Regionernes Videncenter for Miljø og Ressourcer

# Challenges concerning contaminated sites common to the five Danish Regions

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Challenges Common to the Five Danish Region

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**Appendix:**

# 1. Preface

The five Regions of Denmark are the competent authorities in assessing, remediating and monitoring orphan contaminated sites. The Regions are committed to improve the existing methods as well facilitate and document the creation of new solutions. In addition, it is a political priority of the Regions to help promote green business and innovative solutions by setting high standards. On a political as well as on an administrative level, the Regions have a long tradition of cooperation. The aim of this report is to identify challenges common to the five regions, providing a transparent basis for more systematic cooperation within the highly specialized area of contaminated site management.

Challenges evolve, and challenges can be expressed at very different levels of detail. To this purpose, this document should be seen more as a baseline for iterative consultation, and as a starting point for further elaboration, rather than as an authoritative final reference.

## 2. Background

Responsibility for the investigation, prioritization and remediation of contaminated sites in Denmark lies with the five Danish Regions.

Each Region has their own approach to the task and the conditions vary from Region to Region. The legal framework is the same for all Regions as well as the request to accomplish the task at a high technical level and with economic efficiency.

On different organizational levels, all five Regions have defined goals towards innovation, technology development and expansion/growth.

Danish Regions – Environment and Resources (VMR) initiated a project regarding Common Regional Challenges (Fælles Regionale Udfordringer). The project's starting point is a hypothesis that the Danish Regions have, as of now, unidentified common problems and challenges. The project is a survey of technical challenges within soil and groundwater contamination for the five Danish Regions. The objective of the project is to define common denominators for future innovation and development projects shared by two or more of the five Danish Regions.

Previous attempts have been made to identify common challenges for the Regions. In these the focus has been on both technical and administrative challenges /1/. Common Regional Challenges differs from previous projects as it focuses primarily on technical challenges.

Innovation Network for Environmental Technologies (Inno-MT) published a technology outlook concerning soil and groundwater contamination in 2014 /2/.

Each of the five Danish Regions has their own innovation strategy. The strategy is also embedded at different organizational levels in each Region /3-8/.

The current project was initiated with a workshop on April 21st 2015 at VMR with at least one representative from each of the five Regions, two representatives from VMR and consultants from Inno-MT, COWI and INSPITE (one each). Among other things, the initial workshop was used to define success criteria for overcoming the challenges common to the five Danish Regions.

Findings from the initial workshop were used to plan and schedule the rest of the process.

Another strategic intention of the project was to facilitate international partnerships and promote green business. For this purpose Danish Soil Partnership (DSP) was engaged in the project. DSP is a partnership with a vision for Denmark to be known and recognized internationally for excellence and expertise in the field of soil pollution. DSP's mission is to create synergies, development, and export of world standard environmental solutions by mobilizing the parties within the soil contamination sector. These motives are in accordance with the motivation for this project which is to solve some of the identified technical challenges.

The overall timetable for the project is seen in the table below.

| June | July | August | September |
|---|---|---|---|
| Presentation at Danish Soil Partnership steering committee | - | Workshop at Region Zealand | Presentation at Danish Soil Partnership meeting |
| Workshop at North Denmark Region | - | Workshop at Region of Southern Denmark | Consolidating workshop at VMR |
| Workshop at the Capital Region of Denmark | - | Workshop at Central Denmark Region | Presentation of the results at the annual executive meeting |

The challenges in this report should be seen in the context of the Danish legislative framework on soil contamination and a brief introduction to this is therefore provided.

During the last three decades, Danish legislation on contaminated soil and groundwater has changed and evolved considerably. The enforcement of the legislation rests on a *polluter pays* principle. However, since the laws have changed, the onus is now on the authorities to prove that the pollution in question was not in accordance with the legislation at the time of the actual incident in order for the polluter to be held responsible.

Because of this legislation, many contamination incidents in Denmark are considered *orphan*, as the polluter in fact respected the legislation at the time - or because the pollution cannot be dated. All of the orphan contaminations will be investigated and, if necessary, remediated by the responsible Region. The Regions receive a budget from the Danish State every year to finance this. At the moment there are more than 33,000 potentially contaminated or registered contaminated sites in the databases of the five Danish Regions.

The Regions have to meet a criteria for the level of remediation set by the Danish Environmental Protection Agency. Along with the criteria, specific rules and regulations have to be followed.

Another critical issue is the fact that the supply of drinking water in Denmark almost solely consists of groundwater, and the groundwater is clean enough to drink without chemical treatment.

# 3. Procedure

After the initial workshop at VMR, a workshop was arranged for each Region to map their individual challenges. 5-10 employees from each Region attended the workshops along with VMR, COWI and INSPITE. Minutes from each workshop containing all listed challenges were sent for validation to a contact person from the Region and VMR. The minutes can be found in Appendix 1, (only available in Danish). The Regions can use the minutes for internal purposes and they represent the main constituent and documentation of mapping the common challenges for the five Regions.

After the workshops in the Regions, a large matrix was compiled (see Appendix 2). The matrix contains:

- main themes
- an overview of all the mentioned challenges in short
- which Regions are interested in the challenge
- which contaminants the challenge concerns, and finally,
- whether the challenge concerns one or more of the four issues: vapor intrusion, groundwater (source and plume), contact risk and surface water.

This matrix is the background documentation for the description in section 5, which is a listing of the common challenges. It is important to acknowledge that only 5-10 people from each Region attended the workshop meaning all existing knowledge in every area was not necessarily covered. Some of the challenges may be in process as mentioned in the sections "on-going projects" after each work theme.

The consolidating workshop was used to thoroughly describe the 6 challenges that most Regions have in common. Minutes from the consolidating workshop were used to elaborate the descriptions of each challenge as seen in section 5.

A final workshop was held between the five Regions at the executive level. During this session, management discussed the relative importance of the identified challenges to their particular Region.

# 4. Workshops in individual Regions

A 6 hour workshop was conducted at each of the 5 Regions. An introduction to the project and the organizers were given, and there was an opportunity for the participants to ask questions.

The workshop was comprised of solitary and group exercises as well as plenum discussions. Initially, the challenges were described as problems and then elaborated by looking at possible solutions, which made it easier to fine tune the description of the challenge. At the end of the day an informal prioritization of the challenges took place.

Minutes from the workshop can be found in Appendix 1 (in Danish).

In all Regions the challenges had four levels of explanation.

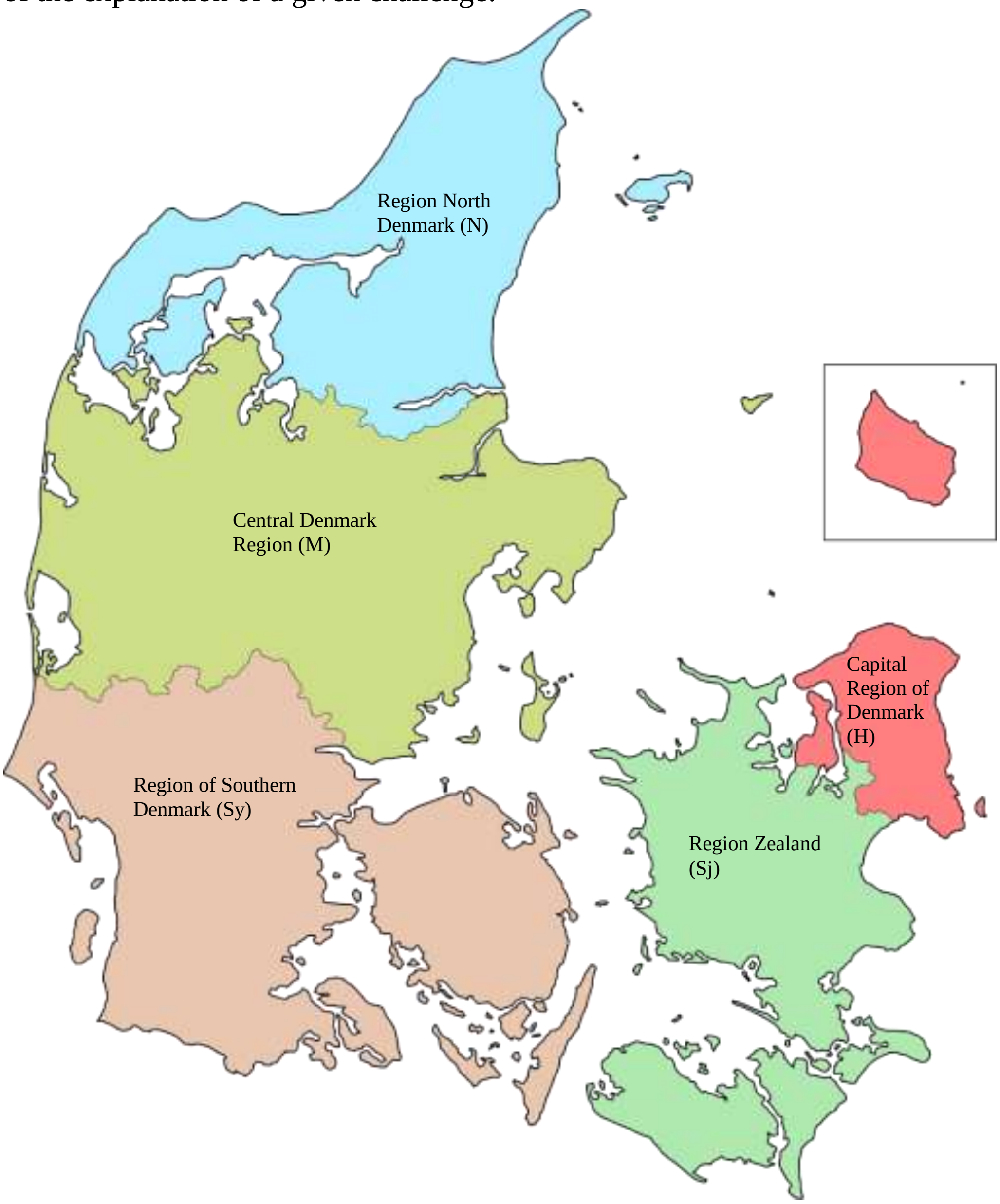
- A main theme, these themes varied from Region to Region depending on focus
- Short description of the challenge
- What could help solve the challenge
- Notes/derived challenge, this can include references to existing projects

At the end of each set of minutes is a list of on-going research and development projects in the Region in question.

## 5. Work Themes

The different challenges were divided into 9 different general work themes. Each work theme covers between 1 and 24 different challenges. Appendix 3 is an index of the work themes and challenges, it states which challenges are common to each Region. All challenges will be described in the following text and divided into the general work themes. The challenges are ***not*** listed in a prioritized order.

To indicate which Regions mentioned the challenges in the individual workshops, an abbreviation for each Region has been used in parentheses at the end of the explanation of a given challenge:




These abbreviations are also used in Appendix 3.

If a Region is not mentioned, it does not mean lack of interest, the challenge simply was not mentioned at the workshops.

**Optimization of Investigations (challenges 1-24)**
Wells are expensive and analysis time consuming. In order to implement a sound risk assessment, a large number of wells are drilled to gain enough knowledge to support the assessment. There is little knowledge on 3D contaminant transport in heterogeneous geology. We only find what we search for and this may make the risk assessment questionable.

1) Heterogeneous geology is a challenge since it results in inaccurate interpretation of geology and hydrogeology. These faulty interpretations can, among other things, lead to incorrect conclusions on contaminant mass and transport. For more correct interpretation, heavier sample density or more intelligent investigations are needed (H, Sj, Sy).

2) Mechanisms in limestone. Understanding of the mechanisms in limestone is lacking. In the eastern part of Denmark, the primary aquifers consist of limestone. Only little knowledge on the behavior of contaminants in limestone exist: How does it sorb? What happens in the matrix? Back diffusion etc.
(H, Sj).

3) Separation of hydrocarbons, natural vs. contaminants. For contaminations with hydrocarbons, the challenge is to separate natural hydrocarbons from contamination when dealing with topsoil contamination. There is a prevalence of

peat in Denmark and using regular analytical method, peat can easily be mistaken for contaminants. There is a need for a better analytical method (N, Sj).

4) Dating of contaminants. As mentioned in the background section, the laws on soil and groundwater contamination have changed, so the authorities have to prove that the pollution in question was made breaking the valid legislation at the time of the actual spill/incident. This makes it quite important for the authorities to be able to date a given contamination. Currently, no method accurate enough is available (H, M, N, Sj).

5) Source tracing is expensive, time consuming and difficult. Has the source been found? Is there more than one source? And how large is it? In some cases, an abstraction well is closed because of pollution; methods to trace the source are needed. These are some of the questions at hand (H, M, Sj).

6) Discontinuous Investigations. With the currently available techniques, it is not possible to investigate a site thoroughly in one phase. Even though dynamic investigations have been tried, it is still a struggling battle to get everything done in one phase in a short period of time. When doing preliminary investigations, the uncertainty is great because of sporadic sampling, this means more sampling rounds. In consequence the site has a long turnaround time in the public system, since it goes back and forth between investigation and "lag time" waiting for reports and decisions (H, M, N, Sj, Sy).

7) Landowner issues. Many private landowners have small, insignificant contaminations. The process from registration of a possible contamination to clarification of whether the contamination poses a risk is often lengthy. In this period, the landowner is often insecure and may have trouble selling the property, even though it often turns out there is no risk. There is a need for faster clarification (H, M, N, Sj, Sy).

8) Clay water samples. The overburden in Denmark is often clay till. This clay till may contain secondary groundwater. Since the clay till is very low-yielding, it is difficult to get a representative water sample (H, Sj).

9) Investigations under buildings, lack of suitable methods.. Many of the contaminated sites are former industrial sites, some are still industrialized and some have been turned into residential areas. In both cases, buildings are often constructed on top of the contamination, this makes it difficult or even impossible to install wells and casings and screens in wells. For preliminary (and more extensive) investigations, it is challenging to place the borings in the correct spot because of the physical conditions at the site (buildings, gates, etc.) (H, Sj, Sy).

10) Utility challenges. Lack of methods to chart existing pipes, drains, power cords, wires, cables etc. Service location plans are always obtained, but these

often only contain utilities in public areas, so when entering private property the information is sparse (H, N).

11) Investigation of surface waters in relation to contaminated sites. The latest change in the legislation in Denmark included surface water in the soil and groundwater laws. This means, there is a new area to enforce. There is a need for methods, knowledge, rules and regulations and criteria for investigation of contaminated surface waters. For the risk assessment, a "sound biological state" is undefined, what is "sound biological state", what does it mean in terms of concentrations and substances. As a consequence, there is also a need for a risk assessment tool that takes this into account (H, M, N, Sj).

12) Surface water with several sources. If there is more than one site that may transport contamination into the nearest surface water, there is a need for tools that can handle this. Tools for handling, prioritizing and risk assessing preferably on a catchment area scale (H, M, N, Sj).

13) Aquifer impact and migration pathways. Lack of knowledge on impact on local and next influential aquifer. Characterization of actual migration pathways from shallow to deep aquifer as well as application of collected data in a credible risk assessment. The wish is a model that can take convergence of more plumes, natural attenuation and cocktail effect into account as well as embrace all data at once (H).

14) One well flow direction tool. A tool that has the ability to describe flow direction using one single well. Tools are available on the market, but more reliable ones are wanted (M, Sj).

15) Fast, non-invasive, effective and cheap investigation methods. In general, there is a need for fast, effective and cheap investigation methods that have a non-invasive character (no physical holes in the ground). Geophysical methods have limitations in the top 10 meters. Lack of methods that provide a "snapshot" of geology, chemistry, hydrology etc. – a 3D goggle. Need for screening methods with lots of data. Determining mass discharge is expensive. A need for a technique analyzing for more components when using field laboratories (H, M, N, Sj, Sy).

16) Emerging Contaminants. Every once in a while new contaminants emerge. This probably means, more are still to come, so what should the analysis measure? There is a need to expand on the existing analysis package. The analysis package for the field laboratories should expand as well. Are these emerging contaminants even a problem? Often when the contaminant is first mentioned, it is tied to one sector of industry and later turns out to originate from several, this may mean insufficient investigations have been carried out and new ones must be conducted, sometimes it even means closed sites have to be reopened (M, N, Sj, Sy).

17) Documentation of Monitored Natural Attenuation. Existing analytical methods for documentation of MNA are expensive. There is a lack of knowledge and experience in the area (Sj, Sy).

18) More reliable risk assessment. Lack of knowledge on how to prioritize from a risk assessment based on toxicology and mobility of contaminants. Instead of making the risk assessment based on a fixed concentration it would make sense to look at the toxicology of a site as a whole. There is a need for risk assessments on a more robust foundation (N, Sj, Sy).

19) Catchment scale investigations. There is a need for methods to investigate on catchment area scale. As one of the main issues for the Regions is protection of drinking water, it makes sense to look at the full catchment area, to make sure that remediating one site will not only be removing a droplet in an ocean of contamination coming from a different site in the same catchment area (Sj).

20) Landfills. Leachate from landfills pose a problem and there is a need for a method to delineate the plumes of leachate, in addition, a method to determine if there is a risk for the adjacent catchment area is needed. The number of sites are enormous, the contaminants that need focus are often unknown and the task at hand is comprehensive and expensive, so a screening method to measure for example seepage concentrations, direction and vertical distribution is desirable (Sj).

21) NAPL mass discharge measurements. A reliable tool for measuring mass discharge is requested, this would be very useful to prioritize which site to remediate first and also decide whether a contamination poses a threat to the drinking water (Sj, Sy).

22) Risk assessment based remediation choice. A support tool to choose which remediation method is best qualified based on risk assessment. There is a lack of method and experience to help make qualified decisions with many new remediation techniques at hand (H, Sj, Sy).

23) Differentiating ambient concentrations from contaminants. There are no ambient guideline concentrations to compare to. The background contents of soil and groundwater may vary depending on geology. For example as mentioned in challenge #3, if the soil is rich in peat, it may seem as if contaminated with hydrocarbons (H, N, Sj, Sy).

24) Water in sub-slab and soil gas samples. When taking sub-slab or soil gas samples in the unsaturated zone, water is sometimes collected and makes the samples useless. Need for technique to sample without collecting pore water (H).

**On-going projects regarding optimization of investigations**
Geophysical methods (H), the Technical University of Denmark's collaboration on limestone (H), Practical test of screening tool for surface water (H, M, N, Sj, Sy), Geocon – project with DTU (M), Freon (M), AOX in groundwater (M), Hg in Fjord sediments (M), Screening of landfill gases using several measuring technologies affiliated with drones (Sj), Tool to ensure climate robust risk assessments for soil contamination (Sy), Testing passive mass discharge meters (H, Sy), The ability of clay minerals to absorb and contain contaminants (Sy). For questions regarding these projects, please contact the responsible Region.

**Investigating Vapor Intrusion (challenges 23-26)**
There is a general lack of understanding the vapor intrusion pathways and mapping of the actual vapor intrusion pathways. In addition, there is a need for methods to separate contaminant concentrations from ambient concentrations caused by smoke, wood-burning stoves, furniture, carpets, car emissions, plastic toys etc.

23) Differentiating ambient concentrations from concentrations caused by contaminants. There are no official ambient concentrations for outdoor or indoor air to compare to. There are many sources of contaminants in the ambient air that has nothing to do with soil and groundwater contamination. It is well known that hard plastic toys evaporate chlorinated solvents. The suit, just brought home from the dry cleaner's, also evaporates chlorinated solvents. Emission of gasses from cars and smoke is found in the ambient air. Two Danish studies have investigated ambient air concentrations for a number of substances /9+10/ (H, N, Sj, Sy).

24) Water in sub-slab samples. When taking sub-slab samples directly under buildings in the unsaturated zone, water is sometimes collected and makes the samples useless. Need for technique to sample without collecting pore water (H).

25) Understanding vapor intrusion pathways. There are many pathways for the vapor to travel. It is crucial to understand *how* the vapors act to be able to understand how the vapor intrudes into a house (H, Sj, Sy).

26) Locate actual vapor intrusion pathways. This is closely linked to challenge # 25. Tools to locate actual patterns of vapor intrusion. A range of trace gases, use of thermal photography or other techniques to locate different vapor intrusion pathways and decide which ones are the crucial ones (H, Sj, Sy).

**On-going projects regarding investigating vapor intrusion:**
Measurements of differential pressure – understanding vapor intrusion pathways (H), Measuring benzene in ambient air (M), Tetra-chloromethane in vapor intrusion measurements (M), Measurements in sewers (M), Dispersion via utilities (Sy). For questions regarding these projects please contact the responsible Region.

**Pesticides (challenges 27-34)**
There is a lack of experience and methods regarding both investigation for and remediation of pesticides. The most persistently mentioned challenge is the inability to differentiate point sources from diffuse sources.


The number of sites is enormous, and pesticides as a group is the chemical compound that causes the majority of drinking water well closures in Denmark each year. So far, the problem has little international interest. Maybe because the acceptable value of the sum of pesticides and degradations products in Denmark is 0.1 µg/l. If the same threshold is applied in other countries, they are likely to face the same problems in the years to come.

27) Differentiating point sources from diffuse sources. It is very difficult to differentiate point sources from diffuse sources, a technique to solve this issue is needed. The number of sites is very large, so a fast (screening) method would be preferred. There is a need for a method to trace and delineate point sources, at present this is expensive, comprehensive and time consuming (H, M, N, Sj, Sy)

28) Cocktail effect. The cocktail effect of several different pesticides and degradation products of these are not known, what about additives? There is a lack of interest on the subject and there is a lack of techniques (M, Sj).

29) Intelligent investigations. This is an alternative to the traditional approach of historical due diligence on all potential sources. Due to the amount of potential sources and their non-stationary character, this method is hard to apply to pesticides. It is a problem to trace the relevant pesticides backwards from an abstraction well. Intelligent investigation methods are under demand (M, N, Sj, Sy).

30) Historical information. In order to locate the contaminated sites, one of the best information sources are the farmers. It is a very difficult and sensitive job to talk to them, they have no interest in helping the authorities as they are afraid to get blamed, in addition, things that today is considered an incident may have been an ordinary daily routine at the time. Unfortunately, many of the farmers are elderly so they pass away and with them important information is lost (Sj).

31) Overall pesticide strategy. Request for an overall common pesticide strategy and tools to implement it (Sj).

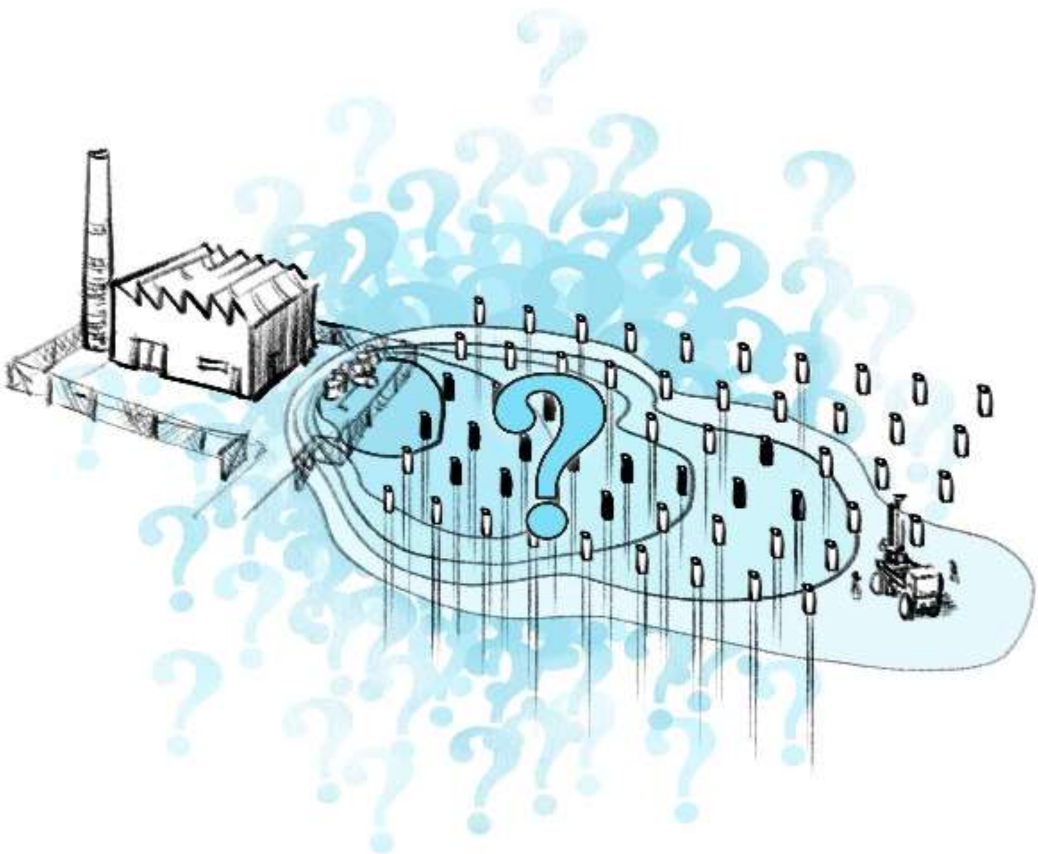
32) Collaboration with Municipalities. Request to collaborate with the municipal government about a solution. Tools, administrative decisions, etc. (Sj, Sy).

33) Methods for source remediation. Dig and dump is the main solution at the moment. Previously, there was no great effort to find alternatives. Alternatives have primarily been investigated for chlorinated compounds and hydrocarbons as pesticides do not have an international interest (H, Sj).

34) Methods for plume remediation. Pump and treat is the main solution at the moment. As with source remediation, little effort has been given to find alternatives (H, Sj).

**On-going projects regarding Pesticides:**
Pesticides analysis (M), Pesticide investigation and remediation (M). The Danish EPA has two reports in course of publication, and some of the challenges will be addressed in these publications. For questions regarding these projects please contact the responsible Region or the Danish EPA.

**Plume Delineation (challenges 35-37)**
It is cost-intensive to establish wells deeper than 15 mbg (meters below ground), and it is also difficult to place the well in its proper location. There is a need for a less expensive drilling method that is able to analyze as it progresses. Alternatively, a novel technique that can 3D visualize the plume could be used.



35) Complex Geology. Request for a technique to map the aquifers. Conceptual site models . What happens to a plume in a complex geological setting? Danish geology is dominated by heterogeneous glacial sediments, this means delineation of plumes requires a complex investigation. For example a buried glacial valley may alter the direction and depth of the plume considerably (H, Sj, Sy).

36) Delineation of deep plumes (in limestone). Because of the complexity of the geological setting, it is a lottery to place wells in the optimal location to delineate the plume. For delineation of deep plumes (> 20 mbg.) or plumes in limestone it is a very expensive lottery and the cost of one well could easily be on the upper side of € 13.000 (H, Sj).

37) Delineation of plumes. Because of the complexity of the quaternary glacial dominated geology it is an expensive, difficult and time consuming investigation to delineate the plume. It requires many monitoring events, and it provides a snapshot of the plume at the moment of the monitoring event, but does not provide information about the evolution of the plume and the flow direction (H, M, Sj, Sy).

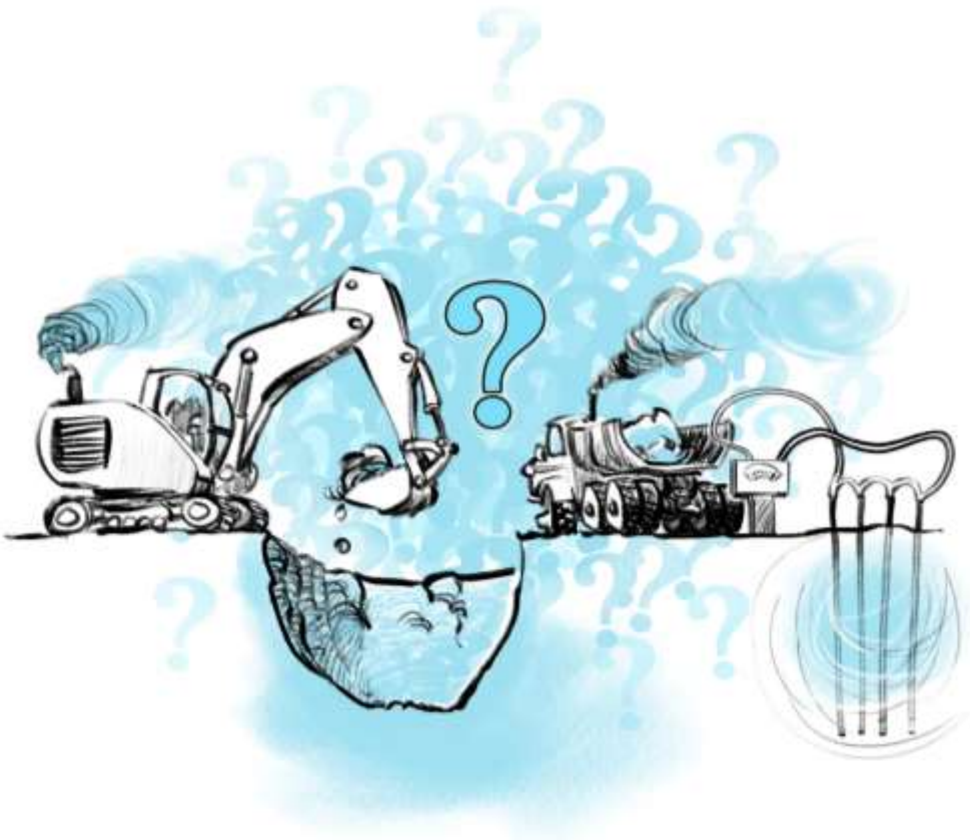
**On-going projects regarding plume delineation:**
NEMLA - New emplacement methods for limestone assessments (H). For questions regarding this project, please contact the responsible Region.

**Data and Visualization (challenge 38)**

38) Digitalization. All the data collected from investigations should be collected and saved in one place. There are many different types of data in many different formats and there are no standards. Some data originate from old paper archives, some from databases, some from laboratories and others from field observations. There is a need to standardize the collecting of raw data. The Regions should develop common data standards. If all data is collected and formatted according to a common standard, the subsequent interpretation and visualization will be much smoother. This task cannot be solved by one Region alone, a consensus on the matter is needed (M, Sj).

**On-going projects regarding Data and Visualization:**
Developing an app for field use (M), establishing webGIS (M and others), Safe network (M and others). Several projects are being carried out regarding these challenges. For questions regarding these projects, please contact the responsible Region.

**Remediation of low permeable deposits (challenges 39-47)**
Could dig and dump solutions be conducted in a more sustainable manner? Or is there an alternative? Is it possible to use an alternative energy source for thermal remediation to lower the carbon footprint of the method? How should geotechnical instabilities following source remediation with thermal methods or soil mixing be handled? There is a request to find alternative more sustainable and less radical solutions to remediation of this particular kind of deposit.



39) Geotechnical stability regarding thermal methods. These challenges cover both the challenge of what happens to the geotechnical properties of the site during the thermal remediation and after the remediation. If, for example, the site holds a layer of peat, the peat will likely combust during the thermal remediation and will cause subsidence of buildings. After a thermal remediation, the properties of the soil may have changed depending on type of deposit. If, for example, the deposit is clay, the clay will resemble a warm tile for quite some time after the remediation, and it will not be possible to grow anything. The soil needs cooling, nutrients and water. The soil will also have expanded, so the geotechnical properties will change as it cools again (H, N).

40) Geotechnical stability soil mixing. Using soil mixing turns the overburden into a quicksand-like deposit. This needs to be stabilized again. At the moment, there is a lack of method to stabilize the sediment (H).

41) Biological/Chemical Methods. There is a lack of methods to document the effect of different remediation techniques. There is also a lack of guidelines on their application nand on relevant site closure criteria. For large areas, the techniques are quite expensive as they require large amounts of biological or chemical reactants. There is an issue with contact between reactants and contamination (see challenge #60). There are constraints on which substances can be used (H, Sj).

42) Energy consumption with thermal methods. The high energy consumption using thermal methods makes them very unsustainable. Is it possible to use a different energy source? (H).

43) Land use during remediation, long time frame. Some remediation methods have a very long duration and this makes them unsuitable for certain types of sites. If the land user is restricted in his use of land during the time of remediation, an alternative needs to be considered (H, N).

44) Source remediation of emerging contaminants. Can well-known methods be used or is there a need for new methods? (H).

45) Dig and dump. It is not very sustainable to transport the soil to a different location for cleaning or, in some cases, just dumping it. The soil is not utilized at the disposal sites. The disposal sites may have limited capacity. The land use may be challenged during the remediation and there may be a need for lowering of the groundwater table during the digging. If the contamination is deep, the installation costs are considerable (M, N, Sy).

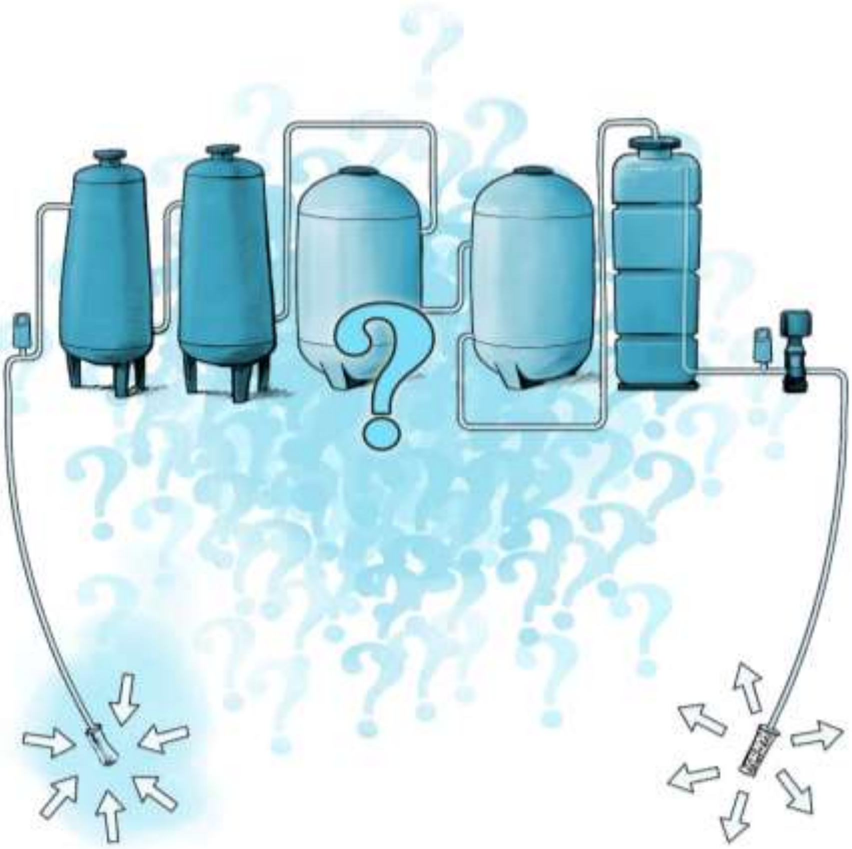
46) Degassing/mobilization of contaminants. Lack of technique to degas or mobilize contaminants (Sj).

47) Land use during source remediation or containment. The installations can result in limited available space, some noise and other inconveniences may be issues that need to be dealt with (N).

**On-going projects regarding remediation of low permeable deposits:**
Project on stabilizers for soil mixing (H), EK-TAP (H), EK-Bio (H), long lived reactants (H), sustainable remediation (M), high pressure ISCO using ozone (Sj). For questions regarding these projects, please contact the responsible Region.

**Containment alternatives to pump and treat (Challenge 47-56)**
There is a lack of containment alternatives to pump and treat. The request is quite specifically not a source remediation alternative, but a containment alternative. The main focus is on the waterborne contamination. The contamination cannot be dispersed or mobilized (more than it already is). Containment is often used when there is more than one source, for example downstream of an industrial area.

A pump and treat system usually consists of one or two pre-filtration units of sand to remove Fe and Mn, and following this, one or more granular activated carbon (GAC) filters to remove the contaminants. The contaminants are sorbed to the GAC, and to maintain the effect, the GAC has to be replaced every once in a while. Spent GAC is disposed of as waste. This waste has an environmental impact as does the transportation and production of GAC. The request for an alternative to pump and treat is a wish to rethink the system from scratch: can pumping be avoided altogether?



47) Land use during source remediation or containment. The installations can result in limited available space, some noise and other inconveniences may be issues that need to be dealt with (N).

48) Alternatives to pump and treat. We need reliable alternatives that can comply with the Danish Drinking Water Standards. Pump and treat facilities are expensive to construct and operate (monitoring, replacement of spent granular activated carbon (GAC), discharge taxes etc.). The environmental impact is fairly high because of power consumption, transportation of GAC, spent GAC/GAC waste etc. Because of impermeable geology, back diffusion makes the system necessary for a very long period of time. It does not remediate - only contain, this means the next generation will inherit the problem, this also has a negative psychological effect. It is a "perpetual motion machine" (H, M, N, Sj).

49) TOC content. If the TOC content of the groundwater pumped to the surface could be treated, then the existing infrastructure (from utilities) could be used (Sj).

50) Alternatives to GAC. Many contaminants have poor affinity for GAC and this means a high amount of spent GAC. A request for a sustainable alternative to GAC (H, Sj).

51) Optimization of pump and treat. If no alternatives can be found, and in the meantime, then the systems should be optimized to be more sustainable (economy, environment and social) (Sj).

52) PRB's. Permeable Reactive Barriers. To be able to comply with Danish Drinking Water Standards, PRBs need inspection and optimization. Some of the problems are hydrological issues, clogging and the longevity of the reactants. For deep PRBs, a good installation method is needed, trenching at more than approx. 10 mbg is not plausible (H).

53) Catchment scale approach. There is a need for methods to remediate on the scale of a catchment. As one of the main issues for the Regions is protection of drinking water, it makes sense to look at a full catchment at a time. This means that remediating downstream in the plume of, for example, an industrial area may make more sense, than remediating one site at a time at a very high cost and perhaps ending up with not being able to remove one or more of the significant sources (N).

54) Programmable logic controller (PLC). The existing PLC system is expensive. The system is not created specifically for the purpose, but was chosen out of necessity since there was no alternative when the first system was built. Request for a system that will try to fix the problem and not just shut down when faults are detected (Sj).

55) Passive solutions for smaller sites. There is a request for effective passive solutions for smaller sites. Preferably maintenance free (Sj).

56) Source encapsulation/containment. Request for systems that can encapsulate or contain source areas. It could be something that would harden the contamination to prevent further dispersion (Sj).

**On-going projects regarding containment alternatives to pump and treat:**
ALAPUM - alternatives to pump and treat (H), alternatives to GAC, including bioremediation in conjunction with GAC (H), sustainable remediation (M), using ozone as an alternative to GAC (Sj). For questions regarding these projects, please contact the responsible Region.

**Remediation for Vapor Intrusion (challenges 54-59)**
When a contamination dwells under a residential building, and it is not an option to remove the building, ventilation of some kind is often the preferred remediation. The existing ventilation solutions have variable effect: Some work fine for several years and then suddenly stop working. Some never work well

enough to get the indoor air below Danish EPA criteria. Common for many of these systems is the need for maintenance, is it possible to give the responsibility for the maintenance to the resident? This is a challenge when residents move.

54) PLC. The existing PLC system is expensive. The system is not created specifically for the purpose, but was chosen out of necessity since there was no alternative when the first system was built. Request for a system that will try to fix the problem and not just shut down when faults are detected (Sj).

55) Passive solutions for smaller sites. There is a request for effective passive solutions at smaller sites. Preferably maintenance-free (Sj).

56) Source encapsulation/containment. Request for systems that can encapsulate or contain source areas, so the vapor will never reach the residence. It could be something that would harden the contamination to prevent further dispersion (Sj).

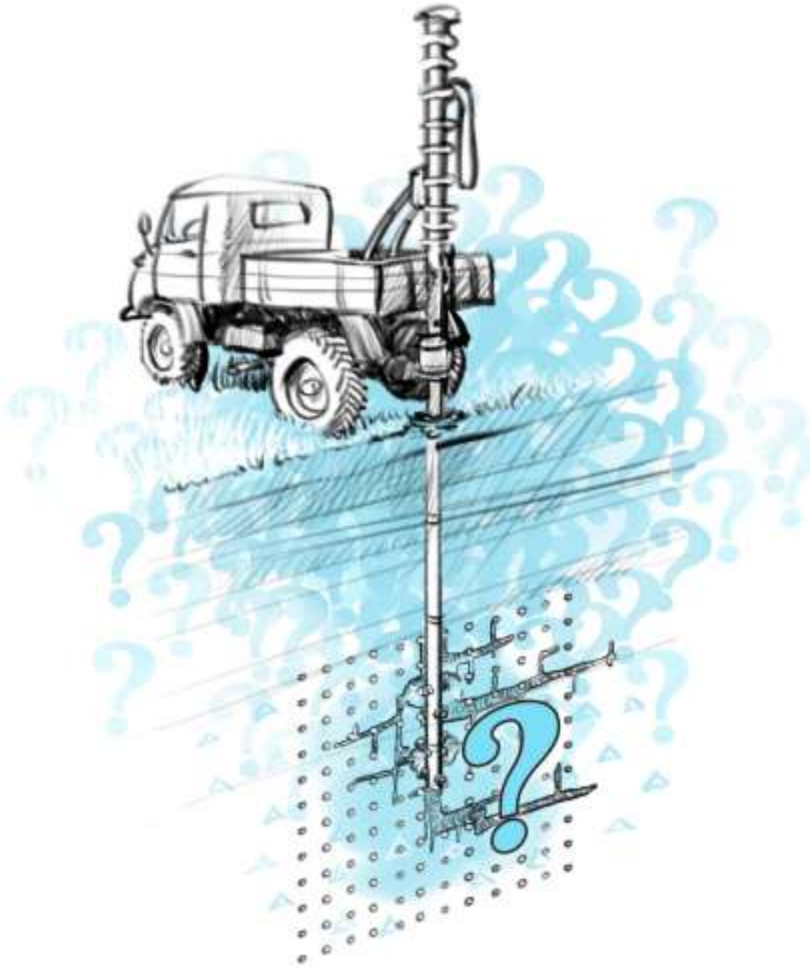
57) Contamination under buildings. Request to develop a method that can remove contamination from under a building without demolishing the building (Sj).

58) Ventilation solutions. The existing solutions cause insecurity for some residents. The existing solutions are not always reliable or effective, they need operation, monitoring and maintenance. They are cost-intensive solutions. On a long term basis (+ 10 years) the reliability is unknown. Whenever there are new residents, there is a communication challenge especially for residential buildings since they will keep their registration as contaminated (H, M, N, Sj, Sy).

59) Membranes. Membranes to prevent vapor intrusion will tenderize with time or under the effect of the surroundings. The effect of the membrane is spoiled when installing new utilities that perforate the membrane (H, N, Sj).

**On-going projects regarding vapor intrusion remediation:**
NYMIND – new methods for vapor intrusion remediation (H), sustainable remediation (M), Experiments using bio-barrier in the unsaturated zone (M). For questions regarding these projects, please contact the responsible Region.

**Reactant distribution (challenge 60)**
A wide variety of reactants for degradation of contaminants in low permeable deposits are available. However, delivery of these reactants into the matrix is a problem yet to be solved.



60) Reactant distribution. It is difficult to ensure, that there is contact between contaminants and reactants. The longevity of the reactants is a constraining factor. There is a request for better and cheaper methods to distribute the reactants into the matrix of the formation, the formation often being a fractured dense clay till or fractured limestone (H, N, Sj).

**On-going projects regarding reactant distribution:**
LLR – long lived reactants (H), fracking using freeze/thaw processes (H), EK-TAP (H), EK-Bio (H), high pressure ISCO using ozone (Sj). For questions regarding these projects, please contact the responsible Region.

The remaining challenges are not necessarily challenges to be solved with a new technical gadget. They are divided into 3 additional themes. The themes are comprised of challenges that may apply to any of the technical themes.

**Surface waters (challenge 61)**

61) There is a need for methods, knowledge, guidelines and criteria for remediation of surface waters (Sj).

**General statements (challenges 62-63)**

62) Revisit old technologies. Request to look at rejected technologies to see if any new research may make them plausible. For example, reactive permeable barriers have been rejected in Denmark after unsuccessful installment and inability to reach Danish EPA criteria downstream, but there has been much development in the area since and the technique may have reached a state, where it can be installed successful and comply with criteria downstream (Sj).

63) Super sites. There are a few super sites in Denmark that are so extensive that the budget of one Region cannot investigate or remediate the site fully (Sy).

**Sustainability (challenges 64-67)**

64) Lack of focus on sustainability. There is a lack of focus on sustainability: It is not prioritized, there is no legal framework and no funds. There is a lack of holistic application (H, M, N, Sj, Sy).

65) Contamination as a resource. Contamination is considered unhealthy, this stigmatizes the soil and groundwater from contaminated sites - can this be changed? And the soil and groundwater from these sites turned into resources by recycling (M).

66) Utility value of bi-products. Lack of business model for utility value of bi-products. For example exchange market for soil (N).

67) Limited resources. There is a limited amount of available raw materials. This is the motivation for thinking sustainable and recycle as many raw materials as possible (Sj).

At the consolidating workshop, 6 of the common challenges were explored further. Each challenge was named and a problem statement was developed. Visions for solutions were formulated along with suggestions for necessary knowledge, useful knowledge and inspirational knowledge for development of a solution. In addition, an illustration of the challenge was sketched, these sketches where later redrafted into the drawings under each of the above work themes. This information can be used in the framing of a potential project. Posters containing the 6 challenges are available in Appendix 4.

# 6. Conclusions/Perspectives

The five Danish Regions have proved to have many challenges in common. Some are common to the eastern part of Denmark due to the Geological setting, some are common to all of the Regions, and few have only been mentioned by one Region.

Collaboration is already taking place, both between the Regions, and especially between the Regions and other players in the industry. These collaborations can benefit from being further developed by coordinating the projects in a central location. To some extent, some of the common projects already being carried out overlap, avoiding these overlaps could potentially give funding to solve more challenges. The project at hand could be the starting point for a new wave of coordination.

There are a lot of possibilities for working with these projects in the future. There is material for many projects on many different levels. The projects can be executed differently: as training of personnel, knowledge transfer, development projects and innovation projects.

This report is meant as a tool to connect likeminded people with common challenges and hopefully it will serve as an encyclopedia for the Regions and their collaborators to solve more challenges in the future.

Appendix 4 posters will make a good starting point for framing future projects.

# 7. References


**/1/** Fællesregional udviklingsstrategi for jordforurening
Udgiver: Alle Regioner, antal sider 13
Dokumentet beskriver: En fællesregional udviklingsstrategi fra 2013, den såkaldte 5+6. Den omtaler 5 teknologiske udfordringer og 6 administrative udfordringer.

**/2/** Jordforurening Technology Outlook
Udgiver: Innovationsnetværk for miljøteknologi, antal sider 32
Dokumentet beskriver: De områder i jordforureningsbranchen hvor der er behov for nye teknologier, og hvor der er fælles interesser mellem områdets aktører.

**/3/** Jordforurening- En strategi for region Sjællands indsats
Udgiver: Region Sjælland, antal sider 15
Dokumentet beskriver: Region Sjællands indsats på jordforureningsområdet fra 2014.

**/4/** Udviklingsstrategi for miljø
Udgiver: Region Midtjylland, antal sider 8
Dokumentet beskriver: Region Midtjyllands målsætninger for udviklingsarbejde på miljø området. Den indeholder desuden en liste over forskellige muligheder for finansiering af projekter og en beskrivelse af projektforløb.

**/5/** Pejlemærker for udvikling
Udgiver: Region Syddanmark, antal sider 1
Dokumentet beskriver: Kort hvilke pejlemærker Region Syddanmark anvender i forbindelse med udvikling (teknologiudvikling). Dokumentet er en integreret del af deres strategi for jordforureningsområdet. Der henvises desuden til 5+6 dokumentet.

**/6/** Innovationsstrategi
Udgiver: Region Nordjylland, antal sider 1
Dokumentet beskriver: Region Nordjyllands generelle innovationsstrategi. Der er fokus på samarbejde med virksomheder. Regionen har desuden udarbejdet en generel udviklingsstrategi.

**/7/** Grøn Region (Del af REVUS)
Udgiver: Region Nordjylland, antal sider 5
Dokumentet beskriver: Region Nordjyllands arbejde med miljøområdet, ellers henvises der til REVUS.

**/8/** Vejen til ren jord og rent vand
Udgiver: Region Hovedstaden, antal sider 12.
Dokumentet beskriver: Region Hovedstadens arbejde på jordforureningsområdet.

**/9/** Prioriteringsniveauer for indeklimasager på kortlagte ejendomme.
VJ. Teknik og Administration Nr. 2, 2010.

**/10/** Samlet sundhedsmæssig vurdering af kemiske stoffer i indeklimaet fra udvalgte forbrugerprodukter.
Miljøstyrelsen. Kortlægning af kemiske stoffer i forbrugerprodukter Nr. 75, 2006