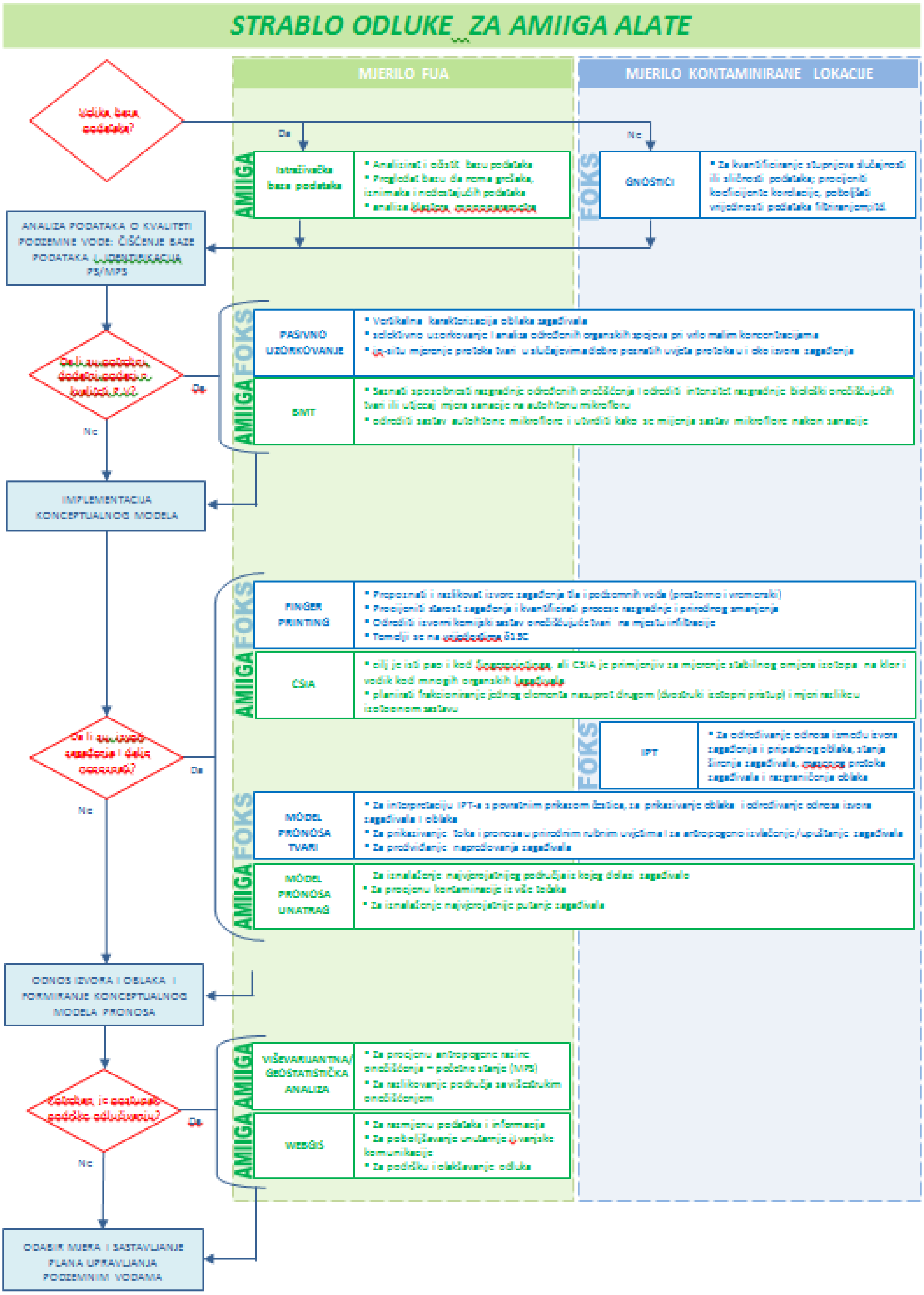
Model pronosa unatrag (vidi D.T1.1.3), za prostorno razgraničenje oblaka tvari, za odvajanje onečišćenja podzemne vode kao posljedica jednog ili više izvora zagađenja, za identificiranje područja za koje je najvjerojatnije pod utjecajem više izvora zagađenja koji je odgovoran za difuzno zagađenje.

I posljednje, ali ne najmanje bitno, multivarijantna i geostatistička analiza i WebGIS su AMIIGA-ini alati koji se primjenjuju s glavnim ciljem podržavanja odabira mjera i sastavljanja plana upravljanja, poboljšavajući postupak podrške odlučivanju (za više detalja o planu upravljanja vidi D.T3.3.7). Multivarijantna i geostatistička analiza omogućuju definiranje područja FUA zahvaćena zagađenjima iz više izvora i procjenu vrijednosti početne (osnovne) koncentracije difuzne kontaminacije na velikim površinama (vidjeti D.T1.1.2). WebGIS predstavlja inovativan pristup za razmjenu podataka i informacija među institucijama i tehničkim uredima, poboljšavajući unutarnju i vanjsku komunikaciju, podržavajući i olakšavajući odluke, unapređujući analizu podataka i tumačenje konceptualnog modela (vidi D.T1.1.1).

U ovom dokumentu se analiziraju prednosti, slabosti, mogućnosti i prijetnje (SWOT analiza) AMIIGA alata čime se omogućuje korisnicima procjena dodane vrijednosti za obradu podataka. Opisuje se metoda određivanja stupnja onečišćenja podzemnih voda, pojašnjava se određivanje podrijetla onečišćenja (odnosi izvor-oblak), poboljšava se izrada konceptualnog modela, procijenjuje se razina antropogene pozadine onečišćenja, procijenjuju se prirodni procesi razgradnje, planiranje i odabir mjera sanacije.

Općenita ključna pitanja koja pokreću odabir AMIIGA alata su:

- da li je li dostupan dovoljno veliki skup podataka na FUA skali? Analiza podataka istraživanja može poboljšati postojeću bazu podataka o podzemnim vodama FUA-e, što uključuje čišćenje skupova podataka i identifikaciju bušotina za nadzor pojedinačnih (PS) i mnogobrojnih (MPS) izvora zagađivala,
- da li su potrebni dodatni podaci o karakterizaciji podzemnih voda? BMT može pomoći kod izrade konceptualnog modela,
- postoje li još uvijek nepoznati izvori onečišćenja? CSIA i modeli pronosa unatrag mogu pojasniti odnose između mjesta unosa zagađivala i poboljšati znanje o konceptualnom modelu pronosa tvari,
- da li je potreban postupak podrške odlučivanju? Multivarijantna, geostatistička analiza i WebGIS mogu podržati postupak donošenja odluka za odabir mjera i sastavljanje plana upravljanja.



Slika 1: Stablo odluke za AMIIGA alate

2. AMIIGA alati za analizu podzemnih voda

U ovom su poglavlju su u donjoj tablici odgovori na vodeća pitanja za analizu prednosti, slabosti, mogućnosti i prijetnji (SWOT) svakog AMIIGA alata. Nadalje, opisani su primjeri aplikacija u pilot područjima projekta AMIIGA kako bi se čitatelju pomoglo da shvati primjenjivost alata u različitim okvirima.

PREDNOSTI	Koje su mogućnosti i prednosti ovog alata ili ovog alata u kombinaciji s drugima za postizanje odabranih ciljeva? Koje vrste podataka nudi alat za svaki cilj? Za koje vrste objekata djeluje bolje? Zašto? Ostale prednosti?
SLABOSTI	Koje su slabosti i nedostaci alata? Koje su slabosti u pogledu odabranih ciljeva? Koji aspekti nisu obuhvaćeni? Za koju je vrstu alata manje pogodan i zašto? Druge slabosti?
MOGUĆNOSTI	Koje su dodatne prednosti za korisnika u primjeni alata? Postoji li potencijal za poboljšanje učinkovitosti alata?
PRIJETNJE	Koje su prijetnje razvijanjem ovog alata u alat dobre prakse za odabrani cilj? Može li biti problema u učinkovitosti? Mogu li postojati problemi s prihvaćanjem?

ISTRAŽIVAČKA ANALIZA PODATAKA (D.T1.1.2)

Opis: Istraživačka analiza podataka uključuje metode statističke analize (čišćenje podataka, nestale vrijednosti, deskriptivna analiza, monoparametarska analiza klastera) korištene na FUA skali za analizu velikih (vremenskih i prostornih) i multiparametarskih skupova podataka podzemnih voda (na primjer praćenje podataka o koncentraciji vrijednosti onečišćenja). Uključuje sve aktivnosti potrebne za otkrivanje grubih pogrešaka i nedostajućih vrijednosti za prepoznavanje žarišta i odvajanje točkastih izvora (PS) od bušotina za praćenje zagađenja iz više izvora (MPS).

Primjenjivost: kod velikog skupa podataka kao što su na primjer vrijednosti koncentracija kontaminanata ili razine podzemne vode prikupljene u FUA iz različitih mreža (privatne, općinske i regionalne).

Kombiniranje s ostalim alatima: kombiniranjem s monoparametarskom analizom klastera se može razlučiti pojedinačne i difuzne opažačke bušotine, a deterministički modeli pronosa i modeli pronosa unatrag daju informacije o raspodjeli oblaka tvari na tom području. Kombinirajući zajedno sve ove informacije mogu poboljšati razumijevanje konceptualnog modela pronosa zagađivala i difuzno širenje onečišćenja. Time se poboljšava proces donošenja odluka za upravljanje podzemnim vodama, što se odnosi, na primjer, na koncipiranje mreže opažačkih bušotina.

CILJEVI	Analiza podataka o podzemnoj vodi: čišćenje baze podataka i identifikacija bušotina za nadzor pojedinačnih i mnogobrojnih zagađivača	X
	implementacija konceptualnog modela	
	odnos izvor-oblak i konceptualni model transporta onečišćujućih tvari	
	odabir mjera i pisanje plana upravljanja GW-om	X

PREDNOSTI	Istraživanje podataka se radi na FUA skali, analiziraju se veliki i složeni skupovi podataka kao i podatci prikupljeni kroz niz godina. Metode istraživanja podataka otkrivaju pogreške i nedostajuće vrijednosti velikih skupova podataka. Analiza monoparametarskog klastera grupira opažanja u klaster i svaki se klaster razlikuje jedan od drugog. Identificiraju se žarišta i omogućava razlikovanje opažačkih bušotina onečišćenih pojedinačnim izvorima (PS) od onih onečišćenih difuznom kontaminacijom povezanih s mnogobrojnim pojedinačnim izvorima (MPS).
SLABOSTI	Prije primjene statističkih metoda potrebno je složeno prikupljanje i priprema podataka. Ova faza zahtijeva velike napore i zbog nedostatka homogenosti podataka prikupljenih od različitih institucija i zbog potrebe da se same institucije uključe u odgovarajuće informacije. Različiti postupci čišćenja podataka (otkrivanje pogrešaka, provjera dosljednosti i postupanje s nedostajućim odgovorima) mogu dati različite rezultate, pa je potrebno posvetiti najveću pažnju tijekom procesa čišćenja podataka. Čišćenjem podataka treba otkloniti minimimalni broj sumnivih podataka koliko je to moguće. Nedostajuće vrijednosti (na primjer kada u bušotini nije dostupna vrijednost koncentracije za jedan od razmatranih parametara) mogu snažno utjecati na rezultate određenih tehnika. Ako nedostaju više od 30% vrijednosti, to obično predstavlja problem i mora se donijeti odluka o postupanju s nedostajućim vrijednostima.
MOGUĆNOSTI	Alat naglašava nedostatak mreže piezometara za nadgledanje podzemnih voda i može identificirati nova potencijalna područja izvora onečišćenja. Ove alate mogu primijeniti javna tijela za odabir mreže praćenja i analitičkog skupa radi poboljšanja stabilnosti rezultata i optimizacije učinkovitosti predloženih mjera.
PRIJETNJE	Rezultati moraju biti u skladu s konceptualnim modelom (hidrogeološkom strukturom, modelom toka podzemnih voda, sudbinom zagađenja i njegovim pronosom). Prijetnja je da se primjenjuju statističke metode bez uzimanja u obzir karakteristika opažačkih bušotina.

PRIMJER PROVEDEN U AMIGA PROJEKTU

Pilot područje u Milanu (IT)

Istraživačka analiza podataka primijenjena je za područje Milana (Milano FUA) gdje su razmatrana dva glavna vodonosnika (plitki i duboki vodonosnik). Skup podataka sastavljen je od mreže koja ima oko 2.000 opažačkih bušotina s dostupnim hidrokemijskim podacima.

Klasterska analiza, primijenjena na više od 45 000 zapisa vrijednosti koncentracije PCE u podzemnoj vodi, omogućila je odvajanje opažačkih bušotina koje su onečišćene pojedinačnim izvorima od onih onečišćenih mnogobrojnim pojedinačnim izvorima. Primijenjen je numerički model pronosa zahvaljujući identificiranim pojedinim većim zagađenjima (vrućim točkama) i uzimajući u obzir piezometre koji identificiranju mnogobrojne pojedinačne izvore.

Osim toga, rezultati su podržali postupak donošenja odluka za upravljanje podzemnim vodama, posebice kako bi se istakli nedostaci u nadzornoj mreži i identificirala područja na kojima su potrebne nove bušotine za nadzor.

BMT - biološki molekularni alat **(D.T1.3.4)**		
Opis: BMT je bio-molekularni alat koji se koristi za karakterizaciju autohtonih bakterijskih kolonija naprednim genetskim metodama (PCR u stvarnom vremenu i sekvenciranje sljedeće generacije). Specifični bakterijski sojevi ili enzimi mogu se analizirati pomoću PCR-a u realnom vremenu, dok se složeni bakterijski konzorciji mogu opisati uporabom NGS. Tipičan zadatak za BMT bio bi provjeriti prisutnost i procijeniti obilje bakterijskih vrsta ili skupina koje mogu metabolizirati određene kontaminante prisutne u tlu ili podzemnim vodama. Nadalje, putem BMT-a moguće je identificirati eksplicitne puteve biorazgradnje i povezati ih s proizvodima ili nusproizvodima biorazgradnje. Kad se biorazgradnja odabere kao ključna metoda sanacije in situ, tada je potrebno karakterizirati sposobnost autohtonih bakterijskih konzorcija da metaboliziraju kontaminante, specifične bakterijske sojeve ili enzime pomoću BMT-a. ***Primjenjivost:*** BMT je primjenjiv za dijagnozu tekućih procesa razgradnje u podzemnim vodama i tlu iz kontaminiranog okoliša. Na temelju prisutnosti i obilja određenih bioloških markera, može se preciznije odlučiti o odgovarajućem saniranju onečišćenog oblaka tvari. Na primjer, ako je količina bakterija sposobnih za biorazgradnju premala, može se jednostavno povećati dodavanjem odgovarajućeg supstrata; ili se dobro uspostavljeni konzorciji za biorazgradnju mogu ubaciti u zdence sa slabom biorazgradnjom. Također je moguće analizirati mikrobne kolonije uspostavljene na nosačima biomase potopljenim u kontaminiranom vodonosniku. ***Kombinacija s drugim alatima***: BMT analiza zajedno s kemijskom analizom, CSIA, fizikalnim parametrima i geološkim podacima je snažno sredstvo za procjenu prirodnog prigušenja i / ili pojačanih aktivnosti bioremedijacije u kontaminiranim područjima.		
CILJEVI	Analiza podataka o podzemnoj vodi: čišćenje baze podataka i identifikacija bušotina za nadzor pojedinačnih i mnogobrojnih pojedinačnih izvora	
	implementacija konceptualnog modela	X
	odnos izvor-oblak i konceptualni model transporta onečišćujućih tvari	
	odabir mjera i pisanje plana upravljanja podzemnom vodom	X
PREDNOSTI	BMT uključuje vrlo preciznu analizu širokog spektra bakterijskih vrsta ili enzima u složenim uzorcima okoliša. U kombinaciji s drugim alatima (CSIA, kemijska analiza) pruža snažan aparat za opis kontaminiranog lokaliteta i procjenu njegove biološke aktivnosti. BMT daje relativne vrijednosti na temelju specifičnog obilja bakterija za karakterizaciju podzemne vode. Tada je moguće predvidjeti metaboličku sposobnost mikroflore u uzorku, i što je najvažnije, sposobnost razgradnje onečišćenja na anaerobni / aerobni način. I posljednje, ali ne najmanje bitno, moguće je predvidjeti ima li podzemni okoliš uvjete pogodne za biorazgradnju (na primjer, prisutnost bakterija koje reduciraju sulfat ili denitrificiraju). qPCR analiza je ciljana, brza i isplativa, dok NGS alat daje složeniju sliku mikrobne zajednice in situ. Stoga bi kombinacija ove dvije metode dovela do najbolje dijagnoze lokaliteta.	
SLABOSTI	Glavna slabost BMT-a je poteškoća u vađenju genetskog materijala (DNA). Neki uzorci mogu sadržavati visoku koncentraciju kemijskih spojeva koji ometaju izolaciju DNA. To može utjecati na prinos i kvalitetu izolirane DNK, a time i na BMT rezultate. Moguće je samo izmjeriti relativnu razinu markera (specifičnih gena) u razdoblju uzorkovanja i procijeniti kako postupak sanacije utječe na autohtone	

	bakterije. Za tumačenje rezultata potrebno je stručno znanje o lokalnim uvjetima (CSIA i kemijske analize). qPCR markeri još nisu razvijeni za biorazgradnju svih mogućih zagađivača u okolišu. Još uvijek postoje mnoge nepoznate specifične bakterije ili enzimi, koji bi mogli biti važni u procesima biorazgradnje. Precizna obrada podataka NGS-a ovisi o pažljivom radu bioinformatičara, što može predstavljati problem, jer općenito nedostaje dobrih bioinformatičara.
MOGUĆNOSTI	Rezultati BMT-a omogućuju nam bolje razumijevanje mikrobnih aktivnosti na onečišćenom lokalitetu. Podaci BMT pokazuju potencijal biorazgradnje na istraživanoom (saniranom) lokalitetu, on također može predvidjeti iskoristivost odabranog postupka kao i ispraviti broj primjena kemijskog tretmana. Tu je i potencijal za proširenje spektra određenih markera jer se znanje o metabolizmu bakterija brzo povećava. Učinkovitost BMT-a mogla bi se poboljšati kombinacijom s drugim metodama (CSIA, kemijska i fizikalna analiza, geološke informacije).
PRIJETNJE	Najveća prijetnja je niska kvaliteta DNA iz uzorka i preniska razina ispitivanih markera. Oboje snažno utječu na rezultate BMT-a i moraju ih se pažljivo tumačiti.

PRIMJER PRIMJENE U AMIIGA PROJEKTU

Pilot područje Parma (IT)

BMT analiza primijenjena je u Parma FUA gdje je zagađenje podzemnih voda (BTEX, CE) uzrokovano nepravilnim radom benzinske postaje. Dvije kampanje uzorkovanja realizirane su u prosincu 2017. i svibnju 2018. godine.

Tijekom kampanje uzorkovanja izmjereni su fizikalni parametri (npr. PH, oksidacijsko-redukcijski potencijal i vodljivost).

Rezultati BMT-a pokazali su trend porasta ukupne bakterijske biomase u drugom uzorkovanju (tisućama puta višim razinama). To se može objasniti višom razinom podzemnih voda, ali i sezonskošću. Uspjeli smo otkriti denitrificirajuće (nirK gen) i reducirajuće sulfat (dsrA gen) bakterije koje potvrđuju smanjenje uvjeta. Niske razine BTEX razgraditelja za anaerobni put (bssA gen) s nešto višom razinom za put aerobne degradacije (DEF / G gen) u oba kruga uzorkovanja potvrdile su trajnu degradaciju BTEX. Nije primijećena prisutnost bakterija koje vraćaju organohalide (bvcA, vcrA geni, Dehalococcoides sp., Desulfitobacterium sp., Dehalobacter sp.) (Na enzimu i na razini bakterijskog roda). Kako su koncentracije CE niske, vjerojatno je detektirano tek blago aktivno organohalidno disanje, ali nisu pronađene redukcije VC. Demonstrirajuća reduktivna dehalogenacija nije otkrivena na ovom lokalitetu, pa možemo nagađati da se ona dogodila aerobnim i kometaboličkim putovima koji se nisu mogli otkriti pomoću naših primera.

Donje tablice prikazuju šest bušotina u dva kruga uzorkovanja (prosinac 2017. - lijevo, svibanj 2018. - desno) i specifično otkrivanje razgradnje. Ukupna bakterijska biomasa (U16SRT), enzimi vinilklorida (bvcA, vcrA), Dehalococcoides sp. (DHC-RT), Desulfitobacterium sp. (Dsb), Dehalobacter sp. (Dre), bakterije koje smanjuju sulfat (dsrA), denitrificirajuće bakterije (nirK), HCH degrader (linA) i BTEX (DEF / G, bssA).

Primer	PM3	PM5	PZ3	PZ4	PZ5	PZ8
U16SRT						
bvcA						
vcrA						
DHC-RT						
Dsb						
Dre						
dsrA2						
nirK						
linA						
DEF/G						
bssA						

Primer	PM3	PM5	PZ3	PZ4	PZ5	PZ8
U16SRT						
bvcA						
vcrA						
DHC-RT						
Dsb						
Dre						
dsrA2						
nirK						
linA						
DEF/G						
bssA						

Prednost BMT-a u ovom je primjeru najbolji pokazatelj lokaliteta. Analize su zamišljene kao dodatno praćenje koje je pomoglo kemijskim analizama i CSIA-i razumjeti biološke procese na lokalitetu. Na temelju BMT analize, dana je preporuka za sljedeći korak sanacije. Za lokalitet Parma predložena je aplikacija supstrata za poboljšanje mikrobne zajednice.

CSIA - Specifična analiza izotopa (D.T1.2.4)		
Opis: Uspješna primjena CSIA može se primijeniti za razlikovanje izvora kontaminanta i za poboljšanje znanja o odnosima izvora i oblaka štetnih tvari. Ona predstavlja dragocjen pristup u identificiranju kontaminiranog mjesta odgovornog za onečišćenje na ciljnom području. Stoga je zahvaljujući rezultatima CSIA moguće poboljšati konceptualni model pronosa onečišćujućih tvari i pomoći u razlikovanju pojedinačnog zagađivača od višestrukih pojedinačnih izvora zagađenja. Nadalje, CSIA omogućava utvrđivanje da li se odvijaju prirodni procesi slabljenja i mogu li razgraditi onečišćenja, što je od velike važnosti u svrhu sanacije. ***Primjenjivost:*** Danas je pomoću CSIA moguće izmjeriti stabilan omjer izotopa na ugljiku, kloru i vodiku mnogih organskih onečišćenja. Minimalna vrijednost koncentracije onečišćenja oko 5/100 µg / l potrebna je ovisno o laboratorijskim instrumentima, odabranim izotopima i spojevima koji se analiziraju. ***Kombinacija s drugim alatima***: CSIA se može primijeniti zajedno s drugim alatima kao što su biološki molekularni alati (BMT), posebno za nadzirane aplikacije prirodnog slabljenja (MNA) te za projektiranje i nadzor poboljšanih strategija biološke sanacije. Na taj način podržava se proces odlučivanja o upravljanju podzemnom vodom što se tiče, na primjer, odabira postupaka sanacije koji će se usvojiti na nivou FUA-e ili onečišćenih mjesta.		
CILJEVI	Analiza podataka o podzemnoj vodi: čišćenje baze podataka i identifikacija bušotina za nadzor pojedinačnih izvora zagađenja i mnogobrojnih izvora zagađenja (PS / MPS)	
	implementacija konceptualnog modela	
	odnos izvor-obak i konceptualni model pronosa onečišćujućih tvari	X
	odabir mjera i pisanje plana upravljanja GW-om	X
PREDNOSTI	Promjene u odnosu između stabilnog izotopa (frakcionacija izotopa) mogu nedvosmisleno pokazati prisutnost razgradnje onečišćenja u podzemnoj vodi i mogu pružiti informacije za kvantificiranje biorazgradnje. Upotreba alata za izotope omogućava bolje razumijevanje ponašanja zagađivala u podzemnoj vodi, kao i značaj fizičkih (tj. razrjeđivanja) i bioloških transformacija. CSIA kvantificira izotopski sastav određenog onečišćivača i stoga pruža dodatna i često jednoznačne odgovore o raspodjeli i razlikovanju izvora organskih spojeva. Nadalje, CSIA pomaže u identificiranju reakcija transformacije i kvantificira masu degradiranog postotka onečišćenja omogućujući predviđanje budućeg razvoja onečišćenja.	
SLABOSTI	Postupak i očuvanje uzorka CSIA mora slijediti najbolju praksu kako bi se spriječilo biorazgradnju ili abiotsku transformaciju kontaminanta. U protivnom, rezultati mogu biti netočni. Minimalna vrijednost koncentracije onečišćenja oko 5/100 µg/l potrebna je ovisno o laboratorijskim instrumentima, odabranim izotopima i spojevima koji se analiziraju. Analitička nesigurnost CSIA može predstavljati problem jer postoji značajna	

	varijabilnost ovisno o internim protokolima i analitičkim metodama koje se primjenjuju u laboratorijima. Odgovornost je korisnika da utvrdi je li neizvjesnost prihvatljiva ili nije za njihovu specifičnu primjenu. Kako bi ovaj alat bio učinkovitiji i rezultati usporedivi u različitim laboratorijima, potrebno je razviti europske analitičke protokole. Nekoliko ograničenja za procjenu biorazgradnje se primjenjuju na uporabu CSIA-e, poput, primjerice, nesigurnosti u vezi s prisustvom više izvora, složenih kontaminiranih mjesta, ali i manjih učinaka poput sorpcije/desorpcije. Drugo važno ograničenje predstavlja pravilno mjerenje izotopskog potpisa na izvoru, jer izvori mogu biti uklonjeni ili još uvijek nisu identificirani.
MOGUĆNOSTI	Rutinskom uporabom CSIA-e za kontaminirana mjesta i karakterizaciju FUA-a pružit će se više podataka koji omogućuju prikladniju procjenu procesa prirodnog prigušivanja i/ili napretka aktivnosti sanacije. Nadalje, bilo bi moguće potvrditi ili poboljšati konceptualni model onečišćenja, ojačavši prognozu o razvoju vremena onečišćenja.
PRIJETNJE	Najbolje je pročišćavanje bušotine prije uzorkovanja. Ako zdenac nije prethodno očišćen, uzorkovana podzemna voda možda neće biti reprezentativna, što dovodi do pogrešne interpretacije rezultata analize. Preporučuje se minimizirati gubitak isparljivih onečišćenja ograničavanjem izloženosti uzorka podzemne vode atmosferskom kisiku. Kao što je općepoznato, kisik može lako dovesti do aerobne razgradnje u otopljenim organskim spojevima. Također se preporučuje stabilizirati uzorak dodavanjem baktericidijala kako bi se izbjeglo bilo kakvo propadanje tijekom čuvanja uzorka. U strategijama uzorkovanja obvezno je sveobuhvatno i primjereno razumijevanje hidrogeološkog konceptualnog modela i mreže opažačkih bušotina. To uglavnom radi ispravnog odabira mjesta uzimanja uzoraka i ispravnog poznavanja dubine prikupljanja podzemnih voda. Često se pomoću nadzornih bušotina s različitim duljinama filtera ili različite dubine može dogoditi loša interpretacija podataka, miješanje podataka koji dolaze iz različitih geoloških sredina.
PRIMJER PRIMJENE U AMIGA PROJEKTU <u>Pilot područje Milana (IT)</u> CSIA je primijenjena na pilot području Milano (IT) s ciljem boljeg razlikovanja granica sliva s obzirom na difuzno zagađenje. Različiti stabilni izotopni pripravci za PCE (i za ugljik [13C] i klor i/ili [37Cl]) uglavnom su korišteni za razlikovanje je li kontaminacija dio određenog koncentriranog upuštanja ili predstavlja difuznu pozadinsku kontaminaciju. Podaci CSIA-e korišteni su za razradu preciznijih konceptualnih modela s obzirom na nekoliko područja unutar pilot područja koja pomažu u pronalaženju, kad god je to moguće, izvornih područja ili potencijalno odgovornog za onečišćenja. Sekundarni cilj bio je procjena procesa biorazgradnje i, općenito, prirodnog prigušivanja pojedinih onečišćivača kao na primjer PCE. Izotopski sastav TCE i cis-DCE korišten je za dobivanje uvida u degradacijske puteve i opseg PCE i za razumijevanje kada je TCE bio produkt razgradnje ili primarno zagađivalo na odabranim mjestima.	

<table>
<tr><th colspan="3">MODEL PRONOSA UNATRAG (D.T1.1.3)</th></tr>
<tr><td colspan="3"> Opis: Model pronosa unatrag se može primijeniti za procjenu utjecaja nesigurnosti parametara vodonosnika na simulaciju pronosa. Uzimajući u obzir različitu moguću raspodjelu hidrogeoloških parametara (npr. hidraulička vodljivost, poroznost itd.) moguće je pronaći najvjerojatnije puteve koje su prošla zagađivala. Tehnika se može koristiti počevši od izvora zagađenja (ako je poznat) i slijedeći najvjerojatniji smjer tečenja ili počevši od nekih zagađenih bunara za praćenje i pomicanje unatrag, duž smjera toka (tj. praćenje unatrag) kako bi se pronašlo najviše vjerojatni izvori (ako su nepoznati). Modeliranje pronosa unatrag omogućava poboljšanje znanja o odnosima između izvorišta i oblaka procjenjujući njegove nesigurnosti. Konačno,model pronosa unatrag predstavlja moćan alat koji može pomoći donositeljima odluka u praćenju i upravljanju aktivnostima vezanim za onečišćenje podzemnih voda.
Primjenjivost: Pristup modeliranju unatrag razvijen u projektu AMIIGA-i treba primijeniti na područjima srednje veličine (FUA), gdje mnogi izvori mogu biti odgovorni za onečišćenje otkriveno u podzemnim vodama. Inverzna tehnika modeliranja može se primijeniti i za otkrivanje PS i MPS. U projektu AMIIGA se primjenjuje kako bi se pronašlo najvjerojatnije područje izvora onečišćenja u odnosu na točke praćenja (za PS i MPS) ili da bi se razgraničio advektivni transport onečišćenja nizvodno od nekih sumnjivih izvora (za PS). U projektu AMIIGA korišteni je program MODFLOW za model tečenja, MODPATH za praćenje čestica i PEST za generiranje polja K i inverzno modeliranje, MT3DMS za advektivno-disperzivno modeliranje. Ipak, metodologija se može primijeniti s bilo kojim drugim programima za modeliranje toka podzemne vode i pronosa. Za primjenu alata potreban je klasični (tj. deterministički) kalibrirani model toka.
Kombinacija s drugim alatima: Ako se primjenjuje u kombinaciji sa statističkim alatima, poboljšava sposobnost lociranja izvora onečišćenja. Štoviše, u kombinaciji s transportnim modelom (advekcija + disperzija) poboljšava sposobnost procjene sumnjivih izvora i proširenja oblaka u okviru vjerojatnosti, što znači da je moguće procijeniti vjerojatnost da oblak ima određeno proširenje. </td></tr>
<tr><td rowspan="4">CILJEVI</td><td>Analiza podataka o podzemnim vodama: čišćenje baze podataka i identifikacija bušotina za nadzor PS / MPS</td><td></td></tr>
<tr><td>implementacija konceptualnog modela</td><td></td></tr>
<tr><td>odnos izvor-oblak i konceptualni model pronosa onečišćujućih tvari</td><td>X</td></tr>
<tr><td>odabir mjera i pisanje plana upravljanja GW-om</td><td>X</td></tr>
<tr><td>PREDNOSTI</td><td colspan="2"> Prisutnost višestrukih točkovnih izvora (MPS) koji određuju difuzno zagađenje podzemne vode u FUA-ima mora se riješiti nekonvencionalnim aktivnostima upravljanja i sanacije. MPS su po definiciji nepoznati izvori, a klasični modeli pronosa nisu u mogućnosti predstavljati difuznu kontaminaciju koju određuju ti izvori. Različiti modeli pronosa unatrag mogu simulirati ovu kontaminaciju. Iz tog su razloga oni osnovni alati za procjenu i predviđanje razvoja onečišćenja i učinkovito planiranje njegovog upravljanja.
Nadalje, model model pronosa unatrag se također može primijeniti kako bi se utvrdio najvjerojatniji PS odgovoran za jedan oblak, omogućavajući određivanje najvjerojatnijeg područja izvora kontaminacije primjenom praćenja čestica unazad. Nema ograničenja u primjeni bilo kakvih kemikalija koje se javljaju u podzemnim vodama </td></tr>
<tr><td>SLABOSTI</td><td colspan="2">Da bi se dobro istražila nesigurnost povezana s hidrogeološkim svojstvima promatrane sredine, bilo bi korisno uzeti u obzir veći broj parametara za svaki</td></tr>
</table>

	inverzni model. Nažalost, trenutno bi se parametri trebali kretati između 1 i 4, kako bi se izbjegla nestabilnost modela ili nekalibrirani rezultati modela. Očekuje se da će se mogućnosti modeliranja unatrag u budućnosti povećavati paralelno s povećanjem kapaciteta računala. Kao rezultat modeliranja se često dobiva velika količina izlaznih podataka (tj. broj čestica koje prolaze kroz ćeliju, u različitim slojevima za svaku simulaciju) i prilično su teške za analizu s GIS okruženjem (tj. preferira se domaći softver za analizu frekvencije i prostorne vjerojatnosti). Trenutno, samo nekoliko modelara ima potrebno iskustvo za primjenu obrnutih modela.
MOGUĆNOSTI	Analiza predviđanja nesigurnosti pomoći će javnim tijelima da optimiziraju javne ekonomske resurse planirajući istragu u onim područjima koja su vjerojatno odgovorna za difuznu kontaminaciju. Nadalje, rezultati modeliranja pronsa tvari unatrag ističu područja na kojima bi trebalo poboljšati mrežu praćenja FUA-e kako bi se bolje ispitala sudbina difuzne kontaminacije. Konačno, i upravljanje crpljenjem podzemne vode za javnu upotrebu također se može poboljšati ako se uzme u obzir razumno prisustvo MPS klastera.
PRIJETNJE	Rezultati trebaju biti pažljivo analizirani i trebaju biti u skladu s konceptualnim modelom (hidrogeološka struktura, tok podzemnih voda, sudbina zagađenja i pronos). Prijetnja je što rezultati modeliranja unatrag ovise o kalibriranom numeričkom / determinističkom modelu, što je osnova za njegovu primjenu, tj. početni uvjet za obrnutu iteraciju.

PRIMJER PRIMJENE U AMIGA PROJEKTU

Pilot područje Milana (IT)

Modeliranje pronosa unatrag primijenjeno je u sektoru Milano FUA kako bi se identificirala područja s najvećom vjerojatnošću da postoje potencijalni MPS. Polazeći od kalibriranog modela (determinističkog) bilo je potrebno generirati 400 različitih raspodjela vrijednosti hidrauličke vodljivosti (tj. K-polja). Među tim distribucijama je bilo 11 isključeno jer nisu mogli zadovoljiti ciljeve kalibracije, odnosno prihvaćanjem ovih K-polja model nije bio u mogućnosti da pravilno predstavlja izmjerene vrijednosti u piezometrima.

Preostalih 389 kalibriranih modela su pokazali neznatne razlike u vrijednostima K i svi su mogli ispravno predstavljati izmjerene vrijednosti u piezometrima, tj. smatrali su se podjednako vjerojatnim. Zatim se svaki od njih koristio za pomicanje čestica iz opažačkih bušotina koje su zahvaljujući fazi istražnih podataka već prepoznate da su difuzno kontaminirane. U ovom slučaju, između onih bušotina koje pokazuju difuzno zagađenje, za fazu povratnog praćenja odabrane su samo točke sa srednjom PCE vrijednošću većom od 10 μg/l (granica PCE prema talijanskom standardu za pitku vodu je 10 μg/l). Kako je analiza praćenja čestica osjetljiva na početne dubine čestica, dodjela njihovih početnih lokacija temeljila se na stvarnom položaju filtra u piezometru. U svaki zdenac dodana je čestica u središtu filtarskog dijela za svaki zahvaćeni sloj. Potom su čestice praćene unatrag na temelju simulirane strujne slike. Nastale su različite putanje istih čestica za 389 slučaja različitih strujnih slika zbog različitih K-polja. Računanjem broja čestica koje su prelazile svaku ćeliju u modelu u svih 389 simulacija, moguće je dobiti karte učestalosti pojavljivanja čestica koje putuju u svakom vodonosnom sloju: u ćelijama modela gdje je broj čestica prolazak najveći, vjerojatnost da su prisutni difuzni izvori kontaminacije veći su nego u ostalim stanicama (tj. MPS). Taj se rezultat smatra reprezentativnim za područja FUA s najvećom vjerojatnošću da sadrže MPS odgovoran za difuznu kontaminaciju koja se opaža u piezometrima.

Nadalje, modeliranje pronosa unatrag korišteno je za identificiranje područja s najvećom vjerojatnoćom da sadrže potencijalni PS. Postupak proizvodnje K-polja i jednako vjerojatni modeli bio je isti kao i gore opisan. No u ovom su slučaju čestice dodavane samo u one zdence koje pokazuju visoku koncentraciju PCE i ne pripadaju točkama koje su difuzno kontaminirane (rezultat aplikacije za istraživačke podatke), što znači da se sada razmatraju samo točke za koje se sumnja da ih je zahvatio oblak zagađivala.

Nakon toga, MODPATH kôd primijenjen je za generiranje povratnih putova čestica za svaki od modela izgrađenih korištenjem usvojenih polja vodopropusnosti. Tako su stvorene karte na kojima je prikazan broj povučenih čestica koje su prešle svaku ćeliju modela u svakom kalibriranom modelu. Smatralo se da su rezultati reprezentativni za područja FUA s najvećom vjerojatnoćom da sadrže PS koji je odgovoran za kontaminaciju. Rezultati su uspoređeni s determiniranim transportnim modelom (tj. oblakom u FUA) i s hidrokemijskim rezultatima dobivenim u AMIIGA kampanjama uzorkovanja.

<table>
<tr><td colspan="3">MULTIVARIJATNA I GEOSTATISTIČKA ANALIZA (D.T1.1.2)</td></tr>
<tr><td colspan="3"> Opis: Multivarijantna analiza (analiza glavnih komponenti, faktorska analiza, multiparametarska analiza klastera, regresijska analiza) i geostatistička analiza statističke su metode, različite od onih koje se koriste za istraživačke analize podataka, koje podržavaju analizu podataka i postupak donošenja odluka za upravljanje podzemnim vodama (tj. potpora određivanju prioriteta, odabir mjera) na srednjoj skali (FUA skala) za procjenu antropogene razine onečišćenja (MPS) i razlikovanje područja različite jačine difuzne kontaminacije u istoj FUA. Posebno:
Multivarijantna analiza: služi za procjenu glavne komponente skupa podataka (to znači na primjer glavne onečišćivače) i obrasce difuzne kontaminacije koji mogu biti prisutni u FUA
Geostatistička analiza: služi za procjenu prostorne raspodjele difuzne kontaminacije.
Primjenjivost: Multivarijantna analiza sastoji se od zbirke statističkih metoda koje se mogu primijeniti kada se napravi nekoliko mjerenja na svakoj bušotini za praćenje. Multivarijantna analiza može se primijeniti na različite vrste mjerenja parametara (npr. koncentracije onečišćujućih tvari, karakteristika vode itd.) uzimajući u obzir prostornu varijablu svake bušotine za praćenje. Indikativno se analiza može primijeniti kada su u FUA dostupne 2 bušotine za praćenje svakih 100 ha. Metode multivarijanske analize mogu se primijeniti za analizu svih parametara na istraživanom području, kao što su otkrivanje lokacije ispuštanja onečišćenja, karakterizacija hidrogeološke sredine, sanacija, nadzor i zatvaranje sanacije. Geostatističke metode mogu se koristiti zajedno s rezultatima multivarijantne analize za bolje rješavanje podataka o okolišu koji su često pristrani, grupirani i prostorno povezani.
Kombinacija s drugim alatima: Rezultati multivarijanske i geostatističke analize u kombinaciji s modelima pronosa i modelima pronosa unatrag razlučuju područja PS i MPS, pružajući informacije o jačini difuzne kontaminacije. Te informacije podržavaju postupak donošenja odluka za upravljanje podzemnim vodama za procjenu pozadinskih koncentracija difuzne kontaminacije. </td></tr>
<tr><td rowspan="4">CILJEVI</td><td>Analiza podataka o podzemnoj void: čišćenje baze podataka i identifikacija bušotina za nadzor PS / MPS</td><td></td></tr>
<tr><td>implementacija konceptualnog modela</td><td></td></tr>
<tr><td>odnos izvora i oblaka zagađivala te konceptualni model transporta onečišćujućih tvari</td><td></td></tr>
<tr><td>odabir mjera i pisanje plana upravljanja podzemnom vodom</td><td>X</td></tr>
<tr><td>PREDNOSTI</td><td colspan="2"> U kontaminiranim područjima se istovremeno mjeri više od jednog parametra na svakoj opažačkoj bušotini. Cilj mnogih multivarijantnih pristupa je pojednostavljenje, pokušaj opisa onoga što se događa u smislu smanjenog niza dimenzija (to na primjer znači grupiranje onečišćivača koji imaju isti obrazac.
Metode multivarijantne analize proučavaju vremensku promjenu parametara i odnose između različitih parametara.
Multivarijantna analiza omogućuje procjenu glavnih komponenti skupa podataka (to znači na primjer glavne onečišćivače) i ponašanja difuzne kontaminacije koji bi mogli biti prisutni u FUA-u, procjenjujući pozadinsku razinu difuzne kontaminacije na velikim površinama.
Prostorna interpolacija (geostatistička analiza) procjenjuje nepoznate vrijednosti podataka na određenim lokacijama koristeći poznate vrijednosti podataka na drugim </td></tr>
</table>

	lokacijama. Geostatistička analiza procjenjuje prostornu raspodjelu difuzne kontaminacije. Rezultati multivarijantnih i geostatističkih analiza podržavaju proces donošenja odluka za upravljanje podzemnim vodama na srednjoj skali (FUA skala).
SLABOSTI	Nakon što se podaci prikupe, čak i kada je istraživački projekt pravilno organiziran i izveden, konačni skup podataka mora se provjeriti, potvrditi i pripremiti prije nego što se nastavi s analizom. Nekoliko je koraka potrebno za pripremu podataka za analizu: uređivanje i kodiranje podataka (npr. provjera pogrešaka ili propusta) i čišćenje podataka (vidi alat za analizu podataka istraživanja). Homogena prostorna i vremenska distribucija podataka olakšava analizu. Povećanje gustoće prostornih i vremenskih podataka poboljšava kvalitetu rezultata.
MOGUĆNOSTI	Rezultati multivarijantne i geostatističke analize mogu se primijeniti za praćenje razvoja onečišćenja, ako se primjenjuju uvijek na istim opažačkim mrežama.
PRIJETNJE	Rezultati moraju biti u skladu s konceptualnim modelom (hidrogeološki aspekti, tok podzemne vode, sudbina zagađenja i pronos). Prijetnja je da se primjenjuju statističke metode bez uzimanja u obzir karakteristika nadzornih bušotina (na primjer, dubina i duljina filtera). Trenutno je u geostatističkoj analizi teško odabrati najbolju metodu prostorne interpolacije za širok raspon georeferencijalnih podataka. Stoga je odabir odgovarajuće metode s odgovarajućim parametrima za određenu primjenu presudan. Različite metode mogu proizvesti sasvim različite prostorne prikaze i potrebno je "dubinsko" poznavanje fenomena da bi se procijenila koja je od njih najbliža stvarnosti. Upotreba neprimjerene metode ili neprikladnih parametara može rezultirati izobličenim modelom prostorne distribucije, što dovodi do potencijalno pogrešnih odluka temeljenih na pogrešnim prostornim informacijama.

PRIMJER KORIŠTENJA U AMIIGA PROJEKTU

Pilot područje Milano (IT)

Multivarijantna i geostatistička analiza primijenjena je u FUA Milano gdje postoje dva vodonosnika (plitki i duboki vodonosnik). Skup podataka je prikupljen od mreže opažačkih bušotina od oko 2.000 točaka s dostupnim hidrokemijskim podacima.

Multiparametarska analiza klastera mogla bi povezati profile koncentracija različitih onečišćenja. Pet klastera identificirano je kao reprezentativno za PCE difuznu kontaminaciju, oni su predstavljali veliku skupinu mjerenja pozadinske vrijednosti. Detaljnije su proučavane karakteristike i srednji vremenski trendovi PCE za pet skupina, koji su predstavljali difuznu kontaminaciju.

Štoviše, geostatistička metoda analizirala je prostornu raspodjelu pet klastera u istraživanom području, a najreprezentativniji klaster za svaku zonu identificiran je rezultatima multivarijantne analize. Stoga je istaknuto da jedinstvena vrijednost difuznog zagađenja na cijelom probnom području nije reprezentativna za nehomogenost stvarne distribucije difuzne kontaminacije, ali više od jedne vrijednosti pozadinske koncentracije mora biti dodijeljeno u FUA.

Statistička i geostatistička analiza u kombinaciji s modelom pronosa i modelom pronosa unatrag razlikuju područja PS i MPS i daju najreprezentativnije vrijednosti koncentracije difuzne kontaminacije u Milanskoj FUA.

Rezultati su podržali postupak donošenja odluka za upravljanje podzemnim vodama, planiranje mjera i identificiranje novih potencijalnih područja izvora onečišćenja koja će se nadzirati.

WEBGIS (D.T1.1.1)		
KRATAK OPIS ALATA ***Opis:*** WebGIS je alat koji se može koristiti za prikaz i obradu podataka na Internetu. Nudi način pristupa internetu i razmjeni informacija na mreži. Poboljšava učinkovitost analize podataka i tumačenje konceptualnog modela, omogućava razmjenu podataka i informacija između institucija i projektantskih ureda. Glavni je cilj prikazati podatke na karti, omogućiti raspravu o podacima / rezultatima projekta i podržati i olakšati postupak donošenja odluka za upravljanje podzemnim vodama. ***Primjenjivost:*** mjerilo FUA. Dostupnost i performanse internetskog pojasa moraju biti učinkovite. ***Kombinacija s drugim alatima:*** Rezultati analize prikupljenih podataka, kemijske analize, razine podzemnih voda, BMT, CSIA, inverzni i deterministički modeli pronosa, multivarijantna i geostatistička analiza mogu se predstaviti istovremeno ili u različitim kombinacijama radi poboljšanja razumijevanja konceptualnog modela područja proučavanja.		
CILJEVI	Analiza podataka o podzemnoj vodi: čišćenje baze podataka i identifikacija bušotina za nadzor PS / MPS	
	implementacija konceptualnog modela	
	odnos izvora i oblaka te konceptualni model pronosa onečišćujućih tvari	
	odabir mjera i pisanje plana upravljanja podzemnim vodama	X
PREDNOSTI	WebGIS je alat otvorenog pristupa za analizu prikupljenih podataka. WebGIS-u se može pristupiti s bilo kojeg mjesta s različitih platformi, zadržavajući autorizaciju definiranu razinama pristupa (uz korisničko ime i lozinku). To znači da je moguće kontrolirati dopuštenja za određene korisnike ili određene grupe kako bi im se omogućio pristup određenom podskupinu podataka ili karata. To je način objavljivanja i dijeljenja višeslojnih značajki na jednoj web mapi. To je dobar način za razmjenu podataka i informacija između institucija i projektantskih ureda, za poboljšanje interne i vanjske komunikacije i međusobne suradnje, za podršku i olakšavanje odluka. Informacije se povremeno mogu ažurirati, prema tome, svi korisnici WebGIS-a istovremeno i u bilo koje vrijeme mogu pristupiti najnovijim informacijama. To omogućuje organizacijama da postanu učinkovitije, produktivnije i reaktivnije na svoje prostorne podatke. Prilikom korištenja se mogu koristiti mnoge značajke kao što su pomicanje, zumiranje, ispis, mogućnost prijenosa podataka i njihovo preklapanje na postojeću kartu, pretraživanje podataka po adresi, obrada podataka. Omogućuje svima a ne samo stručnjacima pristup i razumijevanje geoprostornih podataka jednostavno i sa manje napora. Korisnici, čak i ako nisu poznavaoci geoinformatike, mogu koristiti GIS alate usredotočene na podatke svoje specifične	

	struke. Za upravljanje podacima nisu potrebna vrlo jaka računala. Nema potrebe čuvati podatke na računalu jer su svi podaci pohranjeni u oblaku.
SLABOSTI	Dostupnost i performanse internetskog pristupa mogu biti problem, ali vjerojatno će se poboljšavati u budućnosti. Za implementaciju alata i ažuriranje podataka potrebni su stručnjaci koji su posebno posvećeni razvoju i održavanju skupova podataka o okolišu i funkcionalnosti WebGIS-a.
MOGUĆNOSTI	Zahvaljujući potencijalu Interneta i samog alata, trebalo bi biti moguće izvesti čak i složene analize i obrade vektorskih i rasterskih podataka na webu, surađujući s drugim korisnicima u bilo kojem trenutku.
PRIJETNJE	Dijeljenje podataka nije lak process. Korisnici GIS-a teže razvijaju vlastite skupove podataka. To na primjer znači, da oni možda ne znaju druge dostupne postojeće skupove podataka, pogreške koje su ispravili neki drugi korisnici. Pristup cjelovitim i pouzdanim skupovima podataka općenito je težak. Svaki GIS korisnik nije naviknut dijeliti skupove podataka s drugim sektorima i organizacijama. Neke poteškoće oko razmjene podataka uzrokovane su uobičajenom sumnjom u kvalitetu podataka trećih strana, pretpostavkom da se podaci mogu „pogrešno“ koristiti ako se dijele s trećom stranom, a njihovo vlasništvo može biti izgubljeno ili strahom da bi drugi korisnici mogli otkriti lošu kvalitetu svojih podataka. Stručnjaci koji su posebno posvećeni razvoju i održavanju skupova podataka o okolišu nisu uvijek dostupni u strukturi radnog tima; analitičari zaštite okoliša često rade i u fazi pripreme skupa podataka za određene zadatke kojima se bave. To može značiti da skupovi podataka nisu spremni za dijeljenje za opću upotrebu.

PRIMJER PROVEDEN U AMIIGA PROJEKTU

AMIIGA WebGIS dostupan je na sljedećoj poveznici http://131.175.56.100/lm/. Izvedeno je sedam WebGIS projekata, po jedan za svako pilot područje, i samo AMIIGA partneri mogu pristupiti projektima pomoću osobne prijave i zaporke. WebGIS je dostupan s jednostavnog web preglednika na bilo kojem uređaju.

Sav softver instaliran je na poslužiteljskom računalu, a radi na Ubuntu 14.04 Instalaciji, a sve komponente u arhitekturi su Free and Open Source Software (FOSS). Arhitektura počinje od glavne komponente koja je QGIS, besplatni i otvoreni izvor Softver za geoprostor (FOSS4G). QGIS omogućuje obradu podataka i pohranjivanje svih slojeva u lokalnu bazu podataka. Odabrana baza podataka je PostgreSQL, s dodatkom PostGIS, specifično za rukovanje geoprostornim podacima. Druga komponenta arhitekture je QGIS Server, komponenta koja služi slojevima u QGIS projektu, dakle iz baze podataka, putem weba koristeći OGC standarde kao što su Web Map Service (WMS). Kako bi prikazala sve slojeve u web-pregledniku, arhitektura implementira dinamičnu komponentu nazvanu Lizmap koja generira WebGIS na temelju potreba korisnika.

Svi su partneri bili uključeni u aktivnosti prikupljanja podataka (praćenje karakteristika mreže, vrijednosti koncentracije, karakteristike vodonosnika itd.). Podaci prikazani u AMIIGA WebGIS su: pilot područje i proširenje FUA; nadzor mrežnih karakteristika; krovina i podina vodonosnika; zona značajnih promjena hidrogeološkog karakteristika; rezultati ispitivanja hidrauličke provodljivosti; razine podzemne vode; koncentracije zagađivala; industrijska postrojenja; difuzne karte onečišćenja.

AMIIGA WebGIS za svakog partnera poboljšava učinkovitost analize podataka i interpretaciju konceptualnog modela, pojednostavljuje razmjenu podataka i informacija između institucija i tehničkih ureda s glavnim ciljem da se podrži i olakša proces donošenja odluka za upravljanje podzemnim vodama.

4. Zaključak

AMIIGA projektni alati mogu se sažeti u skladu s njihovim ciljevima. Sljedeće tablice pružaju pregled alata opisanog u prethodnom poglavlju.

Ciljevi AMIIGA alata

Tablica prikazuje ciljeve svakog alata, prema opisu u prethodnom poglavlju.

		CILJEVI			
		Analiza podataka kvalitete podzemne vode: čišćenje baze podataka i identifikacija bušotina za nadzor PS / MPS	implementacija konceptualnog modela	odnos izvor-oblak i konceptualni model pronosa onečišćujućih tvari	odabir mjera sanacije i pisanje plana upravljanja
AMIGA ALATI	ISTRAŽIVČKA ANALIZA PODATAKA	X			X
	BMT		X		X
	CSIA			X	X
	MODELIRANJE PRONOSA UNATRAG			X	X
	MULTIVARIJATNA I GEOSTATISTIČKA ANALIZA				X
	WEBGIS				X

AMIGA alati u pilot područjima

Tablica prikazuje pregled AMIIGA-ovih alata usvojenih u projektu i ciljeva postignutih u pilot područjima.

	Pilot područje (PA)	PA1 (HR)	PA2 (SL)	PA3 (IT)	PA4 (IT)	PA5 (CZ)	PA6 (PL)	PA7 (DE)
	Veličina pilot područja [ha]	6 500	7 000	15 740	600	3,1	2 475	530
	Veličina FUA [ha]	26 000	25 100	52 100	58 594	3 750	20 190	4 810
	Zrste zagađivača	Bakterije i nitrati	Cr VI, NO3, B, desetil-atrazin, novi zagađivač u nastajanju	PCE, TCE	PCE	CHC	Pesticidi, organska otapala	CHC
CILJEVI	**Analiza podataka o kvaliteti podzemne vodea: čišćenje baze podataka i identifikacija bušotina za nadzor PS / MPS**			X	X		X	X
CILJEVI	Implementacija konceptualnog modela	X		X			X	X
CILJEVI	odnos izvora i oblaka te konceptualni model transporta zagađivala	X	X	X	X		X	X
CILJEVI	odabir mjera sanacije i pisanje plana upravljanja	X	X	X	X	X	X	X
AMIIGA ALATI	ISTRAŽIVAČKA ANALIZA PODATAKA		X	X				
AMIIGA ALATI	BMT		X		X	X	X	X
AMIIGA ALATI	CSIA		X	X	X	X	X	X
AMIIGA ALATI	MODELIRANJE PRONOSA UNATRAG	X		X				
AMIIGA ALATI	MULTIVARIJATNA I GEOSTATISTIČKA ANALIZA	X		X				
AMIIGA ALATI	WEBGIS	X	X	X	X	X	X	X

POPIS LITERATURE

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- D.T1.1.1, *WebGIS tool development for groundwater database management and open-access consultation*
- D.T1.1.2, *Guideline for statistical method and geostatistical analysis for GW quality studies at FUA*
- D.T1.1.3, *GW contamination modeling at FUA: "inverse iterative modeling" guideline for implementation and use*
- D.T1.1.4, *Technical protocol for statistical analysis coupled with transport modeling for GW pollution assessment*
- D.T1.2.4, Final version of the CSIA technical protocol for GW pollution assessment and remedial evaluation
- D.T1.3.4, Final version of the BMTs technical protocol for remedial implementation and performance evaluation
- D.T3.3.7 *Management Strategy on groundwater contamination in Functional Urban Areas of Central Europe*