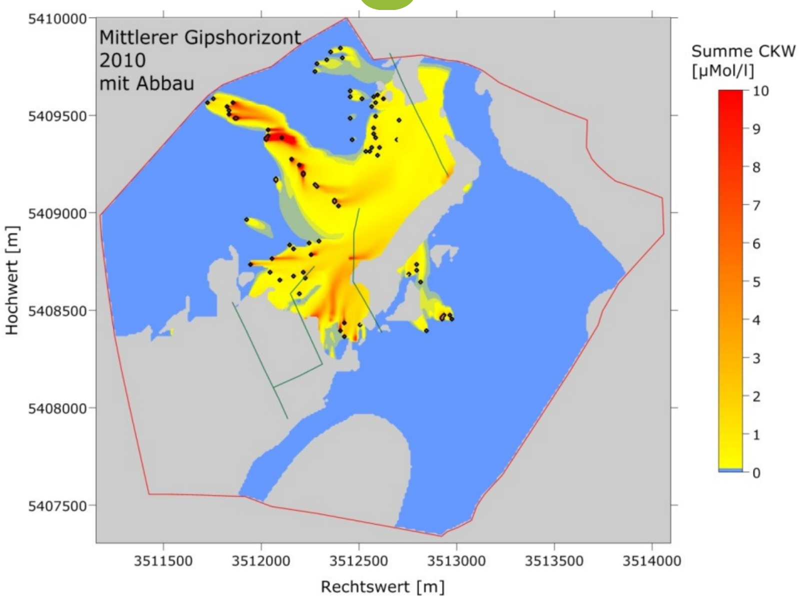
Area oriented Investigation Approach for Groundwater Management



Investing in Opportunities
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Summary

In the last decades groundwater contamination has become an important issue and subject of concern throughout the European countries. There is still a wide gap between expectations considering the (i) quality, (ii) technical and (iii) economical feasibility of groundwater remediation. Therefore, identification, assessment and management of contaminated groundwater bodies are still the challenging tasks for the most of the groundwater remediation projects. In case of many polluted areas even large invested funds can not ensure the expected improvements of the groundwater quality. Consequently, there is a need for innovative technical and administrative tools for groundwater management.

The area oriented investigation approach is an innovative tool for the identification of key sources of groundwater contamination. This approach is considering the fact that the pollution might originate from several sources, which corresponding plumes can merge or even overlay. A main goal of this approach is to trace the pollution plume along the transport pathways back to the sources of pollution. In this way, the polluting area can be (i) identified, (ii) ranked according to its impact on groundwater and finally (iii) prioritized in the way that remediation measures are concentrated only on the relevant sources of pollution.

This report has been elaborated by the following project partners:

- State Capital of Stuttgart (Germany),
- INERIS and ADEME (France),
- OVAM (Belgium) and
- Bodem+ and Gemeente Utrecht (the Netherlands).

In this report the case study Stuttgart-Feuerbach is presented. This case study indicated the methodological aspects and provided important recommendations for the possible general application of this innovative approach. The advantages of the area oriented approach are confirmed by this case study and experience of many years in Stuttgart. Effective and well targeted activities enabled to identify the most relevant plumes of pollution and determined the relevant sources of pollution together with their contribution to the overall pollution.

Additionally to the presented case study, the legal aspects for the implementation of the area oriented investigation approach for each participating country of this project (Germany, the Netherlands, Flanders and France) are included in this report. The corresponding applications and limitations of the area oriented investigation approach regarding national laws are indentified and presented as well.

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List of abbreviations

ATES	aquifer thermal energy storage
BATENEEC	best available technique not entailing excessive costs
BTEX	benzene, tolouene, xylene, ethylbenzene
cDCE	dichloroethene
CHC	chlorinated hydrocarbons
DNAPL	dense non-aqueous phase liquid
IPT	integral pumping test
MTBE	methyl tert-butyl ether
P&T	pump & treat
PAHs	polycyclic aromatic hydrocarbons
TCE	trichlorethylene
VC	vinyl chloride
VOC	volatile organic contaminants

1 Introduction

1.1 CityChlor and the integrated approach

Space is scarce in Europe. Even in the subsurface it is getting busier. Large-scale soil and groundwater contamination with chlorinated solvents are often an obstruction for urban developments. The traditional way of dealing with polluted soil and groundwater does not work in all cases and is not economically and sustainable feasible. In urban environments multiple contaminations with chlorinated solvents are often mixed with each other and spread underneath buildings. This not only leads to technical problems for remediation, but also to liability and financial discussions and hence has an impact on society. An integrated approach and area-oriented approach is needed to tackle the problems. The CityChlor project has demonstrated that remediation and sustainable development can evolve on a parallel timescale.

An integrated approach combines all aspects that are relevant to tackle the problems that pollution with VOC in urban environment causes. Depending on area, site and context different aspects together or parallel to each other can be used. Not only technical solutions are included, but also socio-economical aspects as urban development, communication, financial and legal aspects, time, space, environment and actors (active & passive) have to be handled.

CityChlor did not remain at single case remediation, but looked at the area as a whole in a bigger context: the area-oriented approach. A technical approach that makes it possible to remediate, monitor and control multiple groundwater sources and plumes within a fixed area.

1.2 CityChlor and technical innovations

The managing of knowledge and technical innovations are one of the key to achieve a sustainable city development. A development project has to cope with loads of information coming from different disciplines in different (technical) languages and with different uncertainties. With chlorinated solvents, the knowledge about the pollution will always have a certain uncertainty that can have an impact on the course and the costs of the remediation. An efficient 'managing of knowledge' will try to decrease this degree of uncertainty.

CityChlor therefore also worked on the technical aspects of characterization and remediation. The conventional techniques that are applied for investigation and remediation have their limitations dealing with chlorinated solvents. Promising innovative techniques exist, but do not easily find their way to current application. This barrier is often caused by lack of knowledge on different levels. Experts and contractors do not always have the means to invest in experiments with new techniques, authorities are reluctant to accept techniques of which the results may be uncertain and clients aren't eager to pay for experimental techniques.

Dissemination of knowledge can break this deadlock. CityChlor therefore collected experiences from field application of innovative techniques and implemented itself a number of techniques in pilot projects. For the detailed outcomes, the reader is referred to the specific reports.

2 Aim of this Study

The area oriented investigation approach for groundwater quality management serves for tackling the problems which are caused by certain contaminants in a defined area. Areas can be both (i) complex single locations polluted by commercial or industrial activities with various sources of pollution (brownfields or even natural areas, former landfills) and (ii) larger areas such as city quarters [08].

The area oriented investigation approach is based on results of single site characterizations and a historical investigation. The approach includes a conceptual hydrogeological model. In addition a contaminant transport model may be set up, which enables better to understand the system and to identify and localize the plumes of pollution with their contaminant loads. The plume interactions can be qualified by using techniques like backtracking such as fingerprints or numerical modeling, or integral pumping tests. Consequently, the area oriented investigation approach might be at the first step more extensive than the typical single case approach.

The area oriented investigation approach is particularly suitable for areas with various sources of pollution, which form distinctive plumes of pollution. This means that the approach considers the pollution coming from several sources that might merge or overlay. The basic concept of this approach is to investigate the impact and effect of pollution on different subjects of protection (e.g. groundwater, intake of drinking water, etc.) and thus, to assess contaminant plumes and their relationship to potential contaminant sources. A main task can be to trace the pollution plume along the transport pathways back to the source. In this way, polluting area can be (i) identified, (ii) ranked according to its impact on groundwater, and finally (iii) prioritized in the way that remediation measures shall be concentrated only on the relevant sources of pollution. A complementary approach is explained in the CityChlor report “Area oriented site remediation” (Action 12).

Sources of pollution that are not relevant for groundwater quality management (even though they can be ecologically important, for example on the effect the path soil – human being, volatilization to buildings, potential human risks, etc.) as well as socio economic aspects are not regarded here further. It has to be mentioned, however, that in some areas, such as in the Netherlands, the groundwater velocity is rather low, plumes are mixed and it is impossible to distinguish between them. In such a case, the application of the area oriented investigation approach is limited.

The area oriented groundwater investigation may be at the first step more extensive than the single case (case by case) approach. However, in complex cases only an area oriented investigation approach ensures effective and well targeted activities, which are shown by experience of many years in Stuttgart. In these cases only the area oriented investigation approach enables to identify the most relevant plumes of pollution and thus to determine all groundwater-relevant sources of pollution and their contribution to the overall pollution.

3 Area oriented Investigation Approach for Groundwater Management

3.1 Definition of Terms

The **area oriented investigation approach for groundwater management** is established on a survey and a balance of the pollutant charge (load) in the entire area under consideration. In this context “area oriented” is to be understood in the sense of “spatially over the entire area under consideration”. The main elements of the management approach are investigation and quality evaluation.
Contaminants or **pollutants** are substances with a toxic effect on human beings or the environment (plants, animals, natural assets). The toxic effect depends on the concentration of the pollutants in the environmental media soil, water and air.

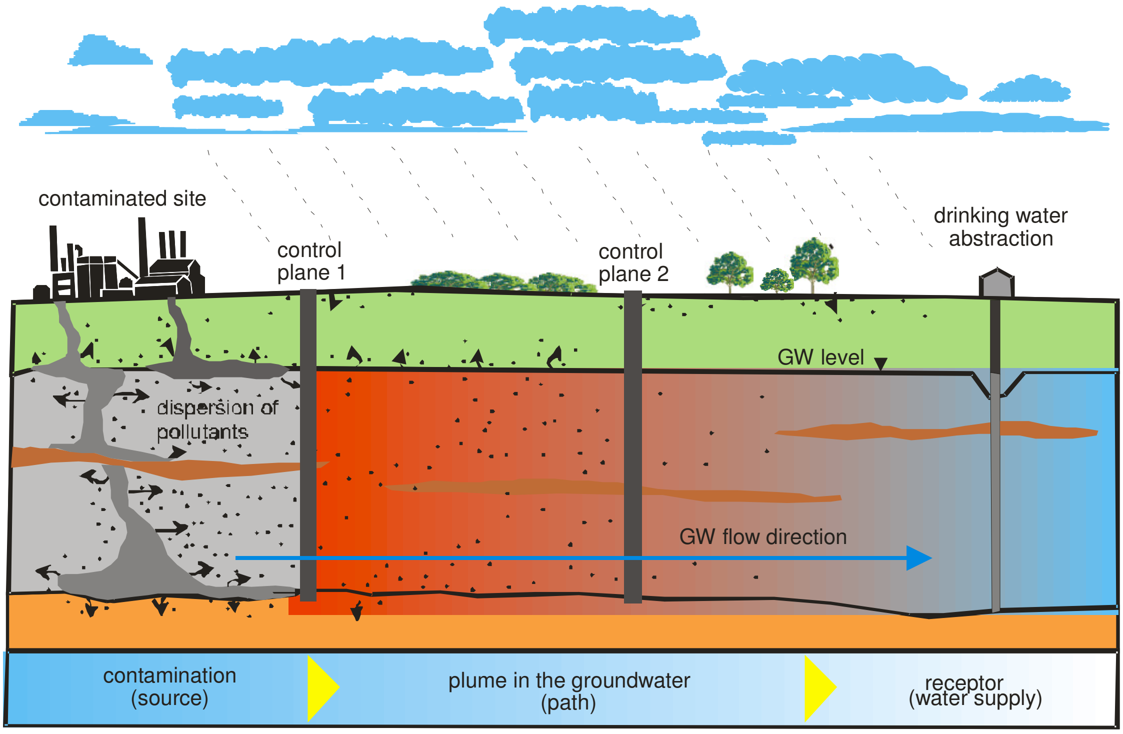

Figure 1. Migration of pollutants in the source of pollution and in the plume of pollution.

The **pollutant plume** originates from the **source of pollution**. The source of pollution is the space, where pollutants entered into the soil and groundwater bodies. The pollutants may be present in pure phase or in high concentrations (see Figure 1).

The **plume length** depends on the damage (i.e. size/impact of the source), the hydrogeological conditions, and the type of the pollutant (pollutant specific plume lengths). One or several plumes of pollution may derive by transport of the solved pollutants. The length of the plume is also limited by retention and degradation or modification of the pollutant.

Control planes are fictive perpendicular profiles formed by groundwater monitoring wells arranged in the aquifer perpendicularly to the groundwater flow direction. They are necessary for the investigation of the emission rate. Control planes used in the area oriented investigation approach can be used for natural attenuation and for groundwater numerical model.

The **pollutant load** emitted from the source of pollution is called **emission rate**. The emission rate is determined in the control plane directly downstream the source of pollution as a product of the groundwater flow rate Q_A and pollutant concentration c_A (see Figure 2). This emission rate corresponds to the defined pollution entry from the source of pollution into the groundwater, simplified to be calculated as the product of leachate flow rate Q_S and leachate concentration c_S in the source of pollution.

Contaminants released to the environment will partly find their direct way to the groundwater and /or they will be stored in the soil matrix and aquifer at or near the place of the release. Depending on the pollutant type, the source of pollution can form one or more pollutant phase bodies in the soil or in the groundwater. It can exist as a residual phase in the soil matrix (soil grain structure) or below the groundwater table. Sources of pollution can feed plumes of pollution in the groundwater over long time periods (several decades up to several centuries). The release of pollutants from contaminated soil can be made via desorption and solution of finely divided residual phase or coherent liquid phase ("pools").

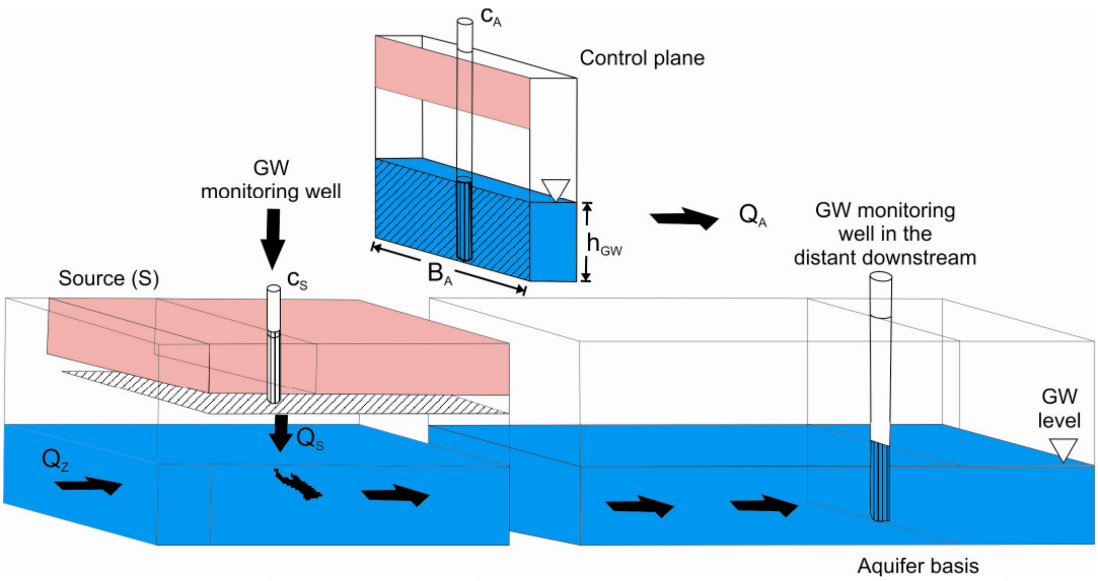

Figure 2. Parameters for the calculation of the emission rate (pollutant load) at the source of pollution.

3.2 The General Objective of Groundwater Quality Management

The general aim of groundwater quality management is to obtain good chemical status of the groundwater body in concern [2000/60/EC, 2006/118/EC]. This requires a survey of the qualitative status and, if necessary, a trend description of the groundwater quality. If no decreasing trend for a qualitatively good condition can be assumed in polluted groundwater bodies, a trend reversal must be achieved with the long-term objective of a good quality.

The trend reversal will be gained if the following goals are achieved:

- prevention of further pollutant impacts,
- prevention of further pollutant spreading, i.e. further transport of pollutants in the groundwater, and
- remediation of the main pollution sources.

The area oriented groundwater investigation facilitates in an efficient way the description of the qualitative condition of the groundwater body – also in a long time perspective – and creates thereby an important basis for the trend reversal. The scheme for the implementation of the area oriented investigation approach for groundwater management is presented in Figure 3.

The area oriented investigation requires a reversion of the investigation approach from the individual case related consideration of sources of pollution (case-by-case-approach, source approach) to the area oriented investigation of the plumes of pollution. It requires a comprehensive understanding of the soil – groundwater system and the interaction of these systems with the pollutants.

3.3 The Most Relevant Questions to be answered

For an adequate evaluation of risks arising from a single source of pollution, it is essential to find out the following:

- What load of groundwater pollution is presently generated by this source?
- What load will be generated in the future?
- What is the function of a single source in a complex system multiple sources and plumes?

The compilation of contaminant transport processes serves for the answering of the following questions:

1. How big is the pool of contaminants?
2. Where is this pool located?
3. How could these contaminants migrate to the environment (groundwater)?
4. Which amount of contaminants is exposed? On which pathways (soil – atmosphere, soil – groundwater, etc) do the contaminants spread?
5. Where do the contaminants remain on their pathways? Dilution, absorption and natural attenuation are possible, but they can be detected only as summarized amount. What is about plume length?
6. Which receptors are concerned or in danger?

After answering these questions, an extended comprehension of the contaminations is given and a suitable remediation strategy can be developed, for example based on a numerical model.

3.4 The Implementation of the Approach

The area oriented investigation approach requires an investigation of different plumes of pollution in the area under consideration. Different technical measures are available for the implementation. The appropriate set of measures has to be identified individually based on the specific local conditions. In Figure 3 these measures are displayed as “Operational technical measures - OPT” (D1 – D10).

All strategic tasks are listed and described. Which of these tasks in a concrete individual case are to be settled, must be determined in the individual design depending on the specific characteristics of the investigation area. For example, for areas where lots of single site investigations have been done, data collection and evaluation (D1) would be a good starting point. On the contrary, in areas where almost no information is available, one would start with setting up a conceptual hydrogeological model (D3) as a base for implementing integral pumping tests (D4) to get an overview on the general pollution.

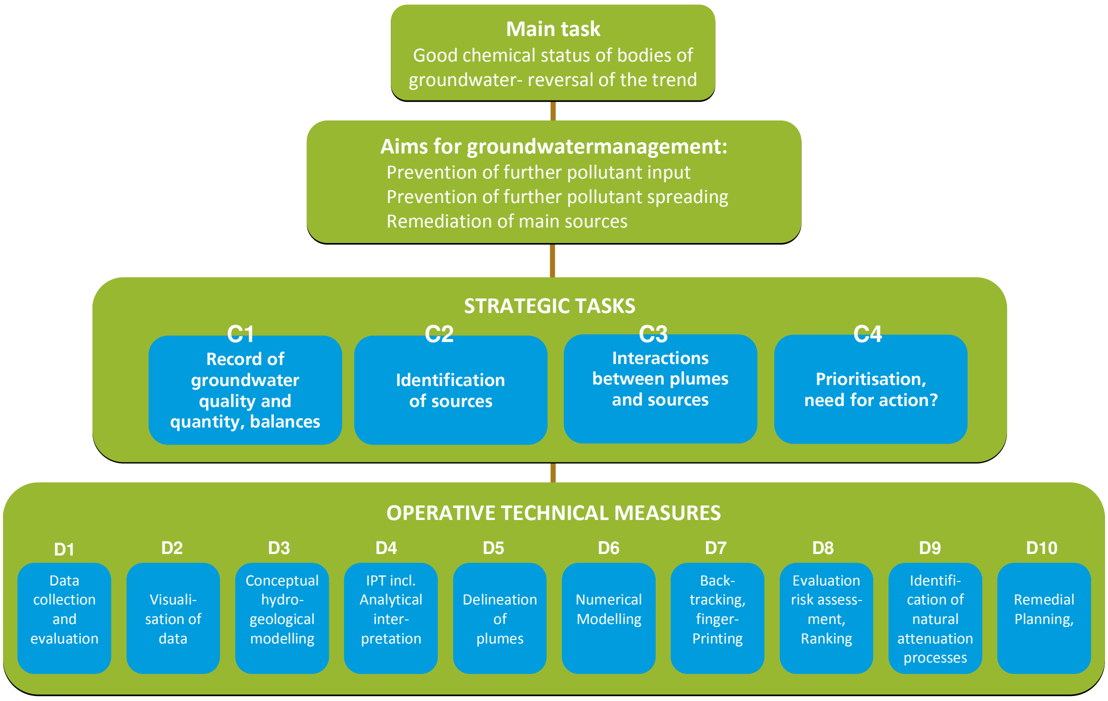

Figure 3. The objectives, the tasks and measures of an area oriented investigation approach for groundwater management [01].

For the area oriented groundwater investigation generally the following **strategic tasks** can be tackled (see Figure 3):

C1	Record of groundwater quantity and quality: 3-dimensional and simultaneous recording and description of the groundwater status in the investigation area in terms of quantitative and qualitative aspects.	[D1, D2, D3]
C2	Identification of the sources of pollution.	[D1, D2, D5]
C3	Interaction between plumes and sources: Identification of plumes of pollution, description of the interactions in terms of quality and quantity, for example in terms of emission rates (mass fluxes) and plume lengths for the description of the pollution impacts.	[D4, D6, D7, D8]
C4	Prioritization: Ranking of the pollutant impacts to prioritize the particularly relevant sources of pollution on which remedial actions should be concentrated and for the exclusion of irrelevant subordinate sources of pollution from the further treatment.	[D7, D8, D9]

To tackle the strategic tasks, **technical measures** are to be carried out (see Figure 3). Depending on the single site or area, specific measures have to be selected and compiled depending on the specific local characteristics. Technical measures are:

- D1 Data collection and evaluation, monitoring of the groundwater quality, trend observation and evaluation by a survey and summary of all former investigation activities on contaminated sites, the single sources of pollution and groundwater monitoring wells (results of former investigations).
- D2 Compilation and mapping of all available information in a data base and in a GIS: sources of pollution and groundwater monitoring wells.
- D3 Conceptual hydro-geological modeling: modeling of the hydrogeological settings, the groundwater flow conditions and the quantitative and qualitative status of the groundwater in the different aquifers.
- D4 Integral pumping tests (IPT): investigation methodology for summarizing, three-dimensional and simultaneous recording and description of the hydrogeological conditions in the investigation area in terms of quantitative and qualitative aspects.
- D5 Delineation of the plumes of pollution with the help of reference values (threshold values, test thresholds), i.e. with the help of concentration values. These are to be specified on the basis of national reference values.
- D6 Numerical modeling the plumes of pollution, i.e. development of a conceptual model of the groundwater flow and pollutant transport to the summarizing record, balance and evaluate the transport processes in the groundwater layers (aquifers) and the interactions, i.e. the current and/or transport mechanisms including the mass fluxes between the aquifers.
- D7 Backtracking of the pollutants from the plumes of pollution to the sources of pollution, i.e. clarification of the source – plume relationships. This can be done e.g. via advanced modeling techniques or fingerprinting.
- D8 Risk assessment for sources and plumes of pollution using evaluation tools, if necessary numerical groundwater modeling. Ranking of the pollutant impacts to prioritize the particularly relevant sources of pollution on which remedial actions should be concentrated and for the exclusion of irrelevant subordinate sources of pollution from the further treatment. This procedure implies that relevant sources of pollution emit large and spacious plumes. All other sources of pollution are not relevant for groundwater quality management, nevertheless they can be important (e.g. on the effect the path soil – human being, which is not regarded here further).
- D9 Identification and description of natural retention and degradation processes.
- D10 Development of remediation concepts with concentration on the priorities of the damages, i.e. derivative and evaluate additional needs for action.

3.5 Characteristics of the Area oriented Groundwater Investigation

The area oriented groundwater investigation shows the following differences to the conventional “case by case – investigation” of pollution sources, which means first searching for sources of pollution and then in the second step investigating the corresponding plumes:

- The plumes of pollution will be identified. Based on their characteristics the sources of pollution will be determined and evaluated.
- The contaminant mass flow rates of the pollution plumes represent the source impact in an appropriate way.

- The source-related consideration taking into account the liability of property owner is tackled after the conclusion of the area oriented groundwater investigation.
- The area oriented groundwater investigation requires a stronger commitment of the competent environmental protection authority.
- The treatment of sources of pollution receives a substantially more qualified basis and can be concentrated on the priorities in terms of groundwater management. It becomes more efficient and more effective and thereby cheaper.
- The area oriented investigation facilitates to calculate a balance of the pollutant mass flow rates (balance of emission rates and pollution extraction).
- The area oriented groundwater investigation facilitates an appropriate and qualified observation and monitoring of the temporal development (significant and sustained upward trend in concentrations of pollutants, trend of the groundwater quality) in a body of groundwater (trend monitoring). Also timely variant and dynamic processes can be tackled in an appropriate way.

The central element of the integral groundwater investigation is the integral pumping test (IPT). This test is a powerful measure to investigate source – plume interactions in the groundwater, which is the basis for the assessment of the actual impact of a source of pollution on the groundwater. The interpretation of the IPTs, together with a conceptual hydrogeological model, contributes to the localization of plumes and their contaminant loads. Furthermore, by using the backtracking techniques (fingerprints, modeling approaches) the source – plume interactions can be qualified.

3.5.1 The Fields of Application

The area oriented investigation approach is particularly suitable for areas with various sources of pollution, which form distinctive plumes of pollution. It takes into account that plumes of pollution derived from several sources of pollution may merge or overlay.

The area oriented groundwater investigation is necessary and has no technical alternative in achieving the key objectives:

- evaluation of the contribution of the individual source of pollution to the entire groundwater environmental damage in cases of several neighboring sources of pollution in an investigation area,
- investigation of sources of pollution and emission rates in areas of strong building activities (e.g. due to the structural land use changes), where primary sources were removed and the secondary sources still have remained (Figure 4),
- investigation of pollution in areas with complex hydrogeological conditions, and
- proper monitoring of the groundwater quality in a complex body of groundwater and observation of trends.

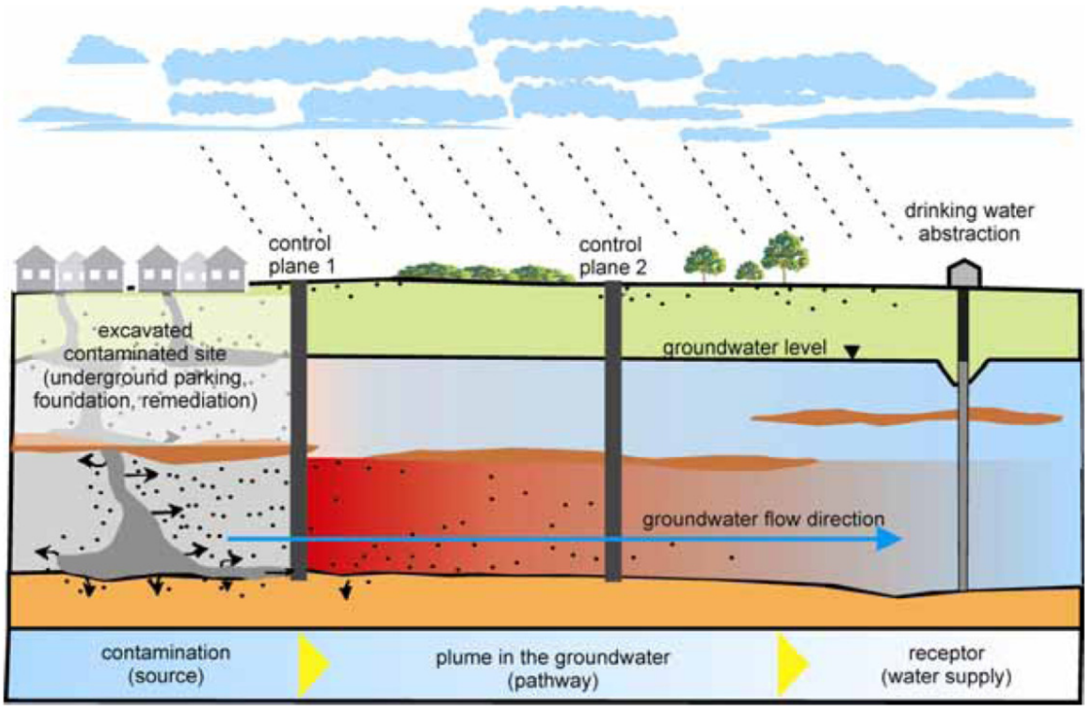

Figure 4. Primary source of pollution removed by building activity and remaining secondary source of pollution.

The applicability of the area orientated groundwater investigation is amongst others dependent on the type of the pollutants. This is due to different lengths of the plumes of pollution. The approach is particularly well suitable for damages with pollutants that form long plumes of pollution, like common organic contaminants as CHC, MTBE and limited also BTEX and PAHs. This approach is less suitable for damages with short plumes of pollution (for example: mineral oil hydrocarbons).

Generally, the area oriented groundwater investigation approach is also suitable for:

- identification and ranking of plumes and sources of pollution as part of the preliminary investigation,
- preparation of a complex concept of remediation measures for large areas, and
- observation of the trends of water quality in groundwater bodies according to the water framework directive and the groundwater directive.

3.5.2 Advantages and Limitations of the Area oriented Investigation Approach

The area oriented investigation approach offers a technology that can be implemented in cases where no alternative is possible. Despite complicated hydrogeological conditions, neighboring sources or even secondary soruces (see Figure 4) of pollution, the area oriented investigation approach enables to identify the groundwater-relevant sources of pollution and their contribution to the overall pollution. At the beginning of the investigation the most important is to determine the plumes and further on, the sources can be found. By remidiating the source, contamination within the investigating area will be reduced.

However there are some limitations of the area oriented investigation approach. The applicability of the approach is limited in case of large investigation areas because short plumes cannot be captured by

investigation and information can be lost. In the case of large water amount, for example in the Netherlands, pumping capacity would be too big, followed by larger amount of polluted water that has to be cleaned. Our experience showed that maximal amount of pumped water should be 5 l/s. Additionally, if groundwater flow velocity is too small and the plumes cannot be distinguished, the application of the approach is also limited. The thickness of an aquifer is an important parameter considering the existing amount of water that has to be pumped. However, if the aquifer is thick but has only thin layers where water is flowing, the amount of pumped water can be small enough to apply the approach.
Financial aspects and corresponding costs of the approach can be found in the final report of the INCORE project [04].

4 Area oriented Investigation Approach in Stuttgart

4.1 Legal Aspects

In legal terms groundwater pollution is to be considered as a breach of law or a breach of the public safety. It is principle of the public law (the law concerning public safety) that the responsible of a breach (the polluter) must provide for the re-establishment of a trouble free condition. This includes the clarification of the facts (the investigation of the pollution). In the case of environmental damages remediation goals are defined on this basis, according to the principle of the proportionality of the measures, and the damage is remediated. Thereby, different tasks are to be tackled by the competent authority:

- Clarification of the facts of the case, i.e. the authority must clarify whether a breach of law is present.
- If a breach is present, the authority must enforce the responsible person to investigate the damage to the necessary extent and scope and completely clarify the facts of the case. In the case of an environmental damage: The polluter has to clarify the area oriented delimitation of the damage and to investigate the consequences for the environment, in particular for the groundwater (including plumes of pollution).
- If the facts of the case are clarified (i.e. the investigation of the damage is completed), the authority must commit the liable person (legal body) to create a concept for remediation. If a liable person (legal body) cannot be determined with sufficient security or if this person is not capable and/or willing, the authority must implement the necessary measures itself.
- The authority must ensure that the damage is remediated in a sufficient way. Thereby it must keep in mind that in certain cases the polluter's liability is limited.
- In the case of an acute endangerment (e.g. the pollution of a waterworks of the public drinking water supply) the authority must provide immediate corrective actions, as soon as it recognizes the acute endangerment, for example to prevent that contaminated water is supplied into the waterworks.
- Finally the authority is responsible for the supervision of the general groundwater quality.

The current standard "case by case – management" of pollution is derived from the liability of the polluter (polluter pays principle). It concerns thereby a generally used approach in the quality management of environmental damages. In the case of single damages and clear liability the "case by case" investigation has proved itself well. This strategy starts in the core of the damage, the location of the entry of pollutants into the soil. It pursues the pollutant transport beyond the soil passage into the groundwater. It bases on the concept that a pollutant entry always proceeds over a defective plant or in other manner of entry from a certain property. This facilitates the tracing of the entry of pollutants and the effects on the subjects of protection (here in particular on the groundwater) of a traceable transport pathway and thus forms a so-called "red thread". This verification justifies the liability of the polluter besides the liability of the property owner. The standard case by case management is essentially an approach for individual sources of pollution. However,

in complex cases with multiple sources of pollution this standard approach is often limited and does not allow identifying the key sources of pollutions and the liable polluters.
The standard approach for quality management of sources of pollution is limited, if:

- many different sources of pollution might contribute to an identified groundwater damage, and it is however unclear, which ones are actually liable for the groundwater damage, or
- many sources of pollution overlay each other and the objective of investigation is to identify the contribution of each source to the entire groundwater damage, or
- the source of pollution was removed, e.g. by excavation, in the larger depth, however exist secondary damages (e.g. pools), which can hardly to be identified, although they continue to emit pollutants (Figure 4).

In the mentioned cases the authority is challenged by the task to investigate such damages technically, and which one of the potential liable persons must be obliged in which manner (and/or for which measure) for further measures. Moreover, the results of the investigation have to be legally self defensible.
Practical implementation problems are (according to the national law):

- The owner liability is restricted to soil damage on the property (damage in the unsaturated zone). The liability for plumes of pollution, which extend beyond the property, is restricted to the polluter.
- The authority is obliged (in Germany among others on the basis of its guarantor position) to investigate and, if necessary due to endangerment of the public safety, to remediate groundwater damages in the public area, if it the polluter cannot be obliged.
- Investors (e.g. building owners) are obliged, in case of groundwater drainage in plumes of pollution (for example temporary draining groundwater for the building pit or permanent draining of buildings), to clean delivered groundwater before the discharge. The investor can hold the polluter liable only on the basis of the civil law.
- The authority has problems with the polluter's identification for plumes of pollution, e.g. groundwater contamination in the public space. Thus the task is to retrace the damage within the framework of official identification of liable persons from the plume back to the source of pollution.
- In complex cases (many neighboring sources of pollution, and/or complex hydrogeological conditions), the task of clarification of the source – plume relationship is difficult for the competent authority in order to set the appropriate priorities.
- If the primary source of pollution was removed for example within the framework of building activities, frequently secondary sources of pollution remain, which cannot be identified or eliminated by the treatment of the sources of pollution (Figure 4).

In all these mentioned cases an area orientated groundwater investigation offers a useful and technically suitable option, in order to identify the polluter and to relieve investors or other persons concerned without polluter contribution.
With the water framework directive (2000/60/EC) and the groundwater directive (2006/118/EC) the European Union introduced new aspects and points of view into the investigation and evaluation of the groundwater quality.

The groundwater directive defines threshold values for a "good chemical status" of the groundwater in Article 3 No. 1. Quality standards (reference values) are indicated in Appendix 1, the list of parameters is, however, limited to nitrate and pesticides. The groundwater directive obliges the Member States to indicate reference values for the further substances listed in Appendix 2 up to 22.12.2008. Among others, sulphate and chloride are mentioned which are in many cases related to mining activities, as well as tetrachloroethylene and trichloroethylene, which produce Europe-wide strongly spread and particularly dangerous groundwater pollutions. Although, not explicitly mentioned polycyclic aromatic hydrocarbons are another group of important substances related to e.g. gasworks sites which should be considered in the national listing of threshold values.

Into Article 5 of the groundwater directive the term "plumes of pollution" is introduced. The reduction of the pollutant entry into the groundwater is explained to be a long-term goal. The water framework directive obliges the Member States in Article 17 to establish a good chemical status in the groundwater bodies up to the year 2015 (water framework directive Article 4, No. 1b).

Important strategic elements of the EU-directives are the principle of the view on larger areas and water bodies (in addition to the national view on individual cases, predominating up to now). This leads to the fact that the Member States must define and examine groundwater bodies (groundwater directive Article 3 No. 1). Thus a scale discussion is to be held. There is the danger of the marginalization of extensive groundwater damages by appropriate scale choice: the scale must be selected in the way to avoid that pollution remains unnoticed.

The groundwater directive introduces the procedure of the trend observation in Article 5. If an increasing concentration of pollutants is discovered by the trend observation, a trend reversal must be achieved.

4.2 Case Study Stuttgart-Feuerbach

4.2.1 Introduction

The area oriented investigation approach for groundwater management was developed and applied since years in Stuttgart. First steps were made with an integral groundwater investigation in the valley of the Neckar River. This concept was then further developed in a hydrogeological more complex system in Stuttgart Feuerbach during the projects MAGIC and FOKS. The FOKS project area of 533 ha is situated in the north of the city centre, in the valley of Brook Feuerbach. As many districts of Stuttgart, the district of Feuerbach (Figure 5) is constricted by severe soil and groundwater contamination generated over decades of industrial and commercial use. Due to the structural changes many former industrial sites are now converted into service and residential purposes. Numerous single site investigation and remediation activities have taken place in Feuerbach since 1984. Thus 300 contaminated sites were identified. 193 of them pollute or potentially pollute groundwater with chlorinated hydrocarbons (CHC), which are known to generate long plumes. Several remediation activities in the form of pump & treat (P&T) are still carried out throughout Feuerbach, both private and public, to reduce the groundwater contamination. As many sources of contamination have not been identified by now, these remediation activities in the plumes are often inefficient and long-standing.

Figure 5. City district Stuttgart Feuerbach.

Due to the neighbouring sources and overlapping of different plumes, the identification of the liable polluters is a challenging task. Additionally, the allocation of the groundwater damages is impeded by the complex hydro-geological conditions in the project area, characterised by a stratified aquifer with numerous layers of sandstone, mudstone and gypsum (Figure 6). Beyond that, groundwater flow direction changes locally about more than 90°, depending on seasonally rising or sinking groundwater level. Although groundwater in the city district of Feuerbach is not used as drinking water, there is a risk of uncontrolled spreading of contaminants to deeper aquifers and the Brook Feuerbach. In Germany groundwater is generally protected as strategic resource, no matter if it is used or not.

The investigation of individual contaminated sites can be inefficient in such cases. Therefore, under the INTERREG project MAGIC, a conceptual model based on data from 900 wells was developed for the Feuerbach site and later on a numerical model providing a general overview on the contaminant spread in different aquifers. However, for some of the main identified plumes significant knowledge gaps still remained. Further analyses of the numerical model revealed that to achieve a real picture of the contaminant migration and source distribution microbial degradation should be taken into consideration.

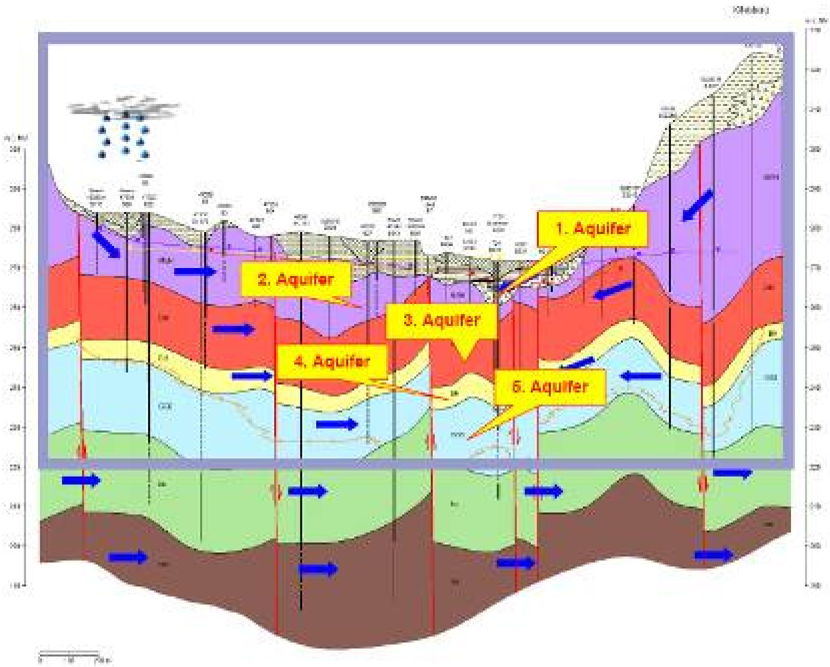

Figure 6. Complex geological structure entailing stratified hydro-geological conditions.

Therefore, the objectives of the FOKS project were as follows:

- to reliably identify and localize the key sources in this area by closing knowledge gaps in site characterization,
- to assess the effects of microbial degradation of CHC and to include this in the existing numerical model, and
- to develop an integrated groundwater quality management / remediation strategy for the whole city district.

The integrated groundwater quality management should be based on the numerical groundwater model.

4.2.2 Development of a Numerical Model

Model Improvement by Inclusion of Microbial Degradation

The assessment of natural attenuation processes clearly indicated effective microbial degradation of CHC in Feuerbach. Therefore, the contaminant transport, originally modeled as simple advective transport of PCE, TCE, cDCE and VC, was redefined as a reactive transport model including degradation [8]. The model area, the control planes used for the calculation of mass flow rates and the four main source areas (mainly large industrial sites) are presented in Figure 7, including their daily released contaminant mass flow rates. The area covers more than 2950 m in E-W direction and 2700 m in N-S, representing five hydrogeological units (see Figure 6). Horizontal discretisation is measured in cells of 10 m x 10 m.

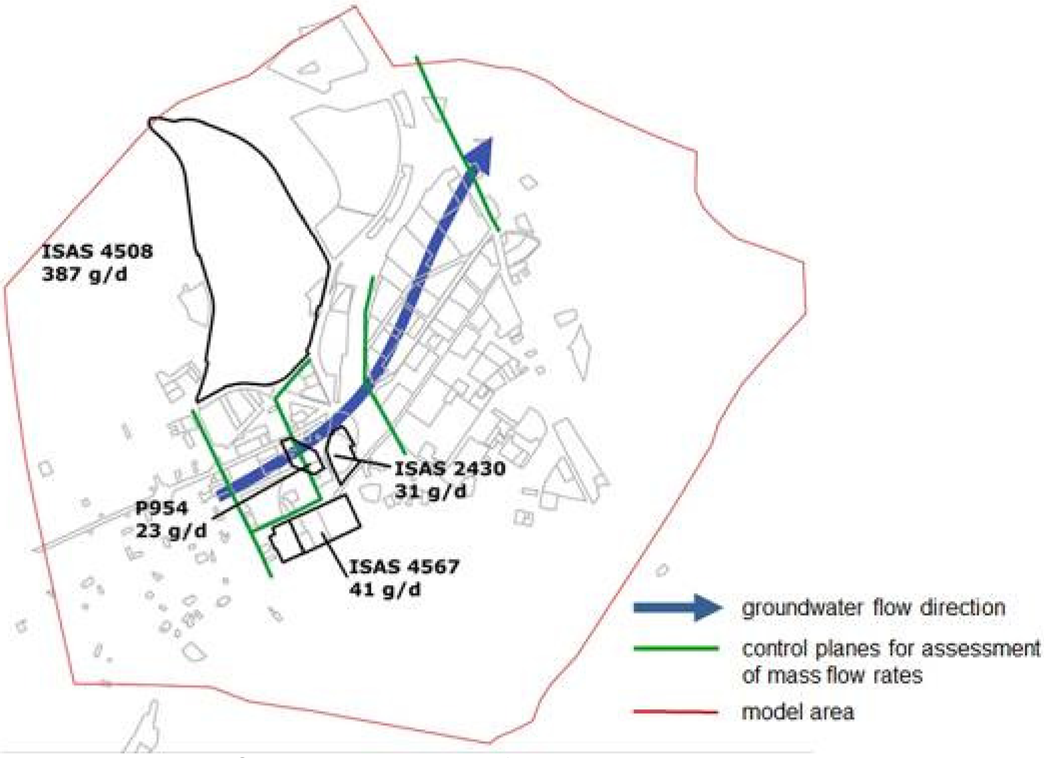

Figure 7. Model area Stuttgart Feuerbach with four main sources.

Degradation was introduced to the transport model as a general decay of the first order for the parameter "CHC total" with a half-time of 2 years.

For such a non-specific degradation it is not necessary to specify the relevant processes. Based on this, the mass flow rates along the control planes were recalculated and compared to the mass flow rates calculation based on IPT (see page 10, operative technical measures D4) results. By considering this degradation, the calibration reached a much better representation of the actual concentrations along those control planes in far distances from the sources, without inducing the underestimation of the concentrations for those planes closer to the sources. This proves that the accuracy of the model fits to the prerequisites for the remediation scenario modeling in the next step.

Figure 8 displays the CHC distribution pattern for two scenarios: excluding degradation and P&T activities on the left and including current P&T activities and degradation processes on the right.

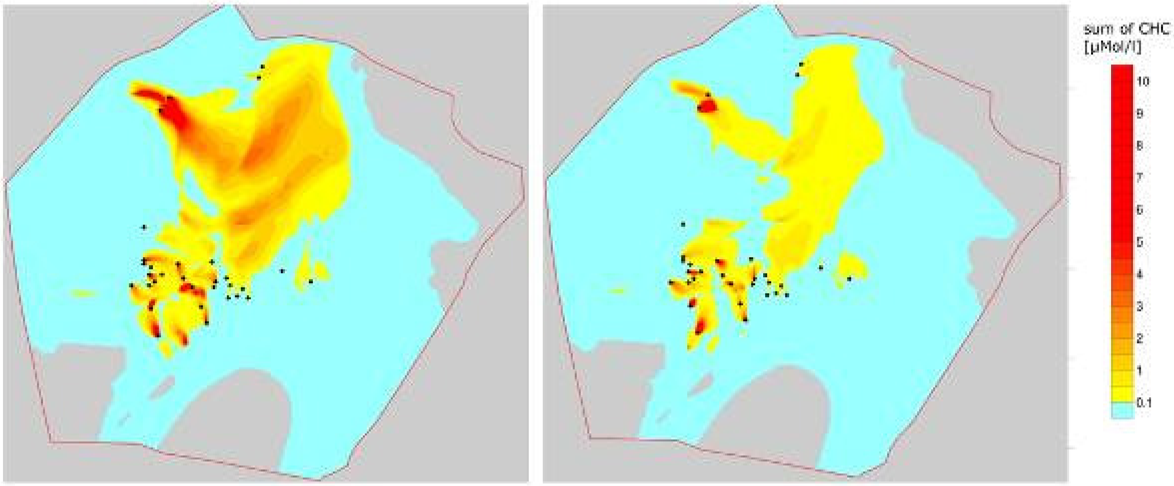

Figure 8. CHC distribution patterns for the two scenarios: without degradation on the left and including degradation on the right.

Conclusions

Besides their importance at a local level for the rehabilitation of the groundwater in Stuttgart, the results of the case studies reveal important methodological aspects and lead to more generic recommendations for the general application of the area oriented investigation approach for groundwater management. Based on the analyzed cases, these are:

- Always start with a characterization of distribution patterns of “traditional” parameters (e.g. total concentration of components, redox parameters) over time and space.
- Chlorinated hydrocarbons usually form narrow contamination plumes in groundwater, which has to be considered in the planning of investigation measures, e.g. sampling intervals for IPT. However, time-variant groundwater flow conditions or historically significantly different groundwater abstractions and uses may results in wider plumes or even more diffuse distribution of contaminants in groundwater.
- Although anaerobic degradation is considered to be the dominant degradation mechanism for CHC in groundwater, aerobic degradation processes can play a significant role as well. Oxic or post-oxic conditions are widespread in European groundwater bodies and provide a favorable environment for microbial degradation of TCE and even better for less chlorinated components. Apart from mapping of redox also time and area oriented distribution profiles of CHC can help characterize and describe the significance of these processes.
- It is of utmost importance to fully understand the relevant driving forces in contaminant fate and transport at the site considered. This should be based on a sound conceptual modeling. In complex cases the numerical groundwater flow and transport model proved to be a powerful tool. The model enables to check the applicability of different hypotheses about the driving processes and their impact on the current local conditions.

- All Stuttgart cases illustrate that combining different characterization tools (see www.citychlor.eu) may be very important and useful for providing a consistent and comprehensive interpretation, particularly in complex cases.

4.2.3 Use of a Model for Groundwater Risk Management Plan FOKS

For Stuttgart-Feuerbach a brief groundwater risk management plan including a groundwater remediation and risk management strategy were developed. For this purpose it was important to clearly identify the relevant sources, pathways and receptors of contamination. These can best be displayed in a conceptual model and illustrated by cross sections as shown in Figure 9.

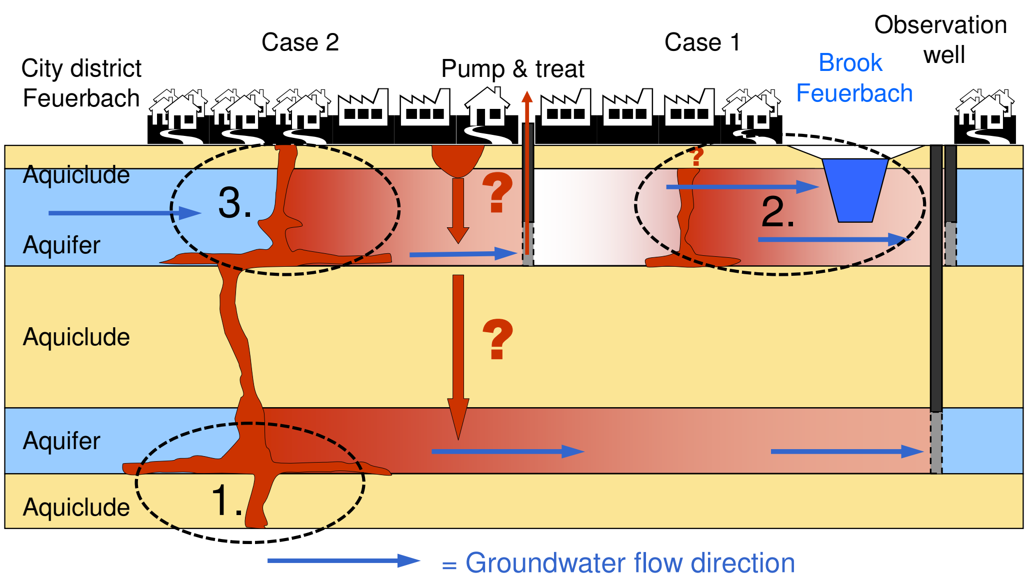

Figure 9. Conceptual model for risk management – key targets for groundwater protection in city district Feuerbach.

Based on the conceptual model, three main risk related remediation targets were defined for Feuerbach:

1. priority	deeper aquifers	Prevention of contaminant input and transport in deeper aquifers. The deeper aquifers are to be safeguarded from any contaminant input.
2. priority	surface water	Prevention of contaminant transfer into the Feuerbach Brook as a surface water system aiming at a medium term minimization.
3. priority	quaternary aquifer	Limitation of the contaminant release to the quaternary aquifer to significantly less than 20 g/day. The general objective is a medium term reduction of contamination.

The four most CHC releasing areas of Feuerbach were selected to be considered in terms of these remediation targets, see Figure 7. The total mass flow rates released from the areas are calculated as g/d PCE-equivalent, according to the molar concentrations.
Several P&T installations are under operation in the city district of Feuerbach, and a significant clean-up of most contaminant plumes can already be observed there. Nevertheless, for the development of a

comprehensive and cost-effective strategy, these should be neglected in order to derive an optimal strategy without any premature setting. So in the first step the current situation was compared to a scenario, in which no pumping installations were active. The resulting mass releases for different pathways or receptors are listed in Table 1, second column.

Then, the calculations were made for the 4 main sites (see Figure 7), covering about 7% of the model area. Due to the modeling results they comprise more than 89% of the contaminant release into the groundwater system. Focusing remedial activities will bear tremendous positive effects on the groundwater quality in Feuerbach. Table 1 indicates the individual contaminant release rates for the main source areas. The table shows that there are big differences between the sites concerning their hazardous potential for the surface water system (Feuerbach Brook) and the deeper groundwater aquifers. Vice versa, this shows directly, to which extent the daily contaminant release would be reduced, if any kind of “source remediation” totally reduced the contaminant load in the aquifer.

Table 1. Calculated effect of a single main source remediation [g/d PE for grams per day PER-Equivalent] for four main key sources presented in Figure 7.

	all 193 sources in Feuerbach	4 main key sources				reduction by complete remediation or degradation of 4 key sources	
		ISAS 4508	P954	ISAS 4567	ISAS 2430		
pathways	g/d	g/d	g/d	g/d	g/d	g/d	% of all sources
sink rate deep aquifers	36	1	10	18	2	31	86
input of the Feuerbach Brook	168	129	2	6	9	146	87
degradation	336	257	11	17	20	305	91
total release	540	387	23	41	31	482	89

The most significant source with the release of 387 g/d PE (72 %) is the very large area ISAS 4508 with a number of different sub-source areas. Their removal would increase the groundwater quality in the upper layers to a very large extent. However, nearly no positive remediation effect can be expected for deeper aquifers.

Already at a glance it becomes clear that focusing remedial actions on these 4 contamination sources would nearly reach 90 % of the level of effect than working on all 193 sites. These four areas can, therefore, really be declared as the “key sources” in Feuerbach. A stronger focus of remedial actions on the sources located in these four areas should result in significant improvement of the groundwater quality in this area.

Based on the obtained results, future activities will focus on site specific remedial planning including considerations what can be achieved by improving the existing P&T installations and additionally, what should be set in place, e.g. to remove the contamination source. However, all these considerations should also take into account what else can be done to increase the effectiveness of natural degradation processes occurring in the aquifer.

5 Area orientated Investigation Approach of Utrecht: Bio-washing Machine

5.1 Background

The CityChlor project aims to develop knowledge about and gain experience on the realization of an area oriented approach to soil remediation. Within this context, the utilization of sustainable energy with ATES (aquifer thermal energy storage) can play an important role. Essential elements of this plan are monitoring and optimization. That is, how can you optimally monitor area oriented groundwater management effectively and efficiently. The choice has been made in Utrecht to deploy ATES as a decontamination tool: the "Bio-washing Machine".

Large-scale contamination of the deeper subsurface aquifers is also present in the studied area. Contaminants mainly consist of chlorinated hydrocarbons and the (intermediary) degradation products thereof. The contamination found in the subsoil cannot always be retraced to the original physical source and/or the responsible party. Additionally, it has emerged that 'plumes' from different sources run into each other at depth. As a single case approach is thus illogical and unmanageable, an area oriented investigation approach is the preferable option.

It is also necessary to have clear objectives with regards to an area oriented investigation approach in terms of the expected and required groundwater quality. Processes such as biological degradation, dilution, evaporation and, large-scale ATES systems impact the concentration and physical distribution of groundwater components. It is thus important to understand which processes are relevant in general, and specifically, which yield contaminant concentration reduction.

Therefore, a substantial area demarcation (the system limit) must be identified within which contamination may be present. However, at the same time, within the demarcated area, system limits, in terms of specific concentrations, may not be exceeded.

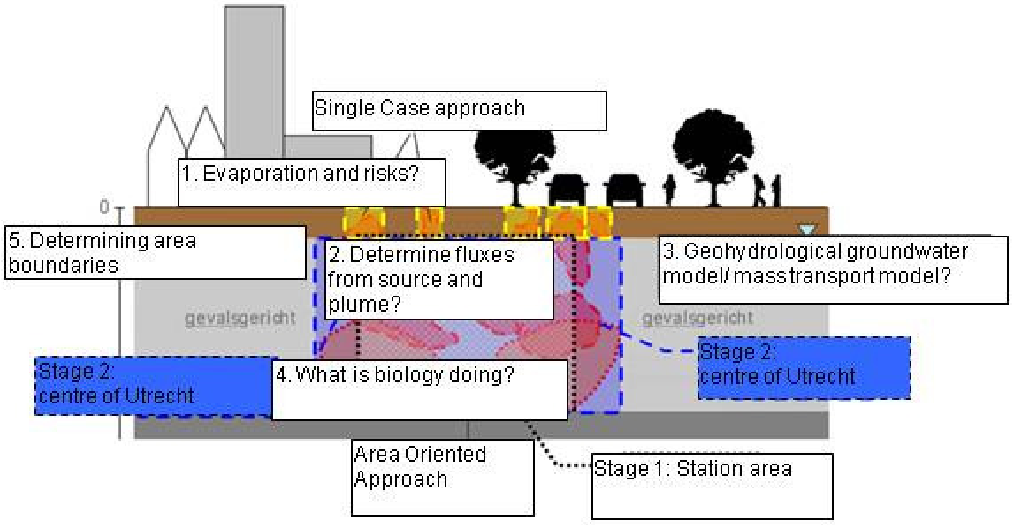

Figure 10. Schematic representation of the items to be addressed in the Utrecht CityChlor project.

Relationship between the different aspects

A number of factors must be considered (see Figure 10) when determining the demarcated area and identifying controllable (= 'sustainable') elements to manage risk. Contamination will be mobilized into the (deeper) groundwater from the different source areas that are still present and have not been decontaminated. This means that these groundwater deposits will be fed and, therefore, will have an impact on the total mass of contamination that is released per unit time. Degradation of the contamination reduces the total mass. Therefore, contaminant degradation must be examined fully in a manner that allows proper measurement rather than relying on numerical modeling. Such measurements contribute to the estimation of both the risks as a result of the contamination (do contaminants reach critical objects?) and to the determination of the system limit. Another process that can possibly remove contamination from the system is volatilisation into the vadose zone. The contamination will be transported from both the unsaturated layer and the groundwater to the vadose zone. It is important to map and monitor volatilization in particular due to the risks associated with this process.

Final contamination boundaries and concentrations must be properly determined through a modeling approach which integrates results from measured degradation potential. Area boundaries can be defined based on these calculations.

Another aspect to be kept in mind is the impact of the (multiple) ATES systems in the area on the contamination present. It is important that the following factors will be determined:

- where will these systems have an impact on the spread of contamination,
- where will the impact be on degradation, and
- where could they lead to risk increase.

Increased risks occur, for example, when highly contaminated groundwater ends up in shallow groundwater layers, which in turn increases volatilization. Similarly, when ATES is applied to DNAPL (dense non-aqueous phase liquid) sensitive areas the contaminant concentrations increase, especially when there is a limited degradation capacity. In other areas, dilution may occur due to the mixing of large volumes of contaminated groundwater with non-contaminated groundwater causing risks to be reduced, in fact.

Additionally, ATES may stimulate underground biology and the related degradation process due changes in parameters such as flow and temperature. Conversely, it could disrupt or slow down biological degradation, depending on the tolerance of subsurface microbial populations and increases in the aforementioned parameters.

We propose that attention should be paid to these aspects in sub-studies.

Based on current monitoring and newly gained knowledge, ultimately, a smart monitoring programme can be designed where the focus will be on indicator parameters that are important for the operation of the system as a whole. Moreover, an indication will be given on the deployment of several ATES systems in an effective manner.

5.2 Necessary Sub-studies to carry out the Utrecht Approach

Essentially, the following elements are involved:

1. Does evaporation of contamination from source areas take place? If so, to what extent and what are the related risks?
2. Does additional volatilization take place when (multiple) ATES systems are employed yielding increased risk with respect to ATES implementation?
3. What portion of the contamination is leached to the plume? Here, an inventory of source locations and a determination of the fluxes from the source and plume are necessary.
4. Where is the contamination flowing towards and can it be found in the subsurface in Utrecht? This involves geohydrological groundwater model and substance transport model
5. Does the soil have degradation capacity? If it does, how large is this expected to be? Which biological processes play a role? Where is this capacity active in terms of time and space?
6. What changes the macrochemistry (redox potential and mineral composition) of the groundwater due to pumping and heating associated with a large-scale ATES system? What is the net impact of groundwater being pumped around on the degradation and spread of the contamination, including the possible impact of DNAPLs?

Different subprojects, as described below, will be set up in order to obtain answers to these studied questions.

Based on the questions above, the specifics can be determined for:

- identifying the area boundaries;
- the smart monitoring of the contaminated area; and
- setting up a smart monitoring plan with innovative measuring techniques.

5.3 Legal Aspects

The Dutch law on soil pollution is from 1987. In these days the government thought it would always be possible to identify the borders of pollution so the basis from this law is the single case approach. That's a problem here because all these single cases are mixed and it's not possible to identify the different cases anymore. That's why we made use of different aspects of the law to make our remediation plan possible.

Clustering of different cases

The law makes it possible to cluster different cases of pollution and remediate them at the same time. With the use of this article of the law we can defend the way we remediate the pollution with the Bio-washing machine. It would of course be much easier if the law would permit an area oriented investigation approach. At this moment the national government is changing the law that way.

Execution in phases

Because of this single case approach the law says that you must identify the borders of the pollution before you can start with the remediation. In this case that wasn't possible. One of the parts of the remediation plan is a grid with monitoring wells and these can help us identifying the outside borders. But not before we start. So that's why we execute the remediation in 2 phases:

- we start the remediation in the center zone of which we are sure that everything is polluted and we start with measurements that we need to identify the outside borders of the polluted area.
- Phase 2 is the remediation of the complete polluted area.

Remediation in parts

We do not include the first 5 meters below surface in our remediation plan. Because in that region it is possible to identify single cases and often you can also find out who is responsible for the pollution. Once the different cases are mixed it's very hard to make someone responsible for the costs of the remediation.
The remediation plan is only made for VOCL's. For other kinds of pollution we make use of the Crisis and restoration law.
As a reaction on the economical crisis the Dutch national government laid down the Crisis and restoration law. Because of this law we have the possibility to get dispensation from some parts of the law for soil protection because the Bio-washing machine is an innovative project and will help us dealing with the effects of the economical crisis.
This means that for the area of the Bio-washing machine we had to lay down the alternative rules in a communal regulation.

6 Area Oriented Investigation Approach in Flanders

In Belgium, the environmental policy is the competence of the Regions. Each region (Flanders, Wallonia and Brussels) has his own policy / legislation on contaminated land. In Flanders since 1995 the Soil Decree is applied.

6.1 Instruments in the Soil Decree

The purpose of the Soil decree is to remediate contaminated land in Flanders and to prevent new contamination. In order to achieve this objective, the following measures are taken:

- **Attribution of soil certificates:** ever since 01.10.1996, a soil certificate is needed when transferring a piece of land. If data about the soil quality are known by OVAM, the soil certificate contains a summary of the quality of the soil and the groundwater. If no data are known about the soil quality, the soil certificate is called 'blank'.
- **Follow up of preliminary and descriptive soil investigations:** a preliminary soil investigation provides indications on the degree of soil contamination. Further steps depend on the degree of contamination and the time it has been established (new or historical). In the next step, a descriptive soil investigation tries to find out about the dispersion of the contamination and its future evolution. Moreover, the risks of the contamination are evaluated. If the contamination needs to be remediated, a soil remediation project must be worked out, in which different relevant remediation techniques must be compared in order to find the BATNEEC (best available technique not entailing excessive costs).
- **Evaluation of soil remediating projects** involves verification of the completeness and sustainability of the remediating projects submitted, requesting necessary advice and supervision on the publication of the project, drafting a certificate of conformity or requesting changes/additions.
- **Follow up and control of remediation works in progress**. If any safety or control measures are needed after finishing the works, OVAM provides a follow up. At the end, OVAM issues a final report, stating the results of the works.

6.2 Remediation Goals

For **new soil contamination**, the objective of remediation is to reach the target values for soil quality. If this is not possible using the BATNEEC, soil remediation is aimed at obtaining a better soil quality than specified by the soil remediation standards. If this is not possible using the BATNEEC, soil remediation is aimed at avoiding that soil quality involves effectively or potentially a risk for people or for the environment.
For **historical soil contamination**, soil remediation is aimed at avoiding that soil quality involves effectively or potentially a risk for people or for the environment, using the BATNEEC.

6.3 Liability

In the Flemish Soil Decree a remediation obligation rests on the **operator** or the **owner** of the land where the pollution entered the soil (**core zone**). This means also that the obligation does not rest on the owner of the land contaminated by migration of contaminating substances from other property. If new contamination is concerned, the obligation exists automatically. In the case of historical contamination, the obligation only arises after the remediation order by the government.

The Flemish Soil Decree introduced a non-retroactive strict liability rule and channeled the liability for the new contamination to those that caused the contamination. Recourse against other responsible parties is however possible. With respect to historical contamination, liability is determined by the rules in effect before the decree came into force.

The owner or operator of the land where the pollution entered the soil is not obliged to carry out the remediation if he can prove that he did not cause the contamination himself (by his fault or otherwise), that the contamination is caused before he became owner/operator of the land and that when acquiring the property, he was not and should not have been aware of the pollution. In addition is the owner for historical contamination not obliged to carry out the remediation if he proves that the contaminated land was acquired prior to 1993 and was since then exclusively used for a non-professional use although he had prior knowledge of the pollution.

In case the parties involved are unable or refuse to remediate, OVAM has the right to intervene in order to prevent worse. Its main objective is to restore, remediate and/or manage environmental damage. Initially these sites are listed on an official 'soil remediation list', established yearly by the Flemish government. Moreover, OVAM takes safety measures if soil contamination can cause immediate danger for man or environment and the owner fails to solve the problem.

6.4 Complex Pollutions need other (Area oriented) Approach

6.4.1 Residential Areas

The application of the Soil Decree revealed some bottlenecks and it became clear that in some cases, especially in contaminated residential areas, a more coordinated approach was needed. The fact that different private parties - often "non-liable owners" - are involved made possible remediation more complex. In order to speed up the complex and costly procedure of examination and remediation, the Soil Decree was changed. On 18.05.2001 a new chapter was added to the Soil Decree, offering the possibility to combine a number of parcels into a so-called 'site'. A site is defined as "a complex of pieces of contaminated land or potentially contaminated land, identified by virtue of this decree".

OVAM may designate a site based on soil contamination and/or potential soil contamination. Also the Flemish Government may designate a site on the basis of other factors than soil contamination or potential soil contamination, after receiving advice from OVAM regarding the soil contamination or the potential soil contamination. This designation may be accompanied by a possible future land use. The designation shall be published in the Belgian Official Journal.

The designation as a site shall mean that within one hundred and eighty days of the day of the publication of the designation in the Belgian Official Journal, a site investigation must be carried out. A site investigation is defined as a soil investigation which is carried out on a site in order to map the effective or potential soil contamination, resulting from the soil contaminating activity for which the site has been identified, and determine its severity. The site investigation shall fulfill the objectives of a preliminary and descriptive soil investigation for the soil contaminating activity for which the site has been identified. All interested parties may, on pain of nullity, within a term of sixty days of the day of publication of the designation of the site in the Belgian Official Journal, submit a motivated request to OVAM by registered letter for exonerate any obligation to carry out a site investigation. OVAM shall communicate its decision within sixty days of receipt of the motivated request. In its decision, OVAM shall not bound by the borders of the land which is the subject of the request for release, and may also decide regarding other pieces of land belonging to the site or the whole site. OVAM shall communicate its decision to the owners and users of the land involved in the decision. After the granting of the release, OVAM may, in the case of a transfer of land which belongs to the site, grant an exemption from the investigation obligation.

This type of approach offers benefits to all involved parties because of the larger scale of the operation, and this in terms of costing, exploratory and remediation strategy, analysis and reporting, and the implementation term within which an end result can be achieved. It may involve a residential district developed on the site of an old dumping ground, a cluster of potentially polluted and inhabited locations in the city centre, a residential district located on potentially contaminated land with an industrial past, and similar sites.

This approach of ‘Sites’ is mostly conducted in residential areas, and since the liable party is often unknown in these cases it is the OVAM that does most of the investigations and remediation. Because of budgetary restraints, it is not possible to tackle all contaminated residential areas at the same time. That's why OVAM has made up a list of potentially contaminated residential areas which are sorted out according to priority. This sorting is based on a set of criteria: the severity of the contamination, the size of the contaminated area and the number of officially declared innocent owners. By following this list, OVAM can be sure the most important contaminated residential areas are handled first.

To ensure a good course of the projects, huge efforts are done to involve municipalities. First, these local authorities are sometimes responsible for the contamination. Second, municipalities are much closer with their inhabitants. Quite often, the environmental service of these municipalities is the first place where people come to ask questions. Third, the organization of meetings with inhabitants of contaminated residential areas is much easier when municipalities are involved in the project.

Besides in residential areas the redevelopment of brownfields or the approach of large contaminations spread over several parcels owned by different parties revealed shortcomings of the Soil Decree, even with the chapter on sites.

6.4.2 Brownfields

For brownfields a new legislative framework was worked out in 2007: the Brownfield Decree. This gives developers the opportunity to sign a contract with the Flemish government and other responsible public authorities about the realization of a brownfield project. The aim is to enter in an agreement on mutual commitments in order to reduce uncertainties in the development process. Approved projects may also enjoy some financial benefits: exemption of registration fees for property transfers and exemption of the obligation of posting financial securities for soil remediation in case of transfer of contaminated land.

Special Case: dry cleaners

For (mostly VOCl-) pollution caused by dry cleaning activities a sector fund ‘Vlabotex’ is supporting the remediation. Dry cleaning SME’s joining the fund, are able to transfer the remediation obligation and execution to Vlabotex. By means of compensation the applicant is obliged to pay a fixed annual contribution spread over maximum 30 years. The Vlabotex-fund is partly (50%) financed by a Flemish government grant.

6.4.3 Complex pollutions

Complex contamination refers to sites where soil and/or groundwater contamination occurs on a more or less large scale, involving several operators and/or owners that are potentially liable for remediation. Typical examples are large industrial sites where the pollution (especially of the groundwater) was caused by more than one company, or industrial parks that are located on a former landfill.

Uncertainty about the origin of the contamination, the impact of remediation works on neighboring sites, technical and legal questions, the issues are rife. Nonetheless, adapted management strategies help to guide these complex contamination issues in a cost-effective and even cost-saving manner through the Soil Decree.

The OVAM has two different approaches for these kinds of situations:

- Approach 1. Looking for opportunities through the classic follow-up of soil-remediation

Even when dealing with complex situations as described above, some companies try to run through the procedure of soil-investigation and remediation on their own. The main task of the OVAM is to evaluate the reports these companies hand in. Because of the complexity of the contamination, good advice of the OVAM is often essential. Sometimes by following up a soil-investigation or remediation, opportunities can be detected which can help to find a solution for the complex problem. It is the task of the OVAM to detect these opportunities and to exploit them. Quite often, it can be sufficient to organize a meeting with all involved parties to compare each others data and to try to come to an agreement. Depending on the situation, OVAM can take up a role as moderator, mediator or referee.

- Approach 2. Problem solving initiatives by a thematic approach

In some cases, the procedure of soil-investigation and remediation ends when dealing with complex situations. Technically so-called unsolvable problems, expensive investigations or juridical disputes can be a major restraint. OVAM can take initiatives to break the impasse. This can be done by determining ex officio the source of a contamination, by defining a distributive formula to divide the costs, to organize projects where different companies are encouraged or obliged to work together.

To get better legal security the OVAM is currently looking into a change of the Soil Decree. A new definition for mixed pollution and the possibility to oblige a distributive code to facilitate complex remediation will be the main objectives. The approach of the ‘sites’ is a good option but even then a lot of legal discussions arise since it is not possible to define which part of the pollution falls under which owner or operator.

In cases of mixed pollution it is not possible to assign one owner liable (or obligated to remediate) for the whole pollution. The mix can be spatial (groundwater pollution entered through different parcels, now as one plume under several parcels) as a mix in time (pollution started on one parcel but in different centuries by different owners or operators).

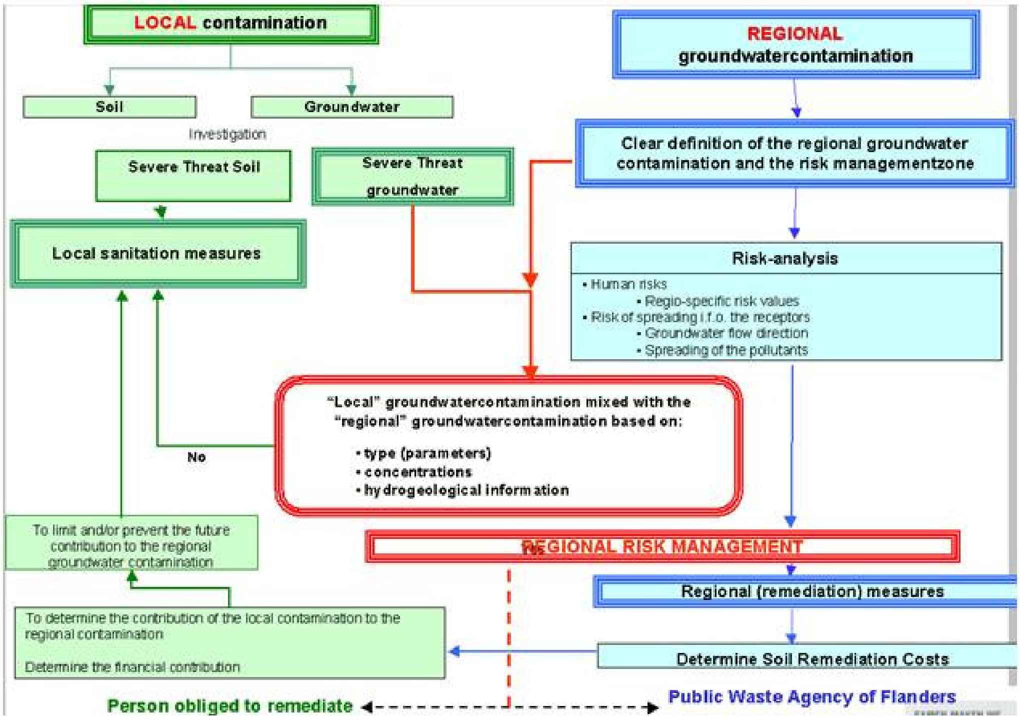

Figure 11. Example of possible area oriented investigation approaches.

7 Area oriented Investigation Approach in France

Developed within the framework of the Classified Installations (ICPE) law, the French policy, in the field of contaminated sites and soil, focuses on two main concepts:

- risk analysis and management rather than consideration of an intrinsic level of pollution;
- management based on the use of the site, i.e. a suitable treatment of the site in terms of its real impact on the environment and its planned use, based on a detailed risk assessment.

But, first and foremost, all possible means of eliminating the sources of pollution and their impacts must be sought. Controlling the sources of pollution is a fundamental aspect of the Management Plan[1]:

- It contributes to reduce the emission of substances responsible for chronic exposure of local populations;
- It contributes to the continuous improvement of the media (Management Plan includes also water resources protection).

Wherever the polluter is at hand or known, the "polluter–pays" principle is strictly applied. The current chain of liability is: the last industry that is responsible under the law on Environmental Permits for industrial sites; by default, the last owner. This chain of liability covers studies, monitoring, remediation work, and even costs associated with land-use restrictions (as a result of plant monitoring or residual contamination).
In France, due to the regional predominance of derelict land, a joint intervention of national, regional, and local actors is necessary. The management of former megasites is coordinated by six Public Land Management Authorities (Etablissements Publics Fonciers). Long-term policies and programmes exist in the traditional industrial regions. The strategy developed in 1986 in Lorraine concentrated on the rapid improvement of ecological conditions by means of large-scale landscape treatment projects. Preparation of the land for new uses, which is much more costly, will be a medium- and long-term task. Subsequently, the land is to be managed on a regional level and in individual cases is left to the open real estate market (to combine remediation with spatial developments).
With respect to the current legislation in France, a weakness remains the management of areas impacted by several sites, plumes, etc. Chlorinated solvents contamination in urban areas belongs to these situations. In order to face those challenges, initiatives do exist due to some local authority or administrative level. Solutions are sought as organizational 'arrangements' in order public and private parties to work together. An example in the Grand Lyon district shows that, in case of collective contamination due to historical facts (with a part of public responsibilities and industrial liabilities), the State and the industrials (partly responsible of the contamination, but without clearly quantification) may cooperate in order to share the costs of the remediation.
In France, some “area oriented approach” has been conducted in several cases, without – as we know – concretization as “mesure de gestion” (legislative and administrative official document) due to juridical

[1] The Management Plan is a new tool described in the Ministerial texts of February 8, 2007. All types of contaminated sites and soils (covered or not by ICPE legal frame) are considered by.

difficulties. The applicability of the area oriented investigation approach for groundwater risk management methodology may be restrained or limited because of those juridical difficulties and due to the amount of costs of the operation.

8 Conclusions

In order to reach a good quality status of groundwater and thus good quality of drinking water, national water authorities are challenged by the difficult task of identifying liable polluters in highly polluted areas, where many plumes of pollution merge together. In such cases, single case investigation is insufficient and provides insufficient information of relevant sources of pollution, which contribute to the overall pollution. Therefore, an area oriented investigation approach has been developed taking into account that plumes of pollution derived from several sources of pollution may overlay. This approach gives a clear overview of the overall groundwater pollution in a certain area and identifies all responsible polluters.

In Germany, groundwater pollution is considered as a breach of law or a breach of the public safety, which means that responsible of a breach (the polluter) must provide the reestablishment of a trouble free condition. The advantages of the area oriented investigation approach are confirmed by experience of many years in Stuttgart. Effective and well targeted activities enable to identify the most relevant plumes of pollution and to determine all relevant sources of pollution together with their contribution to the overall pollution. The presented case study Stuttgart-Feuerbach reveals important methodological aspects and gives recommendations for the general application of the area oriented approach:

- characterization of distribution patterns of “traditional” parameters should be done first,
- even though CHC form narrow contamination plums in groundwater, wider plumes or more diffuse distribution of contaminants in groundwater may occur due to time-variant groundwater flow conditions or historically significant different groundwater abstractions and uses,
- aerobic degradation processes can be very significant, even though anaerobic degradation is considered to be the dominant mechanism for CHC in groundwater,
- it is very important to fully understand the system to solve existing problems, which could be done by the numerical groundwater flow and transport model, and
- combining different characterization tools may be very useful to provide a consistent interpretation in complex cases.

The Dutch area oriented approach considers effective and efficient monitoring as essential element of groundwater management (see CityChlor report on Action 12). However, Dutch law does not permit the area oriented approach, whereas the basis of the law is a single case approach. At the moment the Dutch government is changing the existing law in the way that allows area oriented investigation approach.

In Flanders the situation is similar to the Netherlands. Based on Soil Decree, which purpose is to remediate contaminated land and to prevent new contaminations, area oriented investigation approach is not permitted. Therefore, the government is currently changing the Soil Decree. In France there is no practical example of the area oriented investigation approach.

Finally, it can be concluded that the presented innovative approach can be successfully used to identify, assess and manage contaminated groundwater bodes as presented in this report.

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CityChlor

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Summary: This case study indicated the methodological aspects and provided important recommendations for the possible general application of this innovative approach.

The advantages of the area oriented approach are confirmed by this case study and experience of many years in Stuttgart.

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